Recommendations to Enhance the Resiliency and Recovery of King County's Regional Wastewater Treatment Facilities

FINAL

RESILIENCY RECOMMENDATIONS

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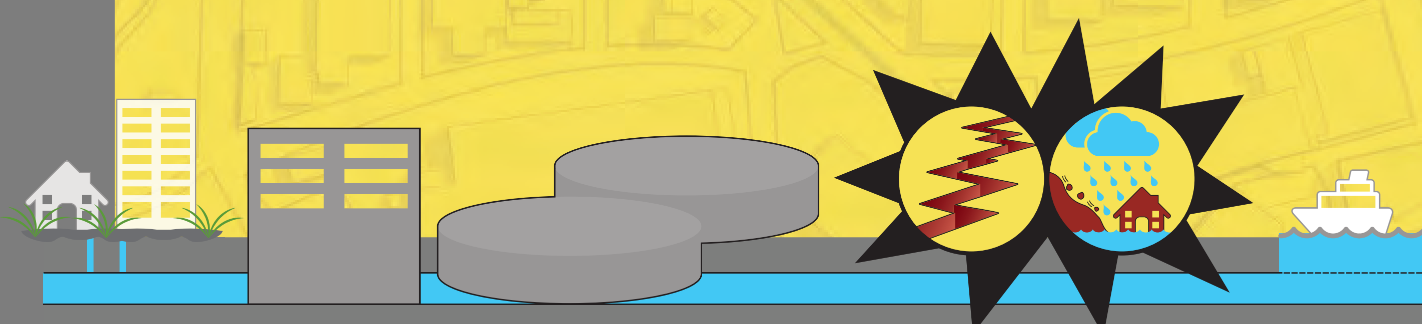
2018



King County

Department of
Natural Resources and Parks
Wastewater Treatment Division

Task 600 Resiliency Recommendations

April 2018

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- Task 600, Resiliency Recommendations Report
- Appendix B – Task 200 Additional Hazards TM
- Appendix C – Task 400 Conceptual Mitigation/Costs

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- Appendix A – Task 200 Seismic TM (geotechnical)
- Appendix B – Task 200 Additional Hazards TM (landslides)
- Appendix C – Task 400 Conceptual Mitigation/Costs (geotechnical)

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- Task 600, Resiliency Recommendations Report
- Appendix B – Task 200 Additional Hazards TM (tsunami and flooding)
- Appendix C – Task 400 Conceptual Mitigation/Costs (tsunami and flooding)

I hereby certify that the above listed sections of the E00425E16 Recommendations to Enhance the Resiliency and Recovery of King County's Regional Wastewater Treatment Facilities report were prepared by me or under my direct supervision, and that I am a duly registered engineer under the laws of Washington State.

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Alternate Formats Available

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List of Acronyms

CIP	Capital Improvement Project
County	King County
CSO	Combined Sewer Overflow
DAT	Damage Assessment Team
DIRECT	Division Incidence Response and Emergency Coordination Team
DNRP	Department of Natural Resources and Parks
ECC	Emergency Coordination Center
ESJ	Equity and Social Justice
FEMA	Federal Emergency Management Agency
HMGP	Hazard Mitigation Grant Program
ICS	Incident Command System
IT	Information Technology
NIMS	National Incidence Management System
O&M	Operations and Maintenance
PRA	Public Records Act
PW	FEMA Project Worksheets
RCW	Revised Code of Washington
SCADA	Supervisory Control and Data Acquisition
WTD	Wastewater Treatment Division

Executive Summary

The King County (County) Wastewater Treatment Division (WTD) proactively addresses risks associated with natural and man-made disasters through both preparedness and mitigation activities. The efforts align with the King County Strategic Plan, which envisions "*a diverse and dynamic community with a healthy economy and environment where all people and businesses have the opportunity to thrive*." This broad County-level vision compels each County agency and department to consider the long-term ramifications of a major catastrophe or natural disaster on the health and welfare of County residents, visitors, employees, customers, and the communities served. In 2013, the King County Executive launched the "Resilient King County" initiative which directly supports the Strategic Plan by recognizing the County's responsibilities to assess WTD's ability to survive and respond to natural disasters in a way that maintains, to the extent possible, its primary goal of protecting the public from the negative impacts of uncontained and untreated wastewater.

This document, *Resiliency Recommendations*, is the first of two reports comprising the *Recommendations to Enhance the Resiliency and Recovery of King County's Regional Wastewater Treatment Facilities*. Technical appendices to this *Resiliency Recommendations* report provide detailed explanations of the approaches, assumptions, findings, and resulting mitigation concepts. The second document, *Preparedness and Recovery Recommendations*, provides preparedness strategies for WTD's recovery from a large-scale event and is presented under separate cover.

In December 2016, WTD began the planning effort to model and assess natural hazard risks of concern to WTD facilities and pipelines in its service area, with the goal of identifying, mitigating, and recovering from system-wide impacts. These hazards included significant seismic, liquefaction, landslide, flooding, and extreme weather events, and required a definition of WTD's critical facility components and service goals, considering four major criticality factors: life safety, public health, consequent damage, and the environment. This study used desktop assessments to determine the highest risk facilities (based on their probability of failure and consequence of failure) to prepare initial risk ratings and identify sites for additional screening, including field assessments for seismically induced hazards.

The Project Team conducted a pro-equity analysis guided by the goals of the County's Equity and Social Justice (ESJ) Strategic Plan. The pro-equity analysis focused on finding bias or structural racism in the project recommendations, and created an ESJ Vulnerability Index to demonstrate which facilities were located in the communities where there is the greatest opportunity to address the determinants of equity. Areas of High Vulnerability rankings for ESJ were factored into project prioritization considerations and can be used to guide the County in tailoring response and recovery efforts for ESJ populations.

The findings from this study indicate that a major natural hazard event in the service area could result in portions of the wastewater system having downtimes ranging from a month to several years. This *Resiliency Recommendations* report recommends implementation of 52 conceptual mitigation strategies for capital improvement projects and programmatic initiatives to address these risks, provides planning-level costs for the strategies, and prioritizes their implementation. Some of these recommendations may require additional studies, while others require detailed design and cost-estimating; all are expected to require senior management support with respect to prioritization, resource allocation, and performance measurement to ensure efficient implementation, return on investment, reduction of risks, and improved organizational resiliency.

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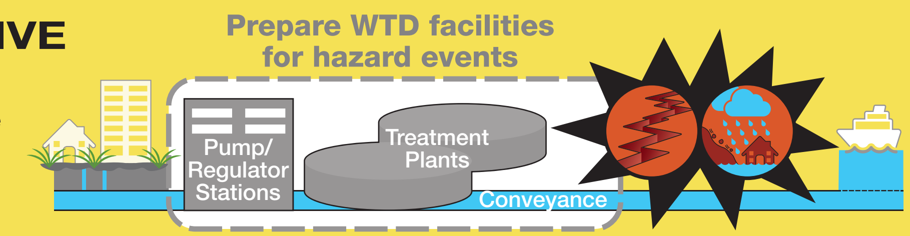
RESILIENCY & RECOVERY PROGRAM OVERVIEW

OBJECTIVE

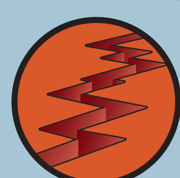


Develop a comprehensive strategy for preparing King County's Wastewater Treatment Division's (WTD) conveyance and treatment facilities for the impacts of a major earthquake, flooding, landslides or extreme weather events.

The intent of this project is to:

1. **Identify risks** in WTD's collection and treatment systems from natural hazard related damage.
2. **Identify mitigation actions** that can be taken before and after an emergency event to reduce impacts on the system.
3. **Develop remediation and resilience strategies** for the benefit of ratepayers, system partners, employees, and residents.

HAZARDS



Seismic/Liquifaction Scenarios

Cascadia Subduction Zone (CSZ)
- Magnitude 9.0
- Approximately 500-year recurrence interval

Seattle Fault (SF)
- Magnitude 7.2
- Approximately 5,000- to 6,000-year recurrence interval

South Whidbey Island Fault (SWIF)
- Magnitude 7.4
- Approximately 4,000- to 5,000-year recurrence interval

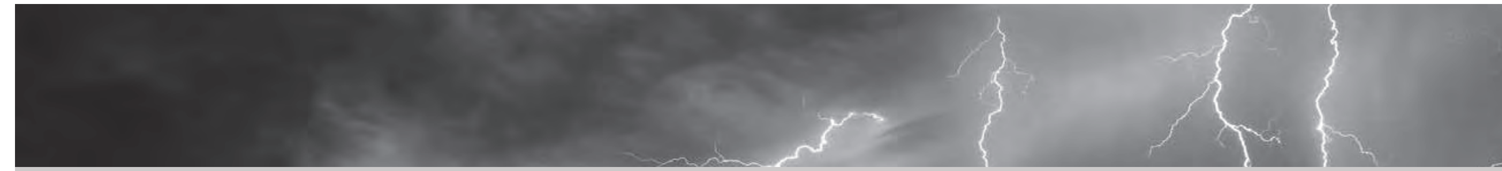
Natural Hazards

Extreme Weather
- Windstorms, lightning, tornadoes/funnel clouds
- Significant snowfall, ice, and/or freezing rain

Flooding
- Riverine, Urban, and Mechanical Flooding

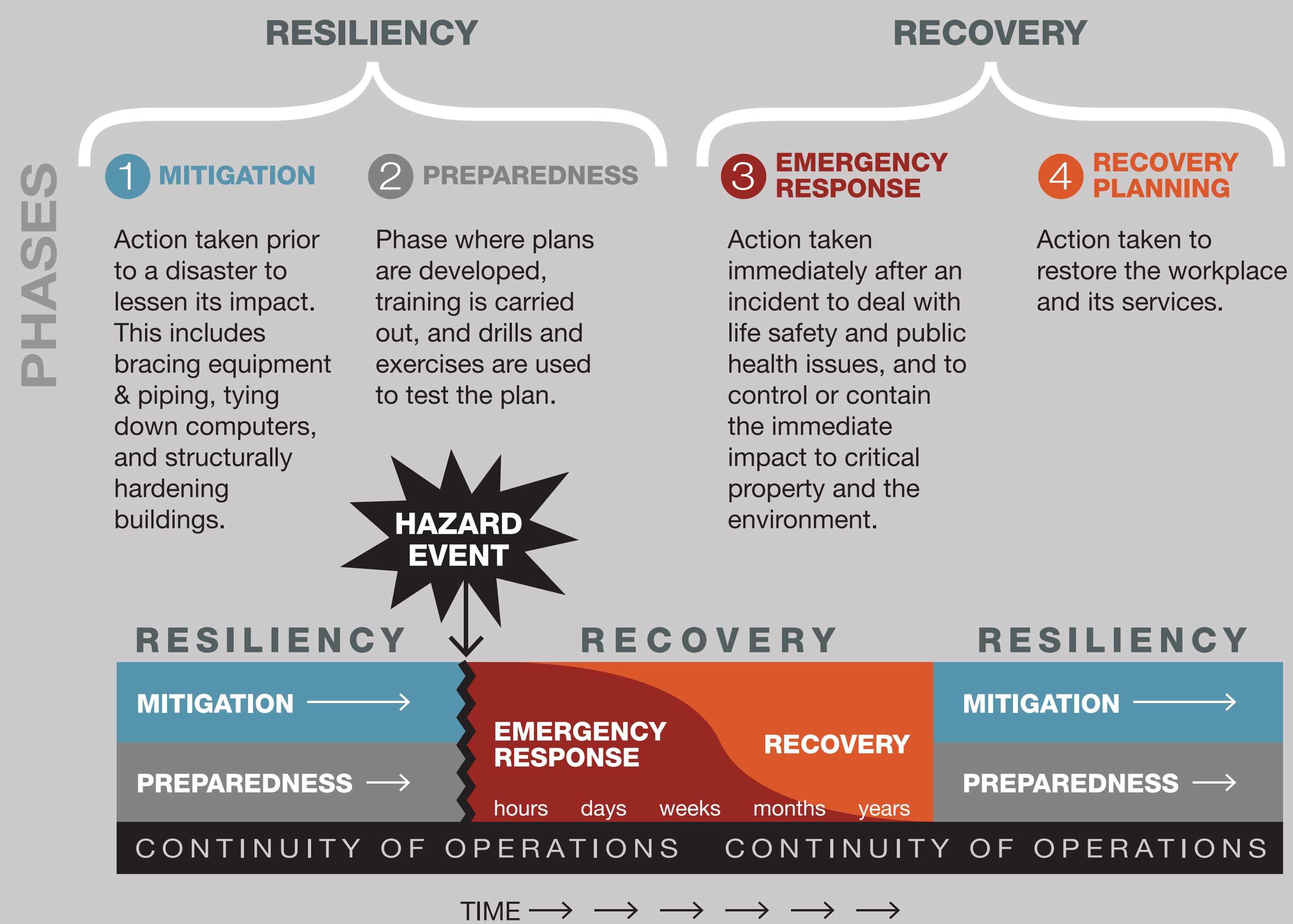
Landslides

Tsunami (SF)



EMERGENCY PREPAREDNESS

Recovery operations begin as soon as possible after a disaster. There is no clearly defined separation between response and recovery. In essence the recovery document is an extension of the emergency response plan. It explains how the organization will reinforce its initial responders, repair damage and work towards the restoration of services. Depending on the severity of the disaster and extent of the damage, recovery could take months or even years.



KING COUNTY WASTEWATER TREATMENT DIVISION (WTD) RESILIENCY & RECOVERY PROGRAM

King County
Department of Natural Resources and Parks
Wastewater Treatment Division

WTD FACILITY ASSESSMENT

SYSTEM OVERVIEW

WTD serves **1.7** million people and growing...

WTD's Service Area is **424** square miles

FACILITIES

- **3** Regional Wastewater Treatment Plants
- **2** Smaller Wastewater Treatment Plants
- **47** Pump Stations
- **25** Regulator Stations
- **4** Combined Sewer Overflow (CSO) Treatment Facilities
- **1** Community Septic System
- **391** Miles of Sewer Pipes

IDENTIFYING AND ASSESSING FACILITIES

1. **Collected Data** about all WTD facilities.
2. **Performed Desktop Evaluation** and identified deficiencies that may require further investigation or hazard mitigation.
3. **Ranked Risks** and prioritized the most critical facilities for more detailed field investigations.
4. **Completed Field Investigations** for high risk facilities to yield insights to probable damage from significant hazard events in WTD service area.

1 Collect data

- Facility Name
- Address and Coordinates
- Construction Date, Type, and Design Code
- Floor Area and Foundation Type
- Previous hazard mitigation implemented
- 100-year and 500-year Floodplain
- Tsunami Inundation Extents
- Facility Rim Elevations
- Topographic Controls
- Landslide Hazard
- Severe + Extreme Weather Reports
- Liquifaction Hazards

2 Perform Desktop Evaluation

- Reviewed relevant and available existing information on WTD facilities.
- Reviewed staff validation metrics
  - a. Peak Capacity
  - b. Storage time
  - c. Overflow location
  - d. Public impact
  - e. Service to other facilities
  - f. Flexibility
- **Seismic** - Primary tool used for desktop evaluation: FEMA 154 RVS (Federal Emergency Management Agency [FEMA] 154: Rapid Visual Screening [RVS] of Buildings for Potential Seismic Hazards).
- **Flooding & Tsunami, Landslide, and Extreme Weather** – GIS used to map potential hazards and determine risk ratings.

3 Rank Risks

Used risk ratings (low-high) and criticality categories to prioritize facilities for further investigation.

RISK = Probability of Failure x Consequence of Failure

Criticality Categories

- Life Safety
- Public Health
- Consequent Damage
- Environmental Impact

4 Complete Seismic Field Investigations

Using standardized facility checklist, experience-based judgement was exercised to interpret risk and associated deficiencies in the following areas:

- Structural
- Architectural
- Mechanical/Electrical

Risk rating was identified for the structural, mechanical and electrical systems.

High-level hazards evaluation provided expectations with respect to anticipated loss.

KING COUNTY WASTEWATER TREATMENT DIVISION (WTD) RESILIENCY & RECOVERY PROGRAM

King County
Department of Natural Resources and Parks
Wastewater Treatment Division

WTD FACILITY MITIGATION PRIORITIZATION AND RECOMMENDATIONS

Conceptual Mitigation and Cost Development Phase

A two-day collaborative brainstorming and development exercise was conducted to produce strategies based on the function of the various types of mitigation needs for high-risk facilities.

Opportunities were identified to reduce risk:

- Using standardized methodology and documentation process
- Implementing cross-discipline and cross-hazard-type coordination by:
  - Project Hazard Assessment Leads
  - Discipline-Specific Technical Leads
  - Cost Estimators

Work Products

- Conceptual Designs for Mitigation Improvement
- Class 5 Conceptual Cost Estimates
- Summary Matrix

Additional Mitigation Prioritization Efforts

Staff Validation: Aggregate scores were designated for each off-site facility and included the following parameters: peak capacity, storage time, overflow location, public impact, service to other facilities, and flexibility. For mitigation concepts located in regional treatment plants, primary treatment structures were prioritized higher in the capital improvement program.

Public Health Analysis: The system was analyzed by identifying facilities with no overflow points where failure would result in a potential backup of sewage. These facilities were then elevated in priority.

Equity and Social Justice (ESJ) Analysis

The Project Team conducted a pro-equity analysis focusing on two areas:

1) Conducting statistical examination to find bias or structural racism throughout the Capital Improvement Project (CIP) identification process, and
2) Creating an ESJ Vulnerability Index to prioritize CIPs moving forward. Facilities found to meet five or more indicators were also elevated in priority.

Equity and Social Justice Indicators:

- Average Income (Income/Household Size)
- Education
- Poverty Level
- 65+ Years Old
- Disabled
- Language
- Non-US Born
- Renter
- Race

Results + Recommendation

A total of 52 conceptual recommendations for capital and programmatic mitigation projects were prepared that would increase system-wide resiliency.

- **17** Seismic Structural
- **10** Seismic Liquefaction
- **1** Landslide
- **8** Flooding
- **5** Programmatic Improvement Projects
- **11** Recommendations for Further Study

MOHAI, Seattle Post-Intelligencer Collection, 1986.5.2356.2

KING COUNTY WASTEWATER TREATMENT DIVISION (WTD) RESILIENCY & RECOVERY PROGRAM

King County
Department of Natural Resources and Parks
Wastewater Treatment Division

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1 Introduction

1.1 Background and Goals

King County Wastewater Treatment Division (WTD) proactively addresses risks associated with natural and man-made disasters through both preparedness and mitigation activities. In December 2016, WTD contracted the HDR Team to provide assistance in the development of a comprehensive strategy to prepare WTD conveyance and treatment facilities for the probable impacts of natural disasters. The specific disasters considered during development of this planning effort for resiliency and recovery included seismic, liquefaction, landslide, flooding, tsunami, and extreme weather events. By identifying the likelihood of impacts and the potential consequences these hazards could create, the Team was able to define relative risks for WTD's facilities, supervisory control and data acquisition (SCADA) and pipeline systems, and work with the County to validate and prioritize the findings on a system-wide basis. With the understanding of the highest priority risks in the system, the Team developed mitigation concepts and associated conceptual level costs for both Capital Improvement Project (CIP) and Programmatic recommendations that are intended to help WTD survive and recover from natural disasters.

Expected Benefits from Implementation of the *Resiliency Recommendations* Report

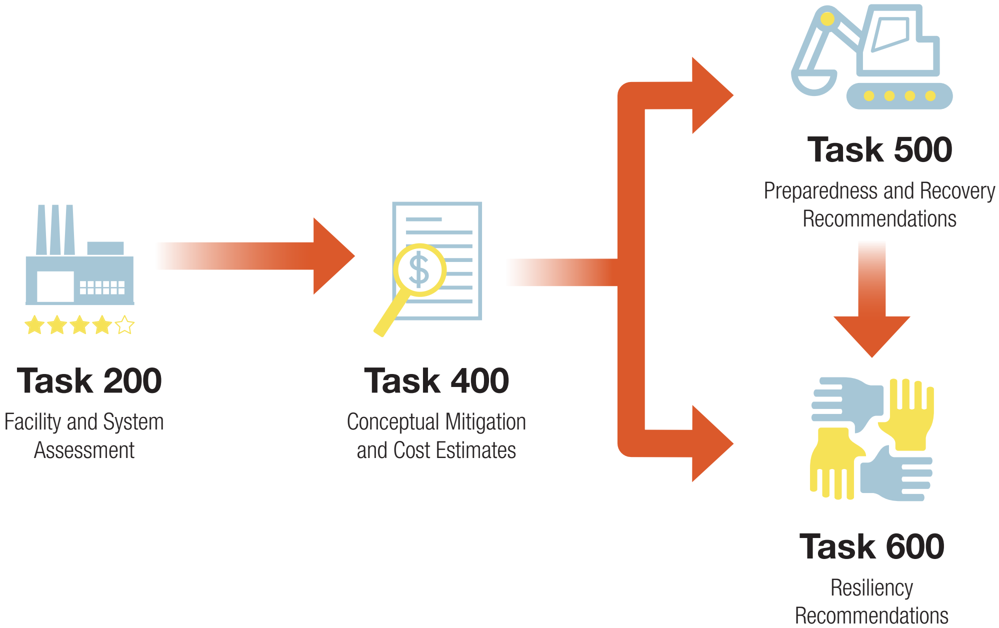
1. Minimization of injury or loss of life among WTD staff.
2. Minimization of public health risks following a disaster by improvement in facility resiliency and more rapid recovery.
3. Reduction in the expected cost of recovery by, where possible, mitigating identified weaknesses prior to a disaster.
4. Improved ability to accomplish post-disaster continuity of operations and long-term system restoration.

1.2 Report Structure

Two reports comprise the *Recommendations to Enhance the Resiliency and Recovery of King County's Regional Wastewater Treatment Facilities*.

- This document, *Resiliency Recommendations*, provides a high-level overview of the approaches used to analyze, prioritize, and mitigate risks to WTD's system, along with recommendations for capital and programmatic improvements. The technical appendices to this *Resiliency Recommendations* report provide detailed explanations of the approaches, assumptions, findings, and resulting recommendations.
- The companion document, *Preparedness and Recovery Recommendations*, provides preparedness strategies for WTD's recovery from a large-scale event and is presented under separate cover.

A schematic of the major components of the overall planning effort, including this *Resiliency Recommendations* report (Task 600) is provided in Figure 1.

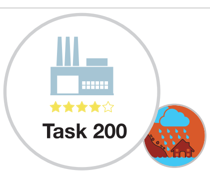
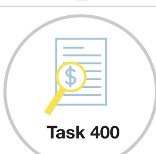


**Note regarding tasks not shown: Task 100 is Project Management, and Task 300 is a related, but separate Digester Inspection effort that will be completed after the West Point Treatment Plant digesters are accessible for inspection. The Task 300 Final Report will provide recommendations for improvements specific to the digesters.*

Figure 1. Resiliency Project Work Plan and Sequence

Table 1 provides a guide to the Technical Memoranda located in the appendices of the *Resiliency Recommendations* report (Task 600). The Technical Memoranda provide detailed explanations of the hazard scenarios, system characteristics and assumptions, criticality factors, risk analyses, conceptual mitigation development, and prioritization efforts that informed the *Resiliency Recommendations* report.

Table 1: Resiliency Recommendations Report Technical Memoranda (Appendices)

	Topics and Section Numbers	Key Features of Technical Memoranda
 Task 200	Task 200 Facility Resiliency Review (Seismic) Technical Memorandum	• Focuses on the critical societal functions that the wastewater system provides and goals for delivering those functions following a natural disaster • Explains how seismic hazards were quantified to provide a basis for evaluating the system components' vulnerabilities • Describes the facility desktop risk evaluation process and the vulnerability field analysis • Explains probabilistic assessment to identify pipelines with the highest risk and provides findings of the assessment • Presents risk findings prioritized on a system-wide basis
 Task 200	Task 200 Facility Resiliency Review (Flooding/Tsunami, Landslide, Extreme Weather) Technical Memorandum	• Same as above (Task 200 Seismic); however, does not include a vulnerability field analysis
 Task 400	Task 400 Conceptual Mitigation and Costs Technical Memorandum	• Describes development approach and provides concept-level suggestions for resiliency improvements and concept-level costs to address the highest priority system risks for all hazards

2 Risk Assessment Approach

The planning effort began with a review of relevant background information, including: WTD system information; seismic, geotechnical, landslide, flood hazard, and extreme weather reports; emergency response and recovery plans; and the County's ESJ Plan.

The Team provided input and reviewed Geographic Information System (GIS) map overlays. The overlays prepared by the County combined WTD facilities and each of the following hazard scenarios:

- Seismic:
    - Cascadia Subduction Zone, Magnitude 9.0
    - Seattle Fault, Magnitude 7.2
    - South Whidbey Island Fault, Magnitude 7.4
- Flooding and Tsunami:
    - 100-Year Recurrence Interval Flooding
    - 500-Year Recurrence Interval Flooding
    - Mechanical Failure-Induced Flooding
    - Tsunami Inundation Associated with the Seattle Fault Scenario
- Landslides Caused by Earthquakes
- Extreme Weather:
    - Tornadoes
    - Damaging Winds
    - Large Hail Events

Figure 2 shows WTD's service area boundary and the facilities (by type) and pipelines that were assessed. Using the GIS map overlays and resulting data quantifying hazard concerns by facility, desktop risk assessments were performed to identify the individual facilities within WTD's system posing the greatest risks under each hazard scenario. The risk ratings were developed based on the facility likelihood of failure (LoF) and consequence of failure (CoF) during the specified event.

Individual LoF values were determined using the GIS data developed to define the scenarios, combined with facility characteristics indicative of vulnerabilities to each particular hazard. For example, characteristics such as age provided insights to design-code standards for a facility and its expected ability to withstand the hazard scenarios; type of building materials allowed for a high-level durability judgment; and the presence of below ground equipment indicated particular vulnerabilities to riverine and mechanical flooding.

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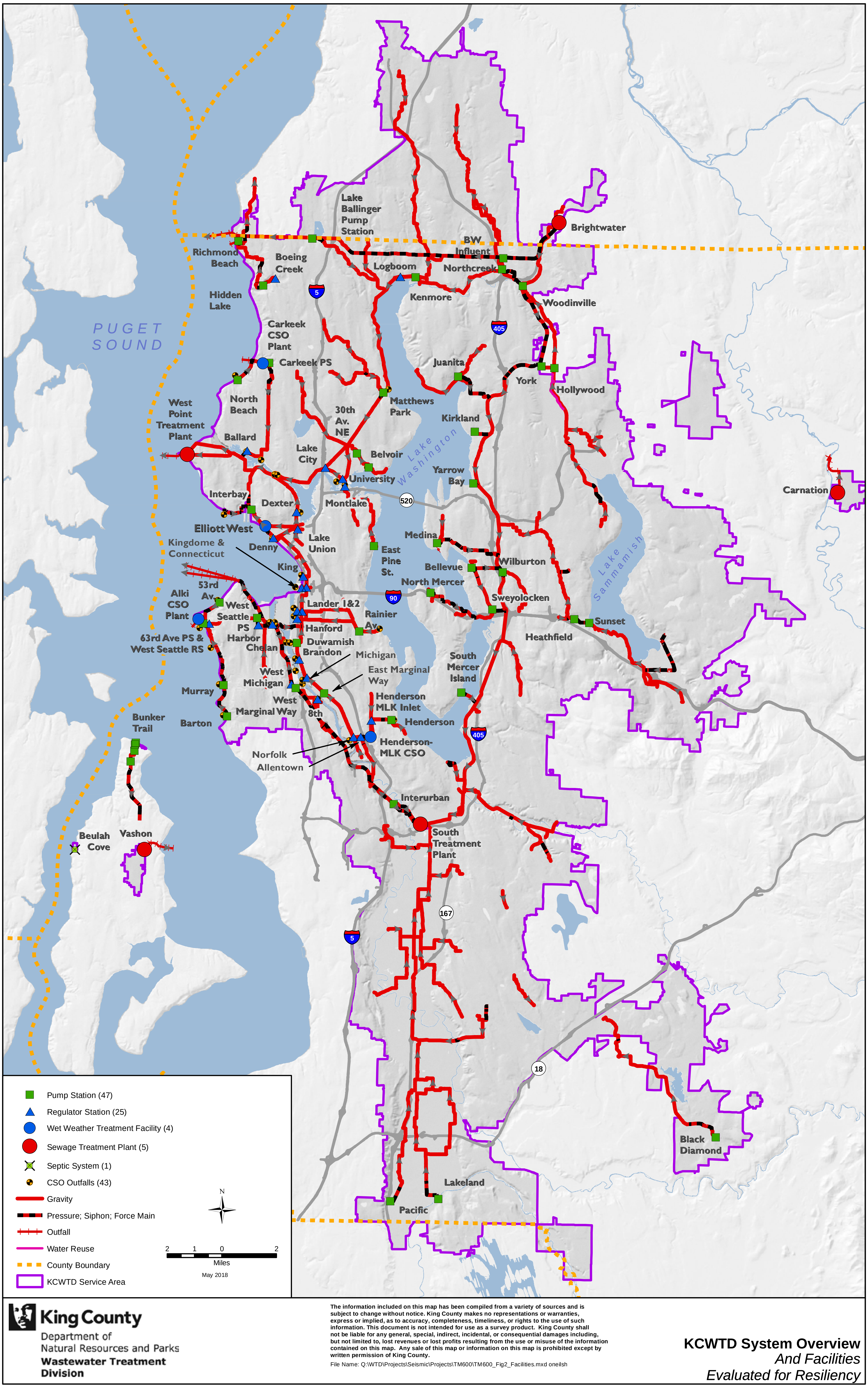

Figure 2. KCWTD System Overview and Facilities Evaluated for Resiliency

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The primary tool used for the **seismic** desktop evaluation was the *Federal Emergency Management Agency (FEMA) 154: Rapid Visual Screening (RVS) of Buildings for Potential Seismic Hazards (FEMA 154).* This national standard provides systematic screening and evaluation procedures to identify potential seismic deficiencies that may require further investigation or hazard mitigation. Based on the seismic performance of buildings in previous earthquakes, these standards provide criteria specific to each common building archetype, the structural configuration, and characteristics of the specific facility, and the seismic hazard at each facility site. Pipelines were assessed using a modified American Lifelines Alliance (ALA) Seismic Fragility Formulation for Water Systems methodology. Because the ALA methodology was developed for water lines, modifications were required to address WTD's gravity pipelines as well.

Although the evaluation process for the **flooding, landslide, and extreme weather** assessments was similar to that of the RVS process for potential seismic hazards and was applied in a consistent, documentable manner, no industry-standard tool such as the *FEMA 154* guideline exists to assess these hazards. The process included an understanding of geographic susceptibility to the hazard in question and facility characteristics that could indicate vulnerability.

Using the *FEMA 154* guideline and other desktop assessment procedures, each of the 47 pump stations, 25 regulator stations, and 4 combined sewer overflow (CSO) treatment facilities were evaluated. Two of the three regional wastewater treatment facilities, West Point Treatment Plant (WPTP) and South Treatment Plant (STP) and two small wastewater treatment facilities were not evaluated in the desktop exercise as they were pre-determined to be categorically important and automatically considered for additional detailed field investigations. The third regional wastewater treatment facility, Brightwater Treatment Plant (BWTP) was not evaluated because it is a newer treatment plant that was designed using current seismic standards, with one exception – the Administration Building at BWTP is an older building. A more thorough *ASCE 41-13: Seismic Evaluation and Retrofit of Existing Buildings (ASCE 41)* Tier 1/2/3 Seismic Evaluation is recommended for this building. The 39 combined sewage overflow outfalls and the community septic system were not evaluated using *FEMA 154* or other RVS procedures due to their lower post-earthquake criticality relative to the other facilities when considering system-wide performance.

Consequence of failure was determined considering criticality factors as defined and prioritized in the scope of work for this study. These factors, in order of priority, are as follows:

- Life Safety – related to building collapse
- Public Health – related to potential for human contact with raw sewage
- Consequent Damage – related to potential failure impacts on adjacent critical infrastructure
- Environmental Impact – related to discharge of raw or inadequately treated wastewater prioritized from high to low criticality into: 1) ditches or streams; 2) rivers flowing into lakes; 3) lakes; 4) rivers flowing into Puget Sound; and 5) Puget Sound.

Consequence of failure also considered the criticality rating rubric scores developed by King County using the following parameters:

- Peak Capacity
- Storage Time
- Overflow Location
- Public Impact

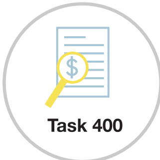
- Services to Other Facilities
- Flexibility

These same criticality factors were used to help quantify recommended restoration times for expected system performance.

The desktop **seismic** assessment results were used as a preliminary indication of risk ratings and guided the selection of sites for additional field screening to supplement gaps in information and to verify inconclusive data. After completing the desktop assessments for the **flooding, landslide, and extreme weather** hazards, no further field screening was performed because the vulnerabilities were adequately defined in the desktop assessment.

Seismic risk assessments were conducted in the field for the 21 highest risk off-site facilities (pump stations and CSO treatment facilities), 10 highest-risk WPTP facilities and 6 highest-risk STP facilities, as identified through the desktop evaluation and collaborative workshops. These 37 individual facilities were evaluated using the *ASCE 41* Tier 1 Checklists methodology (Tier 1 Checklists), the industry standard of care for performing seismic evaluations of buildings and determining seismic rehabilitation techniques, combined with experience-based evaluation techniques from the structural and seismic team-members' professional knowledge. In conjunction with the seismic field investigations, mechanical, electrical, and plumbing investigations were performed by team specialists using checklists they developed similar to the *ASCE 41* Tier 1 Checklists, based on the *American Society of Engineering (ASCE) Technical Council on Lifeline Earthquake Engineering Monograph No. 22* and their professional experience.

Appendix A and Appendix B provide Technical Memoranda detailing the work and results of the Task 200 risk assessments.



3 Conceptual Mitigation and Cost Development Approach

Together with the County, the Team conducted a Conceptual Mitigation Design and Costs Workshop for the seismic, landslide, flooding, tsunami, and extreme weather events evaluated in earlier tasks. This 2-day collaborative work session included the project's hazard assessment leads, discipline-specific technical leads, and cost estimators. It was conducted to develop concepts to address issues identified in the Task 200 assessments using a standardized methodology and documentation process, and to provide opportunities for cross-discipline and cross-hazard-type coordination.

Facilitators led a workshop where teams of conceptual designers and cost estimators created mitigation concepts from ideas developed and vetted with WTD prior to the workshop. Each of the mitigation concepts was entered into a standardized template during the development phase of the workshop to produce similar products across the teams with the same level of detail and documentation standards. Several technical experts moved among the teams, providing insights and advice as needed, sharing relevant ideas and findings across the groups, and ensuring a degree of consistency in the completion of the concept mitigation forms. A County representative served on each of the three teams to provide system information, discuss feasibility of solutions, and help with concept development and quantities used in cost estimating. Using high-level parametric cost estimates that were developed prior to the workshop, the cost estimators worked closely with the technical specialists to produce conceptual estimates for the mitigation solutions.

Sixty-five issues had been brought forward from the hazard assessment phase of the project into the conceptual solution development phase. In the process of developing solutions and costs, most projects remained as stand-alone efforts; however, others were combined or eliminated on further examination in the workshop setting. Reasons for these changes included the identification of mitigating factors that weren't apparent earlier and findings that a project already under design would address the issue.

Recognizing that in July 2017, AECOM conducted an important independent assessment of the WPTP flooding incident, alignment between the independent assessment findings and the Resiliency Recommendation report mitigation concepts was an important consideration. The independent assessment reviewed system-wide WPTP processes and evaluated major functions and components before providing potential mitigation strategies and overall recommendations to improve resiliency. These suggestions are specific to WPTP; however, many may apply to the WTD system as a whole and may be relevant to response and recovery improvements at STP and BWTP in particular. WPTP will be moving forward with implementation of resiliency improvements as a result of the independent assessment findings, and the *Resiliency Recommendation* report Team recommends that the strategies and recommendations from the AECOM report be considered during implementation of this report's resiliency initiatives. A summary of this report's resiliency conceptual mitigation designs by priority rating is provided in Section 4.4 of this document (Table 2).

Appendix C provides a Technical Memorandum detailing the work and the initial results of Task 400. The Technical Memorandum includes an attachment with the **complete set of Class 5 conceptual design and cost sheets** for each of the 52 recommendations that were finalized and prioritized for implementation in the final step of this project, as described in the next section.

Task 600

4 System-Wide Risk Findings Summary and Specific Recommendations

4.1 Facility Risk Findings

The overall system assessment yielded the following findings for the facilities evaluated, grouped by the project's established risk categories, as described below.

- **Life Safety** – six buildings (including administration, maintenance, and storage) were identified where staff is based in vulnerable areas. Life safety could be compromised if the buildings collapsed.
- **Public Health** – while the overflow of sewage to waterbodies is an *environmental* concern (see bullet below), two of the evaluated facilities were identified as cases where failure would result in the back-up of sewage into streets, ditches, or houses/property. Wastewater pipeline collapses could result in sewage backup and public health issues.
- **Consequent Damage** – potential locations were identified by evaluating the proximity of the wastewater pipeline and critical infrastructure systems within areas vulnerable to seismic liquefaction hazards. The highest risk locations are where wastewater pipelines are in close proximity to the BP liquid fuel pipeline (multiple crossings) and major Seattle Public Utility water supply lines from the Tolt (two crossings) and Cedar River Supplies (two crossings).
- **Environmental** – with vulnerable facilities and pipelines where failure could cause discharge into environmentally sensitive receiving waters throughout the system, it is difficult to keep the environmental risk low. The highest risk facilities are located in the Lake Sammamish and Lake Washington watersheds. If the sewage reaches the treatment plant facilities, they would likely be able to provide some basic level of treatment before discharging to Puget Sound (WPTP), or the Duwamish River (STP), but would not likely be able to meet current environmental standards for treatment before discharging. BWTP was recently designed and built to rigorous seismic design criteria and is not considered an environmental risk.

4.2 Pipeline Risk Findings

Results of the seismic desktop assessment indicate that under current conditions, approximately 15 catastrophic wastewater pipeline breaks are likely to occur in a Cascadia Subduction Zone event, and approximately the same number in the Seattle Fault Scenario. The number of breaks is likely to be fairly evenly distributed between gravity and pressure lines. The Task 200 Facility Resiliency Review (Seismic) Technical Memorandum in Appendix A of this *Resiliency Recommendations* report provides a table of pipe segments that are at risk for catastrophic failure.

4.3 Conceptual Project Recommendations

A total of 52 conceptual recommendations for capital and programmatic mitigation projects were prepared for the highest risk WTD facilities and pipelines, along with planning-level cost estimates for each. Figure 3 shows the location of recommended projects and identifies the hazard type(s) that each project is intended to mitigate.

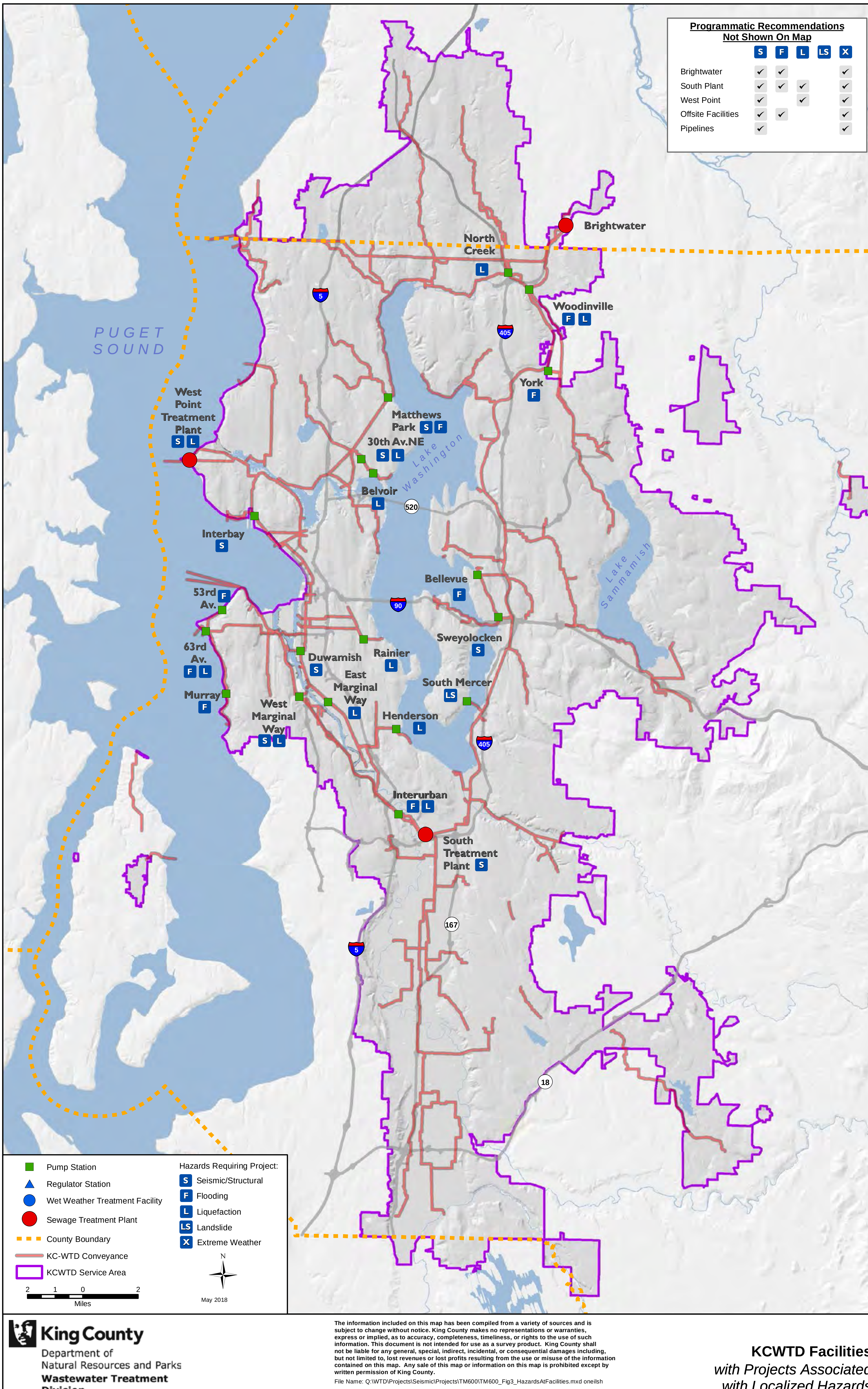


Figure 3. Facilities with Projects Associated with Localized Hazards

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4.4 Additional Prioritization Process and Results

Following the work of the Conceptual Mitigation Design and Costs Workshop, additional prioritization was conducted as outlined in the following three items:

- **Team validation –** In 2014, through a series of meetings, the WTD Engineering Unit Manager, West Office Assistant Manager, and East Office Assistant Manager developed criticality ranking criteria for WTD's off-site facilities. Appendix D provides this criticality information. Aggregate scores comprised the following parameters: peak capacity; storage; overflow location; public impact; service to other facilities; and flexibility. The intent of the 2014 work was to help focus recovery efforts in the event of a large-scale disaster and to determine facility criticality for asset management program needs. The 2014 work was used to validate the mitigation suggestions developed in the *Resiliency Recommendations* report. Scores were not assigned to mitigation concepts located in the regional treatment plants; rather, primary treatment structures were prioritized higher in the CIP.
- **Public health analysis –** The system was analyzed by identifying facilities with no overflow location where failure would result in a potential backup of sewage. Two facilities were identified as having no overflow locations: North Creek Pump Station and York Pump Station. These facilities were then elevated in priority.
- **Equity and Social Justice Analysis –** The Project Team conducted a pro-equity analysis focusing on two areas: (1) conducting statistical examination to find bias or structural racism throughout the CIP identification processes and (2) creating an ESJ Vulnerability Index to prioritize CIPs moving forward.

  The statistical examination, comparing facilities chosen for CIP's against those that were not chosen, showed that there was no implicit bias in choosing the potential CIPs. The results of the ESJ vulnerability analysis indicated project locations with the greatest opportunity to address determinants of equity. The Vulnerability Index scores range from 1-8. The facilities with scores greater than 5 were elevated in priority. The following facilities were further prioritized:

  - West Marginal Way Pump Station
  - Duwamish Pump Station
  - Henderson Pump Station
  - Interurban Pump Station
  - East Marginal Way Pump Station

  Appendix E provides a detailed explanation of the ESJ analysis and findings.

These additional efforts refined the prioritization of the capital and programmatic projects identified to increase WTD's system resiliency.

Table 2 lists the 52 recommended projects grouped by their implementation priority and provides concept identification numbers and titles. All projects on the list are of medium to high priority; those with a rating of "1" are the highest priority. For planning purposes, it should be noted that many of the programmatic projects listed are for more detailed assessments that may lead to additional capital projects.

Table 2. Conceptual Design/Programmatic Recommendations by Priority Rating

Project No.[1]	Priority Rating	Risk Rating	Concept Title	Criticality Factors[2]
Structural/Liquefaction Priority 1				
S-18	1	H	STP Operations Building Nonstructural Seismic Upgrades	E, LS, SD, SC
S-13a	1	H	WPTP Control Building Non-Structural Seismic Upgrades	E, LS, SD, SC
S-1	1	H	STP Influent Pump Station Structural Retrofits	E, LS, SD, FV
S-2	1	H	WPTP Raw Sewage Pump Station Structural Retrofits	E, LS, SD, FV
S-13b	1	H	WPTP Admin/Ops Center Structural Retrofits	E, LS, SD, SC
S-20	1	H	STP Maintenance Building Phase I Structural Retrofits	E, LS, SD
S-19	1	H	STP Santler Building Structural Retrofits	E, LS, SD
SP-1B	1	H	Conduct *ASCE 41* Tier 1/2/3 Seismic Evaluations - STP	E, LS, SD, FV
SP-1A	1	H	Conduct *ASCE 41* Tier 1/2/3 Seismic Evaluations - WPTP	E, LS, SD, FV
SP-1C	1	H	Conduct *ASCE 41* Tier 1/2/3 Seismic Evaluations - Brightwater	E, LS, SD, FV
SP-7	1	H	Programmatic Glass Block Upgrades	LS
Structural/Liquefaction Priority 2				
S-21	2	H	STP Effluent Pump Station Structural Retrofits	E, FV
S-14	2	H	WPTP Maintenance/Effluent Pump Station Structural Retrofits	E, SD
S-23	2	H	STP Digester Equipment Building Structural Retrofits	E, SD, FV
S-5	2	H	Duwamish Pump Station Structural Retrofits	E, SD, FV, ESJ
S-6	2	H	Matthews Park Pump Station Structural Retrofits	E, SD, FV, CR26
S-3	2	H	Interbay Pump Station Structural Retrofits	E, SD, FV, CR23
S-4	2	H	Sweylocken Pump Station Structural Retrofits	E, SD, FV, CR21
Structural/Liquefaction Priority 3				
S-16	3	MH	WPTP Hypo Mixing Structural Retrofits	E, FV
L-6	3	MH	Interurban Pump Station Liquefaction Retrofit	E, ESJ, CR23
S-10	3	MH	30th Avenue Pump Station Structural Retrofits	E, CR23
S-9	3	MH	West Marginal Way Pump Station Structural Retrofits	E, SD, ESJ, CR20
L-4	3	MH	West Marginal Way Pump Station Liquefaction Retrofit	E, SD, ESJ, CR20
L-9	3	MH	Henderson Pump Station Liquefaction Retrofit	E, SD, ESJ, CR20
L-11	3	MH	Rainier Avenue Pump Station Liquefaction Retrofit	E, SD, ESJ, CR19
SP-6	3	H	Programmatic Mechanical-Electrical-Plumbing Upgrades	E, SD
SP-8	3	MH	Develop Seismic Standards for King County Facilities	E, SD, FV
SP-9	3	MH	Develop Seismic Standards for King County Conveyance Facilities	E, SD, FV, CD
Structural/Liquefaction Priority 4				
L-5	4	MH	30th Avenue Pump Station Liquefaction Retrofit	E, SD, CR23
L-3	4	MH	63rd Avenue Pump Station Liquefaction Retrofits	E, SD, CR20
L-2	4	MH	North Creek Pump Station Liquefaction Retrofits	E, PH, SD, FV, CR18

Project No.[1]	Priority Rating	Risk Rating	Concept Title	Criticality Factors[2]
L-8	4	MH	Woodinville Pump Station Liquefaction Retrofit	E, SD, CR19
L-1	4	MH	Belvoir Pump Station Liquefaction Retrofits	E, SD, CR18
L-12	4	M	East Marginal Way Pump Station Liquefaction Retrofit	E, SD, FV, ESJ, CR22
SP-3	4	H	Conduct Additional Pipeline Evaluations	E, CD, SD, FV
LP-2	4	MH	WPTP Facilities Liquefaction Programmatic Assessment	E, SD, FV
LP-3	4	MH	STP Liquefaction Programmatic Assessment	E, SD, FV
SP-4	4	H	Evaluate/Seismic Monitoring Technologies	SD
SP-1D	4	H	Conduct *ASCE 41* Tier 1/2/3 Seismic Evaluations – Offsite Facilities	E, SD, FV
Structural/Liquefaction Priority 5				
LP-1	5	MH	Additional Liquefaction Susceptible Facilities Programmatic Assessment	E, SD, FV
Other Hazards Priority 1				
F-8	1	MH	Woodinville Pump Station Flood Protection Upgrade	E, SD, CR19
F-2	1	H	York Pump Station Flood Protection Upgrade	E, PH, SD, FV, CR23
F-1	1	H	Interurban Pump Station Flood Protection Upgrade	E, ESJ, CR23
FP-2	1	H	Programmatic Flood Risk Evaluations – Offsite Facilities	E, LS, PH, SD, FV
FP-1	1	H	Programmatic Flood Risk Evaluations – STP & BWTP	E, LS, PH, SD, FV
Other Hazards Priority 2				
F-4	2	H	Murray Pump Station Flood Protection Upgrade	E, SD, FV, CR25
F-6	2	H	63rd Avenue Pump Station Flood Protection Upgrade	E, SD, CR23
F-7	2	M	Bellevue Pump Station Flood Protection Upgrade	E, SD, CR19
F-5	2	MH	53rd Avenue Pump Station Flood Protection Upgrade	E, SD, CR19
F-3	2	M	Matthews Park Pump Station Flood Protection Upgrade	E, SD, FV, CR26
Hazards Priority 3				
LS-2	3	MH	S Mercer Pump Station	E, CR17
XP-1	3	M	Tree Trimming/Removal Assessment Programmatic Project	SD

Table Notes:

[1] Key:
- CD – Consequent Damage
- CR(#) – Criticality Rating Aggregate Score
- E – Environment
- ESJ – Equality and Social Justice
- FV – Flow Volume
- LS – Life Safety
- PH – Public Health
- SC – System Control
- SD – System Downtime

[2] Key:
- F – Flooding
- FP – Flooding, Programmatic
- L – Liquefaction
- LP – Liquefaction, Programmatic
- LS – Landslide
- S –Structural
- SP – Structural, Programmatic
- XP – Extreme Weather, Programmatic

5 Response and Recovery Planning Approach

The high-level hazard evaluations of this planning effort provided additional boundaries for recovery planning and expectations with respect to risk and anticipated loss. Through a series of meetings and workshops dedicated specifically to Response and Recovery Planning, the HDR Team and WTD staff collaborated to develop strategies, concepts, and processes, which they bundled into detailed recommendations for implementation. The resulting seven recommendations, along with implementation recommendations and planning-level costs, are provided in a companion document to this *Resiliency Recommendations* report, produced concurrently under separate cover (*Preparedness and Recovery Recommendations, April 2018*). Implementation of recommendations in the *Preparedness and Recovery* report is intended to further improve WTD's natural hazard resiliency.

Appendix A. Task 200 Facility Resiliency Review (Seismic) Technical Memorandum

A-1. Attachment Volume 1: Plates (Large Maps/Figures)

Note: The material for Attachment Volume 2 for the Task 200 (Seismic) Technical Memorandum is provided as an electronic file to King County's Project Management Division

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Task 200 Facility Resiliency Review (Seismic) Technical Memorandum

April 2018

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Alternate Formats Available

Call 206-477-5371 or TTY: 711

List of Acronyms

ALA	American Lifeline Association
ASCE	American Society of Civil Engineers
BWTP	Brightwater Treatment Plant
COF	Consequence of Failure
CMU	Concrete Masonry Unit
CP	Collapse Prevention
CSZ	Cascadia Subduction Zone
CSO	combined sewer overflow
FEMA	Federal Emergency Management Agency
GIS	geographic information system
IBC	International Building Code
LOS	Level of Service
LS	Life Safety
N/A	not applicable
NIST	National Institute of Standards and Technology
POF	Probability of Failure
PGA	Peak Ground Acceleration
PGD	permanent ground displacement
ROM	rough order of magnitude
RVS	rapid visual screening
SCADA	Supervisory Control and Data Acquisition
SF	Seattle Fault
SPU	Seattle Public Utilities
STP	South Treatment Plant
SWIF	South Whidbey Island Fault
WPTP	West Point Treatment Plant
WTD	Wastewater Treatment Division
WWTP	Wastewater Treatment Plants

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Executive Summary

King County Wastewater Treatment Division (WTD) proactively addresses risks associated with natural and man-made disasters through both preparedness and mitigation activities. WTD engaged this study to evaluate the following three significant seismic scenarios in the Pacific Northwest and assess probable impacts to WTD's critical facility components and service capabilities:

- Magnitude 9.0 Cascadia Subduction Zone (CSZ)
- Magnitude 7.2 Seattle Fault (SF)
- Magnitude 7.4 South Whidbey Island Fault (SWIF)

This technical memorandum describes the evaluation process undertaken in Task 200 (Facility Resiliency Review) which included a high-level seismic evaluation of WTD assets, including: 3 large wastewater treatment plants (WWTPs), 2 small WWTPs, 1 community septic system, 4 combined sewer overflow (CSO) treatment facilities, 25 regulator stations, 47 off-site pump stations, 39 CSO outfalls, and approximately 400 miles of wastewater pipelines.

This study used desktop assessments to determine the highest risk of 82 identified facilities (based on each facility's vulnerability and consequence of failure determinations) to prepare initial risk ratings and identify selected facilities for additional field screening. The field assessments and additional desktop assessments yielded insights on potential vulnerabilities and component damage that could occur from a significant seismic event in WTD's service area, as well as the expected system-wide impacts. These high-level seismic screenings were also used in subsequent tasks for recovery planning, system loss estimations, and the development of prioritized conceptual capital and programmatic improvements.

Through a series of iterative and collaborative workshops, the Consultant team and WTD staff co-developed the strategies, concepts, and processes to identify system-wide risk categories, which were prioritized as follows:

- Life Safety – related to building collapse
- Public Health – related to potential for human contact with raw sewage
- Consequential Damage – related to potential wastewater pipeline failure impacts on adjacent critical infrastructure
- Environmental Impact – discharge of untreated or inadequately treated wastewater. Environmental impacts were prioritized based on the following discharge locations into a 1) ditch or stream, 2) river flowing into a lake, 3) lake, 4) river flowing into Puget Sound, or 5) Puget Sound. Of the major waterbodies (lakes and salt water), risk priorities from highest to lowest were given to Lake Sammamish, Lake Washington, Elliott Bay and Puget Sound.

Using the individual facility vulnerability/risk ratings, as well as the system-wide risk categories defined, the system components (facilities and pipeline segments) were evaluated and prioritized based on their risk to the overall system. Conceptual projects were developed as options for mitigating these risks. These projects were organized by service area (West Point service area, South Plant service area, and Brightwater service area) and by project type (e.g., capital improvement project, study, programmatic improvement project). They were also identified according to the risk categories (life safety, public health, consequential damage, and environmental impact) and prioritized accordingly. This preliminary list of recommended projects and identified deficiencies was subsequently used in Task 400 as the basis for the development of planning-level mitigation concepts and conceptual budgets. Ultimately, the conceptual information is intended to help the County to prioritize and begin planning implementation of the Task 600 *Resiliency Recommendations* report suggestions.

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1 Introduction

1.1 Project Background

King County (the County) protects water quality and public health in the central Puget Sound region by providing high-quality and effective treatment to wastewater collected from local sewer agencies. The County's Wastewater Treatment Division (WTD) serves about 1.5 million people within a 415-square-mile service area, which includes most urban areas of the County and parts of south Snohomish County and northeast Pierce County.

The County's wastewater system includes the following assets.

- Three large regional wastewater treatment plants (the West Point Plant in the City of Seattle, the South Plant in the City of Renton, and the Brightwater Plant near Woodinville)
- Two small wastewater treatment plants (one on Vashon Island and one in the City of Carnation)
- One community septic system (Beulah Park and Cove on Vashon Island)
- Four CSO treatment facilities (Alki, Carkeek, Mercer/Elliott West, and Henderson/Norfolk – all in the City of Seattle)
- Almost 400 miles of wastewater pipelines
- Twenty-five regulator stations
- Fourty-seven pump stations
- Thirty-nine CSO outfalls
- A regional Supervisory Control and Data Acquisition (SCADA) system providing regional and local control of facilities

On September 11, 2013, King County Executive Dow Constantine launched the "Resilient King County" initiative – a Countywide planning process for crafting a comprehensive long-term strategy for recovery following a major earthquake or other catastrophe.

The Resilient King County initiative seeks to establish a framework to assist individuals, families, businesses, and government to recover the community in a manner that sustains our physical, emotional, social, and economic well-being. This vision shall balance the need for rapid recovery with the deliberativeness required to meet the vision and value of our communities.

The Executive's initiative is based upon the recognition that WTD, as well as other agencies within the County, fulfills responsibilities to County residents to protect their health and safety during and after a disaster event. The purpose of this WTD *Recommendations to Enhance the Resiliency and Recovery of King County's Regional Wastewater Treatment Facilities* project was to assess WTD's ability to survive and respond to disasters in a way that maintains, to the extent possible, its primary goal of protecting the public from the negative impacts of uncontained and untreated wastewater.

The benefits to be realized from implementation of WTD's *Recommendations to Enhance the Resiliency and Recovery of King County's Regional Wastewater Treatment Facilities* project suggestions are intended to include the following:

- Minimization of injury or loss of life among WTD staff during an earthquake and in the response and recovery phases by improving the resilience of WTD facilities
- Minimization of public health risks following a disaster by improvement in facility resilience and more rapid resumption of conveyance and treatment operations
- Reduction in the expected cost of recovery by, where possible, mitigating identified weaknesses in the system to prevent damage when an earthquake occurs

- Improved ability to accomplish post-earthquake rebuilding and to expeditiously restore the system through consideration of long-term survivability and resiliency of WTD facilities

1.2 Facility Seismic Resiliency Task Overview

The flowchart depicted in Figure 1 provides an overview of the steps and methodology applied to execute the Task 200 Facility (Seismic) Resiliency Review task. This includes the following steps.

- *Step 1 - Data Acquisition:* Acquire the information required for the facilities and pipeline seismic evaluations, including WTD system information and the seismic hazard information.
  - The facility and pipeline information were provided by the County in the form of electronic databases, available record drawings, and previous studies that may be pertinent to the evaluation. As expected for a broad spectrum with hundreds of facilities that were constructed over several decades, not all of the desired information was available, but the project team utilized the available information to the extent possible for the high-level evaluations.
  - Based on the three seismic scenarios identified for the project, analyses were performed to prepare seismic hazard data to be utilized in the evaluations, including earthquake ground motion data (e.g., peak ground acceleration, peak ground velocity, and peak ground displacement) and ground failure hazard data (e.g., liquefaction and landslide susceptibility) across County systems. The seismic hazard development process is summarized in Section 3.
- *Step 2 - Facility Identification*: Identify the specific facilities and pipeline segments to be evaluated in the desktop evaluation. After obtaining the available system information and preliminary seismic hazard data, a workshop with WTD was conducted to clarify facility information (e.g., facilities with multiple names or missing information) and identify which facilities were to be evaluated. This was an iterative, collaborative process through the workshop and subsequent correspondence.
- *Step 3 – Initial Desktop Evaluation*: Perform the initial desktop evaluation of the pipelines and facilities. The desktop evaluation included the Rapid Visual Screening (RVS) methodology for identifying potential facility vulnerabilities, as described in Section 41.1. The desktop evaluation also included the American Lifeline Association (ALA) pipeline vulnerability evaluations, as described in Section 5. The output of this step was preliminary seismic vulnerability ratings for each facility for each of the three earthquake scenarios evaluated (i.e., CSZ, SF, SWIF).
- *Step 4 – High-Risk Facility Identification:* Identify facilities with high risk. The risk ratings are based on the probability of failure and the consequence of failure. Through a series of collaborative workshops, existing facility criticality ratings developed by WTD in 2014 were reviewed and refined for use in evaluating the relative consequence of failure of each of the facilities. Based on the discrete facility vulnerabilities identified in Step 3 and these preliminary criticality ratings, preliminary risk ratings were assigned for each facility and pipeline segment. The high-risk pipelines were identified for additional desktop evaluation; the high-risk facilities were prioritized and 30 specific facilities were identified for additional field assessments.
- *Step 5 – Field Assessments*: Refine the risk assessments. Using *ASCE 41-13* Tier 1 prescriptive checklists and supplemental discipline-specific guidelines, the structural, architectural, mechanical, and electrical systems were observed in the field to identify potential seismic hazard deficiencies. Following the prescriptive checks, system components were identified as compliant, non-compliant, non-applicable, or unknown. Section 4.2 provides a summary of the field assessments.
- *Step 6 – Additional Desktop Evaluation*: Finalize the risk assessments. The findings from the field assessments were reviewed. Based on the type, extent, and occurrence of the deficiencies identified, the vulnerability ratings were interpreted for the structural, architectural, mechanical, and electrical systems at each facility. These scores were weighted to determine overall facility vulnerability ratings. Additionally, the system-wide risk factors (e.g., life safety, public health, consequential damage, and environmental impacts) were considered to determine the risk of failure each facility would have on the overall system. The output of this process was a list of facilities that warrant seismic mitigation

projects, prioritized based on the system-wide risk. More detail on the system-wide assessments is provided in Section 6.

- *Step 7 – Recommended Project Development*: Identify high-risk items that should be advanced to the conceptual mitigation and cost development stage. After the deficient facilities were identified and prioritized, a collaborative process between the County and the Consultant identified opportunities to develop conceptual projects in a later step (Task 400) of this overall *Recommendations to Enhance the Resiliency and Recovery of King County's Regional Wastewater Treatment Facilities* project. These opportunities were organized by service area (West Point service area, South Plant service area, and Brightwater service area) and by project type (e.g., capital improvement project, study, programmatic improvement project). They were also identified according to the risk categories (life safety, public health, consequential damage, and environmental impact) and prioritized accordingly. This preliminary list of recommended projects and identified deficiencies is presented in Section 7.

1.3 Technical Memorandum 200 Context

It should be noted that that the findings of this Task 200 seismic evaluation report were subsequently used in Task 400 to develop more detailed capital improvement projects, and in Task 600 in the development of WTD's *Resiliency Recommendations* report. In these subsequent phases of the project, the recommended facility improvements and programmatic projects were reevaluated, reorganized, and reprioritized based on further analyses and feedback from the County. However, the findings of this technical memorandum are presented as they were contemporaneously determined in the Task 200 phase of work. Therefore, minor discrepancies may exist between this document and the Task 400/Task 600 findings. The WTD *Resiliency Recommendations* report should be reviewed for the finalized recommendations and recommended capital improvement project list.

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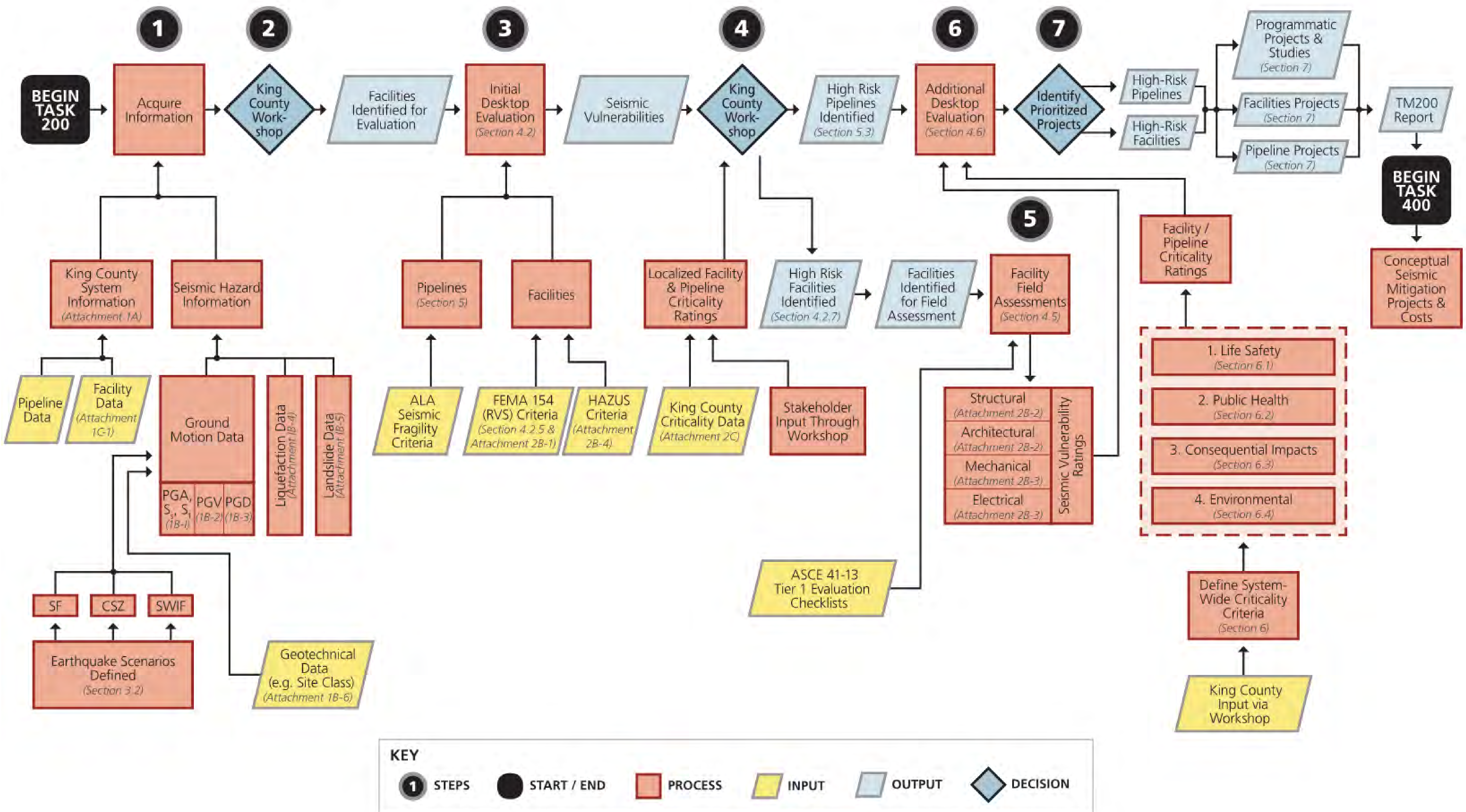

Figure 1: Task 200 - Facility Seismic Assessment Methodology Flowchart

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1.4 Technical Memorandum Overview

This technical memorandum describes the evaluation process undertaken in Task 200 addressing earthquake hazard resilience. The assessment was made for 3 treatment plants, 47 pump stations, 25 regulator stations, 4 CSO treatment facilities, 1 community septic system, 2 small wastewater treatment plants, and approximately 400 miles of wastewater pipelines, as identified by WTD at the onset of this work. CSO outfalls were only evaluated for their vulnerability to liquefaction, as this was determined to be the most relevant hazard of concern given the type of facility.

The sections of this technical memorandum include the following topics:

Table 1: Technical Memorandum Overview

Topic and Section Number	Explanation
Section 2: Risk Prioritization and Performance Criteria	This section provides an overview of the system-wide risk factors that were collaboratively developed in workshops by the Consultant and WTD. It also includes an overview of the performance criteria developed from previous resiliency studies.
Section 3: Seismic Hazards	This section provides an overview of the seismic hazards that were quantified to provide a basis for evaluating the system components' vulnerability. Three scenarios were identified based on three earthquake source zones in order to evaluate how the wastewater system would perform in each hazard event. The output from Section 3 was seismic ground motion and geotechnical data that was used for the evaluations performed on the facilities and wastewater pipelines.
Section 4: Facility Evaluations	This section provides an overview of the two-step facility seismic evaluation process. First, a desktop analysis was performed to determine the facilities with the highest seismic vulnerabilities that warranted a more detailed analysis. Based on facility criticality input from WTD operations staff, the facilities that presented the highest risk were selected for field investigations. Using seismic evaluation standards, expected seismic deficiencies were identified for each facility. Based on an interpretation of the potential impact of these identified deficiencies, the expected consequence of failure was estimated and each facility's vulnerability and risk rating was assigned.
Section 5: Pipeline Assessments	This section provides an overview of the pipeline seismic evaluation process. Specific pipeline locations considered to be vulnerable were identified in discussions with WTD staff and the consultant's knowledge of the system and pipeline vulnerability in past earthquake events.
Section 6: System Assessment	This section provides an overview of the risk assessment conducted considering the likelihood of occurrence, vulnerability, and consequence of failure of the system facilities and wastewater pipelines required to meet the performance goals.
Section 7: Findings and Recommendations	This section provides an overview of the recommended projects based on risk in the system facilities and pipelines.

2 Risk Prioritization and Performance Criteria

Recommended system performance criteria were established to provide a metric to measure the existing WTD system's performance following an earthquake and guide mitigation improvements. The criteria, presented in terms of system function restoration time, provided a basis to determine how resilient a system should be. This methodology is based on the Oregon Resilience Plan (earthquake only), and the National Institute of Standards and Technology's (NIST) Community Resilience Planning Guide for Buildings and Infrastructure (multi-hazard).

2.1 Risk Definitions

The following working definitions were used when evaluating risk:

- *Vulnerability* refers to a system or asset's weakness and the inability to withstand an adverse event.
- *Probability of Failure (POF)* combines vulnerability of a system or asset with the likelihood of an adverse event occurring and its severity.
- *Consequence of Failure (COF)* is the effect or outcome on a system or an asset from an adverse event.
- *Criticality* indicates relative importance; it is based on the Consequence of Failure (higher COF results in higher Criticality). Criticality can be lowered by the addition of protective devices, like redundant equipment, or a change in dependency, etc.
- *Risk* is the possibility of something undesirable happening. It is defined as the product of the POF and the COF. **Risk = (POF) x (COF**) where POF and COF are quantified based on reliable data and/or operational experience.
- *Level of Service (LOS)* defines the desired utility performance over time. The LOS considers operational, programmatic, managerial, financial, and regulatory requirements. A desirable LOS provides the amount and kind of service that meets regulatory requirements and is appropriate to the needs and desires of customers, but is not a financial threat to the utility's viability.

  Clear LOS goals for utilities are well defined, measurable, obtainable, and realistic. Clear goals provide a link between costs and service and are tracked so that people know what they are paying for and whether they are getting it. For example:

  - Breaks will be repaired within 6 hours of initiation of repair 95 percent of the time.
  - Customer complaints will be responded to within 24 hours, Monday through Friday.
  - The system will meet all state and federal regulations.

  "System Performance" was the surrogate for LOS, since formally defining LOS is not a part of this *Recommendations to Enhance the Resiliency and Recovery of King County's Regional Wastewater Treatment Facilities* project. Section 2.4 provides more detailed information on the Recommended System Performance.

2.2 Risk Evaluation Approach

Risk was used as a tool to prioritize the wastewater components and overall system functions, where risk is a function of the likelihood of failure and the consequences of that failure. As defined above, the risk was determined by POF and the identified COF. However, each of these risk factors had several components for this project, as depicted in Figure 2.

First, the POF considered the probability of earthquake occurrence for each defined scenario. Since three earthquake scenarios had been pre-defined (both in earthquake source and magnitude), there was an embedded probability of occurrence. As described in Section 3, there is an approximate statistical return period (the inverse of the probability of occurrence) associated with each of the selected scenarios (500-year return period for a M9.0 CSZ event, 5,000–6,000-year return period for a M7.2 SF event, and 4,000–5,000-year return period for a M7.4 SWIF event). However, it should be noted that the return periods identified are based on the selected scenario magnitude. The chosen scenario magnitudes are approximately the maximum expected event to be produced from each of the tectonic mechanisms. If a smaller magnitude were selected, the expected return period would reduce accordingly, but the probability of earthquake occurrence would remain constant for each earthquake scenario. Therefore, when comparing risk between scenarios and prioritizing risks, the return period was considered. That is, facilities vulnerable to damage or collapse in the more-frequent M9.0 CSZ scenario were weighted over facilities with an equivalent vulnerability to damage/collapse from the M7.2 SF Scenario or M7.4 SWIF scenario, due to the increased probability of occurrence of this event.

Secondly, the POF considered the vulnerability of each facility from the particular hazard characteristics identified for the associated earthquake scenario. More details on the evaluation tools and process for determining facility and pipeline vulnerabilities are provided in Section 4 and Section 5, respectively. The POF is the result of both the characteristics of the facility itself and the hazards presented by the particular earthquake. Using output from the evaluation tools used in this assessment, vulnerability and POF ratings were identified for each facility, and then used in determining the relative risk between facilities.

Thirdly, the local criticality or consequence of failure was identified for each facility. This represents the expected consequences that specific components' failures may have locally. Based on the vulnerabilities identified through the RVS process, as well as the deficiencies identified through the field assessments, consequences of failure were approximated for the structural, architectural, mechanical, and electrical systems. For example, if the structure has insufficient roof-to-wall connections, the consequence may be that the roof could collapse making the building inaccessible and inoperable; if a pipeline connection has a rigid connection, the consequence may be a pipeline fracture and flooding.

Finally, based on the local criticality or COF for each facility, a COF for the overall system was estimated. As described in Section 2.4 below, this system-wide COF was prioritized by the type of risk and consequences that may result from an individual facility's failure. For example, if an administration building suffered structural collapse, it would be a life safety risk to the building occupants; if an influent pump station were to collapse, it would primarily be a risk to the environment from untreated sewage discharge. However, a pump station failure could also represent a public health issue if the public was exposed to the flooding of raw sewage, or it could represent a consequential damage issue if the flooding interrupted traffic on a nearby public road. Additionally, the criticality of a particular facility to the performance of the overall system (e.g., the proportion of flow rate) and the interdependencies between system elements (e.g., a facility in the critical path of system operations) affected the system-wide COF factor.

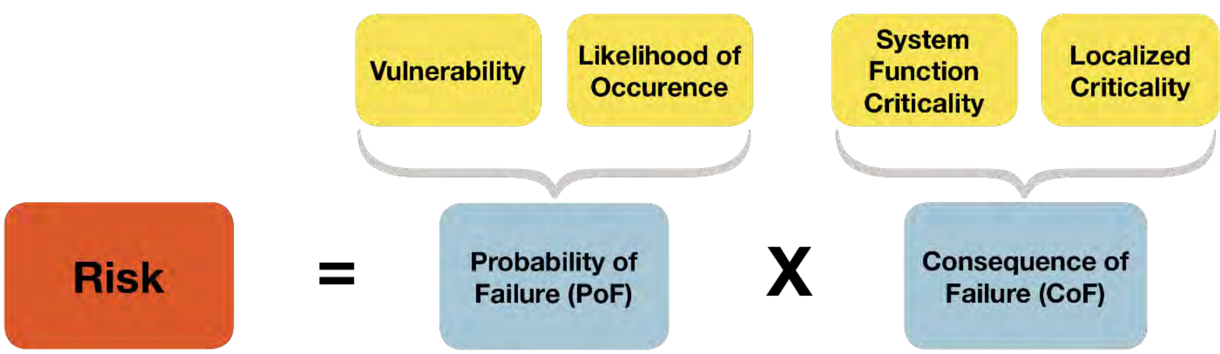

Figure 2: Risk Equation Components

2.3 Risk Prioritization

As described above, risk was determined by the POF and the identified COF that specific facilities, pipeline segments, and system components would have on the overall system. Through collaborative workshops, WTD and the project team identified four risk categories based on the type of consequences that failure would produce. Through a process to solicit input from various County stakeholders, consensus was achieved in the following prioritization of these four risks categories, as identified in Figure 3:

- *Life Safety* – collapse of buildings occupied by WTD staff and the public

- *Public Health* – potential for human contact with raw sewage (e.g., due to backup into basements or overflow into streets)
- *Consequential Damage* – significant impact on critical infrastructure adjacent to WTD facilities should they fail
- *Environmental Impact –* discharge of untreated or inadequately treated wastewater. Environmental impacts were prioritized based on the following discharge locations into a 1) ditch or stream, 2) river flowing into a lake, 3) lake, 4) river flowing into Puget Sound, or 5) Puget Sound. Of the major waterbodies (lakes and salt water), risk priorities from highest to lowest were given to Lake Sammamish, Lake Washington, Elliott Bay and Puget Sound.

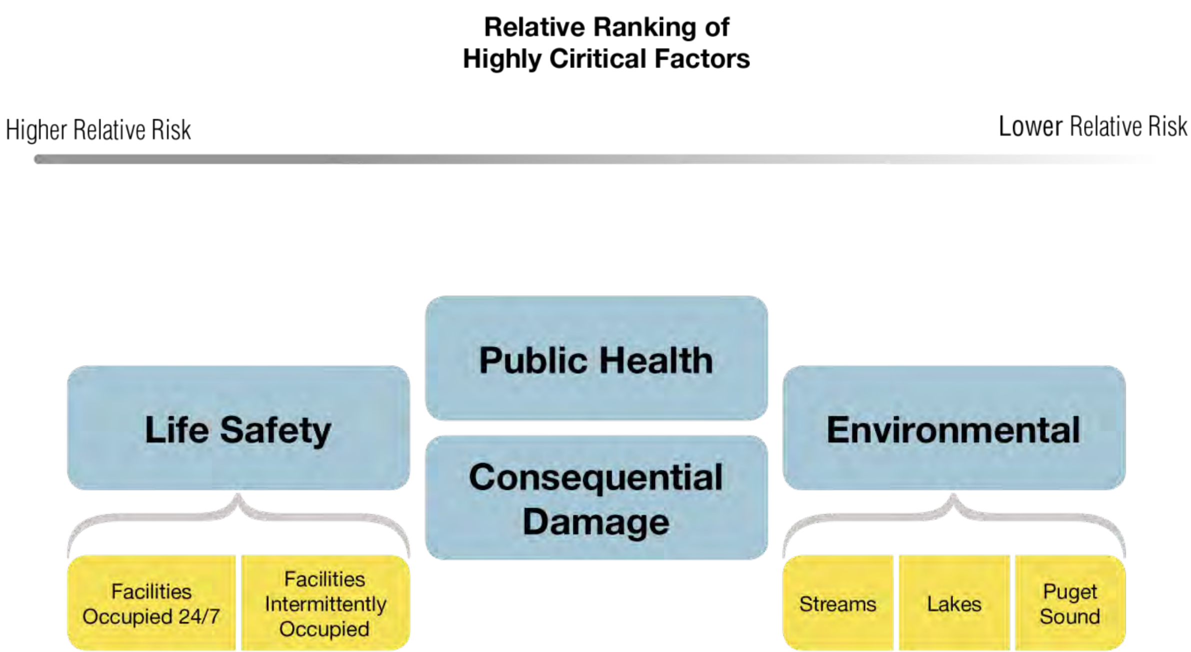

Figure 3: Relative Ranking of Risk Criticality Factors

Additionally, other criticality parameters were used to prioritize system deficiencies and associated mitigation projects, including the following:

- Type of facility – e.g., pump station, regulator
- Flow capacity of a facility or pipe
- Impact of post-earthquake operability/functionality related to one of the primary priorities
- Impact of post-earthquake restoration and its effect on restoration time (particularly related to the very large vulnerable facilities)
- Relative likelihood of the damaging earthquake(s) scenarios
- Vulnerability of the facility or pipe to one of the earthquake scenarios evaluated

2.4 System Performance Reference

Proposed system function performance criteria were based on the four identified risk categories listed above. Each of these risk categories was then associated with system facilities and pipelines that would be required to meet the system performance criteria. Table 2 provides a reference of restoration times shown for a 500-year return earthquake (such as the Cascadia Subduction Zone Scenario), adapted from the 2012 Resilient Washington State Plan, the 2013 Oregon Resilience Plan, and the 2017 NIST Community Resilience Planning Guide Briefs**.** A similar table can be prepared for crustal earthquakes such as the SF, with a longer recurrence interval but stronger shaking. The suggested restoration times would be shifted to the right for a M7.2 SF and M7.4 SWIF event. Using these references for consideration, it is recommended that the County develop performance goals for each earthquake scenario based on the County's earthquake resiliency objectives.

Table 2: System Performance Target Restoration Times for Cascadia Subduction Zone Earthquake (adapted from the Oregon Resilience Plan for Consideration in Developing King County Specific Goals)

SYSTEM FUNCTION	EVENT OCCURS	0-24 HOURS	1-3 DAYS	3-7 DAYS	1-2 WEEKS	2-4 WEEKS	1-3 MONTHS	3-6 MONTHS	6-12 MONTHS
Life Safety - Occupied Building Collapse		◆							
Public Health - Sewage Backup		●	◆						
Consequent Damage		▲		●	◆				
Environmental Impact									
Raw sewage discharge into fresh water		●			◆				
Raw sewage discharge into salt water					●		◆		
Primary/disinfected sewage discharge Average Dry Weather Flow					▲	●	◆		
Secondary discharge Average Dry Weather Flow						▲	●	◆	
Primary/disinfected sewer discharge Mean Wet Weather Flow									◆

Desired time to restore component to 80-90% operational ◆ Desired time to restore component to 50-60% operational ● Desired time to restore component to 20-30% operational ▲

3 Seismic Hazards

3.1 Introduction and Background

This project used three deterministic earthquake scenarios to evaluate likely system performance, resiliency, and recovery. This is in contrast to probabilistic-based ground motions used in building codes for the design of new buildings. Ground motions for a *deterministic* earthquake scenario correspond to fault ruptures of a specific size on a single fault, regardless of the recurrence interval (i.e., how often an earthquake occurs on a fault). This contrasts to *probabilistic* ground motions that are typically an aggregation of ground motion hazard from multiple faults and considers the earthquake recurrence intervals on each of the various faults. The three deterministic scenarios used for this project were selected because they occur relatively frequently or would likely produce the strongest ground shaking within the King County Service Area.

The use of determinist ground motions is intended to provide an assessment of expected damage from a realistic earthquake event on a known fault. If probabilistic ground motions were used to estimate performance over the entire service area, this could overestimate the damage caused by an actual earthquake because the probabilistic ground motions are an aggregation of hazards from multiple faults.

In addition to earthquake-induced ground acceleration, this project also considered the effects of transient and permanent ground deformation from surface fault rupture, and liquefaction and associated lateral spreading. Ground deformation from landslides was considered in several site-specific cases. Tsunamis and service-area wide landslide hazards were considered in the multi-hazard resilience assessment that was also conducted as part of this *Recommendations to Enhance the Resiliency and Recovery of King County's Regional Wastewater Treatment Facilities* project. Task 200 Facility Resiliency Review (Flooding/Tsunami, Landslide, Extreme Weather) Technical Memorandum provides an explanation of the methodology, findings, and recommendations related to the other hazards.

3.2 Earthquake Scenarios Considered

This project used three deterministic earthquake scenarios to evaluate likely system performance, resiliency, and recovery (see Figure 4 and Attachment 1B).

The earthquake recurrence intervals listed are the approximate average time between earthquakes of this magnitude occurring on these faults. Smaller magnitude earthquakes may occur along these faults with shorter recurrence intervals. The magnitudes listed are the earthquake moment magnitudes. The moment magnitude scale is a logarithmic measurement of the amount of earthquake energy released. An increase of 1 on the moment magnitude scale corresponds to 31.6 times ($10^{1.5}$ times) the amount of energy released, and an increase of 2 on the moment magnitude scale corresponds to 1000 times (10^3 times) the amount of energy released. However, the ground shaking intensity at a particular site is a function of not only the earthquake magnitude, but also depth of the earthquake and the distance between the site and the earthquake fault. Ground motions used for these scenarios were those produced by the United States Geological Survey. Seattle Public Utilities (SPU) is currently using similar earthquake scenarios to evaluate the SPU regional water supply system.

Figure 4: Considered Earthquake Scenarios

3.2.1 Cascadia Subduction Zone (CSZ)

The CSZ is formed by the subduction of the Juan de Fuca tectonic plate beneath the North American Plate. The subduction zone extends along the coast of the Western United States from Southern Canada to Northern California. The fault created by the locked portion of the interface between the two plates is expected to produce a M9.0 earthquake on average approximately every 500 years. This earthquake is expected to result in moderate-to-strong shaking intensities throughout the Pacific Northwest extending from British Columbia, Canada to Northern California. Peak horizontal ground acceleration in the King County Service Area is expected to be approximately 30-40 percent of gravity. While this earthquake has a large moment magnitude, the rupture zone would be located approximately 100 miles west of King County, off the Pacific Coast. This distance means that the seismic waves are expected to attenuate somewhat by the time they reach the King County Service Area. However, the duration of shaking is expected to be about a few minutes. Long ground shaking durations and frequent large aftershocks are characteristic of subduction interface earthquakes. This earthquake is expected to produce extensive liquefaction due to its long duration.

3.2.2 Seattle Fault (SF)

The SF extends from nearly Hood Canal on the west to the Sammamish Plateau on the east, following along the I-90 corridor from Seattle through Bellevue. The fault is a zone of multiple south-dipping thrust faults located in the upper crust (near the surface). Many of the faults strands are blind faults (meaning the faults do not show signs at the surface). Peak horizontal ground acceleration is 70-80 percent of gravity in the considered scenario. These PGAs are comparable to those that occurred in the 1994 Northridge Earthquake in Southern California and the 1995 Kobe Earthquake, each causing extensive structural damage and damage to their region's wastewater systems.

The SF may produce surface fault ruptures, which are likely to cause vertical offsets with rupture lines extending horizontally in the direction of the fault. An existing (from a previous seismic event) vertical offset can be seen in Vasa Park in Bellevue, Washington. This vertical offset is approximately 6 to 7 feet. The date of the causative earthquake is unknown. Another event in approximately 900 AD caused an uplift of 23 feet on Bainbridge Island. Based on evidence from previous earthquakes, the vertical offset is expected to be largest near the fault. Coupled with the vertical offset, is the potential of large block rotation changing the gradient of the ground surface. For example, the ground level on the immediate south side of the SF could rise in excess of 6 feet while the ground just south of SeaTac Airport may not move vertically by any appreciable amount.

The SF produces violent ground accelerations near the fault for the considered earthquake scenario that attenuate with distance away from the fault (see Attachment 1B-1: Scenario Seismic Acceleration Maps). This is in contrast to the CSZ scenario, which is expected to produce relatively uniform ground accelerations over the entire King County Service Area. While the variation in ground motion across the service area is greater for the SF scenario than the CSZ scenario, the level of ground shaking in the service area for the SF scenario is greater than the CSZ scenario because the SF is located near the middle of the King County Service Area.

3.2.3 South Whidbey Island Fault (SWIF)

The SWIF is a 4- to 12-mile-wide northwest-trending fault zone in the upper crust (near the surface) with varying and complex reverse, thrust, and strike-slip displacements on different splays within the zone. The fault zone extends from near southeast of Victoria, British Columbia to an area east of Woodinville, Washington. The fault zone passes nearby or through Port Townsend, Washington, Clinton, Washington, and Mukilteo, Washington. The starting and ending points of the fault are not well understood, especially where the faulting gets close to the Cascade Mountains. It is possible the fault extends toward the area southeast of Redmond, Washington and toward Snoqualmie Pass. One of the strands of the SWIF passes through the Brightwater Treatment Plant site (a fact that was considered during its design). Peak horizontal ground acceleration is 70-80 percent of gravity in the considered scenario. These PGAs are comparable to those that occurred in the 1994 Northridge Earthquake in Southern California and the 1995 Kobe Earthquake, each causing extensive structural damage and damage to their region’s wastewater systems.

Similar to the SF, the SWIF produces violent ground accelerations near the fault for the considered earthquake scenario that attenuate with distance away from the fault (see Attachment 1B-1: Scenario Seismic Acceleration Maps). This is in contrast to the CSZ scenario that produces relatively uniform ground accelerations over the entire King County Service Area. Because the SWIF only extends through the northeast portion of the King County Service Area, the southern end of the King County Service Area is expected to be less impacted compared to the northern end, though it is likely ground accelerations will still be strong near the southern end of the King County Service Area.

3.3 Liquefaction and Related Permanent Ground Displacement

Historically, the most significant geotechnical hazard associated with earthquakes, particularly for buried infrastructure, is liquefaction and associated lateral spreading. It typically occurs in loose saturated granular soils such as non-engineered fills and alluvial material below the groundwater table. As shaking occurs, poorly consolidated soil particles consolidate, raising the water pressure surrounding the soil particles, turning it into a viscous liquid. If near a free face—for example, a river—or on even a mild slope, soil blocks can move laterally, carrying buried pipe with them. Gravity pipe can float in the liquefied soil, as occurred on the Eastside Interceptor in the 1965 Seattle Earthquake.

Liquefiable soils are found throughout the Seattle region, including, but not limited to the following areas:

- Duwamish Valley/SODO District including the Port of Seattle and the sports stadiums
- Interbay Pump Station

- Union Bay on the east side of the University of Washington Campus/Football Stadium
- Green River/Kent Valley including Renton
- Southern end of Lake Sammamish/Issaquah
- Area along the Sammamish River connecting Lake Sammamish and Lake Washington

A map of the liquefiable susceptibility areas in the region is shown in Attachment 1B-4.

Permanent ground displacement (PGD) due to liquefaction-induced lateral spread and settlement was developed from information provided by SPU. SPU contracted with geotechnical engineer Dr. Steve Dickenson (2016) of New Albion Consulting to develop a generalized methodology to estimate PGDs based on the liquefaction susceptibility zone, ground shaking intensity, and proximity to a free face or slope gradient. These PGD estimates were then used by SPU in their water system seismic assessment. This methodology was based on work done by Zhang (2002, 2004).

The methodology developed by Dickenson was then converted by Shannon & Wilson to a procedure that applies it spatially using geographic information system (GIS). King County WTD GIS staff implemented that procedure (refer to Attachment 2A-2 and 2A-3), which was then used to estimate pipeline damage for this project's assessment phase.

4 Facility Evaluations

The objective of facility evaluation task was to review existing information relevant to the seismic design and resiliency of WTD facilities, conduct desktop, field, and/or additional analyses for the highest risk assets, and develop a prioritized list of capital improvement projects for WTD's long-term planning timeframe.

The following subtasks, in addition to two workshops with WTD, were included in the Facility Evaluation Task Scope:

- Acquire Information and Document Review
- Perform Initial Desktop Evaluation
- Conduct Facility Field Assessments for Identified High-Risk Facilities
- Perform Additional Desktop Evaluation
- Identify Prioritized Projects

4.1 Facility Initial Desktop Evaluation Approach

Figure 5 provides a flowchart overview of the steps and methodology applied to execute the initial desktop evaluation task (also, see Figure 1 for a flowchart depicting the overall facility assessment methodology). As depicted, the first step was to identify the facilities to be evaluated, described in Section 4.1.1 Facility Identification. The next steps were to gather information regarding the facilities and the scenario-based earthquake hazards, described in Section 4.1.2 Facility Data Gathering and Section 4.1.3 Hazard Data Gathering, respectively. After obtaining this data, a Rapid Visual Screening (RVS) methodology was applied to estimate and rank facility seismic vulnerabilities, as described in Section 4.1.4 Initial Desktop Evaluations: Rapid Visual Screening. Finally, using facility criticality information provided by the County, the facility risks were estimated and used to prioritize facilities for additional field assessments.

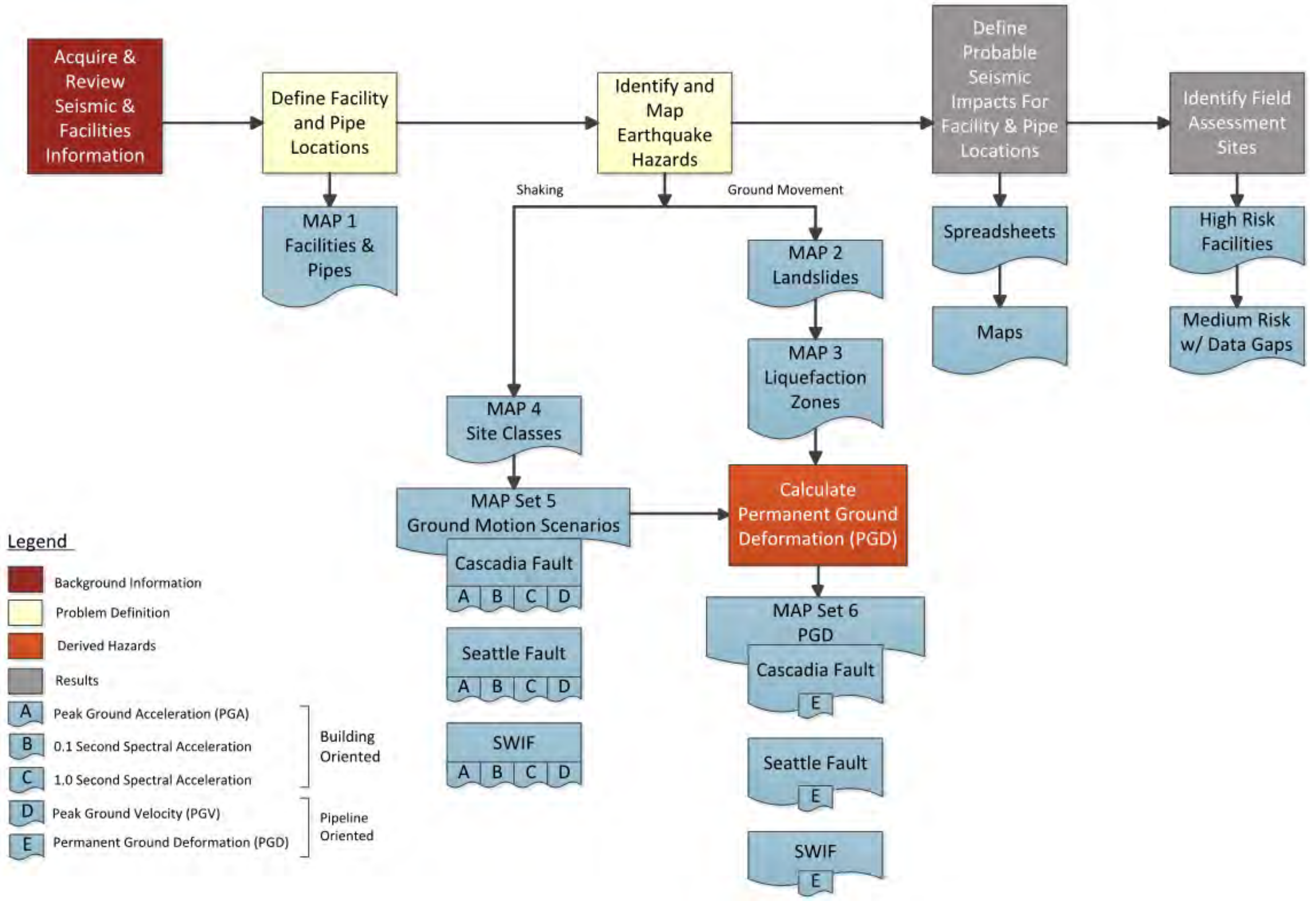

Figure 5: Desktop Evaluation Methodology Flowchart

4.1.1 Facility Identification

Within the HDR Team, facility desktop structural seismic evaluations were performed by Reid Middleton; facility seismic mechanical, electrical, and plumbing assessments were performed by HDR. The facilities consisted of both aboveground and subgrade structures, including pump stations, regulator stations, combined sewer overflow treatment facilities, maintenance warehouses, and administration/operations buildings. Buried pipelines were evaluated separately by Don Ballantyne, LLC, as described in Section 5. The following is a summary of County WTD facilities:

- Off-Site Pump Stations (47 Total) *
- Regulator Stations (25 Total) *
- CSO Treatment Facilities (4 Total)*
- Community Septic System (1 Total)
- Regional Wastewater Treatment Plants (3 Total)
  - West Point Treatment Plant (WPTP) *
  - South Treatment Plant (STP) *
  - Brightwater Treatment Plant (BWTP)

- Small Wastewater Treatment Plants (2 Total)
    - o Carnation Treatment Plant
    - o Vashon Treatment Plant

** Facility was included in seismic evaluation, as selected by King County; other facilities were not prioritized as part of the seismic evaluation scope of work.*

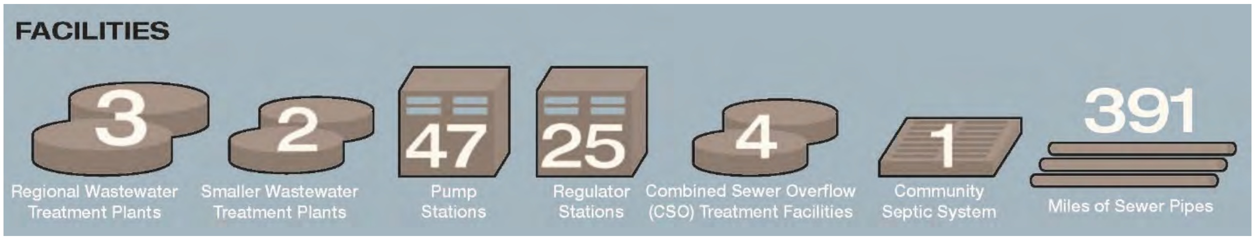

Figure 6: King County WTD System Overview

In order to perform high-level seismic evaluations of WTD facilities, the first task was to identify the facilities to be evaluated. After working with WTD to identify which facilities would be appropriate for the desktop seismic evaluation phase, the following (121) facilities were selected:

- Off-Site Pump Stations (47 Total)
    - o 30th Ave. NE Pump Station
    - o 53rd Ave. Pump Station
    - o 63rd Ave. Pump Station
    - o Barton Pump Station
    - o Bellevue Pump Station
    - o Belvoir Pump Station
    - o Black Diamond Pump Station
    - o Boeing Chiller Pump Station
    - o Boeing Creek Pump Station Facilities
        - Boeing Creek Pump Station
        - Boeing Creek Storage Facility Flow Control Facility
        - Boeing Creek Odor Control Structure
    - o Bunker Trail 1 Pump Station
    - o Bunker Trail 2 Pump Station
    - o Bunker Trail 3 Pump Station
    - o Bunker Trail 4 Pump Station
    - o Carkeek Pump Station
    - o Duwamish Pump Station
    - o East Marginal Way Pump Station

- East Pine St. Pump Station
- Heathfield Pump Station
- Hidden Lake Pump Station
- Hollywood Pump Station
- Interbay Pump Station
- Interurban Pump Station
- Juanita Bay Pump Station
- Kenmore Pump Station
- Kirkland Pump Station
- Lake Ballinger Pump Station
- Lakeland Hills Pump Station
- Matthews Park Pump Station
- Medina Pump Station
- Murray Pump Station
- North Beach Pump Station
- North Creek Pump Station
- North Mercer Island Pump Station
- Pacific Pump Station
- Rainier Av. Pump Station
- Richmond Beach Pump Station
- S Henderson Pump Station
- South Mercer Island Pump Station
- South Treatment Plant Effluent Pump Station
- Sunset Pump Station
- Sweyolocken Pump Station
- West Marginal Way Pump Station
- West Seattle Pump Station
- Wilburton Pump Station
- Woodinville Pump Station
- Yarrow Bay Pump Station
- York Pump Station

- Regulator Stations (25 Total)
  - 8th Ave Regulator Station
  - Allentown Regulator Station
  - Ballard Regulator Station
  - Boeing Creek Regulator Station
  - Brandon Regulator Station
  - Chelan Regulator Station
  - Connecticut Regulator Station
  - Denny Regulator Station
  - Dexter Regulator Station
  - Hanford Regulator Station
  - Harbor Regulator Station
  - King Regulator Station
  - Kingdome Regulator Station
  - Lake City Tunnel Regulator Station
  - Lake Union Tunnel Regulator Station
  - Lander Regulator Station
  - Lander2 Regulator Station
  - Logboom Regulator Station
  - Michigan Regulator Station
  - MLK Tunnel Regulator Station
  - Montlake Regulator Station
  - Norfolk Regulator Station
  - University Regulator Station
  - W Michigan Regulator Station
  - W Seattle Regulator Station
- CSO Outfalls (39 Total)
  - 30th Avenue Northeast Overflow
  - 11th Avenue Northwest Overflow
  - 3rd Avenue West Overflow
  - 53rd Avenue Southwest Pump Station Overflow
  - 63rd Avenue Southwest Overflow
  - 8th Avenue South Overflow

- Ballard Siphon Overflow
- Barton Street Pump Station Overflow
- Belvoir Pump Station Overflow
- Brandon Street Regulator Station Overflow
- Canal Street Overflow
- Chelan Avenue Regulator Station Overflow
- Denny Way Regulator Station Overflow
- Dexter Avenue Regulator Station Overflow
- East Duwamish Pump Station Overflow
- East Marginal Way Pump Station Overflow
- East Pine Street Pump Station Overflow
- Hanford #1 Overflow
- Hanford #2 Regulator Station Overflow
- Harbor Avenue Regulator Station Overflow
- Henderson Street Pump Station Overflow
- King Street Regulator Station Overflow
- Kingdome Regulator Station Overflow
- Lander Street Regulator Station Overflow
- Martin Luther King Junior Way Overflow
- Matthews Park Pump Station Overflow
- Montlake Regulator Station Overflow
- Murray Pump Station Overflow
- Norfolk Street Overflow
- North Beach Pump Station Inlet Overflow
- North Beach Pump Station Wet Well Overflow
- Rainier Avenue Pump Station Overflow
- South Magnolia Overflow
- South Michigan Street Regulator Station Overflow
- Southwest Alaska Street Overflow
- Terminal 115 Overflow
- University Regulator Station Overflow
- West Duwamish Overflow
- West Michigan Street Regulator Station Overflow

- Combined Sewer Overflow Treatment Facilities (4 Total)
  - Alki CSO Plant
  - Carkeek CSO Plant
  - Mercer/Elliott West CSO Facility
  - Henderson/Norfolk CSO Facility
- Community Septic System (1 Total)
  - Beulah Creek & Cove Septic System
- Regional Wastewater Treatment Plants (3 Total)
  - Brightwater Treatment Plant
  - South Treatment Plant
  - West Point Treatment Plant
- Small Wastewater Treatment Plants (2 Total)
  - Carnation Treatment Plant
  - Vashon Island Treatment Plant

Figure 7 provides a map depicting the King County WTD System and shows the facilities that were identified for inclusion in the desktop assessment (note a full-scale version has been included in subsequent Attachment 1A). As depicted in the map key, the facilities have been identified as pump stations, regulator stations, septic system, sewage treatment plants, wet weather treatment facilities, and CSO outfalls based on the facility symbol. Additionally, the conveyance system and corresponding facilities have been identified as gravity, pressure, water reuse, and outfalls based on the color identified for the conveyance pipelines and facilities.

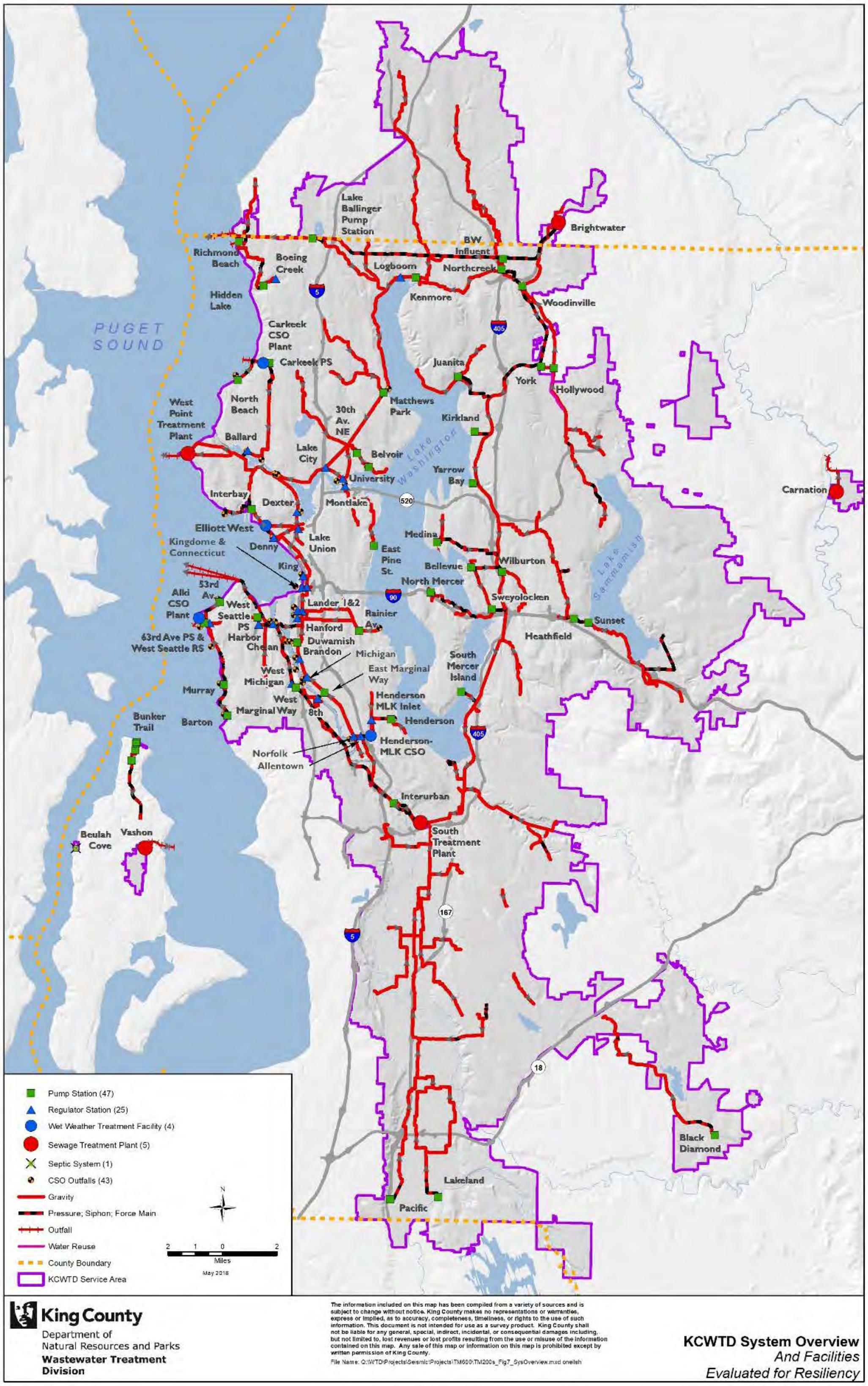

Figure 7: King County WTD System Overview and Facilities Evaluated for Resiliency

4.1.2 Facility Data Gathering

After the (121) facilities were identified, the next step was to gather, consolidate, organize, and review the available facility information required for the desktop evaluation. The available structural record drawings of the facilities were obtained and reviewed. Additionally, earlier seismic evaluations and structural studies were reviewed to identify if previous findings were available that would inform this study. Much of the information provided about existing facilities was incomplete, such as missing record drawings or other information.

The facility data fields were exported from the County's GIS database and restructured such that they could be used for the initial desktop evaluation. The following information was made available for many of the facilities:

- Facility Name
- Facility Address & Coordinates
- Construction Date, Type, & Design Code
- Floor Area & Foundation Type
- Facility Site Class
- Previously-Identified Deficiencies, Seismic Upgrades, and Surface Access

4.1.3 Hazard Data Gathering

The following three earthquake scenarios were considered for the initial desktop evaluation:

- CSZ M9.0 Earthquake
- SF M7.2 Earthquake
- SWIF M7.4 Earthquake

The geotechnical/seismology analyses produced the following seismic hazard characteristics for each of the three earthquake scenarios at each of the facility site locations:

- S_S (0.3-second spectral acceleration)
- S_1 (0.3-second spectral acceleration)
- PGA (peak ground acceleration)
- PGV (peak ground velocity)
- PGD (peak ground displacement)
- Liquefaction susceptibility (low, low-moderate, moderate, moderate-high, high)

4.1.4 Initial Desktop Evaluations: Rapid Visual Screening

The objective of the desktop-level RVS task was to screen the wastewater treatment facilities to define the (30 +/-) highest-risk facilities that are most critical to the overall post-earthquake performance of the County's wastewater system. It is important to note that the scope of work budgeted approximately 20-minutes of engineering time for each facility, so the initial desktop evaluation procedure was performed at a high-level in order to rapidly and efficiently identify the most critical facilities that should be evaluated in more detail.

The primary tool used for the desktop evaluation was the *Federal Emergency Management Agency (FEMA) 154: Rapid Visual Screening (RVS) of Buildings for Potential Seismic Hazards*. This national standard provides systematic screening and evaluation procedures used to identify potential seismic deficiencies indicating the possible need for further evaluation and a possible corresponding seismic retrofit. Based on extensive data and research on the seismic performance of buildings in previous earthquakes, these standards provide criteria specific to each common building archetype, the structural system, configuration, and characteristics of the specific facility, and the seismic hazard at each facility site.

The *FEMA 154 Rapid Visual Screening* procedures use a scoring system to provide a quantitative comparison of the potential seismic vulnerability of a structure. A base score is identified based on the seismicity (i.e., the amplitude of specific standard ground motion accelerations). Other important factors are the building's lateral-force-resisting systems (e.g., wood or concrete shear walls, steel braced or moment frames, masonry shear walls, etc.). This base score is then reduced based on the geological hazards (e.g., site class, landslide, and liquefaction hazards) and inherent vulnerabilities in the building's configuration (e.g., vertical and horizontal irregularities). The building score is also adjusted based on the construction year relative to benchmark years in which seismic design code requirements changed significantly. As a result, the lower the RVS score, the higher the expected seismic vulnerability.

To perform the RVS screenings, the structural drawings were reviewed to the extent pertinent structural information was available. Previous seismic studies and structural reports, as well as the provided facility database information, were reviewed to identify the structural characteristics of each facility and populate the pertinent information in the RVS form. Although on-site observation of the facilities was not included in this desktop screening, on-line geospatial tools (e.g., Google Maps satellite view and street view) were used to locate the facilities and "electronically observe" them to the extent possible with these technologies. The ground characteristics and facility age (relative to the benchmark years) were identified on the RVS form. Finally, the scenario-based earthquake hazard information (e.g., S_s, S_1, and liquefaction susceptibility) was also used. Using the basic score and modifiers based on the facility characteristics and hazard data, an RVS score was defined for each facility for each of the (3) earthquake scenarios.

Using the *FEMA 154* RVS procedures, each of the 47 pump stations, 25 regulator stations, and 4 CSO treatment facilities were evaluated. Two of the three Regional Wastewater Treatment Facilities (WPTP and STP) and two Small Wastewater Treatment Facilities were not evaluated in the desktop exercise as they were pre-determined to be categorically important and automatically considered for additional detailed field investigations. The third Regional Wastewater Treatment Facility (BWTP) was not evaluated because it is a newer treatment plant that was designed using current seismic standards, with one exception – the Administration Building at BWTP is an older building. A more thorough *ASCE 41* Tier 1/2/3 Seismic Evaluation is recommended for this building. The 39 Combined Sewage Outfalls and the Community Septic System were not evaluated using RVS procedures due to their lower post-earthquake criticality relative to the other facilities when considering system-wide performance.

Facility assessments were conducted using ground motions from the three scenario earthquakes (Attachments 1B-1, 1B-2, and 1B-3). Shaking duration was taken into account (increasing the building vulnerability) for the otherwise moderate ground motions in the CSZ scenario by applying an (imprecise) factor corresponding to research on the probability of collapse for long-duration seismic events. The CSZ scenario resulted in moderate to high vulnerabilities across the entire WTD system based on the broad distribution of ground motion expected from a CSZ event. The Seattle Fault earthquake scenario has very strong ground motions passing through the center of Seattle and Bellevue, resulting in many structures being rated as highly vulnerable in those regions of the WTD system. The SWIF scenario earthquake produces very strong ground motions at the Brightwater Treatment Plant. Structures at the West Point and South Treatment Plants are some distance away from the SWIF fault, but may still be subjected to moderate-to-significant ground motions that may result in damage.

In general, it is recommended that more detailed seismic evaluations be performed for buildings with an RVS score less than 2.0. Therefore, an RVS score of less than 2.0 was determined to be High, as indicated in the Facility Vulnerability Rating scale provided in Table 3. A vulnerability scale from 1–5, (Low to High ratings), was developed corresponding to a range of RVS scores above 2.0. The facilities were evaluated and their vulnerabilities are listed in Table 14 and shown in Attachment 1C-2. Many of the structures were built in the 1960s and designed using seismic design criteria that was limited compared to what is used today. As a result, RVS concluded that most of the structures may be highly vulnerable and warrant additional, more-detailed seismic evaluations. In order to prioritize the facilities to be investigated with field assessment, the facility vulnerability and criticality were considered to estimate the risk of failure, as described below.

Table 3: RVS Vulnerability Ratings

Vulnerability Rating		RVS Score		
1	Low	3.5	< X	
2	Low-Moderate	3.0	< X <	3.5
3	Moderate	2.5	< X <	3.0
4	Moderate-High	2.0	< X <	2.5
5	High		X <	2.0

4.1.5 Initial Desktop Evaluation – Hazus Analysis

In addition to the RVS and other initial desktop evaluation tasks, a supplemental Hazus analysis was conducted on the facilities included in the study. The Hazus methodology, developed by FEMA, allows engineers to estimate the expected damage of a building due to specific scenario ground motions. Hazus is a high-level loss estimation tool that is useful for predicting overall losses in an earthquake. However, the analysis is based on generalized fragility curves for various building archetypes constructed over the 20th and 21st centuries, making it less accurate for assessing the seismic vulnerability of a specific structure. Therefore, while Hazus analyses produce useful and informative results for estimated expected losses from an event, the results of these analyses are considered supplemental to the RVS and *ASCE 41-13* Tier 1 evaluation conducted for this resiliency study.

This Hazus analysis section has been provided for reference only; Hazus analysis was not used for any decision making or for developing prioritized projects. RVS is the primary tool that was used for initial desktop facility seismic vulnerability evaluations. For this reason, the detailed methodology and results of the Hazus Analysis are not described in this section of the report, but are provided in Attachment 2B-4.

4.1.6 Initial Desktop Evaluation – Facility Prioritization

4.1.6.1 Risk Evaluation

After evaluating and ranking the facilities based on their individual structural vulnerabilities, the next step was to determine their overall risk in order to prioritize the most critical facilities for more detailed field investigations. Vulnerability ratings were applied by categorizing the RVS scores into five levels in accordance with the score ranges identified in Table 3. Similarly, the facilities were categorized into five criticality levels based on a criticality rating rubric developed by WTD that accounts for each facility's peak capacity, storage time, overflow location, public impact, flexibility, and other facilities serviced. Each facility's criticality ratings were then developed by multiplying the (1-5) Vulnerability Rating by the (1-5) Criticality Rating to determine a (1-25) relative Risk Rating for each earthquake scenario considered. The Facility Risk Rating Scale is provided in Table 4.

Table 4: Facility Risk Rating Scale

Criticality / Consequence of Failure	High	5	5	10	15	20	25	High Risk: 18-25
	Moderate-High	4	4	8	12	16	20	Moderate-High Risk: 10-17
	Moderate	3	3	6	9	12	15	Moderate Risk: 6-9
	Low-Moderate	2	2	4	6	8	10	Low-Moderate Risk: 4-5
	Low	1	1	2	3	4	5	Low Risk: 1-3
			1	2	3	4	5	
			Low	Low-Moderate	Moderate	Moderate-High	High	
			Facility Vulnerability/Hazard					

In addition to the RVS evaluation, a separate high-level assessment was made for the vulnerability to liquefaction based on the liquefaction susceptibility mapping.

The high vulnerability and high-risk facilities were then summarized in color-coded maps for each of the three earthquake scenarios, CSZ M9.0, SF M7.2, SWIF M7.4. Table 5 represents the vulnerability tables and maps that were printed as wall-sized figures and used to communicate the summary of the vulnerability findings in the desktop evaluation workshop with WTD. An initial Desktop Evaluation Workshop was held on February 28, 2017 in which the project objective, desktop evaluation methodology, and preliminary RVS findings were presented to WTD. A subsequent workshop was held on March 2, 2017 in which a pair-wise comparison exercise was used to facilitate discussions with WTD to determine which consequence of failure criteria were most impactful and should be used for determining facility criticalities. Finally, a third Desktop Evaluation Workshop was held on March 7, 2017 in which the risk evaluation findings, critical criteria from the prior workshop, and operational goals were discussed with WTD administrators and facility operators. Through a collaborative review of each facility's criticality and the desktop evaluation findings, a prioritized list of facilities was determined to warrant additional field investigation based on the direction of the County. Table 6 presents a summary of the (37) facilities that were identified as warranting additional field investigation. As indicated, they were selected either because they are categorically important (i.e., the six facilities at South Treatment Plant and ten facilities at West Point Treatment Plant), high risk due to their seismic vulnerability and criticality, or they were selected as critical due to their criticality (locally or system-wide) as representative of similar facilities in the system.

Table 5: RVS-Based Vulnerability Evaluation Summary

King County Facility Name	RVS Vulnerability Score			Overall
	CSZ M9.0 Adjusted	SF, M7.2	SWIF, M7.4	
30th Avenue NE Pump Station	High	Moderate-High	Moderate-High	High
53rd Avenue	High	High	Moderate-High	High
63rd Av. Pump Station	High	High	Moderate-High	High
8th Avenue South	High	High	High	High
Alki CSO Plant	High	High	High	High
Allentown	Low-Moderate	Moderate	Low	Moderate
Ballard	High	Moderate-High	Moderate-High	High
Barton	High	High	High	High
Bellevue	Low-Moderate	Moderate	Low	Moderate
Belvoir Pump Station	High	Moderate-High	Moderate-High	High
Black Diamond	High	High	High	High
Boeing Chiller Pump Station	Unknown	Unknown	Unknown	Not Enough Info
Boeing Creek	Unknown	Unknown	Unknown	Not Enough Info
Boeing Creek Storage Facility Flow Control Facility	Unknown	Unknown	Unknown	Not Enough Info
Boeing Creek Odor Control Structure	Unknown	Unknown	Unknown	Not Enough Info
Brandon Street	Unknown	Unknown	Unknown	High
Bunker Trail 1 Pump Station	Unknown	Unknown	Unknown	Not Enough Info
Bunker Trail 2 Pump Station	Unknown	Unknown	Unknown	Not Enough Info
Bunker Trail 3 Pump Station	Unknown	Unknown	Unknown	Not Enough Info
Bunker Trail 4 Pump Station	Unknown	Unknown	Unknown	Not Enough Info
Carkeek CSO Plant	High	Moderate-High	Moderate-High	High
Carkeek	High	High	High	High
Chelean Avenue	High	High	High	High
Connecticut Street	Unknown	Unknown	Unknown	High
Denny Way Pump Regulator Station	High	High	High	High
Dexter Avenue	High	Moderate-High	Moderate-High	High
Duwamish Pump Station	High	High	High	High
East Marginal Way Pump Station	High	High	High	High
East Pine St. Pump Station	High	High	High	High
Mercer/Elliott West CSO Facility	Low-Moderate	Low	Low	Moderate
Hanford Street Regulator and Out	Unknown	Unknown	Unknown	High
Harbor Avenue	High	High	Moderate-High	High
Heathfield Pump Station	High	High	Moderate-High	High
Henderson/Norfolk CSO Facility	Unknown	Unknown	Unknown	Not Enough Info
Hidden Lake	High	High	High	High
Hollywood	High	Moderate-High	Moderate-High	High
Interbay Pump Station	High	High	High	High
Interurban Pump Station	High	High	Moderate-High	High
Juanita Bay	Moderate	Low-Moderate	Low-Moderate	Moderate
Kenmore	High	Moderate-High	Moderate-High	High
King Street	Unknown	Unknown	Unknown	Not Enough Info
Kingdom/Connecticut Street	Unknown	Unknown	Unknown	Not Enough Info
Kirkland	High	High	High	High
Lake Ballinger Pump Station	High	Moderate-High	Moderate-High	High
Lake City Tunnel	High	High	High	High
Lake Union Tunnel Regulator Station	Unknown	Unknown	Unknown	Not Enough Info
Lakeland Hills	High	High	High	High
Lander Street	Unknown	Unknown	Unknown	Not Enough Info
Lander2 Regulator Station	Unknown	Unknown	Unknown	Not Enough Info
Logboom Park	Unknown	Unknown	Unknown	Not Enough Info
Matthews Park Pump Station	High	High	High	High
Medina	High	High	High	High
Michigan Regulator Station	High	High	High	High
MLK Outlet Tunnel	Moderate-High	Moderate-High	Low	Moderate-High
Montlake Boulevard	High	High	High	High
Murray	High	High	Moderate-High	High
Norfolk Street	High	High	Moderate-High	High
North Beach	High	Moderate-High	Moderate-High	High

King County Facility Name	RVS Vulnerability Score			Overall
	CSZ M9.0 Adjusted	SF, M7.2	SWIF, M7.4	
North Creek Pump Station	Moderate-High	Moderate	Moderate	Moderate-High
North Mercer Island	High	High	High	High
Pacific Pump Station	High	Moderate-High	Moderate-High	High
Rainier Av.	High	High	Moderate-High	High
Richmond Beach	High	High	High	High
S Henderson Pump Station	High	High	High	High
South Mercer Island	High	High	High	High
South Treatment Plant Effluent Pump Station	Unknown	Unknown	Unknown	Not Enough Info
Sunset Pump Station	High	High	Moderate-High	High
Sweyolocken Pump Station	High	High	High	High
University Regulator Station	High	High	High	High
West Marginal Way Pump Station	High	High	High	High
West Michigan Street	High	High	High	High
West Seattle	Low-Moderate	Moderate	Low	Moderate
W Seattle Regulator Station	Low-Moderate	Moderate	Low	Moderate
Wilburton	High	High	High	High
Woodinville	High	Moderate-High	Moderate-High	High
Yarrow Bay	High	High	High	High
York Pump Station	High	High	High	High

General Note for Table 5: Several of the offsite pump stations have inconclusive results from the initial desktop evaluation process. Facilities with an "Unknown" did not have sufficient information to perform the desktop rapid visual screening (RVS) evaluation, either due to unavailability of drawings, insufficient information on the available drawings, or insufficient ground motion information for that particular site. The overall score was taken as the worst score from the CSZ M9.0 Adjusted RVS score, the SF M7.2 score, the SWIF M7.4 score, and the liquefaction vulnerability score. Therefore, in some cases, an overall score is provided from the liquefaction vulnerability, despite an "Unknown" indicated for the RVS score.

Table 6: High-Risk Facilities Identified for Field Investigation

Initial Desktop Evaluation Category: High Priority - Categorically Important
South Treatment Plant
SP Digester Gas Equipment Building
SP Santler Building
SP Maintenance Facilities Building
SP Influent Pump Station
SP Effluent PS
SP Operations Building
West Point Treatment Plant
WP Admin/Operations Building
WP Maintenance/Stores Building
WP Electrical Substations
WP LOX/OGADs Building
WP Primary Clarifiers
WP Digester Boilers Building
WP Effluent Pump Station
WP Raw Sewage (Influent) Pump Station
WP Intermediate Pump Station
Hypochlorite Mixing/Storage
Initial Desktop Evaluation Category: High Risk
63rd Avenue Pump Station
Duwamish Pump Station
Heathfield Pump Station
Interurban Pump Station
Matthews Park Pump Station
Sweyolocken Pump Station
West Marginal Way Pump Station
York Pump Station
Alki CSO Plant
East Pine St. Pump Station
Sunset Pump Station
30th Av. NE Pump Station
Belvoir Pump Station
Carkeek CSO Plant
Lake Ballinger Pump Station
Initial Desktop Evaluation Category: High Vulnerability, Lower Consequences of Failure
Pacific Pump Station
Initial Desktop Eval. Category: Lower Vulnerability and, or Lower Consequences of Failure
Mercer/Elliott West CSO Facility
Denny Way Regulator Station
Interbay Pump Station

Initial Desktop Evaluation Category: Facilities with Only Vulnerability Listed
MLK Outlet Tunnel Regulator
Initial Desktop Evaluation Category: Facilities with Only Consequences of Failure Listed
Henderson/Norfolk CSO Facility

4.2 Field Investigations

4.2.1 Field Investigation Teams & Schedule

In order to complete field investigations of thirty-seven facilities within a condensed schedule, two field teams performed the work in parallel. The electrical engineer only attended the field investigations in which evaluation of the electrical systems was determined to be critical. Table 7 provides a summary of the facilities investigated, which team performed which investigation, and the corresponding schedule.

Table 7: Field Investigation Facility List & Schedule

Visit No.	Name	Facility Type	Team	Date	Electrical Attending
1&2	Operations Building	South Treatment Plant	Team 1 & Team 2 (all staff)	4/5/2017	X
	Santler Building	South Treatment Plant			
	Maintenance Facilities	South Treatment Plant			
3	Influent Pump Station	South Treatment Plant	Team 1 - Erik Bishop	4/6/2017	X
	Effluent Pump Station	South Treatment Plant			
	Primary/Solids Handling Building	South Treatment Plant			
4	Lake Ballinger	Pump Station	Team 1 - Erik Bishop	4/11/2017	
	York	Pump Station			
5	Carkeek CSO Plant	CSO Treatment Plant	Team 2 - Kenny O'Neill	4/11/2017	X
	Mathews Park	Pump Station			
6	Mercer/Elliott West CSO Facility	CSO Treatment Facility	Team 1 - Erik Bishop	4/12/2017	X
	Denny Way	Regulator Station			
	Interbay	Pump Station			
7	East Pine St	Pump Station	Team 2 - Kenny O'Neill	4/12/2017	
	Duwamish	Pump Station			
8	Alki CSO	CSO Treatment Facility	Team 1 - Erik Bishop	4/13/2017	X
	63rd Ave	Pump Station			
	West Marginal Way	Pump Station			
9	Belvoir	Pump Station	Team 2 - Kenny O'Neill	4/13/2017	
	Sweyolocken	Pump Station			
10	Heathfield	Pump Station	Team 1 - Erik Bishop	4/18/2017	
	Sunset	Pump Station			

Visit No.	Name	Facility Type	Team	Date	Electrical Attending
11	30th Ave NE	Pump Station	Team 2 - Kenny O'Neill	4/18/2017	X
	Henderson-Norfolk CSO Facility	CSO Treatment Facility			
	MLK Outlet Tunnel	Regulator Station			
12	Interurban	Pump Station	Team 2 - Kenny O'Neill	4/19/2017	
	Pacific	Pump Station			
13	Admin/Operations Building	West Point Treatment Plant	Team 1 - Erik Bishop	4/20/2017	X
	Maintenance/Stores	West Point Treatment Plant			
	Electrical Substations	West Point Treatment Plant			
14	LOX/OGADs	West Point Treatment Plant	Team 2 -Kenny O'Neill	4/20/2017	
	Primary	West Point Treatment Plant			
	Heat source for digesters	West Point Treatment Plant			
15	Hypochlorite Mixing	West Point Treatment Plant	Team 1 - Erik Bishop	4/25/2017	
	Raw Sewage Pumps	West Point Treatment Plant			
16	Intermediate Pump Station	West Point Treatment Plant	Team 2 - Kenny O'Neill	4/25/2017	X
	Effluent Pump Station	West Point Treatment Plant			

4.2.2 Structural Evaluation Tools

ASCE 41-13: Seismic Rehabilitation of Existing Buildings is the standard of care for performing seismic evaluations of buildings and determining rehabilitation techniques. It includes a three-tiered review process that is implemented by following a series of predefined checklists and "quick check" structural calculations. Each successive tier is designed to perform an increasingly refined evaluation procedure for seismic deficiencies identified in previous tiers in the process. Each "level" of seismic evaluation may be selected based on the scope, objectives, and complexity of the evaluation. Tier 1 includes prescriptive checklists and quick checks to rapidly screen buildings for seismic deficiencies. Tier 2 is used to perform more detailed evaluations of buildings, including structural modeling and the calculation of demand-to-capacity ratios for structural components. Tier 3 is used to perform advanced analysis of complex buildings, including non-linear dynamic time history analyses.

For the structural evaluation, *ASCE 41-13* Tier 1 checklists were used as the primary tool for documenting the field evaluations of the County facilities. Tier 1 structural checklists are specific to each common building type and contain seismic evaluation statements based on observed structural damage in past earthquakes. These checklists screen for potential seismic deficiencies by examining the lateral-force-resisting systems and details of construction that have historically caused poor seismic performance in similar buildings. Tier 1 screenings include basic "Quick Check" analyses for primary components of the lateral system and prescriptive checks for proper seismic detailing of connections, diaphragm spans and continuity, and overall system configuration. The checklists items are not quantitative, but indicate if each checklist item is compliant (C), non-compliant (NC), not applicable (N/A), or unknown (U).

In addition to the Tier 1 structural checklists, Tier 1 architectural checklists were completed to identify the nonstructural/architectural components that may be vulnerable to damage or collapse in an earthquake. Architectural elements included (but were not limited to):

- Nonstructural and partition walls
- Ceiling systems
- Lighting fixtures
- Emergency egress systems (stairs, railings, emergency lighting, doorways, etc.)
- Cladding and glazing
- Masonry veneer
- Masonry chimneys
- Building contents and furnishings
- Parapets, cornices, ornamentation, and appendages

Additionally, the RVS forms were reviewed in the field to either validate previous assumptions on the building configuration or to refine the characterization of the facility based on more accurate on-site field observations. The findings from the Tier 1 structural checklists, Tier 1 architectural checklists, and RVS forms were documented in the field with annotations on the primary seismic deficiencies/vulnerabilities observed. Due to the limited field investigation time, field observations were limited to the primary accessible areas of the facilities. Therefore, the structural and architectural features observed and documented in the checklists were assumed to be representative of the entire facility. The structural/architectural Tier 1 checklists for the (37) facilities have been included in Attachment 2B.

It is important to note that in 2000, the building codes such at the International Building Code, started basing seismic design on 2 percent chance of occurrence in 50 years (2475 average return interval) ground motions instead of 10 percent chance of occurrence in 50 years (475 year average return interval) ground motions. It was not until the 1990s that surface fault zones such as the Seattle Fault Zone were even active in the Puget Sound region. Large, shallow earthquakes in the Puget Sound that can generate strong ground shaking intensity typically have average return intervals from approximately one thousand to several thousand years. The understanding of building vulnerabilities to seismic motions has also increased significantly since the 1990s. Consequently, the understanding of the seismic vulnerability of many County facilities may have significantly increased since the facilities were designed, seismically retrofitted, or previously evaluated.

4.2.3 Mechanical/Electrical Evaluation Tools

For the mechanical and electrical evaluations, *ASCE 41-13* Tier 1 checklists were used as the primary tool for documenting the field evaluations of County facilities. However, these checklists were also supplemented with checklist items from *ASCE Technical Council on Lifeline Earthquake Engineers (TCLEE), Monograph No. 22*, as well as items from HDR's seismic bracing standards.

Mechanical checklist elements included but were not limited to:

- Life Safety Systems
    - Fire Suppression Systems
    - Emergency Lighting
    - Emergency Power
    - Fueled Systems

- Mechanical Equipment/Tanks
    - Suspended Equipment
    - Fall-Prone Equipment
    - Tanks
    - Instrument Air Systems
    - Filters/Screens
    - Cranes
- Pumps
    - Vertical Pumps
    - Horizontal Pumps
    - Submersible Pumps
    - Pump Support Equipment
- Chemical/Hazardous Material Systems
    - Chemical/Hazardous Storage
    - Chemical/Hazardous Secondary Containment
    - Chemical/Hazardous Equipment
- Piping/Valves
    - Pipe Bracing, Non-Hazardous Materials
    - Pipe Bracing, Chemical/Hazardous materials
    - Valves, Anchorage, and Accessories

Electrical checklist elements included:

- Pad and Floor-Mounted Equipment
- Elevated and Pole-Mounted Transformers
- Cables and Conduit
- Other Electrical Equipment

The findings from the mechanical and electrical checklists were documented in the field with annotations on the primary seismic deficiencies/vulnerabilities observed. Due to the limited field investigation time, field observations were limited to the primary accessible areas of the facilities. Therefore, the mechanical and electrical features observed and documented in the checklists were assumed to be representative of the entire facility. The mechanical and electrical checklists for the (37) facilities have been included in Attachment 2B-3.

4.2.4 Field Investigation Data Compilation

After completing the field investigations, the data from the (37) checklists (totaling over 1000 pages) was reviewed, organized, condensed, and compiled into tabular form for use in the subsequent desktop evaluations. See Table 8 through Table 13 for a summary of the field investigation findings. To capture the perspectives of all field team members, internal workshops were held with both teams to concurrently review the field photography and completed checklists to jointly make judgments on the facility vulnerability. Based on the deficiencies identified in the checklists and the field annotations, each facility was rated with a 1-5 (Low, Low-Moderate, Moderate, Moderate-High, High) vulnerability rating separately for the structural, mechanical and electrical systems. The primary deficiencies were documented in the summary table using abbreviations and a checklist coding system to consolidate the field investigation data into a manageable table. Based on the deficiencies identified and the professional judgment of the team members, a brief list of expected consequences/impacts resulting from the identified deficiencies was documented. These consequences focused on the systems/components that are expected to affect the overall functionality/operations of that facility.

It is important to note that the goal for the field investigation data compilation process was to simplify the complex, nuanced, and extensive field observations into concise data for the purpose of this resiliency study. Therefore, experience-based judgment was exercised to interpret the numerous deficiencies and rate the facilities' vulnerability and the expected consequences of the deficiencies. The primary value of these ratings was to make comparative judgments between the facilities in order to generate prioritized lists of seismic rehabilitation projects and rough order of magnitude (ROM) costs for planning purposes. These findings were intended for subsequent use in determining the conceptual scope and costs associated with specific seismic retrofit projects in Task 400.

Table 8: Field Investigation Summary Table - Structural Summary & Deficiencies

King County Facility Name	Structural / Architectural Vulnerability	Structural Field Investigation Findings Summary
		Deficiencies
High Priority - Categorically Important		
South Treatment Plant - Primary System		
SP Digester Gas Equipment Building	Low-Mod	Insufficient seismic joint, lights
SP Santler Building	Mod-High	Tilt-up wall conn/requirements;
SP Maintenance Facilities Building	Mod-High	
SP Influent Pump Station	High	Z-Beam - diaph/load path, PC Wall conn; sus. CLGs, lights, canopies, contents
SP Effluent PS	Low-Mod	
SP Operations Building	High	Penthouse load path; server room equipment; partitions/CLGs/lights
West Point Treatment Plant - Primary System		
WP Admin/Operations Building	High	Weak story/geometry; BF requirements; server room/CLGs/lights/contents
WP Maintenance/Stores Building	Mod-High	Seismic joint, BF requirements; diaph openings; partitions/CLGs/lights/storage/ contents
WP Electrical Substations	Low-Mod	PC diaph panel conns unknown; coupling beams; lights/contents
WP LOX/OGADs Building	Low-Mod	Seismic joint; Ceilings/Lights
WP Primary Clarifiers	High	Z-Beam -diaph/load path; irregularities; lights
WP Digester Boilers Building	Mod-High	Adj. building; shear wall openings, diaph openings, irregularities; PC Cladding
WP Effluent Pump Station (EPS)	Mod-High	Seismic joint, BF requirements; diaph openings; partitions/CLGs/lights/storage/contents
WP Raw Sewage (Influent) Pump Station	High	Z-Beam diaph/load path; weak story; SBWC; PC wall panels; RC MFs; CMU walls; lights/CLGs/contents
WP Intermediate Pump Station (IPS)	Low-Mod	Subgrade structural joints; lights; glass blocks
Hypochlorite Mixing/Storage	Mod-High	Adj. building; load path; lights; canopies; appendages

King County Facility Name	Structural / Architectural Vulnerability	Structural Field Investigation Findings Summary Deficiencies
High Risk		
63rd Av. Pump Station	Low-Mod	NS only - fall-prone/sus. Contents
Duwamish Pump Station	High	Load path; adj. builidng; irregularities; diaph; Conc MFs; infill walls; lights/CLGs/cladding/contents
Heathfield Pump Station	Low	Landslide; lights
Interurban Pump Station	Low-Mod	Glass block; lights
Matthews Park Pump Station	High	PC walls at high bay; inverted V roof; geometry/mass; wall/CB reinf; lights/CLGs/contents
Sweyolocken Pump Station	Mod-High	Load path unclear; diaphragm cross-ties; lights; appendages/contents
West Marginal Way Pump Station	Mod	Diaphragm openings;
York Pump Station	Mod	
Alki CSO Plant	Mod-High	Adj. bldgs; masonry SW openings; diaph conn; wall anchorage; contents
East Pine St. Pump Station	Mod	Geometry; landslide; coupling beams; diaph; ceilings/lights/veneer
Sunset Pump Station	Low-Mod	Landslide/slope; heavy partition; lights
30th Av. NE Pump Station	Mod-High	Geometry; wall/CB reinf; landslide; lights
Belvoir Pump Station	Mod-High	Landlside susceptiabiltiy; CP reinf; lights
Carkeek CSO Plant	High	
Lake Ballinger Pump Station	Mod	Geometry; torsion; redundancy; lights/cladding/glass block/contents
High Vulnerability, Lower Consequences of Failure		
Pacific Pump Station	Low-Mod	Lights
Lower Vulnerability and/or Lower Consequences of Failure		
Mercer/Elliott West CSO Facility	Low-Mod	Diaphragm openings;
Denny Way Pump Regulator Station	High	Load path; wall anchorage; cross-ties; SW openings; diaphragm;
Interbay Pump Station	High	Load/Geometry/Mass; Infill walls/Columns; Redundancy; Diaph;OOP Walls; CLGs/lights/Veneer
Facilities with Only Vulnerability Listed		
MLK Outlet Tunnel	Mod	Geometry/Mass;Lights;
Facilities with Only Consequences of Failure Listed		
Henderson/Norfolk CSO Facility	Low	Geometry; glass block windows

Table 9: Field Investigation Summary Table – Liquefaction & Structural Deficiency Consequences

King County Facility Name	Structural Field Investigation Findings Summary Expected Consequence
High Priority - Categorically Important	
South Treatment Plant - Primary System	
SP Digester Gas Equipment Building	Pounding damage, nonfunctional lights
SP Santler Building	Wall damage, OOP failure; collapse risk; fallen storage/equipment
SP Maintenance Facilities Building	
SP Influent Pump Station	Roof collapse risk; wall/RC col damage; nonstructural damage
SP Effluent PS	
SP Operations Building	Server equipment failure; NS damage; penthouse damage
West Point Treatment Plant - Primary System	
WP Admin/Operations Building	Wall & BF damage; NS Damage; server equipment down
WP Maintenance/Stores Building	Pounding damage; BF damage; diaphgragm damage; NS damage
WP Electrical Substations	Diaph damage; coupling beam damage; fallen shelves
WP LOX/OGADs Building	Pounding damage; ceilings/lights damage
WP Primary Clarifiers	Diaph damage; possible roof collapse; collapse risk
WP Digester Boilers Building	Diaph damage; pounding damage; NS damage
WP Effluent Pump Station (EPS)	Pounding damage; BF damage; diaphgragm damage; NS damage
WP Raw Sewage (Influent) Pump Station	Roof collapse hazard; significant structural damage; NS damage
WP Intermediate Pump Station (IPS)	Damage at subgrade structural connections; lights; broken glass blocks
Hypochlorite Mixing/Storage	Impact with adj. structures; nonstructural damage; lights;
High Risk	
63rd Av. Pump Station	Nonstructural damage to contents
Duwamish Pump Station	Significant structural damage, collapse potential; significant NS damage
Heathfield Pump Station	Building movement/connection to subgrade piples damaged; damaged lights
Interurban Pump Station	Broken glass block; lights
Matthews Park Pump Station	Significant structural damage, collapse potential; NS damage to lights/contents
Sweyolocken Pump Station	Damaged roof/MF/glazing; broken lights/fallen contents
West Marginal Way Pump Station	Diaphragm damage
York Pump Station	
Alki CSO Plant	Significant structural damage, collapse potential; NS damage to lights/contents
East Pine St. Pump Station	Moderate structural damage; possible veneer; NS damage to CLGs/lights
Sunset Pump Station	Landslide potential; lights
30th Av. NE Pump Station	Landslide potential; moderate structural damage; lights

King County Facility Name	Structural Field Investigation Findings Summary Expected Consequence
Belvoir Pump Station	Landslide potential; moderate structural damage; lights
Carkeek CSO Plant	
Lake Ballinger Pump Station	Moderate structural damage; possible veneer/PC panels; NS damage
High Vulnerability, Lower Consequences of Failure	
Pacific Pump Station	Liquefaction settlement potential; damaged lights
Lower Vulnerability and/or Lower Consequences of Failure	
Mercer/Elliott West CSO Facility	Minimal damage
Denny Way Pump Regulator Station	Roof damage/collapse potential
Interbay Pump Station	Significant structural damage, collapse potential; significant NS damage
Facilities with Only Vulnerability Listed	
MLK Outlet Tunnel	
Facilities with Only Consequences of Failure Listed	
Henderson/Norfolk CSO Facility	Minimal damage; glass block

Table 10: Field Investigation Summary Table – Mechanical Vulnerability Ratings & Deficiencies

King County Facility Name	Mechanical Field Investigation Findings Summary	
	Vulnerability	Deficiencies
High Priority - Categorically Important		
South Treatment Plant - Primary System		
SP Digester Gas Equipment Building	Moderate	M1, M2, M6, P1, P2, F2, C4, C5
SP Santler Building	Low-Mod	C1, C4, R1, P7
SP Maintenance Facilities Building	Moderate	R, P3, P7, M1, F3, M8, D1, M5, S2, S1, V2, M6
SP Influent Pump Station	Mod-High	P1, P2, P3, P7, R, M1, M8, D1, X1, X2, X5, V2, F2, F3, M5, M1, M6
SP Effluent PS	Mod-High	P2, P3, P7, R, M8, X1, X2, X5, V2, F2, F3, M5, E8, D1, M6
SP Operations Building	Low-Mod	M1, M2, P3, L1
West Point Treatment Plant - Primary System		
WP Admin/Operations Building	Mod-High	R, P3, P7, M1, C5, F3, M8, D1, V2, M6
WP Maintenance/Stores Building	Mod-High	R, P3, P7, M1, F3, M8, D1, D3, M5, C4, V2, M6
WP Electrical Substations	Moderate	R, M1, M8, D1, S1, M6
WP LOX/OGADs Building	Low-Mod	R, M1, M2, P1, P2, F2, V2, S1, C5
WP Primary Clarifiers	Low-Mod	P1, P2, M1, M2
WP Digester Boilers Building	Low-Mod	R, P1,P4, V2, X3, F4
WP Effluent Pump Station (EPS)	Moderate	S2, R1, R3, P1, P2, D1, M1, X2, C4, M8, F6, V2
WP Raw Sewage (Influent) Pump Station	Mod-High	P4/V2, M1, R3, P, D, M2, M6, X2
WP Intermediate Pump Station (IPS)	Moderate	R, R3, M1, M2, M7, P3, L1

King County Facility Name	Mechanical Field Investigation Findings Summary	
	Vulnerability	Deficiencies
Hypochlorite Mixing/Storage	Moderate	R, S1, P6, F2, F6, M7, C2
High Risk		
63rd Av. Pump Station	Low-Mod	X1, L1, F2, F3, M6
Duwamish Pump Station	Moderate	R, R1, C5, P2, F2, F5, M1, G3
Heathfield Pump Station		
Interurban Pump Station	Moderate	P2, P3, P5, R, M1, M8, D1, X1, X2, X5, V2, F2, F3, M5, L1, C4, M6
Matthews Park Pump Station	Moderate	P2, P3, P5, R, M1, M8, D1, D2, X1, X2, X5, V2, F2, F3, F4, M5, S1, L1, C1, C3, P6, M6
Sweyolocken Pump Station	Moderate	P1, P2, P3, P5, P7, R, M1, D1, D2, D4, X1, X2, X5, V2, F2, F3, E4, E5, M6
West Marginal Way Pump Station	Low-Mod	R, M2, M6, F2, G3
York Pump Station	Low-Mod	P1, P2, P3, P5, P6, P7, R, M1, M8, D1, D2, D3, D4, X1, X2, X5, V2, F2, F3, F5, G3, C1, M6
Alki CSO Plant	Low-Mod	R, C5, F4, F6, P6, M2, M7, G3, G4
East Pine St. Pump Station	Low-Mod	R, P3, G2, G3, G4, F5
Sunset Pump Station		
30th Av. NE Pump Station	Low-Mod	P1, P2, P3, P5, R, M1, M5, M8, D1, D2, X1, X2, X5, V2, F2, F3, F5, G4, M6
Belvoir Pump Station	Low-Mod	P1, P2, P3, P5, R, S1, M1, M5, M8, D1, D2, X1, X2, X5, V2, F2, F3, F5, G2, G4, M6
Carkeek CSO Plant	Moderate	R, M2, M7, C1, C2, X2, F5, G4
Lake Ballinger Pump Station	Low-Mode	R, D2, M2, F2, L1
High Vulnerability, Lower Consequences of Failure		
Pacific Pump Station	Low-Mod	R, R4, F1, F2, D1, D2, D4
Lower Vulnerability and/or Lower Consequences of Failure		
Mercer/Elliott West CSO Facility	Low-Mod	R, M2, M7, P4, P7, F2, F5, F6, D1, D2, V2, G4
Denny Way Pump Regulator Station	Low-Mod	M2, M3, M7, F1, F2
Interbay Pump Station	Low-Mod	R, M1, M2, C5, P2, E1, G3
Facilities with Only Vulnerability Listed		
MLK Outlet Tunnel	Low-Mod	R, M6, M7, D1, F5, F6, G4
Facilities with Only Consequences of Failure Listed		
Henderson/Norfolk CSO Facility	Low-Mod	R, F2, F4, F6, M6, X3, S1, D2, D4, G4, P4

Table 11: Field Investigation Summary Table – Mechanical Vulnerability Ratings & Consequences

King County Facility Name	Mechanical Field Investigation Findings Summary Expected Consequence
High Priority - Categorically Important	
South Treatment Plant - Primary System	
SP Digester Gas Equipment Building	Equipment failure, Seal water failure, Digester gas leak
SP Santler Building	Propane Leak, Sprinkler system failure, Rack falling, Parts falling
SP Maintenance Facilities Building	Falling equip, pump and hot water support equip failure, sprinkler failure
SP Influent Pump Station	Grit pumping failure, pump and support equip failure, flooding
SP Effluent PS	Pump and support equipment failure, flooding, electrical failure
SP Operations Building	AC failure in elec & control rooms, C2 Syst failure, HW syst failure
West Point Treatment Plant - Primary System	
WP Admin/Operations Building	Falling equipment, pump and support equip failure, haz material spill
WP Maintenance/Stores Building	Falling equip, pump and support equip failure, compressed gas release
WP Electrical Substations	HVAC system damage, falling equipment, power failure
WP LOX/OGADs Building	O2 leak/syst failure, IA syst failure, HVAC syst failure, Blower failure
WP Primary Clarifiers	Grit syst, sludge syst, aeration syst and scum syst failure
WP Digester Boilers Building	Flooding, Propane leak/ failure, Biogas leak/failure, boiler failure
WP Effluent Pump Station (EPS)	Pump/seal failure, flooding, chem spill, exity safety, flammable liquid spill
WP Raw Sewage (Influent) Pump Station	Pump motor failure, gas leak, flammable liquid spill, flooding
WP Intermediate Pump Station (IPS)	Pump failure, Blower failure, Hydraulic syst failure, chemical spill
Hypochlorite Mixing/Storage	Chemical spill, Hypo syst failure, IA syst failure
High Risk	
63rd Av. Pump Station	Flooding, Electrical Equipment failure, Flush syst failure
Duwamish Pump Station	Pump/Motor failure, Generator/fuel syst failure
Heathfield Pump Station	
Interurban Pump Station	Pump and support equip failure, flooding
Matthews Park Pump Station	Pump and support equip failure, flooding, chemical spills, generator fail
Sweyolocken Pump Station	Pump and support equip failure, flooding
West Marginal Way Pump Station	Pump/seal water failure, Generator/fuel syst failure, IA syst failure
York Pump Station	Pump and support equip failure, flooding, chemical spills, generator fail
Alki CSO Plant	Gas leak, Chem spill, Generator failure, flooding, sampler failure
East Pine St. Pump Station	Generator failure
Sunset Pump Station	
30th Av. NE Pump Station	Pump and support equip failure, flooding
Belvoir Pump Station	Pump and support equip failure, flooding
Carkeek CSO Plant	Chem spill/syst failure, flooding, Gen failure, smplr failure, AB failure
Lake Ballinger Pump Station	FM bladder tk failure, C2 syst failure, OC duct failure

King County Facility Name	Mechanical Field Investigation Findings Summary
	Expected Consequence
High Vulnerability, Lower Consequences of Failure	
Pacific Pump Station	Pump failure, IA syst failure, OC syst failure
Lower Vulnerability and/or Lower Consequences of Failure	
Mercer/Elliott West CSO Facility	Chem spill/syst failure, Pump failure, gas leak, Generator failure
Denny Way Pump Regulator Station	Chemical spill, Bisulfate syst failure, IA syst failure
Interbay Pump Station	Pump failure, Generator failure, hydraulic syst failure, IA syst failure
Facilities with Only Vulnerability Listed	
MLK Outlet Tunnel	Chemical spill/syst failure, Sampler failure, Generator failure
Facilities with Only Consequences of Failure Listed	
Henderson/Norfolk CSO Facility	Gas leak, flooding, Chem spill/syst failure, Gen failure, IA syst failure

Table 12: Field Investigation Summary Table – Electrical Vulnerability Ratings & Deficiencies

King County Facility Name	Electrical Field Investigation Findings Summary	
	Vulnerability	Deficiencies
High Priority - Categorically Important		
South Treatment Plant - Primary System		
SP Digester Gas Equipment Building	Moderate	Bracing, mounting
SP Santler Building	Low-Mod	Restraints
SP Maintenance Facilities Building	Moderate	Access to MCC, bracing, lighting on conduit
SP Influent Pump Station	High	Anchoring, restraints, non-related elements, instrumentation
SP Effluent PS	Low-Mod	Mounting, bracing, non-related elements
SP Operations Building	High	Anchoring, restraints, non-related elements
West Point Treatment Plant - Primary System		
WP Admin/Operations Building	Mod-High	Anchoring, bracing, restraints, scada wiring
WP Maintenance/Stores Building	Low-Mod	Restraint, defective anchoring, comm equip
WP Electrical Substations	Low-Mod	Bracing, restraint
WP LOX/OGADs Building	Low-Mod	Panel/cabinet bracing
WP Primary Clarifiers	Low-Mod	None noted
WP Digester Boilers Building	Low-Mod	Conduit/tray bracing, water over elect equipment
WP Effluent Pump Station (EPS)	Low-Mod	Anchoring, restraints
WP Raw Sewage (Influent) Pump Station	Moderate	Bracing, defective anchoring, comm equip, battery
WP Intermediate Pump Station (IPS)	Low-Mod	Panel/cabinet bracing, conduit/tray bracing
Hypochlorite Mixing/Storage	Low-Mod	Water over electrical equipment
High Risk		
63rd Avenue Pump Station	Moderate	Restraints, no pad
Duwamish Pump Station	Low-Mod	Unsecured Xfmr, unbraced panels, unsecured UPS

King County Facility Name	Electrical Field Investigation Findings Summary	
	Vulnerability	Deficiencies
Heathfield Pump Station		
Interurban Pump Station		
Matthews Park Pump Station	Low-Mod	Bracing, restraints, mounting
Sweyolocken Pump Station		
West Marginal Way Pump Station	Low-Mod	Bracing, comm equip, battery
York Pump Station		
Alki CSO Plant	Mod-High	Anchoring, mount, restraints, comm equip, battery, lighting
East Pine St. Pump Station	Low-Mod	Unbraced panels, Unsecured UPS
Sunset Pump Station		
30th Av. NE Pump Station	Low-Mod	Bracing, restraints, battery
Belvoir Pump Station	Low-Mod	Restraint, defective anchoring, comm equip, battery
Carkeek CSO Plant	Moderate	Anchoring, bracing, defective mounting, battery
Lake Ballinger Pump Station	Low-Mod	Bracing, anchoring
High Vulnerability, Lower Consequences of Failure		
Pacific Pump Station	Low-Mod	Restraint, defective anchoring, bracing
Lower Vulnerability and/or Lower Consequences of Failure		
Mercer/Elliott West CSO Facility	Moderate	Insuff motor flex wiring length, comm equip, batt.
Denny Way Pump Regulator Station	Mod-High	Generator, anchoring, non-related elements restraint
Interbay Pump Station	Low-Mod	Mounting, defective anchoring, battery, bracing
Facilities with Only Vulnerability Listed		
MLK Outlet Tunnel	Low-Mod	(4203 S FAIRB). Bracing, anchoring
Facilities with Only Consequences of Failure Listed		
Henderson/Norfolk CSO Facility	Low-Mod	Restraint

Table 13: Field Investigation Summary Table – Electrical Vulnerability Ratings & Consequences

King County Facility Name	Electrical Field Investigation Findings Summary	
	Vulnerability	Expected Consequence
High Priority - Categorically Important		
South Treatment Plant - Primary System		
SP Digester Gas Equipment Building	Moderate	Control loss, wiring damage, exit safety, equipment fall hazards
SP Santler Building	Low-Mod	Exit safety, equipment fall hazards
SP Maintenance Facilities Building	Moderate	Equipment fall hazards, reduced access to mcc area
SP Influent Pump Station	High	Overturned servers, scada loss, comm loss, cfl, flood, mcc ctrls
SP Effluent PS	Low-Mod	Instrumentation signal loss, sump fail, e-power loss

King County Facility Name	Electrical Field Investigation Findings Summary	
	Vulnerability	Expected Consequence
SP Operations Building	High	Overturned server racks, scada loss, comm loss, equip damage
West Point Treatment Plant - Primary System		
WP Admin/Operations Building	Mod-High	Overturned server racks, scada loss, comm loss, fire
WP Maintenance/Stores Building	Low-Mod	Comm loss, power loss, e-lighting loss
WP Electrical Substations	Low-Mod	Power loss, panel damage, switches unintentionally toggled
WP LOX/OGADs Building	Low-Mod	Overturned Electrical/control panels
WP Primary Clarifiers	Low-Mod	
WP Digester Boilers Building	Low-Mod	Water on electrical equipment
WP Effluent Pump Station (EPS)	Low-Mod	Equipment fall hazards, control panels overturning
WP Raw Sewage (Influent) Pump Station	Moderate	Comm loss, power loss, e-power loss, acid, fire
WP Intermediate Pump Station (IPS)	Low-Mod	Overturned panel/cabinet, water on elect equipment
Hypochlorite Mixing/Storage	Low-Mod	Water on electrical equipment
High Risk		
63rd Avenue Pump Station	Moderate	Sump fail, water hazard
Duwamish Pump Station	Low-Mod	Overturned panels, Xfmr failure, UPS failure
Heathfield Pump Station		
Interurban Pump Station		
Matthews Park Pump Station	Low-Mod	E-power loss, e-lighting loss, exit safety, comm loss, fire
Sweyolocken Pump Station		
West Marginal Way Pump Station	Low-Mod	Equipment fall hazard, comm loss, e-power loss
York Pump Station		
Alki CSO Plant	Mod-High	Equipment fall hazard, comm loss, sump fail, cfl hazard, exit safety
East Pine St. Pump Station	Low-Mod	Overturned panels, UPS failure
Sunset Pump Station		
30th Avenue NE Pump Station	Low-Mod	E-power loss, exit safety
Belvoir Pump Station	Low-Mod	Comm loss, e-power loss, exit safety
Carkeek CSO Plant	Moderate	Equipment fall hazard, dryer movement, sump fail
Lake Ballinger Pump Station	Low-Mod	Equipment fall hazard
High Vulnerability, Lower Consequences of Failure		
Pacific Pump Station	Low-Mod	Equipment fall hazards
Lower Vulnerability and/or Lower Consequences of Failure		
Mercer/Elliott West CSO Facility	Moderate	Pump instrumentation loss, comm loss, e-power loss
Denny Way Pump Regulator Station	Mod-High	E-power loss, equipment fall hazards, bubbler damage, sampler
Interbay Pump Station	Low-Mod	Bubbler loss, dryer toppling, e-power loss, cfl hazards
Facilities with Only Vulnerability Listed		
MLK Outlet Tunnel	Low-Mod	Dryer movement

King County Facility Name	Electrical Field Investigation Findings Summary	
	Vulnerability	Expected Consequence
Facilities with Only Consequences of Failure Listed		
Henderson/Norfolk CSO Facility	Low-Mod	Sampler equipment movement

4.2.5 Field Investigation Findings

The facilities evaluated based on field investigations and *ASCE 41-13* Tier 1 checklists are listed in Table 14. This includes 10 treatment plant facilities at West Point Treatment Plant, 6 treatment plant facilities at South Treatment Plant, 15 offsite pump stations, 4 CSO facilities, and 2 regulator stations that were evaluated with a field assessment. The observed structural, architectural, and MEP deficiencies were reviewed considering the expected consequence of failure and rated with a vulnerability score. The overall vulnerability score was weighted to provide greater consideration for the structural and liquefaction vulnerability than for the architectural and MEP vulnerabilities, as it is expected that MEP services could be replaced relatively quickly after an event. The vulnerability scores were also scaled based on the amplitude and relative duration of ground motion for each of the scenarios in order to provide probability of failure for each earthquake event, as presented in Table 14. The facilities' structural, liquefaction, MEP, and overall vulnerability ratings for each scenario are also depicted in system-wide maps presented in Attachment 1D.

Table 14: Field Investigation Vulnerability Findings

King County Facility Name	OVERALL VULNERABILITY		
	CSZ M9.0 Scenario	SF, M7.2 Scenario	SWIF, M7.4 Scenario
High Priority - Categorically Important			
South Treatment Plant - Primary System			
SP Digester Gas Equipment Building	Mod-High	Mod-High	Mod-High
SP Santler Building	Mod-High	High	Mod-High
SP Maintenance Facilities Building	High	High	High
SP Influent Pump Station	High	High	Mod-High
SP Effluent PS	Mod-High	Mod-High	Mod-High
SP Operations Building	High	High	Mod-High
West Point Treatment Plant - Primary System			
WP Admin/Operations Building	High	High	Mod-High
WP Maintenance/Stores Building	Mod-High	Mod-High	Mod
WP Electrical Substations	Low-Mod	Low-Mod	Low-Mod
WP LOX/OGADs Building	Low-Mod	Low-Mod	Low-Mod
WP Primary Clarifiers	High	High	Mod-High
WP Digester Boilers Building	Mod-High	Mod-High	Mod
WP Effluent Pump Station (EPS)	Mod-High	Mod-High	Mod
WP Raw Sewage (Influent) Pump Station	High	High	Mod-High
WP Intermediate Pump Station (IPS)	Low-Mod	Low-Mod	Low-Mod
Hypochlorite Mixing/Storage	Mod-High	Mod-High	Mod

King County Facility Name	OVERALL VULNERABILITY		
	CSZ M9.0 Scenario	SF, M7.2 Scenario	SWIF, M7.4 Scenario
High Risk			
63rd Av. Pump Station	Mod-High	Mod-High	Mod-High
Duwamish Pump Station	High	High	High
Heathfield Pump Station	Low	Low	Low
Interurban Pump Station	Mod-High	Mod-High	Mod-High
Matthews Park Pump Station	High	High	High
Sweyolocken Pump Station	Mod-High	High	Mod
West Marginal Way Pump Station	Mod-High	Mod-High	Mod-High
York Pump Station	Mod	Mod	Mod
Alki CSO Plant	Mod-High	High	Mod
East Pine St. Pump Station	Mod	Mod	Low-Mod
Sunset Pump Station	Mod-High	Mod-High	Mod-High
30th Av. NE Pump Station	Mod-High	Mod-High	Mod-High
Belvoir Pump Station	High	High	High
Carkeek CSO Plant	High	High	Mod-High
Lake Ballinger Pump Station	Mod	Low-Mod	Mod
High Vulnerability, Lower Consequences of Failure			
Pacific Pump Station	Mod-High	Mod-High	Mod-High
Lower Vulnerability and/or Lower Consequences of Failure			
Mercer/Elliott West CSO Facility	Mod-High	Mod-High	Mod-High
Denny Way Pump Regulator Station	High	High	High
Interbay Pump Station	High	High	High
Facilities with Only Vulnerability Listed			
MLK Outlet Tunnel	Mod-High	Mod-High	Mod-High
Facilities with Only Consequences of Failure Listed			
Henderson/Norfolk CSO Facility	Low	Low	Low

4.3 Additional Desktop Evaluations

The field investigation findings were documents based on each facility's inherent structural, mechanical, and electrical seismic deficiencies and vulnerabilities, irrespective of the seismic hazards considered. Therefore, to estimate the performance of each facility in each of the three earthquake scenarios, scaling of the seismic vulnerability was required to consider the amplitude of ground motion (i.e., S_S & S_1), duration of shaking, and geotechnical hazard (liquefaction, landslide, and fault rupture) at each facility site for each scenario.

The deficiencies defined are based on evaluation checklists that are intended to evaluate facilities based on code-level ground motions. However, the earthquake scenarios have a range of ground motions that may be greater or less in amplitude than the code-defined, design-level ground motion for each particular site. For this reason, the ground motions were categorized into five levels (Low, Low-Moderate, Moderate, Moderate-High, High) corresponding to seismicity categories defined in *FEMA 154: Rapid Visual Screening (RVS) of Buildings for Potential Seismic Hazards*. A corresponding scale factor was applied to scale the vulnerability score relative to a “moderate” level of seismic ground motion that approximately correlates to a design-level event. A summary of the seismic ground motion categories and corresponding scale factors are provided in Table 15. As indicated, the Moderate-High and High seismicity levels receive a more substantial scale factor to adequately identify the increased hazard with scenario-based ground motions that are greater than a code-level event. Additionally, the CSZ scenario seismic hazards also include a scale factor of 1.2 to account for the duration of subduction zone ground motions relative to SF and SWIF crustal fault events.

Table 15: Seismic Ground Motion Categorizations

Hazard Level	S_S (g)			Scale Factor
Low	0.3	< X		0.8
Low-Moderate	0.3	< X <	0.5	0.9
Moderate	0.5	< X <	1.0	1
Moderate-High	1.0	< X <	1.5	1.25
High		X <	1.5	1.5

To determine an overall score for each scenario, the mechanical, electrical, and piping ratings were combined into a total MEP score, taken as the maximum of the MEP individual scores. The overall facility score was then taken as a weighted average between the structural and MEP scores (0.8 Structural + 0.2 MEP), in order to give the structural score more relative importance considering the expectation that a collapsed/damaged structure would require more time to repair than collapsed/damaged MEP equipment. Finally, the overall score was taken as the maximum between the combined facility rating and the liquefaction rating as global facility movement due to liquefaction-induced ground failure would superseded the functionality of an otherwise undamaged facility. Figure 8 provides a summary of the 37 field investigation facilities’ overall vulnerability ratings.

Figure 8, Figure 9, and Figure 10 provide the MEP, structural, liquefaction, and overall ratings for the CSZ M9.0, SF M7.2, and SWIF M7.4 scenarios, respectively (more legible, high-resolution versions of these maps are also included in Attachment 1D). Also, see Figure 11 for the key for these figures that identifies the vulnerability rating system. The keys in the figure borders of these GIS maps were originally used as wall-size figures and were more legible at that scale than the current document scale.

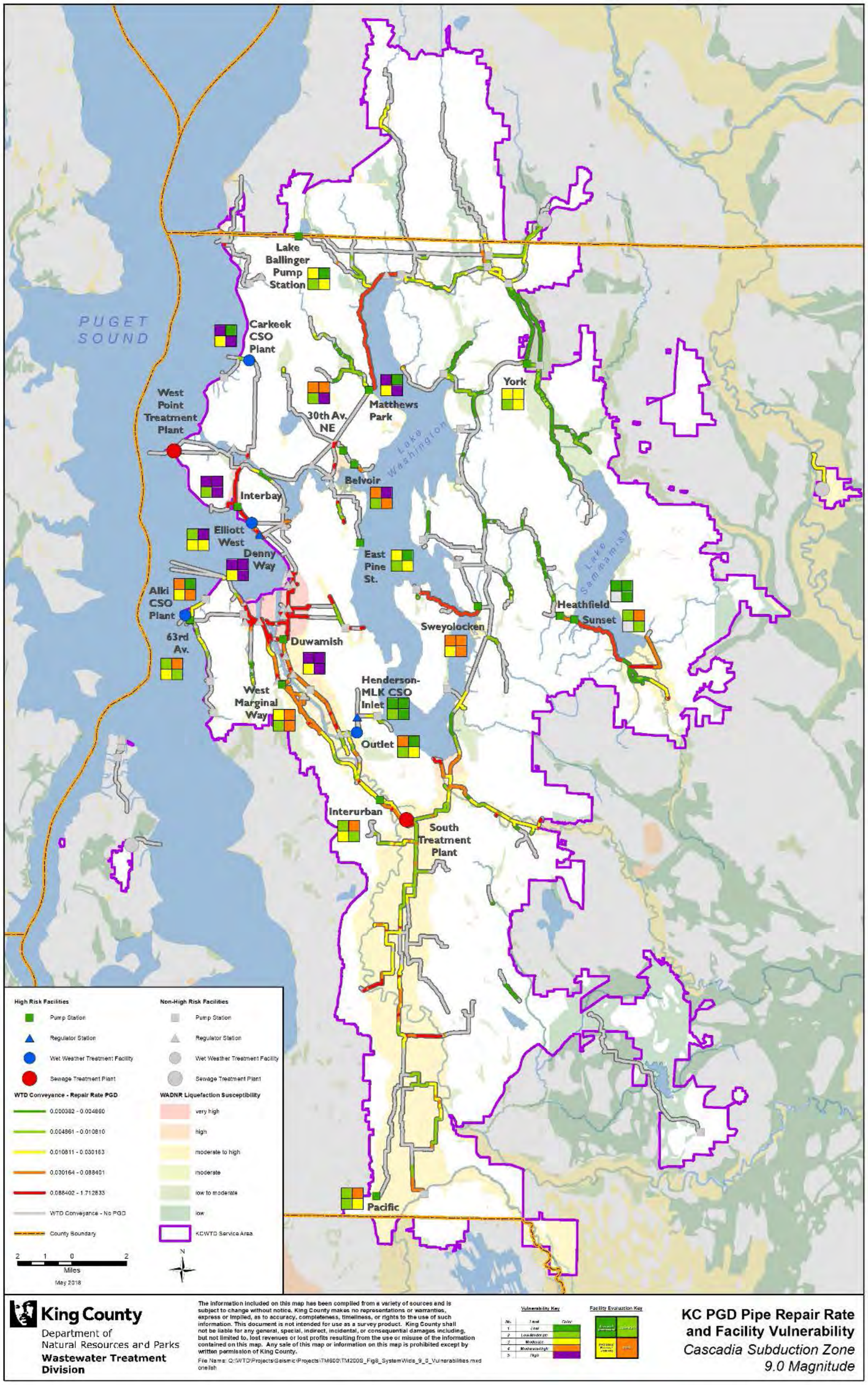

Figure 8: Field Investigation Facilities – Overall Vulnerability Ratings Map (CSZ M9.0)

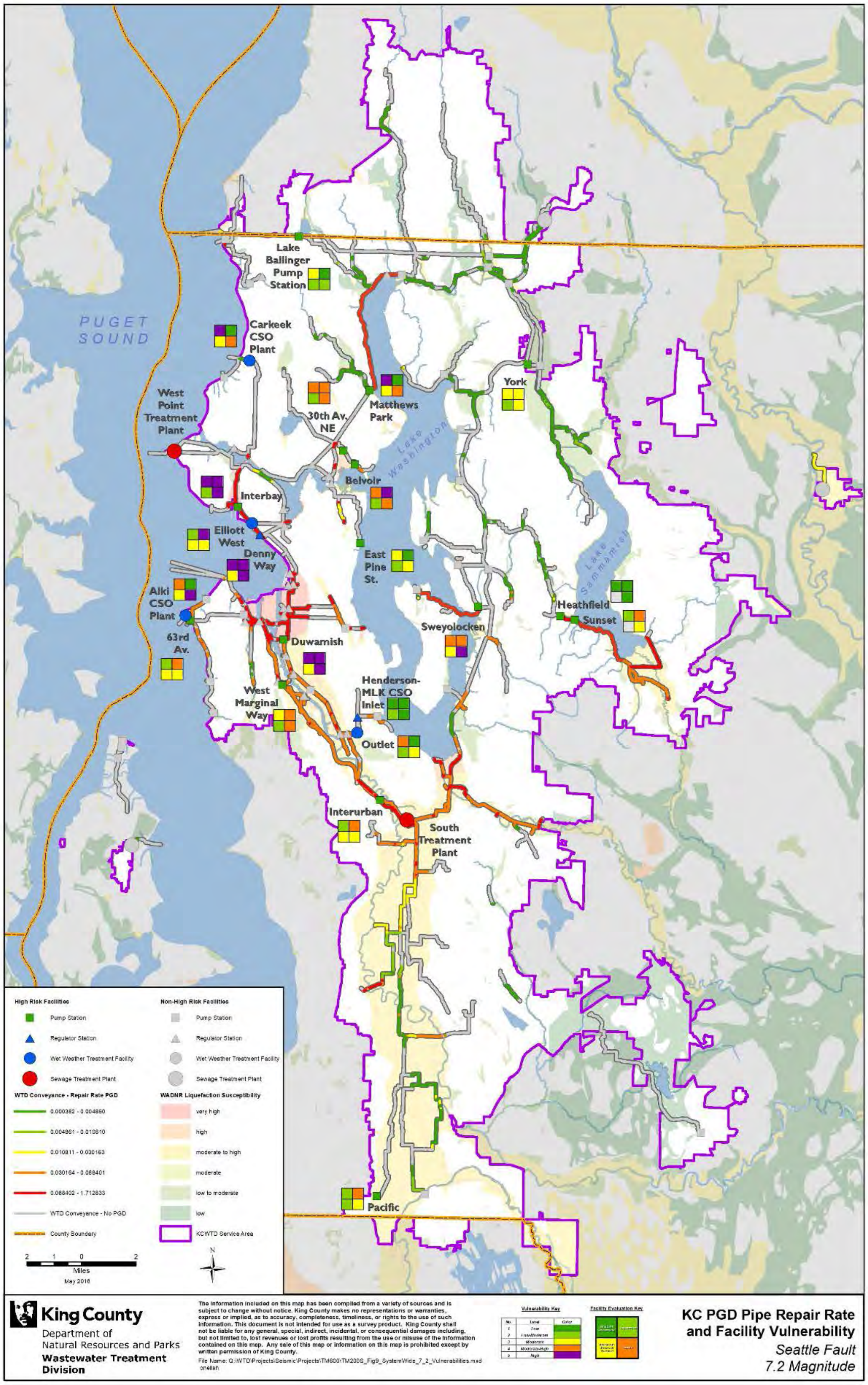

Figure 9: Field Investigation Facilities – Overall Vulnerability Ratings Map (SF M7.2)

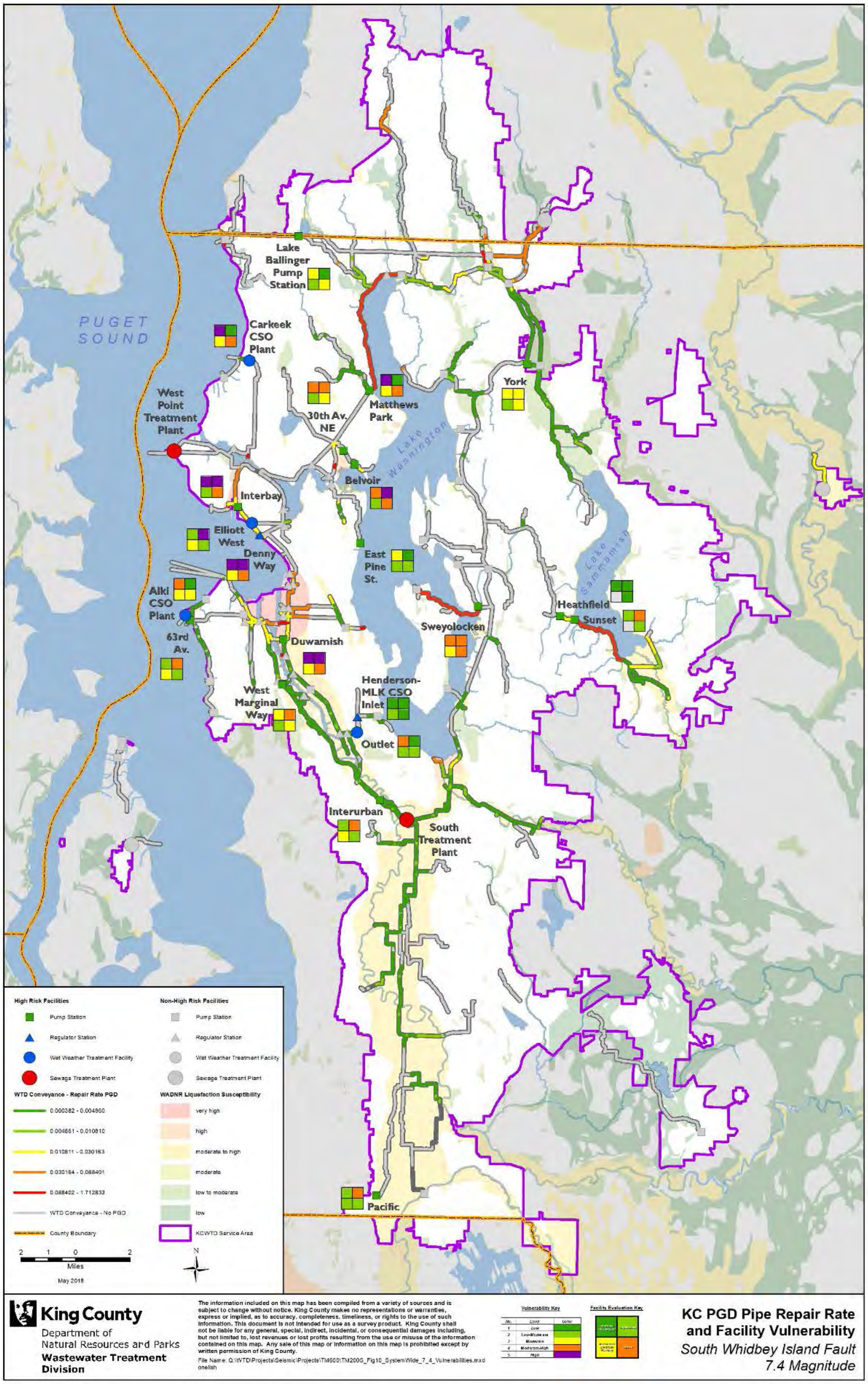

Figure 10: Field Investigation Facilities – Overall Vulnerability Ratings Map (SWIF M7.4)

Vulnerability Key

No.	Level	Color
1	Low	
2	Low-Moderate	
3	Moderate	
4	Moderate-High	
5	High	

Facility Evaluation Key

Figure 11: Vulnerability Key & Facility Evaluation Key for Vulnerability Rating Maps

4.4 Facility Prioritization & Recommendations

4.4.1 Potential Recommended Structural Projects

This section provides an initial prioritization of potential structural projects based strictly on the identified seismic vulnerabilities observed in the field assessment and their relative importance, excluding the criticality-based risk assessments. Table 16 provides a summary of the recommended structural projects based on the findings of the desktop evaluations and field investigations. The prioritization process involving criticality factors is outlined in the next portion of this technical memorandum, Section 4.4.2.

- For Priority 1, the South Plant Operations Buildings and West Point Admin/Operations Building server rooms have been identified, as the cost is expected to be relatively low considering the operations impact of the failure of the server room equipment.
- For Priority 2, the influent pump stations at South Plant and West Point have been identified as they are critical to the operations of the entire wastewater treatment plants. Based on the limited *ASCE 41-13* Tier 1 evaluation, it is expected that the deficiencies identified will warrant a seismic retrofit. Therefore, an *ASCE 41-13* Tier 3 structural and nonstructural evaluation is recommended to define the deficiencies and develop design approaches for mitigation of those deficiencies. The allocation of funds for a subsequent seismic retrofit construction project is also recommended.
- For Priority 3, Matthews Park, Interbay, Duwamish, and Lake Ballinger Pump Stations have been identified based on a combination of their seismic deficiencies and their importance to the operations of the system (e.g., they have significantly larger flow rates than the other facilities). Similar to Priority 2 facilities, it is expected that a seismic evaluation and retrofit will be warranted.
- For Priority 4, several additional pump stations and CSO treatment facilities have been identified based on the expected deficiencies identified. Similar to Priority 2 facilities, it is expected that a seismic evaluation and retrofit will be warranted. Additionally, it is recommended that a seismic monitoring system and corresponding post-earthquake response plans be developed to allow the County to immediately understand the expected post-earthquake damage to the system and manage the response.
- For Priority 5, several facilities have been identifies as warranting a more detailed seismic evaluation based on the deficiencies observed in the field observations and *ASCE 41-13* Tier 1 checklist, RVS evaluation, and HAZUS evaluation procedures. These detailed seismic evaluations should be performed in order to allow the County to determine if seismic retrofit construction projects are warranted.
- For Priority 6, several programmatic recommendations have been identified, including bracing light supports, bracing storage racks/contents, and removing glass block masonry walls. Although these are relatively low cost to implement, they are prioritized lower as they are likely to be implemented incrementally as facilities are upgraded rather than through a discreet, system-wide project.

Table 16: Recommended Potential Facility Structural Projects

Project No.	Priority Level	Structural Project List
1	1	South Plant Operations Building - server room repairs & nonstructural seismic evaluation
2	1	West Point Admin/Operations Building - server room repairs & nonstructural seismic evaluation
3	2	South Plant influent PS roof replacement/seismic evaluation
4	2	West Point Raw Water Pump Station - Tier 3 structural & nonstructural evaluation & retrofit
5	3	Duwamish Pump Station - Tier 3 structural & nonstructural evaluation & retrofit
6	3	Matthews Park Pump Station - Tier 3 structural & nonstructural evaluation & retrofit
7	3	Lake Ballinger Pump Station - Tier 3 structural & nonstructural evaluation & retrofit
8	3	Interbay Pump Station - Tier 3 structural & nonstructural evaluation & retrofit
9	4	West Point Hypochlorite Mixing - Tier 3 structural & nonstructural evaluation & retrofit replacement with new mixing and storage facility
10	4	Alki CSO Plant - Tier 3 structural & nonstructural evaluation & retrofit
11	4	East Pine St. Pump Station - Tier 3 structural & nonstructural evaluation & retrofit
12	4	Install seismic monitoring system & communication system
13	5	Santler Building Tier 3 seismic evaluation
14	5	West Point Admin/Operations Building - Tier 3 seismic evaluation
15	5	West Point Maintenance/Effluent Building - Tier 3 structural & nonstructural evaluation
16	5	West Marginal Pump Station - Tier 3 structural evaluation
17	5	30th Ave. NE Pump Station - Tier 3 structural evaluation
18	5	Perform detailed seismic evaluation of all facilities identified as high vulnerability in the RVS evaluation
19	5	Perform detailed seismic evaluation of all facilities identified as extensive damage from the HAZUS evaluation
20	5	Sweyolocken Pump Station - Tier 3 structural evaluation
21	6	Brace/Tie down storage racks and contents (e.g. tall, narrow shelving)
22	6	Light supports at all buildings
23	6	Remove & replace all facilities with glass block masonry infill walls.

4.4.2 Facility Prioritization

The following is a summary of the quantity of facilities for which information was provided and/or that were evaluated for each task.

- Facilities for which criticality ratings were provided by the County:
  - East Section: 28 Facilities
  - West Section: 38 Facilities
  - CSO: 4 Facilities
- Initial Desktop Evaluation Facilities:
  - RVS: 79 Facilities Evaluated; 56 Scores (WWTPs & CSO Outfalls excluded, some missing or limited facility information)
  - HAZUS: 229 Facilities (71 w/o sufficient information)
  - Facilities Where Risk Ratings Were Able to Be Assigned: 53 Facilities
- Field Investigation Facilities:
  - South Treatment Plant: 6 Facilities
  - West Point Treatment Plant: 10 Facilities

- Pump Stations: 15 Facilities
- CSO Treatment Plants: 4 Facilities
- Regulator Stations: 2 Facilities
- Total: 37 Facilities

- Total Facilities Evaluated (counting WWTPs as 1):
  - Pump Stations (47 Total)
  - Regulator Stations (25 Total)
  - Combined Sewer Overflow Treatment Facilities (4 Total)
  - Regional Wastewater Treatment Plants (2 Total)
  - Total: 78 Facilities

4.4.2.1 Criticality Factors and Prioritization

For the facility prioritizations conducted in this portion of the project, the following criticality factors were considered when prioritizing projects, as described in Section 2:

- Life Safety – vulnerable to building collapse
- Public Health – sewage backup
- Consequential – impacts on adjacent critical infrastructure
- Environmental – sewage discharge location and level of treatment
- Other
  - Operational capability
  - Response and restoration capability

When considering facility vulnerability and the various seismic hazards, the following facility information was considered in prioritizing projects:

- Vulnerability
  - Structural
    - Field Assessment of 37 facilities – primary criteria
    - Hazus – all facilities – secondary criteria
    - Desktop – preliminary assessment
  - Liquefaction susceptibility Very High (VH), High (H), Medium High (MH)
- Consequence of Failure
  - Discharge location (water quality impacts)
  - Capacity as a proxy for restoration time

4.4.2.2 Scenarios

As discussed in Section 3, three scenarios were used for the evaluation. The following provides a brief summary of the relative characteristics between these events that were used to prioritize the identified vulnerabilities. In general, the Cascadia Subduction Zone was used as the primary scenario because it has a significantly smaller return period, and the ground motions it produces are distributed across the extent of the King County WTD system (as well as the entire region).

- Cascadia Subduction Zone Scenario
  - Primary focus as the most likely scenario (500-year return period)
  - Longer duration of shaking (several minutes estimated) compared to other events
  - Moderate (lower amplitude/lower frequency) shaking that is expected to resonate with taller and softer buildings
  - Ground motion shaking distributed across entire WTD system
  - Significant ground deformation and liquefaction expected
- Seattle Fault Scenario
  - Less likely scenario (5,000–6,000-year return period)
  - Shorter duration of shaking compared to CSZ
  - Intense (higher amplitude/higher frequency shaking) that is expected to resonate with stiffer/shorter buildings.
  - Very strong ground motion along I-90 corridor
  - Surface fault rupture can result in pipeline grade change – EBI, Eastside Interceptor
- SWIF Scenario
  - Less likely scenario (4,000–500-year return period)
  - Shorter duration of shaking compared to CSZ
  - Intense (higher amplitude/higher frequency shaking) that is expected to resonant with stiffer/shorter buildings.
  - Very strong ground motion along north end of the system near Brightwater Treatment Plant
  - Surface fault rupture can result in pipeline grade change near Brightwater Treatment Plant

4.4.3 Potential Recommended Projects

4.4.3.1 Life Safety: Potential Recommended Projects

The following list identifies facilities that have been determined to be a high priority primarily due to the life safety criticality factor (although, other criticality factors and vulnerabilities may also exist for these facilities). The primary life safety deficiency is also listed for each facility.

- WP Admin Operations Building – server room and seismic/structural vulnerabilities
- SP Operations Building – server room (noted that the server room is not explicitly life safety related but in an occupied building and critical for post-earthquake operations)
- SP Santler Building & Maintenance/storage building – seismic/structural vulnerabilities
- WP Maintenance/Effluent Pump Station - seismic/structural vulnerabilities
- Additional list of Life Safety facilities requested from the County
- Conduct *ASCE 41* Tier 3 seismic assessment of listed buildings and additional buildings listed by the County. Upgrade facilities found to be deficient.

4.4.3.2 Public Health: Expected Performance and Potential Recommended Projects

CSOs, Regulators, and wastewater pipelines are considered critical to allow movement of sewage through the system and out into a receiving water body if downstream facilities are not functional. Many of these facilities are in high liquefaction zones. Some pumps stations may be critical to prevent sewage backup, as well. The CSOs and Regulators in high liquefaction susceptibility areas are listed below in Table 17 and Table 18, respectively. Other facilities critical to public health should be reviewed and identified by the County. Additionally, collapsed pipelines in high liquefaction areas are described in more detail in Section 5.

Table 17: CSOs with Liquefaction Susceptibilities (12 in West Service Area, 2 in South Service Area)

Name	Area	Liquefaction Susceptibility
Brandon	West	very high
Hanford #2	West	very high
King Street	West	very high
Kingdome	West	very high
Lander	West	very high
Duwamish East	West	very high
Hanford #1	West	very high
East Marginal	West	high
Belvoir	West	high
30th Ave NE	West	high
Michigan	West	moderate to high
Norfolk	West	moderate to high
Henderson Street	South	moderate to high
MLK Way	South	moderate to high

Table 18: Regulator Stations with Liquefaction Susceptibilities (13 in West Service Area, 2 in South Service Area)

Name	Area	Liquefaction Susceptibility
Chelan	West	Very high
Harbor	West	very high
Lander2	West	very high
King	West	very high
Lander	West	very high
Kingdome	West	very high
Connecticut	West	very high
Brandon	West	very high
Hanford2	West	very high
Denny	West	very high
Michigan	West	moderate to high

Name	Area	Liquefaction Susceptibility
West Michigan	West	moderate to high
West Seattle	West	moderate to high
Allentown	South	moderate to high
Norfolk	South	moderate to high

4.4.3.3 Public Health Potential Recommended projects:

- Assess facility vulnerability to liquefaction to determine the likelihood of failure. Mitigate liquefaction if failure could result in blocking sewage flow.
- Conduct *ASCE 41-13* Tier 1 structural vulnerability assessment of all facilities not previously evaluated; conduct Tier 2/3 assessment based on the results. Mitigate structural vulnerability through retrofit construction projects. Mitigate liquefaction if failure could result in blocking sewage flow.
- Assess the seismic vulnerability of wastewater pipelines in Very High, High, and Moderate High liquefaction susceptibility areas. Determine their likelihood of catastrophic failure and the likelihood of resulting sewage backup if catastrophic failure occurred. Develop a strategy to address this deficiency. See Section 5 for more information on the pipeline assessments.

4.4.3.4 Environmental: Expected Performance and Potential Recommended Projects

Facilities are listed by service area, prioritized by water quality impacts, and organized by the Brightwater, South Plant, and West Point service areas. See Table 20: Pump Station Prioritization below for additional information. The following notes explain the use of prioritization codes.

Note 1. Facilities listed are prioritized VH, H, or MH for liquefaction.

Note 2. If liquefaction is noted following the facility, its vulnerability is controlled by liquefaction.

Note 3. Facilities are particularly vulnerable and or have very large capacities that may lead to particularly long restoration times.

Note 4. Pipelines are in MH – VH liquefaction zones. See Section 5 for more information on the pipeline assessments.

- *Brightwater Service Area* – Facilities have been identified that are vulnerable to the SWIF earthquake scenario; however, these facilities are listed in the South Plant Service Area (below) because of diversion capabilities.
- *South Plant Service Area*
  - Lake Sammamish
    - Sunset Pump Station - liquefaction
    - Issaquah Interceptor, submerged - 3 miles (Note 4)
  - The Eastside Interceptor system
    - South Plant Influent Pump Station (Note 3)
    - Sweylocken Pump Station (Note 3)
    - North Creek Pump Station – liquefaction (flow can also be directed to Brightwater)
    - Woodinville Pump Station – liquefaction (flow can also be directed to Brightwater)
    - South Mercer Pump Station - liquefaction

- Eastside Interceptor Pipeline 20 miles
- South Interceptor – 7 miles (Note 4)

- Green River Valley
  - Pipeline – Auburn Interceptor, 7 miles (Note 4)
  - Interurban Pump Station (from west)
- Other South Treatment Plant Facilities
  - Effluent Pump Station – MH

- *West Point Service Area*
  - Lake Washington Discharge
    - Mathews Park Pump Station (Note 3)
    - Belvoir Pump Station
    - 30th Avenue Pump Station
    - Rainier Avenue Pump Station – liquefaction
    - Henderson Pump Station – liquefaction
  - Duwamish River/Elliott Bay/Sound
    - West Point Treatment Plant - Raw Sewage Pump Station (Note 3)
    - Interbay Pump Station (Note 3)
    - Duwamish Pump Station (Note 3)
    - East Marginal Way Pump Station – liquefaction
    - West Marginal Way Pump Station
    - Barton St. Pump Station - liquefaction
    - 63rd Ave. Pump Station
    - North Beach Pump Station
    - West Seattle Pump Station
    - EBI – 15 miles
  - Other West Point Treatment Plant Facilities
    - Primary Tank Z beams – H
    - Hypo mixing Facility– H
    - Effluent Pump Station – MH
    - Solids Handling Building

4.4.3.5 Environmental Potential Recommended Projects:

- Evaluate the vulnerability to liquefaction for all facilities noted as being in MH to VH liquefaction zones. See Table 20. Mitigate the liquefaction for those found to be deficient.

- Evaluate the structural vulnerability of all pump stations rated as having MH – VH structural vulnerability. See Table 20. Mitigate the structural deficiency for those found deficient.
- Evaluate and mitigate as required the pipelines listed as part of the same project as Public Health Project 3. See Section 5 for more information on the pipeline assessments.
- Evaluate available technologies that would enhance the near-real-time post-earthquake assessment of damage of off-site facilities, and the value each would bring to the post- earthquake response.
    - SCADA communication redundancy/radio
    - Shakemap – near real-time damage estimation
    - Structural monitoring of facilities and response plans – See Structural Programmatic Recommendation D below for more information.
    - Pipeline Movement Monitoring – EBI, optical fiber
- Evaluate the structural vulnerability of the remaining facilities not previously addressed.

4.4.3.6 Geotechnical Potential Recommended Projects

- West Point Landslide Hazard. Evaluate the risk and mitigate.

4.4.3.7 Programmatic Potential Recommendations

It is recommended that the following programs be developed and maintained on an ongoing basis:

- Develop and adopt Post-Earthquake Level of Service goals within two years for the three scenario earthquakes for each performance goal category for both short-term (20 years) and long-term (50 years).
- Develop and implement seismic design criteria for all new facilities and pipelines in line with adopted Post-Earthquake Levels of Service goal.
- Implement Mechanical Programmatic Recommendations
    - Anchor and brace equipment and above grade pipe
    - Anchor storage racks/contents
- Implement Electrical Programmatic Recommendations
    - Check anchorage on electrical cabinets and anchor if required
    - Evaluate the vulnerability of treatment plant substations (particularly the South Plant main substation rigid busses). Mitigate as required
    - Tie all hanging light fixtures to prevent them from swinging during an earthquake
- Implement Programmatic Recommendations
    - Remove/replace glass blocks in all buildings
    - Conduct *ASCE 41* Tier 1/2/3 Seismic Evaluations, as appropriate, for all facilities.
      This high-level seismic resiliency study of King County WTD's system included an initial desktop seismic screening of the off-site pump stations utilizing the *FEMA 154* RVS procedures. Based on the findings of this screening and input from the County, (37) facilities were identified for field observations and more detailed seismic evaluations using *ASCE 41-13* Tier 1 prescriptive deficiency evaluation checklists. However, it is recommended that more detailed seismic evaluations be performed on the remainder of the facilities.

- o For facilities that have not already been identified as requiring or not requiring seismic mitigation, a study must first be undertaken to determine which facilities require mitigation and the nature of the mitigation required, if any. Based on the findings of the King County WTD seismic resiliency study, Table 19 summarizes the expected number quantity of facilities that will require *ASCE 41-13* Tier 1, Tier 2, and Tier 3 seismic evaluations. It is expected that the actual number of facilities will vary based on which particular facilities are found to have seismic deficiencies through the Tier 1 evaluations. It is recommended that the evaluation study include the following steps:
  - Complete a *ASCE 41* Tier 1 evaluation of structural and nonstructural components (excluding MEP, which is addressed in another capital improvement project) for the identified facilities
  - As recommended based on the outcome of the Tier 1 evaluations, complete either a Tier 2 or Tier 3 evaluation of structural and nonstructural components (excluding MEP, which is addressed in another capital improvement project) for the identified facilities
  - Identify deficiencies in demand and capacity ratios
  - Develop concept-level mitigation schemes (2–5 percent design)
  - Develop concept-level costs (Class 5)

Table 19: *ASCE 41-13* Tier 1, 2, & 3 Seismic Evaluation Recommendations

Project Location	Tier 1	Tier 2	Tier 3	Total
West Point Treatment Plant	27	16	5	48
South Treatment Plant	22	14	5	41
Brightwater Treatment Plant	1	1	0	2
Off-Site Facilities	55	29	15	99
Total Combined	***105***	***60***	***25***	***190***

- o Evaluate Seismic Monitoring Technologies
  In the event of seismic activity, WTD emergency response efforts could benefit from the ability to quickly evaluate and direct resources to facilities, including all vertical and horizontal assets, where damage may have occurred. Currently, there are no standard procedures for the collection, assembly, and analysis of seismic activity information specific to WTD facilities. If this issue is not addressed by the Resiliency and Recovery Program, there exists the potential that a seismic event and its impacts on WTD infrastructure may not be identified and addressed in a timely manner, leading to additional damage or environmental impacts. WTD should continue their efforts to be aware of advances in remote monitoring technologies that could make the cost of programmatic changes a better fit for the return on investment. There may also be opportunities to implement remote monitoring incrementally at high-risk facilities that could be the most difficult to access for reconnaissance following a disaster. This project would include a study to develop recommendations for implementation of a seismic monitoring system and other technologies that could enable WTD to use real-time data to make data-driven decisions on their earthquake response. This study should consider the following components:
  - Seismic Ground Motion Monitoring System: assess the approach, cost, and benefits associated with implementing a seismic ground motion monitoring system that utilizes a strong-motion seismometer distributed throughout the County's system. This should consider the availability of existing seismometers from other existing networks (e.g., USGS, Pacific Northwest Seismic Network). This study should assess and make recommendations regarding ability of the system to:

        - monitor the real-time distribution of seismic ground motions across the system during an earthquake
        - compare those ground motions with those expected to cause damage to facilities and distributed pipelines systems
        - document/report the expected performance of the system
        - communicate/disseminate the information furnished by the seismic ground motion monitoring system
        - make actionable decision in how WTD allocates resources and operates their system based on the provided data and information
    - Above-Ground Facility Seismic Monitoring System: assess the approach, cost, and benefits associated with implementing strong-motion instrumentation networks within key above-ground facilities. The study shall identify which facilities would warrant a structural seismic monitoring system, and provide recommendations for the type, number, and distribution of sensors. This study should assess and make recommendations regarding ability of the system to:
        - monitor the real-time response of building structures,
        - process the data in real time to convert compare data to performance thresholds,
        - evaluate the expected performance of the structure based on pre-defined inter-story drift thresholds based on performance-based earthquake engineering evaluation procedures,
        - document/report the expected performance of the structure,
        - communicate/disseminate the information furnished by the structural Seismic Monitoring System to facility managers and decision-makers, and
        - make actionable decisions in how WTD allocates resources to evaluate and occupy the structure based on output of the system.
    - Pipeline Seismic Monitoring System: assess the approach, cost, and benefits associated with implementing a seismic monitoring system (e.g., fiber-optic sensors) that can identify breaks/damage to the transmission pipelines. This study should assess and make recommendations regarding ability of the system to:
        - monitor the real-time response of pipelines,
        - document/report the expected performance of the pipelines (e.g., if/where breaks are expected),
        - communicate/disseminate the pipeline performance information to facility managers and decision-makers, and
        - make actionable decisions in how WTD allocates resources to repairing the pipelines.
    - Automated Seismic Shut-Off: assess the approach, cost, and benefits associated with installing automatic shut-off valves and controls based on the data provided from seismic sensors.
    - Early-Warning System: assess the ability of WTD to integrate their system with earthquake early-warning system currently under development by ShakeAlert, an earthquake early warning system for the west coast of the United States, and their partners.
- Consider Post-Earthquake Response Plans: develop recommendations pertaining to how WTD could develop customized facility-specific earthquake response plans for performing post-earthquake safety evaluations of each of their facilities. The objective of these response plans

would be to customize existing post-earthquake building safety evaluation standards (i.e., ATC-20) to allow County staff to perform rapid evaluations in an expedited, target fashion based on the unique characteristics and vulnerabilities of each facility.

4.4.3.8 Pump Station Risk Prioritization

Table 20 provides a summary of the findings of the desktop evaluation, Hazus evaluation, field assessment, and liquefaction susceptibility for each of the pump stations. The discharge location and peak capacity are also identified for each pump station. Based on the findings of these evaluations, a priority has been identified. See Attachment 1C and Attachment 1D for additional information.

Table 20: Pump Station Prioritization

Pump Station Name	Section	Discharge Location[1]	Peak Cap (MGD) [2]	Desktop Vulnerability Rating[3]	Hazus Damage Rating[4]	Field Assessment Vulnerability Rating[3]	Lique-faction Rating[5]	Risk Rating[6]
Interbay	West	PS	133	H	M	H	VH	VH
Sweylocken	East	LW	31	H	M	MH	MH	H
Duwamish	West	DR	125	H	E	H	VH	H
Matthews Park	West	LW	123	H	M	H	L	H
Belvoir	West	LW	5	H	E	MH	H	MH
North Creek	East	SR	23	H	M		MH	MH
West Seattle	West	PS	8	LM	E		VH	MH
63rd Avenue	West	PS	17	H	E	LM	MH	MH
West Marginal Way	West	DR	8	H	E	M	MH	MH
30th Avenue	West	LW	6	H	E	MH	MH	MH
Interurban	East	D	29	H	M	LM	MH	MH
Sunset	East	LkS	15	H	M	LM	MH	MH
Woodinville	East	SR	27	H	M		MH	MH
Henderson	East	LW	22		M		MH	MH
South Mercer	East	LW	12	H	M		MH	MH
Rainier Ave	West	LW	9	H	M		MH	MH
East Marginal Way	West	PD	23	H	M		MH	MH
Barton Street	West	PS	23	H	M		MH	MH
York	East	LW	68	H	M	M	LM	M
Murray Ave	West	PS	17	H	M		NA	M
Kenmore	West	LW	15	H	M		NA	M
Bellevue	East	LW	14	LM	M		NA	M
Hollywood	East	LW	14	H	M		LM	M
53rd Avenue	West	PS	9	H	M		MH	M
Lake Ballinger	West	LW	8	H	M	M	NA	M
Lakeland Hills	East	DR	5	H	M		MH	M

Pump Station Name	Section	Discharge Location[1]	Peak Cap (MGD) [2]	Desktop Vulnerability Rating[3]	Hazus Damage Rating[4]	Field Assessment Vulnerability Rating[3]	Lique-faction Rating[5]	Risk Rating[6]
Pacific	East	DR	4	H		L	MH	M
Juanita Bay	East	LW	31	M	S		LM	LM
Brightwater Intermediate Pump Station	BW	LW	110				NA	LM
Yarrow Bay	East	LW	3	H	M		MH	L
Medina	East	LW	7	H	M		NA	L
North Mercer	East	LW	6	H	M		NA	L
North Beach	West	PS	5	H	M		LM	LM
Wilburton	East	LW	5	H	M		NA	L
Richmond Beach	West	PS	5	H	M		NA	L
Carkeek	West	PS	5	H			NA	L
East Pine Street	West	LW	4	H	M	M	NA	L
Hidden Lake	West	PS	2	H	M		NA	L
Kirkland	East	W	8	H	S		NA	L
Heathfield	East	LkS	15	H	M	L	NA	L
Black Diamond	East	L	2	H	M		NA	L
Beulah Park	East		1				NA	

Notes:
1. Discharge Locations (LW = Lake Washington, LkS = Lake Sammamish, L = Other Lake, PS = Puget Sound, DR = Duwamish River, SR = Sammamish River)
2. Peak Capacity values provided by King County WTD
3. Facility Vulnerability Ratings (H = High, M = Medium, L = Low)
4. Hazus Damage Ratings (E = Extensive, M = Moderate, S = Slight)
5. Liquefaction Rating (VH = Very High, H = High, MH = Moderate-High, M = Moderate, LM = Low-Moderate, L = Low)
6. Risk Rating (VH = Very High, H = High, MH = Moderate-High, M = Moderate, LM = Low-Moderate, L = Low)

5 Pipeline Assessments

5.1 Wastewater Pipeline Assets

The wastewater pipeline system consists of 276 miles of gravity lines, 100 miles of pressure lines, 16 miles of outfalls and overflows, and 14 miles of other types of pipelines. Pipelines range in diameter/width from 2 to 204 inches, with a median diameter of 42 inches and are constructed primarily of reinforced concrete pipe with smaller amounts of other materials. The median date of installation is 1971, almost 50 years ago. The most common pipe materials are shown in Table 21.

Table 21: Wastewater Pipe Material

Material	Percent of System	K_1[a]	K_2[a]
Concrete (primarily reinforced)	74	0.8	0.8
Ductile Iron	12	0.5	0.5
Brick	3	0.7	1.3
HDPE	3	0.15	0.15
PVC (SDR 35)	3	0.6	0.9
Cast Iron	2	1.0	1.0
Asbestos Cement	1	0.5	0.8
Steel	1	0.15	0.15
Other (assumed to be concrete or similar to concrete)	1	0.8	0.8

[a.] See 5.2.1.1 for definition

Approximately 32 percent of the gravity pipelines are in soils with a liquefaction susceptibility of moderate to high (a threshold of liquefaction concern) or greater and about 39 percent of pressure pipelines are in that same moderate to high category.

5.2 Probabilistic Assessment

The pipeline vulnerability assessment was performed by Ballantyne Consulting, LLC. It is a high-level probability-based analysis that is not intended to identify specific vulnerability *locations* or where hazard-related failures might occur.

5.2.1 Methodology

The probabilistic assessment for pipeline vulnerability used a modified ALA Seismic Fragility Formulations for Water Systems methodology. This same approach was used for a similar study for Metro Vancouver, British Columbia, Canada. The methodology was developed for water pipelines using empirical data from past earthquakes. Since water pipelines often have different structural properties than wastewater lines, results are intended to provide only an order of magnitude estimate on the pipeline damage.

5.2.1.1 ALA Seismic Fragility Formulation

The ALA equations to calculate the pipe repair rate are as follows:

1. RR = K1 x 0.00187 x PGV (for wave propagation), where RR = repair rate/1,000 feet of pipe;
   - K1 = constant representing the relative vulnerability of pipe (see Table 21, above)
   - PGV = Peak Ground Velocity, and measure of shaking intensity (in in/sec) (provided by the USGS)

2. RR = K2 x 1.06 x $PGD^{0.319}$ (for permanent ground deformation) where RR = repair rate/1,000 feet of pipe
   - K2 = constant representing the relative vulnerability of pipe (see Table 21).
   - PGD = permanent ground deformation (inches) (see PGD determination methodology in Volume 2: Task 200 Background Documentation)

5.2.1.2 Modified Methodology

Wastewater pressure pipelines could be expected to perform the same way as water pipelines following a major event. For this project and other wastewater pipeline projects (Metro Vancouver 2017), the water-pipeline-specific ALA methodology required modification to be of more use in understanding the expected performance of gravity wastewater pipe. For gravity wastewater pipelines, repairs are grouped into two categories: short-term and long-term repairs; whereas, all breaks and leaks for wastewater pressure pipelines need to be repaired in the near term (days) to restore service. For gravity wastewater pipelines, short term repairs need to be made for lines that have collapsed or misaligned to the extent that they can no longer transmit sewage. The impacts of this performance standard difference were demonstrated in the 1994 Northridge earthquake in Los Angeles. Los Angeles Department of Water and Power made approximately 1,000 water pipeline repairs in the San Fernando Valley in the weeks following the event. However, the Los Angeles Department of Public Works only had to use about ten “pump-arounds” to keep the gravity wastewater pipeline system operable. However, within several years following the event, Los Angeles Department of Public Works had to replace or repair a significant portion of pipelines that had been damaged in the earthquake.

5.2.1.3 Assumptions

To modify the ALA Seismic Fragility Formulations for Water Systems methodology for the WTD system gravity pipeline model, it was assumed that no “catastrophic” damage (breaks) would result due to wave propagation. For this reason, the PGV-based equation (1) from Section 5.2.1.1 using K1 was not applied. The PGD-based equation (2) was used to estimate sewer system repair rates. Most of the damage due to PGD could be expected to result in immediate loss of function that would require short-term repairs. However, if the PGD is less than six inches, it is expected that the damage to the pipelines would not be catastrophic, eliminating the need to estimate short-term damage for these smaller PGDs.

It is not expected that all of the soil in the areas subject to liquefaction would liquefy to the extent that PGD would occur in the various liquefaction susceptibility zones. That probability is a function of the peak PGA for the particular scenario (Attachment 1B-1, 1B-2, 1B-3), and the liquefaction susceptibility zone. For example, the probability of liquefaction will be higher in the Very High Liquefaction Susceptibility Zone (Attachment 1B-4), than it will be in the Moderate High Zone.

5.2.2 Findings

Applying this methodology using GIS, it was estimated that about 15 catastrophic (short-term repairs required) wastewater pipeline breaks would occur in both the CSZ and the Seattle Fault scenarios. No liquefaction-related breaks were expected in the SWIF scenario. These numbers were about the same for both events because while the probability of liquefaction is higher for the Seattle Fault scenario with its stronger shaking intensity, it would not be as widespread. Many of these breaks would occur in the very high susceptibility liquefaction zones such as in the Elliott Bay Interceptor running along the Seattle waterfront (Attachment 1B-4). Some of the pipelines in this area are on piles (such as the Hanford Interceptor); therefore, it is recommended that pile-supported pipelines are identified. Many of the lines in the very high liquefaction susceptibility zone are very large diameter, and failures could result in the development of large sinkholes. Several failures could be expected in the Effluent Transfer line from STP to the outfall in Elliott Bay, as much of this line runs parallel to the Duwamish River, where liquefaction-related PGDs would be likely. However, if this line was compromised, treated sewage could be discharged directly into the Duwamish River.

5.3 Deterministic Assessment

The findings of this assessment indicated that site-specific failures could be expected in a number of locations considering: 1) crustal fault locations, 2) previous work performed by the County, and 3) information identified in discussions with WTD operations and maintenance personnel. The potential locations described below are shown in Figure 12.

- The Seattle Fault Scenario would likely heavily impact the Elliott Bay Interceptor, Eastside Interceptor, and possibly the Issaquah Interceptor. There is a potential for a vertical surface offset (north side drops) of 6 feet (as occurred in Vasa Park, Bellevue, date unknown) and up to 23 feet (as occurred on Bainbridge Island in about 900 AD). There is also potential for a regional change in the topography modifying the pipeline grade. The Seattle Fault displacement would occur somewhere within the Seattle Fault Zone, a mile or more in width, so it is difficult to recommend mitigation not knowing its exact location.
- The SWIF Scenario poses the possibility that wastewater pipelines in the vicinity of BWTP could be offset when an earthquake occurs, shearing off influent or effluent pipelines connected to the plant. This could result in the lines becoming nonfunctional. The SWIF has a number of fault strands trending northwest to southeast, with one passing through the BWTP site. Surface faulting could occur along any one of the strands.
- The Eastside Interceptor floated in Renton in the 1965 Seattle earthquake. The resulting low area along its invert was filled to minimize solids deposition. A parallel pipeline was installed over the past decade to make up for its reduced capacity. While the pipeline damage in the 1965 event was not catastrophic, in a larger earthquake it could be. Refer to Attachment 1B-4 showing the pipe overlaying the liquefaction susceptibility.
- South Plant Influent Channels are part of STP, but are buried structures similar to the wastewater pipelines. They are on liquefiable soils and could result in their flotation or shearing due to lateral spread.
- Issaquah Interceptor and Kenmore Interceptor are supported on piles under Lake Sammamish and Lake Washington, respectively. In 2003, WTD studied the vulnerability of submerged pipelines and identified these to be vulnerable due to the instability of the submerged alignment. If the piles failed, they could pull the lines laterally, separating the joints, and allow raw sewage to enter the respective lakes.
- The Lake Union Tunnel was constructed of brick in 1890. It was partially lined with cast-in-place concrete in the 1960s, but 3,000 feet remain unlined and could be vulnerable. The Mercer Tunnel provides some redundancy. The Fort Lawton Tunnel, another brick tunnel, was partially lined in the early 1990s; the remainder remains vulnerable. The Bayview Tunnel has been slip-lined, which should have reduced its vulnerability concerns.
- Crown corrosion is a concern in the Eastside Interceptor and could increase the odds of structural collapse due to extreme shaking intensities or PGD.
- The Elliott Bay Interceptor at Interbay is an exposed line, supported on piles, and it is corroded and subject to asymmetric soil loading. This suggests potential vulnerability. Similarly, the Eastside Interceptor is exposed and subjected to asymmetric loading near the May Creek overflow location.
- The Effluent Transfer System is in liquefiable soils along its alignment, crosses the Seattle Fault, and crosses an escarpment in the submerged portion. These hazardous conditions could lead to failure. However, if the Effluent Transfer System failed, South Plant could discharge treated effluent into the Duwamish River.

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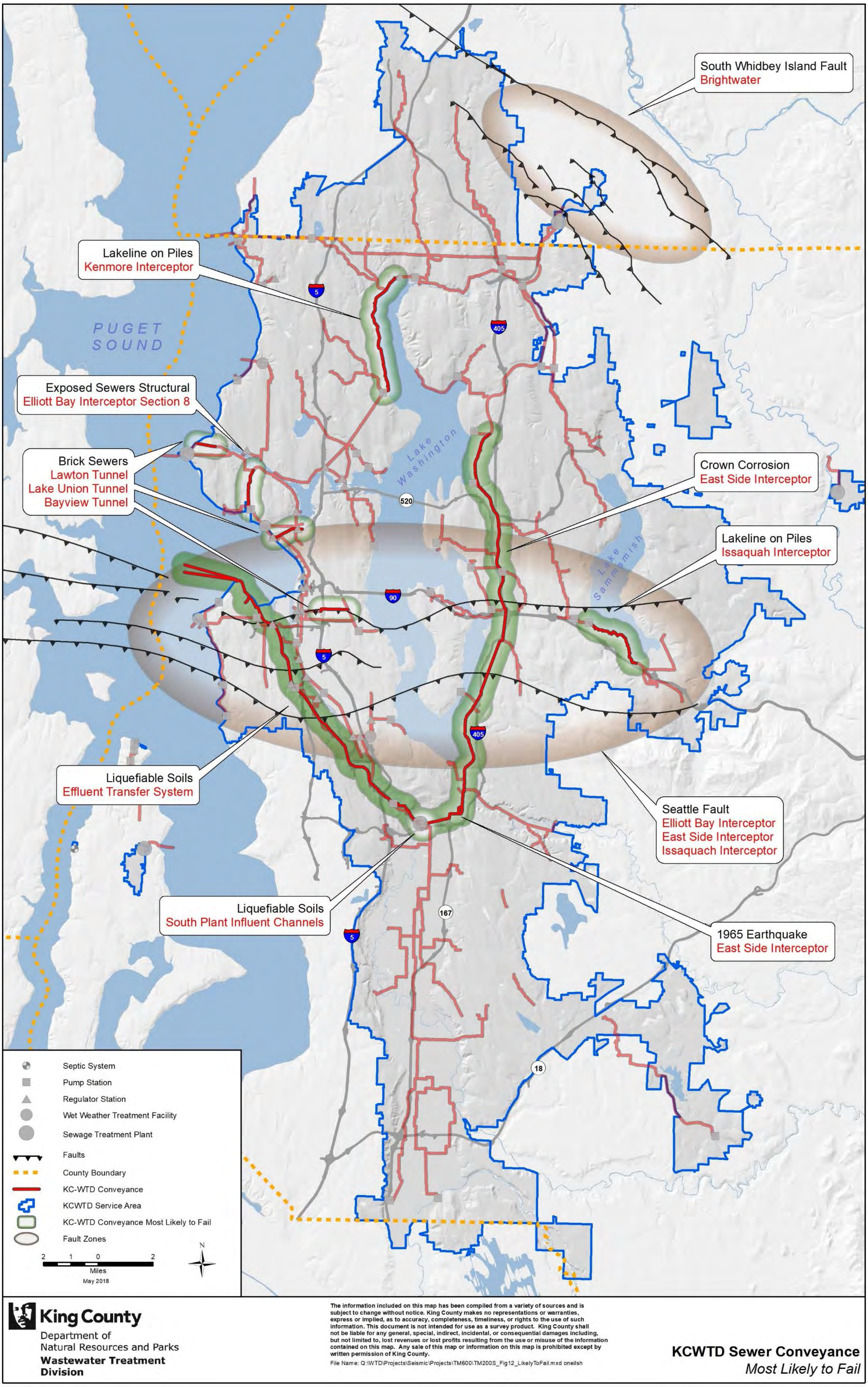

Figure 12: Wastewater Conveyance Most Likely to Fail

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Table 22: Gravity Wastewater Pipelines with the Highest Earthquake Repair Rates in the King County WTD System based on American Lifelines Alliance methodology. (See Attachment 2A)

Width	Height	Trunk	Type Group	Liquefaction Susceptibility	Repair Rate/1,000'
12	12	EBI Section 3	Gravity	very high	1.71
138	138	North Interceptor	Gravity	High	1.52
42	42	Hanford Street Trunk	Gravity	High	0.87
24	24	West Seattle FM	Gravity	very high	0.85
36	36	Kingdome Trunk	Gravity	very high	0.71
30	30	Boeing Creek Trunk	Gravity	High	0.69
24	24	West Hill Trunk	Gravity	moderate to high	0.38
24	24	Bryn Mawr Trunk	Gravity	high	0.36
54	54	South 277th Interceptor	Gravity	moderate to high	0.34
30	30	Boeing Chiller	Gravity	moderate to high	0.19
96	96	Laurelhurst Trunk	Gravity	moderate to high	0.18
72	72	Arboretum Trunk	Gravity	moderate to high	0.18
54	54	Bayview Tunnel	Gravity	moderate to high	0.18
75	75	Hanford Street Trunk	Gravity	moderate to high	0.18

Table 23: Pressure Wastewater Pipelines with the Highest Repair Rates in the King County System based on American Lifelines Alliance methodology. (See Attachment 2A)

Width	Height	Trunk	Type Group	Liquefaction Susceptibility	Repair Rate/1,000'
18	18	South Magnolia Interceptor	Pressure	very high	1.34
30	30	West Seattle Force Main	Pressure	very high	0.86
36	36	EBI Section 3	Pressure	very high	0.86
30	30	West Seattle Force Main	Pressure	very high	0.62
36	36	EBI Section 8	Pressure	very high	0.53
24	24	Bryn Mawr Trunk	Pressure	high	0.47
16	16	West Duwamish Interceptor	Pressure	moderate to high	0.19
16	16	Rainier Vista Interceptor	Pressure	moderate to high	0.19
24	24	EBI Section 2	Pressure	moderate to high	0.15

6 System Assessment

This section steps through the system for each of the performance criterion, focusing primarily on the CSZ scenario. The four performance criteria, in order of priority (with 2 and 3 essentially tied), are:

- Life Safety
- Public Health
- Consequential Damage
- Environmental Impact

Other parameters were used to prioritize system deficiencies and associated mitigation projects, including:

- Type of facility – e.g., pump station, regulator and their criticality in the system
- Flow capacity of a facility or pipe – larger is given higher priority
  - Impact of post-earthquake operability/functionality related to one of the priorities
  - Impact of post-earthquake restoration and its effect on overall system restoration time – failure of major facilities requiring a long restoration time are given a higher priority
  - Relative likelihood of the damaging earthquake(s) scenarios – CSZ likelihood is higher than Seattle Fault or SWIF scenarios
  - Vulnerability of the facility or pipe to one of the earthquake scenarios evaluated

The Seattle Fault Scenario results in much stronger ground motions along the fault alignment, the I-90 corridor. Most of the facilities exposed to this strong ground motion are already identified as having a high vulnerability in the CSZ. Mitigation of these facilities should be to the level of ground motions expected in the Seattle Fault Scenario. The SWIF Scenario primarily affects the northeast part of the system, particularly the Brightwater Treatment Plant. The SWIF hazard was understood during its design, and was addressed in the seismic design criteria that were used. The only deficiency identified prior to this study was the Brightwater Treatment Plant Administration Building, which was repurposed from an earlier function when the plant was built.

6.1 Life Safety

The buildings in which WTD staff work and could be compromised are identified by the County as the following:

- West Point Administration and Operations Building
- West Point Maintenance/Effluent Building
- South Plant Operations Building
- South Plant Santler (Parts and Supplies Storage) Building
- South Plant Maintenance Building
- Brightwater Administration Building (note that this facility was not evaluated as part of this study, but has been identified as a life safety risk by the County)

The West Point Administration and Operations Buildings, and the South Plant Operations Building operations rooms are constructed with a raised computer floor that is vulnerable to shaking. While this is not a life safety issue, failure of the operation and server rooms could significantly impact post-earthquake operation and recovery of the entire WTD system.

6.2 Public Health

At the time of the Task 200 evaluations, no system facilities were identified by WTD staff where failure would result in backup of sewage. It was noted that in subsequent work on this project, findings might be subject to change, so it is recommended that the County continue to consider damage resulting in backup of sewage during implementation of final mitigation concept recommendations. The collapse of pipelines could introduce sewage backup if the collapse occurred in a location where an upstream overflow was not close enough to discharge sewage. That situation could result in a hydraulic grade line below basements or manhole ground elevations (i.e., the backup of sewage). CSOs, regulator facilities, and pump stations with no overflows would seem to have the greatest risk potential. Many of these facilities are in liquefiable areas and could move in an earthquake. Of the 43 CSOs, 14 are in Very High, High, and Moderate High liquefaction susceptibility zones, 12 of which are in the West Division. Of the 25 regulators, 15 are in Very High, High, and Moderate High liquefaction susceptibility zones, and 13 of those in the West Division.

CSOs and regulators are widely dispersed throughout the West Point service area, a combined sewer system, because of the extreme flows generated during storm events. As a result, there is a small likelihood that sewage backups would occur in this area.

The South Plant and the Brightwater service areas are not combined systems, so they do not experience wide flow fluctuations necessitating extensive overflow capabilities. Collapse of a pipeline in this system could potentially result in considerable backups.

The Eastside Interceptor is gravity flow its entire length until it reaches the South Plant Influent Pump Station. Pump stations on the Eastside pump into the Eastside Interceptor, but its function is not dependent on pump stations. Sections 1, 2, and 3 of the Eastside Interceptor are relatively flat. A pipe collapse could result in a significant sewage backup. There are only two overflows that are available to relieve any backup, and both require removal of a concrete panel to be operable. There is one overflow location at May Creek. The 12,000-foot Hazelwood Tunnel has a steep gradient upstream of the May Creek overflow facility. The second overflow location is at the north end of the Hazelwood Tunnel, on the downstream side of the Coal Creek Crossing transition structure. Because of these concerns, it is recommended that WTD evaluate the potential for backup on the East System.

In the South End in the Green River Valley, the Lakeland Hills and Pacific Pump Stations have no overflows. That area is also relatively flat. The only overflow in the Valley is on the West Hill Trunk.

6.3 Consequential Damage

WTD GIS staff has queried the regional infrastructure database identifying WTD pipeline locations within 100 feet of major highways and rail lines, and within 50 feet of water supply, natural gas, and liquid fuel pipelines. Figure 13 shows where these nearby infrastructure systems are located over a background of moderate high to very high liquefaction susceptibility zones. The highest risk installations based on proximity, vulnerability, and consequence of failure are the locations where the nearby pipelines are located in areas of liquefaction susceptibility (see blue and black lines in Figure 13 that are within liquefaction zones). Failure of the wastewater pipeline could result in failure of the adjacent pipeline and vice versa. It is recommended that WTD evaluate the risk of pipelines that are in close proximity to major water, liquid fuel, and natural gas pipelines as shown on the map.

6.4 Environmental

This section describes the system environmental impact by service areas – Brightwater, South Plant and West Point.

6.4.1 Brightwater Service Area

Located in the SWIF zone, this service area generally has low vulnerability from the Seattle and Cascadia Scenarios. The SWIF scenario could impact the Administration Building and the North Creek and Woodinville pump stations. A surface fault rupture could result in offset of buried pipelines. Vulnerability to this scenario was prioritized relatively low because of the scenario’s long return period compared to the

CSZ, and because the facility was recently designed and constructed in accordance with more modern building codes.

6.4.2 South Plant Service Area

This service area is vulnerable to both the CSZ and the Seattle Fault scenarios. The Seattle Fault scenario produces very large ground motions along its I-90 alignment. It could also result in a surface fault rupture from 7 feet to as much as 23 feet. The surface fault rupture could result in change of the topography along the Eastside Interceptor, possibly requiring construction of a new pump station. The consequences of failure are high as raw sewage could be discharged to fresh water bodies including Lake Sammamish, the Sammamish River, Lake Washington, and the Green River.

The Issaquah Interceptor is supported on piles in Lake Sammamish, and is vulnerable to slope stability impacting those piles. It discharges into the Sunset Pump Station, which is potentially vulnerable to liquefaction and slope instability. Failure of either could result in discharge of raw sewage into Lake Sammamish.

The Eastside Interceptor system is 20 miles long, and flows into the South Plant Influent Pump Station. The Eastside Interceptor floated in the 1965 Seattle Earthquake in Renton due to liquefaction. A similar failure, or worse would be expected in a CSZ or Seattle Fault event, and could result in overflow into Lake Washington (upstream of the failure), and the Cedar River (at the failure location). Failure of the South Plant Influent Pump Station would result in overflow into the Duwamish River. The vulnerable Sweylocken and South Mercer pump station failures would result in discharges into Lake Washington. Failures at the vulnerable North Creek and Woodinville pump stations would result in discharges ultimately into the Sammamish River and Lake Washington. Flows from these two pump stations could be redirected to Brightwater. Failure of the Eastside Interceptor or its tributaries would result in discharge into Lake Washington.

Failure of the Green River Valley system, the Auburn Interceptor and its tributaries would result in raw sewage discharge into the Green River. This system carries significant flows from the plateaus on both the east and west sides of the Valley. The failure of the vulnerable Interurban Pump Station would result in overflows into the Duwamish River.

The South Plant Effluent Pump Station is also vulnerable. Its failure could result in overflow of treated sewage into the Duwamish River. The Effluent Pump Station pumps into the Effluent Transfer line which parallels the Duwamish River and discharges into Elliott Bay. Much of its alignment is in liquefiable soils making it vulnerable. If it failed, treated sewage would be discharged into the Duwamish River. The submerged portion of the outfall crosses a scarp, and it may be vulnerable to landslide in that location.

6.4.3 West Point Service Area

This service area is vulnerable to both the CSZ and the Seattle Fault scenarios. The surface fault rupture could result in change of the topography along the 15-mile long Elliott Bay Interceptor, possibly requiring construction of a new pump station. The Elliott Bay Interceptor is in highly liquefiable soils along much of its alignment, which could result in flotation or failure. The consequences of failure are high as raw sewage could be discharged into Lake Washington, Elliott Bay, and Puget Sound.

Failure of the vulnerable Mathews Park, Belvoir and 30th Avenue pump stations and Rainier Ave and Henderson pump stations (liquefaction), could result in raw sewage discharge into Lake Washington. Failure of the vulnerable West Point Raw Sewage Pump Station, Interbay, Duwamish, East Marginal Way, West Marginal Way, Barton Street, 63rd Avenue, North Beach and the West Seattle pump stations could result in discharge to the Duwamish River, Elliott Bay or Puget Sound.

Other vulnerable facilities that were evaluated at WPTP include primary tanks (Z beams), hypo mixing facilities, the effluent pump station, and the solids building. Failure of these facilities could result in inadequately treated sewage being discharged into Puget Sound. Refer to the Attachments for these findings.

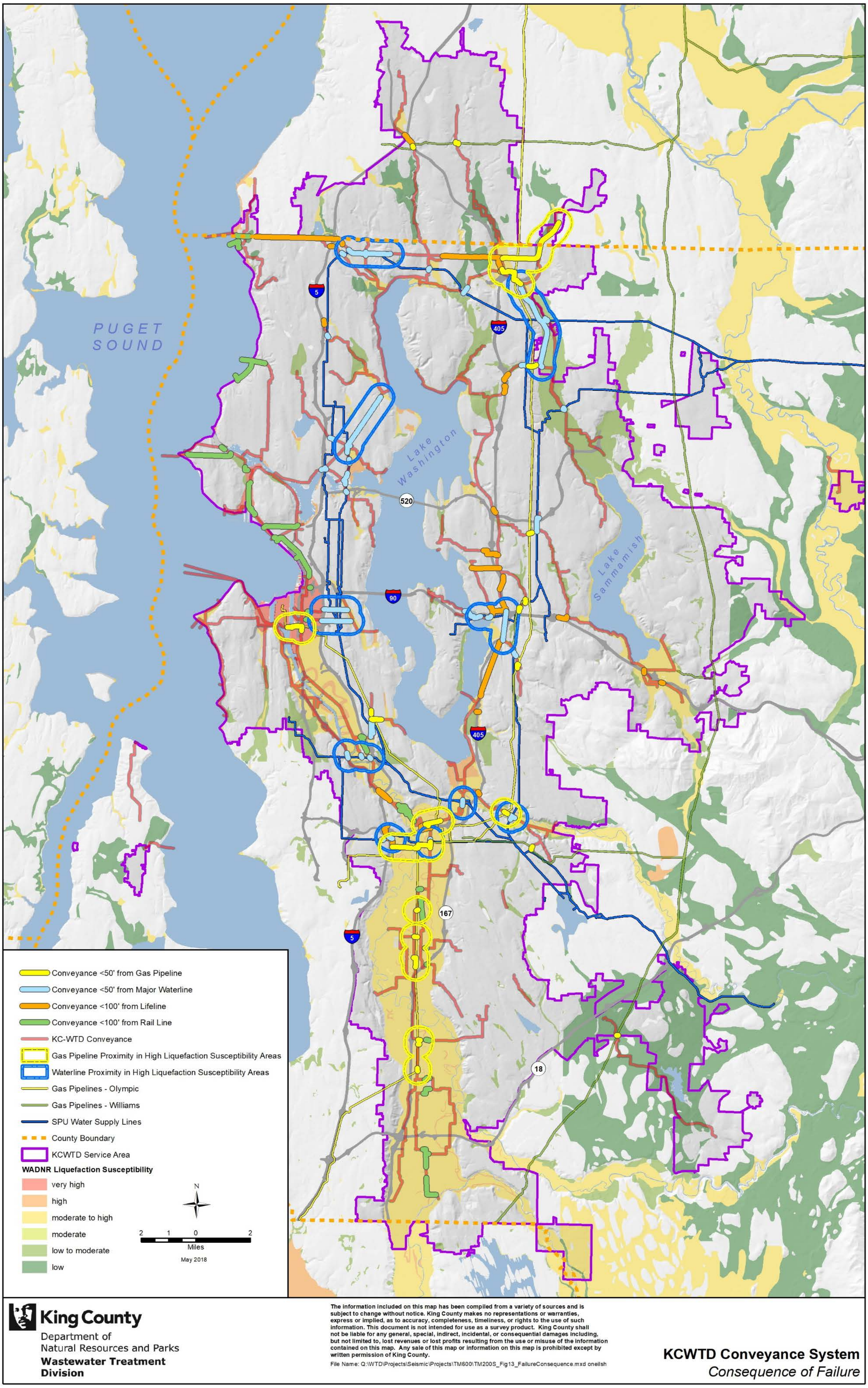

Figure 13: Conveyance System Consequence of Failure

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7 Findings and Recommendations

This section lists the recommended projects prioritized by consequence of failure criteria, and identifies the high-risk facilities at the pump stations and the three treatment plants. Specifically, Table 24 lists all potential projects including further studies, programmatic projects, and seismic upgrades (in groups of similar projects). Table 25 through Table 28 list the potential seismic improvement projects including deficiencies noted during site visits, and potential failure consequences resulting from those deficiencies. **It should be noted that the recommendations presented in Tables 24–28 reflect discussions at the time of the Task 200 Seismic assessment work, with the express purpose of advancing to the development of concept level mitigation projects in Task 400. These tables should not be referenced for final mitigation recommendations.** See Attachment 1C for additional information on the facility evaluation tables, Attachment 1D for facility evaluation maps, and Attachment 2B for more detailed seismic evaluation information.

Table 24: Potential Seismic Mitigation Projects for Advancement and Consideration in Task 400

Priority	Project Number	Project Description
Life Safety (LS)		
VH	LS–1	Conduct *ASCE 41* Tier 3 assessments of 5 buildings. (See Table 26, Table 27, and Table 28)
Public Health (PH)		
H	PH – 1	Determine whether failure of any regulators, CSOs, pump stations, or wastewater pipelines would result in sewage back; If any facilities or pipe in PH-1 are identified, continue with projects PH-2, 3 and 4
H	PH -2	Evaluate liquefaction vulnerability of regulators and CSOs that if failed would cause sewage backup
H	PH–3	Conduct seismic vulnerability of regulators and CSOs that if failed would cause sewage backup, conduct *ASCE 41* Tier 3 assessments based on the initial evaluation
H	PH/E–4	Assess the seismic vulnerability of the wastewater collection system that could result in sewage backups. Develop a strategy to address the deficiency
Consequential Damage (CD)		
H	CD – 1	Evaluate the vulnerability of the pipelines where they are located in MH to VH liquefaction susceptibility zones and where they are within 50 feet of critical water, natural gas, or liquid fuel pipelines.
Environmental (E)		
H	E-1	Evaluate liquefaction vulnerability of High Risk (H) pump stations (6) (See Table 20)
H	E-2	Evaluate structural vulnerability of H pump stations using *ASCE 41* Tier 3 analysis (6), (See Table 20)
MH	E-3	Evaluate liquefaction vulnerability of MH pump stations (12) and listed treatment facilities at South Plant (5), (See Table 20)
MH	E-4	Evaluate structural vulnerability of MH pump stations and treatment facilities; Conduct *ASCE 41* Tier 3 assessments based on the initial evaluation (12) (See Table 26, Table 27, and Table 28)
L	E-5	Evaluate liquefaction vulnerability of all remaining pump stations and treatment facilities; Conduct *ASCE 41* Tier 3 assessments based on the initial evaluation (60+-)
L	E-6	Evaluate structural vulnerability of all remaining pump stations and treatment facilities; Conduct *ASCE 41* Tier 3 assessments based on the initial evaluation (60+-)

Priority	Project Number	Project Description
H	E-7	Evaluate and recommend implementation of available technologies to enhance post-earthquake assessment
Programmatic (P)		
H	P-1	Develop and adopt Post-Earthquake Level of Service Goals
H	P-2	Develop and implement seismic design criteria for all new projects
H	P-3	Electrical –Evaluate TP substation vulnerability
M	P-3	Electrical – Check anchorage electrical cabinets, anchorage
Seismic upgrades (S)		
H	S-1 (LS-1)	Seismically upgrade buildings found to be vulnerable (5). (See Table 26, Table 27, and Table 28). Consider immediate occupation
H	S-2	Seismically upgrade computer floors at SP and WP operations buildings
MH	S-3	Mitigate liquefaction of H priority large PSs (4), (See Table 20)
MH	S-4 (E-2)	Seismically upgrade H priority large PSs (up to 6), (See Table 20)
MH	S-5	Implement recommended technologies to enhance post-earthquake assessment
MH	S-6 (Electrical)	Mitigate TP substations vulnerability
M	S-7 (PH-1)	Mitigate liquefaction vulnerability for regulators/CSOs that would result in backup of sewage (number TBD
M	S-8 (PH-2)	Seismically upgrade regulators/CSOs that would result in sewage backup (number TBD)
M	S-9 (PH/E-3)	Implement wastewater pipeline vulnerability strategy (scope TBD)
M	S-10 (E-3)	Mitigate liquefaction of MH vulnerable PSs (up to 12) and listed treatment facilities at South Plant (up to 5), (See Table 20)
M	S-11 (E-4)	Seismically upgrade MH priority pump stations and treatment facilities (up to 18)
L	S-12 (Mechanical)	Anchor and brace equipment, above grade pipe, and storage racks (implement as doing other work at the facility)
L	S-13 (Electrical)	Anchor electrical cabinets (implement as doing other work at the facility)
VL	S-14 (E-5)	Seismically upgrade (liquefaction and structural) remaining vulnerable pump stations and TP facilities (up to 60)
VL	S-15 (Electrical)	Tie back hanging lights (implement as doing other work at the facility)

Notes:

H – High, MH - Moderate High, M – Moderate, LM – Low Moderate, L – Low, VL – Very Low

For Seismic upgrades (S), the priority of implementation is dependent on a seismic evaluation, which must be completed first.

Table 25: Pump Station Mitigation Priority (Mitigation priority based on structural vulnerability field investigation, liquefaction, capacity and discharge location)

Facility Name	Project Number	Section	Discharge Location (See Note 1)	Peak Cap (MGD) (See Note 2)	Desktop	Hazus	Field	Lique-faction	Mitigation Priority	Deficiencies (See Note 3)	Expected Consequences
Onsite Pump Stations											
STP Influent PS	E-1, E-2	EAST	S	300			H	MH	H	Z-Beam - diaphragm/load path, PC Wall conn; suspended. ceilings, canopies, liquefaction potential	Roof collapse risk; wall/RC collateral damage; nonstructural damage, building float, sink, rotate
WPTP Raw Sewage PS	E-2	WEST	S	440		M	H	VL	H	Z-Beam diaphragm/load path; weak story; SBWC; PC wall panels; RC MFs; CMU walls; ceilings	Roof collapse hazard; significant structural damage; NS damage
Offsite Pump Stations											
Interbay	E-1, E-2	WEST	S	133	H	M	H	VH	H	Load/Geometry/Mass; Infill walls /Columns; Redundancy; Diaphragm; OOP Walls; ceilings/lights/Veneer, liquefaction potential	Significant structural damage, collapse potential; significant NS damage, building float, sink, rotate
Sweylocken	E-1, E-2	EAST	W	31	H	M	MH	MH	H	Load path unclear; diaphragm cross-ties; appendages, liquefaction potential	Damaged roof/MF/glazing; building float, sink, rotate
Duwamish	E-1, E-2	WEST	D	125	H	E	H	VH	H	Load path; adj. building; irregularities; diaphragm; Concrete MFs; infill walls; lights/ceilings/cladding, liquefaction potential	Significant structural damage, collapse potential; significant NS damage, building float, sink, rotate
Matthews Park	E-2	WEST	W	123	H	M	H	L	H	PC walls at high bay; inverted V roof; geometry/mass; wall/CB reinforcing/ceilings/contents	Significant structural damage, collapse potential; NS damage
Belvoir	E-3, E-4	WEST	W	5	H	E	MH	H (Note 4)	MH	Liquefaction and landslide potential; CP reinforcing	Building float, sink, rotate or move laterally ; moderate structural damage;
North Creek	E-3	EAST	SR	23	H	M	M (Note 5, 6)	MH	MH	No structural noted, liquefaction potential	Building float, sink, rotate
63rd Avenue	E-3	WEST	S	17	H	E	LM (Note 5)	MH	MH	NS only - fall-prone/suspended, liquefaction potential.	Nonstructural, building float, sink, rotate
West Marginal Way	E-3	WEST	D	8	H	E	M (Note 5)	MH	MH	Diaphragm openings; liquefaction potential.	Diaphragm damage, building float, sink, rotate
30th Avenue	E-3, E-4	WEST	W	6	H	E	MH	MH (Note 4)	MH	Geometry; wall/CB reinforcing, liquefaction and landslide potential.	Moderate structural damage, building float, sink, rotate or move laterally
Interurban	E-3	EAST	D	29	H	M	LM (Note 5)	MH	MH	Glass block, liquefaction potential.	Broken glass block, building float, sink, rotate
Sunset	E-3	EAST	LkS	15	H	M	LM (Note 5)	MH (Note 4)	MH	Heavy partition, liquefaction and landslide potential.	Building float, sink, rotate or move laterally
Woodinville	E-3, E-4	EAST	SR	27	H	M	Note 6	MH	MH	None noted, liquefaction potential.	None noted, building float, sink, rotate
Henderson	E-3, E-4	EAST	W	22		M	Note 6	MH	MH	None noted, liquefaction potential.	None noted, building float, sink, rotate
South Mercer	E-3, E-4	EAST	W	12	H	M	Note 6	MH	MH	None noted, liquefaction potential.	None noted, building float, sink, rotate
Rainier Ave	E-3, E-4	WEST	W	9	H	M	Note 6	MH	MH	None noted, liquefaction potential.	None noted, building float, sink, rotate
East Marginal Way	E-3, E-4	WEST	D	23	H	M	Note 6	MH	MH	None noted, liquefaction potential.	None noted, building float, sink, rotate

Notes:

1. D - Duwamish discharge
   LkS/L - Lake Sammamish/Local water discharge
   S - Saltwater discharge
   SR - Sammamish River Discharge
   W - Lake Washington discharge

2 Peak Capacity values provided by King County WTD
3 Most facilities have light fixtures that may swing and break, and contents that may fall causing damage
4 Also landslide potential
5 Facilities noted with M or lower vulnerability should have a lower priority for structural analysis
6 No site visits to these facilities - structural vulnerability should be assessed in project number E-4.

Table 26: West Point Facility Mitigation Priority

Facility Name	Project Number	Hazus	Field	Priority	Deficiencies (Note 1)	Expected Consequences
Admin/Ops Center	LS-1	S	H	VH	Weak story/geometry; BF requirements; server room/CEILINGs/contents	Wall & BF damage; NS Damage; server equipment down
Maintenance/Effluent Pump Station	LS-1	S	MH	VH	Seismic joint, BF requirements; diaphragm openings; partitions/ CEILINGs/storage/contents	Pounding damage; BF damage; diaphragm damage; NS damage
Primary Clarifiers	E-4		H	MH	Z-Beam -diaphragm/load path; irregularities; lights	Diaphragm damage; possible roof collapse; collapse risk
Hypo Mixing	E-4	S	MH	MH	Adj. building; load path; lights; canopies; appendages	Adj. building; load path; lights; canopies; appendages
Raw Water Pump Station	E-4	S	MH	MH	Z-Beam diaphragm/load path; weak story; SBWC; PC wall panels; RC MFs; CMU walls; CEILINGs	Roof collapse hazard; significant structural damage; NS damage

Note

1. Most facilities have light fixtures that may swing and break

Table 27: South Plant Facility Mitigation Priority

Facility Name	Project Number	Hazus	Field	Priority	Deficiencies	Expected Consequences
Operations Building	LS-1, E-3	M	H	VH	Penthouse load path; server room equipment; partitions/ceilings/lights	Server equipment failure; NS damage; penthouse damage
Santler Building	LS-1, E-3		MH	VH	Tilt-up wall conn/requirements;	Wall damage, OOP failure; collapse risk; fallen storage/equipment
Maintenance Building	E-3, E-4		H	MH	Z-beams, mezzanine Load Path, tilt-up wall detailing	Roof and mezzanine collapse, wall damage
Effluent Pump Station Forebay Main Station	E-3		LM	MH (Liquefaction only); ML-structural	Foundation to resist liquefaction, Retrofit apparent; detailing/purpose of retrofit unknown; potential weak/soft story; tilt-up wall panel connections	Building settlement or flotation
Digester Equipment Building	E-3, E-4	M	MH	MH	Insufficient seismic joint, lights	Pounding damage, nonfunctional lights

Table 28: Brightwater Facility Mitigation Priority

Facility Name	Project Number	Hazus	Field	Priority	Deficiencies	Expected Consequences
Administration Building	LS-1			VH	No site visits to this facility. Building existed and was used for other purposes prior to design of the plant. It did not undergo seismic upgrade for the SWIF	

8 References

8.1 Pipeline Evaluation References

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Volume 1: Plates (Large Maps/Figures)

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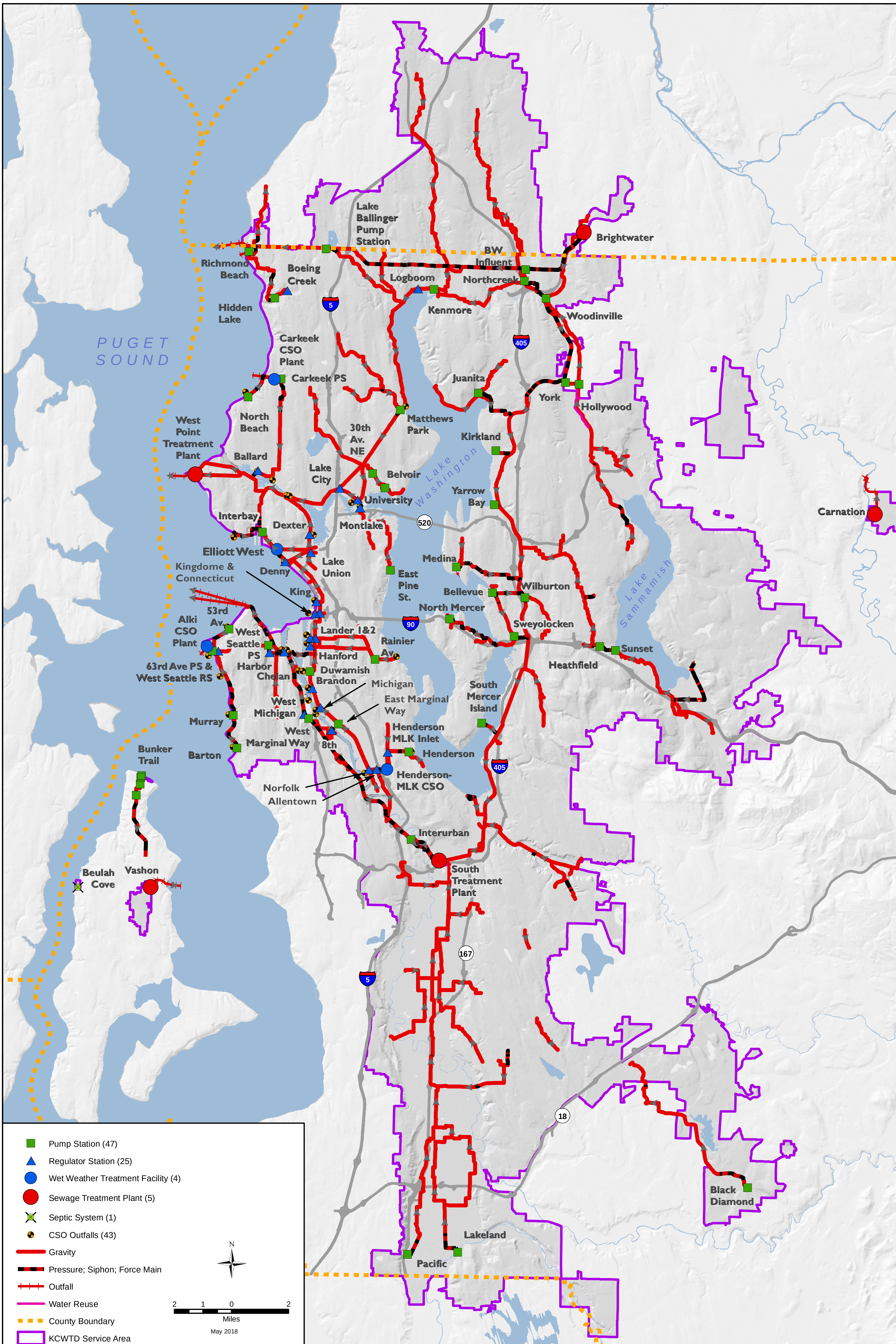

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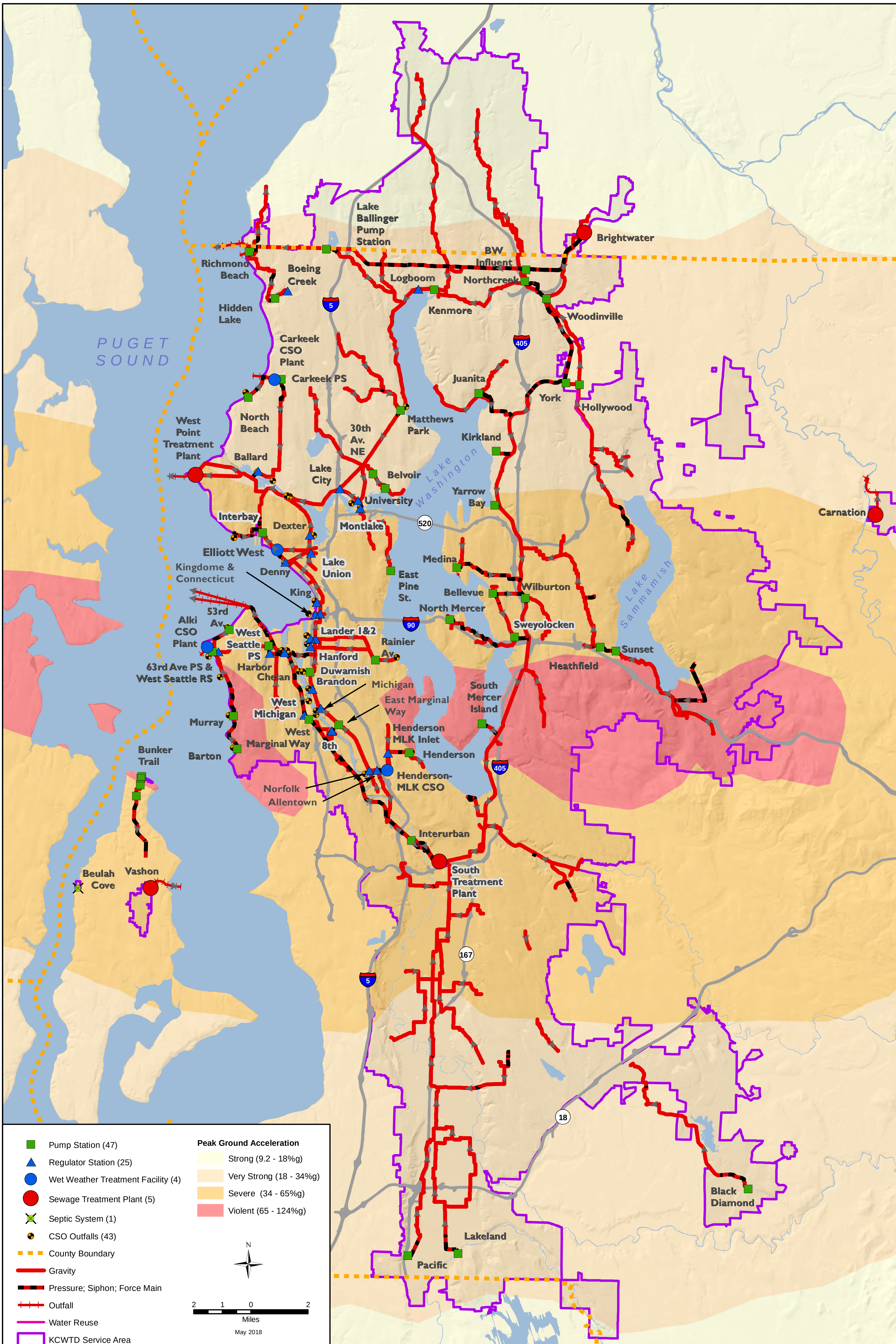
WTD System Map



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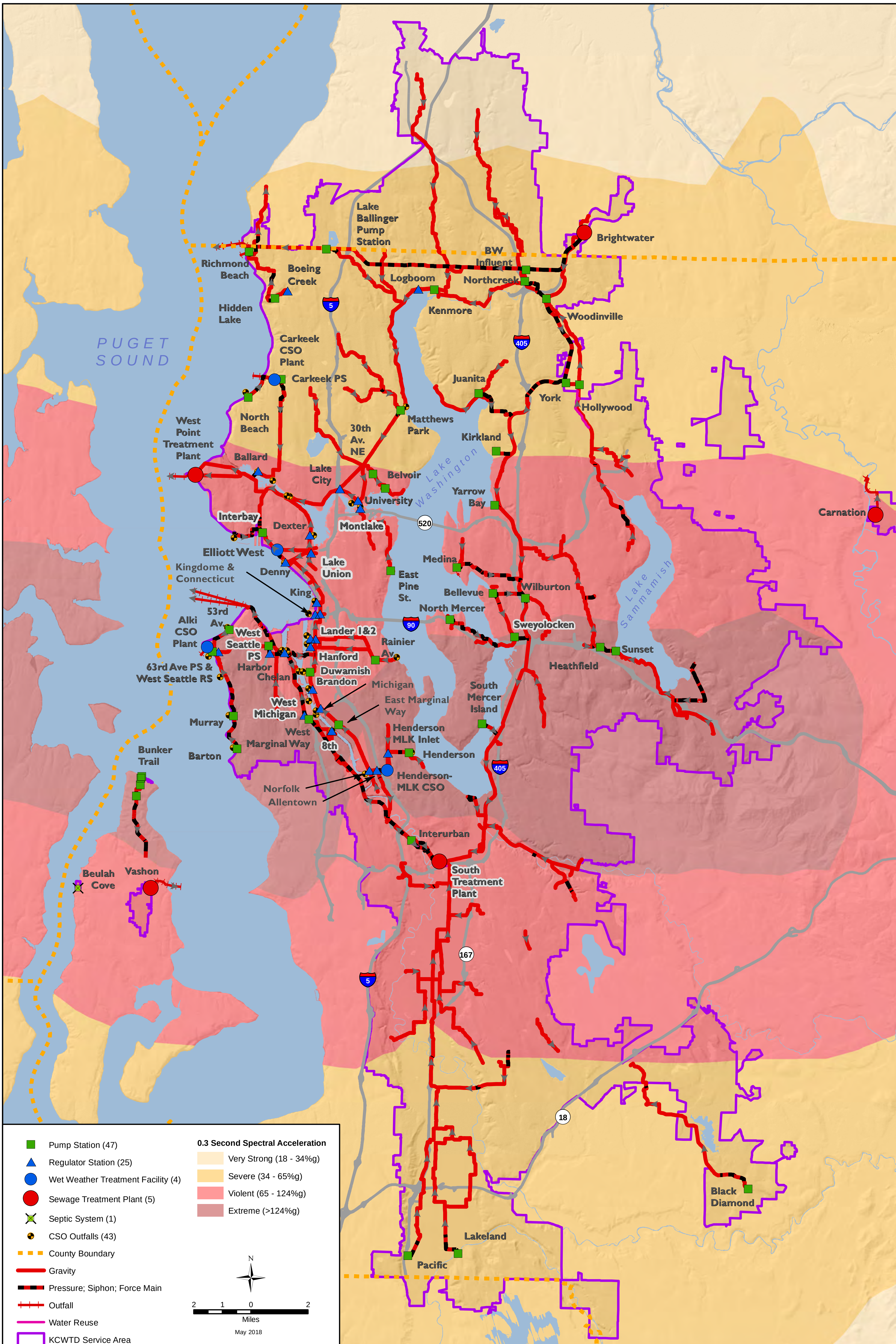
Scenario Seismic Acceleration
Seattle Fault M7.2
Peak Ground Acceleration



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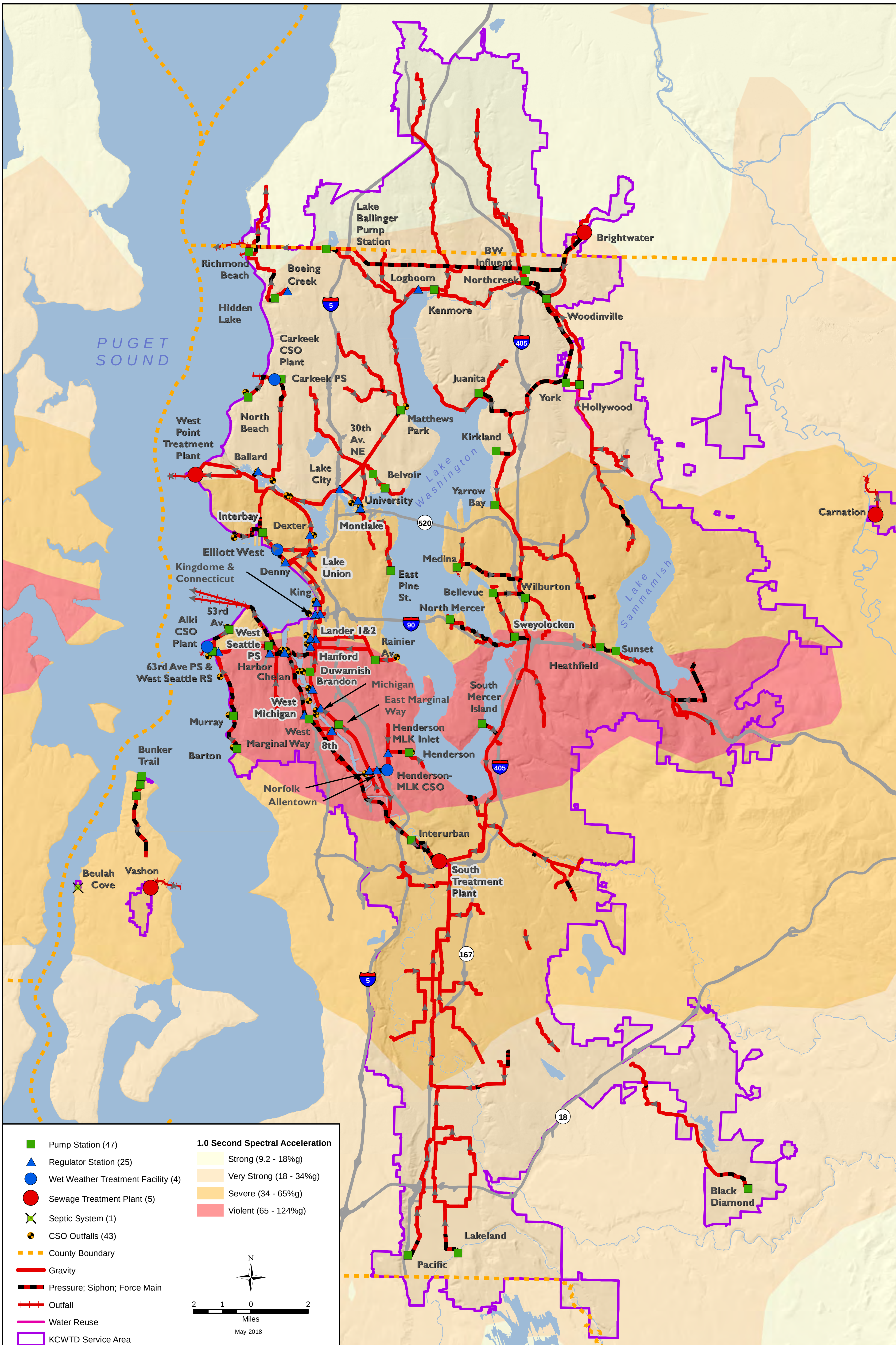
Scenario Seismic Acceleration

Seattle Fault M7.2

0.3 Second Spectral Acceleration



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Scenario Seismic Acceleration
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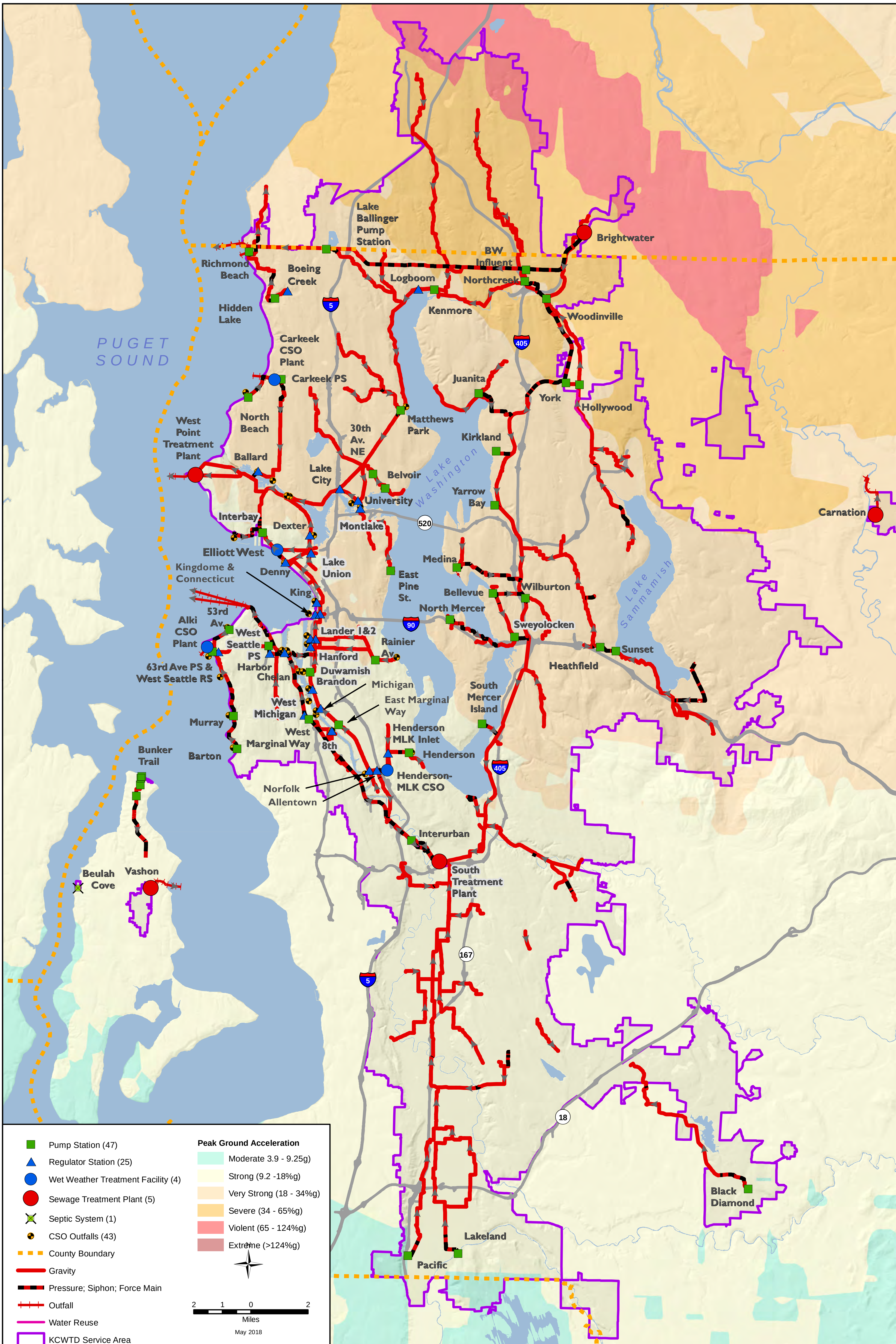
1.0 Second Spectral Acceleration



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Scenario Seismic Acceleration
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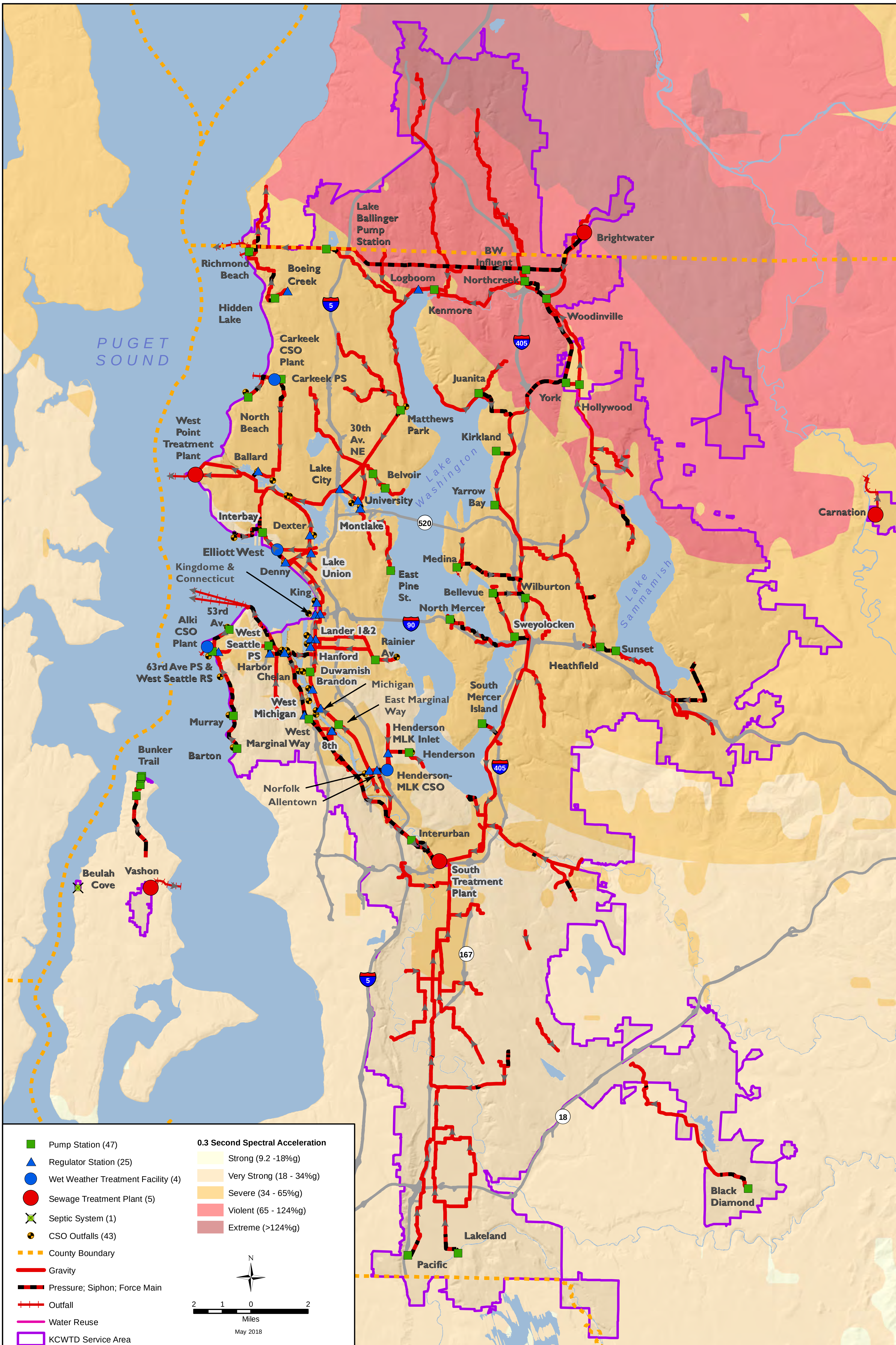
Peak Ground Acceleration



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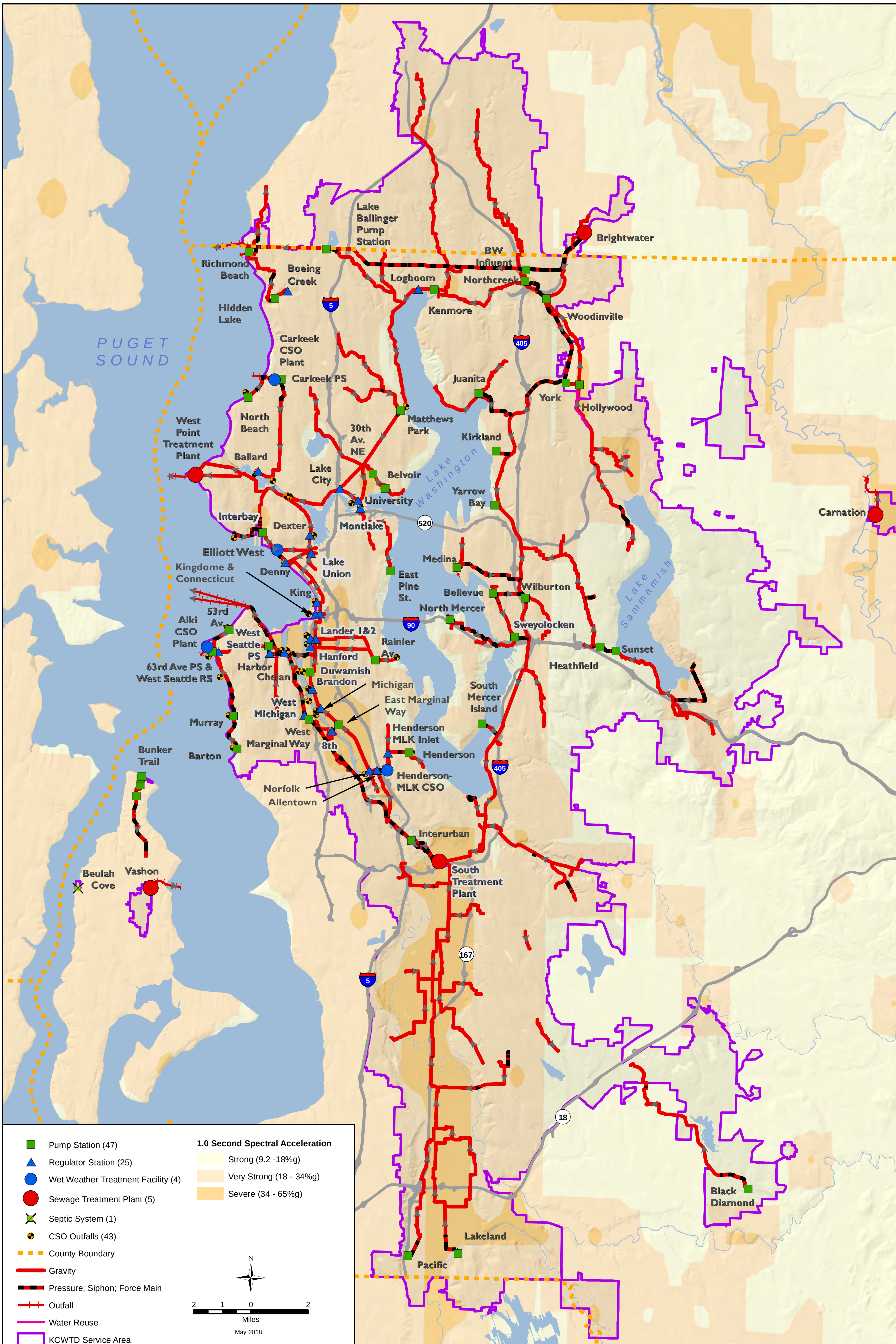
0.3 Second Spectral Acceleration



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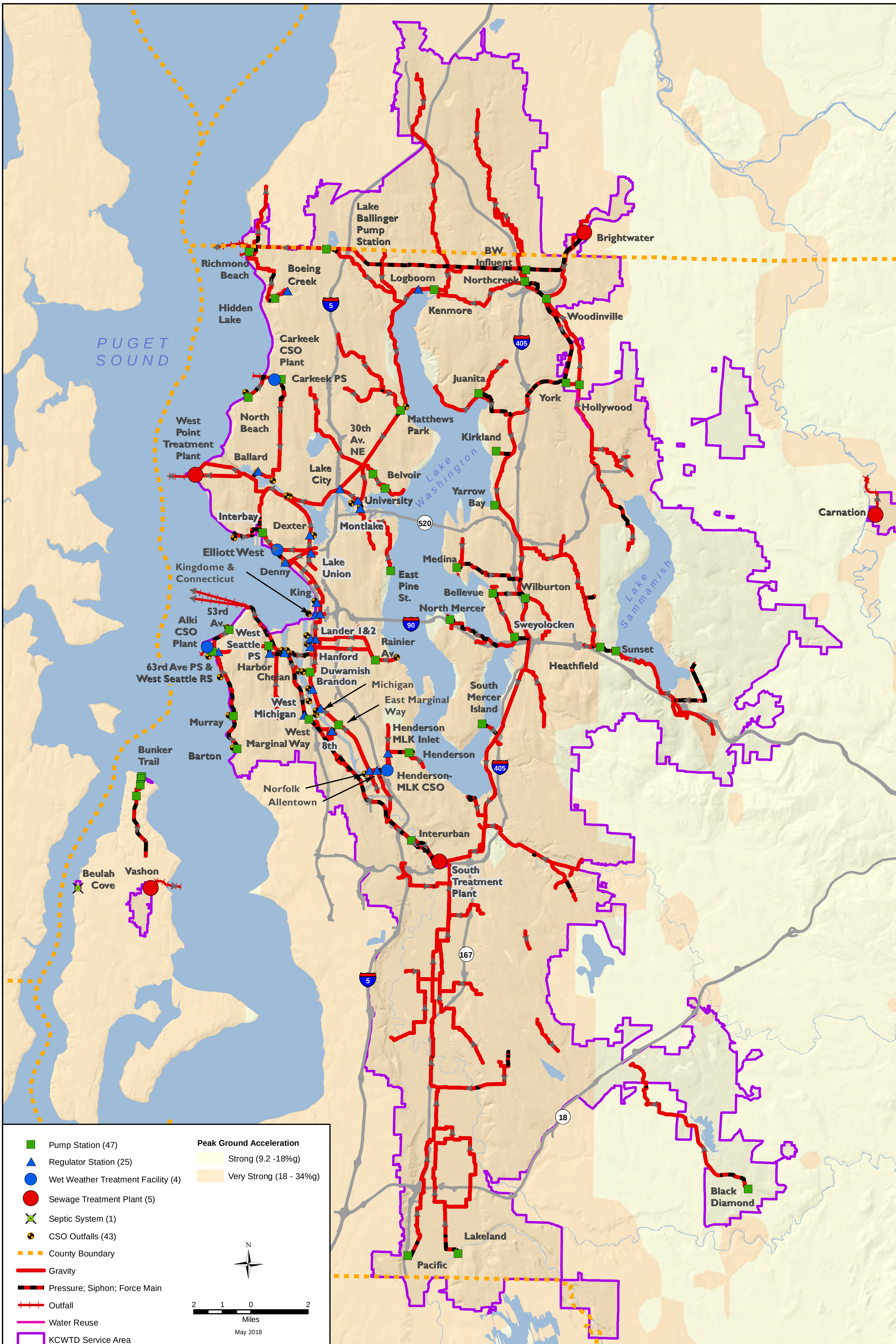
Scenario Seismic Acceleration
Cascadia Subduction Zone M9.0
1.0 Second Spectral Acceleration



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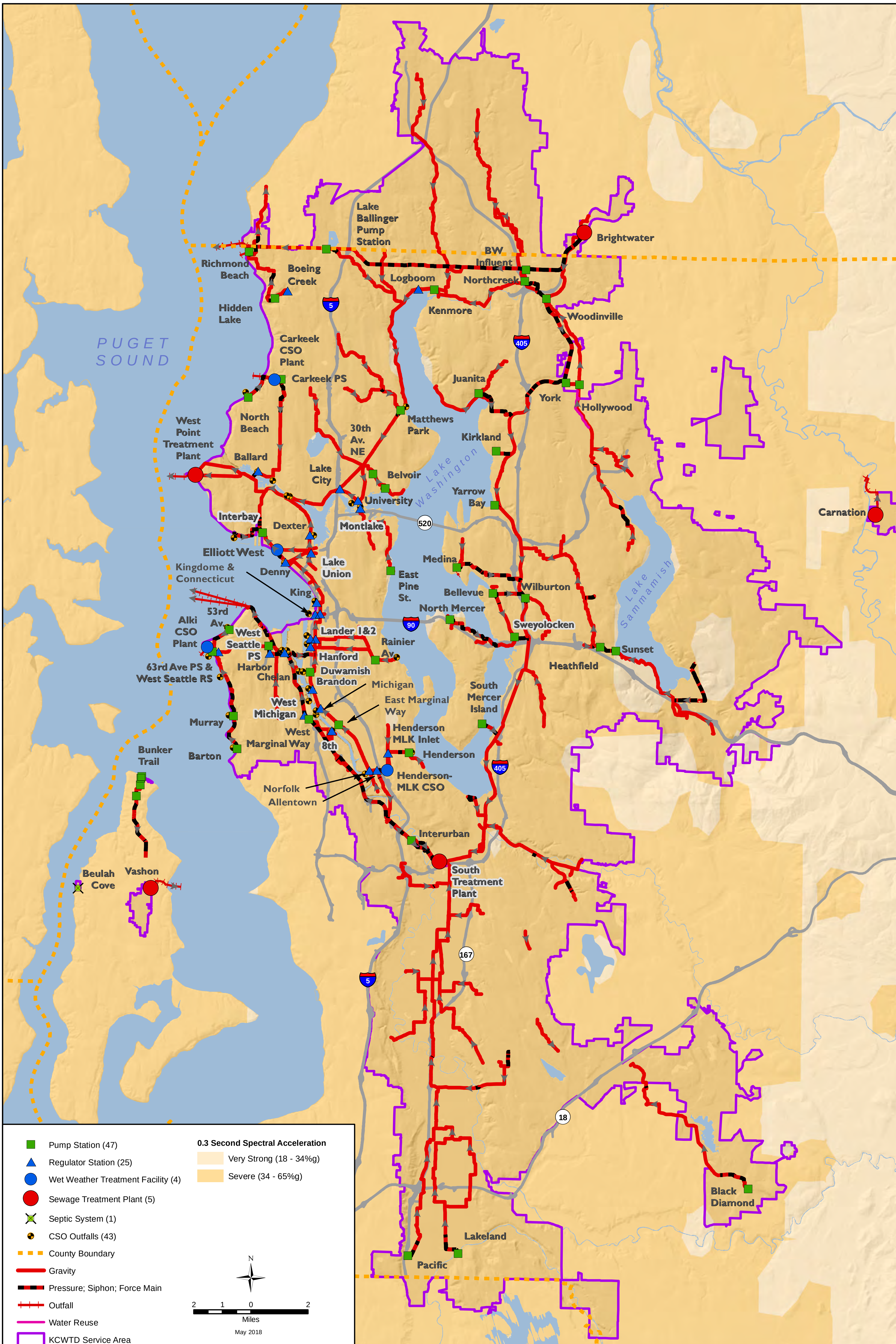
Scenario Seismic Acceleration
Cascadia M9.0
Peak Ground Acceleration



King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

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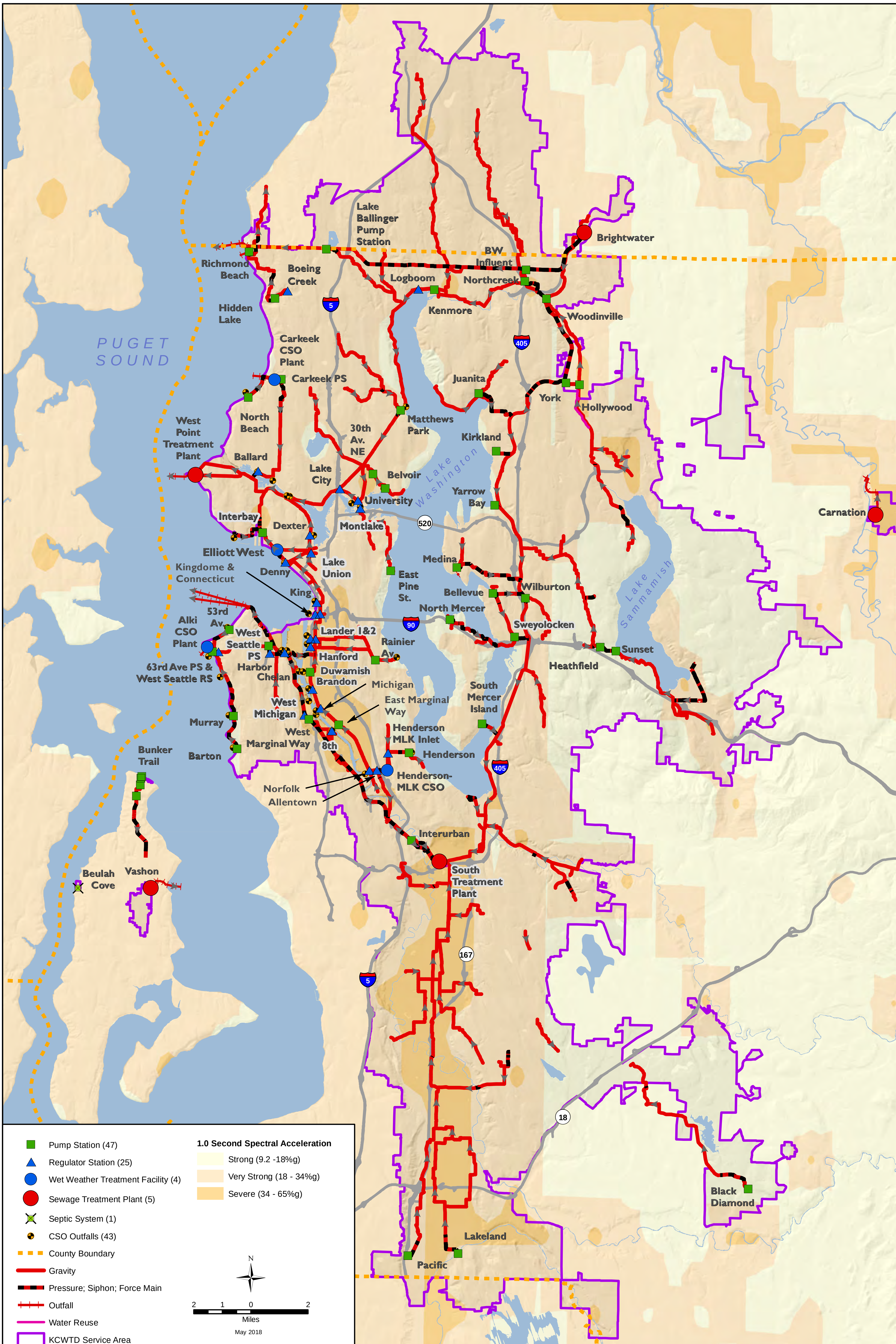

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Wastewater Treatment Division

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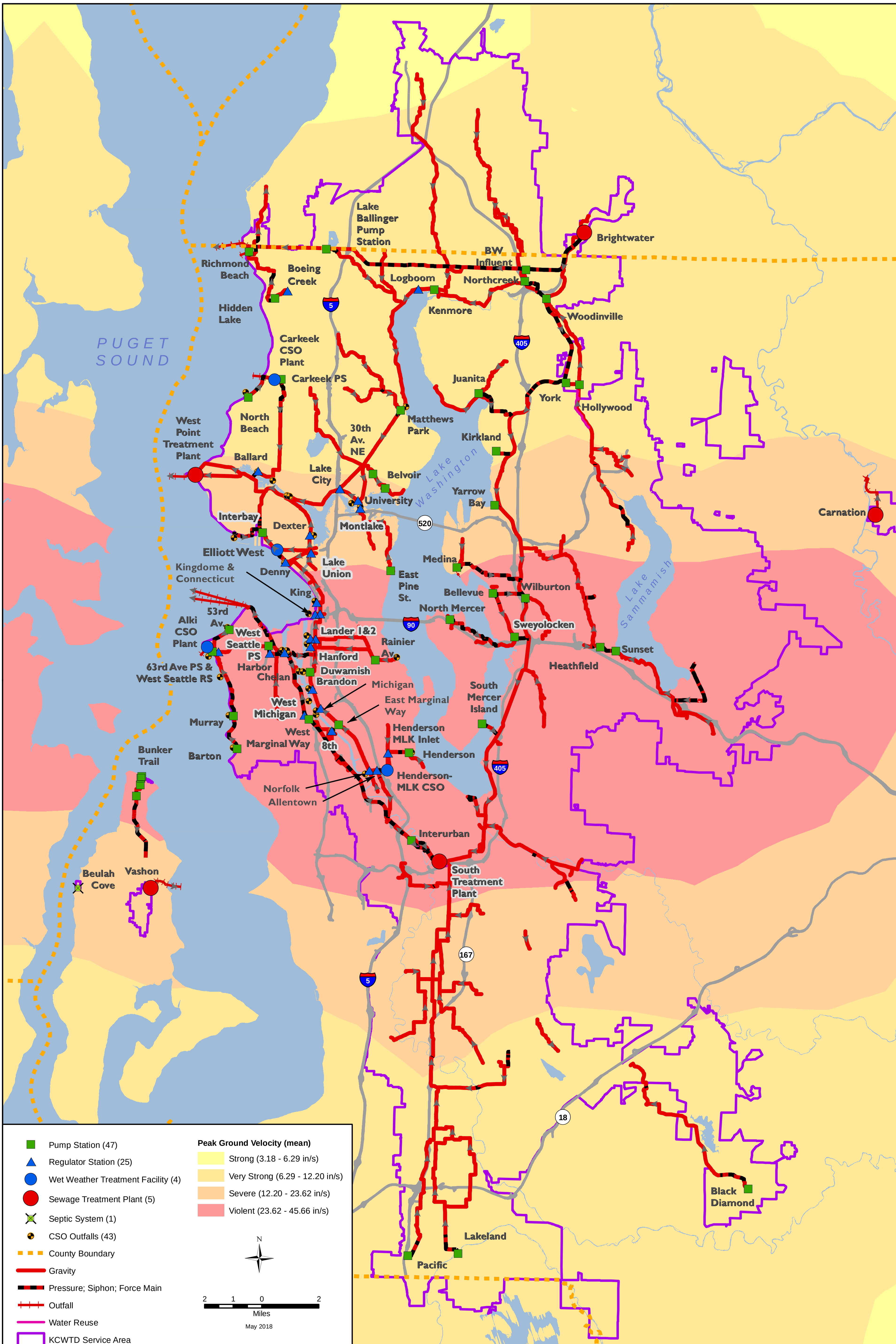
Scenario Seismic Acceleration

Cascadia M9.0

1.0 Second Spectral Acceleration



King County
Department of Natural Resources and Parks
Wastewater Treatment Division

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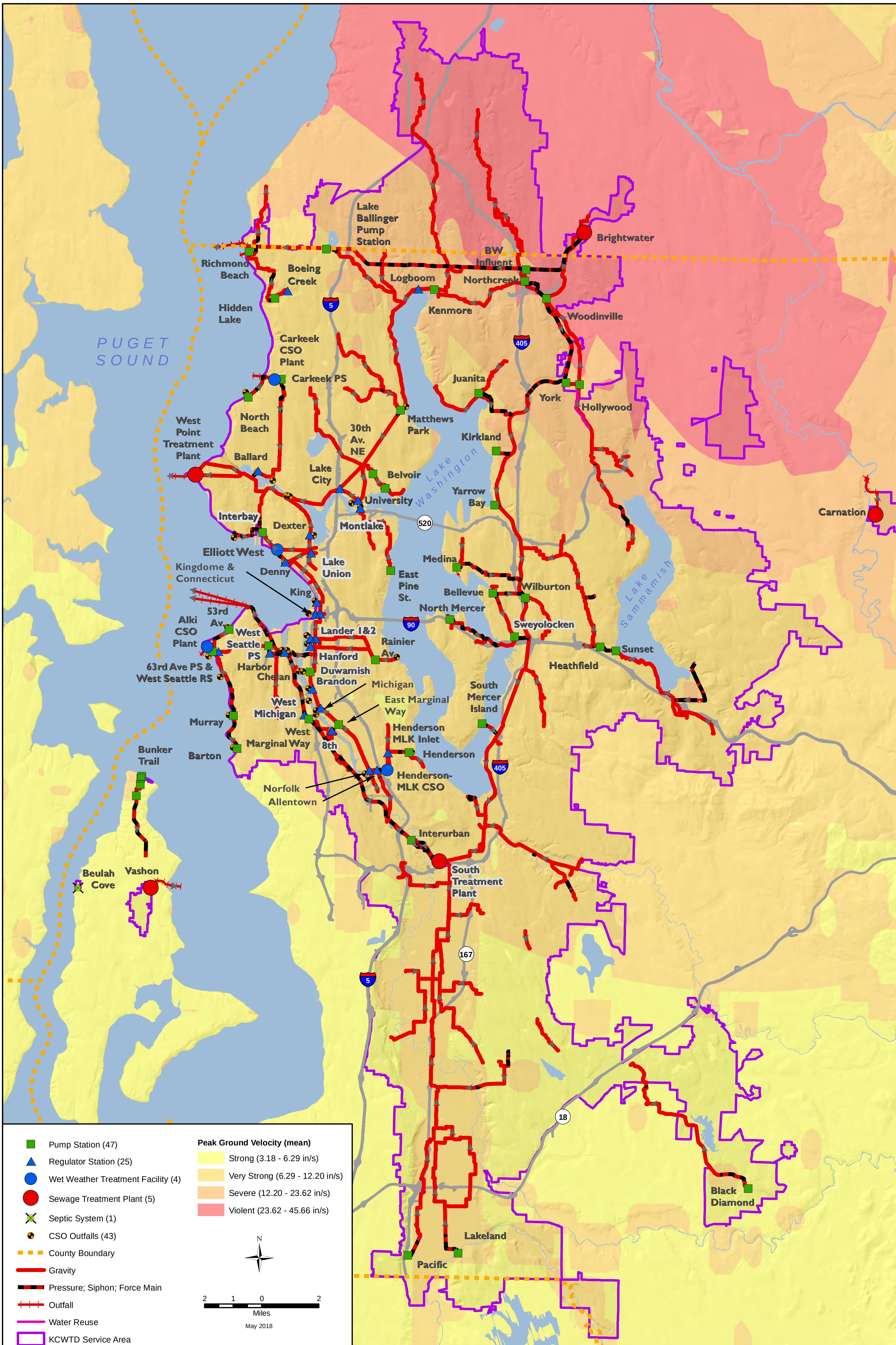
Peak Ground Velocity

Seattle Fault M7.2



King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

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Peak Ground Velocity

South Whidbey Island Fault M7.4

King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

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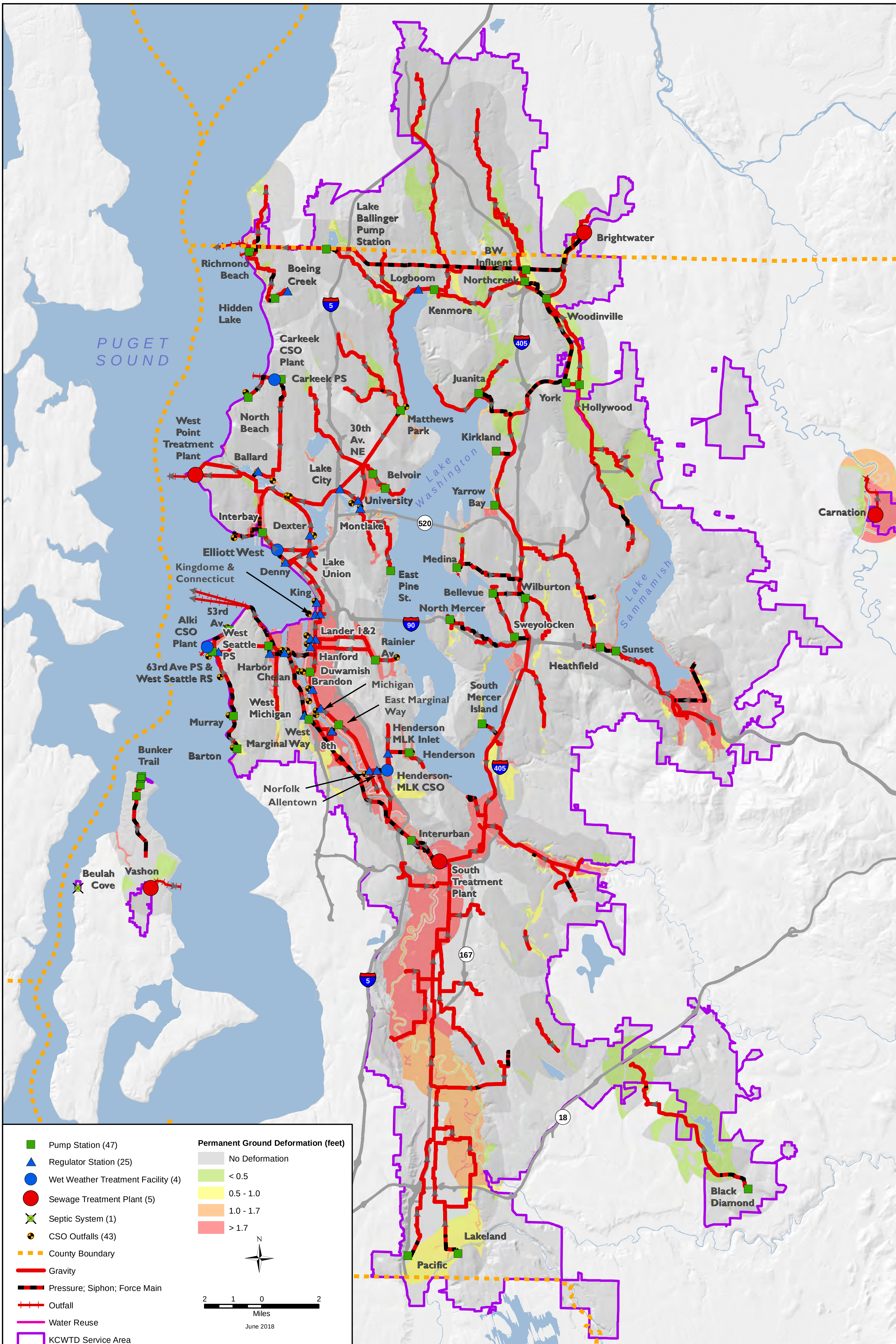
Peak Ground Velocity

Cascadia M9.0



King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

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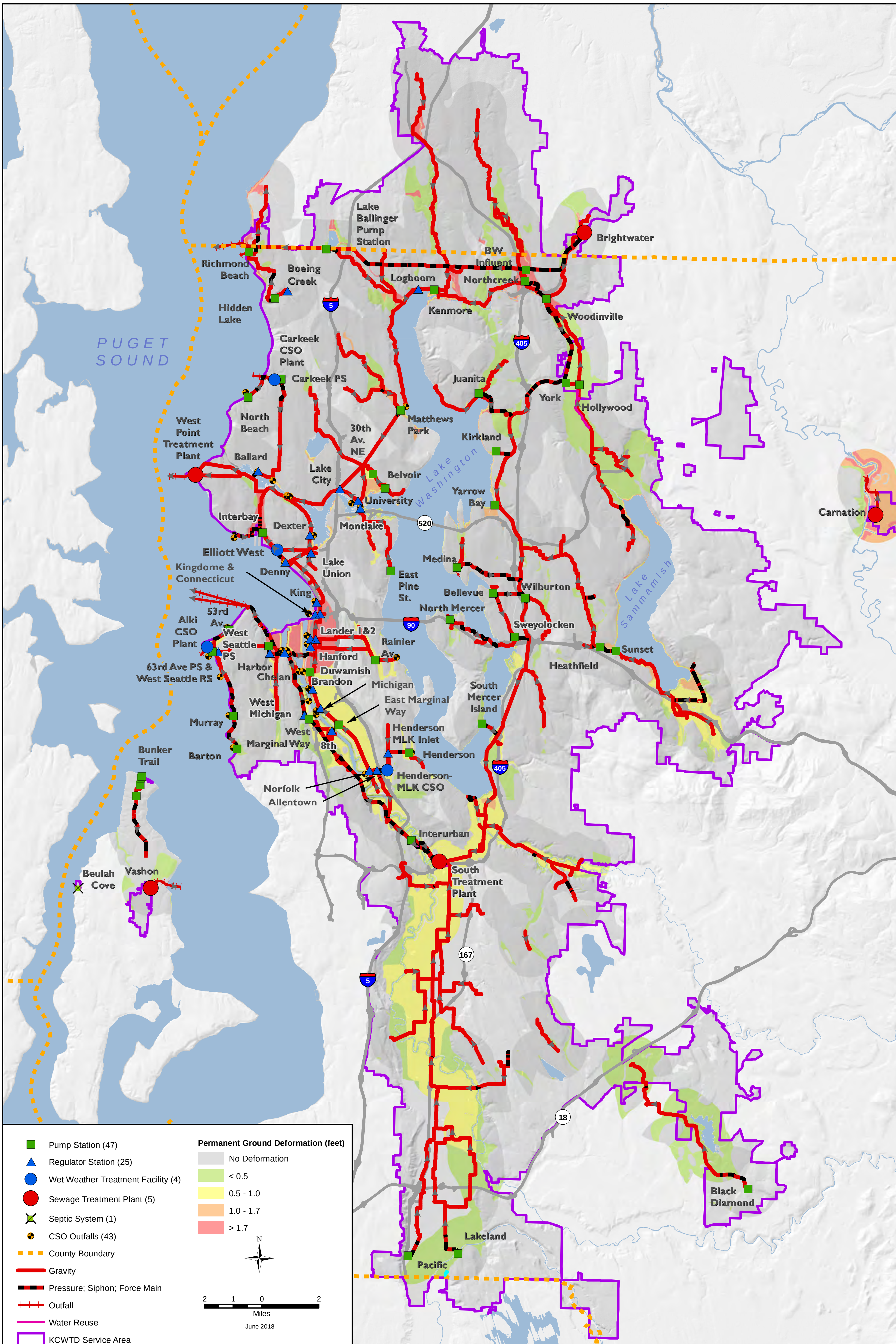
Permanent Ground Deformation

Seattle Fault M7.2



King County

Department of Natural Resources and Parks

Wastewater Treatment Division

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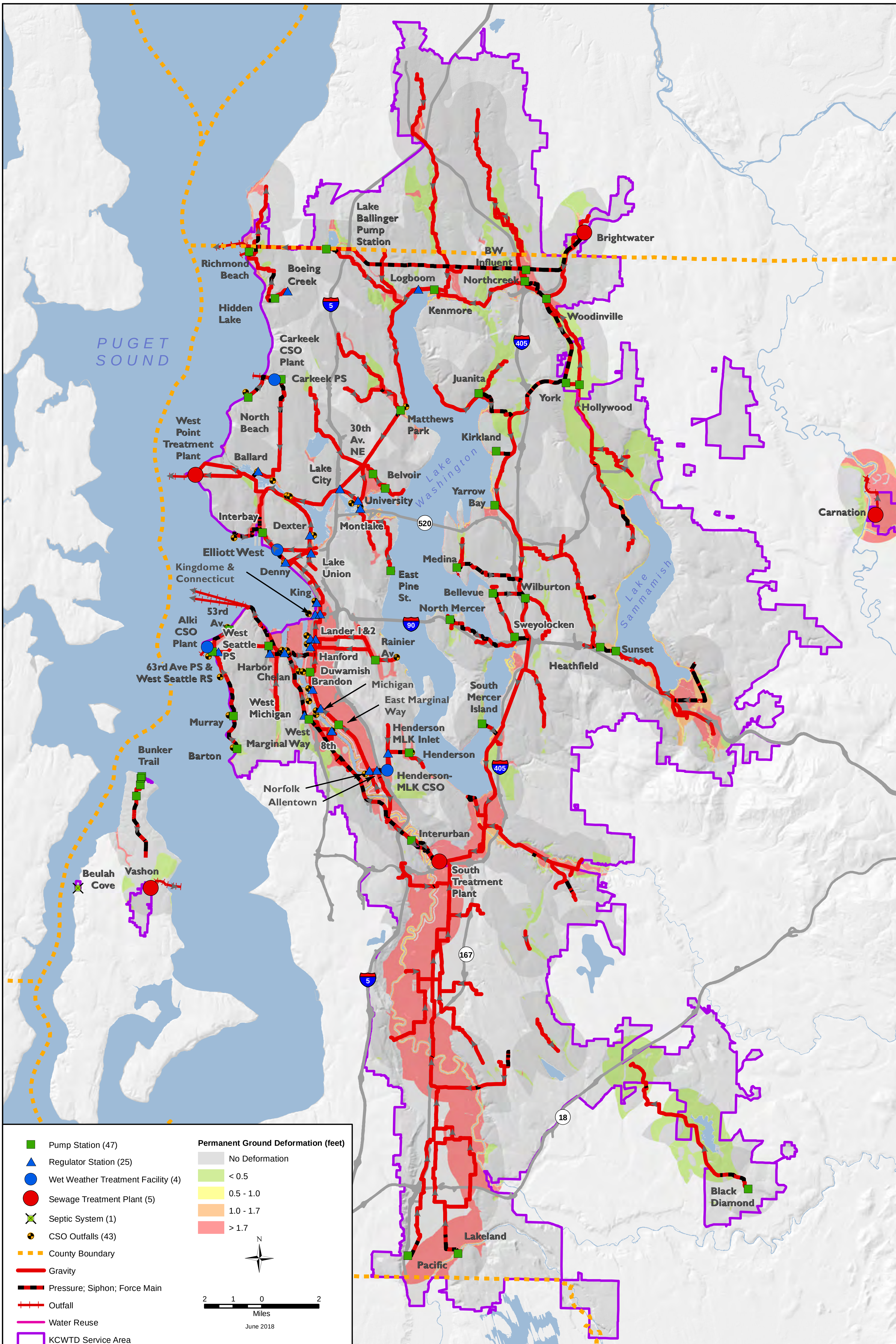
Permanent Ground Deformation

South Whidbey Island Fault M7.4



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Department of
Natural Resources and Parks
Wastewater Treatment Division

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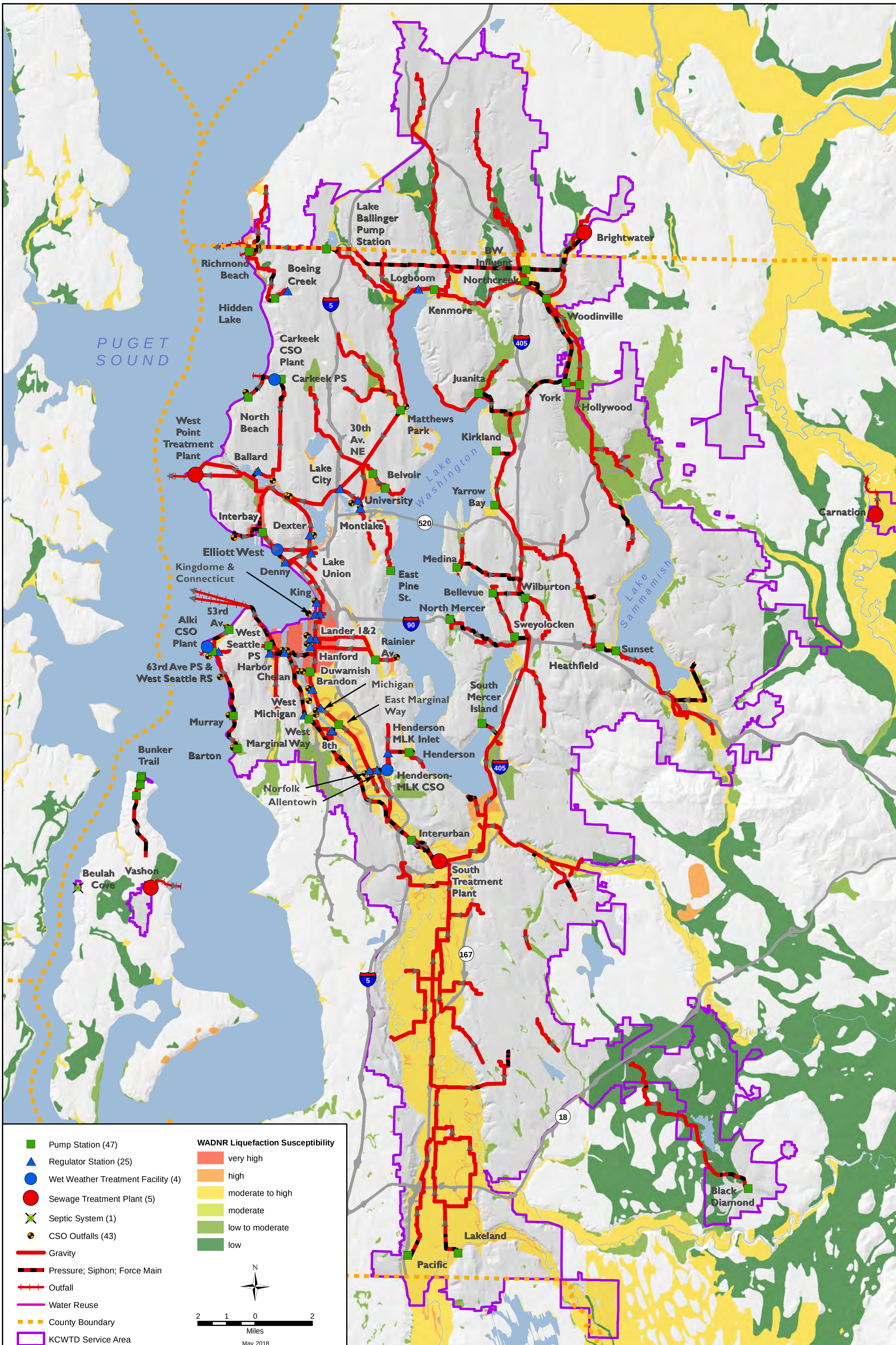
Permanent Ground Deformation

Cascadia M9.0



King County
Department of
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Wastewater Treatment Division

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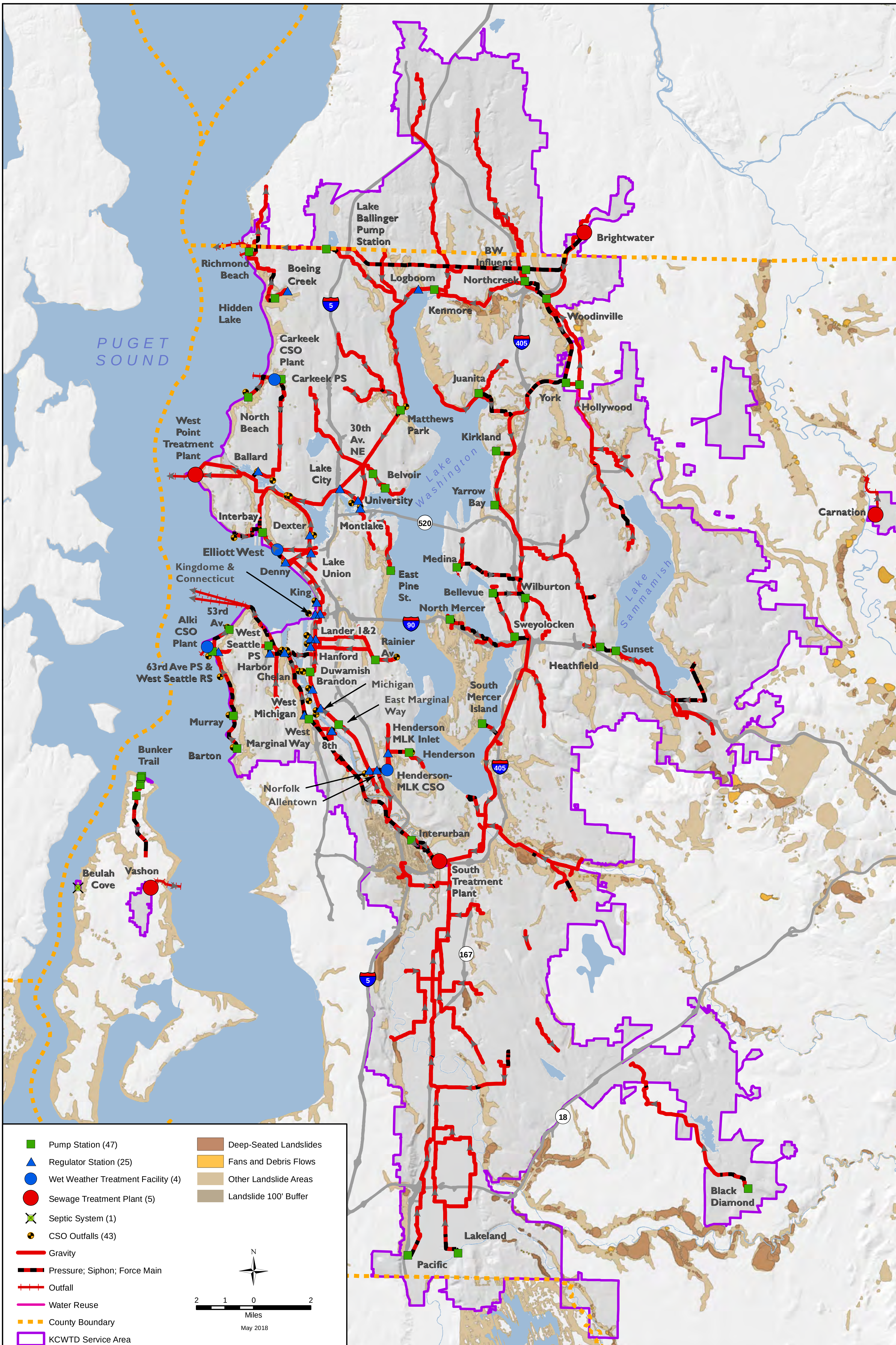
KCWTD System

Liquefaction Susceptibility Map



King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

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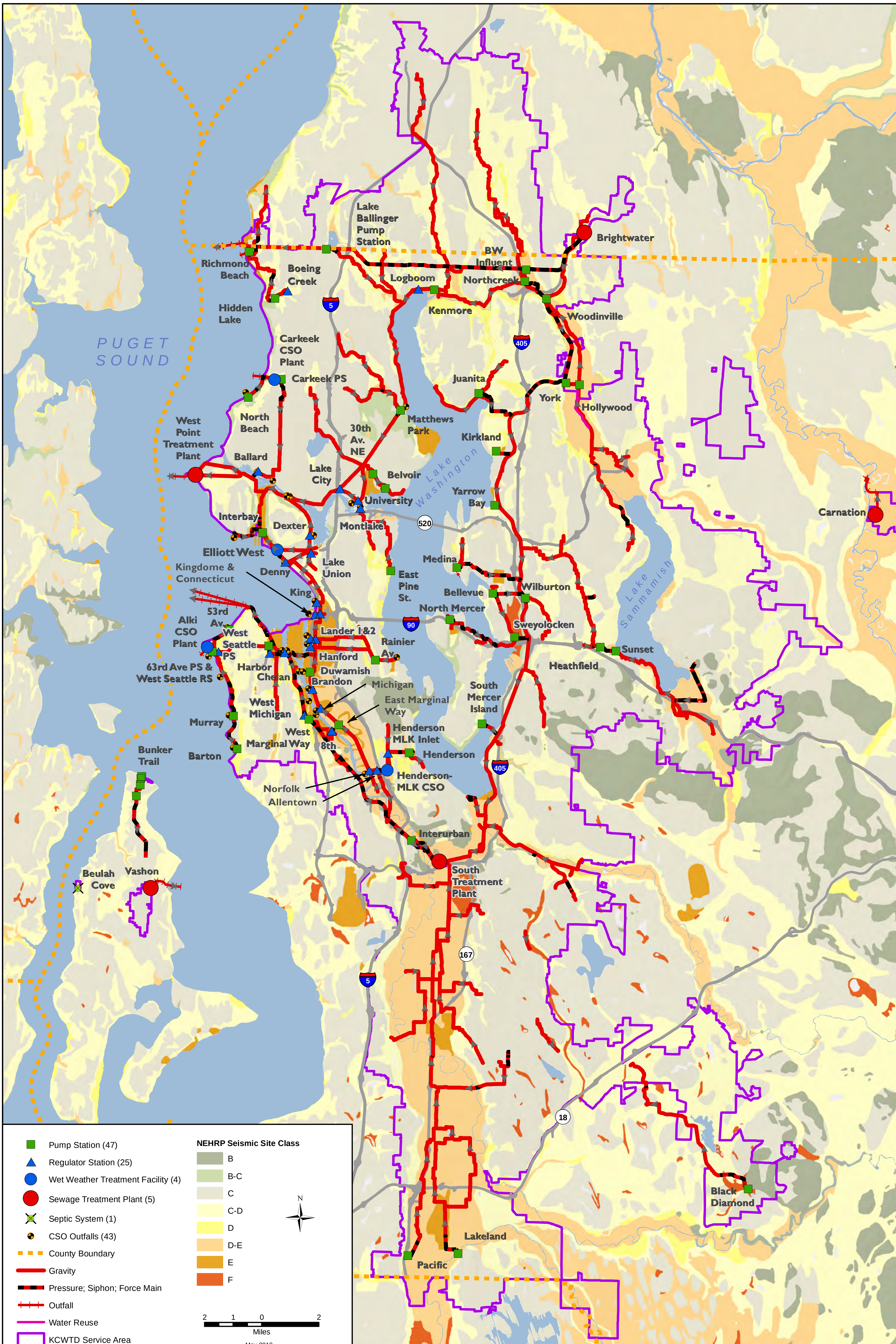
KCWTD System
Landslide Susceptibility Map



King County
Department of Natural Resources and Parks
Wastewater Treatment Division

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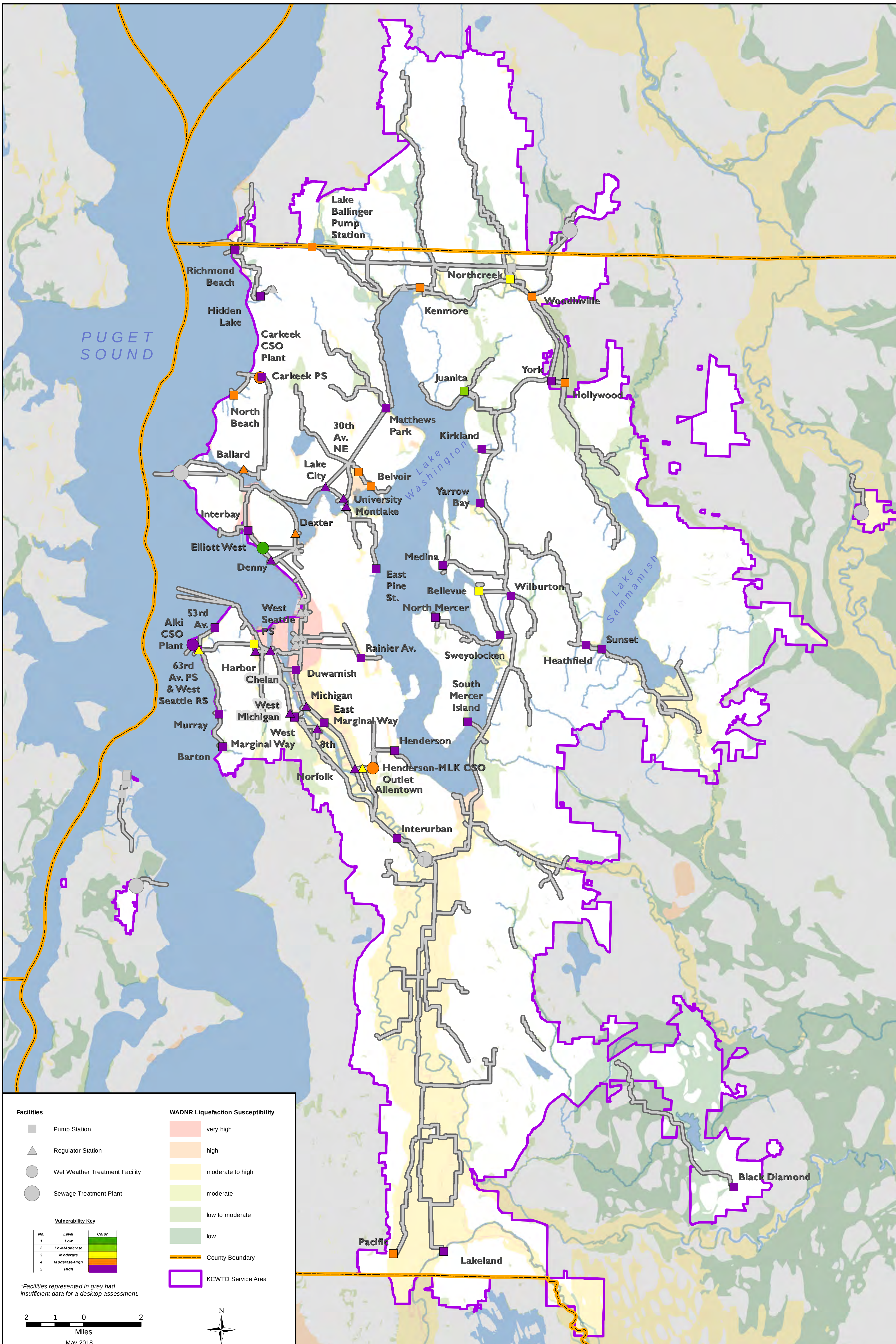
Seismic Site Class

Seismic Site Class



King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

File Name: Q:\WTD\Projects\Seismic\Projects\TM600\Vol1_1D_1_72_DeskVul.mxd
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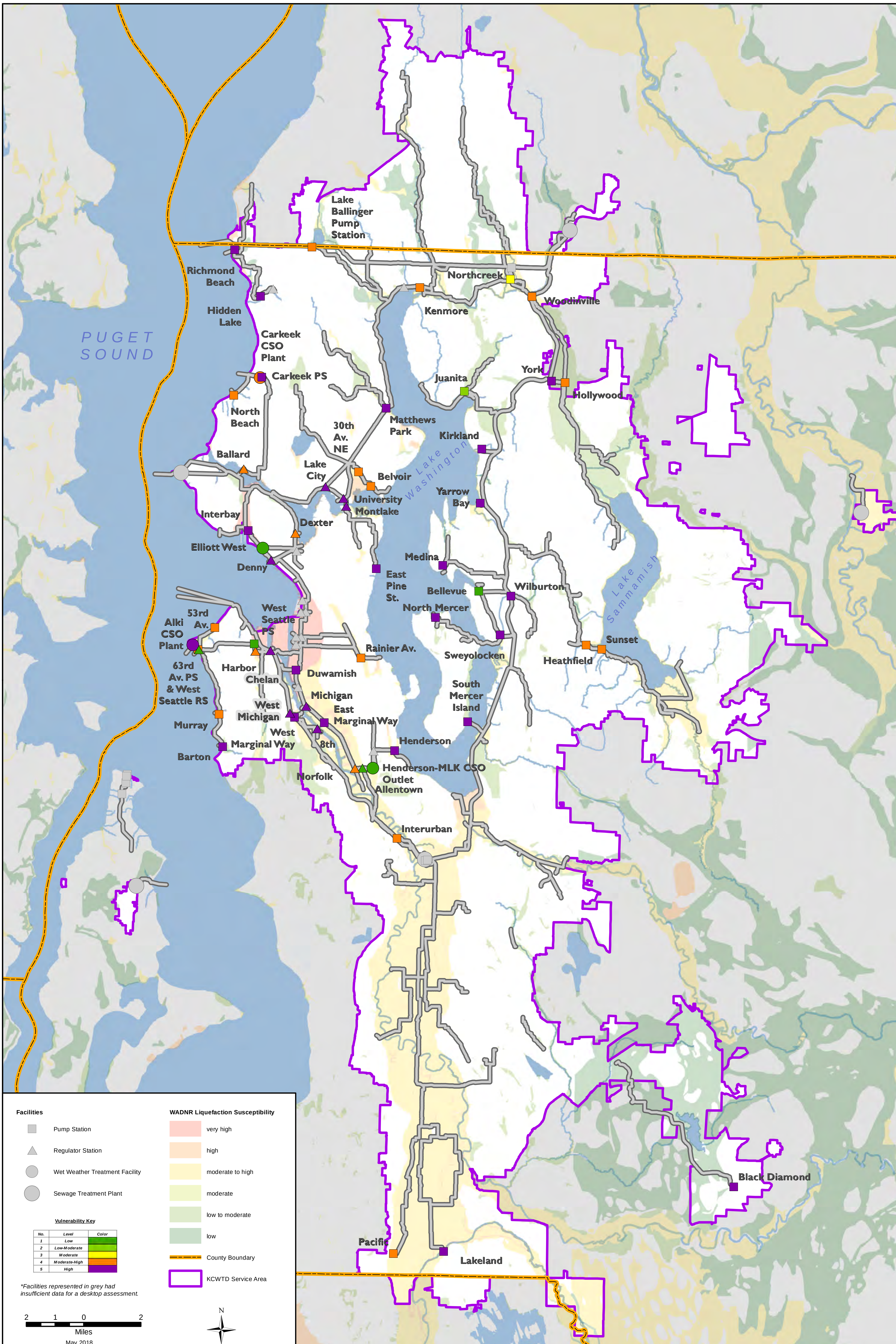
Desktop Facility Vulnerability Summary

Seattle Fault M7.2



King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

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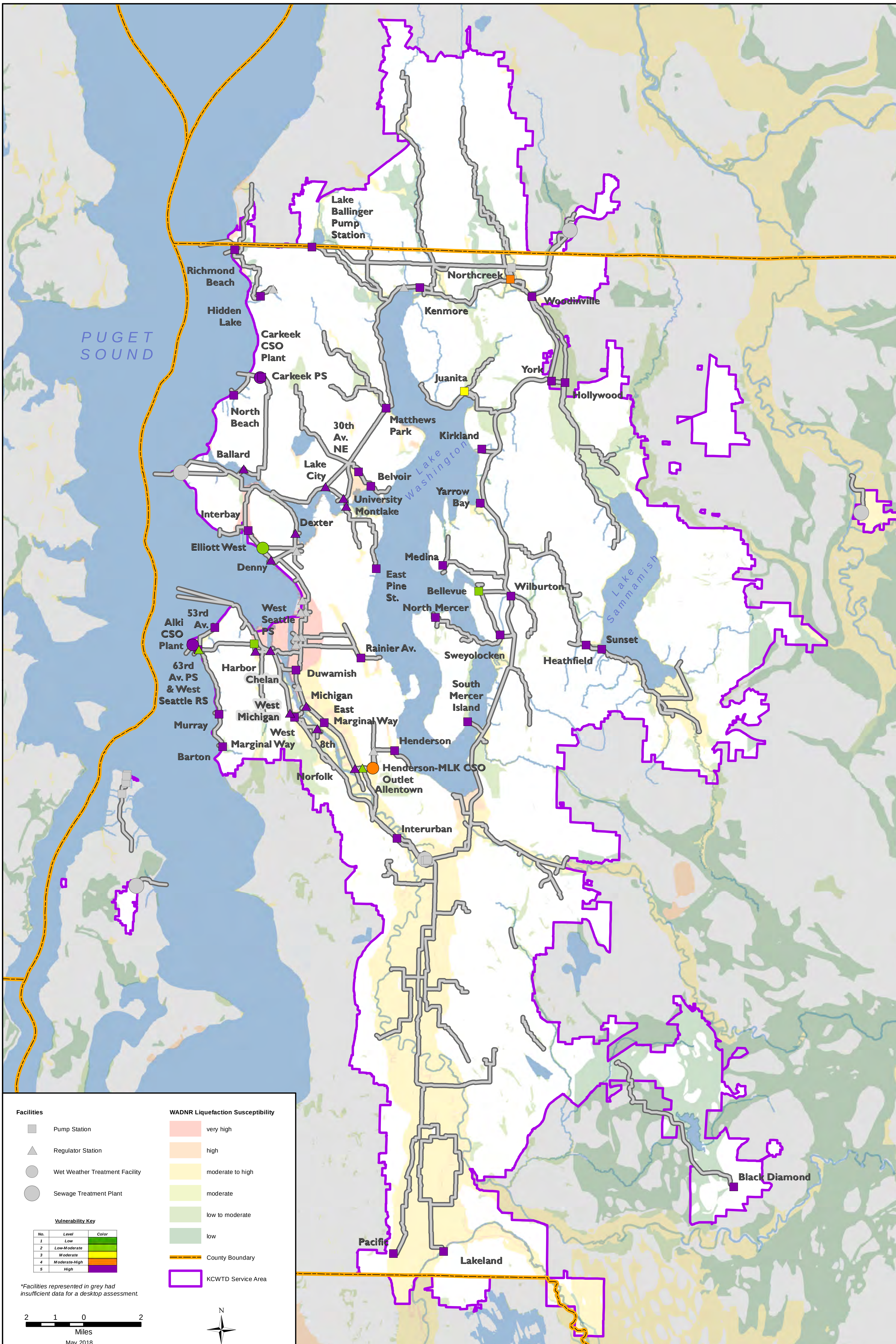
Desktop Facility Vulnerability Summary

South Whidbey Island Fault M7.4



King County
Department of Natural Resources and Parks
Wastewater Treatment Division

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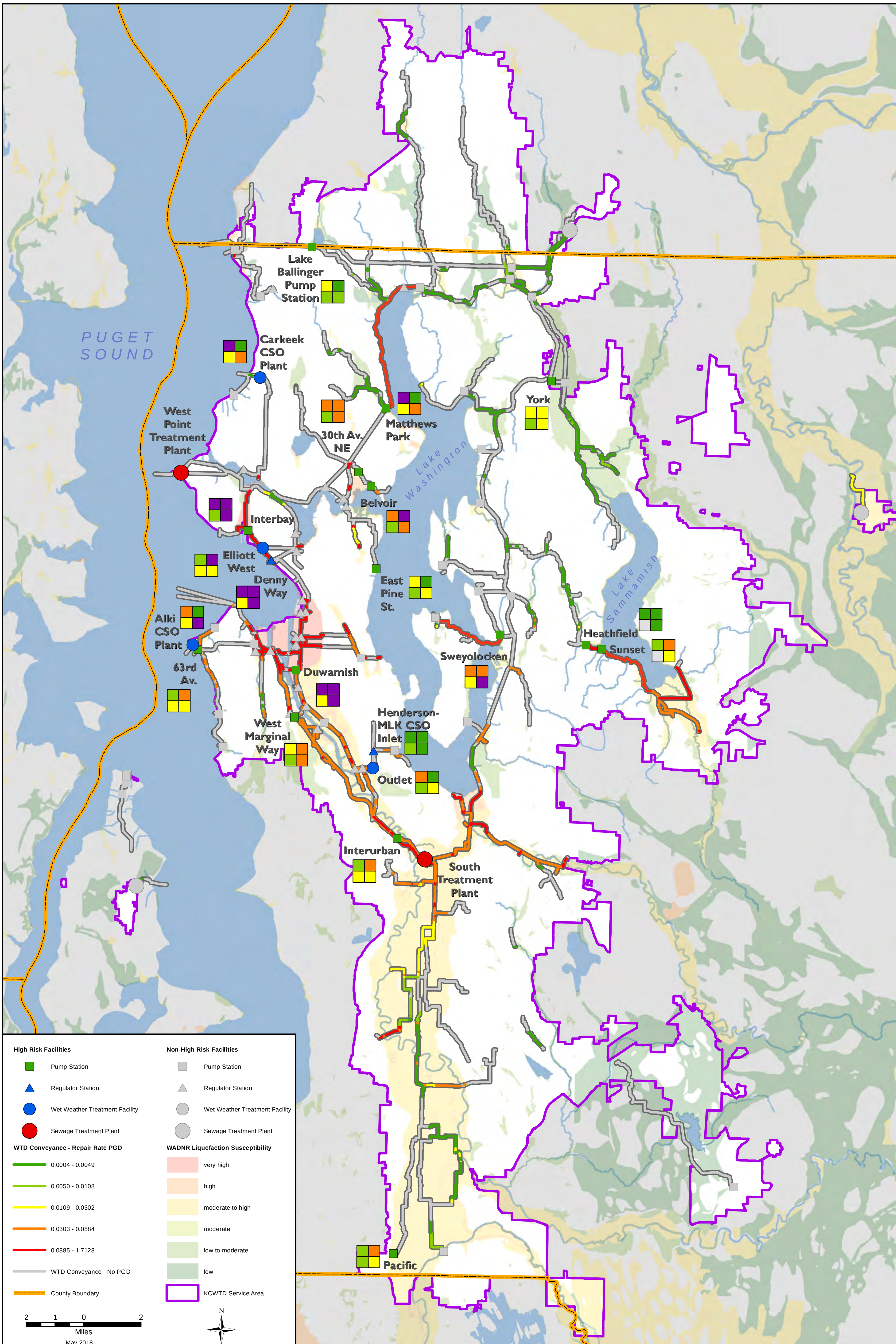
Desktop Facility Vulnerability Summary

Cascadia M9.0



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Wastewater Treatment Division

File Name: Q:\WTD\Projects\Seismic\Projects\TM600\Vol1_1D_2_72_FieldVul.mxd
oneilsh

Vulnerability Key

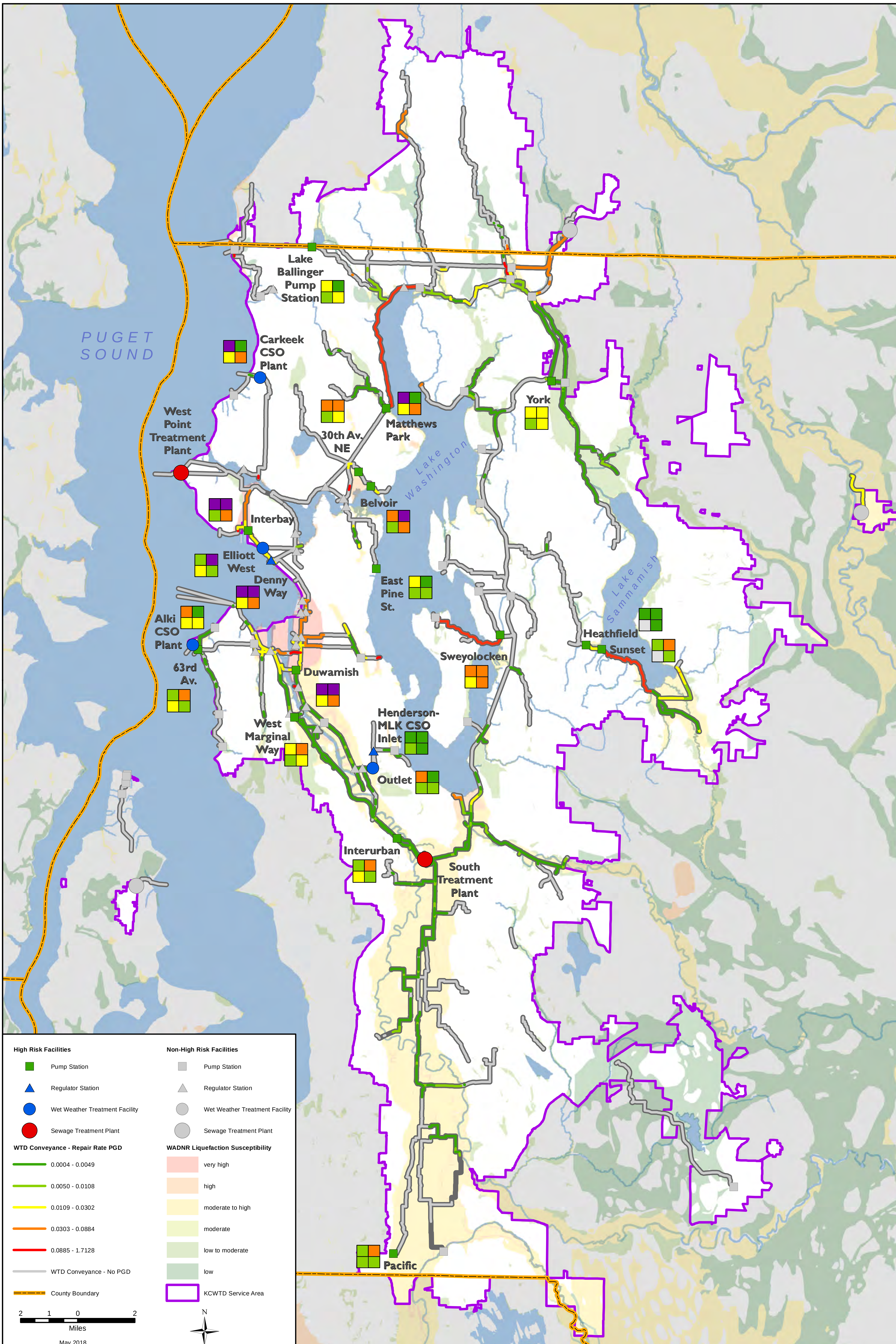
No.	Level	Color
1	Low	
2	Low-Moderate	
3	Moderate	
4	Moderate-High	
5	High	

Facility Evaluation Key

Structural/ Architectural	Liquefaction
Mechanical\ Electrical\ Plumbing	Overall

Facility Vulnerability Summary

Seattle Fault M7.2



King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

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oneilsh

Vulnerability Key

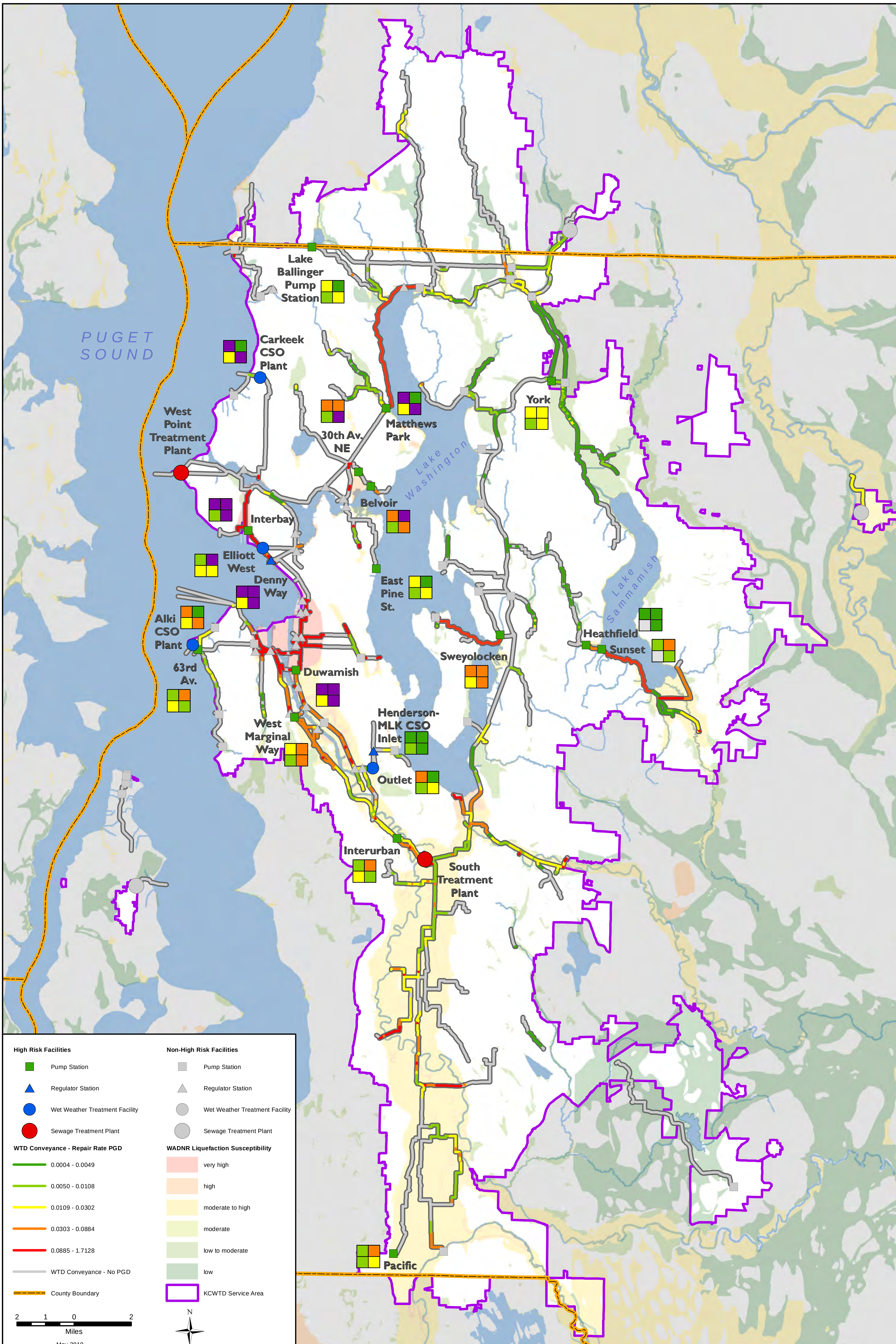
No.	Level	Color
1	Low	
2	Low-Moderate	
3	Moderate	
4	Moderate-High	
5	High	

Facility Evaluation Key

Structural/ Architectural	Liquefaction
Mechanical/ Electrical/ Plumbing	Overall

Facility Vulnerability Study

South Whidbey Island Fault M7.4



King County

Department of Natural Resources and Parks

Wastewater Treatment Division

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oneilsh

Vulnerability Key

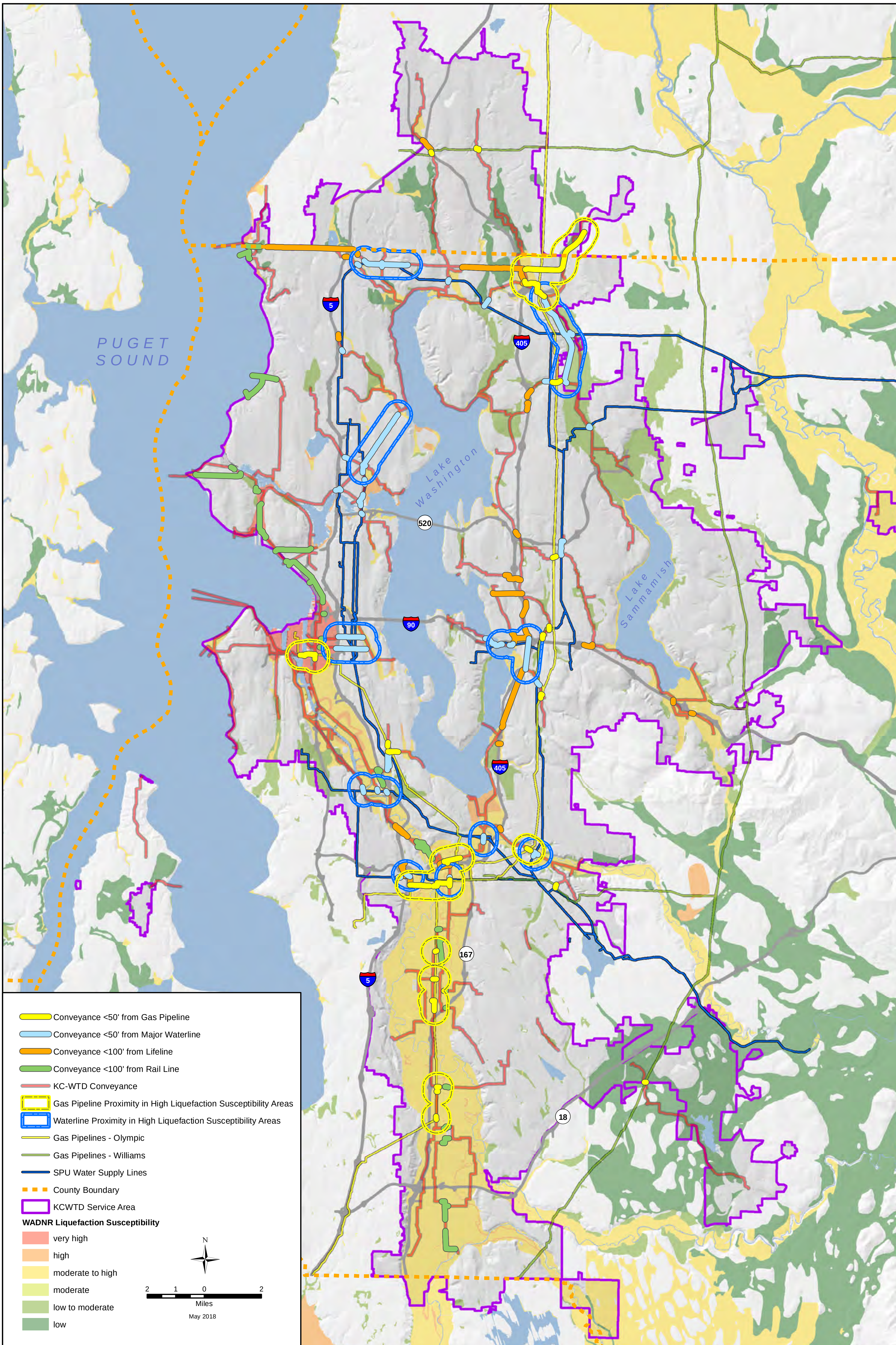
No.	Level	Color
1	Low	
2	Low-Moderate	
3	Moderate	
4	Moderate-High	
5	High	

Facility Evaluation Key

Structural/ Architectural	Liquefaction
Mechanical\ Electrical\ Plumbing	Overall

Facility Vulnerability Summary

Cascadia M9.0



King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

File Name: Q:\WTD\Projects\Seismic\Projects\TM600\Vol1_1E_FailureConsequence.mxd oneilsh

KCWTD Conveyance System
Consequence of Failure

Volume 2: Task 200 Background Documentation

Note: The material for Attachment Volume 2 for the Task 200 (Seismic) Technical Memorandum is provided as an electronic file to King County's Project Management Division

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Appendix B. Task 200 Facility Resiliency Review (Flooding/Tsunami, Landslide, Extreme Weather) Technical Memorandum

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Task 200 Facility Resiliency Review (Flooding/Tsunami, Landslide, Extreme Weather) Technical Memorandum

April 2018

Prepared by

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King County

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Alternate Formats Available

Call 206-477-5371 or TTY: 711

List of Acronyms

BWTP	Brightwater Treatment Plant
CoF	Consequence of Failure
CRS	Criticality Ranking Score
CSO	Combined Sewer Overflow
County	King County
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
LOS	Level of Service
PoF	Probability of Failure
POR	Period of Record
NOAA	National Oceanic and Atmospheric Association
SCADA	Supervisory Control and Data Acquisition
STP	South Treatment Plant
VS	Vulnerability Score
WDNR	Washington Department of Natural Resources
WPTP	West Point Treatment Plant
WTD	Wastewater Treatment Division
WWTP	Wastewater Treatment Plant

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Executive Summary

The King County Wastewater Treatment Division (WTD) proactively addresses risks associated with natural and manmade disasters through both preparedness and mitigation activities. Along these lines, WTD held a study to evaluate natural disaster hazards and assess probable impacts to the agency's critical facility components and service capabilities. This study used desktop assessments to determine the highest risk facilities (based on vulnerability and consequence of failure determinations) to prepare initial risk ratings and develop mitigation concepts. The high-level hazards evaluation provides additional boundaries for recovery planning and expectations with respect to anticipated loss.

This technical memorandum describes the evaluation process undertaken in Task 200, Facility Resiliency Review. This technical memorandum addresses risks associated with flooding, tsunami, landslide, and extreme weather.

Criticality factors that contributed to the risk determinations were defined and prioritized in the scope of work for this study. These factors, in order of priority, are as follows:

1. Life Safety – related to potential for loss of life as a result of hazard occurrence; generally associated with occupied buildings.
2. Public Health – related to potential for human contact with raw sewage.
3. Consequent Damage – related to potential failure impacts on adjacent critical infrastructure.
4. Environmental Impact – discharge of untreated or inadequately treated wastewater. Environmental impacts were prioritized based on the following discharge locations into a 1) ditch or stream, 2) river flowing into a lake, 3) lake, 4) river flowing into Puget Sound, or 5) Puget Sound. Of the major waterbodies (lakes and salt water), risk priorities from highest to lowest were given to Lake Sammamish, Lake Washington, Elliott Bay and Puget Sound.

King County WTD serves approximately 1.5 million people with a system comprising the following assets: 3 large wastewater treatment plants (WWTPs), 2 small WWTPs, 1 community septic system, 4 combined sewer overflow (CSO) treatment facilities, 25 regulator stations, 47 pump stations, 39 CSO outfalls, and almost 400 miles of wastewater pipelines. Facilities were assessed employing a desktop evaluation using available information such as geographic information system (GIS) shapefiles, published maps, published reports, and other information provided by WTD staff. The highest-risk facilities for each hazard were selected in collaborative workshops with WTD staff.

Flooding hazards are limited to those facilities that are vulnerable to riverine flooding (i.e., within or near a floodplain) or facilities that could flood due to mechanical failure. Pump stations can flood if floodwaters rise above the pump station flood design level. Water can come in through the doors or backup through the pump station drain system or ventilation system if they were improperly designed. If pipelines inside the pump station break they can discharge sewage into the drywell (such as during an earthquake). Wet Weather Treatment Plant galleries/utility doors can flood catastrophically due to large influent flows coupled with pump failures and control system failure. They can also flood due to mechanical failure if pipelines in the galleries fail and discharge into the galleries. There is the potential of draining the contents of tanks into the gallery system because of a mechanical failure, pipe breaks, or tank wall damage. In some cases, the plants are susceptible to riverine flooding due to proximity to known floodplains.

The tsunami risks are associated with the Seattle fault seismic event and are limited to facilities along Puget Sound. A risk score was assigned for each of the reviewed facilities, with tsunamis and flooding considered together. The highest risk facilities (as a group, not in ranked order) are identified below:

- Interurban Pump Station Flooding Risk

- York Pump Station Flooding Risk
- Matthews Park Pump Station Flooding Risk
- Murray Pump Station Flooding Risk
- 53rd Avenue Pump Station Flooding Risk
- 63rd Avenue Pump Station Flooding Risk
- Bellevue Pump Station Flooding Risk
- Woodinville Pump Station Flooding Risk
- South Treatment Plant Flooding Risk (mechanical failure)

Note: Riverine flooding drives the risk for all facilities except South Treatment Plant, which was selected due to potential for flooding in the event of mechanical failure. Flooding from overtopping or failure of the Howard Hansen Dam (Green River Flood Response Plan, 2009) was not considered in the analysis, because it was outside of this project.

While there are numerous areas prone to landslides throughout the service area, only 12 facilities were identified as being located in a potentially landslide-susceptible area or with access to the facility through a potentially landslide-susceptible area. Of these facilities, landslide potential was specifically addressed and mitigated or likely addressed and mitigated (based on the age of the facility) at 8 of the 12 identified facilities. Once the relative criticality of the remaining four facilities are considered, only the South Mercer pump is identified with a moderate-to-high risk rating. Note that the West Point Treatment Plant was not given a landslide hazard rating based on the extensive landslide mitigation measures that have been implemented at that site and active monitoring of those mitigation measures. The landslide risk rating at the other three facilities is either moderate or low-to-moderate.

Although the occurrence of severe storms or extreme winter weather is rather rare in the WTD service area, the consequences of such events is rather high. Risk ratings were developed for the 82 facilities/ locations within this study, which yielded an understanding of the highest relative risk ranking for 7 facilities/locations. These most at-risk facilities/locations include in order of risk, starting with the highest:

- West Point Treatment Plant
- South Treatment Plant
- Alki CSO Plant
- Matthews Park Pump Station
- Carkeek CSO Plant
- Boeing Chiller
- Brightwater Treatment Plant

1 Introduction

The purpose of this project is to provide services to assist King County (County) in developing a comprehensive strategy for preparing the *King County Wastewater Treatment Division's (WTD) Recommendations to Enhance the Resiliency and Recovery of King County's Regional Wastewater Treatment Facilities* project for the impacts of a natural disaster. Earlier tasks identified vulnerabilities in WTD's collection and treatment systems from earthquake-related damage and identified mitigation actions that can be taken before and after an earthquake to reduce impacts on the system. Task 200 extends the analysis to the additional hazards of flooding, tsunamis, landslides, and extreme weather, which are referred to as the amendment hazards. The outcome of this analysis is to produce opportunities for system improvement to increase resiliency. As a result of this analysis, recommendations are made under Tasks 400, 500, and 600 of this project for remediation and resiliency strategies for the benefit of ratepayers, system partners, employees, and residents. Figure 1 shows the workplan sequence.

Figure 1. Resiliency Project Workplan and Sequence

*Note: Task 100 is Project Management, and Task 300 is a related, but separate Digester Inspection effort that will be completed after the West Point Treatment Plant digesters are accessible for inspection (tentatively Spring 2018) with its own Final Report providing recommendations for improvements specific to the digesters.

This technical memorandum focuses on the desktop analysis and findings for the amendment hazards. The results presented herein have been presented in workshop environments with WTD staff for vetting and to facilitate the development of mitigation strategies. High level cost estimates and specific mitigation strategies have been developed under Task 400 of this project and are covered in a separate technical memorandum.

Flooding and Tsunami

A desktop analysis was conducted for all facilities to determine the risk associated with flooding, tsunamis, and mechanical failure. Available information, such as facility location and elevation, was compared to the floodplain and tsunami limits and a risk score was associated with each one. Flooding risks are associated with riverine flooding or flooding due to mechanical failure. Tsunamis are associated with the Seattle fault earthquake event (7.3 magnitude, 1/2,500-year return period). Tsunami risk for a Cascadia subduction zone earthquake event was not considered, because that earthquake event is unlikely to cause a tsunami in the study area. The facilities associated with the tsunami risk are limited to those along Puget Sound. Flooding due to mechanical failure relied on assumptions based on facility type (discussed more in subsequent sections) and excluded West Point Treatment Plant due to recent assessment studies at that facility.

Landslide

Similarly, a desktop analysis was conducted for all facilities and pipelines to determine the risk associated with landslide events. Facilities were reviewed to determine if they were in an area potentially susceptible to landslides or if access to the facility was through a landslide-susceptible area. The risk assessment focused on the geographic locations of the facilities and their relation to an area identified as a potential landslide area, and were not associated with either a specific seismic or flooding event.

Extreme Weather

A process was developed to be able to analyze vulnerabilities to severe weather (wind, tornadoes, etc.) and extreme winter weather. The geographic location of each facility, as well as the historic record of weather events, was used in this analysis to determine if a given facility might be susceptible to severe weather. Available climatological data and a virtual field inspection using Google Earth satellite and street level imagery were the primary tools in this analysis.

1.1 Project Background

King County WTD protects water quality and public health in the central Puget Sound region by providing high quality and effective treatment to wastewater collected from local wastewater agencies. WTD serves about 1.5 million people within a 415-square-mile service area, which includes most urban areas of King County and parts of south Snohomish County and northeast Pierce County.

The County's wastewater system includes the following assets:

- Three large regional wastewater treatment plants (West Point Treatment Plant (WPTP) in the City of Seattle, South Treatment Plant (STP) in the City of Renton, and the Brightwater Treatment Plant (BWTP) near the City of Woodinville).
- Two small wastewater treatment plants (one on Vashon Island and one in the City of Carnation).
- One community septic system (Beulah Park and Cove on Vashon Island).
- Four combined sewer overflow (CSO) treatment facilities (Alki, Carkeek, Mercer/Elliott West, and Henderson/Norfolk – all in the City of Seattle). These include four outfalls in addition to the thirty-nine CSO outfalls called out below.
- Almost 400 miles of wastewater pipelines.
- Twenty-five regulator stations.
- Forty-seven pump stations.
- Thirty-nine CSO outfalls.

- A regional Supervisory Control and Data Acquisition (SCADA) system, providing regional and local control of facilities.

This hazard resiliency desktop analysis was limited to the 82 facilities listed from 1 to 7 above for flooding, tsunamis, and extreme weather. The landslide analysis also included those 82 facilities, but was extended to include pipelines as well.

On September 11, 2013, King County Executive Dow Constantine launched the “Resilient King County” initiative – a county-wide planning process for crafting a comprehensive long-term strategy for recovery following a major earthquake or other catastrophe. The Resilient King County initiative seeks to establish a framework to assist individuals, families, businesses, and government to recover the community in a manner that sustains our physical, emotional, social, and economic well-being. This vision balances the need for rapid recovery with the care required to meet the vision and value of our communities.

The Executive’s initiative is based on the recognition that WTD, as well as other agencies within the County, needs to fulfill responsibilities to County residents to protect their health and safety during and after a disaster event. The focus of this project is to assess WTD’s ability to survive and respond to disasters in a way that maintains, to the extent possible, its primary goal of protecting the public from the negative impacts of uncontained and untreated wastewater. The benefits to be realized from implementation of WTD’s *Recommendations to Enhance the Resiliency and Recovery of King County’s Regional Wastewater Treatment Facilities* project suggestions are intended to include the following:

- Minimization of injury or loss of life among WTD staff during a natural hazard event and in the response and recovery phases by improving the resilience of WTD facilities
- Minimization of public health risks following a disaster by improvement in facility resilience and more rapid resumption of conveyance and treatment operations
- Reduction in the expected cost of recovery by, where possible, mitigating identified weaknesses in the system to prevent damage before an earthquake occurs
- Improved ability to accomplish post-hazard rebuilding and to expeditiously restore the system through consideration of long-term survivability and resiliency of WTD facilities

1.2 Objective

The purpose of this task is to review relevant and available existing information on the WTD facilities, listed by facility type in Section 1.1, above, and perform a desktop assessment of their risk (vulnerability and consequence of failure) from natural hazards identified for Amendment #1 of this project. Through strategic evaluation of the risks, to the wastewater system posed by these findings, a prioritized list of opportunities for capital improvement projects will be developed.

2 Desktop Assessment Approach

Desktop assessments were performed for WTD's 82 facilities by Aqualyze (flooding and tsunami), Shannon and Wilson (landslide), and HDR (extreme weather), as categorized below:

- Pump Stations (47 Total)
- Regulator Stations (25 Total)
- Combined Wastewater Overflow Treatment Facilities (4 Total)
- Community Septic System (1 Total)
- Regional Wastewater Treatment Plants (3 Total)
- Small Wastewater Treatment Plants (2 Total)

2.1 Overall Approach

Figure 2 provides a flowchart overview of the steps and methodology applied to execute the desktop assessment task. These steps include collecting previously published information and relevant data, identifying and mapping the facilities to be evaluated, and identifying and mapping available GIS information relevant to each of the key additional hazards. These hazards included rain flooding from rivers and creeks, flooding due to mechanical failure, flooding from tsunami, landslides, and extreme weather. The next steps were to use this information to develop a desktop assessment methodology to estimate and rank facility vulnerabilities for each hazard. Finally, using facility criticality information provided by WTD, the facility risks were estimated and used to prioritize the individual facilities for additional assessments.

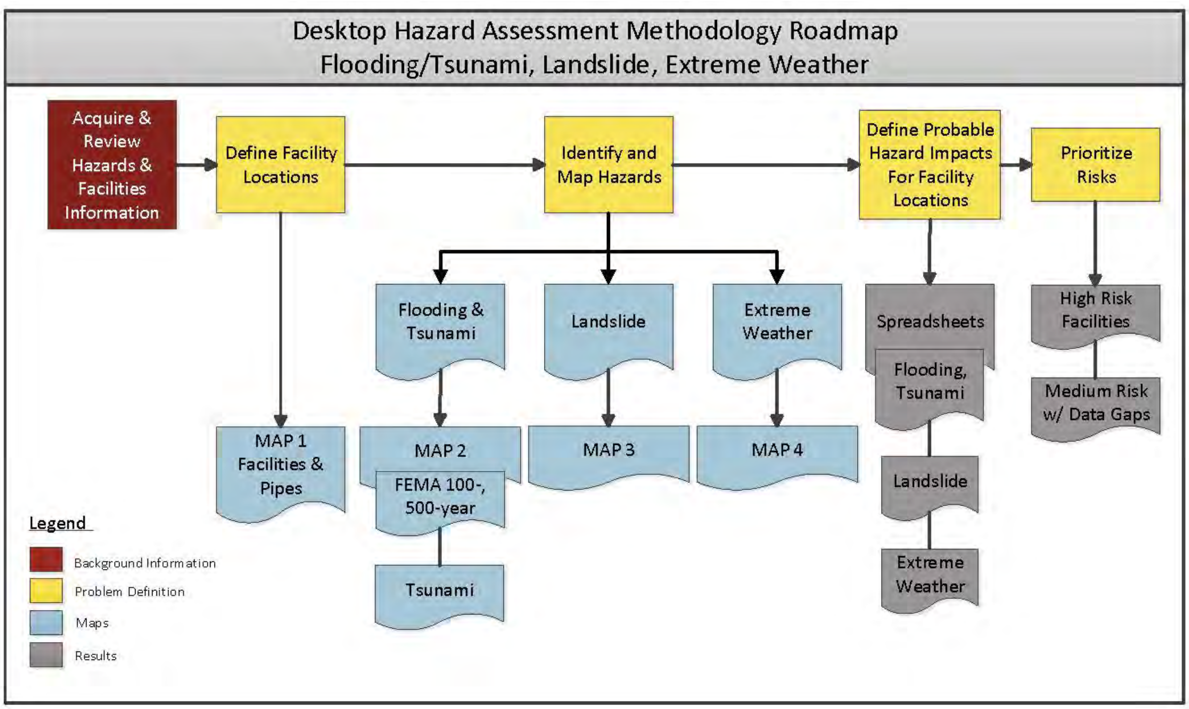

Figure 2. Desktop Assessment Methodology Flowchart

2.1.1 Desktop-Level Assessment Methodology

The desktop assessment of the 82 facilities included data sources such as relevant GIS data from WTD, previously published reports, and additional data from sources outside the County as seen as pertinent. Risk score for each facility was calculated using an established methodology for each hazard area. More details of data collection and computations are included in the following sections.

2.1.2 Data Collection

Data used during desktop assessment included several GIS layers provided by WTD and reports of previous studies for reference. Additional data was researched and obtained from various sources as required. A comprehensive list of data sets used in this assessment is provided below.

GIS

The following GIS data layers were obtained from WTD GIS department and used in the desktop assessment of hazards:

- KC WTD Facility Locations (*KC_Facilities.shp*)
- KC WTD Conveyance System (*KCWTD Conveyance.shp*)
- KC WTD Service Area (*WTD Flow service area.shp*)
- 100-year Floodplain (*KC 100 Year Floodplain.shp*)
- 500-year Floodplain (*KC 500 Year Floodplain.shp*)
- Tsunami Inundation Extents (*WADNR tsunami_inundation.shp*)
- Facility Rim Elevations (*Facility_Elevations_point_20170804.shp*)
- Topographic Contours (*Contours_5ft folder containing 16 sets of shapefiles, not including Seattle*)
- King County River Corridors (data originated by King County)
- Landslide/slope stability geologically critical areas (data originated by King County and other municipalities within the County)

Table 1 summarizes the 82 facilities identified and used in the desktop assessment. This table is arranged by facility type.

Table 1. King County WTD Wastewater System Facilities Used in Desktop Assessment

Facility Name	Address
Pump Stations	
30th Ave Pump Station	4703 30th Ave NE, Seattle, WA 98105
53rd Ave Pump Station	2301 Alki Ave SW, Seattle, WA 98116
63rd Ave Pump Station	3535 Beach Dr SW, Seattle, WA 98116
Barton Pump Station	9005 Fauntleroy Way SW, Seattle, WA 98136
Bellevue Pump Station	595 102nd Ave SE, Bellevue, WA 98004
Belvoir Pump Station	3901 Surber Dr NE, Seattle, WA 98105
Black Diamond Pump Station	32923 Railroad Ave, Black Diamond, WA 98010
Boeing Chiller	1200 Monster Rd SW, Renton, WA 98057
BWTP Influent Pump Station	11711 NE 195th St, Bothell, WA 98106
Bunker Trail 1 Pump Station	Vashon Island, WA 98070
Bunker Trail 2 Pump Station	Vashon Island, WA 98070

Facility Name	Address
Bunker Trail 3 Pump Station	Vashon Island, WA 98070
Bunker Trail 4 Pump Station	Vashon Island, WA 98070
Carkeek Pump Station	1201 NW Carkeek Park Dr, Seattle, WA 98177
Duwamish Pump Station	4501 E Marginal Way S, Seattle, WA 98134
E Marginal Way Pump Station	7319 E Marginal Way S, Seattle, WA 98108
East Pine Pump Station	1600 Lake Wash Blvd, Seattle, WA 98122
Heathfield Pump Station	3541 163rd Ave SE, Bellevue, WA 98008
Hidden Lake Pump Station	16700 10th Ave NW, Shoreline, WA 98177
Hollywood Pump Station	14815 NE 124th St, Redmond, WA 98052
Interbay Pump Station	1601 W Garfield St, Seattle, WA 98119
Interurban Pump Station	13980 Interurban Ave S, Tukwila, WA 98168
Juanita Bay Pump Station	11700 93rd Ave NE, Juanita, WA 98034
Kenmore Pump Station	6719 NE 175th St, Kenmore, WA 98028
Kirkland Pump Station	3rd St and Park Lane, Kirkland, WA 98033
Lake Ballinger Pump Station	2205 N 205th St, Shoreline, WA 98133
Lakeland Hills Pump Station	699 Oravetz Rd, Auburn, WA 98092
Matthews Park Pump Station	9310 Sand Pt Way NE, Seattle, WA 98115
Medina Pump Station	NE 8th St and 81st Ave NE, Medina, WA 98039
Murray Pump Station	7015 Beach Dr SW, Seattle, WA 98136
North Beach Pump Station	9921 Triton Dr NW, Seattle, WA 98117
North Creek Pump Station/Storage	18707 N Creek Pkwy, Bothell, WA 98011
North Mercer Pump Station	7631 SE 22nd St, Mercer Island, WA 98040
Pacific Pump Station	100 Frontage Road N, Pacific, WA 98047
Rainier Pump Station	3761 Rainier Ave S, Seattle, WA 98144
Richmond Pump Station	20001 Richmond Beach Dr NW, Shoreline, WA 98177
S Henderson Pump Station	5327 S Henderson St, Seattle, WA 98118
S Mercer Pump Station	E Mercer Way and SE 72nd St, Mercer Island, WA 98040
STP Effluent Pump Station	1200 Monster Rd SW, Renton, WA 98057
Sunset Pump Station	3730 W Lake Sammamish Pkwy SE, Bellevue, WA 98027
Sweyolocken Pump Station	3100 Bellevue Way SE, Bellevue, WA 98004
W Marginal Pump Station	7119 W Marginal Way SW, Seattle, WA 98106
W Seattle Pump Station	3051 Harbor Ave SW, Seattle, WA 98126
Wilburton Pump Station	SE 10th St and 121 St Ave, Bellevue, WA 98005
Woodinville Pump Station	12900 Woodinville-Duvall Rd, Woodinville, WA 98072
Yarrow Bay Pump Station	4400 Lake Washington Blvd NE, Kirkland, WA 98033
York Pump Station	14120 NE 124th St, Redmond, WA 98034
Regulator Stations	
8th Ave Regulator Station	760 S Portland St, Seattle, WA 98108
Allentown Regulator Station	Airport Way S and S Norfolk St, Seattle, WA 98108
Ballard Regulator Station	5110 Shilshole Ave NW, Seattle, WA 98107
Boeing Creek Regulator Station	17229 3rd Ave NW, Shoreline, WA 98177
Brandon Regulator Station	5241 E Marginal Way S, Seattle, WA 98134

Facility Name	Address
Chelan Regulator Station	3455 Chelan Ave SW, Seattle, WA 98106
Connecticut Regulator Station	1199 Alaskan Way S, Seattle, WA 98134
Denny Regulator Station	3165 Alaskan Way, Seattle, WA 98121
Dexter Regulator Station	1419 Dexter Ave N, Seattle, WA 98109
Hanford Regulator Station	2999 E Marginal Way S, Seattle, WA 98134
Harbor Regulator Station	3432 Harbor Ave SW, Seattle, WA 98126
King Regulator Station	499 Alaskan Way S, Seattle, WA 98134
Kingdome Regulator Station	1198 Occidental Ave S, Seattle, WA 98134
Lake City Tunnel Regulator Station	708 40th St NE, Seattle, WA 98105
Lake Union Tunnel Regulator Station	Republican St and 8th Ave N, Seattle, WA 98109
Lander Regulator Station	S Lander St and E Marginal Way S, Seattle, WA 98134
Lander2 Regulator Station	S Lander St and Colorado Ave S, Seattle, WA 98134
Logboom Regulator Station	6001 NE Bothell Way, Kenmore, WA 98028
Michigan Regulator Station	159 S Michigan St, Seattle, WA 98108
MLK Tunnel Regulator Station	4207 S Fairbanks St, Seattle, WA 98039
Montlake Regulator Station	2910 Mountlake Blvd E, Seattle, WA 98105
Norfolk Regulator Station	10000 E Marginal Way S, Seattle, WA 98108
University Regulator Station	1901 NE Pacific Place, Seattle, WA 98105
W Michigan Regulator Station	6769 W Marginal Way SW, Seattle, WA 98106
W Seattle Regulator Station	6208 SW Spokane St, Seattle, WA 98116
Septic System	
Beulah Cove Septic System	Vashon Island, WA 98070
Sewage Treatment Plants	
BWTP	Woodinville-Snohomish Rd NE, Woodinville, WA 98072
Carnation Treatment Plant	4405 Larson Ave W, Carnation, WA 98014
STP	1200 Monster Rd SW, Renton, WA 98057
Vashon Treatment Plant	9615 SW 171 St, Vashon Island, WA 98072
WPTP	1400 Discovery Park Blvd, Seattle, WA 98199
Wet Weather Treatment Facilities	
Alki CSO Plant	3380 Beach Dr. SW, Seattle, WA 98116
Carkeek CSO Plant	1201 NW Carkeek Park Dr, Seattle, WA 98177
Mercer/Elliott West CSO Facility	545 Elliott Ave W, Seattle, WA 98119
Henderson/Norfolk CSO Facility	9829 42nd Ave S, Seattle, WA 98039

Figure 3 provides a map of WTD wastewater system facilities that were identified for inclusion in the desktop assessment. Map symbols indicate the different facility types: pump stations; regulator stations; a septic system; sewage treatment plants; and wet weather treatment facilities. The conveyance system is also shown for reference and to show the system connectivity.

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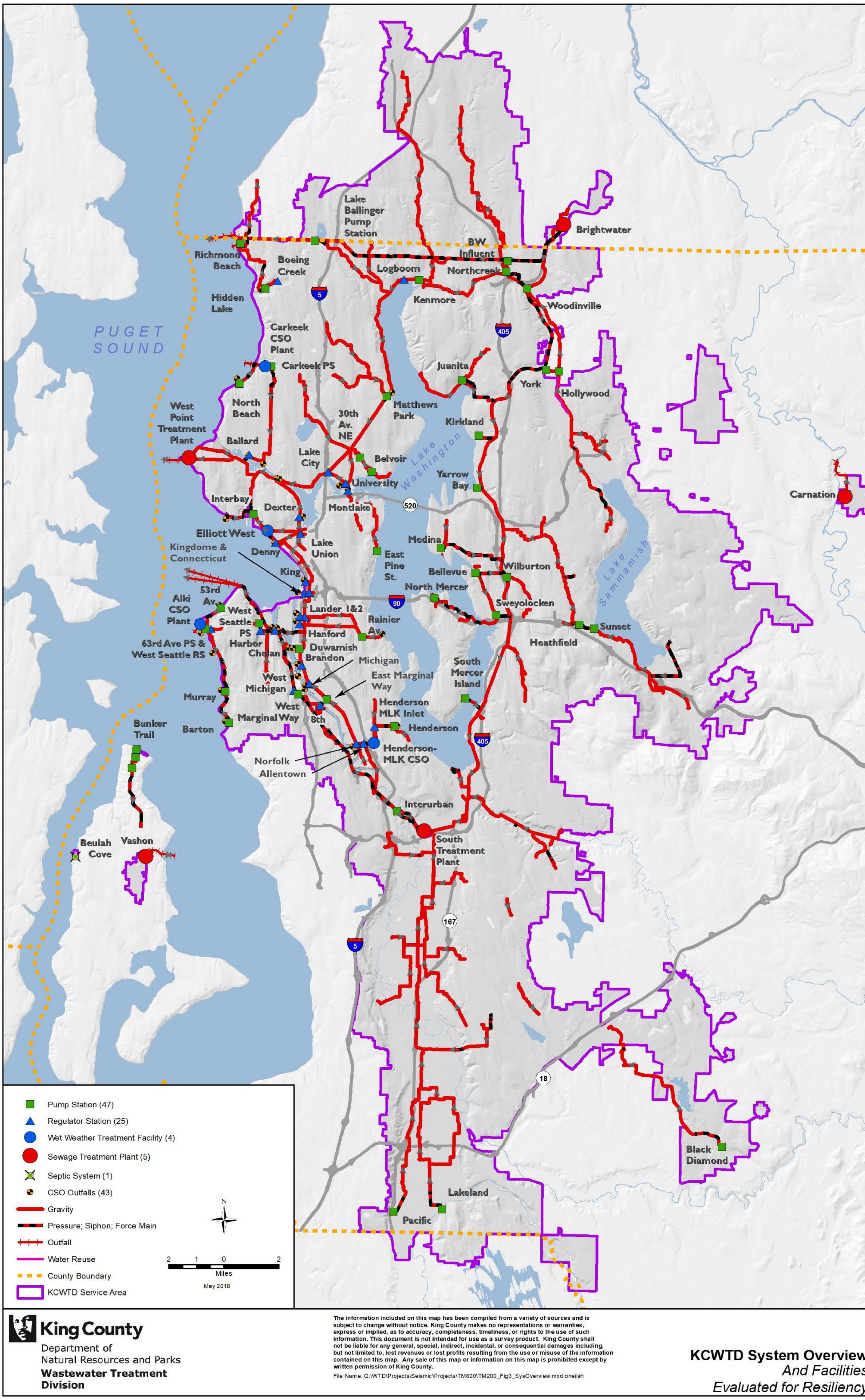

Figure 3. KC WTD Wastewater System Facilities Evaluated for Resiliency

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FEMA Maps

Flood Insurance Rate Maps (FIRM) from the Federal Emergency Management Agency (FEMA) were downloaded for the locations of the following 28 facilities (*source:* https://msc.fema.gov). These facilities were selected based on their proximity to the 100-year and 500-year floodplains. Table 2 lists these facilities.

Table 2. WTD Facilities for which FIRM Obtained

Facility ID	Facility Name
AE*ALKI.STP	Alki CSO Plant
AE*BEACH.53RD	53rd Ave Pump Station
AE*BEACH.63RD	63rd Ave Pump Station
AE*BEACH.BARTON	Barton Pump Station
AE*BEACH.MURRAY	Murray Pump Station
BE*BRIGHTWATER.IPS	BWTP Influent Pump Station
BW*BOEING.HIDDENLK	Hidden Lake Pump Station
CE*CARNATION.STP	Carnation Treatment Plant
CW*CARKEEK.PS	Carkeek Pump Station
CW*CARKEEK.STP	Carkeek CSO Plant
CW*NBEACH.NBEACH	North Beach Pump Station
RE*BELLEVUE.BELLEVUE	Bellevue Pump Station
RE*BLKDIA.BLKDIA	Black Diamond Pump Station
RE*FACTOR.WILBURTON	Wilburton Pump Station
RE*ISSAQ1.SUNSET	Sunset Pump Station
RE*LAKELAND.LAKELAND	Lakeland Hills Pump Station
RE*NORTHCREEK.NORTHCREEK	North Creek Pump Station/Storage
RE*TUKT.INTERURBAN	Interurban Pump Station
RE*YORK.YORK	York Pump Station
VE*BUNKER.BUNKERTRAIL	Bunker Trail 1 Pump Station
VE*VASHON.STP	Vashon Treatment Plant
WE*EBI2.EMARGINAL	E Marginal Way Pump Station
WE*WDUWAM.8TH	8th Ave Regulator Station
WE*WSEATTLE.REG	W Seattle Regulator Station
WW*DENNY.DENNY	Denny Regulator Station
WW*MATTHEWS.MATTHEWS	Matthews Park Pump Station
WW*SAMVAL.HOLLYWOOD	Hollywood Pump Station
WW*SAMVAL.WOODINVIL	Woodinville Pump Station

Note: The FIRM maps were obtained for these facilities due to their proximity to the 100-year and 500-year floodplains.

The following figures provide a visual representation of the flooding and tsunami concerns in this study.

- Sample FEMA FIRM Map (Figure 4)
- Floodplain extents for 100-year and 500-year recurrence intervals: (Figure 5)
- Seattle Fault tsunami inundation extents. (Figure 6)

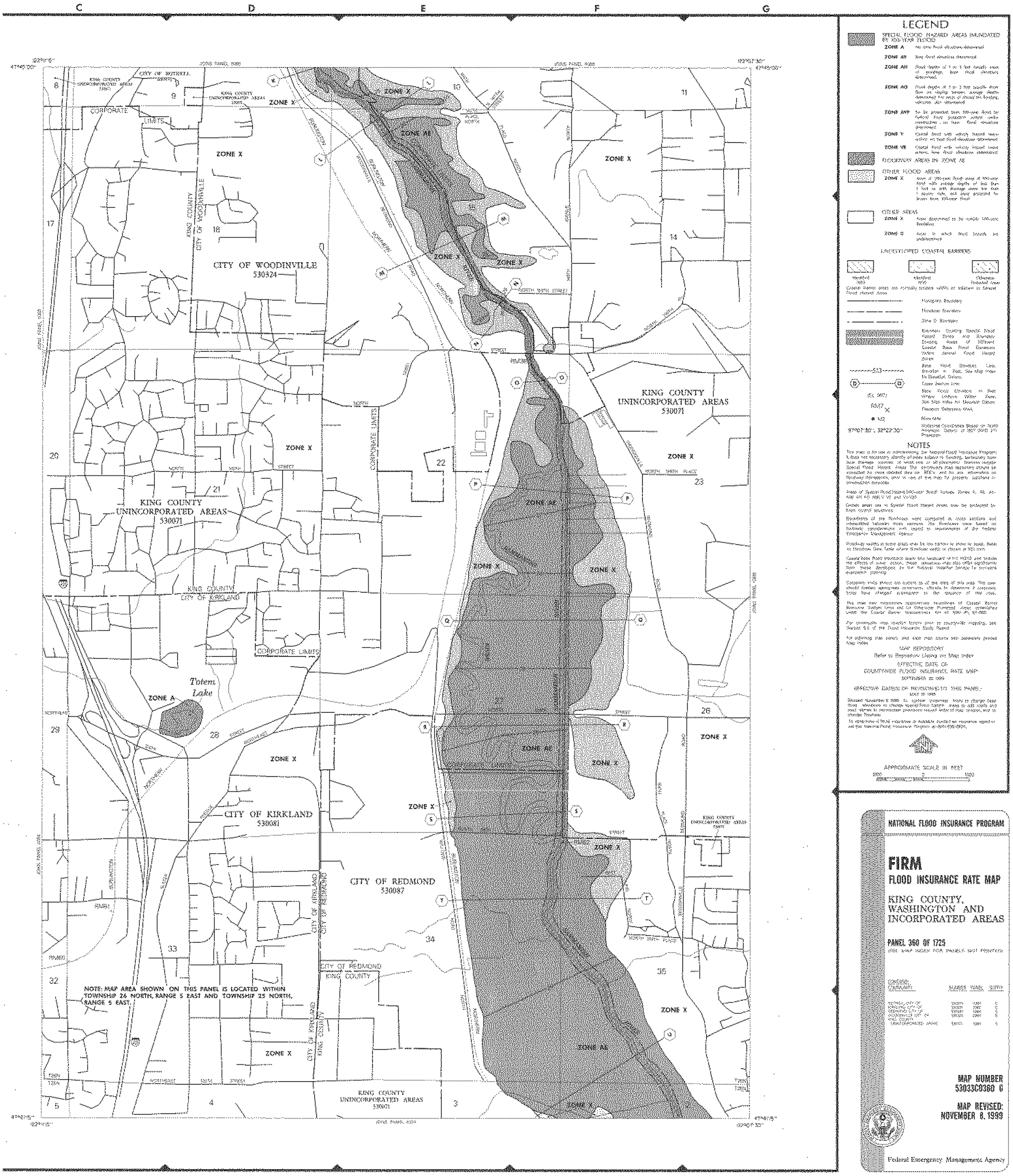

Figure 4. Sample FEMA FIRM Map (*Hollywood and York Pump Station Locations*)

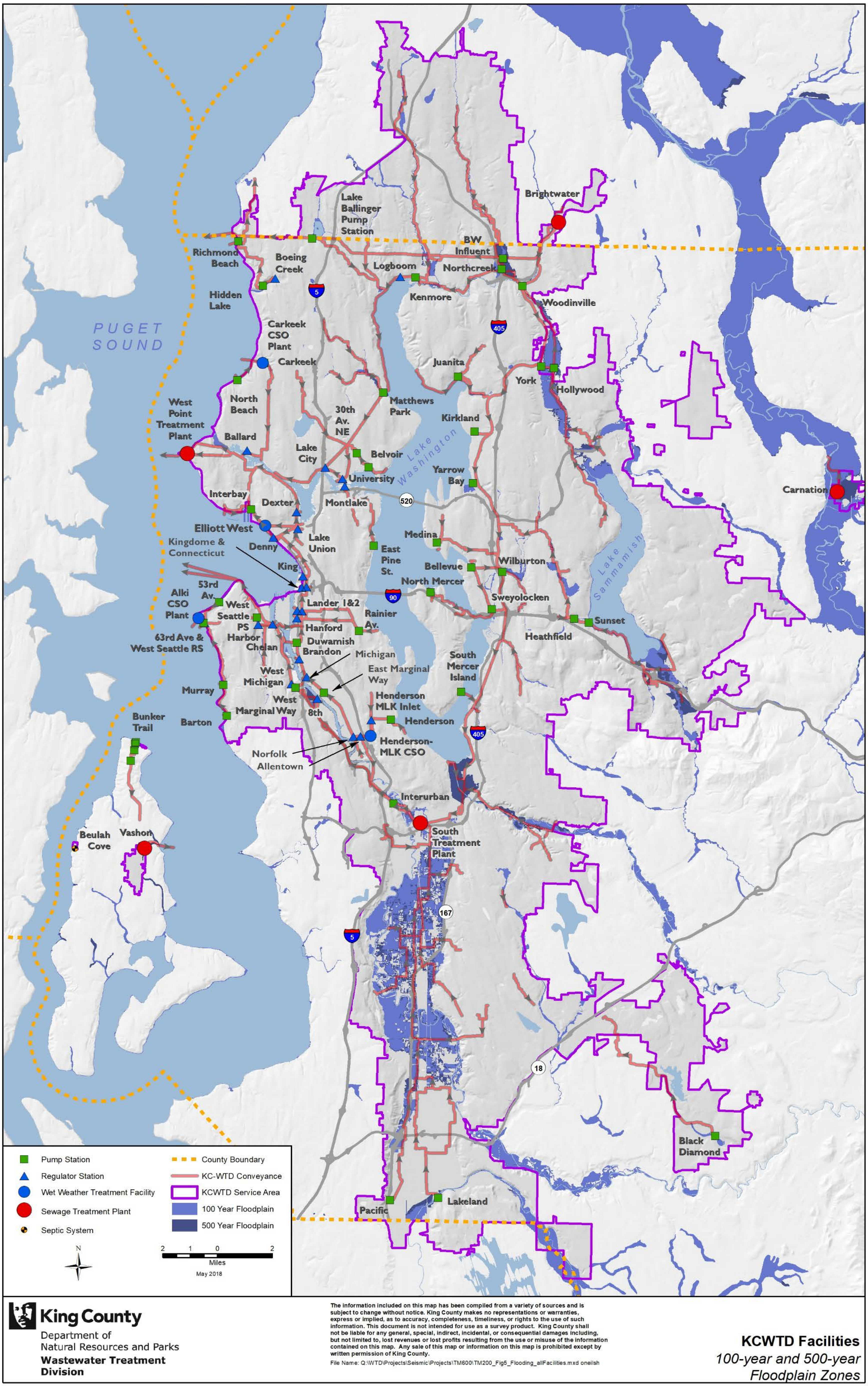

Figure 5. 100- and 500-year Flood Plain Extents

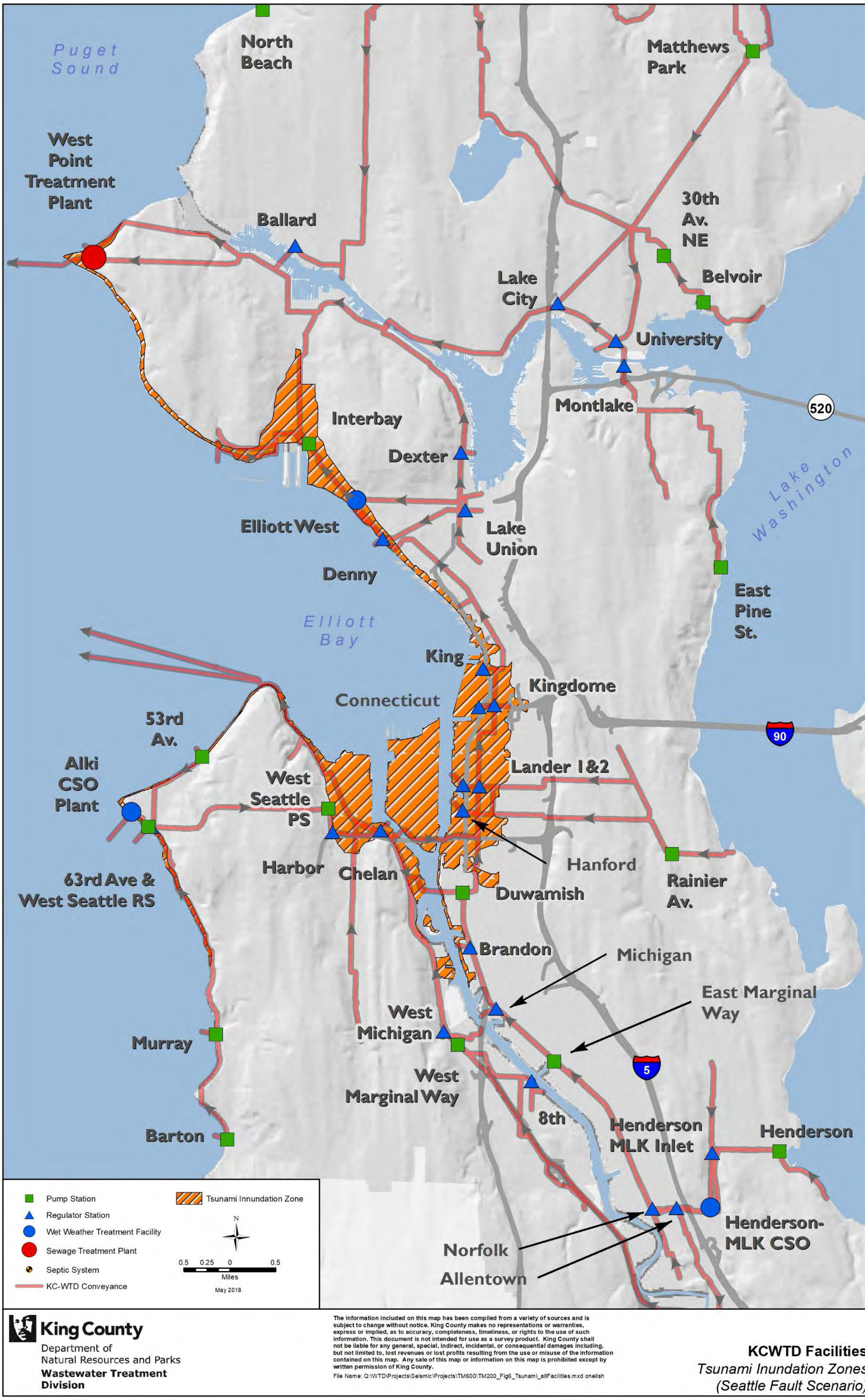

Figure 6. Tsunami Inundation Extents (Seattle Fault Scenario)

EXTREME WEATHER

The National Oceanic and Atmospheric Association (NOAA) Storm Prediction Center maintains a complete archive of all reported cases of severe weather and winter storm information specific to a given region. HDR used this database to derive a historic accounting of all severe weather types that have occurred within the County during the period of record (POR) 1950–2017. Table 3 is an accounting of these events. Figure 7 shows the occurrence of extreme weather events in the region.

Table 3. NOAA Severe Report Summary

Severe Report Type	King County POR[1] Total Reports
Avalanche	20
Blizzard	1
Coastal Flood	1
Debris Flow	4
Excessive Heat	2
Flash Flood	1
Flood	6
Funnel Cloud	11
Hail	4
Heat	1
Heavy Rain	17
Heavy Snow	98
High Wind	20
Ice Storm	2
Landslide	9
Lightning	22
Strong Wind	26
Thunderstorm Wind	7
Tornado	5
Winter Storm	2
Winter Weather	4

[1] POR = Period of Record

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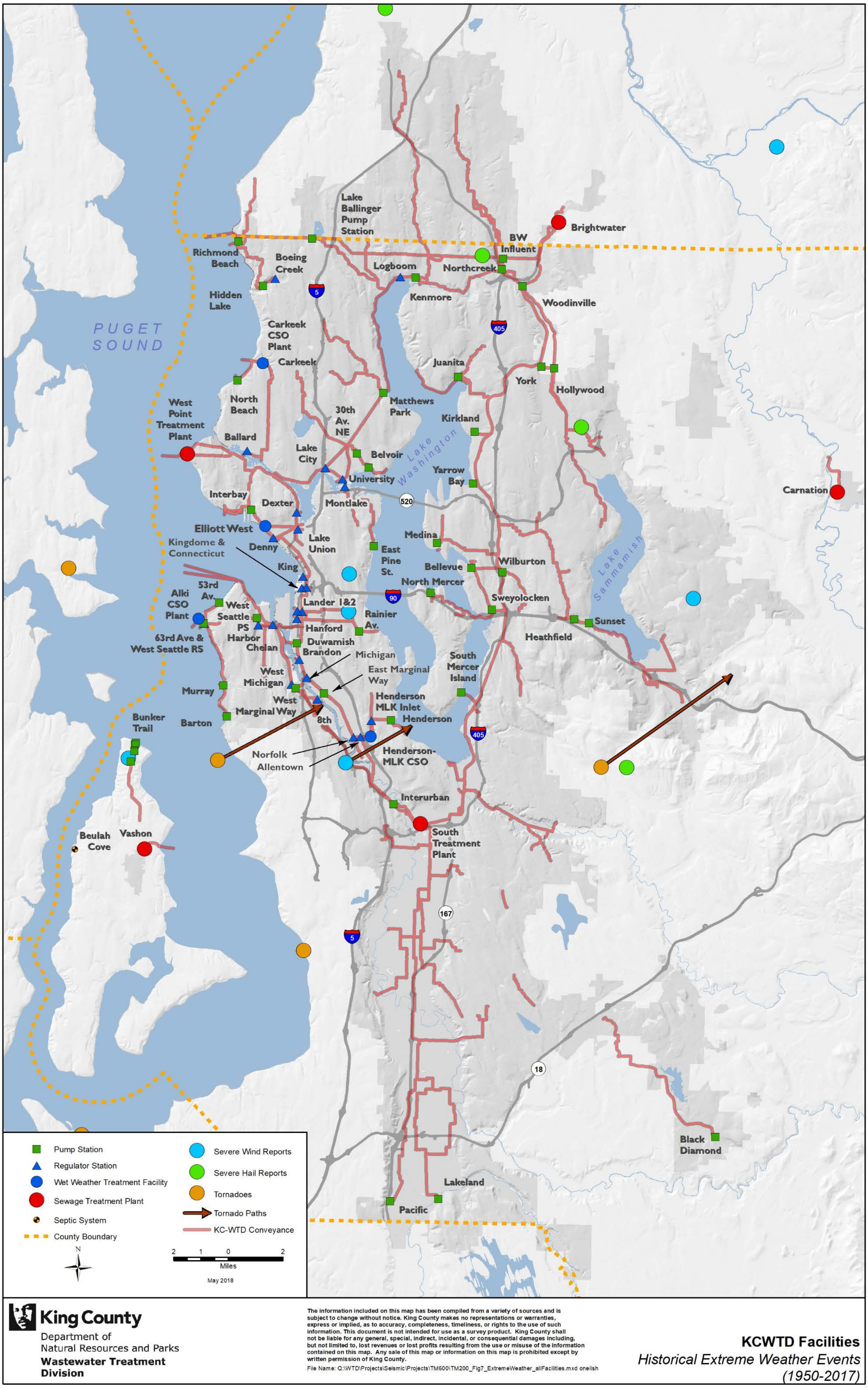

Figure 7. Distribution of Extreme Weather Events 1950–2017

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Other Published Reference Materials

Additional published materials, such as reports and maps, were used for reference during the desktop assessment of the hazards identified in this technical memorandum. A list of these materials is provided below:

- *King County Regional Hazard Mitigation Plan Update, Volume 1: Planning-Area-Wide Elements, Final Draft*, November 2014, Prepared by Tetra Tech for the King County Office of Emergency Management.
- *Vulnerability of Wastewater Facilities to River Flooding*, King County Division of Natural Resources and Parks, Wastewater Treatment Division, July 2014.
- *Tsunamis and Seiches - Seattle Hazard Identification and Vulnerability Analysis*, Seattle Office of Emergency Management.
- Tsunami Hazard Map of the Elliott Bay Area, Seattle, Washington: Modeled Tsunami Inundation from a Seattle Fault Earthquake, Washington State Department of Natural Resources and NOAA Time Center, 2003.
- Mapping of Potential Landslide Hazards along the River Corridors of King County, Washington. Prepared by River and Floodplain Management Section, Water and Land Resources Division, Department of Natural Resources and Parks. Seattle, WA. August, 2016.
- Landslide/slope stability maps for geologically critical areas for King County and other municipalities in the service area.
- Landslide hazard GIS data from Washington State Division of Geology and Earth Resources (WDNR), 2017, Geologic information portal: Available: http://www.dnr.wa.gov/geologyportal

2.2 Risk Assessment Methodology

An overall risk score was computed to prioritize the most critical facilities for the development of conceptual resiliency solutions. The Vulnerability Score (VS) was first computed, and is described in more detail for each hazard later in this technical memorandum. The VS was categorized into five ratings in accordance with the score ranges as identified on Table 4.

Table 4. Vulnerability Ratings

Vulnerability Score (VS)	VS Rating
1	Low
2	Low-Moderate
3	Moderate
4	Moderate-High
5	High

The WTD facilities were given criticality rankings based on a criticality rating rubric developed by the County that considers several key factors. To determine the total criticality ranking score (CRS) for each facility, WTD staff used individual ranks determined for the following parameters:

- Peak Capacity
- Storage Time
- Overflow Location
- Public Impact

- Service to Other Facilities
- Flexibility

The total criticality ranking score was then computed by WTD as the sum of individual rankings. Note that these rankings were computed for a total of 66 facilities. The criticality ranking scores for the remaining facilities were assigned by the consultant team based on facility type and discussions with WTD staff. Table 5 summarizes the criticality ranking scores.

The criticality ranking scores for the County facilities range from 0 (lowest possible criticality ranking score) to 33 (highest possible criticality ranking score). The higher the criticality ranking score for a facility, the higher the potential impact to affect the County wastewater treatment system.

Table 5. WTD Facilities Criticality Ranking Score (CRS)

Facility Name	Peak Capacity (MGD)	Rankings						Total Criticality Ranking Score
		Peak Capacity	Storage Time	Overflow Location	Public Impact	Service to Other Facilities	Flexibility	
Matthews Park Pump Station	–	13	5	2	3	1	2	26
Murray Pump Station	17.2	11	9	1	1	1	2	25
Duwamish Pump Station	—	13	4	3	2	1	2	25
Interurban Pump Station	28.9	9	5	3	3	1	2	23
York Pump Station	68	11	5	4	2	1	0	23
Interbay Pump Station	133	13	5	1	1	1	2	23
30th Ave Pump Station	6.05	7	9	2	2	1	2	23
63rd Ave Pump Station	16.9	11	7	1	1	1	2	23
E Marginal Way Pump Station	23.05	9	5	3	2	1	2	22
Sweyolocken Pump Station	31	9	5	2	2	1	2	21
Heathfield Pump Station	15	7	5	2	3	1	2	20
S Henderson Pump Station	21.9	9	5	2	2	0	2	20
W Marginal Pump Station	7.95	7	5	3	2	1	2	20
Bellevue Pump Station	13.6	7	5	3	2	0	2	19
Woodinville Pump Station	26.7	7	4	3	2	1	2	19
53rd Ave Pump Station	8.5	7	7	1	2	0	2	19
Kenmore Pump Station	14.9	7	5	3	3	1	0	19
Rainier Pump Station	9.1	7	5	2	3	0	2	19
North Creek Pump Station/Storage	23	9	2	4	3	0	0	18
Barton Pump Station	23	7	7	1	1	0	2	18
Belvoir Pump Station	5	5	7	2	2	0	2	18
Richmond Pump Station	4.9	5	7	1	2	1	2	18
Juanita Bay Pump Station	30.6	9	3	2	1	0	2	17
S Mercer Pump Station	11.6	7	5	2	1	0	2	17
Lake Ballinger Pump Station	8.4	5	5	3	2	0	2	17

Facility Name	Peak Capacity (MGD)	Rankings						Total Criticality Ranking Score
		Peak Capacity	Storage Time	Overflow Location	Public Impact	Service to Other Facilities	Flexibility	
North Beach Pump Station	4.8	3	9	1	2	0	2	17
Sunset Pump Station	15	7	2	2	3	0	2	16
East Pine Pump Station	3.75	3	7	2	2	0	2	16
Kirkland Pump Station	7.7	5	4	2	2	0	2	15
Medina Pump Station	6.55	5	5	2	1	0	2	15
North Mercer Pump Station	6	5	4	2	2	0	2	15
Pacific Pump Station	3.5	3	4	3	3	0	2	15
Wilburton Pump Station	5.1	3	5	3	2	0	2	15
W Seattle Pump Station	–	9	1	1	1	1	2	15
Yarrow Bay Pump Station	3.4	3	5	2	2	0	2	14
Lakeland Hills Pump Station	5.1	3	2	4	3	0	2	14
Black Diamond Pump Station	1.5	1	5	4	2	0	2	14
Carkeek Pump Station	4.6	5	3	1	1	1	0	11
Carnation Treatment Plant	1.3	1	1	4	2	0	2	10
Hidden Lake Pump Station	1.7	3	3	1	1	0	2	10
8th Ave Regulator Station	–	–	–	3	2	0	2	7
Brandon Regulator Station	–	–	–	3	2	0	2	7
Logboom Regulator Station	–	–	–	3	3	1	0	7
Michigan Regulator Station	–	–	–	3	2	0	2	7
University Regulator Station	–	–	–	2	2	1	2	7
Vashon Treatment Plant	1.4	1	1	1	1	0	2	6
Ballard Regulator Station	–	–	–	2	2	0	2	6
Chelan Regulator Station	–	–	–	3	1	0	2	6
Dexter Regulator Station	–	–	–	2	2	0	2	6
Harbor Regulator Station	–	–	–	3	1	0	2	6
Lake City Tunnel Regulator Station	–	–	–	2	2	0	2	6
Montlake Regulator Station	–	–	–	2	2	0	2	6
Norfolk Regulator Station	–	–	–	3	2	1	0	6
W Michigan Regulator Station	–	–	–	2	2	0	2	6
Hanford Regulator Station	–	–	–	2	1	0	2	5
Lander Regulator Station	–	–	–	2	1	0	2	5
King Regulator Station	–	–	–	1	1	0	2	4
Denny Regulator Station	–	–	–	1	1	0	2	4
Kingdome Regulator Station	–	–	–	1	1	0	2	4
BWTP Influent Pump Station	110	13	4	4	3	1	0	25

Facility Name	Peak Capacity (MGD)	Rankings: Peak Capacity	Storage Time	Overflow Location	Public Impact	Service to Other Facilities	Flexibility	Total Criticality Ranking Score
Bunker Trail 2 Pump Station	0.9	1	1	4	3	1	2	12
Bunker Trail 3 Pump Station	0.9	1	1	4	3	1	2	12
Bunker Trail 4 Pump Station	0.9	1	1	4	3	1	2	12
Beulah Cove Septic System	0.9	1	1	4	3	0	2	11
Bunker Trail 1 Pump Station	0.9	1	1	4	3	0	2	11
Hollywood Pump Station	13.5	7	2	0	0	0	2	11
Boeing Chiller[1]	–	–	–	–	–	–	–	11
STP Effluent Pump Station[1]	–	–	–	–	–	–	–	20
Allentown Regulator Station[1]	–	–	–	–	–	–	–	7
Boeing Creek Regulator Station[1]	–	–	–	–	–	–	–	4
Connecticut Regulator Station[1]	–	–	–	–	–	–	–	4
Lake Union Tunnel Regulator Station[1]	–	–	–	–	–	–	–	6
Lander2 Regulator Station[1]	–	–	–	–	–	–	–	4
MLK Tunnel Regulator Station[1]	–	–	–	–	–	–	–	6
W Seattle Regulator Station[1]	–	–	–	–	–	–	–	4
BWTP[1]	–	–	–	–	–	–	–	24
STP[1]	–	–	–	–	–	–	–	25
WPTP[1]	–	–	–	–	–	–	–	26
Alki CSO Plant[1]	–	–	–	–	–	–	–	20
Carkeek CSO Plant[1]	–	–	–	–	–	–	–	20
Mercer/Elliott West CSO Facility[1]	–	–	–	–	–	–	–	20
Henderson/Norfolk CSO Facility[1]	–	–	–	–	–	–	–	20

[1] CRS determined from facility type and through discussions with WTD staff
Note: "–" denotes information that was not provided in original CRS table received from WTD and was unknown at the time of this analysis.

The risk score was used as a tool to prioritize facilities where risk is a function of the probability of failure (PoF) and the consequence of that failure (CoF). The PoF is a function of the likelihood of occurrence of a given hazard and the vulnerability of the facility in terms of potential loss of function. The CoF is related to the criticality rating of each facility as determined by its Criticality Ranking Score (Table 4). The Risk determination was computed as the product of PoF and CoF, as shown in Figure 8.

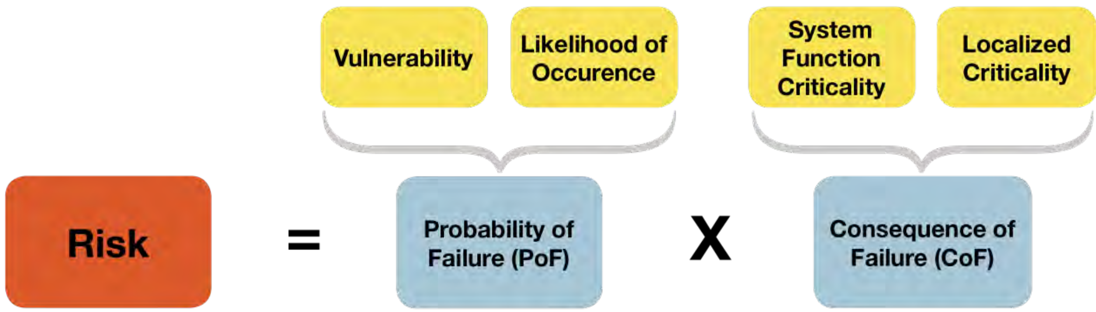

Figure 8. Components of Risk Determination where: *Risk Score = PoF x CoF …(1)*

While WTD has not yet defined and adopted system performance or level of service (LOS) goals, the 2013 *Oregon Resilience Plan* goals were used to relate risk categories and wastewater system function to provide guidance on goals for restoring WTD functions following a significant event. As part of this planning effort, the team reached out to four major water and wastewater utilities on the West Coast; three of the four are currently using guidance similar to the *Oregon Resilience Plan* LOS goals as they consider updates more specific to their systems. The fourth is not yet considering post-disaster LOS standards.

The PoF value was determined for each hazard in a slightly different way, as described in the following sections.

2.2.1 Flooding and Tsunami

This section covers riverine flooding, flooding due to tsunamis, and flooding due to mechanical failure. To determine the vulnerability of a wastewater facility due to riverine flooding and flooding due to tsunami, certain assumptions were made as summarized below:

- The critical flooding elevation of a wastewater facility is the finished floor or rim elevation.
- The majority of the critical equipment is underground (for example, pump motors are in an underground pit).
- If the flood elevation exceeds the critical elevation, the facility is rendered vulnerable.
- Rim elevations derived by WTD GIS staff using LIDAR data were accurate enough for this desktop assessment.

GIS overlays were created to determine which facility lies within 250 feet of the 100-year and 500-year floodplain as shown in Figure 4. The floodplain coverage was extended to 250 feet beyond the floodplain to compensate for old, incomplete, or imprecise data (King County Vulnerability Study 2014). A similar process was followed for the tsunami hazard in that GIS overlays were done to determine if the facility lies within the tsunami zone (Figure 6).

FEMA FIRM maps were used to best estimate the base flood elevations of facilities falling within the flood zones. In the absence of available elevation from the FIRM maps, other sources were used that included mean tide elevation of 8.15 feet NAVD88 for coastal facilities or topographic contours. The difference between the facility's critical elevation and the best estimated base flood elevation was then computed to determine how vulnerable the facility is. The smaller the difference, the more vulnerable the facility is to flooding.

To determine a vulnerability score and assign a vulnerability rating (Table 4) the elevation differences were normalized using the following relationship:

$$Normalized\ (ei) = \frac{(e_i - E_{Min})}{(E_{Max} - E_{Min})} \quad (2)$$

Where:

E_{min} = the minimum value for elevation difference

E_{max} = the maximum value for elevation difference

This categorized each e_i value into a range from 0 to 1. The normalized score was then computed as:

Normalized Score (NS) = 1 – Normalized (e_i)..(3)

The following ranges were then used to compute the VS Rating, from 1 to 5:

VS Rating = 1: 0 < NS ≤ 0.2

VS Rating = 2: 0.2 < NS ≤ 0.4

VS Rating = 3: 0.4 < NS ≤ 0.6

VS Rating = 4: 0.6 < NS ≤ 0.8

VS Rating = 5: 0 .8 < NS ≤ 1.0

Next, the PoF was computed using the following relationship:

$$PoF = Max\left(\frac{1}{100}VS_{100}, \frac{1}{500}VS_{500}\right) + \frac{1}{2500}VS_{tsunami} \quad (4)$$

The probability for 100-year and 500-year flood recurrence intervals were computed as 1/100 and 1/500 respectively, and the probability for tsunami recurrence intervals as 1/2500 (as associated with a Seattle fault seismic event).

Note: According to the *Seattle Hazard Identification and Vulnerability Analysis* by the Seattle Office of Recovery Management, the return period of a Seattle fault seismic event is 1/5,000 years. A 1/2,500-year return period was selected for this study, a more conservative estimate due to the large amount of uncertainty in this return period.

Finally, the composite risk score was computed using equation (1) and normalized using equation (3) and ranked to come up with the final Risk Score at each facility.

A similar process was followed to complete the desktop analysis for flooding due to mechanical failure. A below grade equipment score (BGES) was assigned to each facility based on type, as shown in Table 6. These scores are based on general assumptions on the below grade equipment that is typically at a given facility. Each BGES was then multiplied by the CoF and normalized to develop the failure scores between 1 and 5.

Table 6. Below Grade Equipment Score by Facility Type

Facility Type	Below Grade Equipment Score (BGES)
Sewage Treatment Plant	5
Wet Weather Treatment Facility	3
Pump Station	1
Regulator Station	1

Note that pipelines are not included in the flooding and tsunami desktop assessment as it is assumed that those facilities are not susceptible to these hazards.

2.2.2 Landslide

A similar process to the flooding and tsunami analysis was followed for the landslide hazard; using a probabilistic approach based on geotechnical hazards and pipe materials. These hazards are not tied to a return period (i.e., a 100-year event). The PoF criteria and assigned scores for the landslide hazard were:

- **Site** – Site is located inside or outside of a mapped landslide hazard area
  - In = High Hazard (site score = 1)
  - Out = Low Hazard (site score = 0)
- **Facility Age –** If the site is located within a mapped landslide area, likelihood that landslide hazard was identified in design and mitigated
  - Least likely considered if site developed prior to 1950 (age score = 2)
  - Less likely considered if site developed between 1950 and 1985 (age score = 1)
  - Most likely considered if site developed since 1985. 1985 Building Code had specific requirements to evaluate distance from slopes (age score = 0)
- **Facility Access –** Access to the facility is through a mapped landslide hazard area
  - Only access through landslide hazard area = High Hazard (access score = 1)
  - Access through non-landslide hazard area = Low Hazard (access score = 0)

A composite PoF hazard score was then calculated as:

$$\text{PoF Hazard Composite Score} = \text{Site} \times (1+\text{Age}/3) + \text{Access}/3 \quad (5)$$

The lowest possible composite score is 0.00, the highest possible score is 2.00, and the score increments at 1/3 (0.33) intervals. The scores were then normalized, and a risk score was computed using equation (1).

Gravity pipelines located within the slide block when the movement is more than a few inches are likely to fail. Force mains with restrained joints may be able to accommodate 6 inches or a foot of movement before they fail. In surficial (shallow) landslide areas, wastewater pipelines may be below the slide, and would not be affected.

Wastewater pipelines are usually “shallow” installed using cut and cover techniques. However, in some cases they are installed using tunneling techniques and would only be subject to landslides at the tunnel portals.

Examples of tunneled pipelines include BWTP Effluent Discharge/Outfall, WPTP Influent Tunnel, and the discharge line from the Matthews Park Pump Station. Some lines are supported on piles submerged below the water. The Issaquah and Kenmore interceptors are both in this category, and run perpendicular to the submarine slope vulnerable to landslides. The STP Effluent Transfer System outfall crosses an escarpment that is subject to landslide movement.

In at least one case, South 277th Street, the pipeline is hung on a bridge crossing the Green River and avoids the landslide zone. However, this bridge crossing is potentially vulnerable due to post-construction settlement loading the vertical flexible couplings on the west side of the bridge. These couplings were designed to allow longitudinal movement of the pipe, and may no longer allow that flexibility.

2.2.3 Extreme Weather

The development of the risk score and final risk rating follows a schema that originates through the development of a VS per the following factors:

- Whether the facility is aboveground or below ground
- Whether staff would require access to the facility during a severe/extreme weather event
- Whether trees or vegetation could be impacted by severe/extreme weather in a way that could disable or limit access to a facility
- Whether wind from extreme storms or severe weather (i.e., tornadoes) could adversely impact the facility's infrastructure
- Whether winter weather (i.e., snow, ice storms) could impact the facility or prevent access

The information in Figure 7, above, was used in this analysis. The scores were developed on a 1 to 5 scale based on a facility location's vulnerability to wind, severe weather, and winter weather. Each of these threats have their own VS, which are multiplied together to create a total VS for each facility location. This value is then multiplied by the CoF to develop the final Risk Score, and this score is normalized to a scale of 1 to 5 (Low to High) based on an even partitioning of the range of final Risk Score values of 0-208 as seen in the Extreme Weather Vulnerability Assessment table in Attachment C.

Note that pipelines are not included in the extreme weather desktop assessment as it is assumed that those facilities are not susceptible to these hazards.

3 Findings and Facility Prioritization

The following sections list the sites that present opportunities for system improvement via capital investments for each of the amendment hazards based on the risk scores. It should be noted that these sites were carried forward into Task 400 activities to develop conceptual mitigation designs and cost estimates. Not all of the sites listed in the sections below were developed into discrete mitigation concepts. Some might have been combined into programmatic projects, while others might have been eliminated with further evaluation. See the Task 400 technical memorandum for more information.

3.1.1 Flooding

Normalized risk scores using the methodology presented in Section 2.1.1 were used to determine the overall flood risk score rating, which are provided in Attachment A. The highest risk facilities were identified as shown in Figure 9 (riverine/tsunami flooding drives the risk for all facilities except STP, which was selected due to potential for flooding because of mechanical failure). These facilities included the following locations:

- Interurban Pump Station Flooding Risk
- York Pump Station Flooding Risk
- Matthews Park Pump Station Flooding Risk
- Murray Pump Station Flooding Risk
- 53rd Avenue Pump Station Flooding Risk
- 63rd Avenue Pump Station Flooding Risk
- Bellevue Pump Station Flooding Risk
- Woodinville Pump Station Flooding Risk
- STP Flooding Risk (mechanical failure)

In general, these are the facilities that had the highest CRS, were located in (or within 250 feet) of a known floodplain, and had a relative elevation near the identified base flood elevation. Tsunami risks had little impact on the overall ranking given the low PoF. The analysis for flooding due to mechanical failure yielded four high-risk facilities based on the assumptions in Table 6; however, only STP was considered for mitigation strategies after discussing the results with WTD staff in a workshop. Note that WPTP was not considered for mechanical failure as it is assumed that any issues related to that facility would have been identified in the extensive analysis following the plant failure in February 2017. Flooding from overtopping or failure of the Howard Hansen Dam (*Green River Flood Response Plan*, 2009) was not considered in this analysis because it was outside of the scope of this project. See Attachment A for the full scoring for each facility.

3.1.2 Landslide

Only 12 facilities had a risk score greater than 0 because they are located in a landslide hazard area or are accessed through a landslide hazard area. Of these 12 facilities, landslide potential was specifically addressed and mitigated, or, based on their age, likely addressed and mitigated, at 8 facilities. Once the CRS of the remaining 4 facilities is considered, only the South Mercer Pump Station is identified with a moderate-to-high risk rating. Note that the WPTP was not given a landslide hazard rating based on the extensive landslide mitigation measures that have been implemented at that site and active monitoring of those mitigation measures. The landslide risk rating at the other 3 facilities is either moderate or low-to-moderate. It is recommended that WTD further assess the landslide vulnerability of pipelines.

The landslide hazard PoF scores and risk ratings for all facilities are provided in Attachment B.

The risk to pipelines was also considered when evaluating the landslide hazards. Figure 10, High Risk KC WTD Facilities from Landslide Hazards, shows wastewater pipe segments in red that are in landslide zones. The GIS analysis highlights pipeline segments in landslide zones. Landslide zones include a variety of source data and can include historic landslides as well as areas where topography is steeper than the selected landslide threshold. In some cases, closer analysis may result in determining that the area is not subject to landslides.

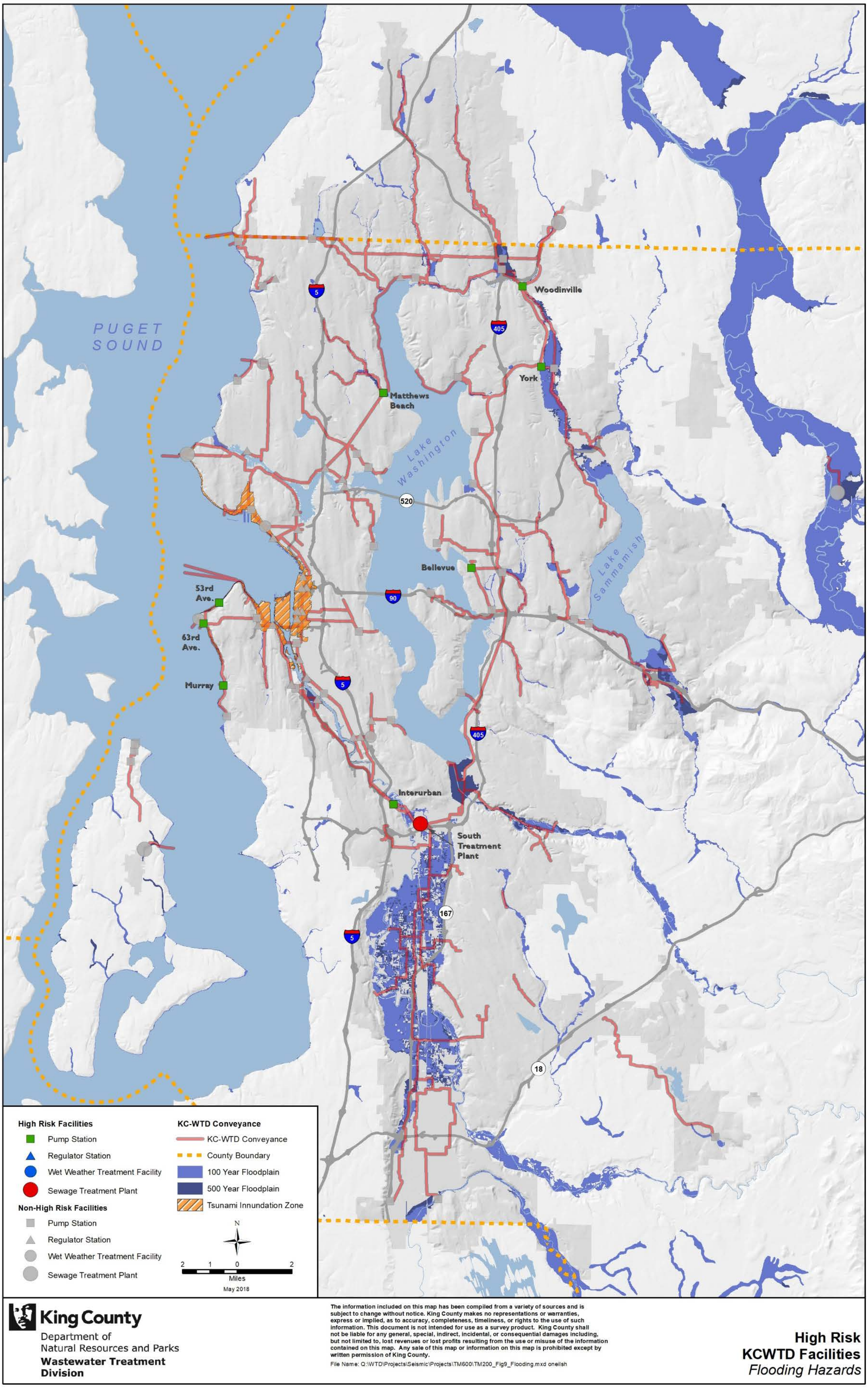

Figure 9. High Risk KC WTD Facilities from Flooding Hazards

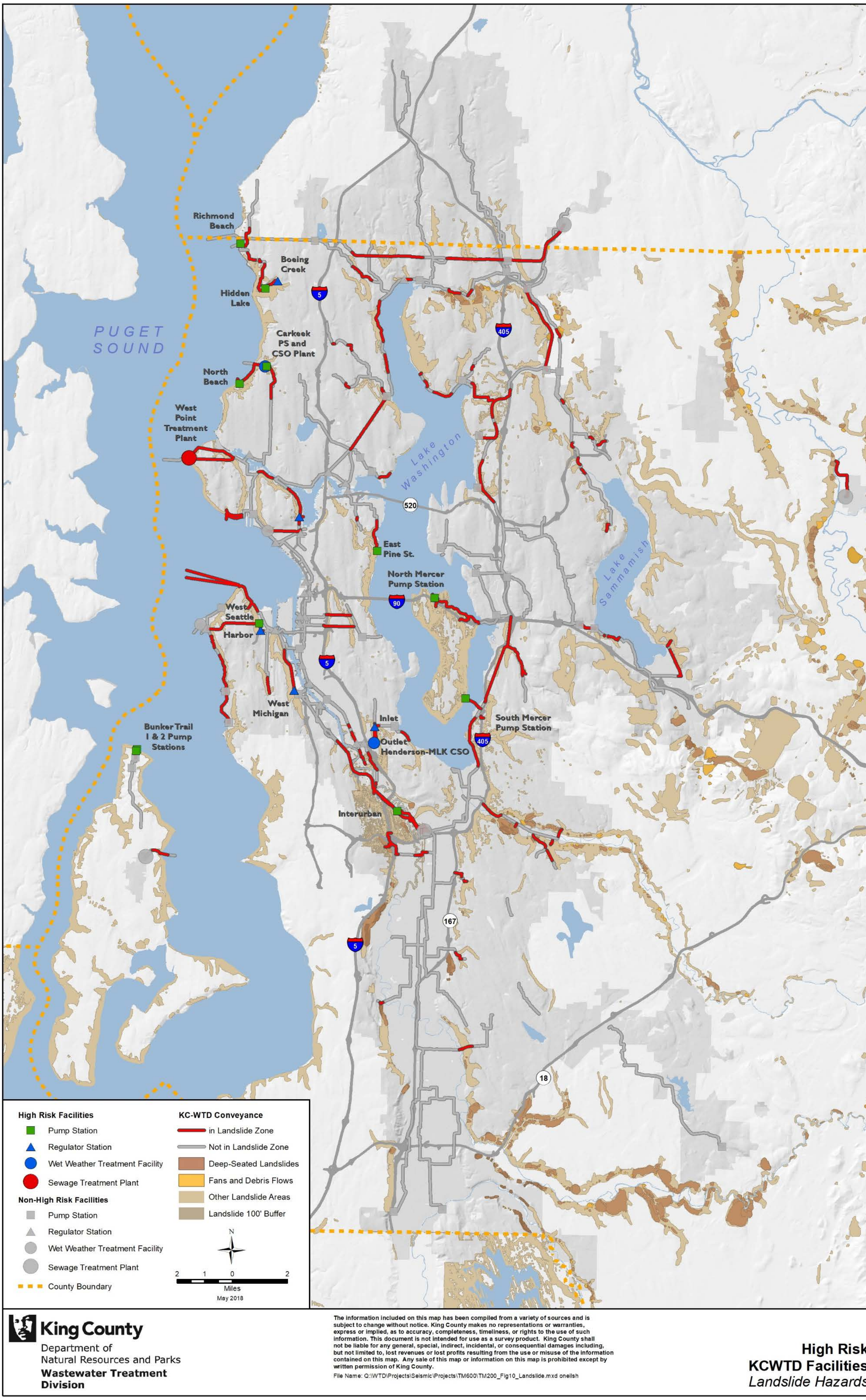

Figure 10. High Risk KC WTD Facilities from Landslide Hazards

3.1.3 Extreme Weather

Through the methodology described in previous sections, Risk Ratings from Low to High were developed and individual facilities were assigned varying level of risk from extreme weather. There were seven facilities that clearly ranked in the High category of relative risk. These facilities included the following locations in order of relative risk, starting with the highest:

- WPTP
- STP
- Alki CSO Plant
- Matthews Park Pump Station
- Carkeek CSO Plant
- Boeing Chiller
- BWTP

These seven facilities are characterized by the following: significant criticality (consequence of failure), aboveground, generally require staff interaction to operate, and are in regions (i.e., Boeing Chiller) that have been found to experience greater impacts (i.e., high wind) than other facilities in the region. All of the rankings are available in Attachment C. Figure **11** shows the location of the highest risk facilities, along with all of the studied facilities as they should also be considered for mitigation efforts.

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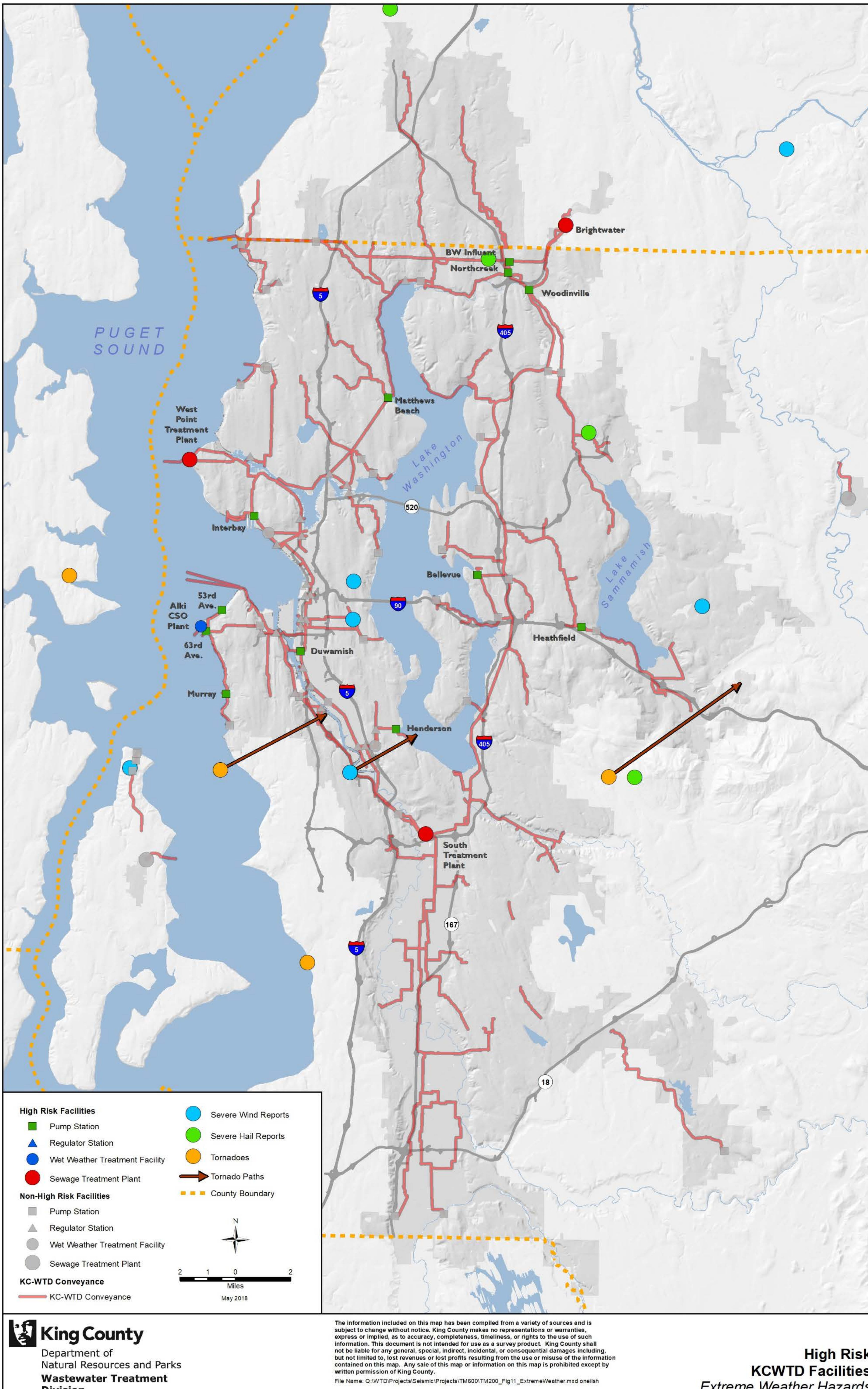

Figure 11. High Risk KC WTD Facilities from Extreme Weather Hazards

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Attachment A. Flooding and Tsunami Hazard Results

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Client: King County

Prime Consultant: HDR
Project: King County Resiliency - Task 200
Project No. 262016.107
Computations By: RH
Checked By: AH
Date Last Updated: 9/8/2017
Title: Desktop Assessment Findings - Flooding and Tsunami

AQUALYZE
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206.582.2031

			100-Yr Flood		500-Yr Flood		Tsunami (2500-Yr)						Overall Flood		Equipment	
Facility Name	Facility Type	Address	Vulnerability Score	Vulnerability Rating	Vulnerability Score	Vulnerability Rating	Vulnerability Score	Vulnerability Rating	Composite Flood Probability of Failure Score	Consequence of Failure or Criticality	Flood Probability x Criticality	Normalized Risk Score	Score	Rating	Failure Score	Vulnerability Rating
Interurban Pump Station	PUMP STATION	13980 Interurban Ave S, Tukwila, WA 98168	5	High	5	High	0	Low	0.0500	23	1.1500	1.00	5	High	1	Low
York Pump Station	PUMP STATION	14120 NE 124th St, Redmond, WA 98034	5	High	5	High	0	Low	0.0500	23	1.1500	1.00	5	High	1	Low
Matthews Park Pump Station	PUMP STATION	9310 Sand Pt Way NE, Seattle, WA 98115	4	Moderate-High	4	Moderate-High	0	Low	0.0400	26	1.0400	0.90	5	High	1	Low
Murray Pump Station	PUMP STATION	7015 Beach Dr SW, Seattle, WA 98136	4	Moderate-High	4	Moderate-High	0	Low	0.0400	25	1.0000	0.87	5	High	1	Low
53rd Ave Pump Station	PUMP STATION	2301 Alki Ave SW, Seattle, WA 98116	5	High	5	High	1	Low	0.0504	19	0.9576	0.83	5	High	1	Low
63rd Ave Pump Station	PUMP STATION	3535 Beach Dr SW, Seattle, WA 98116	4	Moderate-High	4	Moderate-High	4	Moderate-High	0.0416	23	0.9568	0.83	5	High	1	Low
Bellevue Pump Station	PUMP STATION	595 102nd Ave SE, Bellevue, WA 98004	5	High	5	High	0	Low	0.0500	19	0.9500	0.83	5	High	1	Low
Woodinville Pump Station	PUMP STATION	12900 Woodinville Duvall Rd, Woodinville, WA 98072	5	High	5	High	0	Low	0.0500	19	0.9500	0.83	5	High	1	Low
Barton Pump Station	PUMP STATION	9005 Fauntleroy Way SW, Seattle, WA 98136	5	High	5	High	0	Low	0.0500	18	0.9000	0.78	4	Moderate-High	1	Low
E Marginal Way Pump Station	PUMP STATION	7319 E Marginal Wy S, Seattle, WA 98108	4	Moderate-High	4	Moderate-High	0	Low	0.0400	22	0.8800	0.77	4	Moderate-High	1	Low
Wilburton Pump Station	PUMP STATION	SE 10th St and 121 St Ave, Bellevue, WA 98005	5	High	5	High	0	Low	0.0500	15	0.7500	0.65	4	Moderate-High	1	Low
Lakeland Hills Pump Station	PUMP STATION	699 Oravetz Rd, Auburn, WA 98092	5	High	5	High	0	Low	0.0500	14	0.7000	0.61	4	Moderate-High	1	Low
Sunset Pump Station	PUMP STATION	3730 W Lake Sammamish Pkwy SE, Bellevue, WA 98027	5	High	4	Moderate-High	0	Low	0.0500	16	0.8000	0.70	4	Moderate-High	1	Low
Carnation Treament Plant	SEWAGE TREATMENT PLANT	4405 Larson Ave W, Carnation, WA 98014	5	High	5	High	0	Low	0.0500	10	0.5000	0.43	3	Moderate	4.2	High
Alki CSO Plant	WET WEATHER TREATMENT FACILITY	3380 Beach Dr. SW, Seattle, WA 98116	3	Moderate	3	Moderate	4	Moderate-High	0.0316	20	0.6320	0.55	3	Moderate	3	Moderate
Black Diamond Pump Station	PUMP STATION	32923 Railroad Ave, Black Diamond, WA 98010	4	Moderate-High	4	Moderate-High	0	Low	0.0400	14	0.5600	0.49	3	Moderate	1	Low
Hollywood Pump Station	PUMP STATION	14815 NE 124th St, Redmond, WA 98052	5	High	5	High	0	Low	0.0500	11	0.5500	0.48	3	Moderate	1	Low
Hidden Lake Pump Station	PUMP STATION	16700 10th Ave NW, Shoreline, WA 98177	5	High	5	High	0	Low	0.0500	10	0.5000	0.43	3	Moderate	1	Low
Carkeek CSO Plant	WET WEATHER TREATMENT FACILITY	1201 NW Carkeek Park Dr, Seattle, WA 98177	2	Low-Moderate	2	Low-Moderate	0	Low	0.0200	20	0.4000	0.35	2	Low-Moderate	3	Moderate
Brightwater Influent Pump Station	PUMP STATION	11711 NE 195th St, Bothell, WA 98106	0	Low	5	High	0	Low	0.0100	25	0.2500	0.22	2	Low-Moderate	1.2	Low-Moderate
Bunker Trail 1 Pump Station	PUMP STATION	Emergency 206-684-1280, Vashon Island, WA 98070	4	Moderate-High	4	Moderate-High	0	Low	0.0400	11	0.4400	0.38	2	Low-Moderate	1	Low
8th Ave Regulator Station	REGULATOR STATION	760 S Portland St, Seattle, WA 98108	5	High	5	High	0	Low	0.0500	7	0.3500	0.30	2	Low-Moderate	1	Low
North Beach Pump Station	PUMP STATION	9921 Triton Dr NW, Seattle, WA 98117	2	Low-Moderate	2	Low-Moderate	0	Low	0.0200	17	0.3400	0.30	2	Low-Moderate	1	Low
West Point Treatment Plant	SEWAGE TREATMENT PLANT	1400 Discovery Park Blvd, Seattle, WA 98199	0	Low	0	Low	5	High	0.0020	26	0.0520	0.05	1	Low	5	High
South Treatment Plant	SEWAGE TREATMENT PLANT	1200 Monster Rd SW, Renton, WA 98057	0	Low	0	Low	0	Low	0.0000	25	0.0000	0.00	1	Low	5	High
Vashon Treatment Plant	SEWAGE TREATMENT PLANT	9615 SW 171 St, Vashon Island, WA 98072	0	Low	5	High	0	Low	0.0100	6	0.0600	0.05	1	Low	4.2	High
Elliott West CSO Facility	WET WEATHER TREATMENT FACILITY	545 Elliott Ave W, Seattle, WA 98119	0	Low	0	Low	5	High	0.0020	20	0.0400	0.03	1	Low	3	Moderate
Brightwater Treatment Plant	SEWAGE TREATMENT PLANT	Woodinville Snohomish Rd NE, Woodinville, WA 98072	0	Low	0	Low	0	Low	0.0000	24	0.0000	0.00	1	Low	3	Moderate
Henderson-MLK CSO Facility	WET WEATHER TREATMENT FACILITY	9829 42nd Ave S, Seattle, WA 98039	0	Low	0	Low	0	Low	0.0000	20	0.0000	0.00	1	Low	3	Moderate
Interbay Pump Station	PUMP STATION	1601 W Garfield St, Seattle, WA 98119	0	Low	0	Low	1	Low	0.0004	23	0.0092	0.01	1	Low	1.2	Low-Moderate
Denny Regulator Station	REGULATOR STATION	3165 Alaskan Way, Seattle, WA 98121	5	High	5	High	4	Moderate-High	0.0516	4	0.2064	0.18	1	Low	1	Low
North Creek Pump Station/Storage	PUMP STATION	18707 N Creek Pkwy, Bothell, WA 98011	0	Low	5	High	0	Low	0.0100	18	0.1800	0.16	1	Low	1	Low
W Seattle Regulator Station	REGULATOR STATION	6208 SW Spokane St, Seattle, WA 98116	4	Moderate-High	4	Moderate-High	4	Moderate-High	0.0416	4	0.1664	0.14	1	Low	1	Low
Carkeek Pump Station	PUMP STATION	1201 NW Carkeek Park Dr, Seattle, WA 98177	1	Low	1	Low	0	Low	0.0100	11	0.1100	0.10	1	Low	1	Low
W Seattle Pump Station	PUMP STATION	3051Harbor Ave SW, Seattle, WA 98126	0	Low	0	Low	5	High	0.0020	15	0.0300	0.03	1	Low	1	Low
Harbor Regulator Station	REGULATOR STATION	3432 Harbor Ave SW, Seattle, WA 98126	0	Low	0	Low	5	High	0.0020	6	0.0120	0.01	1	Low	1	Low
Lander Regulator Station	REGULATOR STATION	S Lander St and E Marginal Way S, Seattle, WA 98134	0	Low	0	Low	5	High	0.0020	5	0.0100	0.01	1	Low	1	Low
Hanford Regulator Station	REGULATOR STATION	2999 E Marginal Wy S, Seattle, WA 98134	0	Low	0	Low	4	Moderate-High	0.0016	5	0.0080	0.01	1	Low	1	Low
King Regulator Station	REGULATOR STATION	499 Alaskan Way S, Seattle, WA 98134	0	Low	0	Low	5	High	0.0020	4	0.0080	0.01	1	Low	1	Low
Kingdome Regulator Station	REGULATOR STATION	1198 Occidental Ave S, Seattle, WA 98134	0	Low	0	Low	5	High	0.0020	4	0.0080	0.01	1	Low	1	Low
Lander2 Regulator Station	REGULATOR STATION	S Lander St and Colorado Ave S, Seattle, WA 98134	0	Low	0	Low	5	High	0.0020	4	0.0080	0.01	1	Low	1	Low
Chelan Regulator Station	REGULATOR STATION	3455 Chelan Ave SW, Seattle, WA 98106	0	Low	0	Low	1	Low	0.0004	6	0.0024	0.00	1	Low	1	Low
Connecticut Regulator Station	REGULATOR STATION	1199 Alaskan Way S, Seattle, WA 98134	0	Low	0	Low	1	Low	0.0004	4	0.0016	0.00	1	Low	1	Low
30th Ave Pump Station	PUMP STATION	4703 30th Ave NE, Seattle, WA 98105	0	Low	0	Low	0	Low	0.0000	23	0.0000	0.00	1	Low	1	Low
Allentown Regulator Station	REGULATOR STATION	Airport Way S and S Norfolk St, Seattle, WA 98108	0	Low	0	Low	0	Low	0.0000	7	0.0000	0.00	1	Low	1	Low
Ballard Regulator Station	REGULATOR STATION	5110 Shilshole Ave NW, Seattle, WA 98107	0	Low	0	Low	0	Low	0.0000	6	0.0000	0.00	1	Low	1	Low
Belvoir Pump Station	PUMP STATION	3901 Surber Dr NE, Seattle, WA 98105	0	Low	0	Low	0	Low	0.0000	18	0.0000	0.00	1	Low	1	Low
Boeing Chiller	PUMP STATION	1200 Monster Rd SW, Renton, WA 98057	0	Low	0	Low	0	Low	0.0000	11	0.0000	0.00	1	Low	1	Low
Boeing Creek Regulator Station	REGULATOR STATION	17229 3rd Ave NW, Shoreline, WA 98177	0	Low	0	Low	0	Low	0.0000	4	0.0000	0.00	1	Low	1	Low
Brandon Regulator Station	REGULATOR STATION	5241 E Marginal Way S, Seattle, WA 98134	0	Low	0	Low	0	Low	0.0000	7	0.0000	0.00	1	Low	1	Low
Bunker Trail 2 Pump Station	PUMP STATION	Emergency 206-684-1280, Vashon Island, WA 98072	0	Low	0	Low	0	Low	0.0000	12	0.0000	0.00	1	Low	1	Low
Bunker Trail 3 Pump Station	PUMP STATION	Emergency 206-684-1280, Vashon Island, WA 98072	0	Low	0	Low	0	Low	0.0000	12	0.0000	0.00	1	Low	1	Low
Bunker Trail 4 Pump Station	PUMP STATION	Emergency 206-684-1280, Vashon Island, WA 98072	0	Low	0	Low	0	Low	0.0000	12	0.0000	0.00	1	Low	1	Low
Dexter Regulator Station	REGULATOR STATION	1419 Dexter Ave N, Seattle, WA 98109	0	Low	0	Low	0	Low	0.0000	6	0.0000	0.00	1	Low	1	Low
Duwamish Pump Station	PUMP STATION	4501 E Marginal Wy S, Seattle, WA 98134	0	Low	0	Low	0	Low	0.0000	25	0.0000	0.00	1	Low	1	Low
East Pine Pump Station	PUMP STATION	1600 Lake Wash Blvd, Seattle, WA 98122	0	Low	0	Low	0	Low	0.0000	16	0.0000	0.00	1	Low	1	Low
Heathfield Pump Station	PUMP STATION	3541 163rd Ave SE, Bellevue, WA 98008	0	Low	0	Low	0	Low	0.0000	20	0.0000	0.00	1	Low	1	Low
Juanita Bay Pump Station	PUMP STATION	11700 93rd Ave NE, Juanita, WA 98034	0	Low	0	Low	0	Low	0.0000	17	0.0000	0.00	1	Low	1	Low
Kenmore Pump Station	PUMP STATION	6719 NE 175th St, Kenmore, WA 98028	0	Low	0	Low	0	Low	0.0000	19	0.0000	0.00	1	Low	1	Low
Kirkland Pump Station	PUMP STATION	3rd St and Park Lane, Kirkland, WA 98033	0	Low	0	Low	0	Low	0.0000	15	0.0000	0.00	1	Low	1	Low

Prime Consultant: HDR
Project: King County Resiliency - Task 200
Project No. 262016.107
Computations By: RH
Checked By: AH
Date Last Updated: 9/8/2017
Title: Desktop Assessment Findings - Flooding and Tsunami

AQUALYZE
810 Third Ave, Suite 320, Seattle WA 98104
206.582.2031

			100-Yr Flood		500-Yr Flood		Tsunami (2500-Yr)						Overall Flood		Equipment	
Facility Name	Facility Type	Address	Vulnerability Score	Vulnerability Rating	Vulnerability Score	Vulnerability Rating	Vulnerability Score	Vulnerability Rating	Composite Flood Probability of Failure Score	Consequence of Failure or Criticality	Flood Probability x Criticality	Normalized Risk Score	Score	Rating	Failure Score	Vulnerability Rating
Lake Ballinger Pump Station	PUMP STATION	2205 N 205th St, Shoreline, WA 98133	0	Low	0	Low	0	Low	0.0000	17	0.0000	0.00	1	Low	1	Low
Lake City Tunnel Regulator Station	REGULATOR STATION	708 40th St NE, Seattle, WA 98105	0	Low	0	Low	0	Low	0.0000	6	0.0000	0.00	1	Low	1	Low
Lake Union Tunnel Regulator Station	REGULATOR STATION	Republican St and 8th Ave N, Seattle, WA 98109	0	Low	0	Low	0	Low	0.0000	6	0.0000	0.00	1	Low	1	Low
Logboom Regulator Station	REGULATOR STATION	6001 NE Bothell Way, Kenmore, WA 98028	0	Low	0	Low	0	Low	0.0000	7	0.0000	0.00	1	Low	1	Low
Medina Pump Station	PUMP STATION	NE 8th St and 81st Ave NE, Medina, WA 98039	0	Low	0	Low	0	Low	0.0000	15	0.0000	0.00	1	Low	1	Low
Michigan Regulator Station	REGULATOR STATION	159 S Michigan St, Seattle, WA 98108	0	Low	0	Low	0	Low	0.0000	7	0.0000	0.00	1	Low	1	Low
MLK Tunnel Regulator Station	REGULATOR STATION	4207 S Fairbanks St, Seattle, WA 98039	0	Low	0	Low	0	Low	0.0000	6	0.0000	0.00	1	Low	1	Low
Montlake Regulator Station	REGULATOR STATION	2910 Mountlake Blvd E, Seattle, WA 98105	0	Low	0	Low	0	Low	0.0000	6	0.0000	0.00	1	Low	1	Low
Norfolk Regulator Station	REGULATOR STATION	10000 E Marginal Wy S, Seattle, WA 98108	0	Low	0	Low	0	Low	0.0000	6	0.0000	0.00	1	Low	1	Low
North Mercer Pump Station	PUMP STATION	7631 SE 22nd St, Mercer Island, WA 98040	0	Low	0	Low	0	Low	0.0000	15	0.0000	0.00	1	Low	1	Low
Pacific Pump Station	PUMP STATION	100 Frontage Road N, Pacific, WA 98047	0	Low	0	Low	0	Low	0.0000	15	0.0000	0.00	1	Low	1	Low
Rainier Pump Station	PUMP STATION	3761 Rainier Ave S, Seattle, WA 98144	0	Low	0	Low	0	Low	0.0000	19	0.0000	0.00	1	Low	1	Low
Richmond Pump Station	PUMP STATION	20001 Richmond Beach Dr NW, Shoreline, WA 98177	0	Low	0	Low	0	Low	0.0000	18	0.0000	0.00	1	Low	1	Low
S Henderson Pump Station	PUMP STATION	5327 S Henderson St, Seattle, WA 98118	0	Low	0	Low	0	Low	0.0000	20	0.0000	0.00	1	Low	1	Low
S Mercer Pump Station	PUMP STATION	E Mercer Wy and SE 72nd St, Mercer Island, WA 98040	0	Low	0	Low	0	Low	0.0000	17	0.0000	0.00	1	Low	1	Low
South Treatment Plant Effluent Pump Station	PUMP STATION	1200 Monster Rd SW, Renton, WA 98057	0	Low	0	Low	0	Low	0.0000	20	0.0000	0.00	1	Low	1	Low
Sweyolocken Pump Station	PUMP STATION	3100 Bellevue Wy SE, Bellevue, WA 98004	0	Low	0	Low	0	Low	0.0000	21	0.0000	0.00	1	Low	1	Low
University Regulator Station	REGULATOR STATION	1901 NE Pacific Place, Seattle, WA 98105	0	Low	0	Low	0	Low	0.0000	7	0.0000	0.00	1	Low	1	Low
W Marginal Pump Station	PUMP STATION	7119 W Marginal Wy SW, Seattle, WA 98106	0	Low	0	Low	0	Low	0.0000	20	0.0000	0.00	1	Low	1	Low
W Michigan Regulator Station	REGULATOR STATION	6769 W Marginal Wy SW, Seattle, WA 98106	0	Low	0	Low	0	Low	0.0000	6	0.0000	0.00	1	Low	1	Low
Yarrow Bay Pump Station	PUMP STATION	4400 Lake Washington Blvd NE, Kirkland, WA 98033	0	Low	0	Low	0	Low	0.0000	14	0.0000	0.00	1	Low	1	Low
Beulah Cove Septic System	SEPTIC SYSTEM	unknown	0	Low	0	Low	0	Low	0.0000	11	0.0000	0.00	1	Low	0.2	Low

Attachment B. Landslide Hazard Results

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Client: HDR
Project: King County Resiliency - Task 200
Desktop Assessment - Landslide Vulnerability
Project No. 21-2-22404-200
By: WJP
Date Last Updated: 9/1/2017

DESKTOP LANDSLIDE VULNERABILITY ASSESSMENT

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS
400 N. 34th St., Suite 100, Seattle WA
(206) 632-8020

Facility Name	Facility Type	Address	Site Landslide Hazard		Building / Site Development Age		Access Landslide Hazard		Composite Landslide Hazard Score	Consequence of Failure OR Criticality	Landslide Risk		
			Hazard Score 0 = site outside hazard zone 1 = site within hazard zone	Hazard Rating Low = 0 High = 1	Hazard Score 0 = 1985 or newer 1 = 1985 to 1950 2 = older than 1950	Hazard Rating Low = 0 Low-Moderate = 1 Moderate = 2	Hazard Score 0 = access outside hazard zone 1 = access within hazard zone	Hazard Rating Low = 0 High = 1	Score = Site x (1+Age/3) + Access/3)		Landslide Risk Risk = Composite Landslide Hazard x Criticality	Normalized Score	Risk Rating Low = 0 to 0.1 Low-Moderate = 0.1 to 0.4 Moderate = 0.4 to 0.6 Moderat-High = 0.6 to 0.85 High = 0.85 to 1.0
West Point Treatment Plant	SEWAGE TREATMENT PLANT	1400 Discovery Park Blvd, Seattle, WA 98199	1	High	1	Low-Moderate	0	Low	1.33	26	34.67	1.00	High*
S Mercer Pump Station	PUMP STATION	E Mercer Wy and SE 72nd St, Mercer Island, WA 98040	1	High	1	Low-Moderate	1	High	1.67	17	28.33	0.82	Moderate-High
North Mercer Pump Station	PUMP STATION	7631 SE 22nd St, Mercer Island, WA 98040	1	High	1	Low-Moderate	0	Low	1.33	15	20.00	0.58	Moderate
Henderson-MLK CSO Facility	WET WEATHER TREATMENT FACILITY	9829 42nd Ave S, Seattle, WA 98039	1	High	0	Low	0	Low	1.00	20	20.00	0.58	Moderate
W Seattle Pump Station	PUMP STATION	3051Harbor Ave SW, Seattle, WA 98126	1	High	0	Low	0	Low	1.00	15	15.00	0.43	Moderate
Carkeek Pump Station	PUMP STATION	1201 NW Carkeek Park Dr, Seattle, WA 98177	1	High	0	Low	1	High	1.33	11	14.67	0.42	Moderate
Bunker Trail 1 Pump Station	PUMP STATION	Emergency 206-684-1280, Vashon Island, WA 98070	1	High	0	Low	0	Low	1.00	11	11.00	0.32	Low-Moderate
Hidden Lake Pump Station	PUMP STATION	16700 10th Ave NW, Shoreline, WA 98177	1	High	0	Low	0	Low	1.00	10	10.00	0.29	Low-Moderate
Dexter Regulator Station	REGULATOR STATION	1419 Dexter Ave N, Seattle, WA 98109	1	High	1	Low-Moderate	0	Low	1.33	6	8.00	0.23	Low-Moderate
Carkeek CSO Plant	WET WEATHER TREATMENT FACILITY	1201 NW Carkeek Park Dr, Seattle, WA 98177	0	Low	1	Low-Moderate	1	High	0.33	20	6.67	0.19	Low-Moderate
MLK Tunnel Regulator Station	REGULATOR STATION	4207 S Fairbanks St, Seattle, WA 98039	1	High	0	Low	0	Low	1.00	6	6.00	0.17	Low-Moderate
Vashon Treatment Plant	SEWAGE TREATMENT PLANT	9615 SW 171 St, Vashon Island, WA 98072	1	High	0	Low	0	Low	1.00	6	6.00	0.17	Low-Moderate
Beulah Cove Septic System	SEPTIC SYSTEM	0, 0, WA 0	0	Low	2	Moderate	0	Low	0.00	11	0.00	0.00	Low
Alki CSO Plant	WET WEATHER TREATMENT FACILITY	3380 Beach Dr. SW, Seattle, WA 98116	0	Low	1	Low-Moderate	0	Low	0.00	20	0.00	0.00	Low
53rd Ave Pump Station	PUMP STATION	2301 Alki Ave SW, Seattle, WA 98116	0	Low	0	Low	0	Low	0.00	19	0.00	0.00	Low
63rd Ave Pump Station	PUMP STATION	3535 Beach Dr SW, Seattle, WA 98116	0	Low	1	Low-Moderate	0	Low	0.00	23	0.00	0.00	Low
Barton Pump Station	PUMP STATION	9005 Fauntleroy Way SW, Seattle, WA 98136	0	Low	0	Low	0	Low	0.00	18	0.00	0.00	Low
Murray Pump Station	PUMP STATION	7015 Beach Dr SW, Seattle, WA 98136	0	Low	0	Low	0	Low	0.00	25	0.00	0.00	Low
Brightwater Influent Pump Station	PUMP STATION	11711 NE 195th St, Bothell, WA 98106	0	Low	2	Moderate	0	Low	0.00	25	0.00	0.00	Low
Brightwater Treatment Plant	SEWAGE TREATMENT PLANT	Woodinville Snohomish Rd NE, Woodinville, WA 98072	0	Low	0	Low	0	Low	0.00	24	0.00	0.00	Low
Boeing Creek Regulator Station	REGULATOR STATION	17229 3rd Ave NW, Shoreline, WA 98177	0	Low	0	Low	0	Low	0.00	4	0.00	0.00	Low
Richmond Pump Station	PUMP STATION	20001 Richmond Beach Dr NW, Shoreline, WA 98177	0	Low	0	Low	0	Low	0.00	18	0.00	0.00	Low
Carnation Treament Plant	SEWAGE TREATMENT PLANT	4405 Larson Ave W, Carnation, WA 98014	0	Low	0	Low	0	Low	0.00	10	0.00	0.00	Low
North Beach Pump Station	PUMP STATION	9921 Triton Dr NW, Seattle, WA 98117	0	Low	1	Low-Moderate	0	Low	0.00	17	0.00	0.00	Low
Pacific Pump Station	PUMP STATION	100 Frontage Road N, Pacific, WA 98047	0	Low	0	Low	0	Low	0.00	15	0.00	0.00	Low
Bellevue Pump Station	PUMP STATION	595 102nd Ave SE, Bellevue, WA 98004	0	Low	1	Low-Moderate	0	Low	0.00	19	0.00	0.00	Low
Black Diamond Pump Station	PUMP STATION	32923 Railroad Ave, Black Diamond, WA 98010	0	Low	0	Low	0	Low	0.00	14	0.00	0.00	Low
Boeing Chiller	PUMP STATION	1200 Monster Rd SW, Renton, WA 98057	0	Low	2	Moderate	0	Low	0.00	14	0.00	0.00	Low
Wilburton Pump Station	PUMP STATION	SE 10th St and 121 St Ave, Bellevue, WA 98005	0	Low	1	Low-Moderate	0	Low	0.00	15	0.00	0.00	Low
Heathfield Pump Station	PUMP STATION	3541 163rd Ave SE, Bellevue, WA 98008	0	Low	0	Low	0	Low	0.00	20	0.00	0.00	Low
Sunset Pump Station	PUMP STATION	3730 W Lake Sammamish Pkwy SE, Bellevue, WA 98027	0	Low	0	Low	0	Low	0.00	16	0.00	0.00	Low
Juanita Bay Pump Station	PUMP STATION	11700 93rd Ave NE, Juanita, WA 98034	0	Low	0	Low	0	Low	0.00	17	0.00	0.00	Low
Kirkland Pump Station	PUMP STATION	3rd St and Park Lane, Kirkland, WA 98033	0	Low	1	Low-Moderate	0	Low	0.00	15	0.00	0.00	Low
Lakeland Hills Pump Station	PUMP STATION	699 Oravetz Rd, Auburn, WA 98092	0	Low	1	Low-Moderate	0	Low	0.00	14	0.00	0.00	Low
Medina Pump Station	PUMP STATION	NE 8th St and 81st Ave NE, Medina, WA 98039	0	Low	2	Moderate	0	Low	0.00	15	0.00	0.00	Low
North Creek Pump Station/Storage	PUMP STATION	18707 N Creek Pkwy, Bothell, WA 98011	0	Low	0	Low	0	Low	0.00	18	0.00	0.00	Low
South Treatment Plant Effluent Pump Station	PUMP STATION	1200 Monster Rd SW, Renton, WA 98057	0	Low	2	Moderate	0	Low	0.00	20	0.00	0.00	Low
South Treatment Plant	SEWAGE TREATMENT PLANT	1200 Monster Rd SW, Renton, WA 98057	0	Low	2	Moderate	0	Low	0.00	25	0.00	0.00	Low
Sweyolocken Pump Station	PUMP STATION	3100 Bellevue Wy SE, Bellevue, WA 98004	0	Low	1	Low-Moderate	0	Low	0.00	21	0.00	0.00	Low
Interurban Pump Station	PUMP STATION	13980 Interurban Ave S, Tukwila, WA 98168	0	Low	0	Low	0	Low	0.00	23	0.00	0.00	Low
Yarrow Bay Pump Station	PUMP STATION	4400 Lake Washington Blvd NE, Kirkland, WA 98033	0	Low	1	Low-Moderate	0	Low	0.00	14	0.00	0.00	Low
York Pump Station	PUMP STATION	14120 NE 124th St, Redmond, WA 98034	0	Low	0	Low	0	Low	0.00	23	0.00	0.00	Low
Bunker Trail 2 Pump Station	PUMP STATION	Emergency 206-684-1280, Vashon Island, WA 98072	0	Low	0	Low	0	Low	0.00	12	0.00	0.00	Low
Bunker Trail 3 Pump Station	PUMP STATION	Emergency 206-684-1280, Vashon Island, WA 98072	0	Low	0	Low	0	Low	0.00	12	0.00	0.00	Low
Bunker Trail 4 Pump Station	PUMP STATION	Emergency 206-684-1280, Vashon Island, WA 98072	0	Low	0	Low	0	Low	0.00	12	0.00	0.00	Low
Brandon Regulator Station	REGULATOR STATION	5241 E Marginal Way S, Seattle, WA 98134	0	Low	2	Moderate	0	Low	0.00	7	0.00	0.00	Low
E Marginal Way Pump Station	PUMP STATION	7319 E Marginal Wy S, Seattle, WA 98108	0	Low	1	Low-Moderate	0	Low	0.00	22	0.00	0.00	Low
Duwamish Pump Station	PUMP STATION	4501 E Marginal Wy S, Seattle, WA 98134	0	Low	1	Low-Moderate	0	Low	0.00	25	0.00	0.00	Low
Harbor Regulator Station	REGULATOR STATION	3432 Harbor Ave SW, Seattle, WA 98126	0	Low	1	Low-Moderate	0	Low	0.00	6	0.00	0.00	Low
Allentown Regulator Station	REGULATOR STATION	Airport Way S and S Norfolk St, Seattle, WA 98108	0	Low	2	Moderate	0	Low	0.00	7	0.00	0.00	Low
S Henderson Pump Station	PUMP STATION	5327 S Henderson St, Seattle, WA 98118	0	Low	1	Low-Moderate	0	Low	0.00	20	0.00	0.00	Low
Norfolk Regulator Station	REGULATOR STATION	10000 E Marginal Wy S, Seattle, WA 98108	0	Low	1	Low-Moderate	0	Low	0.00	6	0.00	0.00	Low
Michigan Regulator Station	REGULATOR STATION	159 S Michigan St, Seattle, WA 98108	0	Low	1	Low-Moderate	0	Low	0.00	7	0.00	0.00	Low
8th Ave Regulator Station	REGULATOR STATION	760 S Portland St, Seattle, WA 98108	0	Low	1	Low-Moderate	0	Low	0.00	7	0.00	0.00	Low
Chelan Regulator Station	REGULATOR STATION	3455 Chelan Ave SW, Seattle, WA 98106	0	Low	2	Moderate	0	Low	0.00	6	0.00	0.00	Low
W Marginal Pump Station	PUMP STATION	7119 W Marginal Wy SW, Seattle, WA 98106	0	Low	1	Low-Moderate	0	Low	0.00	20	0.00	0.00	Low
W Michigan Regulator Station	REGULATOR STATION	6769 W Marginal Wy SW, Seattle, WA 98106	0	Low	2	Moderate	0	Low	0.00	6	0.00	0.00	Low
W Seattle Regulator Station	REGULATOR STATION	6208 SW Spokane St, Seattle, WA 98116	0	Low	0	Low	0	Low	0.00	4	0.00	0.00	Low
Ballard Regulator Station	REGULATOR STATION	5110 Shilshole Ave NW, Seattle, WA 98107	0	Low	1	Low-Moderate	0	Low	0.00	6	0.00	0.00	Low
Lake Ballinger Pump Station	PUMP STATION	2205 N 205th St, Shoreline, WA 98133	0	Low	0	Low	0	Low	0.00	17	0.00	0.00	Low
Connecticut Regulator Station	REGULATOR STATION	1199 Alaskan Way S, Seattle, WA 98134	0	Low	2	Moderate	0	Low	0.00	4	0.00	0.00	Low

Client: HDR
Project: King County Resiliency - Task 200
Desktop Assessment - Landslide Vulnerability
Project No. 21-2-22404-200
By: WJP
Date Last Updated: 9/1/2017

DESKTOP LANDSLIDE VULNERABILITY ASSESSMENT

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS
400 N. 34th St., Suite 100, Seattle WA
(206) 632-8020

Facility Name	Facility Type	Address	Site Landslide Hazard		Building / Site Development Age		Access Landslide Hazard		Composite Landslide Hazard Score Score = Site x (1+Age/3) + Access/3)	Consequence of Failure OR Criticality	Landslide Risk		
			Hazard Score 0 = site outside hazard zone 1 = site within hazard zone	**Hazard Rating** Low = 0 High = 1	**Hazard Score** 0 = 1985 or newer 1 = 1985 to 1950 2 = older than 1950	**Hazard Rating** Low = 0 Low-Moderate = 1 Moderate = 2	**Hazard Score** 0 = access outside hazard zone 1 = access within hazard zone	**Hazard Rating** Low = 0 High = 1			**Landslide Risk** Risk = Composite Landslide Hazard x Criticality	**Normalized Score**	**Risk Rating** Low = 0 to 0.1 Low-Moderate = 0.1 to 0.4 Moderate = 0.4 to 0.6 Moderat-High = 0.6 to 0.85 High = 0.85 to 1.0
Denny Regulator Station	REGULATOR STATION	3165 Alaskan Way, Seattle, WA 98121	0	Low	1	Low-Moderate	0	Low	0.00	4	0.00	0.00	Low
Interbay Pump Station	PUMP STATION	1601 W Garfield St, Seattle, WA 98119	0	Low	1	Low-Moderate	0	Low	0.00	23	0.00	0.00	Low
Elliott West CSO Facility	WET WEATHER TREATMENT FACILITY	545 Elliott Ave W, Seattle, WA 98119	0	Low	0	Low	0	Low	0.00	20	0.00	0.00	Low
Hanford Regulator Station	REGULATOR STATION	2999 E Marginal Wy S, Seattle, WA 98134	0	Low	1	Low-Moderate	0	Low	0.00	5	0.00	0.00	Low
Rainier Pump Station	PUMP STATION	3761 Rainier Ave S, Seattle, WA 98144	0	Low	2	Moderate	0	Low	0.00	19	0.00	0.00	Low
Logboom Regulator Station	REGULATOR STATION	6001 NE Bothell Way, Kenmore, WA 98028	0	Low	0	Low	0	Low	0.00	7	0.00	0.00	Low
Kenmore Pump Station	PUMP STATION	6719 NE 175th St, Kenmore, WA 98028	0	Low	0	Low	0	Low	0.00	19	0.00	0.00	Low
King Regulator Station	REGULATOR STATION	499 Alaskan Way S, Seattle, WA 98134	0	Low	2	Moderate	0	Low	0.00	4	0.00	0.00	Low
Kingdome Regulator Station	REGULATOR STATION	1198 Occidental Ave S, Seattle, WA 98134	0	Low	0	Low	0	Low	0.00	4	0.00	0.00	Low
Lander Regulator Station	REGULATOR STATION	S Lander St and E Marginal Way S, Seattle, WA 98134	0	Low	1	Low-Moderate	0	Low	0.00	5	0.00	0.00	Low
Lander2 Regulator Station	REGULATOR STATION	S Lander St and Colorado Ave S, Seattle, WA 98134	0	Low	0	Low	0	Low	0.00	4	0.00	0.00	Low
30th Ave Pump Station	PUMP STATION	4703 30th Ave NE, Seattle, WA 98105	0	Low	1	Low-Moderate	0	Low	0.00	23	0.00	0.00	Low
Belvoir Pump Station	PUMP STATION	3901 Surber Dr NE, Seattle, WA 98105	0	Low	2	Moderate	0	Low	0.00	18	0.00	0.00	Low
Lake City Tunnel Regulator Station	REGULATOR STATION	708 40th St NE, Seattle, WA 98105	0	Low	1	Low-Moderate	0	Low	0.00	6	0.00	0.00	Low
Lake Union Tunnel Regulator Station	REGULATOR STATION	Republican St and 8th Ave N, Seattle, WA 98109	0	Low	0	Low	0	Low	0.00	6	0.00	0.00	Low
Matthews Park Pump Station	PUMP STATION	9310 Sand Pt Way NE, Seattle, WA 98115	0	Low	2	Moderate	0	Low	0.00	26	0.00	0.00	Low
University Regulator Station	REGULATOR STATION	1901 NE Pacific Place, Seattle, WA 98105	0	Low	1	Low-Moderate	0	Low	0.00	7	0.00	0.00	Low
Hollywood Pump Station	PUMP STATION	14815 NE 124th St, Redmond, WA 98052	0	Low	1	Low-Moderate	0	Low	0.00	11	0.00	0.00	Low
Woodinville Pump Station	PUMP STATION	12900 Woodinville Duvall Rd, Woodinville, WA 98072	0	Low	1	Low-Moderate	0	Low	0.00	19	0.00	0.00	Low
East Pine Pump Station	PUMP STATION	1600 Lake Wash Blvd, Seattle, WA 98122	0	Low	1	Low-Moderate	0	Low	0.00	16	0.00	0.00	Low
Montlake Regulator Station	REGULATOR STATION	2910 Mountlake Blvd E, Seattle, WA 98105	0	Low	1	Low-Moderate	0	Low	0.00	6	0.00	0.00	Low

Attachment C. Extreme Weather Hazard Results

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Client: King County
Prime Consultant: HDR
Project: King County Resiliency - Task 200
Desktop Assessment - Extreme Weather Vulnerability
Project No. 262016.107
Computations By: Shane Motley and Nathan Clements
Checked By: Mike McMahon
Date Last Updated: 8/31/2017

Normalized Score	Ratings
5	High
4	Moderate-High
3	Moderate
2	Low-Moderate
1	Low

Extreme Weather Vulnerability Assessement

			Wind Vulnerability		Severe Weather Vulnerability		Winter Weather Vulnerability			Extreme Weather Risk (Wind + Severe Weather + Winter Weather) X Criticality		
Facility Name	Facility Type	Address	Score	Rating	Score	Rating	Score	Rating	Criticality	Score	Normalized Score	Rating
West Point Treatment Plant	SEWAGE TREATMENT PLANT	1400 Discovery Park Blvd, Seattle, WA 98199	3	Moderate	2	Low-Moderate	3	Moderate	26	208	5	High
South Treatment Plant	SEWAGE TREATMENT PLANT	1200 Monster Rd SW, Renton, WA 98057	3	Moderate	2	Low-Moderate	2	Low-Moderate	25	175	5	High
Alki CSO Plant	WET WEATHER TREATMENT FACILITY	3380 Beach Dr. SW, Seattle, WA 98116	3	Moderate	2	Low-Moderate	2	Low-Moderate	20	140	5	High
Matthews Park Pump Station	PUMP STATION	9310 Sand Pt Way NE, Seattle, WA 98115	2	Low-Moderate	1	Low	1	Low	26	104	5	High
Carkeek CSO Plant	WET WEATHER TREATMENT FACILITY	1201 NW Carkeek Park Dr, Seattle, WA 98177	2	Low-Moderate	1	Low	2	Low-Moderate	20	100	5	High
Boeing Chiller	PUMP STATION	1200 Monster Rd SW, Renton, WA 98057	3	Moderate	2	Low-Moderate	2	Low-Moderate	14	98	5	High
Brightwater Treatment Plant	SEWAGE TREATMENT PLANT	Woodinville Snohomish Rd NE, Woodinville, WA 98072	2	Low-Moderate	2	Low-Moderate	3	Moderate	14	98	5	High
Bellevue Pump Station	PUMP STATION	595 102nd Ave SE, Bellevue, WA 98004	2	Low-Moderate	1	Low	2	Low-Moderate	19	95	4	Moderate-High
Woodinville Pump Station	PUMP STATION	12900 Woodinville Duvall Rd, Woodinville, WA 98072	2	Low-Moderate	1	Low	2	Low-Moderate	19	95	4	Moderate-High
63rd Ave Pump Station	PUMP STATION	3535 Beach Dr SW, Seattle, WA 98116	2	Low-Moderate	1	Low	1	Low	23	92	4	Moderate-High
Interbay Pump Station	PUMP STATION	1601 W Garfield St, Seattle, WA 98119	2	Low-Moderate	1	Low	1	Low	23	92	4	Moderate-High
North Creek Pump Station/Storage	PUMP STATION	18707 N Creek Pkwy, Bothell, WA 98011	2	Low-Moderate	1	Low	2	Low-Moderate	18	90	4	Moderate-High
Heathfield Pump Station	PUMP STATION	3541 163rd Ave SE, Bellevue, WA 98008	2	Low-Moderate	1	Low	1	Low	20	80	4	Moderate-High
S Henderson Pump Station	PUMP STATION	5327 S Henderson St, Seattle, WA 98118	2	Low-Moderate	1	Low	1	Low	20	80	4	Moderate-High
Henderson-MLK CSO Facility	WET WEATHER TREATMENT FACILITY	9829 42nd Ave S, Seattle, WA 98039	2	Low-Moderate	1	Low	1	Low	20	80	4	Moderate-High
South Treatment Plant Effluent Pump S	PUMP STATION	1200 Monster Rd SW, Renton, WA 98057	2	Low-Moderate	1	Low	1	Low	20	80	4	Moderate-High
53rd Ave Pump Station	PUMP STATION	2301 Alki Ave SW, Seattle, WA 98116	2	Low-Moderate	1	Low	1	Low	19	76	4	Moderate-High
Duwamish Pump Station	PUMP STATION	4501 E Marginal Wy S, Seattle, WA 98134	1	Low	1	Low	1	Low	25	75	4	Moderate-High
Murray Pump Station	PUMP STATION	7015 Beach Dr SW, Seattle, WA 98136	1	Low	1	Low	1	Low	25	75	4	Moderate-High
Brightwater Influent Pump Station	PUMP STATION	11711 NE 195th St, Bothell, WA 98106	1	Low	1	Low	1	Low	24	72	3	Moderate
Barton Pump Station	PUMP STATION	9005 Fauntleroy Way SW, Seattle, WA 98136	2	Low-Moderate	1	Low	1	Low	18	72	3	Moderate
Black Diamond Pump Station	PUMP STATION	32923 Railroad Ave, Black Diamond, WA 98010	2	Low-Moderate	1	Low	2	Low-Moderate	14	70	3	Moderate
30th Ave Pump Station	PUMP STATION	4703 30th Ave NE, Seattle, WA 98105	1	Low	1	Low	1	Low	23	69	3	Moderate
Interurban Pump Station	PUMP STATION	13980 Interurban Ave S, Tukwila, WA 98168	1	Low	1	Low	1	Low	23	69	3	Moderate
York Pump Station	PUMP STATION	14120 NE 124th St, Redmond, WA 98034	1	Low	1	Low	1	Low	23	69	3	Moderate
Juanita Bay Pump Station	PUMP STATION	11700 93rd Ave NE, Juanita, WA 98034	2	Low-Moderate	1	Low	1	Low	17	68	3	Moderate
North Beach Pump Station	PUMP STATION	9921 Triton Dr NW, Seattle, WA 98117	2	Low-Moderate	1	Low	1	Low	17	68	3	Moderate
E Marginal Way Pump Station	PUMP STATION	7319 E Marginal Wy S, Seattle, WA 98108	1	Low	1	Low	1	Low	22	66	3	Moderate
East Pine Pump Station	PUMP STATION	1600 Lake Wash Blvd, Seattle, WA 98122	2	Low-Moderate	1	Low	1	Low	16	64	3	Moderate
Sweyolocken Pump Station	PUMP STATION	3100 Bellevue Wy SE, Bellevue, WA 98004	1	Low	1	Low	1	Low	21	63	3	Moderate
W Marginal Pump Station	PUMP STATION	7119 W Marginal Wy SW, Seattle, WA 98106	1	Low	1	Low	1	Low	20	60	3	Moderate
W Seattle Pump Station	PUMP STATION	3051Harbor Ave SW, Seattle, WA 98126	2	Low-Moderate	1	Low	1	Low	15	60	3	Moderate
Elliott West CSO Facility	WET WEATHER TREATMENT FACILITY	545 Elliott Ave W, Seattle, WA 98119	1	Low	1	Low	1	Low	20	60	3	Moderate
Kenmore Pump Station	PUMP STATION	6719 NE 175th St, Kenmore, WA 98028	1	Low	1	Low	1	Low	19	57	3	Moderate
Rainier Pump Station	PUMP STATION	3761 Rainier Ave S, Seattle, WA 98144	1	Low	1	Low	1	Low	19	57	3	Moderate
Belvoir Pump Station	PUMP STATION	3901 Surber Dr NE, Seattle, WA 98105	1	Low	1	Low	1	Low	18	54	3	Moderate
Richmond Pump Station	PUMP STATION	20001 Richmond Beach Dr NW, Shoreline, WA 98177	1	Low	1	Low	1	Low	18	54	3	Moderate

Client: King County
Prime Consultant: HDR
Project: King County Resiliency - Task 200
Desktop Assessment - Extreme Weather Vulnerability
Project No. 262016.107
Computations By: Shane Motley and Nathan Clements
Checked By: Mike McMahon
Date Last Updated: 8/31/2017

Normalized Score	Ratings
5	High
4	Moderate-High
3	Moderate
2	Low-Moderate
1	Low

Extreme Weather Vulnerability Assessement

			Wind Vulnerability		Severe Weather Vulnerability		Winter Weather Vulnerability			Extreme Weather Risk (Wind + Severe Weather + Winter Weather) X Criticality		
Facility Name	Facility Type	Address	Score	Rating	Score	Rating	Score	Rating	Criticality	Score	Normalized Score	Rating
Lake Ballinger Pump Station	PUMP STATION	2205 N 205th St, Shoreline, WA 98133	1	Low	1	Low	1	Low	17	51	3	Moderate
S Mercer Pump Station	PUMP STATION	E Mercer Wy and SE 72nd St, Mercer Island, WA 98040	1	Low	1	Low	1	Low	17	51	3	Moderate
Carnation Treament Plant	SEWAGE TREATMENT PLANT	4405 Larson Ave W, Carnation, WA 98014	1	Low	2	Low-Moderate	2	Low-Moderate	10	50	3	Moderate
Sunset Pump Station	PUMP STATION	3730 W Lake Sammamish Pkwy SE, Bellevue, WA 98027	1	Low	1	Low	1	Low	16	48	2	Low-Moderate
Kirkland Pump Station	PUMP STATION	3rd St and Park Lane, Kirkland, WA 98033	1	Low	1	Low	1	Low	15	45	2	Low-Moderate
Medina Pump Station	PUMP STATION	NE 8th St and 81st Ave NE, Medina, WA 98039	1	Low	1	Low	1	Low	15	45	2	Low-Moderate
North Mercer Pump Station	PUMP STATION	7631 SE 22nd St, Mercer Island, WA 98040	1	Low	1	Low	1	Low	15	45	2	Low-Moderate
Pacific Pump Station	PUMP STATION	100 Frontage Road N, Pacific, WA 98047	1	Low	1	Low	1	Low	15	45	2	Low-Moderate
Wilburton Pump Station	PUMP STATION	SE 10th St and 121 St Ave, Bellevue, WA 98005	1	Low	1	Low	1	Low	15	45	2	Low-Moderate
Lakeland Hills Pump Station	PUMP STATION	699 Oravetz Rd, Auburn, WA 98092	1	Low	1	Low	1	Low	14	42	2	Low-Moderate
Yarrow Bay Pump Station	PUMP STATION	4400 Lake Washington Blvd NE, Kirkland, WA 98033	1	Low	1	Low	1	Low	14	42	2	Low-Moderate
Bunker Trail 2 Pump Station	PUMP STATION	Emergency 206-684-1280, Vashon Island, WA 98072	1	Low	1	Low	1	Low	12	36	2	Low-Moderate
Bunker Trail 3 Pump Station	PUMP STATION	Emergency 206-684-1280, Vashon Island, WA 98072	1	Low	1	Low	1	Low	12	36	2	Low-Moderate
Bunker Trail 4 Pump Station	PUMP STATION	Emergency 206-684-1280, Vashon Island, WA 98072	1	Low	1	Low	1	Low	12	36	2	Low-Moderate
Beulah Cove Septic System	SEPTIC SYSTEM	unknown	1	Low	1	Low	1	Low	11	33	2	Low-Moderate
Bunker Trail 1 Pump Station	PUMP STATION	Emergency 206-684-1280, Vashon Island, WA 98070	1	Low	1	Low	1	Low	11	33	2	Low-Moderate
Carkeek Pump Station	PUMP STATION	1201 NW Carkeek Park Dr, Seattle, WA 98177	1	Low	1	Low	1	Low	11	33	2	Low-Moderate
Hollywood Pump Station	PUMP STATION	14815 NE 124th St, Redmond, WA 98052	1	Low	1	Low	1	Low	11	33	2	Low-Moderate
Hidden Lake Pump Station	PUMP STATION	16700 10th Ave NW, Shoreline, WA 98177	1	Low	1	Low	1	Low	10	30	2	Low-Moderate
Michigan Regulator Station	REGULATOR STATION	159 S Michigan St, Seattle, WA 98108	2	Low-Moderate	1	Low	1	Low	7	28	2	Low-Moderate
MLK Tunnel Regulator Station	REGULATOR STATION	4207 S Fairbanks St, Seattle, WA 98039	2	Low-Moderate	1	Low	1	Low	6	24	1	Low
Vashon Treatment Plant	SEWAGE TREATMENT PLANT	9615 SW 171 St, Vashon Island, WA 98072	2	Low-Moderate	1	Low	1	Low	6	24	1	Low
Allentown Regulator Station	REGULATOR STATION	Airport Way S and S Norfolk St, Seattle, WA 98108	1	Low	1	Low	1	Low	7	21	1	Low
8th Ave Regulator Station	REGULATOR STATION	760 S Portland St, Seattle, WA 98108	1	Low	1	Low	1	Low	7	21	1	Low
Brandon Regulator Station	REGULATOR STATION	5241 E Marginal Way S, Seattle, WA 98134	1	Low	1	Low	1	Low	7	21	1	Low
Logboom Regulator Station	REGULATOR STATION	6001 NE Bothell Way, Kenmore, WA 98028	1	Low	1	Low	1	Low	7	21	1	Low
University Regulator Station	REGULATOR STATION	1901 NE Pacific Place, Seattle, WA 98105	1	Low	1	Low	1	Low	7	21	1	Low
Lake Union Tunnel Regulator Station	REGULATOR STATION	Republican St and 8th Ave N, Seattle, WA 98109	1	Low	1	Low	1	Low	6	18	1	Low
Ballard Regulator Station	REGULATOR STATION	5110 Shilshole Ave NW, Seattle, WA 98107	1	Low	1	Low	1	Low	6	18	1	Low
Chelan Regulator Station	REGULATOR STATION	3455 Chelan Ave SW, Seattle, WA 98106	1	Low	1	Low	1	Low	6	18	1	Low
Dexter Regulator Station	REGULATOR STATION	1419 Dexter Ave N, Seattle, WA 98109	1	Low	1	Low	1	Low	6	18	1	Low
Harbor Regulator Station	REGULATOR STATION	3432 Harbor Ave SW, Seattle, WA 98126	1	Low	1	Low	1	Low	6	18	1	Low
Lake City Tunnel Regulator Station	REGULATOR STATION	708 40th St NE, Seattle, WA 98105	1	Low	1	Low	1	Low	6	18	1	Low
Montlake Regulator Station	REGULATOR STATION	2910 Mountlake Blvd E, Seattle, WA 98105	1	Low	1	Low	1	Low	6	18	1	Low
Norfolk Regulator Station	REGULATOR STATION	10000 E Marginal Wy S, Seattle, WA 98108	1	Low	1	Low	1	Low	6	18	1	Low
W Michigan Regulator Station	REGULATOR STATION	6769 W Marginal Wy SW, Seattle, WA 98106	1	Low	1	Low	1	Low	6	18	1	Low
Boeing Creek Regulator Station	REGULATOR STATION	17229 3rd Ave NW, Shoreline, WA 98177	2	Low-Moderate	1	Low	1	Low	4	16	1	Low

Client: King County
Prime Consultant: HDR
Project: King County Resiliency - Task 200
Desktop Assessment - Extreme Weather Vulnerability
Project No. 262016.107
Computations By: Shane Motley and Nathan Clements
Checked By: Mike McMahon
Date Last Updated: 8/31/2017

Normalized Score	Ratings
5	High
4	Moderate-High
3	Moderate
2	Low-Moderate
1	Low

Extreme Weather Vulnerability Assessement

			Wind Vulnerability		Severe Weather Vulnerability		Winter Weather Vulnerability			Extreme Weather Risk (Wind + Severe Weather + Winter Weather) X Criticality		
Facility Name	Facility Type	Address	Score	Rating	Score	Rating	Score	Rating	Criticality	Score	Normalized Score	Rating
Hanford Regulator Station	REGULATOR STATION	2999 E Marginal Wy S, Seattle, WA 98134	1	Low	1	Low	1	Low	5	15	1	Low
Lander Regulator Station	REGULATOR STATION	S Lander St and E Marginal Way S, Seattle, WA 98134	1	Low	1	Low	1	Low	5	15	1	Low
Connecticut Regulator Station	REGULATOR STATION	1199 Alaskan Way S, Seattle, WA 98134	1	Low	1	Low	1	Low	4	12	1	Low
Lander2 Regulator Station	REGULATOR STATION	S Lander St and Colorado Ave S, Seattle, WA 98134	1	Low	1	Low	1	Low	4	12	1	Low
W Seattle Regulator Station	REGULATOR STATION	6208 SW Spokane St, Seattle, WA 98116	1	Low	1	Low	1	Low	4	12	1	Low
Denny Regulator Station	REGULATOR STATION	3165 Alaskan Way, Seattle, WA 98121	1	Low	1	Low	1	Low	4	12	1	Low
King Regulator Station	REGULATOR STATION	499 Alaskan Way S, Seattle, WA 98134	1	Low	1	Low	1	Low	4	12	1	Low
Kingdome Regulator Station	REGULATOR STATION	1198 Occidental Ave S, Seattle, WA 98134	1	Low	1	Low	1	Low	4	12	1	Low

Item No.	Notes
1	All analyses conducted as part of this study are based on desktop/digital information provided by King County, NWS, NCDC, SPC. No field verifications have been
2	The 82 facilities included in rankings were obtained from KC GIS data
3	Each facility is treated as single entity in the weather-related resiliency analysis
4	Higher vulnerability scores were primarily attributable to above ground infrastrucure
5	Locations in northern KC and in higher terrain indicated a greater threat of winter weather
6	Coastal locations and those further south indicated a higher risk level from wind (see climate results)
7	Vulnerability scores were generally higher for facilities that required human interaction (i.e. treatment plants), which pertains to site accessibility (see 12)
8	Vulnerability scores for wind were generally higher in locations with above ground infrastruture and tall trees in the vicinity.
9	Criticality score (determined by KC) were multiplied with the addititive vulnerability score to compute risk
10	Facilities missing criticality score were given a value of 14, which is the average of all criticality scores
11	As can be seen climate results and severe weather tabs, extreme weather events can and do occur in KC, althought they are fairly rare events.
12	Accessbility to facilities was a vulnerability consideration, particularly for winter weather events.

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Appendix C. Task 400 Conceptual Mitigation and Costs Technical Memorandum

C-1. Conceptual Mitigation and Planning-Level Cost Sheets

Note: The Cost Estimate Backup to Appendix C-1 Conceptual Mitigation and Planning-Level Cost Sheets is provided as an electronic file to King County's Project Management Division.

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Task 400

Task 400 Conceptual Mitigation and Costs Technical Memorandum

April 2018

Prepared by

<u>The HDR Team:</u>
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King County

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Attachments

Alternate Formats Available.

Call 206-477-5371 or TTY: 711

List of Acronyms

AACE	Association for the Advancement of Cost Engineering International
AFI	Allowance for Indeterminates
BWTP	Brightwater Treatment Plant
CIP	Capital Improvement Program
CSO	Combined Sewer Overflow
County	King County
ESJ	Equity and Social Justice
MEP	Mechanical/Electrical Piping
SCADA	Supervisory Control and Data Acquisition
STP	South Treatment Plant
VMS	Valve Management Systems
WPTP	West Point Treatment Plant
WTD	Wastewater Treatment Division
WWTP	Wastewater Treatment Plant

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Executive Summary

King County Wastewater Treatment Division (WTD) proactively addresses risks associated with natural and man-made disasters through both preparedness and mitigation activities.

Through prior work in this master planning effort, WTD engaged in a study to model natural hazard events of concern in its service area, with the goal of assessing probable impacts to WTD's critical facility components and the resiliency of the overall system in a major disaster event. This study used desktop assessments to determine the highest risk facilities (based on vulnerability and consequence of failure determinations for all hazards) and field investigations for selected sites vulnerable to seismic damage. The assessments yielded insights to probable damage and through a series of workshops with County staff, priorities for pre-event mitigation measures were identified to minimize the overall risk to WTD's facilities and stakeholders. With the issues identified and prioritized by risk categories (Life Safety, Public Health, Consequent Damage, and Environmental Impact), a conceptual mitigation design and costing effort was undertaken to define capital and programmatic improvement projects along with potential costs to provide input to the County's 6-year planning budget and the biennial budget process.

This technical memorandum describes the assumptions, processes, and findings from the Task 400 Conceptual Mitigation Design and Costs Workshop. This 2-day collaborative work session with County representation, discipline-specific technical leads, and cost estimators was conducted to develop concepts using a standardized methodology and documentation process, and to provide opportunities for cross-discipline and cross-hazard-type coordination. This technical memorandum covers conceptual mitigation development for the seismic, landslide, flooding, tsunami, and extreme weather events evaluated in earlier tasks.

WTD serves approximately 1.5 million people with a system comprising the following assets: 3 large wastewater treatment plants (WWTPs), 2 small WWTPs, 1 community septic system, 4 combined sewer overflow (CSO) treatment facilities, 25 regulator stations, 47 pump stations, 39 CSO outfalls, and approximately 400 miles of sewer pipelines. The highest risk offsite facilities and treatment plant facilities were selected in collaborative workshops during Task 200 with WTD staff. The vulnerability of each of these highest risk facilities were rated from Low to High risk for each of the hazard assessments. Based on these ratings, 55 issues were brought forward into the conceptual solution phase of Task 400. The development of conceptual solutions and costs involved the grouping of some projects, the elimination of others, and the separation of some into multiple projects, resulting in 52 recommendations for capital and programmatic mitigation projects.

The Conceptual Mitigation Design and Costs Workshop took place on September 12 and 13, 2017. After the facilitators presented an overview and discussion of the project technical issues, the group performed a brainstorming exercise to develop strategies based on the function of the various types of mitigation needs. These strategies were used as a basis for mitigation solutions developed during the workshop, and helped guide the customization of solutions.

Three conceptual development teams were formed based on hazard type (seismic structural, seismic liquefaction/landslide, and flooding/tsunami/extreme weather) to rapidly produce concepts during concurrent work sessions. Each of the mitigation concepts was entered into a standardized template during the development phase of the workshop to produce similar products across the teams with the same level of detail and documentation standards. Several technical experts moved among the teams, providing insight and advice as needed, sharing relevant ideas and findings across the groups, and ensuring a degree of consistency in the completion of the concept mitigation forms. A County representative participated on each of the three teams to provide system information, discuss feasibility of solutions, and to help with concept development and quantities for cost estimating. Using high-level parametric cost estimates that were developed prior to the workshop, the cost estimators worked closely with the technical specialists to produce conceptual estimates for the mitigation solutions.

A debrief was held with all workshop participants at the end of the first day to discuss challenges, process improvement, and schedule status. Opportunities for teams to help each other complete the work during the second day of the workshop were identified and planned for through adjustments to the second day's agenda.

Findings and recommendations that resulted from the concept design workshop, including seismic upgrades, programmatic measures, and further studies, are listed in Table 9 (Section 4.1) by performance criteria and implementation group (high, moderate high, moderate) priority.

The work of Task 400 yielded 49 conceptual mitigation recommendations, as shown by natural hazard type in summary Table E-1. The table also provides conceptual level cost summaries by hazard type.

Table E-1. Conceptual Mitigation Design and Cost Estimating Results by Hazard Type

Hazard Type	Number of Capital Improvement Project Recommendations	Number of Programmatic Improvement or Further Study Recommendations	Total Recommendations by Hazard Type
Seismic Structural	17	10	27
Seismic Liquefaction	10	3	13
Landslide	1	0	1
Flooding/ Tsunami	8	2	10
Extreme Weather	0	1	1
Total	36	16	52

1.0 Introduction

This technical memorandum describes the assumptions and processes undertaken in Task 400 of the *Recommendations to Enhance the Resiliency and Recovery of King County's Regional Wastewater Treatment Facilities* project to develop conceptual level mitigation solutions and cost estimates. These capital and programmatic improvements are recommended to increase WTD system resilience in the face of the natural hazards of greatest concern to the King County Wastewater Treatment Division (WTD) service area, as follows:

- Seismic (structural damage and liquefaction)
- Flooding and Tsunami
- Landslide
- Extreme Weather (severe weather and severe winter weather)

Opportunities to reduce risk (where risk = probability of failure x consequence of failure) in WTD's system were based on findings from the multi-hazard assessments conducted in Task 200. These assessments considered 3 treatment plants, 47 pump stations, 25 regulator stations, 4 combined sewer overflow (CSO) treatment facilities, 1 community septic system, 2 small wastewater treatment plants and approximately 400 miles of sewer pipelines, as identified by WTD at the onset of this work. CSO outfalls were only evaluated for their vulnerability to liquefaction.

Earlier work by the project team allocated risks of natural hazard damage to studied components of the wastewater system and to the system overall. The four identified risk categories are listed by priority:

1. Life Safety – collapse of buildings occupied by WTD staff and the public.
2. Public Health – potential for human contact with raw sewage (e.g., because of backup into basements, overflow into streets, or overflow into small streams or ditches).
3. Consequent Damage – significant impact on critical infrastructure adjacent to WTD facilities should they fail.
4. Environmental Impact – discharge of untreated or inadequately treated wastewater. Environmental impacts were prioritized based on the following discharge locations into a 1) ditch or stream, 2) river flowing into a lake, 3) lake, 4) river flowing into Puget Sound, or 5) Puget Sound. Of the major waterbodies (lakes and salt water), risk priorities from highest to lowest were given to Lake Sammamish, Lake Washington, Elliott Bay and Puget Sound.

Other parameters used to prioritize system deficiencies that lead to the associated conceptual mitigation projects detailed in this memorandum are composed of the following:

- Type of facility – e.g., pump station, regulator
- Flow capacity of a facility or pipe
- Impact of post-earthquake operability/functionality related to one of the primary priorities
- Impact of post-earthquake restoration and its effect on restoration time (particularly related to the very large vulnerable facilities)
- Transfer flow ability
- Equity and social justice factors
- Team validation

The following sections of this technical memorandum cover the topics listed below:

- **Mitigation Improvement Opportunities**: presents the facilities and pipelines determined to be of highest risk for WTD in a significant natural hazard event.
- **Mitigation Development Approach**: explains the assumptions, processes, resources, and tools used to ensure consistent, defensible conceptual mitigation measures to increase WTD's system resiliency, along with their conceptual cost estimates for budgetary planning purposes.
- **Mitigation Results and Recommendations**: details the conceptual mitigation design ideas and cost estimates developed during the 2-day workshop and, through follow-up efforts, to provide quality control reviews and resolve the limited number of items that were still under discussion among the workshop participants.

2.0 Mitigation Improvement Opportunities

This section lists the opportunities for improvement that were identified by the HDR/Consultant Team and validated and prioritized with the County during Task 200 assessment efforts. These issues were carried forward into Task 400 for developing conceptual mitigation designs and cost estimates. It should be noted that not all of the issues resulted in discrete mitigation concepts. Some issues were combined or eliminated during the workshop; for example, the case of nine extreme weather risk mitigation actions that could be combined into one overall programmatic solution. Table 1 through Table 5 list the risk by hazard type, with table notes indicating when issues were eliminated by combining or removing altogether. Attachment C provides a summary matrix that contains the rationale for these decisions.

2.1 Seismic (Structural and Liquefaction) Risks

Table 1 presents the key system features identified in earlier task work as being seismically deficient, thus presenting opportunities to improve the WTD system's seismic structural resiliency. Table 2 presents the key system features identified in earlier task work as being deficient due to liquefaction issues, thus presenting opportunities for improvements to seismic liquefaction resiliency. These items were addressed during the 2-day Conceptual Mitigation Design and Costs Workshop.

Table 1. Recommended Seismic Structural Risk Improvement Opportunities Identified in Task 200

Seismic Structural Risks	
Issue No.	**Issue Title**
S-1	South Treatment Plant (STP) Influent Pump Building Seismic Deficiencies
S-2	West Point Treatment Plant (WPTP) Raw Sewage Pump Station Seismic Deficiencies
S-3	Interbay Pump Station Seismic Deficiencies
S-4	Sweylocken Pump Station Seismic Deficiencies
S-5	Duwamish Pump Station Seismic Deficiencies
S-6	Matthews Park Pump Station Seismic Deficiencies
S-7[1]	Belvoir Pump Station Seismic Deficiencies
S-8[2]	63rd Avenue Pump Station Seismic Deficiencies
S-9	West Marginal Way Pump Station Seismic Deficiencies
S-10	30th Avenue Pump Station Seismic Deficiencies
S-11[2]	Interurban Pump Station Seismic Deficiencies
S-12[3]	Sunset Pump Station Seismic Deficiencies
S-13	WPTP Admin/Ops Center Seismic Deficiencies
S-14	WPTP Maintenance/Effluent Pump Station Seismic Deficiencies
S-15[3]	WPTP Primary Clarifiers Seismic Deficiencies
S-16	WPTP Hypo Mixing Seismic Deficiencies
S-17[1]	WPTP Solids Handling Building Seismic Deficiencies
S-18	STP Division Control Building Seismic Deficiencies
S-19	STP Santler Building Seismic Deficiencies
S-20	STP Maintenance Building Seismic Deficiencies
S-21	STP Effluent Transfer Station (ETS) Seismic Deficiencies
S-22[1]	STP Forebay Main Station Seismic Deficiencies

Seismic Structural Risks	
Issue No.	**Issue Title**
S-23	STP Digester Equipment Building Seismic Deficiencies
S-24[2]	BWTP Treatment Plant Administration Building Seismic Deficiencies
SP-1	*ASCE 41* Tier 1, 2, 3 Seismic Evaluations
SP-3	Additional Pipeline Evaluations
SP-4	Post-Earthquake Technologies (Monitoring) Evaluation/Implementation
SP-6	Programmatic Mechanical-Electrical Upgrades
SP-7	Programmatic Glass Block Upgrades

Notes (see Appendix C for details by issue)**:**

[1] Removed.

[2] Combined with another solution.

[3] Already sufficiently underway, or is small project to be handled outside of the CIP.

Table 2. Recommended Seismic Risk Liquefaction Improvement Opportunities Identified in Task 200

Seismic Liquefaction Risks	
Issue No.	**Issue Title**
L-1	Belvoir Pump Station Liquefaction Deficiencies
L-2	North Creek Pump Station Liquefaction Deficiencies
L-3	63rd Avenue Pump Station Liquefaction Deficiencies
L-4	West Marginal Way Pump Station Liquefaction Deficiencies
L-5	30th Avenue Pump Station Liquefaction Deficiencies
L-6	Interurban Pump Station Liquefaction Deficiencies
L-7	Sunset Pump Station Liquefaction Deficiencies
L-8	Woodinville Pump Station Liquefaction Deficiencies
L-9	Henderson Pump Station Liquefaction Deficiencies
L-10[1]	South Mercer Pump Station Liquefaction Deficiencies
L-11	Rainier Avenue Pump Station Liquefaction Deficiencies
L-12	East Marginal Way Pump Station Liquefaction Deficiencies
L-13	WPTP Liquefaction Susceptible Facilities Retrofit
L-14	STP Liquefaction Susceptible Facilities Retrofits
LP-1	Additional Liquefaction Susceptible Facilities Retrofits

[1] Removed (see Attachment C for details).

2.2 Landslide Risks

Table 3 presents the key system features identified in earlier task work as having risks due to landslides, thus presenting opportunities to improve the WTD system’s landslide resiliency. These items were addressed during the 2-day Conceptual Mitigation Design and Costs Workshop.

Table 3. Recommended Landslide Risk Improvement Opportunities Identified in Task 200

Landslide Risks	
Issue No.	**Issue Title**
LS-1	WPTP Landslide Risk
LS-2	S Mercer Pump Station Landslide Risk

2.3 Flooding and Tsunami Risks

Table 4 presents the key system features identified in earlier task work as having flooding risks, thus presenting an opportunity to improve the WTD system's flooding resiliency. These items were addressed during the 2-day Conceptual Mitigation Design and Costs Workshop. Although considered during the assessment work, no tsunami risks were prioritized for mitigation.

Table 4. Recommended Flooding and Tsunami Risk Improvement Opportunities Identified in Task 200

Flooding Risks	
Issue No.	**Issue Title**
F-1	Interurban Pump Station Flooding Risk
F-2	York Pump Station Flooding Risk
F-3	Matthews Park Pump Station Flooding Risk
F-4	Murray Pump Station Flooding Risk
F-5	53rd Avenue Pump Station Flooding Risk
F-6	63rd Avenue Pump Station Flooding Risk
F-7	Bellevue Pump Station Flooding Risk
F-8	Woodinville Pump Station Flooding Risk
F-9	South Plant Treatment Plant Flooding Risk
F-10[1]	Vashon Treatment Plant Flooding Risk

[1] Removed (see Attachment C for details).

2.4 Extreme Weather Risks

Table 5 presents the key features identified in earlier task work as having extreme weather risks, thus presenting opportunities to improve the WTD system's extreme weather resiliency. These items were addressed during the 2-day Conceptual Mitigation Design and Costs Workshop.

Table 5. Recommended Extreme Weather Risk Improvement Opportunities Identified in Task 200

Extreme Weather Risks	
Issue No.	**Issue Title**
X-1[1]	West Point Treatment Plant Extreme Weather Risk
X-2[1]	South Plant Treatment Plant Extreme Weather Risk
X-3[1]	Alki CSO Plant Extreme Weather Risk
X-4[1]	Matthews Park Pump Station Extreme Weather Risk

Extreme Weather Risks	
Issue No.	**Issue Title**
X-5[1]	Carkeek CSO Plant Extreme Weather Risk
X-6[1]	Boeing Chiller Extreme Weather Risk
X-7[1]	BWTP Treatment Plant Extreme Weather Risk
X-8[1]	Henderson/Norfolk CSO Facility Extreme Weather Risk
XP-1	Extreme Weather Risk (Programmatic)

[1] Combined with another solution (see Attachment C for details by issue).

3.0 Conceptual Mitigation Development Approach

This section describes the approach taken to develop conceptual designs and related cost estimates to address the WTD system risks and priorities established through earlier project tasks. These mitigation solutions were developed primarily through a 2-day facilitated workshop involving the HDR/Consultant Team, facilitators and cost estimators from Value Management Systems (VMS), and County representatives. An overview of the planning, logistics, and goals of the workshop is provided herein.

3.1 Conceptual Mitigation Design and Costs Workshop Logistics and Goals

A 2-day Conceptual Mitigation Design and Costs Workshop was held on September 12 and 13, 2017, at the Bellevue HDR office. The Workshop agenda is presented in Attachment A.

The goals of the workshop were to collaboratively and efficiently develop conceptual mitigation solutions and determine the related conceptual costs for consideration and use by the County capital development program. With the overall group broken into three teams by discipline and subject matter experts working across the groups, designs and cost estimates were generated in a standard, consistent format. Table 6 shows the structure and the composition of each team.

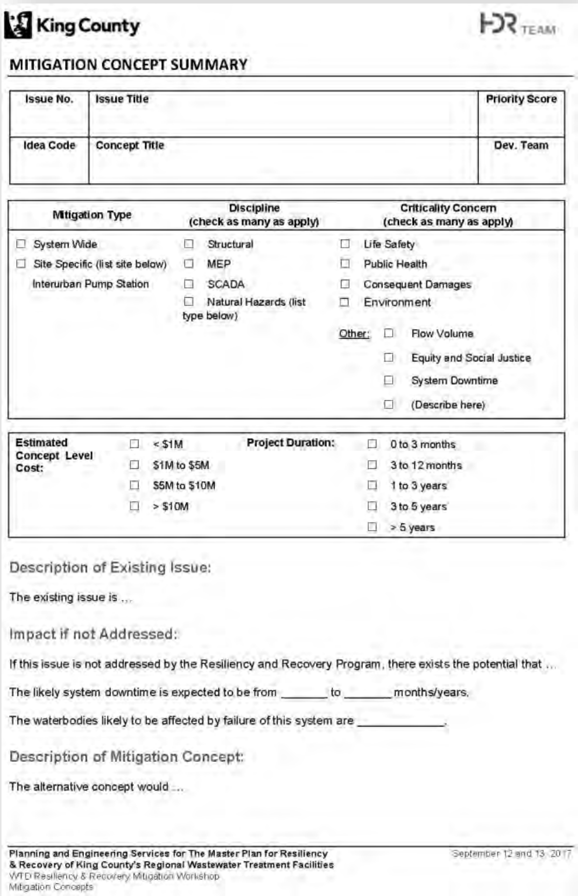
Table 6. Conceptual Mitigation Design and Conceptual Cost Development Workshop Participants by Team

Team 1: Seismic Structural	Team 2: Seismic Liquefaction/Landslide	Team 3: Extreme Weather/ Flooding and Tsunami
Facilitator: **Greg Brink** Assistant: **Damon Yeutter** Estimator: **Forrest Dill**	Facilitator: **Ashley Carson** Assistant: **Mariah Brink** Estimator: **Eric Benton**	Facilitator: **Eric Trimble** Assistant: **Candice Helsing** Estimator: **Richard Greer**
Erik Bishop, Structural Lead **Kenny O'Neill**, Structural SME **Michael Popiwny**, WTD PM	**Bill Perkins**, Geotechnical and Landslides Lead **Don Ballantyne**, Seismic Lead, Pipelines Lead (also worked with Teams 1 and 3 as needed) **Sonia-Lynn Abenojar**, WTD Deputy PM	**Andrew Henson**, Flooding/ Tsunami SME **Nathan Clements**, Extreme Weather SME/GIS **Brian Ward,** Stormwater Design **Butch Perry**, WTD Infrastructure Coordinator
PM and Subject Matter Experts (SMEs) available to each team		
Teresa Platin, PM Ed Griffenberg, Wastewater Operations SME	Tom Thramer, Mechanical SME (primarily with Team 1) Vicki Sironen, Pipelines SME (primarily with Team 3)	Eric Chan, Electrical/I&C SME (primarily with Team 1)

A template for each of the conceptual solutions was developed prior to the workshop to ensure consistency in documentation of project issues, solutions, and costs. A representation of the template is show in Figure 1. The categories documented are as follows.

- **Issue # -** sequential numbering within a hazard category, starting with 1. This numbering does not represent priority of the project or the order in which projects should occur. A letter designation precedes the number, indicating “S” for Structural issues, “L” for Liquefaction, “LS” for Landslide, “F” for Flooding, and “X” for Extreme Weather. When a “P” follows the first letter, it indicates that the issue is programmatic rather than a discrete Capital Improvement Program (CIP) concern.

- **Issue Title** – Descriptive name given to an opportunity for resiliency improvement.
- **Concept Title** – Descriptive name given to the conceptual mitigation idea that was developed.
- **Mitigation Type (checkboxes)** – either system-wide or site-specific.
- **Discipline (checkboxes)** – Structure, Mechanical/Electrical/Piping (MEP), Supervisory Control and Data Acquisition (SCADA), Other (non-seismic natural hazard).
- **Criticality Concern (checkboxes)** – Criticalities determined by the County for use in this strategic planning effort (Life Safety, Public Health, Consequent Damage, and Environmental), as well as factors developed by the team to further highlight criticality drivers.
- **Estimated Concept Level Cost (checkboxes)** – ranges of probable costs for strategic planning purposes (<$1M, $1M to $5M, $5M to $10M, >$10M).
- **Project Duration (checkboxes)** – the anticipated time between the damaging event and repair or replacement of the facility. Likely to include design, permitting, construction, and commissioning time (0 to 3 months, 3 to 12 months, 1 to 3 years, 3 to 5 years, >5 years). This is not to be confused with the “system downtime” that follows in a subsequent bullet and refers to the amount of time before a temporary solution or workaround is implemented to restore system function.
- **Description of Existing Issue –** description of the possible mechanism of failure.
- **Risk if not Addressed** – identification of criticality factor impacted and/or implications for the WTD system. Includes estimation of the following:
  - <u>Retrofit project durations</u>: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.
  - <u>Downtime durations</u>: the duration of time required to restore the facility to its pre-earthquake functionality.
- **Description of Mitigation Concept** – listing of items involved in the mitigation solution.
- **Advantages** – expected positive outcomes as a consequence of implementing the mitigation.
- **Disadvantages** – expected negative outcomes as a consequence of implementing the mitigation.
- **Main Benefit** – key advantage expected as the result of implementing the mitigation.
- **Discussion of Schedule** – operational or systematic schedule concerns during mitigation implementation.
- **Discussion of Risk** – operational or systematic risk concerns during mitigation implementation.
- **Assumptions and Calculations** – listing of assumptions regarding facility (size, type, etc.) and/or unit prices; summary table of conceptual cost estimating calculations.



King County — HDR TEAM

MITIGATION CONCEPT SUMMARY

Issue No.	Issue Title	Priority Score
Idea Code	Concept Title	Dev. Team

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☐ Structural	☐ Life Safety
☐ Site Specific (list site below)	☐ MEP	☐ Public Health
Interurban Pump Station	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards (list type below)	☐ Environment
		Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☐ System Downtime
		☐ (Describe here)

Estimated Concept Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☐ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

The existing issue is ...

Impact if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program, there exists the potential that ...

The likely system downtime is expected to be from _______ to _______ months/years.

The waterbodies likely to be affected by failure of this system are _____________.

Description of Mitigation Concept:

The alternative concept would ...

Planning and Engineering Services for The Master Plan for Resiliency & Recovery of King County's Regional Wastewater Treatment Facilities — September 12 and 13, 2017
WTD Resiliency & Recovery Mitigation Workshop
Mitigation Concepts

King County — HDR TEAM

MITIGATION CONCEPT SUMMARY

Advantages:

- Wastewater Operations are improved by ...
- Long-term Impacts are improved by ...
- Maintainability is improved by...
- Constructability is improved by...

Disadvantages:

- Wastewater Operations are degraded by...
- Long-term Impacts are degraded by...
- Maintainability is degraded by...
- Constructability is degraded by...

Main Benefit:

The main benefit of this mitigation concept is to...

Discussion of Schedule Impacts:

This mitigation concept will require...

Discussion of Risk Impacts:

Although this mitigation concept will address basic seismic stability needs...

Assumptions and Calculations:

The initial mitigation concept cost estimate includes the following assumptions:

- Cost Assumption A
- Cost Assumption B
- Cost Assumption C

Table 1: Initial Cost Estimate

[insert – *template for cost estimate under development*]

Planning and Engineering Services for The Master Plan for Resiliency & Recovery of King County's Regional Wastewater Treatment Facilities — September 12 and 13, 2017
WTD Resiliency & Recovery Mitigation Workshop
Mitigation Concepts

Figure 1. Template for Mitigation Concept Summary Sheets Used in September 12/13, 2017 Workshop

3.2 Conceptual Designs

After the Consultant Team and the County presented an overview and discussion of the project technical issues, a facilitator led the group through a brainstorming exercise to develop strategies based on the function of the various types of mitigation needs. These strategies were recorded (Attachment B) as a basis for mitigations developed during the workshop; they helped guide the customization of solutions.

Three conceptual development teams were formed based on hazard type (seismic structural, seismic liquefaction/landslide, and flooding/tsunami/extreme weather) to produce concepts during concurrent work sessions. Several technical experts moved among the teams, providing insight and advice as needed, sharing relevant ideas and findings across the groups, and ensuring a degree of consistency in the completion of the concept mitigation forms. A County representative participated on each of the three teams to provide system information, discuss feasibility of solutions, and to help with concept development and quantities for cost estimating. Background information collected during the course of the project was available for use by workshop participants. County staff helped with “real-time outreach” to coworkers who could provide missing information, validate assumptions, and answer questions, which allowed the teams to continue to progress through the solutions development phase.

The VMS facilitator and assistant facilitator in each group helped team members populate the front-end concept summary templates (title, checkboxes, etc.) and identify advantages, disadvantages, risks, and otherwise complete the concept sheets. A cost estimator assigned to each group worked closely with the technical teams, as described in Section 3.3, Conceptual Cost Estimates. The mitigation concepts were developed collaboratively using the engineering judgment of the development teams with the intent of mitigating deficiencies identified during the screening and limited field assessments described in the Task 200 technical memoranda. Detailed evaluations of the facilities were not performed, nor were detailed design calculations to validate the mitigation concepts. The high-level approach used to develop the mitigation concepts should be considered when making use of the study results and recommendations.

A debrief was held with all workshop participants at the end of the first day to discuss challenges, process improvement, and schedule status. Opportunities were identified for teams to help each other complete the work during the second day of the workshop, and were built into the second day's agenda following the debrief. Another debrief was held at the end of the second day to conclude the workshop and discuss the expected Draft products from the workshop.

3.3 Conceptual Cost Estimates

In accordance with County practice, the King County Estimating Guidelines (dated April 29, 2004) were used to develop the cost estimates. The estimates were prepared consistent with Association for the Advancement of Cost Engineering International (AACE) Recommended Practice RP18R-97 (*Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries*), which is used for projects that are primarily heavy in the manufacturing and production of chemicals, petrochemicals, and hydrocarbon processing. AACE accuracy ranges and summary characteristics for a Class 5 estimate are highlighted in Table 7.

Table 7. Cost Estimate Classification Matrix for Process Industries, AACE 18R-97

	Primary Characteristic	***Secondary Characteristic***		
Estimate Class	**Maturity Level of Project Definition Deliverables (%)**	**End Usage**	**Methodology**	**Expected Accuracy Range**
Class 5	0 to 2	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1 to 15	Study or Feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10 to 40	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30 to 75	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65 to 100	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Per AACE, the expected accuracy range of a Class 5 estimate is minus 20 to 50 percent on the low end, and plus 30 to 100 percent on the high end. These accuracy factors are applied based on professional judgment of the estimator and owner/organizational experience with cost estimating.

3.4 Unit Prices

The mitigation estimates have been prepared using available information (as-built drawings, project descriptions, aerial views) at each location to determine size, type, and elevation of structures both above and below ground. Unit prices were based on using a top-down estimating approach for each location as recommended by the AACE Practice RP18R-97 (as noted above). The estimates were compiled using the following:

- RS Means 2017 Cost Data
- Richardson's 2017 Cost Data
- Adjustments for locations and site access based on professional knowledge
- Known supplier costs such as concrete, gravel, and disposal, based on professional knowledge
- Engineer-supplied estimates based on professional knowledge
- Current/anticipated general contractor markups based on professional knowledge
- Estimator professional knowledge

Unit costs as found in these mitigation estimates represent an Installed Cost, which includes all labor, material, equipment, and general contractor markups to complete a specific scope of work as listed in the estimate. As an example, the unit cost of replacing existing underground pipe would include removal of surface materials such as asphalt pavement, trench excavation, trench shoring, removal of existing pipe, installation of new pipe, installation of pipe bedding, backfill of trench, and restoration of surfacing materials.

Prior to the Task 400 Conceptual Design and Cost Estimating Workshop, the estimators, along with the workshop facilitators, met to determine an estimating approach that would provide continuity of costs and solutions. Table 8 contains the unit cost solutions that were agreed on for use during the Cost Estimating Workshop by the estimating team as the base costs for a range of possible mitigation concept components. This table shows columns for Low, Median, and High Unit Costs for each scope of work. During the workshop, the estimators used these ranges of prices as guidelines. Pricing was adjusted according to the anticipated difficulty of installation, which included such factors as confined space, congested areas, and difficulty of access.

Table 8. Prepared CIP Unit Costs for Use during Conceptual Mitigation Design and Costs Workshop

Item	Unit	Loaded Unit Price		
		Low	Median	High
Structural				
Seismic Upgrade/Retrofit	SF[1]	$50	$75	$100
Foundation Stabilization	SF[2]	$25	$40	$75
Roof Stabilization	SF[3]	$15	$20	$40
Wall Stabilization	SF[4]	$20	$35	$75
Pipe Bracing	EA[5]	$50	$100	$200
Equipment Anchors	EA[6]	$100	$150	$400
Liquefaction				
Ground Stabilization - Geofill	SF[7]	$50	$75	$125
Ground Stabilization - CDF	CF[8]	$40	$50	$80

Item	Unit	Loaded Unit Price		
		Low	Median	High
Ground Stabilization - Compaction Grouting	LF[9]	$188	$375	$480
Ground Stabilization - Jet Grouting	LF[9]	$1,250	$2,500	$3,200
Ground Stabilization - Chemical Grouting	LF[9]	$1,875	$3,750	$4,800
Non-structual Seismic Retrofit				
MEP	SF[10]	$12	$17	$25
Abatement Allowances (HazMat)	SF[10]	$4	$6	$9
Cladding and glazing	SF[10]	$9	$13	$18
Light fixtures	SF[10]	$5	$7	$10
Ceilings	SF[10]	$9	$12	$17
Partitions	SF[10]	$5	$7	$12
Life safety systems	SF[10]	$2	$3	$5
Elevators	SF[10]	$0.5	$1	$2
Extreme Weather				
Waterproofing	SF[11]	$5	$15	$25
Flood Protection	SF[12]	$25	$60	$120
High Wind Bracing	SF[1]	$15	$40	$65
Staging				
Temporary Equipment / Workaround	%[13]	7.2	9.0	11.7
Swing / Staged Operations Space	%[13]	27.8	34.8	45.2
General Soft Costs				
Consultant Fees (Design & Construction)	%[13]	17.3	21.6	28.1
Inspection and Testing	%[13]	10.8	13.5	17.6
Permits	%[13]	2.2	2.7	3.5

[1] Costs based on facility size
[2] Costs based on facility type/size
[3] Costs based on roof area
[4] Costs based on wall area
[5] Costs per bracket, depending on type/size of pipe. Estimate using anticipated LF of piping.
[6] Costs per unit of equipment, depending on type/size.
[7] Costs based on surface area being treated.
[8] Costs based on volume being treated.
[9] Costs based on facility perimeter; Assumes 20 SF per column; Assume 50 ft depth.
[10] Costs based on facility size, escalated from 2015, adjusted for general conditions
[11] Costs based on area to be treated
[12] Costs based on area of improvements for protection, including complexity/type
[13] Percentage of identified construction costs

In addition to the prepared unit costs for capital projects shown in Table 8, the estimating team included a General Contractor Mobilization/Demobilization of 10 percent with all conceptual-level estimates for construction costs.

Anticipating that conceptual mitigation solutions to reduce the identified natural hazard risks might involve further studies and programmatic costs, programmatic assessment direct costs were developed by identifying an order of magnitude level of effort associated with conducting the necessary work. A fully burdened unit rate was then estimated and applied to the level of effort, along with the application of a general contingency allowance for further scope definition of the services to be provided. The additional indirect costs were developed with the aid of the algorithms underlying WTD's Project Information System Management Database (PRISM) program. This is a conceptual estimate and it should be recognized that rates and level of effort identified are subject to further scope definition and the associated level of effort.

During the workshop, the estimating team worked closely with the engineers, concept-specific technical experts, and County staff to determine the anticipated scope of mitigation anticipated for each location. As the mitigation solutions were developed, the estimators defined the conceptual costs using the loaded unit prices and the estimated mitigation quantities with close input from the mitigation team.

3.5 Allowance for Indeterminates

Each cost estimate carries an allowance for indeterminates (AFI), also referred to by the County as a Design Definition Uncertainty Factor. The AFI is not a contingency; rather, it accounts for the cost of known but undefined requirements necessary for a complete and workable project.

Given the highly conceptual nature of the developed mitigation concepts, the estimating team elected to apply a 40 percent AFI (as opposed to the typical 25 percent) to better capture items where the limited workshop duration, high-level nature of the risk assessment, and available facility details precluded a higher confidence range.

The AFI is calculated on the subtotal construction cost, including contractor overhead and profit, less street use permit, construction permits, and fees.

3.6 Indirect and Allied Costs (PRISM)

"The Total Project Costs" in each estimate are derived based on the identified preliminary construction costs. Indirect and allied costs are then factored from the construction costs, based on type of project classification (e.g., conveyance, treatment, pump station). The indirect and allied cost tool used has been developed to mimic WTD's own cost model (PRISM) as it is applied to capital project estimates when deriving a total project cost. The algorithms have been developed based on $6 billion of historical project data to forecast the anticipated expenditures for a given project type and scale, and they were most recently updated January 23, 2017. Using the cost tool allowed for the direct scaling of anticipated indirect costs, primarily WTD staff labor and burden, for the estimation of an order-of-magnitude total cost to the organization for conducting a given programmatic assessment.

The smaller the project, the more indirect/allied costs are applied, recognizing that smaller capital projects take proportionally more owner's costs to deliver than larger capital projects.

Indirect and Allied Model Costs are based on construction costs, AFI, and Change Order Allowance costs. This total is shown in the "Subtotal Primary Construction Amount" on the "1 Page Summary," which can be found in Attachment B.

3.7 Assumptions and Exclusions

The cost estimates included in this document are conceptual in nature and are derived from preliminary mitigation design concepts. Though reasonable care has been taken by all involved to provide the best possible probable cost of construction, the accuracy of the associated cost estimate is dependent on the various underlying assumptions, inclusions, and exclusions described herein. Actual project costs may differ, and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, and other factors that may impact the estimate basis or otherwise affect the project. Conceptual cost estimate accuracy ranges are only assessments based on the methods and data employed in preparing the estimate, and are not a guarantee of actual project costs.

Unless noted otherwise, the following assumptions apply to the conceptual estimates.

- There are no contaminated soils or hazardous materials that would cause extra cost in handling and disposal
- There is no opposition from the public or other government entities
- There will be no stream or waterway improvements other than restoration
- There will be no road improvements other than restoration
- There will be no landscape improvements other than restoration
- There is no escalation of materials and labor to midpoint of construction
- There is no cost estimate for permits (such as street use, construction, trade, and others)

4.0 Results and Recommendations

This section presents the recommended conceptual hazard mitigation projects and their planning-level costs.

4.1 Results and Recommendations

Table 9 presents a summary of the recommended conceptual solutions. These solutions are grouped by implementation priority as determined by the County after reviewing the Consultant Team's project list and considering criticality factors. Attachment D contains the individual Mitigation Concept Summary Sheets that are summarized in this table. Figure 2 shows these projects on the King County WTD service area map.

The project conducted an Equity and Social Justice (ESJ) analysis that is discussed in greater detail in the *Resiliency Recommendations* report for which this technical memorandum is an attachment. This analysis was factored into the project prioritization, reflected in Table 10.

Table 9. Conceptual Design/Programmatic Recommendations and Associated Conceptual Level Costs

Project No.[1]	Priority Rating	Risk Rating	Concept Title	Criticality Factors[2]
Structural/Liquefaction Priority 1				
S-18	1	H	STP Operations Building Nonstructural Seismic Upgrades	E, LS, SD, SC
S-13a	1	H	WPTP Control Building Non-Structural Seismic Upgrades	E, LS, SD, SC
S-1	1	H	STP Influent Pump Station Structural Retrofits	E, LS, SD, FV
S-2	1	H	WPTP Raw Sewage Pump Station Structural Retrofits	E, LS, SD, FV
S-13b	1	H	WPTP Admin/Ops Center Structural Retrofits	E, LS, SD, SC
S-20	1	H	STP Maintenance Building Phase I Structural Retrofits	E, LS, SD
S-19	1	H	STP Santler Building Structural Retrofits	E, LS, SD
SP-1B	1	H	Conduct *ASCE 41* Tier 1/2/3 Seismic Evaluations - STP	E, LS, SD, FV
SP-1A	1	H	Conduct *ASCE 41* Tier 1/2/3 Seismic Evaluations - WPTP	E, LS, SD, FV
SP-1C	1	H	Conduct *ASCE 41* Tier 1/2/3 Seismic Evaluations – Brightwater (BWTP)	E, LS, SD, FV
SP-7	1	H	Programmatic Glass Block Upgrades	LS
Structural/Liquefaction Priority 2				
S-21	2	H	STP Effluent Pump Station Structural Retrofits	E, FV
S-14	2	H	WPTP Maintenance/Effluent Pump Station Structural Retrofits	E, SD
S-23	2	H	STP Digester Equipment Building Structural Retrofits	E, SD, FV
S-5	2	H	Duwamish Pump Station Structural Retrofits	E, SD, FV, ESJ
S-6	2	H	Matthews Park Pump Station Structural Retrofits	E, SD, FV, CR26

Project No.[1]	Priority Rating	Risk Rating	Concept Title	Criticality Factors[2]
S-3	2	H	Interbay Pump Station Structural Retrofits	E, SD, FV, CR23
S-4	2	H	Sweylocken Pump Station Structural Retrofits	E, SD, FV, CR21
Structural/Liquefaction Priority 3				
S-16	3	MH	WPTP Hypo Mixing Structural Retrofits	E, FV
L-6	3	MH	Interurban Pump Station Liquefaction Retrofit	E, ESJ, CR23
S-10	3	MH	30th Avenue Pump Station Structural Retrofits	E, CR23
S-9	3	MH	West Marginal Way Pump Station Structural Retrofits	E, SD, ESJ, CR20
L-4	3	MH	West Marginal Way Pump Station Liquefaction Retrofit	E, SD, ESJ, CR20
L-9	3	MH	Henderson Pump Station Liquefaction Retrofit	E, SD, ESJ, CR20
L-11	3	MH	Rainier Avenue Pump Station Liquefaction Retrofit	E, SD, ESJ, CR19
SP-6	3	H	Programmatic Mechanical-Electrical Upgrades	E, SD
SP-8	3	MH	Develop Seismic Standards for King County Facilities	E, SD, FV
SP-9	3	MH	Develop Seismic Standards for King County Conveyance Facilities	E, SD, FV, CD
Structural/Liquefaction Priority 4				
L-5	4	MH	30th Avenue Pump Station Liquefaction Retrofit	E, SD, CR23
L-3	4	MH	63rd Avenue Pump Station Liquefaction Retrofits	E, SD, CR20
L-2	4	MH	North Creek Pump Station Liquefaction Retrofits	E, PH, SD, FV, CR18
L-8	4	MH	Woodinville Pump Station Liquefaction Retrofit	E, SD, CR19
L-1	4	MH	Belvoir Pump Station Liquefaction Retrofits	E, SD, CR18
L-12	4	M	East Marginal Way Pump Station Liquefaction Retrofit	E, SD, FV, ESJ, CR22
SP-3	4	H	Conduct Additional Pipeline Evaluations	E, CD, SD, FV
LP-2	4	MH	West Point Treatment Plant Facilities Liquefaction Programmatic Assessment	E, SD, FV
LP-3	4	MH	STP Liquefaction Programmatic Assessment	E, SD, FV
SP-4	4	H	Evaluate/Seismic Monitoring Technologies	SD
SP-1D	4	H	Conduct *ASCE 41* Tier 1/2/3 Seismic Evaluations – Offsite Facilities	E, SD, FV
Other Hazards Priority 1				
F-8	1	MH	Woodinville Pump Station Flood Protection Upgrade	E, SD, CR19
F-2	1	H	York Pump Station Flood Protection Upgrade	E, PH, SD, FV, CR23
F-1	1	H	Interurban Pump Station Flood Protection Upgrade	E, ESJ, CR23
FP-2	1	H	Programmatic Flood Risk Evaluations – Offsite Facilities	E, LS, PH, SD, FV
FP-1	1	H	Programmatic Flood Risk Evaluations – STP & BWTP	E, LS, PH, SD, FV

Project No.[1]	Priority Rating	Risk Rating	Concept Title	Criticality Factors[2]
Other Hazards Priority 2				
F-4	2	H	Murray Pump Station Flood Protection Upgrade	E, SD, FV, CR25
F-6	2	H	63rd Avenue Pump Station Flood Protection Upgrade	E, SD, CR23
F-7	2	M	Bellevue Pump Station Flood Protection Upgrade	E, SD, CR19
F-5	2	MH	53rd Avenue Pump Station Flood Protection Upgrade	E, SD, CR19
F-3	2	M	Matthews Park Pump Station Flood Protection Upgrade	E, SD, FV, CR26
Hazards Priority 3				
LS-2	3	MH	S Mercer Pump Station	E, CR17
XP-1	3	M	Tree Trimming/Removal Assessment Programmatic Project	SD

Table Note:

[1] Key:

CD – Consequent Damage
CR(#) – Criticality Rating Aggregate Score
E – Environment
ESJ – Equality and Social Justice
FV – Flow Volume
LS – Life Safety
PH – Public Health
SC – System Control
SD –System Downtime

[2] Key:

F – Flooding
FP – Flooding, Programmatic
L – Liquefaction
LP – Liquefaction, Programmatic
LS – Landslide
S –Structural
SP – Structural, Programmatic
XP – Extreme Weather, Programmatic

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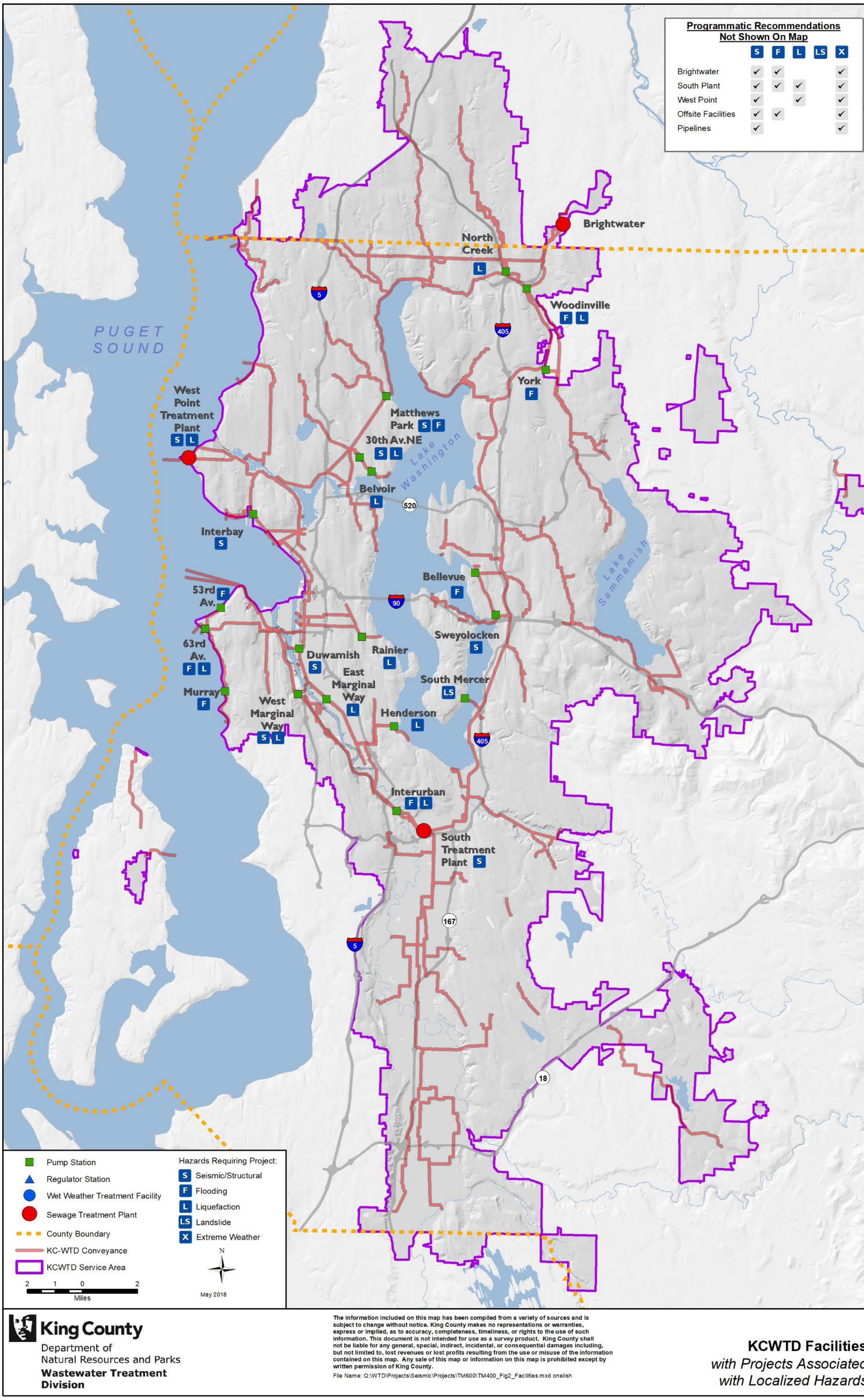

Figure 2. KC WTD Facilities with Projects Associated with Localized Hazards

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Attachment A. Agenda: Task 400.045 Conceptual Mitigation Design and Costs Workshop

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King County

Master Plan for Resiliency and Recovery of King County's Regional Wastewater Treatment Facilities

MEETING AGENDA

Meeting Date: September 12 and 13, 2017

Time: 8:30 am to 5:00 pm

Location: **HDR, 500 108th Avenue NE**
Bellevue, WA 98004

Check-in at Main Desk on 12th Floor
Conference Room: Olympic / Training (11th Floor)
Breakout Rooms: Rainier (11th floor, both days)
Alki (4th Floor, Tuesday)
Northwest (12th Floor, Wednesday)

Meeting Purpose: Task 400.045 Conceptual Mitigation Design and Costs Workshop

Expected Participants:

Team 1 Structural	Team 2 Liquefaction / Landslide	Team 3 Extreme Weather & Flooding
Facilitator: **Greg Brink** Assistant: **Damon Yeutter** Estimator: **Forrest Dill**	Facilitator: **Ashley Carson** Assistant: **Mariah Brink** Estimator: **Eric Benton**	Facilitator: **Eric Trimble** Assistant: **Candice Helsing** Estimator: **Richard Greer**
Erik Bishop, Structural Lead	**Bill Perkins**, Geotechnical and Landslides Lead	**Andrew Henson**, Flooding / Tsunami SME
Kenny O'Neill, Structural SME		**Nathan Clements**, Extreme Weather SME / GIS
		Brian Ward, Stormwater Design
Program Advisors & Subject Matter Experts (SME)		
Teresa Platin, PM	**Don Ballantyne**, Seismic Lead	**Eric Chan**, Electrical / I&C SME
Tom Thramer, Mechanical SME	**Ed Griffenberg**, Wastewater Operations SME	
King County Stakeholders		
Michael Popiwny, PM; **Sonia-Lynn Abenojar**, Deputy PM; **Butch Perry**, Infrastructure Coordinator		

Agenda

Day 1 – Tuesday, September 12, 2017

1. **Welcome & Introductions** (Teresa, Greg) .... 8:30 – 8:45
2. **Workshop Objectives & Process** (Greg) .... 8:45 – 9:00
3. **Team Project Review & Discussion of System Technical Issues** (Don) ... 9:00 – 9:15
   a) Hazards (Seismic, Liquefaction, Landslides, Flooding, Extreme Weather)
   b) Criticality
   c) System-wide Risks
4. **Team Review of Technical Issues and Strategy Identification** (Leads) .. 9:15 – 11:30
   a) Structural Issues Overview / Brainstorming
   b) Liquefaction & Landslide Issues Overview / Brainstorming
   c) Flooding & Extreme Weather Issues Overview / Brainstorming
5. **Team Discussion and Validation of Preliminary Strategies** (All) .... 11:30 – 12:00
6. **LUNCH** (provided in Olympic / Training Conference Room) .... 12:00 – 12:30
7. **Team Development of Concepts & Estimates** (Working Session) .... 12:30 – 4:30
8. **Group Discussion & Status Check** (All) .... 4:30 – 5:00
9. **Adjourn** 5:00

Day 2 – Wednesday, September 13, 2017

1. **Welcome** (Teresa & Greg) .... 8:30 – 8:35
2. **Review and Group Status Check** (Greg) .... 8:35 – 9:00
3. **Team Development of Concepts & Estimates** (Working Session) .... 9:00 – 12:00
4. **LUNCH** (provided in Olympic / Training Conference Room) .... 12:00 – 12:30
5. **Team Development of Concepts & Estimates** (Working Session) .... 12:30 – 3:30
6. **Team Discussion – Status Check & Solution Integration** (All) .... 3:30 – 4:30
7. **Group Discussion & Next Steps** (All) .... 4:30 – 5:00
8. **Adjourn** 5:00

Attachment B.
Group Brainstorming Matrix:
Task 400.045 Conceptual Mitigation Design and Costs Workshop

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King County WTD Task 400.045 Conceptual Mitigation Design and Costs Workshop: Function/Solution Brainstorming Notes

9/12/17 – 9/13/17

Structural & Seismic

Function	Strategy
Retrofit Superstructure	• Z-beams: Remove and replace with new roof system • Fiber wrapping • Shotcrete • Remove and replace walls • Supplemental walls/framing • Add braced frames / moment frames • Exterior frame • Additional connections between members
Retrofit Substructure	• New foundations • Foundations as required to support upgrades • Additional connections between members
Retrofit Mechanical	• Stabilize equipment • Stabilize piping and ductwork • Add isolation valves on main influent and effluent pipelines • Install bypasses to pump stations
Retrofit Electrical	• Stabilize light fixtures • Replace/upgrade light fixtures • Stabilize equipment (transformers, electrical panels, etc.) • Monitoring systems • Ongoing instrumentation inspection program (physical testing of devices) • Electrical inspection program • Bracing and anchoring • Retrofit equipment housing/shelves • Evaluate substations and sub-substations
Retrofit Other Nonstructural	• Provide new anchoring for exterior and interior architectural nonstructural components • Remove and replace exterior and interior architectural nonstructural components • Replace glass block masonry • Brace raised floors in computer rooms • Brace ceilings
Upgrade Facility	• Replace facility
Retrofit In-water Process Systems	• Strengthen baffle walls • Design equipment to be breakaway

Liquefaction & Landslide

Function	Strategy

Stabilize Soil	• Ground improvement
	  ○ Deep dynamic compaction
	  ○ Vibro-compaction
	  ○ Earthquake drain
	  ○ Manhole drain
	  ○ Jet grouting
	  ○ Chemical grouting

Retain Earth	• Avoid area
	• Retention
	  ○ Drilled shaft
	  ○ Stabilized earth walls
	  ○ MSE wall
	  ○ Earth berm
	  ○ Rock fall net
	• Groundwater drainage

Retrofit Substructure	• Structural solution (repair/replace foundation)
Maintain Configuration	• Ball joints • Flexible joint connection • Seismic joints
	•

Extreme Weather & Flooding

Function	Strategy
Maintain Access	• Berms • Onsite drainage • Elevation (new construction) • Provide multiple access routes • Clear access routes • Tree trimming
Remove Water	• Sump pumps • Increase sump pump size/capacity • Drainage (below ground facilities) • Portable pumps • Portable generators (backup fuel)
Protect Facility; Water (structure, equipment, people)	• Water-tight doors • Equipment placement within the facility • Early detection (priority alarmed) / monitoring (sump alarms) • Automatic isolation valves • Berms • Floodwall • Accessibility of instrumentation • Dry pit submersibles • Elevate structure
Protect Facility; Wind (structure, equipment, people)	• Tree trimming/removal • Undergrounding of powerlines • Snow and ice removal • Removal/fastening of light material, tools, debris

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Attachment C.
Conceptual Design and Cost Estimation Workshop Summary Matrix with Notes on Issue Elimination

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Task 400.045 Conceptual Mitigation Issues - ELIMINATED ITEMS ONLY
Summary for Attachment C of Draft Task 400 TM

Category	**Idea Code**	**Issue Title**	**Mitigation Concept Approach**
Structural	S-7a	Belvoir Pump Station Seismic Deficiencies	Removed from structural consideration, as the primary issue facing this facility is related to liquefaction and landslide risk. See L-1.
Structural	S-8a	63rd Avenue Pump Station Seismic Deficiencies	All non-structural retrofit. Place into Programmatic Mechanical-Electrical Upgrades concept (SP-6).
Structural	S-11a	Interurban Pump Station Seismic Deficiencies	The issue is primarily related to liquefaction. Glass block to be added to the Programmatic Glass Block Upgrades concept (SP-7).
Structural	S-12a	Sunset Pump Station Seismic Deficiencies	There is only 1 CMU wall that could fall over at this site. Small dollar project. Michael will ask O&M to brace the wall in question.
Structural	S-15a	WPTP Primary Clarifiers Seismic Deficiencies	Already under design.
Structural	S-17a	WPTP Solids Handling Building Seismic Deficiencies	Did not look at RVs, though did Hazard Analysis. No field-check was conducted. This facility may have been mixed up with something else.
Structural	S-22a	SPTP Forebay Main Station Seismic Deficiencies	No known issues; tank would overflow into exterior spaces.
Structural	S-24a	BWTP Administration Building Seismic Deficiencies	• Evaluate at Level 1 those facilities not visited as a part of our review. • Those where required review at Level 2, and where required review at Level 3. South Plant and West Point; all structures at Brightwater only admin/maintenance building.
Category	**Idea Code**	**Issue Title**	**Mitigation Concept Approach**
Liquefaction	L-10a	South Mercer Pump Station Liquefaction Deficiencies	Boring logs show approximately 10 feet of fill overlying hard glacially overridden soil. This indicates there is little risk of liquefaction for the South Mercer Pump Station or the associated piping. The pump station does not appear to be constructed on liquefaction-susceptible soils; it appears to be founded in competent soil. For this exercise, the review team does not recommend any mitigation action for the pump station.
Category	**Idea Code**	**Issue Title**	**Mitigation Concept Approach**
Flooding	F-10a	Vashon Treatment Plant Flooding Risk	Flood Mitigation – Carnation and Vashon do not need mitigation. Risk / issue not high. Vashon TP was removed as it was determined that the Vashon TP (and Carnation TP) was not as critical in terms of flood risk once it was reviewed by the team (and after consultation with Chad Clay).
Category	**Idea Code**	**Issue Title**	**Mitigation Concept Approach**
Extreme Weather	X-1a	West Point Treatment Plant Extreme Weather Risk	Consolidated mitigation concepts for X-1 to X-8 into a programmatic concept project, XP-1: *Contract arborist to perform programmatic assessment of trees located near all WTD pump stations, regulator gates, wet weather treatment plants, and wastewater treatment facilities (roughly 75 facilities)*
Extreme Weather	X-2a	South Treatment Plant Extreme Weather Risk	Same as X-1
Extreme Weather	X-3a	Alki CSO Plant Extreme Weather Risk	Same as X-1
Extreme Weather	X-4a	Matthews Park Pump station Extreme Weather Risk	Same as X-1
Extreme Weather	X-5a	Carkeek CSO Plant Extreme Weather Risk	Same as X-1
Extreme Weather	X-6a	Boeing Chiller Extreme Weather Risk	Same as X-1
Extreme Weather	X-7a	Brightwater Treatment Plant Extreme Weather Risk	Same as X-1
Extreme Weather	X-8a	Henderson-MLK CSO Facility Extreme Weather Risk	Same as X-1
Category	**Idea Code**	**Issue Title**	**Mitigation Concept Approach**
Landslide	LS-1a	West Point Treatment Plant Landslide Risk	

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Attachment D.
Mitigation Concept Summary Sheets

D-1: Seismic Structural
D-2: Seismic Liquefaction
D-3: Landslides
D-4: Flooding and Tsunamis
D-5: Extreme Weather

Note: The costs represented in Attachment D are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent on the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project.

Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

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D-1: Seismic Structural

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MITIGATION CONCEPT SUMMARY - STRUCTURES

Concept Title

S-1	STP Influent Pump Station Structural Retrofits
S-2	WPTP Raw Sewage Pump Station Structural Retrofits
S-3	Interbay Pump Station Structural Retrofits
S-4	Sweylocken Pump Station Structural Retrofits
S-5	Duwamish Pump Station Structural Retrofits
S-6	Matthews Park Pump Station Structural Retrofits
S-9	West Marginal Way Pump Station Structural Retrofits
S-10	30th Avenue Pump Station Structural Retrofits
S-13A	WPTP Control Building Nonstructural Seismic Upgrades
S-13B	WPTP Admin/Ops Center Structural Retrofits
S-14	WPTP Maintenance/Effluent Pump Station Structural Retrofits
S-16	WPTP Hypo Mixing Structural Retrofits
S-18	STP Division Control Building Nonstructural Seismic Upgrades
S-19	STP Santler Building Structural Retrofits
S-20	STP Maintenance Building Structural Retrofits
S-21	STP Effluent Pump Station Structural Retrofits
S-23	STP Digester Equipment Building Structural Retrofits
SP-1A	Conduct ASCE 41 Tier 1/2/3 Seismic Evaluations- WPTP
SP-1B	Conduct ASCE 41 Tier 1/2/3 Seismic Evaluations- STP
SP-1C	Conduct ASCE 41 Tier 1/2 Seismic Evaluations- Brightwater
SP-1D	Conduct ASCE 41 Tier 1/2/3 Seismic Evaluations – Off-Site Facilities
SP-3	Conduct Additional Pipeline Assessments
SP-4	Evaluate Seismic Monitoring Technologies
SP-6	Conduct Programmatic Mechanical-Electrical Evaluations for WWTPs, CSOs and offsite facilities
SP-7	Programmatic Glass Block Upgrades
SP-8	Seismic Standards for KC Facilities
SP-9	Seismic Standards for Conveyance Pipelines

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MITIGATION CONCEPT SUMMARY - STRUCTURES

S-1 STP Influent Pump Station Structural Retrofits

Issue No.	Issue Title	Priority Score
S-1	STP Influent Pump Station Seismic Deficiencies	H
Idea Code	**Concept Title**	**Dev. Team**
S-1a	STP Influent Pump Station Structural Retrofits	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
South Treatment Plant	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☒ Flow Volume
		☒ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☒ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

This facility is at risk for structural failure or roof collapse which is likely to result in the facility becoming inoperable. Mechanical and electrical system damage may also cause the facility to become inoperable.

Influent pump stations are the high flow area of process.

Risk if not Addressed:

If the roof collapses, all flow to STP would be cut off, potentially resulting in impacts to life safety.

SCADA system backup servers are in this facility and are not adequately secured or anchored down.

In the event of a partial roof collapse, the facility would be considered uninhabitable, thereby rendering the facility inoperable. If the facility is inoperable, the inflow would not be pumped to South Plant, rendering the treatment facility ineffective and resulting in significant back-up of raw sewage.

This facility houses critical operations and if it were rendered inoperable it would not be able to provide key services.

There are two separate durations discussed in the worksheet:

1. Retrofit project durations: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.
2. Downtime durations: the duration of time require to restore the facility to its pre-earthquake functionality.

The likely system downtime is expected to last 1-3 years, particularly if the roof collapses on operational equipment. Given the significant flow rate through the facility, is expected to require a replacement of equipment, rather than a bypass, in order to restore operations. Therefore, since many of the components and equipment in this facility have long procurement lead-times and the repair of a significant damage/collapse of the structure could be extensive, the potential downtime is expected to be significant.

The waterbody likely to be affected by failure of this system is the Green River.

Description of Mitigation Concept:

The mitigation concept would involve:

- Seismic retrofit upgrades
  - Selective demolition of the z-beams and replacement with a new roof framing system
  - Seismic upgrading of deficient precast concrete cladding (removal, repair, replacement)
  - Upgrades to the lower level diaphragm piece (to precast roof panels) via a topping slab or reinforcement
  - Upgrades to some of the columns that support the lower level roof
- Major nonstructural upgrades include, but are not limited to:
  - Backup server room improvements
  - Suspended ceilings
  - Canopies
  - General mechanical/electrical upgrades (anchoring, bracing, restraining)

Advantages:

- Maintains capability for remote facility monitoring and redundant facility control (given that a backup server room is located in this facility)
- Wastewater operations are maintained (inflow maintained to treatment plant)
- Long-term impacts are improved by reducing the probability of collapse
- Post-earthquake damage is mitigated

Disadvantages:

- Given that this facility cannot be shut down during construction, negative impacts to the cost and schedule for construction are anticipated as well as impacts to current operations of this facility.
- May lose full capacity of the facility as some elements will need to come offline during construction

MITIGATION CONCEPT SUMMARY - STRUCTURES

Main Benefit:

The main benefit of this mitigation concept is to provide structural retrofits and additional stability to the pipelines that convey flows to and from the STP, while addressing the stability of the structure and pipelines in the direct vicinity of the pump station itself.

Discussion of Schedule:

This mitigation concept will require 1 to 3 years for design and construction. This facility will need to remain operational during construction.

Discussion of Risk:

This mitigation concept may impact operations at the facility.

The ultimate performance objectives of the concept design will need to be further clarified during project scoping.

Figure 1. STP Influent Pump Station – Exterior View

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 2. STP Influent Pump Station – Interior View of Z-Beams

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Z-beam roof area is 2,900 square feet
- Remaining roof area is 6,600 square feet
- Total roof area is 9,500 square feet; unit price of $204/SF used for estimating purposes
- Assumed 20 feet high, 10 feet clad

King County

HDR TEAM

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 1. Initial Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	SPTP Influent Pump Station Structural Retrofits			**Date:**	9/13/2017
Location:				**Estimator:**	Forrest Dill
Description:				**Idea Code:**	S-1a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Roof Z-Beam Replacement and Reroof	2,900	SF	$ 200	$ 580,000
2	Replace Precast Cladding with Metal Siding	5,320	SF	$ 60	$ 319,200
3	Add Topping Slab on Level Diaphragm	6,600	SF	$ 4	$ 24,444
4	Columns Seismic Upgrade	30	EA	$ 5,000	$ 150,000
5	Brace Canopies	1,000	SF	$ 12	$ 12,000
6	Brace Suspended Ceilings	6,600	SF	$ 17	$ 112,200
7	SCADA System Seismic Upgrade	1,000	SF	$ 17	$ 17,000
8	Maintain Building Operations	1,214,844	SF	45%	$ 549,259
9	Mobilization / Demobilization (10%)	10	%	$ 176,410	$ 176,410
				Subtotal Construction Costs	***$ 1,940,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 776,000
				Construction Change Order Allowance	$ 271,600
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 2,987,600***
				Street Use Permit	$ -
				Construction Sales Tax	$ 301,748
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 3,289,348***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 5,975
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 3,295,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 1,181,203
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 19,788
				Right-of-Way	$ 38,800
				Misc. Service & Materials	$ 53,777
				Non-WTD Support	$ 25,395
				WTD Staff Labor	$ 483,658
				Subtotal Non-Construction Costs	***$ 1,802,620***
				Project Contingency	$ 1,541,740
				Initiatives	$ 41,192
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 3,386,000***
				TOTAL PROJECT COST	***$ 6,681,000***

MITIGATION CONCEPT SUMMARY - STRUCTURES

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

S-2 WPTP Raw Sewage Pump Station Structural Retrofits

Issue No.	Issue Title	Risk Rating
S-2	WPTP Raw Sewage Pump Station Seismic Deficiencies	H
Idea Code	**Concept Title**	**Dev. Team**
S-2a	WPTP Raw Sewage Pump Station Structural Retrofits	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
West Point Treatment Plant	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☒ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☐ 1 to 3 years
	☒ > $10M		☒ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

Seismic deficiencies have been identified, which may cause structural failure or roof collapse that could result in the facility no longer being operational. Mechanical and electrical system damage may also lead to the facility being inoperable.

The z-beam roof system, moment frame, tilt-up walls, precast cladding system, and diaphragm are structurally deficient. Note that there are also load path issues.

Multiple nonstructural components require retrofit.

Risk if not Addressed:

The building lacks adequate seismic design, which if not addressed, may result in collapse during a seismic event. If the facility is inoperable, the inflow would not be pumped to West Point Treatment Plant, rendering the treatment facility ineffective and resulting in significant back-up of raw sewage. Failure of this facility may result in temporary overflows requiring bypass to the Puget Sound.

MITIGATION CONCEPT SUMMARY - STRUCTURES

There are two separate durations discussed in the worksheet:

1. Retrofit project durations: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.
2. Downtime durations: the duration of time require to restore the facility to its pre-earthquake functionality.

The likely system downtime is expected to last 1-3 years, particularly if the roof collapses on operational equipment. Given the significant flow rate through the facility, the repair is expected to require a replacement of equipment, rather than a bypass, in order to restore operations. Therefore, since many of the components and equipment in this facility have long procurement lead-times and the repair of a significant damage/collapse of the structure could be extensive, the potential downtime is expected to be significant.

The waterbody affected by failure of this system is Puget Sound.

Description of Mitigation Concept:

- Structural seismic retrofit
  - Selective demolition of the z-beams and replacement with a new roof framing system
  - The precast concrete cladding is currently deficient and require seismic upgrading (removal, repair, replacement)
  - Lower level diaphragm piece requires upgrades
  - The moment frame requires upgrades
  - The lower area of the facility requires moment frame retrofit, diaphragm strengthening
  - Tilt-up wall anchorage to foundation
  - Connections between panels and diaphragm
  - May require strong backs and wall panels for out of plane
- Specific major nonstructural upgrades include, but are not limited to
  - Suspended ceilings
  - CMU in-fill wall retrofit
- Further investigation of potential replacement strategies for this structure should be evaluated
- The ultimate performance objectives of the concept design will need to be further clarified during project scoping

Advantages:

- Wastewater operations are maintained (inflow maintained to treatment plant)
- Long-term impacts are improved by reducing the probability of collapse
- Post-earthquake damage is mitigated

Disadvantages:

- Given that this facility cannot be shut down during construction, impacts to the cost and schedule for construction are anticipated as well as impacts to current operations of this facility.

- May lose full capacity of the facility as some elements will need to come offline during construction

Main Benefit:

The main benefit of this mitigation concept is to provide structural retrofits to allow conveyance of flows for treatment to WPTP. This facility is a critical element of the primary treatment functions of WPTP.

Discussion of Schedule:

This mitigation concept will require a 3 to 5-year design and construction duration. This facility will need to remain operation during construction.

Discussion of Risk:

This mitigation concept may impact operations at the facility. It is not immediately clear that seismic retrofit is the best option relative to facility replacement.

Figure 3. Exterior View of Raw Water Pump Station

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 4. Interior View of Raw Water Pump Station, Including Z-Beams and Weak Story

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Z-beam roof area is 3,350 square feet
- Remaining roof area is 10,200 square feet
- Total roof area is 13,500 square feet; unit price assumption is $244/SF
- Total cladding area is 10,000 square feet

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 2: Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	WPTP Raw Sewage Pump Station Structural Retrofits			**Date:**	9/13/2017
Location:				**Estimator:**	Forrest Dill
Description:				**Idea Code:**	S-2a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Demo and Replace Z Beam Roof System	3,325	SF	$ 200	$ 665,000
2	Replace Precast Cladding	10,000	SF	$ 60	$ 600,000
3	Add Tilt Up Panel Anchors to Floor	87	EA	$ 500	$ 43,333
4	Add Tilt Up Panel-Panel Ties	87	EA	$ 750	$ 65,000
5	Add Tilt Up Panel to Roof Ties	87	EA	$ 1,000	$ 86,667
6	Adding Strongbacks Across Tilt Up Panels	87	EA	$ 600	$ 52,000
7	Strengthen Moment Frame - Add Shear 8" Concrete Walls	6,912	SF	$ 69	$ 477,867
8	Upgrade Low Diaphragms - Topping Slab	10,220	SF	$ 7	$ 75,704
9	Maintain Building Operations	2,065,570	%	45%	$ 933,892
10	Mobilization / Demobilization (10%)	10	%	$ 299,946	$ 299,946
				Subtotal Construction Costs	***$ 3,300,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 1,320,000
				Construction Change Order Allowance	$ 462,000
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 5,082,000***
				Street Use Permit	$ -
				Construction Sales Tax	$ 513,282
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 5,595,282***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 10,164
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 5,605,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 1,825,279
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 33,660
				Right-of-Way	$ 66,000
				Misc. Service & Materials	$ 91,476
				Non-WTD Support	$ 43,197
				WTD Staff Labor	$ 761,215
				Subtotal Non-Construction Costs	***$ 2,820,827***
				Project Contingency	$ 2,548,902
				Initiatives	$ 70,068
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 5,440,000***
				TOTAL PROJECT COST	***$ 11,045,000***

Notes:
1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.
2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

S-3 Interbay Pump Station Structural Retrofits

Issue No.	Issue Title	Risk Rating
S-3	Interbay Pump Station Seismic Deficiencies	H
Idea Code	**Concept Title**	**Dev. Team**
S-3a	Interbay Pump Station Structural Retrofits	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific	☐ MEP	☐ Public Health
Interbay Pump Station	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☒ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☐ 1 to 3 years
	☐ > $10M		☒ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

The moment frame, tilt-up walls, precast cladding system, and diaphragm are structurally deficient. Structural failure or roof collapse could result in the facility no longer being operational. There are also load path issues, and multiple nonstructural components require retrofit, including ceilings and veneer.

This pump station was recently mechanically retrofitted in 2015, however seismic upgrades were not completed. A limited seismic upgrade was completed in the nineties.

Risk if not Addressed:

This is among the largest pump stations by flow volume to WPTP. Structural damage to this facility from a seismic event could lead to the facility becoming inoperable. If the facility is inoperable, the significant flow to this facility would not be pumped to West Point Treatment Plant, rendering the pump station facility ineffective and resulting in significant back-up of raw sewage. In the event of a pump failure, unpermitted releases of wastewater would likely enter the Duwamish River and Puget Sound.

MITIGATION CONCEPT SUMMARY - STRUCTURES

There are two separate durations discussed in the worksheet:

- Retrofit project durations: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.
- Downtime durations: the duration of time require to restore the facility to its pre-earthquake functionality.

The following comment has been updated:

The likely system downtime is expected to last 2-4 years if this building is severely damaged or collapses. Given the significant flow rate through the facility, the repair is expected to require a replacement of equipment, rather than a bypass, in order to restore operations. Therefore, since many of the components and equipment in this facility have long procurement lead-times and the repair of a significant damage/collapse of the structure could be extensive, the potential downtime is expected to be significant.

The waterbodies likely to be affected by failure of this system is the Duwamish River and Puget Sound.

Description of Mitigation Concept:

- Structural seismic retrofit:
  - The precast concrete cladding is currently deficient and require seismic upgrading (removal, repair, replacement)
  - The moment frame requires upgrades
  - Add additional shear walls
  - Roof diaphragm upgrades
- Specific major nonstructural upgrades include, but are not limited to:
  - Ceilings and veneer
- Further investigation of potential replacement strategies for this structure should be evaluated, although the below grade structure does not have identified deficiencies, so it may be possible to only demolish and replace the above grade structure
- The ultimate performance objectives of the concept design will need to be further clarified during project scoping

Advantages:

- Wastewater operations are improved by maintaining pumping operations, avoiding the unpermitted release of untreated wastewater into Puget Sound
- Long-term impacts are improved by reducing the probability of collapse
- Post-earthquake damage is mitigated

Disadvantages:

- Given that this facility cannot be shut down during construction, negative impacts to the cost and schedule for construction are anticipated as well as impacts to current operations of this facility.
- May lose full capacity of the facility as some elements will need to come offline during construction

MITIGATION CONCEPT SUMMARY - STRUCTURES

Main Benefit:

The main benefit of this mitigation concept is to provide structural retrofits to allow conveyance of flows for treatment to WPTP. This is among the largest pump stations by flow volume to WPTP.

Discussion of Schedule:

This mitigation concept will require a 2 to 4-year design and construction duration. This facility will need to remain operational during construction.

Discussion of Risk:

This mitigation concept may impact operations at the facility.

The scope of previous retrofits is unclear, and additional investigation will be required to determine the scope of the proposed retrofit.

Figure 5. Exterior View of Interbay Pump Station

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 6. Interior View of Interbay Pump Station

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Total building foot print is 2,800 square feet
- High-bay area is 1,300 square feet
- Unit price used for estimating purposes is $216/SF

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 3. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Interbay Pump Station Structural Retrofits			**Date:**	11/14/2017
Location:				**Estimator:**	Forrest Dill
Description:				**Idea Code:**	S-3a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Replace Precast Cladding	5,496	SF	$ 60	$ 329,760
2	Strengthen Moment Frame - Add Shear 8" Concrete Walls	1,080	SF	$ 69	$ 74,667
3	Add Shear Walls	1,728	SF	$ 69	$ 119,467
4	Upgrade Roof Diaphragms	1,260	SF	$ 50	$ 63,000
5	Brace Ceilings	2,784	SF	$ 15	$ 41,760
6	Brace Veneer	2,640	SF	$ 20	$ 52,800
7	Maintain Operations	681,453	%	45%	$ 308,101
8	Mobilization / Demobilization (10%)	10	%	$ 98,955.40	$ 98,955.40
				Subtotal Construction Costs	***$ 1,090,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 436,000
				Construction Change Order Allowance	$ 152,600
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 1,678,600***
				Street Use Permit	$ -
				Construction Sales Tax	$ 169,539
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 1,848,139***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 3,357
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 1,851,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 943,992
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 19,511
				Right-of-Way	$ 21,800
				Misc. Service & Materials	$ 13,429
				Non-WTD Support	$ 14,268
				WTD Staff Labor	$ 309,843
				Subtotal Non-Construction Costs	***$ 1,322,843***
				Project Contingency	$ 959,245
				Initiatives	$ 23,144
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 2,305,000***
				TOTAL PROJECT COST	***$ 4,157,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

S-4 Sweylocken Pump Station Structural Retrofits

Issue No.	Issue Title	Risk Rating
S-4	Sweylocken Pump Station Seismic Deficiencies	H
Idea Code	**Concept Title**	**Dev. Team**
S-4a	Sweylocken Pump Station Structural Retrofits	Team 1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
Sweylocken Pump Station	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☒ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☒ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

There are existing seismic deficiencies associated with components at the Sweylocken Pump Station. Issues recommended for structural retrofit include the unclear load path, diaphragm cross-ties and appendages.

Risk if not Addressed:

Structural damage to this facility from a seismic event could lead to the facility becoming damaged. If the facility is inoperable, the flow to this facility would not be pumped to South Treatment Plant, rendering the pump station facility ineffective and resulting in significant back-up of raw sewage. In the event of a pump failure, unpermitted releases of wastewater would likely enter the Mercer Slough and Lake Washington.

There are two separate durations discussed in the worksheet:

- Retrofit project durations: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.

- Downtime durations: the duration of time require to restore the facility to its pre-earthquake functionality.

The likely system downtime is expected to last 3-12 months if this building is severely damaged or collapses. Since many of the components and equipment in this facility have long procurement lead-times and the repair of a significant damage/collapse of the structure could be extensive, the potential downtime is expected to be significant. However, it is expected that the structural damage would not render the pumps ineffective, although it would require clean-up to access the pumps.

The waterbodies likely to be affected by failure of this system are the Mercer Slough and Lake Washington.

Description of Mitigation Concept:

- Structural seismic retrofit:
  - Moment frame connections
  - Strengthening diaphragms and connections
- The ultimate performance objectives of the concept design will need to be further clarified during project scoping; additional clarification may result in the elimination of this project

Advantages:

- Wastewater operations are improved by maintaining pumping operations, thereby avoiding the unpermitted release of untreated wastewater into Mercer Slough and Lake Washington
- Long-term impacts are improved by reducing the probability of damage
- Post-earthquake damage is mitigated

Disadvantages:

- Given that this facility cannot be shut down during construction, impacts to the cost and schedule for construction are anticipated as well as impacts to current operations of this facility.

Main Benefit:

The main benefit of this mitigation concept is to provide structural retrofits to allow conveyance of flows for treatment to STP.

Discussion of Schedule:

This mitigation concept will require a 6 to 18-month design and construction duration. This facility will need to remain operational during construction.

Discussion of Risk:

This mitigation concept may impact operations at the facility.

This is in a liquefaction zone, which should be addressed as part of the larger retrofit project. Reference mitigation concept LP-1.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 7. Exterior View of Sweyolocked Pump Station

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 8. Interior View of Sweyolocked Pump Station

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 3. Non-Moment Frame (Shear Tab) Connection in Transverse Direction

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Assume 1,600 square feet
- Unit pricing used for estimating purposes was $69/SF
- Assume limited temporary staging and work-arounds

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 4. Concept-Level Cost Estimate

Estimate - AACEI Class 5						
Concept Title:	Sweylocken Pump Station Structural Retrofits			**Date:**		9/13/2017
Location:				**Estimator:**		Forrest Dill
Description:				**Idea Code:**		S-4a
DIRECT: SUBTOTAL CONSTRUCTION COSTS						
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**		**Item Cost**
1	Seismic Brace Structural Frame	1,600	SF	$ 50	$	80,000
2	Maintain Building Operations	80,000	%	28%	$	22,258
3	Mobilization / Demobilization (10%)	10	%	$ 10,226	$	10,225.84
				Subtotal Construction Costs	***$***	***110,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS						
				Mitigation Construction Contracts	$	-
				Allowance for Indeterminates (Design Allowance)	$	44,000
				Construction Change Order Allowance	$	15,400
				Material Pricing Uncertainty Allowance	$	-
				Subtotal Primary Construction Amount	***$***	***169,400***
				Street Use Permit	$	-
				Construction Sales Tax	$	17,109
				Owner Furnished Equipment	$	-
				Outside Agency Construction	$	-
				Subtotal KC Contribution to Construction	***$***	***186,509***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES						
				KC/WTD Direct Implementation	$	-
				Misc. Capital Costs	$	339
				TOTAL DIRECT CONSTRUCTION COSTS	***$***	***187,000***
INDIRECT: NON-CONSTRUCTION COSTS						
				Design and Construction Consulting	$	134,566
				Other Consulting Services	$	-
				Permitting & Other Agency Support	$	1,969
				Right-of-Way	$	2,200
				Misc. Service & Materials	$	1,355
				Non-WTD Support	$	1,440
				WTD Staff Labor	$	46,343
				Subtotal Non-Construction Costs	***$***	***187,873***
				Project Contingency	$	113,117
				Initiatives	$	2,336
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$***	***303,000***
				TOTAL PROJECT COST	***$***	***490,000***

Notes:
1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.
2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimate.

MITIGATION CONCEPT SUMMARY - STRUCTURES

S-5 Duwamish Pump Station Structural Retrofits

Issue No.	Issue Title	Risk Ratings
S-5	Duwamish Pump Station Seismic Deficiencies	H
Idea Code	**Concept Title**	**Dev. Team**
S-5a	Duwamish Pump Station Structural Retrofits	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
Duwamish Pump Station	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☒ Flow Volume
		☒ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☐ 1 to 3 years
	☐ > $10M		☒ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

Existing seismic deficiencies could lead to structural failure or roof collapse, resulting in the facility no longer being operational. A limited seismic upgrade was completed for this facility in the mid-1990s.

The moment frame, precast cladding system, and diaphragm are structurally deficient. Note that there are also load path issues, and multiple nonstructural components require retrofit, including ceilings and veneer.

Risk if not Addressed:

Structural damage to this facility from a seismic event could lead to the facility collapsing and/or becoming inoperable due to severe damage. If the facility is inoperable, the significant flow to this facility would not be pumped to West Point Treatment Plant, rendering the pump station facility ineffective and resulting in significant back-up of raw sewage. In the event of a pump failure, unpermitted releases of wastewater would likely enter the Duwamish River.

MITIGATION CONCEPT SUMMARY - STRUCTURES

There are two separate durations discussed in the worksheet:

- Retrofit project durations: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.
- Downtime durations: the duration of time require to restore the facility to its pre-earthquake functionality.

The likely system downtime is expected to last 2-4 years if this building is severely damaged or collapses. Given the significant flow rate through the facility, is expected to require a replacement of equipment, rather than a bypass, in order to restore operations. Therefore, since many of the components and equipment in this facility have long procurement lead-times and the repair of a significant damage/collapse of the structure could be extensive, the potential downtime is expected to be significant.

The Duwamish River would be affected by failure of this system.

Description of Mitigation Concept:

- Structural seismic retrofit:
    - The precast concrete cladding is currently deficient and require seismic upgrading (removal, repair, replacement)
    - The moment frame requires upgrades
    - Add additional shear walls
    - Roof diaphragm upgrades
    - Seismically upgrade lower roof addition
- Specific major nonstructural upgrades include, but are not limited to:
    - Ceilings and veneer
- Further investigation of potential replacement strategies for this structure should be evaluated, although the below grade structure does not have identified deficiencies, so it may be possible to only demolish and replace the above grade structure
- The ultimate performance objectives of the concept design will need to be further clarified during project scoping

Advantages:

- Wastewater operations are improved by maintaining pumping operations, thereby avoiding the unpermitted release of untreated wastewater into Duwamish River
- Long-term impacts are improved by reducing the probability of collapse
- Post-earthquake damage is mitigated

Disadvantages:

- Given that this facility cannot be shut down during construction, impacts to the cost and schedule for construction are anticipated as well as impacts to current operations of this facility.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Main Benefit:

The main benefit of this mitigation concept is to provide structural retrofits to allow conveyance of flows for treatment to WPTP.

Discussion of Schedule:

This mitigation concept will require a 2 to 4-year design and construction duration. This facility will need to remain operational during construction.

Discussion of Risk:

This mitigation concept may impact operations at the facility.

This is in a liquefaction zone, which should be addressed as part of the larger retrofit project. Reference mitigation concept LP-1.

Figure 9. Exterior View of Duwamish Pump Station

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 10. Interior View of Duwamish Pump Station, including Limited "Bolts Plus" Seismic Upgrade of Non-Ductile Moment Frame Column

MITIGATION CONCEPT SUMMARY - STRUCTURES

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Building total roof area is 2,992 square feet
- High bay roof area is 1,536 square feet
- The building addition roof area is 1,632 square feet

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 5. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Duwamish Pump Station Structural Retrofits			**Date:**	9/13/2017
Location:				**Estimator:**	Forrest Dill
Description:				**Idea Code:**	S-5a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Replace Precast Cladding	3,564	SF	$ 60	$ 213,840
2	Strengthen Moment Frame - Add Shear 8" Concrete Walls	968	SF	$ 69	$ 66,923
3	Add Shear Walls	1,496	SF	$ 69	$ 103,427
4	Upgrade Roof Diaphragms	1,536	SF	$ 50	$ 76,800
5	Brace Ceilings	1,456	SF	$ 12	$ 17,472
6	Brace Veneer	1,872	SF	$ 13	$ 23,400
7	Seismically Upgrade the New Addition Building	1,632	SF	$ 75	$ 122,400
8	Maintain Operations	624,263	%	45%	$ 282,243
9	Mobilization / Demobilization (10%)	10	%	$ 90,650.60	$ 90,651
				Subtotal Construction Costs	***$ 1,000,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 400,000
				Construction Change Order Allowance	$ 140,000
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 1,540,000***
				Street Use Permit	$ -
				Construction Sales Tax	$ 155,540
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 1,695,540***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 3,080
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 1,699,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 877,259
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 17,900
				Right-of-Way	$ 20,000
				Misc. Service & Materials	$ 12,320
				Non-WTD Support	$ 13,090
				WTD Staff Labor	$ 288,181
				Subtotal Non-Construction Costs	***$ 1,228,750***
				Project Contingency	$ 884,581
				Initiatives	$ 21,233
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 2,135,000***
				TOTAL PROJECT COST	***$ 3,833,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

S-6 Matthews Park Pump Station Structural Retrofits

Issue No.	Issue Title	Risk Rating
S-6	**Matthews Park Pump Station Seismic Deficiencies**	H
Idea Code	**Concept Title**	**Dev. Team**
S-6a	**Matthews Park Pump Station Structural Retrofits**	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below) Matthews Park Pump Station	☐ MEP	☐ Public Health
	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☒ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☒ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

There could be a structural failure or roof collapse at this location that could result in the facility no longer being operational. Note that there are load path issues.

Multiple nonstructural components require retrofit, including ceilings, veneer, partition walls, and facility contents.

Risk if not Addressed:

This is among the largest pump stations by flow volume to WPTP. Structural damage to this facility from a seismic event could lead to the facility becoming inoperable. If the facility is inoperable, the significant flow to this facility would not be pumped to West Point Treatment Plant, rendering the pump station facility ineffective and resulting in significant back-up of raw sewage. In the event of a pump failure, unpermitted releases of wastewater would likely enter Lake Washington.

MITIGATION CONCEPT SUMMARY - STRUCTURES

There are two separate durations discussed in the worksheet:

- Retrofit project durations: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.
- Downtime durations: the duration of time require to restore the facility to its pre-earthquake functionality.st 1-3 years if this building is severely damaged or collapses.

The likely system downtime is expected to last 1-3 years if this facility is severely damaged or collapses. Given the significant flow rate through the facility, is expected to require a replacement of equipment, rather than a bypass, in order to restore operations. Therefore, since many of the components and equipment in this facility have long procurement lead-times and the repair of a significant damage/collapse of the structure could be extensive, the potential downtime is expected to be significant.

Lake Washington would be affected by failure of this system.

Description of Mitigation Concept:

- Structural seismic retrofit:
  - Remove and replace existing precast roof system, including the clerestory wall-to-roof element (approximately 3-5 feet in height)
  - Strengthening shear walls and coupling beams
- Specific major nonstructural upgrades include, but are not limited to:
  - Ceilings, veneer, and partition walls
- The ultimate performance objectives of the concept design will need to be further clarified during project scoping

Advantages:

- Wastewater operations are improved by maintaining pumping operations, thereby avoiding the unpermitted release of untreated wastewater into Lake Washington
- Long-term impacts are improved by reducing the probability of collapse
- Post-earthquake damage is mitigated

Disadvantages:

- Given that this facility cannot be shut down during construction, impacts to the cost and schedule for construction are anticipated as well as impacts to current operations of this facility.
- May lose full capacity of the facility as some elements will need to come offline during construction

Main Benefit:

The main benefit of this mitigation concept is to provide structural retrofits to allow conveyance of flows for treatment to WPTP. This is among the largest pump stations by flow volume to WPTP.

Discussion of Schedule:

This mitigation concept will require a 1 to 3-year design and construction duration. This facility will need to remain operational during construction.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Discussion of Risk:

This mitigation concept may impact operations at the facility.

This assumes the adjacent electrical building on site meets current seismic requirements due to its recent construction.

Figure 11. Exterior View of Matthews Park Pump Station

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 12. Exterior View of Matthews Park Pump Station

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 3. Interior View of Matthews Park Pump Station, Including Interveted-V Roof System and Pre-Cast Concrete Weak Story Framing

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Building area is 10,100 square feet
- High bay roof area is 5,300 square feet
- Total roof area is the same as building area
- Total high bay roof replacement
- Unit price used for cost estimating purposes: $288/SF

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 6. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Matthews Park Pump Station Structural Retrofits			**Date:**	9/13/2017
Location:				**Estimator:**	Forrest Dill
Description:				**Idea Code:**	S-6a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Roof Z-Beam Replacement and Reroof	5,300	SF	$ 200	$ 1,060,000
2	Temporay Roof	5,300	SF	$ 15	$ 79,500
3	Replace Clear Story Wall with 8" Concrete Wall	2,142	SF	$ 84	$ 180,219
4	Strengthen Existing Walls and Coupling Beams	4,896	SF	$ 44	$ 217,600
5	Upgrade Roof Diaphragms	5,300	SF	$ 50	$ 265,000
6	Brace Ceilings	4,800	SF	$ 12	$ 57,600
7	Brace Veneer	4,896	SF	$ 13	$ 61,200
8	Maintain Operations	1,921,119	%	45%	$ 868,582
9	Mobilization / Demobilization (10%)	10	%	$ 278,970.06	$ 278,970
				Subtotal Construction Costs	***$ 3,070,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 1,228,000
				Construction Change Order Allowance	$ 429,800
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 4,727,800***
				Street Use Permit	$ -
				Construction Sales Tax	$ 477,508
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 5,205,308***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 9,456
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 5,215,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 2,279,628
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 54,953
				Right-of-Way	$ 61,400
				Misc. Service & Materials	$ 37,822
				Non-WTD Support	$ 40,186
				WTD Staff Labor	$ 745,268
				Subtotal Non-Construction Costs	***$ 3,219,258***
				Project Contingency	$ 2,549,762
				Initiatives	$ 65,185
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 5,834,000***
				TOTAL PROJECT COST	***$ 11,049,000***

Notes:
1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.
2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimate.

MITIGATION CONCEPT SUMMARY - STRUCTURES

S-9 West Marginal Way Pump Station Structural Retrofits

Issue No.	Issue Title	Risk Rating
S-9	West Marginal Way Pump Station Seismic Deficiencies	MH
Idea Code	**Concept Title**	**Dev. Team**
S-9a	West Marginal Way Pump Station Structural Retrofits	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below) West Marginal Way Pump Station	☐ MEP	☐ Public Health
	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☐ Flow Volume
		☒ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☒ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

The pump station was built in an era with seismic design standards that do not comply with modern requirements. The ground level diaphragm has a large opening which may be seismically deficient.

There are no identified deficiencies for the above grade structure – further analysis will indicate any seismic structural retrofit that may be required.

Risk if not Addressed:

If not addressed, this facility may be damaged in a seismic event beyond what is acceptable for continued stability and operations. Catastrophic collapse is unlikely. It is expected that this moderate level of damage make render the facility inoperable until shoring and repairs have been implemented.

There are two separate durations discussed in the worksheet:

- Retrofit project durations: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.

- Downtime durations: the duration of time require to restore the facility to its pre-earthquake functionality.

The likely system downtime is expected to last 6 to 12-months if this building is severely damaged. It is expected that a moderate level of damage may render the facility inoperable until shoring and repairs have been implemented to provide access to operate the equipment inside.

No waterbodies are likely to be affected by failure of this system.

Description of Mitigation Concept:

The mitigation concept would include structural retrofits, such as strengthening of the ground level diaphragm and above grade wall.

The ultimate performance objectives of the concept design will need to be further clarified during project scoping

Advantages:

- Wastewater operations are improved by maintaining pumping operations
- Long-term impacts are improved by reducing the probability of severe damage
- Post-earthquake damage is mitigated

Disadvantages:

- Given that this facility cannot be shut down during construction, minor impacts to the cost and schedule for construction are anticipated as well as impacts to current operations of this facility.

Main Benefit:

The main benefit of this mitigation concept is to provide structural retrofits to allow conveyance of flows from West Marginal Way.

Discussion of Schedule:

This mitigation concept will require a 6 to 18-month design and construction duration. This facility will need to remain operational during construction.

Discussion of Risk:

This mitigation concept may slightly impact operations at the facility.

This is in a liquefaction zone, which should be addressed as part of the larger retrofit project. Reference mitigation concept L-4.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 13. Exterior View of West Marginal Way Pump Station

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 14. Interior View of West Marginal Way Pump Station, including Diaphragm Openings

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Building area is 1,100 square feet
- Shotcrete area of the brick wall is 1,700 square feet

Table 7. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	West Marginal Way Pump Station Structural Retrofits			**Date:**	9/17/2017
Location:				**Estimator:**	Forrest Dill
Description:				**Idea Code:**	S-9a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Seismically Retrofit Diaphragm at Grade	138	LF	$ 125	$ 17,250
2	Shotcrete Brick Wall	1,656	SF	$ 15	$ 24,533
3	Maintain Building Operations	41,783	%	28%	$ 11,625
4	Mobilization / Demobilization (10%)	10	%	$ 5,341	$ 5,341
				Subtotal Construction Costs	***$ 60,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 24,000
				Construction Change Order Allowance	$ 8,400
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 92,400***
				Street Use Permit	$ -
				Construction Sales Tax	$ 9,332
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 101,732***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 185
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 102,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 80,503
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 1,074
				Right-of-Way	$ 1,200
				Misc. Service & Materials	$ 739
				Non-WTD Support	$ 785
				WTD Staff Labor	$ 28,319
				Subtotal Non-Construction Costs	***$ 112,621***
				Project Contingency	$ 64,744
				Initiatives	$ 1,274
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 179,000***
				TOTAL PROJECT COST	***$ 281,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

S-10 30th Avenue Pump Station Structural Retrofits

Issue No.	Issue Title	Risk Rating
S-10	30th Avenue Pump Station Seismic Deficiencies	MH
Idea Code	**Concept Title**	**Dev. Team**
S-10a	30th Avenue Pump Station Structural Retrofits	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
30th Avenue Pump Station	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☐ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☒ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☒ 3 to 12 months
	☐ $5M to $10M		☐ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

Seismic deficiencies could cause structural damage that could result in the facility no longer being operational.

The cast in place concrete shear walls are in poor condition and are non-ductile. There are also ingress/egress issues with existing doors to confined space.

Risk if not Addressed:

Structural damage to this facility from a seismic event could lead to the facility becoming inoperable due to severe damage. Disrupted accessibility from a seismic event may hinder the operation of the facility. Therefore, it is expected that this moderate level of damage may render the facility inoperable until shoring and repairs have been implemented.

MITIGATION CONCEPT SUMMARY - STRUCTURES

There are two separate durations discussed in the worksheet:

- Retrofit project durations: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.
- Downtime durations: the duration of time require to restore the facility to its pre-earthquake functionality.

The likely system downtime is expected to last 1-3 months if this building is severely damaged. It is expected that a moderate level of damage may render the facility inoperable until shoring and repairs have been implemented to provide access to operate the equipment inside.

Note that if liquefaction/landslide hazards are determined to be an issue in accordance with corresponding projects, the downtime would be expected to increase significantly. See L-5 for reference.

The waterbody likely affected by failure of this system is Lake Washington.

Description of Mitigation Concept:

- Seismic strengthening of reinforced concrete shear walls and coupling beams
- The ultimate performance objectives of the concept design will need to be further clarified during project scoping

Advantages:

- Given that this facility cannot be shut down during construction, moderate impacts to the cost and schedule for construction are anticipated as well as impacts to current operations of this facility.
- Long-term impacts are improved by reducing the probability of structural damage
- Post-earthquake damage is mitigated

Disadvantages:

- Wastewater operations may be moderately challenged during the retrofit of this facility, given that this facility cannot be shut down during construction

Main Benefit:

The main benefit of this mitigation concept is to provide structural retrofits to allow conveyance of flows for treatment to WPTP.

Discussion of Schedule:

This mitigation concept will require a 6 month to 1-year design and construction duration. This facility will need to remain operational during construction.

Discussion of Risk:

This mitigation concept may moderately impact operations at the facility.

This is in a liquefaction zone, which should be addressed as part of the larger retrofit project. Reference mitigation concept L-5.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 15. Exterior View of 30th Ave. Pump Station

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 16. Short Coupling Beam in Poor Condition

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Building area is approximately 400 square feet
- Wall height is 9 LF
- Perimeter is 100 LF
- Unit price estimate for this calculation: $104/SF

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 8. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	30th Avenue Pump Station Structural Retrofits			Date:	9/17/2017
Location:				Estimator:	Forrest Dill
Description:				Idea Code:	S-10a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	Item Description	Quantity	Units	Unit Cost	Item Cost
1	Supplement the Existing CIP Concrete Shear Walls and Coupling Beams	380	SF	$ 100	$ 38,000
2	Mobilization / Demobilization (10%)	10	%	$ 5,518	$ 5,518
				Subtotal Construction Costs	***$ 60,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 24,000
				Construction Change Order Allowance	$ 8,400
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 92,400***
				Street Use Permit	$ -
				Construction Sales Tax	$ 9,332
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 101,732***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 185
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 102,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 80,503
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 1,074
				Right-of-Way	$ 1,200
				Misc. Service & Materials	$ 739
				Non-WTD Support	$ 785
				WTD Staff Labor	$ 28,319
				Subtotal Non-Construction Costs	***$ 112,621***
				Project Contingency	$ 64,744
				Initiatives	$ 1,274
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 179,000***
				TOTAL PROJECT COST	***$ 281,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

S-13A WPTP Control Building Nonstructural Seismic Upgrades

Issue No.	Issue Title	Risk Rating
S-13A	WPTP Control Seismic Deficiencies	H
Idea Code	**Concept Title**	**Dev. Team**
S-13a	WPTP Control Building Nonstructural Seismic Upgrades	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☒ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
WPTP Control Bulding	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☐ Environment
		Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☒ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☒ 3 to 12 months
	☐ $5M to $10M		☐ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

Structural deficiencies at the Administration/Operations building.

Nonstructural deficiencies at the WPTP Control Building include the server room ceiling and floor, and its contents.

Risk if not Addressed:

There is potential for significant damage to the facility in a seismic event. Additionally, this facility houses a control room and servers, and a seismic event would pose a threat to WTD's ability to maintain operational capabilities for the west service area.

If these nonstructural issues are not addressed, the server room equipment will be unstable and may fall.

There are two separate durations discussed in the worksheet:

- Retrofit project durations: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.

- Downtime durations: the duration of time require to restore the facility to its pre-earthquake functionality.

The likely system downtime is expected to last 6-12 months for repairs following a seismic event. Work-arounds may allow operations to resume in 1-3 months. Many of the components and equipment in this facility require long lead-times for procurement.

If this facility is deemed unsafe to enter after an earthquake, the downtime previously assumed may be extended.

Description of Mitigation Concept:

The mitigation concept would involve:

- Bracing and securing of server and control room floors and ceiling, including equipment
    - Install additional wall bracket mounts

Advantages:

- Life safety is improved
- Operations and controls for WTD’s west services are maintained
- Post-earthquake damage is mitigated

Disadvantages:

- During constriction, the control room, lab, and various office functions may require swing space for uninterrupted operation

Main Benefit:

The main benefit of this mitigation concept is to provide additional stability to the facility to prevent damage to the control building during a seismic event. Given that this facility houses multiple employees, life safety is improved. Additionally, the control and server rooms (and their contents) will be better secured and protected. This increases the likelihood that WTD will be able to maintain services to the west region.

Discussion of Schedule:

This mitigation concept will require a 3 to 6 month design and construction duration. The control room will need to be temporarily relocated to swing space.

Discussion of Risk:

The mitigation concept will not impact operations, but will require swing space.

The ultimate performance objective of the concept design will need to be further clarified during project scoping.

Figure 17. Exterior View of WPTP Admin-Operations Building

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure3. Raised Floor Missing Braces/Hold-Downs in WPTP Admin-Operations Building

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Server and control room equipment floor are elevated plenums; these two rooms represent a total of 1,350 square feet.
- Ceiling density and partition density are assumed to be low.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 9. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	WPTP Control Building Non-Structural Seismic Upgrades			**Date:**	11/30/2017
Location:				**Estimator:**	Tom Thramer / Eric Benton
Description:	Building Non Structural Upgrade			**Idea Code:**	S-13a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Brace Server and Control Room Elevated Floors	1,800	SF	$ 12	$ 21,600
2	Brace Equipment	1,800	SF	$ 7	$ 12,600
3	Brace Partitions	1,800	SF	$ 7	$ 12,600
4	Brace Ceilings	1,800	SF	$ 12	$ 21,600
5	Brace Lignt Fixtures	1,800	SF	$ 7	$ 12,600
6	Maintain Facility Operations	81,000	%	28%	$ 22,537
7	Mobilization / Demobilization (10%)	10	%	$ 10,353.66	$ 10,354
				Subtotal Construction Costs	***$ 114,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 45,600
				Construction Change Order Allowance	$ 15,960
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 175,560***
				Street Use Permit	$ -
				Construction Sales Tax	$ 17,732
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 193,292***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 351
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 194,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 116,326
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 1,163
				Right-of-Way	$ 2,280
				Misc. Service & Materials	$ 3,160
				Non-WTD Support	$ 1,492
				WTD Staff Labor	$ 45,194
				Subtotal Non-Construction Costs	***$ 169,615***
				Project Contingency	$ 109,703
				Initiatives	$ 2,421
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 282,000***
				TOTAL PROJECT COST	***$ 475,000***

Notes:
1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.
2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

S-13B WPTP Admin/Ops Center Structural Retrofits

Issue No.	Issue Title	Risk Rating
S-13B	WPTP Admin/Ops Center Seismic Deficiencies	H
Idea Code	**Concept Title**	**Dev. Team**
S-13b	WPTP Admin/Ops Center Structural Retrofits	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☒ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
WPTP Admin/Ops Center	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☐ Environment
		Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☒ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

Structural deficiencies at the Administration/Operations center of the West Point Treatment Plant include a weak story / geometry configuration, and braced frame with lack of seismic detailing.

Risk if not Addressed:

There is potential for significant damage to the facility in a seismic event, increasing the probability of partial building collapse which poses a threat to life safety. Additionally, this facility houses a control room and servers, and a seismic event would pose a threat to WTD's ability to maintain operational capabilities for the west service area.

MITIGATION CONCEPT SUMMARY - STRUCTURES

There are two separate durations discussed in the worksheet:

- Retrofit project durations: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.
- Downtime durations: the duration of time require to restore the facility to its pre-earthquake functionality.

The likely system downtime is expected to last 6-12 months for repairs following a seismic event. Work-arounds may allow operations to resume in 1-3 months. Many of the components and equipment in this facility require long lead-times for procurement.

If this facility is deemed unsafe to enter after an earthquake, the downtime previously assumed may be extended.

Description of Mitigation Concept:

The mitigation concept would involve:

- Install new seismic braced frame at all locations
  - Includes: New spread footings, new columns, new beams, new braces
- Strengthening of cladding anchorage
- The ultimate performance objectives of the concept design will need to be further clarified during project scoping.

Advantages:

- Life safety is improved
- Operations and controls for WTD’s west services are maintained
- A structural retrofit will enhance the facility performance during future seismic events
- Long-term impacts are improved by reducing the probability of severe damage
- Post-earthquake damage is mitigated

Disadvantages:

- During constriction, the control room, lab, and various office functions may require swing space for uninterrupted operation

Main Benefit:

The main benefit of this mitigation concept is to provide additional stability to the facility to prevent partial collapse during a seismic event. Given that this facility houses multiple employees, life safety is improved. Additionally, the control and server rooms (and their contents) will be better secured and protected. This increases the likelihood that WTD will be able to maintain services to the west region.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Discussion of Schedule:

This mitigation concept will require a 1 to 2-year design and construction duration. The control room will need to be temporarily relocated to swing space.

Discussion of Risk:

This concept assumes that all braced frame locations will require replacement. However this may be conservative.

Replacement of cladding may require additional seismic connections and/or replacement

Figure 18. Exterior View of WPTP Admin-Operations Building

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 19. Non-Concentric Braced Frame in WPTP Admin-Operations Building

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Assume perimeter at 520 feet
- Assume wall height is 12 feet per floor with total facility height of 25 feet
- Assume glazing is 25% of the surface area of the walls

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 10. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	WPTP Admin/Ops Center Structural Retrofits			**Date:**	11/30/2017
Location:				**Estimator:**	Tom Thramer /. Eric Benton
Description:				**Idea Code:**	S-13b
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Seismic Brace Structural Frame	27,400	SF	$ 100	$ 2,740,000
2	Anchor Exterior Wall Cladding	9,750	SF	$ 30	$ 292,500
3	Add Exterior Wall Cladding Seismic Joints	650	LF	$ 150	$ 97,500
4	Maintain Operations	3,130,000	%	35%	$ 1,088,573
5	Mobilization / Demobilization (10%)	10	%	$ 421,857.27	$ 421,857
				Subtotal Construction Costs	***$ 4,640,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 1,856,000
				Construction Change Order Allowance	$ 649,600
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 7,145,600***
				Street Use Permit	$ -
				Construction Sales Tax	$ 721,706
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 7,867,306***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 14,291
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 7,882,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 2,413,408
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 47,328
				Right-of-Way	$ 92,800
				Misc. Service & Materials	$ 128,621
				Non-WTD Support	$ 60,738
				WTD Staff Labor	$ 1,019,991
				Subtotal Non-Construction Costs	***$ 3,762,885***
				Project Contingency	$ 3,522,901
				Initiatives	$ 98,520
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 7,384,000***
				TOTAL PROJECT COST	***$ 15,266,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

S-14 WPTP Maintenance/Effluent Pump Station Structural Retrofits

Issue No.	Issue Title	Risk Rating
S-14	WPTP Maintenance/Effluent Pump Station Seismic Deficiencies	H
Idea Code	**Concept Title**	**Dev. Team**
S-14a	WPTP Maintenance/Effluent Pump Station Structural Retrofits	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☒ Life Safety
☒ Site Specific (list site below) WPTP Maintenance/Effluent Pump Station	☐ MEP	☐ Public Health
	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards (list type below)	☐ Environment
		Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☒ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

Structural deficiencies include braced frame lack of seismic detailing, diaphragm openings, and cladding anchorage.

Nonstructural deficiencies include the ceiling and floor.

Storage racks are not secured and are susceptible to toppling during a seismic event. The contents of the racks are susceptible to falling off.

Risk if not Addressed:

There is a potential for significant damage to the facility in a seismic event, increasing the probability of partial building collapse which poses a threat to life safety.

The storage shelving and their contents pose a life safety threat to operations personnel.

The equipment stored in this facility is mission critical and would be damaged in a seismic event.

MITIGATION CONCEPT SUMMARY - STRUCTURES

There are two separate durations discussed in the worksheet:

- Retrofit project durations: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.
- Downtime durations: the duration of time require to restore the facility to its pre-earthquake functionality.

The likely system downtime is expected to last 6-12 months if this building is severely damaged or collapsed. A temporary building could potentially be erected to mitigate impacts within 12 months.

No waterbodies are likely to be affected by failure of this system.

Description of Mitigation Concept:

The mitigation concept involves:

- Bracing and securing equipment, which includes installing additional wall bracket mounts
- Braced frame seismic retrofits, including new braces and connections
- Strengthening of cladding anchorage
- Diaphragm strengthening around openings
- Seismic strengthening to ceilings and partitions in the office space
- The ultimate performance objectives of the concept design will need to be further clarified during project scoping

Advantages:

- Life safety is improved
- Wastewater operations are improved by ensuring access to maintenance equipment and spares during a seismic event
- Long-term impacts are improved by reducing the probability of collapse
- Post-earthquake damage is mitigated

Disadvantages:

- Operations may be challenged during construction, however, operations should be maintained without the use of swing space

Main Benefit:

The main benefit of this mitigation concept is that it would help prevent the structure from incurring severe damage during a seismic event. This is particularly important as it would protect the occupants who work in this facility and because it is a maintenance building and spare parts storage location that would be immediately required for disaster response operations after a seismic event.

Discussion of Schedule:

This mitigation concept will require a 1- to 2-year design and construction duration.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Discussion of Risk:

This concept assumes that all braced frame locations will require strengthening. However, this may be conservative.

Further investigation of cladding anchorage may indicate that anchorage strengthening is not necessary.

Figure 20. Exterior View of WPTP Maintenance Building (Effluent Pump Station Subgrade Below)

Figure 21. Non-Ductile Detailing of Chevron Braced Frame

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 3. Insufficient Seismic Joint between Adjacent Building

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Assume 2,000 lineal feet of shelving
- Assume total building square feet is 26,000
- Assume 4,200 square feet of office space
- Assume 9,200 square feet of cladding
- Assume 490 linear feet perimeter

Table 11. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	WPTP Maintenance/Effluent Pump station Structural Retrofits			**Date:**	9/13/2017
Location:				**Estimator:**	Forrest Dill
Description:				**Idea Code:**	S-14a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Seismic Brace Structural Frame	26,000	SF	$ 60	$ 1,560,000
2	Anchor Exterior Wall Cladding	9,188	SF	$ 30	$ 275,625
3	Brace Office Ceilings	4,200	SF	$ 12	$ 50,400
5	Seismic Brace Storage Racks	2,000	LF	$ 50	$ 100,000
6	Secure Parts to Storage Racks	2,000	LF	$ 10	$ 20,000
7	Maintain Building Operations	2,006,025	%	20%	$ 401,205
8	Mobilization / Demobilization (10%)	10	%	$ 240,723	$ 2,407,230
				Subtotal Construction Costs	***$ 4,810,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 1,924,000
				Construction Change Order Allowance	$ 673,400
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 7,407,400***
				Street Use Permit	$ -
				Construction Sales Tax	$ 748,147
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 8,155,547***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 14,815
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 8,170,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 2,485,654
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 49,062
				Right-of-Way	$ 96,200
				Misc. Service & Materials	$ 133,333
				Non-WTD Support	$ 62,963
				WTD Staff Labor	$ 1,052,081
				Subtotal Non-Construction Costs	***$ 3,879,293***
				Project Contingency	$ 3,645,536
				Initiatives	$ 102,130
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 7,627,000***
				TOTAL PROJECT COST	***$ 15,797,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

S-16 WPTP Hypo Mixing Structural Retrofits

Issue No.	Issue Title	Risk Rating
S-16	WPTP Hypo Mixing Seismic Deficiencies	MH
Idea Code	**Concept Title**	**Dev. Team**
S-16a	WPTP Hypo Mixing Structural Retrofits	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
WPTP Hypo Mixing	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards (list type below)	☒ Environment
		Other: ☒ Flow Volume
		☐ Equity and Social Justice
		☐ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

This facility stores and injects sodium hypochlorite. There are two separate buildings and a temporary 4-tank farm at this location. The buildings are adjacent to the secondary tanks, and there is a potential for pounding. Both buildings have load path issues.

The temporary 4-tank farm lacks adequate seismic anchorage and containment. The piping conveying the hypochlorite from the temporary tanks to the day tanks is inadequate.

Nonstructural issues include canopies and appendages.

Risk if not Addressed:

If not addressed, the permanent structures could pound against the adjacent secondary tanks. Due to irregularities in the structures, there is a potential for increased structural damage from a seismic event.

If the temporary tanks are breached, an uncontained spill of sodium hypochlorite could occur and the disinfection system could fail.

MITIGATION CONCEPT SUMMARY - STRUCTURES

There are two separate durations discussed in the worksheet:

- Retrofit project durations: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.
- Downtime durations: the duration of time require to restore the facility to its pre-earthquake functionality.

The likely system downtime is expected to last 1-2 years if this building and the tanks are severely damaged. A temporary treatment system could be installed to mitigate impacts within 1-3 months.

The waterbody likely to be affected by failure of this system is the Puget Sound.

Description of Mitigation Concept:

Mitigation concepts include:

- Structural upgrade to the permanent buildings
  - Add additional shear walls or shotcrete
  - Add seismic joint between permanent buildings and the secondary tanks
- Replace tanks and piping with proper seismic anchoring and bracing
- Construct new containment system

Advantages:

- Wastewater operations are improved by ensuring operability of the disinfection system
- Long-term impacts are improved by reducing the probability of severe damage
- Temporary tank farm is replaced with a permanent tank farm, reducing the probability of spills

Disadvantages:

- A temporary system would need to be installed during construction to maintain operations

Main Benefit:

The main benefit of this mitigation concept is that it would allow for continued disinfection related to primary treatment following a seismic event. It mitigates the risks associated with undisinfected wastewater reaching the Puget Sound as well as the risk of chemical spills from the tank farm.

Discussion of Schedule:

This mitigation concept will require a 1 to 2-year design and construction duration. This facility will need to remain operation during construction, requiring the installation of a temporary disinfection system.

Discussion of Risk:

No technical drawings were available for this facility at the time of evaluation, which could impact future scope definition.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 22. WPTP Hypo Mixing Tank and Support Frame

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 2. WPTP Hypo Mixing Tanks

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Assume new polyethylene tanks at 12-foot diameter, 20 feet tall
- Assume new containment structure (slab and walls) at 60 by 40 feet, 3-foot walls
- Assume 800 square feet of new shear walls

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 12. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	WPTP Hypo Mixing Structural Retrofits			**Date:**	9/13/2017
Location:				**Estimator:**	Forrest Dill
Description:				**Idea Code:**	S-16a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Add Roof Seismic Joints	200	SF	$ 125	$ 25,000
2	Add Floor Seismic Joints	200	SF	$ 75	$ 15,000
3	Brace Canopies	200	SF	$ 12	$ 2,400
4	Add Shear Walls	800	SF	$ 25	$ 19,753
5	Construct New Tank Slab with 3' Tall Walls	2,400	SF	$ 50	$ 120,000
6	Remove Temporary Tanks	4	EA	$ 10,000	$ 40,000
7	Replace Tanks and Piping with Seismic Anchoring and Bracing	4	EA	$ 35,000	$ 140,000
8	Mobilization / Demobilization (10%)	10	%	$ 36,215	$ 36,215
				Subtotal Construction Costs	***$ 400,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 160,000
				Construction Change Order Allowance	$ 56,000
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 616,000***
				Street Use Permit	$ -
				Construction Sales Tax	$ 62,216
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 678,216***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 1,232
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 679,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 324,452
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 4,080
				Right-of-Way	$ 8,000
				Misc. Service & Materials	$ 11,088
				Non-WTD Support	$ 5,236
				WTD Staff Labor	$ 127,890
				Subtotal Non-Construction Costs	***$ 480,746***
				Project Contingency	$ 350,606
				Initiatives	$ 8,493
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 840,000***
				TOTAL PROJECT COST	***$ 1,519,000***

Notes:
1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.
2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

S-18 STP Division Control Building Nonstructural Seismic Upgrades

Issue No.	Issue Title	Risk Rating
S-18	STP Division Control Building Seismic Deficiencies	H
Idea Code	**Concept Title**	**Dev. Team**
S-18a	STP Division Control Building Nonstructural Seismic Upgrades	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☐ Structural	☒ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
STP Operations Building	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards (list type below)	☐ Environmental
	☒ Nonstructural	Other: ☐ Flow Volume
		☒ Equity and Social Justice
		☒ System Downtime
		☒ System Control

Estimated Concept-Level Cost:	☒ < $1M	**Project Duration:**	☐ 0 to 3 months
	☐ $1M to $5M		☒ 3 to 12 months
	☐ $5M to $10M		☐ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

The seismic deficiencies in the STP Division Control Building include the following:

Penthouse lateral load path may lack sufficient strength (anchorage is unknown). In the event of an earthquake, the amount of lateral load delivered is equivalent to the mass of whatever is being shaken; at this facility, the penthouse needs to be able to sustain those loads.

Server and control room floors are currently on an elevated plenum that is not braced and the servers and their associated equipment are not adequately anchored down. Light fixtures, partitions, and ceiling lack adequate bracing to resist lateral seismic loads.

Risk if not Addressed:

If these nonstructural issues are not addressed, the equipment and controls will be unstable and may fall, rendering the facility inoperable. This facility is required to control the operations of South Plant. Therefore, if inoperable, the County's ability to control and operate the treatment plant would be limited.

MITIGATION CONCEPT SUMMARY - STRUCTURES

If bracing of lateral loads is not performed, the control room may collapse and become inoperable, the penthouse may collapse and impact the operability of the mechanical and electrical systems, and the light fixtures may fall, rendering the facility un-occupiable.

There are two separate durations discussed in the worksheet:

- Retrofit project durations: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.
- Downtime durations: the duration of time require to restore the facility to its pre-earthquake functionality.

The likely system downtime is estimated at up to 12 months to restore the facility to pre-earthquake condition. The likely system downtime is estimated at up to 12 months to restore the facility to pre-earthquake condition. Since many of the components and equipment in this facility have long procurement lead-times and the repair of a significant damage/collapse of the system controls could be extensive, the potential downtime is expected to be significant.

The waterbody likely to be affected by failure of this system is the Green River.

Description of Mitigation Concept:

The mitigation concept would involve…

- Bracing and securing of server and control room floors, including equipment
  - Install additional wall bracket mounts
- Strengthening penthouse to endure lateral loads
  - Flat strap bracing
  - Plywood or light-gauge sheer wall strengthening and anchorage

Advantages:

- Long-term impacts are improved by reducing the probability of collapse
- Post-earthquake damage is mitigated

Disadvantages:

None noted

Main Benefit:

The main benefit of this mitigation concept is to provide additional stability to the pipelines that convey flows to and from the affected pump stations, but it also addresses the stability of the pipelines in the direct vicinity of the pump stations, themselves.

Discussion of Schedule:

This mitigation concept will require a 3 to 6-month design and construction window. The control room will need to be temporarily relocated to swing space.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Discussion of Risk:

This mitigation concept will not impact operations, but it will require swing space.

The ultimate performance objectives of the concept design will need to be further clarified during project scoping.

Figure 23. Exterior View of STP Operations Building

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 24. STP Operations Building Mechanical Penthouse Framing

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Penthouse area is 2,100 square feet
- Floorplate area is 3,150 square feet
- Server and control room equipment floor are elevated plenums; these two rooms represent a total of 1,350 square feet
- Ceiling density and partition density should be assumed to be low

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 13. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	SPTP Operations Building Structural Retrofits			**Date:**	9/13/2017
Location:				**Estimator:**	Forrest Dill
Description:	Building Non Structural Upgrade			**Idea Code:**	S-18a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Brace Server and Control Room Elevated Floors	1,350	SF	$ 12	$ 16,200
2	Penthouse Roof Retrofit	2,100	SF	$ 20	$ 42,000
3	Brace Partitions	3,154	SF	$ 7	$ 22,078
4	Brace Ceilings	3,154	SF	$ 12	$ 37,848
5	Brace Lignt Fixtures	3,154	SF	$ 7	$ 22,078
6	Maintain Facility Operations	140,204	%	28%	$ 39,009
7	Mobilization / Demobilization (10%)	10	%	$ 17,921	$ 17,921
				Subtotal Construction Costs	***$ 200,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 80,000
				Construction Change Order Allowance	$ 28,000
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 308,000***
				Street Use Permit	$ -
				Construction Sales Tax	$ 31,108
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 339,108***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 616
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 340,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 184,116
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 2,040
				Right-of-Way	$ 4,000
				Misc. Service & Materials	$ 5,544
				Non-WTD Support	$ 2,618
				WTD Staff Labor	$ 71,882
				Subtotal Non-Construction Costs	***$ 270,200***
				Project Contingency	$ 184,251
				Initiatives	$ 4,247
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 459,000***
				TOTAL PROJECT COST	***$ 798,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

S-19 STP Santler Building Structural Retrofits

Issue No.	Issue Title	Risk Rating
S-19	STP Santler Building Seismic Deficiencies	H
Idea Code	**Concept Title**	**Dev. Team**
S-19a	STP Santler Building Structural Retrofits	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☒ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
STP Santler Building	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards (list type below)	☐ Environment
		Other: ☐ Flow Volume
		☒ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

The tilt-up walls of this facility do not have sufficient in-plane and out-of-plane strength. Without adequate in-plane and out-of-plane strength, the facility is susceptible to collapse. Storage racks are not secured and are susceptible to toppling during a seismic event. The contents of the racks are likely to fall off.

Risk if not Addressed:

If not addressed, the lack of in-plane and out-of-plane strength may cause the facility to collapse during a seismic event. Additionally, the storage shelving and their contents pose a life safety threat to operations personnel.

The equipment stored in this facility is mission critical, and it would be damaged in a seismic event.

There are two separate durations discussed in the worksheet:

- Retrofit project durations: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.

- Downtime durations: the duration of time require to restore the facility to its pre-earthquake functionality.

The likely system downtime is expected to last 6-12 months if this building collapses or is severely damaged. A temporary building could potentially be erected to mitigate impacts within 12 months.

No waterbodies are likely to be affected by failure of this system.

Description of Mitigation Concept:

- Structural seismic retrofit
  - Tilt-up wall anchorage to foundation
  - Connections between panels and diaphragm
  - Strong backs and wall panels for out-of-plane
  - Replace brace frame with seismic brace frame
- Nonstructural seismic retrofit
  - Secure spare part rack storage system
  - Secure contents

Further investigation of potential replacement strategies for this structure should be evaluated.

This concept assumes retrofitting the facility; however, additional study may determine that replacement is a more cost-effective mitigation concept.

Advantages:

- Life safety of building occupants markedly improved
- Wastewater operations are improved by ensuring access to maintenance equipment and spares during a seismic event
- Long-term impacts are improved by reducing the probability of collapse
- Post-earthquake damage is mitigated
- If this facility were expanded, exterior storage could be moved to the interior of the facility, thereby providing higher quality protection and storage.

Disadvantages:

- Given that this facility cannot be shut down during construction, impacts to the cost and schedule for construction are anticipated. Contents of the facility would need to be relocated to swing space during the retrofit.

Main Benefit:

The main benefit of this mitigation concept is that it would help prevent the structure from collapsing during a seismic event. This is particularly important as it would protect the occupants working in this facility. Additionally, this site stores spare parts that would be immediately required for disaster response operations after a seismic event.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Discussion of Schedule:

This mitigation concept will require a 1 to 2-year design and construction duration. The functions of this facility will require swing space during retrofit.

Discussion of Risk:

None observed.

Figure 25. Exterior View of Santler Building

Figure 26. Santler Building – Existing Tilt-Up Wall Retrofits

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 3. Santler Building – Existing Braced Frame

MITIGATION CONCEPT SUMMARY - STRUCTURES

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Total building is 19,200 square feet
- Assume 6,000 lineal feet of rack

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 14. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	SPTP Santler Building Structural Retrofits			**Date:**	9/13/2017
Location:				**Estimator:**	Forrest Dill
Description:	Tilt Up Warehouse with Office Space			**Idea Code:**	S-19a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Add Tilt Up Panel Anchors to Floor	30	EA	$ 500	$ 15,000
2	Add Tilt Up Panel-Panel Ties	30	EA	$ 750	$ 22,500
3	Add Tilt Up Panel to Roof Ties	30	EA	$ 3,500	$ 105,000
4	Adding Strongbacks Vertical on Tilt Up Panels	30	EA	$ 2,500	$ 75,000
5	Replace Interior Brace Frames	360	LF	$ 1,000	$ 360,000
6	Seismic Brace Storage Racks	6,000	LF	$ 50	$ 300,000
7	Secure Parts to Storage Racks	6,000	LF	$ 10	$ 60,000
8	Maintain Building Operations	937,500	%	28%	$ 260,840
9	Mobilization / Demobilization (10%)	10	%	$ 119,834	$ 119,834
				Subtotal Construction Costs	***$ 1,320,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 528,000
				Construction Change Order Allowance	$ 184,800
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 2,032,800***
				Street Use Permit	$ -
				Construction Sales Tax	$ 205,313
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 2,238,113***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 4,066
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 2,242,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 861,769
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 13,464
				Right-of-Way	$ 26,400
				Misc. Service & Materials	$ 36,590
				Non-WTD Support	$ 17,279
				WTD Staff Labor	$ 348,829
				Subtotal Non-Construction Costs	***$ 1,304,332***
				Project Contingency	$ 1,072,361
				Initiatives	$ 28,027
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 2,405,000***
				TOTAL PROJECT COST	***$ 4,647,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

S-20 STP Maintenance Building Structural Retrofits

Issue No.	Issue Title	Risk Rating
S-20	STP Maintenance Building Seismic Deficiencies	H
Idea Code	**Concept Title**	**Dev. Team**
S-20a	STP Maintenance Building Structural Retrofits	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☒ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
STP Maintenance Building	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards (list type below)	☐ Environment
		Other: ☐ Flow Volume
		☒ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☒ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

There could be structural failure or roof collapse that could result in the facility no longer being operational. Mechanical and electrical system damage may also lead to the facility being inoperable.

The z-beam roof system, moment frame, tilt-up walls, and precast cladding system are structurally deficient.

In the low area, the moment frame, precast roof diaphragm, and CMU in-fill walls are structurally deficient.

Multiple nonstructural components require retrofitting.

Risk if not Addressed:

The building lacks adequate seismic design, and if not addressed, may cause a collapse during a seismic event. It contains mission-critical maintenance equipment, and it houses operations that are vital for repair and disaster response in a seismic event. If not addressed, these critical operations may not be functional following an earthquake.

MITIGATION CONCEPT SUMMARY - STRUCTURES

If this building is not retrofitted and does collapse it will be challenging to move operations to swing space.

System downtime is expected to last 1-3 years if this building is severely damaged or collapses.

No waterbodies are likely to be affected by failure of this system.

Description of Mitigation Concept:

The mitigation concept would involve:

- Structural seismic retrofit
  - Selective demolition of the z-beams and replacement with a new roof framing system
  - The precast concrete cladding is currently deficient and requires seismic upgrading (removal, repair, replacement)
  - Lower level diaphragm piece requires upgrades (to precast roof panels) via a topping slab or reinforcement
  - The moment frame to support the high bay roof requires upgrades
  - The lower area of the facility requires moment frame retrofit, diaphragm strengthening, and potentially in-fill wall retrofit
  - Tilt-up wall anchorage to foundation
  - Connections between panels and diaphragm
  - Strong backs and wall panels for out of plane
- Specific major nonstructural upgrades include, but are not limited to:
  - Suspended ceilings
  - Canopies
  - General mechanical/electrical upgrades (anchoring, bracing, and restraining)
- Suspended mezzanine requires retrofit
- Further investigation of potential replacement strategies for this structure should be evaluated

Advantages:

- Life safety of building occupants markedly improved
- Disaster response preparedness following a seismic event is improved by ensuring access to maintenance equipment that would be mission critical for restoring wastewater operations
- Long-term impacts are improved by reducing the probability of collapse
- Post-earthquake damage is mitigated

Disadvantages:

- Given that this facility cannot be shut down during construction, impacts to the cost and schedule for construction are anticipated. Contents of the facility would need to be relocated to swing space during the retrofit.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Main Benefit:

The main benefit of this mitigation concept is that it would help prevent the structure from collapsing during a seismic event. This is particularly important as it would protect the occupants who work in this facility, and also because it is the site where repair and maintenance is completed for facilities throughout WTD.

Discussion of Schedule:

There are two separate durations discussed in the worksheet:

- Retrofit project durations: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.
- Downtime durations: the duration of time require to restore the facility to its pre-earthquake functionality.

This mitigation concept will require 1 to 3 years for design and construction, and it will require swing space for operations that are currently housed in the facility.

Discussion of Risk:

This concept assumes retrofitting the facility; however, additional study may determine that replacement is a more cost-effective mitigation concept.

Moment frame is the lateral system, but the tilt-up wall is expected to take the load. Thus, both should be retrofitted.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 27. Exterior View of STP Maintenance Building

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 28. Interior View of STP Maintenance Building, Including Z-Beam Roof

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 3. STP Maintenance Building, Weak Column-Strong Beam Framing

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- High bay (z-beam room) roof area is 4,250 square feet
- Low roof area is 5,800 square feet
- Exterior wall (tilt-up) area is 5,200 square feet

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 15. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	SPTP Maintenance Building Phase I Structural Retrofits			Date:	9/13/2017
Location:				Estimator:	Forrest Dill
Description:				Idea Code:	S-20a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	Item Description	Quantity	Units	Unit Cost	Item Cost
1	Roof Z-Beam Replacement and Reroof	4,250	SF	$ 200	$ 850,000
2	Replace Precast Cladding	5,200	SF	$ 60	$ 312,000
3	Add Tilt Up Panel Anchors to Floor	87	EA	$ 500	$ 43,333
4	Add Tilt Up Panel-Panel Ties	87	EA	$ 750	$ 65,000
5	Add Tilt Up Panel to Roof Ties	87	EA	$ 3,500	$ 303,333
6	Adding Strongbacks Across Tilt Up Panels	87	EA	$ 1,000	$ 86,667
7	Strengthen Moment Frame - Add Shear Walls	1,440	SF	$ 69	$ 99,556
8	Add Topping Slab on Level Diaphragm	5,800	SF	$ 7	$ 42,963
9	Maintain Building Operations	1,802,852	%	45%	$ 815,111
10	Mobilization / Demobilization (10%)	10	%	$ 261,796	$ 261,796
				Subtotal Construction Costs	***$ 2,880,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 1,152,000
				Construction Change Order Allowance	$ 403,200
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 4,435,200***
				Street Use Permit	$ -
				Construction Sales Tax	$ 447,955
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 4,883,155***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 8,870
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 4,892,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 1,632,623
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 29,376
				Right-of-Way	$ 57,600
				Misc. Service & Materials	$ 79,834
				Non-WTD Support	$ 37,699
				WTD Staff Labor	$ 677,488
				Subtotal Non-Construction Costs	***$ 2,514,620***
				Project Contingency	$ 2,240,339
				Initiatives	$ 61,150
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 4,816,000***
				TOTAL PROJECT COST	***$ 9,708,000***

Notes:
1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.
2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

S-21 STP Effluent Pump Station Structural Retrofits

Issue No.	Issue Title	Risk Rating
S-21	STP Effluent Pump Station Seismic Deficiencies	H
Idea Code	**Concept Title**	**Dev. Team**
S-21a	STP Effluent Pump Station Structural Retrofits	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
STP Effluent Pump Station	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards (list type below)	☒ Environment
		Other: ☒ Flow Volume
		☒ Equity and Social Justice
		☐ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

There could be structural failure or roof collapse that could result in the facility no longer being operational. Mechanical and electrical system damage may also lead to the facility being inoperable.

In contrast to other facilities where there are full-system deficiencies, in this case, the connections between systems are the primary concern. Currently, their status is unknown.

A previous retrofit has been completed. Evaluations of this retrofit should be done during project scoping.

Risk if not Addressed:

The building lacks adequate seismic design, and if not addressed, may cause severe damage or collapse (less likely) during a seismic event. If the facility is inoperable, the outflow from South Treatment Plant would be directed to the Green River, rather than pumped to the Puget Sound.

System downtime is expected to last 1-3 years if this building is severely damaged or collapses.

The waterbody likely to be affected by failure of this system is the Green River.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Description of Mitigation Concept:

The mitigation concept would involve:

- Structural seismic retrofit
  - Tilt-up wall anchorage to foundation
  - Connections between panels and diaphragm
  - Strong backs and wall panels for out-of-plane
  - Connection of precast double tee roof framing to exterior moment frame
  - Connection of precast double tee roof framing to each other

Advantages:

- Life safety of building occupants improved
- Wastewater operations are maintained (outflow to Green River prevented, outfall to Puget Sound maintained)
- Long-term impacts are improved by reducing the probability of collapse
- Post-earthquake damage is mitigated

Disadvantages:

- Wastewater operations may be partially challenged during the retrofit of this facility because retrofit process can happen piecemeal
- Operations may be challenged during construction; contents of the facility may need to be partially relocated to swing space during retrofit

Main Benefit:

The main benefit of this mitigation concept is that it would help prevent the structure from collapsing during a seismic event. This is particularly important as it would protect the occupants who work in this facility and allow WTD to maintain flow to Puget Sound, ensuring that permit conditions can be met.

Discussion of Schedule:

There are two separate durations discussed in the worksheet:

- Retrofit project durations: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.
- Downtime durations: the duration of time require to restore the facility to its pre-earthquake functionality.

This mitigation concept will require a 1- to 2-year design and construction duration. This facility will need to remain operational during construction.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Discussion of Risk:

This concept assumes a preliminary solution for stabilization. However, further investigation will need to be conducted during scoping to determine the full extent of retrofit actions required. This will further clarify project scope and cost.

Figure 29. Exterior View of STP Effluent Pump Station

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 30. Interior View of STP Effluent Pump Station

(Double-T Pre-Cast Framing Connections to Moment Frame Unknown)

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 3. Interior View of STP Effluent Pump Station, Seismic Retrofit to Concrete Column

(Extent and Criteria/Objectives of Retrofit Unknown)

Table 16. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	SPTP Effluent Pump Station Structural Retrofits			**Date:**	9/13/2017
Location:				**Estimator:**	Forrest Dill
Description:	Rough Draft - Need to Complete			**Idea Code:**	S-21a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Tie Precast Roof to Walls and Each Other	9,200	SF	$ 50	$ 460,000
2	Add Tilt Up Panel Anchors to Floor	136	EA	$ 500	$ 68,000
3	Add Tilt Up Panel-Panel Ties	136	EA	$ 750	$ 102,000
4	Add Tilt Up Panel to Roof Ties	136	EA	$ 1,100	$ 149,600
5	Adding Strongbacks Vertical Tilt Up Panels	136	EA	$ 600	$ 81,600
6	Maintain Building Operations	861,200	%	28%	$ 239,611
25	Mobilization / Demobilization (10%)	10	%	$ 110,081	$ 110,081
				Subtotal Construction Costs	***$ 1,210,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 484,000
				Construction Change Order Allowance	$ 169,400
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 1,863,400***
				Street Use Permit	$ -
				Construction Sales Tax	$ 188,203
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 2,051,603***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 3,727
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 2,055,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 802,519
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 12,342
				Right-of-Way	$ 24,200
				Misc. Service & Materials	$ 33,541
				Non-WTD Support	$ 15,839
				WTD Staff Labor	$ 324,070
				Subtotal Non-Construction Costs	***$ 1,212,511***
				Project Contingency	$ 988,060
				Initiatives	$ 25,692
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 2,226,000***
				TOTAL PROJECT COST	***$ 4,282,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

S-23 STP Digester Equipment Building Structural Retrofits

Issue No.	Issue Title	Risk Rating
S-23	STP Digester Equipment Building Seismic Deficiencies	H
Idea Code	**Concept Title**	**Dev. Team**
S-23a	STP Digester Equipment Building Structural Retrofits	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide ☒ Site Specific (list site below) STP Digester Equipment Building	☒ Structural ☐ MEP ☐ SCADA ☐ Natural Hazards (list type below)	☐ Life Safety ☐ Public Health ☐ Consequent Damages ☒ Environment Other: ☒ Flow Volume ☒ Equity and Social Justice ☒ System Downtime ☐ (Describe here)

Estimated Concept-Level Cost:	☐ < $1M ☒ $1M to $5M ☐ $5M to $10M ☐ > $10M	**Project Duration:**	☐ 0 to 3 months ☐ 3 to 12 months ☒ 1 to 3 years ☐ 3 to 5 years ☐ > 5 years

Description of Existing Issue:

There could be structural failure from pounding between the digesters and the digester equipment building that could lead to damage of the roof structure. Mechanical and electrical system damage may also lead to the facility being inoperable.

Four digesters with significant mechanical equipment to support digesters.

Risk if not Addressed:

The building lacks adequate seismic design, and if not addressed, may cause roof damage during a seismic event.

Impacts to digesters may release methane gas and pose a life safety risk to building occupants.

The likely system downtime is expected to be minimal. There may be some operational interference, but equipment will remain largely operable.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Description of Mitigation Concept:

Saw cut the slab and install a new, larger seismic joint. This will also require installation of a new perimeter beam.

Advantages:

- Life safety of building occupants improved
- Wastewater operations are maintained
- Long-term impacts are improved by reducing the probability of structural damage and impacts to digesters
- Post-earthquake damage is minimized

Disadvantages:

- Will be a challenging improvement to implement because the frame will need to be modified at various locations
- This improvement could become costly with a lower return on investment for the retrofit

Main Benefit:

The main benefit of this mitigation concept is that it reduces the likelihood of pounding damage to the digesters and to the roof, itself. Without the digesters, WTD cannot implement primary treatment functions, which is the primary goal following a seismic event.

Discussion of Schedule:

There are two separate durations discussed in the worksheet:

- Retrofit project durations: the duration of time required to implement the design, permitting, and construction phases of the recommended seismic upgrade projects, identified in the box above.
- Downtime durations: the duration of time require to restore the facility to its pre-earthquake functionality

This mitigation concept will require a 1 to 2-year design and construction duration. This facility will need to remain operational during construction.

Discussion of Risk:

It is not immediately clear the extent to which the retrofit will require modifications to framing.

The ultimate performance objectives of the concept design will need to be further clarified during project scoping.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 31. Exterior View of STP Digester Equipment Building (Between four Digesters)

MITIGATION CONCEPT SUMMARY - STRUCTURES

Figure 32. STP Digester Equipment Building, Seismic Joint at Interface with Digesters

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- New seismic joint around perimeter of digester equipment building
- Modifications to framing requiring installation of new beams

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 17. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	SPTP Digester Equipment Building Structural Retrofits			**Date:**	9/13/2017
Location:				**Estimator:**	Forrest Dill
Description:				**Idea Code:**	S-23a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	New Roof Seismic Joints	200	LF	$ 125	$ 25,000
2	New Floor Seismic Joints	200	LF	$ 75	$ 15,000
3	Add Perimeter Beam/Columns	400	LF	$ 1,037	$ 414,815
4	Mobilization / Demobilization (10%)	10	%	$ 45,481	$ 45,481
				Subtotal Construction Costs	***$ 500,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 200,000
				Construction Change Order Allowance	$ 70,000
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 770,000***
				Street Use Permit	$ -
				Construction Sales Tax	$ 77,770
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 847,770***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 1,540
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 849,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 389,405
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 5,100
				Right-of-Way	$ 10,000
				Misc. Service & Materials	$ 13,860
				Non-WTD Support	$ 6,545
				WTD Staff Labor	$ 154,103
				Subtotal Non-Construction Costs	***$ 579,013***
				Project Contingency	$ 431,682
				Initiatives	$ 10,616
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 1,021,000***
				TOTAL PROJECT COST	***$ 1,871,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

SP-1A Conduct ASCE 41 Tier 1/2/3 Seismic Evaluations- WPTP

Issue No.	Issue Title	Risk Rating
SP-1A	Need More Detailed Seismic Evaluations of Facilities	H
Idea Code	**Concept Title**	**Dev. Team**
SP-1a	Conduct ASCE 41 Tier 1/2/3 Seismic Evaluations- WPTP	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☒ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
West Point Treatment Plant	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☒ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

WTD owns a variety of facilities and structures that were constructed over multiple decades, built with varying designs, design standards, codes, materials, and practices. The seismic expected performance of multiple WTD facilities is unknown and requires further study. The objective of these studies will be to identify seismic deficiencies that require mitigation in accordance with ASCE 41 to increase system resiliency.

Facilities Not Considered for this Concept Structural Project (SP-1):

A previously seismic resiliency study of King County WTD's system included an initial desktop seismic screening of the off-site pump stations utilizing the FEMA 154 Rapid Visual Screening procedures. Based on the findings of this screening and input from King County, (37) facilities were identified for field observations and more detailed seismic evaluations using ASCE 41-13 Tier 1 prescriptive deficiency evaluation checklists. This resulted in a prioritized list of capital projects.

MITIGATION CONCEPT SUMMARY - STRUCTURES

The facilities already identified as capital projects resulting from the seismic resiliency study will not be further evaluated through this Concept Structural Project (SP-1). Additionally, the facilities determined to have a “low” or “moderate” vulnerability from the seismic resiliency study are not included in this Concept Structural Project (SP-1).

Facilities Assumed for this Project:

Based on the findings of the King County WTD seismic resiliency study, the following are the number of assumed quantity of facilities that will require ASCE 41-13 Tier 1, Tier 2, and Tier 3 seismic evaluations. It is expected that the actual number of facilities will vary depending on which particular facilities are identified to be evaluated for the Concept Structural Project (SP-1). Additionally, the number of Tier 2 and Tier 3 evaluations is expected to vary depending on the findings from the initial Tier 1 evaluations, as recommended by the engineering consultant performing the seismic study.

Project Location	Tier 1	Tier 2	Tier 3	Total
West Point Treatment Plant	27	16	5	48
South Treatment Plant	22	14	5	41
Brightwater Treatment Plant	1	1	0	2
Off-Site Facilities	55	29	15	99
Total Combined	*105*	*60*	*25*	*190*

Risk if not Addressed:

If seismic deficiencies are not identified, mitigation cannot occur and resiliency may not be increased.

Following a seismic event, reconstruction costs will likely be higher and system down time longer than if mitigation were to occur in advance of an event.

If not addressed, the stated goals of improving life safety, public health, reducing consequential damage, and protecting environmental conditions will not be met. Many of these facilities are mission critical.

Description of Mitigation Concept:

For facilities that have not already been identified as requiring or not requiring seismic mitigation, a study must first be undertaken to determine which facilities require mitigation and the nature of the mitigation required, if any. This study will involve:

- An ASCE 41 Tier 1 evaluation of structural and nonstructural components (excluding MEP, which is addressed in another capital improvement project) for the identified facilities
- As recommended based on the outcome of the Tier 1 evaluations, either Tier 2 or Tier 3 evaluation of structural and nonstructural components (excluding MEP, which is addressed in another capital improvement project) for the identified facilities
- Define deficiencies in demand and capacity ratios
- Concept-level mitigation schemes (2-5% design)
- Concept-level costs (level 5)

MITIGATION CONCEPT SUMMARY - STRUCTURES

Advantages:

- Allows WTD to better understand their system vulnerabilities and to develop a seismic resiliency program reducing post-seismic-event downtime and reconstruction costs

Disadvantages:

- Requires coordination with operations and maintenance staff to limit disruption to daily operations

Main Benefit:

By performing these analyses, WTD will be better able to meet King County's resiliency goals and objectives by identifying and addressing seismic deficiencies in their facilities.

Discussion of Schedule:

Each of the following four phases would require approximately 1-2 years to execute:

- STP structures review
- WPTP structures review
- Brightwater and select offsite facilities structures review
- Off-Site Facilities

This excludes facilities identified in other seismic resiliency capital projects.

Discussion of Risk:

Challenges may emerge if technical documents and related design and construction information associated with these facilities are not available to the project team.

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

1. The costs assume information gathering phase, field investigation phase, and a seismic analysis/evaluation phase, summary report and associated meetings.
2. The costs exclude nondestructive and destructive testing (concrete cores, soil borings, geotechnical evaluation, steel coupon tests).
3. The range of evaluation complexity depends on the size/complexity of the facility, the selected evaluation approach (e.g. nonlinear dynamic time history analyses vs. linear static analysis), and the evaluation scope/objectives.
4. The costs below are for structural/seismic evaluations only and excluded additional consulting services (e.g. geotechnical, architectural, mechanical/electrical/plumbing) associated with the development of concept-level mitigation designs.
5. The costs are estimated on stand-alone, per building basis.
6. The costs are assumed for "average" facility size and complexity. Costs may vary on an individual facility basis, and depend on how the project is contracted and how the scope requirements of that contract; the costs provided below are for programmatic planning purposes only.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Total Approximate Cost Estimate:

The following tables summarizes an approximate range of architectural-engineering consulting fees (direct costs) for performing ASCE 41-13 Tier 1, Tier 2 and Tier 3 evaluations for "simple", "moderate", and "complex" facilities:

	Simple	Moderate	Complex
Tier 1 Evaluation	$5,000	$10,000	$20,000
Tier 2 Evaluation	$15,000	$50,000	$100,000
Tier 3 Evaluation	$50,000	$250,000	$500,000

Based on the assumed number of facilities at each location (each of the three regional WWTPs and off-site facilities) and an average assumption of "Moderate" facility complexity, the following table summarizes the expected total architectural-engineering consulting fees (direct costs) for this project. However, it is important to note that these fees could vary significantly based on a.) how the project is contracted (e.g. there is an efficiency if multiple evaluations are combined into a single contract), b.) the level of evaluation selected (e.g. nonlinear dynamic time history analyses vs. linear static analysis and combinations thereof), and c.) the requirements of the scope (e.g. level of detail in summary report, workshop/meetings, schematic sketches required, etc.). Additionally, as noted above, the facility totals listed are baseline assumptions; the actual number of facilities to be evaluated and type of evaluation required for each facility will vary depending King County WTD's selection of facility for evaluations, and the recommended level of evaluation that each facility warrants.

Estimated Seismic Evaluation direct costs per facility:

Project Location	Tier 1	Tier 2	Tier 3	Total
West Point Treatment Plant	27	16	5	48
	$270,000	$800,000	$1,250,000	$2,320,000
South Treatment Plant	22	14	5	41
	$220,000	$700,000	$1,250,000	$2,170,000
Brightwater Treatment Plant	1	1	0	2
	$10,000	$50,000	$0	$60,000
Off-Site Facilities	55	29	15	99
	$550,000	$1,450,000	$3,750,000	$5,750,000
Total Combined	105	60	25	190
	$1,050,000	*$3,000,000*	*$6,250,000*	*$10,300,000*

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 1. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Conduct ASCE 41 Tier 1, 2, 3 Seismic Evaluations - WPTP			**Date:**	11/13/2017
Location:	West Point Treatment Plant			**Estimator:**	Eric Benton, CPE
Description:	Conduct Seismic Evaluations for Facilities listed below			**Idea Code:**	SP-1A
DIRECT: PROGRAMMATIC ASSESSMENT COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	West Point Treatment Plant; Tier 1	27	EA	$ 10,000	$270,000
2	West Point Treatment Plant; Tier 2	16	EA	$ 50,000	$800,000
3	West Point Treatment Plant; Tier 3	5	EA	$ 250,000	$1,250,000
				Subtotal Assessment Costs	***$2,320,000***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				Misc. Capital Costs	$ 30,000
				TOTAL ASSESSMENT COSTS	***$ 2,350,000***
INDIRECT: WTD ASSESSMENT COSTS					
				Design and Construction Consulting	n/a
				Other Consulting Services	n/a
				Permitting & Other Agency Support	n/a
				Right-of-Way	n/a
				Misc. Service & Materials	n/a
				Non-WTD Support	n/a
				WTD Staff Labor	$ 343,489
				Subtotal WTD Assessment Costs	***$ 343,489***
				Project Contingency	$ 823,011
				Initiatives	n/a
				TOTAL INDIRECT WTD ASSESSMENT COSTS	***$ 1,166,499***
				TOTAL PROJECT COST	***$ 3,516,000***

Notes:
1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.
2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimate.

MITIGATION CONCEPT SUMMARY - STRUCTURES

SP-1B Conduct ASCE 41 Tier 1/2/3 Seismic Evaluations- STP

Issue No.	Issue Title	Risk Rating
SP-1B	Need More Detailed Seismic Evaluations of Facilities	H
Idea Code	**Concept Title**	**Dev. Team**
SP-1a	Conduct ASCE 41 Tier 1/2/3 Seismic Evaluations- STP	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☒ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
South Plant Treatment Plant	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☒ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:	☐ < $1M	**Project Duration:**	☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

WTD owns a variety of facilities and structures that were constructed over multiple decades, built with varying designs, design standards, codes, materials, and practices. The seismic expected performance of multiple WTD facilities is unknown and requires further study. The objective of these studies will be to identify seismic deficiencies that require mitigation in accordance with ASCE 41 to increase system resiliency.

Facilities Not Considered for this Concept Structural Project (SP-1):

A previously seismic resiliency study of King County WTD's system included an initial desktop seismic screening of the off-site pump stations utilizing the FEMA 154 Rapid Visual Screening procedures. Based on the findings of this screening and input from King County, (37) facilities were identified for field observations and more detailed seismic evaluations using ASCE 41-13 Tier 1 prescriptive deficiency evaluation checklists. This resulted in a prioritized list of capital projects.

The facilities already identified as capital projects resulting from the seismic resiliency study will not be further evaluated through this Concept Structural Project (SP-1). Additionally, the facilities determined to have a “low” or “moderate” vulnerability from the seismic resiliency study are not included in this Concept Structural Project (SP-1).

Facilities Assumed for this Project:

Based on the findings of the King County WTD seismic resiliency study, the following are the number of assumed quantity of facilities that will require ASCE 41-13 Tier 1, Tier 2, and Tier 3 seismic evaluations. It is expected that the actual number of facilities will vary depending on which particular facilities are identified to be evaluated for the Concept Structural Project (SP-1). Additionally, the number of Tier 2 and Tier 3 evaluations is expected to vary depending on the findings from the initial Tier 1 evaluations, as recommended by the engineering consultant performing the seismic study.

Project Location	Tier 1	Tier 2	Tier 3	Total
West Point Treatment Plant	27	16	5	48
South Treatment Plant	22	14	5	41
Brightwater Treatment Plant	1	1	0	2
Off-Site Facilities	55	29	15	99
Total Combined	*105*	*60*	*25*	*190*

Risk if not Addressed:

If seismic deficiencies are not identified, mitigation cannot occur and resiliency may not be increased.

Following a seismic event, reconstruction costs will likely be higher and system down time longer than if mitigation were to occur in advance of an event.

If not addressed, the stated goals of improving life safety, public health, reducing consequential damage, and protecting environmental conditions will not be met. Many of these facilities are mission critical.

Description of Mitigation Concept:

For facilities that have not already been identified as requiring or not requiring seismic mitigation, a study must first be undertaken to determine which facilities require mitigation and the nature of the mitigation required, if any. This study will involve:

- An ASCE 41 Tier 1 evaluation of structural and nonstructural components (excluding MEP, which is addressed in another capital improvement project) for the identified facilities
- As recommended based on the outcome of the Tier 1 evaluations, either Tier 2 or Tier 3 evaluation of structural and nonstructural components (excluding MEP, which is addressed in another capital improvement project) for the identified facilities
- Define deficiencies in demand and capacity ratios
- Concept-level mitigation schemes (2-5% design)
- Concept-level costs (level 5)

Advantages:

- Allows WTD to better understand their system vulnerabilities and to develop a seismic resiliency program reducing post-seismic-event downtime and reconstruction costs

Disadvantages:

- Requires coordination with operations and maintenance staff to limit disruption to daily operations

Main Benefit:

By performing these analyses, WTD will be better able to meet King County's resiliency goals and objectives by identifying and addressing seismic deficiencies in their facilities.

Discussion of Schedule:

Each of the following four phases would require approximately 1-2 years to execute:

- STP structures review
- WPTP structures review
- Brightwater and select offsite facilities structures review
- Off-Site Facilities

This excludes facilities identified in other seismic resiliency capital projects.

Discussion of Risk:

Challenges may emerge if technical documents and related design and construction information associated with these facilities are not available to the project team.

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

1. The costs assume information gathering phase, field investigation phase, and a seismic analysis/evaluation phase, summary report and associated meetings.
2. The costs exclude nondestructive and destructive testing (concrete cores, soil borings, geotechnical evaluation, steel coupon tests).
3. The range of evaluation complexity depends on the size/complexity of the facility, the selected evaluation approach (e.g. nonlinear dynamic time history analyses vs. linear static analysis), and the evaluation scope/objectives.
4. The costs below are for structural/seismic evaluations only and excluded additional consulting services (e.g. geotechnical, architectural, mechanical/electrical/plumbing) associated with the development of concept-level mitigation designs.
5. The costs are estimated on stand-alone, per building basis.
6. The costs are assumed for "average" facility size and complexity. Costs may vary on an individual facility basis, and depend on how the project is contracted and how the scope requirements of that contract; the costs provided below are for programmatic planning purposes only.

Total Approximate Cost Estimate:

The following tables summarizes an approximate range of architectural-engineering consulting fees (direct costs) for performing ASCE 41-13 Tier 1, Tier 2 and Tier 3 evaluations for "simple", "moderate", and "complex" facilities:

MITIGATION CONCEPT SUMMARY - STRUCTURES

	Simple	Moderate	Complex
Tier 1 Evaluation	$5,000	$10,000	$20,000
Tier 2 Evaluation	$15,000	$50,000	$100,000
Tier 3 Evaluation	$50,000	$250,000	$500,000

Based on the assumed number of facilities at each location (each of the three regional WWTPs and off-site facilities) and an average assumption of "Moderate" facility complexity, the following table summarizes the expected total architectural-engineering consulting fees (direct costs) for this project. However, it is important to note that these fees could vary significantly based on a.) how the project is contracted (e.g. there is an efficiency if multiple evaluations are combined into a single contract), b.) the level of evaluation selected (e.g. nonlinear dynamic time history analyses vs. linear static analysis and combinations thereof), and c.) the requirements of the scope (e.g. level of detail in summary report, workshop/meetings, schematic sketches required, etc.). Additionally, as noted above, the facility totals listed are baseline assumptions; the actual number of facilities to be evaluated and type of evaluation required for each facility will vary depending King County WTD's selection of facility for evaluations, and the recommended level of evaluation that each facility warrants.

Estimated Seismic Evaluation direct costs per facility:

Project Location	Tier 1	Tier 2	Tier 3	Total
West Point Treatment Plant	27	16	5	48
	$270,000	$800,000	$1,250,000	$2,320,000
South Treatment Plant	22	14	5	41
	$220,000	$700,000	$1,250,000	$2,170,000
Brightwater Treatment Plant	1	1	0	2
	$10,000	$50,000	$0	$60,000
Off-Site Facilities	55	29	15	99
	$550,000	$1,450,000	$3,750,000	$5,750,000
Total Combined	105	60	25	190
	$1,050,000	*$3,000,000*	*$6,250,000*	*$10,300,000*

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 1. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Conduct ASCE 41 Tier 1, 2, 3 Seismic Evaluations - STTP			**Date:**	11/13/2017
Location:	South Treatment Plant			**Estimator:**	Eric Benton, CPE
Description:	Conduct Seismic Evaluations for Facilities listed below			**Idea Code:**	SP-1B
DIRECT: PROGRAMMATIC ASSESSMENT COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	South Treatment Plant; Tier 1	22	EA	$ 10,000	$220,000
2	South Treatment Plant; Tier 2	14	EA	$ 50,000	$700,000
3	South Treatment Plant; Tier 3	5	EA	$ 250,000	$1,250,000
				Subtotal Assessment Costs	***$2,170,000***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				Misc. Capital Costs	$ 30,000
				TOTAL ASSESSMENT COSTS	***$ 2,200,000***
INDIRECT: WTD ASSESSMENT COSTS					
				Design and Construction Consulting	n/a
				Other Consulting Services	n/a
				Permitting & Other Agency Support	n/a
				Right-of-Way	n/a
				Misc. Service & Materials	n/a
				Non-WTD Support	n/a
				WTD Staff Labor	$ 325,825
				Subtotal WTD Assessment Costs	***$ 325,825***
				Project Contingency	$ 764,046
				Initiatives	n/a
				TOTAL INDIRECT WTD ASSESSMENT COSTS	***$ 1,089,871***
				TOTAL PROJECT COST	***$ 3,290,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimate.

MITIGATION CONCEPT SUMMARY - STRUCTURES

SP-1C Conduct ASCE 41 Tier 1/2 Seismic Evaluations- Brightwater

Issue No.	Issue Title	Risk Rating
SP-1C	Need More Detailed Seismic Evaluations of Facilities - Brightwater	H
Idea Code	**Concept Title**	**Dev. Team**
SP-1a	Conduct ASCE 41 Tier 1/2 Seismic Evaluations- Brightwater	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☒ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
Brightwater WWTP	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☒ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☒ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

WTD owns a variety of facilities and structures that were constructed over multiple decades, built with varying designs, design standards, codes, materials, and practices. The seismic expected performance of multiple WTD facilities is unknown and requires further study. The objective of these studies will be to identify seismic deficiencies that require mitigation in accordance with ASCE 41 to increase system resiliency.

Facilities Not Considered for this Concept Structural Project (SP-1):

A previously seismic resiliency study of King County WTD's system included an initial desktop seismic screening of the off-site pump stations utilizing the FEMA 154 Rapid Visual Screening procedures. Based on the findings of this screening and input from King County, (37) facilities were identified for field observations and more detailed seismic evaluations using ASCE 41-13 Tier 1 prescriptive deficiency evaluation checklists. This resulted in a prioritized list of capital projects.

The facilities already identified as capital projects resulting from the seismic resiliency study will not be further evaluated through this Concept Structural Project (SP-1). Additionally, the facilities determined to have a “low” or “moderate” vulnerability from the seismic resiliency study are not included in this Concept Structural Project (SP-1).

Facilities Assumed for this Project:

Based on the findings of the King County WTD seismic resiliency study, the following are the number of assumed quantity of facilities that will require ASCE 41-13 Tier 1, Tier 2, and Tier 3 seismic evaluations. It is expected that the actual number of facilities will vary depending on which particular facilities are identified to be evaluated for the Concept Structural Project (SP-1). Additionally, the number of Tier 2 and Tier 3 evaluations is expected to vary depending on the findings from the initial Tier 1 evaluations, as recommended by the engineering consultant performing the seismic study.

Project Location	Tier 1	Tier 2	Tier 3	Total
West Point Treatment Plant	27	16	5	48
South Treatment Plant	22	14	5	41
Brightwater Treatment Plant	1	1	0	2
Off-Site Facilities	55	29	15	99
Total Combined	*105*	*60*	*25*	*190*

Risk if not Addressed:

If seismic deficiencies are not identified, mitigation cannot occur and resiliency may not be increased.

Following a seismic event, reconstruction costs will likely be higher and system down time longer than if mitigation were to occur in advance of an event.

If not addressed, the stated goals of improving life safety, public health, reducing consequential damage, and protecting environmental conditions will not be met. Many of these facilities are mission critical.

Description of Mitigation Concept:

For facilities that have not already been identified as requiring or not requiring seismic mitigation, a study must first be undertaken to determine which facilities require mitigation and the nature of the mitigation required, if any. This study will involve:

- An ASCE 41 Tier 1 evaluation of structural and nonstructural components (excluding MEP, which is addressed in another capital improvement project) for the identified facilities
- As recommended based on the outcome of the Tier 1 evaluations, either Tier 2 or Tier 3 evaluation of structural and nonstructural components (excluding MEP, which is addressed in another capital improvement project) for the identified facilities
- Define deficiencies in demand and capacity ratios
- Concept-level mitigation schemes (2-5% design)
- Concept-level costs (level 5)

Advantages:

- Allows WTD to better understand their system vulnerabilities and to develop a seismic resiliency program reducing post-seismic-event downtime and reconstruction costs

MITIGATION CONCEPT SUMMARY - STRUCTURES

Disadvantages:

- Requires coordination with operations and maintenance staff to limit disruption to daily operations

Main Benefit:

By performing these analyses, WTD will be better able to meet King County's resiliency goals and objectives by identifying and addressing seismic deficiencies in their facilities.

Discussion of Schedule:

Each of the following four phases would require approximately 1-2 years to execute:

- STP structures review
- WPTP structures review
- Brightwater and select offsite facilities structures review
- Off-Site Facilities

This excludes facilities identified in other seismic resiliency capital projects.

Discussion of Risk:

Challenges may emerge if technical documents and related design and construction information associated with these facilities are not available to the project team.

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

1. The costs assume information gathering phase, field investigation phase, and a seismic analysis/evaluation phase, summary report and associated meetings.
2. The costs exclude nondestructive and destructive testing (concrete cores, soil borings, geotechnical evaluation, steel coupon tests).
3. The range of evaluation complexity depends on the size/complexity of the facility, the selected evaluation approach (e.g. nonlinear dynamic time history analyses vs. linear static analysis), and the evaluation scope/objectives.
4. The costs below are for structural/seismic evaluations only and excluded additional consulting services (e.g. geotechnical, architectural, mechanical/electrical/plumbing) associated with the development of concept-level mitigation designs.
5. The costs are estimated on stand-alone, per building basis.
6. The costs are assumed for "average" facility size and complexity. Costs may vary on an individual facility basis, and depend on how the project is contracted and how the scope requirements of that contract; the costs provided below are for programmatic planning purposes only.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Total Approximate Cost Estimate:

The following tables summarizes an approximate range of architectural-engineering consulting fees (direct costs)for performing ASCE 41-13 Tier 1, Tier 2 and Tier 3 evaluations for “simple”, “moderate”, and “complex” facilities:

	Simple	Moderate	Complex
Tier 1 Evaluation	$5,000	$10,000	$20,000
Tier 2 Evaluation	$15,000	$50,000	$100,000
Tier 3 Evaluation	$50,000	$250,000	$500,000

Based on the assumed number of facilities at each location (each of the three regional WWTPs and off-site facilities) and an average assumption of “Moderate” facility complexity, the following table summarizes the expected total architectural-engineering consulting fees (direct costs) for this project. However, it is important to note that these fees could vary significantly based on a.) how the project is contracted (e.g. there is an efficiency if multiple evaluations are combined into a single contract), b.) the level of evaluation selected (e.g. nonlinear dynamic time history analyses vs. linear static analysis and combinations thereof), and c.) the requirements of the scope (e.g. level of detail in summary report, workshop/meetings, schematic sketches required, etc.). Additionally, as noted above, the facility totals listed are baseline assumptions; the actual number of facilities to be evaluated and type of evaluation required for each facility will vary depending King County WTD’s selection of facility for evaluations, and the recommended level of evaluation that each facility warrants.

Estimated Seismic Evaluation direct costs per facility:

Project Location	Tier 1	Tier 2	Tier 3	Total
West Point Treatment Plant	27	16	5	48
	$270,000	$800,000	$1,250,000	$2,320,000
South Treatment Plant	22	14	5	41
	$220,000	$700,000	$1,250,000	$2,170,000
Brightwater Treatment Plant	1	1	0	2
	$10,000	$50,000	$0	$60,000
Off-Site Facilities	55	29	15	99
	$550,000	$1,450,000	$3,750,000	$5,750,000
Total Combined	105	60	25	190
	$1,050,000	*$3,000,000*	*$6,250,000*	*$10,300,000*

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 1. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Conduct ASCE 41 Tier 1, 2 Seismic Evaluations - BWTP			**Date:**	11/13/2017
Location:	Brightwater Treatment Plant			**Estimator:**	Eric Benton, CPE
Description:	Conduct Seismic Evaluations for Facilities listed below			**Idea Code:**	SP-1C
DIRECT: PROGRAMMATIC ASSESSMENT COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Brightwater Treatment Plant; Tier 1	1	EA	$ 10,000	$10,000
2	Brightwater Treatment Plant; Tier 2	1	EA	$ 50,000	$50,000
				Subtotal Assessment Costs	***$60,000***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				Misc. Capital Costs	$ 30,000
				TOTAL ASSESSMENT COSTS	***$ 90,000***
INDIRECT: WTD ASSESSMENT COSTS					
				Design and Construction Consulting	n/a
				Other Consulting Services	n/a
				Permitting & Other Agency Support	n/a
				Right-of-Way	n/a
				Misc. Service & Materials	n/a
				Non-WTD Support	n/a
				WTD Staff Labor	$ 21,269
				Subtotal WTD Assessment Costs	***$ 21,269***
				Project Contingency	$ 33,768
				Initiatives	n/a
				TOTAL INDIRECT WTD ASSESSMENT COSTS	***$ 55,037***
				TOTAL PROJECT COST	***$ 145,000***

Notes:
1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.
2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimate.

MITIGATION CONCEPT SUMMARY - STRUCTURES

SP-1D Conduct ASCE 41 Tier 1/2/3 Seismic Evaluations – Off-Site Facilities

Issue No.	Issue Title	Risk Rating
SP-1D	**Need More Detailed Seismic Evaluations of Facilities**	H
Idea Code	**Concept Title**	**Dev. Team**
SP-1a	**Conduct ASCE 41 Tier 1/2/3 Seismic Evaluations – Off-Site Facilities**	**1**

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☒ Life Safety
☒ Site Specific (list site below) Off-Site Facilities: • Pump Stations • Regulator Stations • CSO Facilities • Small WWTPs	☐ MEP ☐ SCADA	☐ Public Health ☐ Consequent Damages
	☐ Natural Hazards	☒ Environment Other: ☒ Flow Volume ☐ Equity and Social Justice ☒ System Downtime ☐ (Describe here)

Estimated Concept-Level Cost:		**Project Duration:**	
	☐ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☒ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

WTD owns a variety of facilities and structures that were constructed over multiple decades, built with varying designs, design standards, codes, materials, and practices. The seismic expected performance of multiple WTD facilities is unknown and requires further study. The objective of these studies will be to identify seismic deficiencies that require mitigation in accordance with ASCE 41 to increase system resiliency.

Facilities Not Considered for this Concept Structural Project (SP-1):

A previously seismic resiliency study of King County WTD's system included an initial desktop seismic screening of the off-site pump stations utilizing the FEMA 154 Rapid Visual Screening procedures. Based on the findings of this screening and input from King County, (37) facilities were identified for field observations and more detailed seismic evaluations using ASCE 41-13 Tier 1 prescriptive deficiency evaluation checklists. This resulted in a prioritized list of capital projects.

The facilities already identified as capital projects resulting from the seismic resiliency study will not be further evaluated through this Concept Structural Project (SP-1). Additionally, the facilities determined to have a “low” or “moderate” vulnerability from the seismic resiliency study are not included in this Concept Structural Project (SP-1).

Facilities Assumed for this Project:

Based on the findings of the King County WTD seismic resiliency study, the following are the number of assumed quantity of facilities that will require ASCE 41-13 Tier 1, Tier 2, and Tier 3 seismic evaluations. It is expected that the actual number of facilities will vary depending on which particular facilities are identified to be evaluated for the Concept Structural Project (SP-1). Additionally, the number of Tier 2 and Tier 3 evaluations is expected to vary depending on the findings from the initial Tier 1 evaluations, as recommended by the engineering consultant performing the seismic study.

Project Location	Tier 1	Tier 2	Tier 3	Total
West Point Treatment Plant	27	16	5	48
South Treatment Plant	22	14	5	41
Brightwater Treatment Plant	1	1	0	2
Off-Site Facilities	55	29	15	99
Total Combined	*105*	*60*	*25*	*190*

Risk if not Addressed:

If seismic deficiencies are not identified, mitigation cannot occur and resiliency may not be increased.

Following a seismic event, reconstruction costs will likely be higher and system down time longer than if mitigation were to occur in advance of an event.

If not addressed, the stated goals of improving life safety, public health, reducing consequential damage, and protecting environmental conditions will not be met. Many of these facilities are mission critical.

Description of Mitigation Concept:

For facilities that have not already been identified as requiring or not requiring seismic mitigation, a study must first be undertaken to determine which facilities require mitigation and the nature of the mitigation required, if any. This study will involve:

- An ASCE 41 Tier 1 evaluation of structural and nonstructural components (excluding MEP, which is addressed in another capital improvement project) for the identified facilities
- As recommended based on the outcome of the Tier 1 evaluations, either Tier 2 or Tier 3 evaluation of structural and nonstructural components (excluding MEP, which is addressed in another capital improvement project) for the identified facilities
- Define deficiencies in demand and capacity ratios
- Concept-level mitigation schemes (2-5% design)
- Concept-level costs (level 5)

MITIGATION CONCEPT SUMMARY - STRUCTURES

Advantages:

- Allows WTD to better understand their system vulnerabilities and to develop a seismic resiliency program reducing post-seismic-event downtime and reconstruction costs

Disadvantages:

- Requires coordination with operations and maintenance staff to limit disruption to daily operations

Main Benefit:

By performing these analyses, WTD will be better able to meet King County's resiliency goals and objectives by identifying and addressing seismic deficiencies in their facilities.

Discussion of Schedule:

Each of the following four phases would require approximately 1-2 years to execute:

- STP structures review
- WPTP structures review
- Brightwater and select offsite facilities structures review
- Off-Site Facilities

This excludes facilities identified in other seismic resiliency capital projects.

Discussion of Risk:

Challenges may emerge if technical documents and related design and construction information associated with these facilities are not available to the project team.

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

1. The costs assume information gathering phase, field investigation phase, and a seismic analysis/evaluation phase, summary report and associated meetings.
2. The costs exclude nondestructive and destructive testing (concrete cores, soil borings, geotechnical evaluation, steel coupon tests).
3. The range of evaluation complexity depends on the size/complexity of the facility, the selected evaluation approach (e.g. nonlinear dynamic time history analyses vs. linear static analysis), and the evaluation scope/objectives.
4. The costs below are for structural/seismic evaluations only and excluded additional consulting services (e.g. geotechnical, architectural, mechanical/electrical/plumbing) associated with the development of concept-level mitigation designs.
5. The costs are estimated on stand-alone, per building basis.
6. The costs are assumed for "average" facility size and complexity. Costs may vary on an individual facility basis, and depend on how the project is contracted and how the scope requirements of that contract; the costs provided below are for programmatic planning purposes only.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Total Approximate Cost Estimate:

The following tables summarizes an approximate range of architectural-engineering consulting fees (direct costs) for performing ASCE 41-13 Tier 1, Tier 2 and Tier 3 evaluations for “simple”, “moderate”, and “complex” facilities:

	Simple	Moderate	Complex
Tier 1 Evaluation	$5,000	$10,000	$20,000
Tier 2 Evaluation	$15,000	$50,000	$100,000
Tier 3 Evaluation	$50,000	$250,000	$500,000

Based on the assumed number of facilities at each location (each of the three regional WWTPs and off-site facilities) and an average assumption of “Moderate” facility complexity, the following table summarizes the expected total architectural-engineering consulting fees (direct costs) for this project. However, it is important to note that these fees could vary significantly based on a.) how the project is contracted (e.g. there is an efficiency if multiple evaluations are combined into a single contract), b.) the level of evaluation selected (e.g. nonlinear dynamic time history analyses vs. linear static analysis and combinations thereof), and c.) the requirements of the scope (e.g. level of detail in summary report, workshop/meetings, schematic sketches required, etc.). Additionally, as noted above, the facility totals listed are baseline assumptions; the actual number of facilities to be evaluated and type of evaluation required for each facility will vary depending King County WTD’s selection of facility for evaluations, and the recommended level of evaluation that each facility warrants.

Estimated Seismic Evaluation direct costs per facility:

Project Location	Tier 1	Tier 2	Tier 3	Total
West Point Treatment Plant	27	16	5	48
	$270,000	$800,000	$1,250,000	$2,320,000
South Treatment Plant	22	14	5	41
	$220,000	$700,000	$1,250,000	$2,170,000
Brightwater Treatment Plant	1	1	0	2
	$10,000	$50,000	$0	$60,000
Off-Site Facilities	55	29	15	99
	$550,000	$1,450,000	$3,750,000	$5,750,000
Total Combined	105	60	25	190
	$1,050,000	*$3,000,000*	*$6,250,000*	*$10,300,000*

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 1. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Conduct ASCE 41 Tier 1, 2, 3 Seismic Evaluations - Off Site			**Date:**	11/13/2017
Location:	Off-Site Facilities			**Estimator:**	Eric Benton, CPE
Description:	Conduct Seismic Evaluations for Facilities listed below			**Idea Code:**	SP-1D
DIRECT: PROGRAMMATIC ASSESSMENT COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Off-Site Facilities; Tier 1	55	EA	$ 10,000	$550,000
2	Off-Site Facilities; Tier 2	29	EA	$ 50,000	$1,450,000
3	Off-Site Facilities; Tier 3	15	EA	$ 250,000	$3,750,000
				Subtotal Assessment Costs	***$5,750,000***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				Misc. Capital Costs	$ 30,000
				TOTAL ASSESSMENT COSTS	***$ 5,780,000***
INDIRECT: WTD ASSESSMENT COSTS					
				Design and Construction Consulting	n/a
				Other Consulting Services	n/a
				Permitting & Other Agency Support	n/a
				Right-of-Way	n/a
				Misc. Service & Materials	n/a
				Non-WTD Support	n/a
				WTD Staff Labor	$ 708,704
				Subtotal WTD Assessment Costs	***$ 708,704***
				Project Contingency	$ 1,983,699
				Initiatives	n/a
				TOTAL INDIRECT WTD ASSESSMENT COSTS	***$ 2,692,403***
				TOTAL PROJECT COST	***$ 8,472,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimate.

MITIGATION CONCEPT SUMMARY - STRUCTURES

SP-3 Conduct Additional Pipeline Assessments

Issue No.	Issue Title	Risk Rating
SP-3	Need for Additional Pipeline Assessments	H
Idea Code	**Concept Title**	**Dev. Team**
SP-3a	Conduct Additional Pipeline Assessments	3

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☒ System Wide	☒ Structural	☒ Life Safety
☐ Site Specific (list site below)	☐ MEP	☐ Public Health
	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards (list type below)	☒ Environment
		Other: ☒ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☒ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

The main issue revolves around the stability of the existing pipe in three classifications:

- Liquefaction lateral spread vulnerability
- Specific vulnerable locations identified by King County staff
- Specific vulnerable locations with consequent damage potential

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program, there exists the potential that a significant earthquake could trigger multiple catastrophic pipeline failures.

MITIGATION CONCEPT SUMMARY - STRUCTURES

The likely system downtime is:

- Up to 6 months for an interim, work-around fix
- Up to 3 years for a permanent fix (dependent upon several variable factors, including location, age of conveyance system, material type, depth, accessibility, etc.)

The waterbodies likely to be affected by each classification is as follows:

- Liquefaction lateral spread vulnerability will affect areas with very high, high, and moderate liquefaction susceptibility (e.g. Elliot Bay Interceptor and East Side Interceptor)
- Specific vulnerable locations identified by King County staff in Technical Memorandum Task 200, Section 5.3
- Specific vulnerable locations with consequent damage potential (locations with high pressure liquid fuel and water lines)

Description of Mitigation Concept:

The mitigation concept is to perform an assessment of the identified issue categories to gain a better understanding of the likelihood that these failures will occur, followed by mitigation approaches to minimize their occurrence. The mitigation approaches may include: pipe replacement, reinforcement or lining, and soil improvement (jet grouting).

The initial recommendation would be to avoid full pipe replacement and to focus on high risk/ high consequence areas such as liquid fuel pipelines and high-pressure water main crossings.

Advantages:

- Wastewater operations should be improved by gaining a better understanding of potential exposure to WTD from pipeline failures.

Disadvantages:

- None noted

Main Benefit:

As noted above, the main benefit of this mitigation concept is to identify potential WTD pipeline failures and to develop possible mitigation approaches that may limit potential damages – not only to WTD horizontal assets, but also to other publicly and privately-owned assets. It is expected that WTD will also develop the necessary processes and protocols to address potential issues and limit damage should they occur.

Discussion of Schedule Impacts:

This mitigation concept will require a variable performance window to conduct the assessment and develop future mitigation strategies.

Discussion of Risk Impacts:

This mitigation concept should reduce overall risk exposure to WTD and potentially limit the possibility of other horizontal or vertical asset collateral damage.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- 1 consultant (420 hours) to evaluate pipelines
- 1 GIS consultant (420 hours)
- 1 Technical consultant (420 hours)

Table 18. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Conduct Additional Pipeline Assessments			**Date:**	11/14/2017
Location:	Multiple Locations			**Estimator:**	Richard Greer / Eric Benton
Description:	Pipeline Programmatic Assessment			**Idea Code:**	SP-3
DIRECT: PROGRAMMATIC ASSESSMENT COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Consultant Hours to make assesssment of failures to pipelines	420	Hours	$ 210	$88,200
2	GIS	420	Hours	$ 150	$63,000
3	Tech	420	Hours	$ 150	$63,000
				Subtotal Assessment Costs	***$214,200***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				Misc. Capital Costs	$ 428
				TOTAL ASSESSMENT COSTS	***$ 215,000***
INDIRECT: WTD ASSESSMENT COSTS					
				Design and Construction Consulting	n/a
				Other Consulting Services	n/a
				Permitting & Other Agency Support	n/a
				Right-of-Way	n/a
				Misc. Service & Materials	n/a
				Non-WTD Support	n/a
				WTD Staff Labor	$ 54,722
				Subtotal WTD Assessment Costs	***$ 54,722***
				Project Contingency	$ 82,187
				Initiatives	n/a
				TOTAL INDIRECT WTD ASSESSMENT COSTS	***$ 137,000***
				TOTAL PROJECT COST	***$ 352,000***

Notes:
1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.
2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

SP-4 Evaluate Seismic Monitoring Technologies

Issue No.	Issue Title	Risk Rating
SP-4	Need for Real-Time Seismic Data and System Failure Information	H
Idea Code	**Concept Title**	**Dev. Team**
SP-4a	Evaluate Seismic Monitoring Technologies	3

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☒ System Wide	☒ Structural	☐ Life Safety
☐ Site Specific (list site below)	☒ MEP	☐ Public Health
	☐ SCADA	☐ Consequent Damages
	☒ Natural Hazards (list type below)	☒ Environment
	Seismic	Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☒ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☒ 3 to 12 months
	☐ $5M to $10M		☐ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

In the event of seismic activity, King County WTD lacks the ability to quickly evaluate and direct resources to facilities, including all vertical and horizontal assets, where damage may have occurred. Currently, there are no standard procedures for the collection, assembly, and analysis of seismic activity information specific to WTD facilities.

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program, there exists the potential that a seismic event and its impacts on the WTD infrastructure may not be identified and addressed in a timely manner, leading to additional damage or environmental impacts that could otherwise be avoided.

The likely system downtime is:

- Up to 6 months for an interim, work-around fix
- Up to 3 years for a permanent fix (dependent upon several variable factors, including age of facility or conveyance system, material types, location, depth, site accessibility, etc.)

Description of Project:

This project would include a study to develop recommendations for implementation of a seismic monitoring system and other technologies that could enable King County WTD to utilize real-time data to make data-driven decisions on their earthquake response. This study should consider the following components:

- *Seismic Ground Motion Monitoring System*: assess the approach, cost, and benefits associated with implementing a seismic ground motion monitoring system that utilizes a strong-motion seismometer distributed throughout King County's system. This should consider the availability of existing seismometers from other existing networks ((e.g. USGS, Pacific Northwest Seismic Network). This study should assess and make recommendations regarding ability of the system to:
  - monitor the real-time distribution of seismic ground motions across the system during an earthquake,
  - compare those ground motions with those expected to cause damage to facilities and distributed pipelines systems,
  - document/report the expected performance of the system,
  - communicate/disseminate the information furnished by the seismic ground motion monitoring system, and
  - make actionable decision in how WTD allocates resources and operates their system based on the provided data and information.
- *Above-Ground Facility Seismic Monitoring System (SMS)*: assess the approach, cost, and benefits associated with implementing a strong-motion instrumentation networks within key above-ground facilities. The study shall identify which facilities would warrant a structural seismic monitoring system, and provide recommendations for the type, number, and distribution of sensors. This study should assess and make recommendations regarding ability of the system to:
  - monitor the real-time response of building structures,
  - process the data in real time to convert compare data to performance thresholds,
  - evaluate the expected performance of the structure based on pre-defined inter-story drift thresholds based on performance-based earthquake engineering evaluation (PBEE) procedures,
  - document/report the expected performance of the structure,
  - communicate/disseminate the information furnished by the structural SMS to facility managers and decision-makers, and
  - make actionable decisions in how WTD allocates resources to evaluate and occupy the structure based on output of the system.
- *Post-Earthquake Response Plans*: develop recommendations on how King County WTD's could develop customized facility-specific earthquake response plans for performing post-earthquake safety evaluations of each of their facilities. The objective of these response plans would be to customize existing post-earthquake building safety evaluation standards (i.e. ATC-20) to allow King County staff

to perform rapid evaluations in an expedited, target fashion based on the unique characteristics and vulnerabilities of each facility.

- *Pipeline Seismic Monitoring System*: assess the approach, cost, and benefits associated with implementing a seismic monitoring system (e.g. fiber-optic sensors) that can identify breaks/damage to the transmission pipelines. This study should assess and make recommendations regarding ability of the system to:
  - monitor the real-time response of pipelines,
  - document/report the expected performance of the pipelines (e.g. if/where breaks are expected),
  - communicate/disseminate the pipeline performance information to facility managers and decision-makers, and
  - make actionable decisions in how WTD allocates resources to repairing the pipelines.
- *Automated Seismic Shut-Off*: assess the approach, cost, and benefits associated with installing automatic shut-off valves and controls based on the data provided from seismic sensors.
- *Early-Warning System*: assess the ability of King County WTD to integrate their system with earthquake early-warning system currently under development by *ShakeAlert: An Earthquake Early Warning System for the West Coast of the United States,* and their partners.

Advantages:

Wastewater system operations could be improved through the potential addition of modern seismic monitoring system technologies that could provide real-time feedback on the post-earthquake condition of their system.

Disadvantages:

If pursued, the addition of a new monitoring and reporting system would require a significant investment in technology hardware, software, and operator training.

Main Benefit:

Wastewater system operations could be improved through the potential addition of modern seismic monitoring system technologies that could provide real-time feedback on the post-earthquake condition of their system.

Discussion of Schedule:

This study could be performed without interruptions to existing WTD operations.

Discussion of Risk:

It is not anticipated that this mitigation concept would increase risk exposure to WTD. However, there are opportunities to partner with other local agencies to share seismic information and mitigate potential regional impacts.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- 500-1000 hours for consultants to research the available technologies, consult with King County to determine which tools which be most suitable, develop recommendations and concept-level approach for implementation, and document findings in a report.

Table 1. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Study Implementation of Post-Earthquake Technologies			**Date:**	11/14/2017
Location:	Multiple Locations			**Estimator:**	Richard Greer / Eric Benton
Description:	Evaluate/Implement Real-Time Seismic Data and System Failure Information			**Idea Code:**	SP-4
DIRECT: PROGRAMMATIC ASSESSMENT COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**Phase 1**				
2	Research Available Technologies	500	Hours	$ 210	$ 105,000
3	**Phase 2**				
4	Consult with King County and develop most suitable concept-level approach for Implementation.	500	Hours	$ 210	$ 105,000
				Subtotal Assessment Costs	***$ 210,000***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				Misc. Capital Costs	$ 420
				TOTAL ASSESSMENT COSTS	***$ 210,000***
INDIRECT: WTD ASSESSMENT COSTS					
				Design and Construction Consulting	n/a
				Other Consulting Services	n/a
				Permitting & Other Agency Support	n/a
				Right-of-Way	n/a
				Misc. Service & Materials	n/a
				Non-WTD Support	n/a
				WTD Staff Labor	$ 52,145
				Subtotal WTD Assessment Costs	***$ 52,145***
				Project Contingency	$ 80,376
				Initiatives	n/a
				TOTAL INDIRECT WTD ASSESSMENT COSTS	***$ 133,000***
				TOTAL PROJECT COST	***$ 343,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

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Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

SP-6 Conduct Programmatic Mechanical-Electrical Evaluations for WWTPs, CSOs and offsite facilities

Issue No.	Issue Title	Risk Rating
SP-6	**Programmatic Mechanical-Electrical Upgrades**	**H**
Idea Code	**Concept Title**	**Dev. Team**
SP-6	**Conduct Programmatic Mechanical-Electrical Evaluations for WWTPs, CSOs and offsite facilities**	**1**

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☒ System Wide	☐ Structural	☒ Life Safety
☐ Site Specific (list site below)	☒ MEP	☐ Public Health
	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

Mechanical and electrical equipment and piping is not adequately braced, anchored, and restrained. Additionally, existing piping and equipment may not have adequate flexible couplings, and lighting fixtures are not adequately anchored. Emergency lighting is missing or in disrepair in some locations.

See the table below for a more thorough list of mechanical and electrical issues that have been identified across WTD's facilities. Expect these issues and additional unidentified items to exist in a variety of combinations at WTD facilities.

Risk if not Addressed:

If not addressed, mechanical and electrical equipment may fail and piping may break during a seismic event. These failures may lead to power loss, communications loss, flooding, gas leaks, falling hazards, etc.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Description of Mitigation Concept:

The mitigation concept would involve performing studies to evaluate MEP issues at all STP and WPTP facilities, all offsite PS/Regulator/CSO facilities and the Vashon and Carnation WWTPs. Studies would review and document MEP issues including:

- Anchoring of mechanical and electrical equipment (pumps, control panels, MCC, etc.)
- Bracing and restraining of piping, ductwork, cable tray, and equipment
- Adding flex connections to piping and duct connections
- Adding seismic isolators where required
- Repairing existing defective mounting hardware
- Securing parts, spares, glass bulbs, etc.
- Additional investigation may indicate that other mitigation concepts are required to address the issues identified across WTD facilities

Advantages:

- Avoid disruption of wastewater treatment services
- Increases system reliability and robustness
- Maintains operational capacity during and following a seismic event
- Mitigates life safety hazards
- Mitigates collateral damage
- Decreases the likelihood of chemical spills

Disadvantages:

Repairs will:

- Require shutdown of operational activities for limited periods of time depending on the nature of the repairs
- Require working around existing equipment and ongoing operations
- Requires extensive communication and coordination with operations staff to implement improvements at each facility and across WTD’s system

Main Benefit:

The main benefit is that the studies and resulting repairs will allow continued operations during and following a seismic event. This will also minimize post-event damage to facilities and limit associated recovery costs.

Life safety is significantly improved because equipment and piping will be properly anchored and secured.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Discussion of Schedule:

This mitigation concept will require 1 to 3 years for completion of the evaluations/studies. Repairs will follow evaluations based on facility priority and will be funded separately.

Discussion of Risk:

Unexpected extended downtime may be encountered during retrofitting activities.

Currently, the extent of the retrofitting required at each facility is unknown. The table below shows typical deficiencies found at facilities during initial seismic screening visits:

Typical Identified Deficiencies Table

Deficiency Code	Description
M	Mechanical Equipment:
M1	Unsecure or inadequate equipment mounts
M2	Tall equipment not braced at top
M3	No seismic stops on spring mounted equipment
M4	Unsecured equipment guards
M5	Unsecured crane or monorail
M6	Inline pipe or duct supported equipment not braced
M7	Samplers not secured/braced
M8	Corroded equipment base or anchor bolts
R	Unsecured Storage and Maintenance Equipment:
R1	Storage Racks
R2	Storage cabinets
R3	Flammable Liquids storage cabinets
R4	Ladders or maintenance equipment
L	Unsecured Life Safety Equipment:
L1	Eye wash/Safety shower
G	Standby Generators:
G1	No seismic stops on spring mounted equipment
G2	Fuel Tanks or Day Tanks not secured or braced
G3	Batteries not secured
G4	Exhaust system has no flex connections or is unbraced
C	Chemical and Compressed Gas:
C1	Tanks not secured
C2	Pumps or filters not secured
C3	no flex connections on Polyethylene tanks
C4	Gas Cylinders not secured
C5	Chemical drums not secured
C6	Dry Chemicals not secured
P	Unbraced Piping:
P1	Primary Process piping
P2	Critical Secondary piping (IA, Seal Water, Hydraulics, Lube oil)
P3	Secondary Piping
P4	Fuel Gas Piping
P5	Diesel Piping
P6	Chemical Piping
P7	Sprinkler Piping

MITIGATION CONCEPT SUMMARY - STRUCTURES

Deficiency Code	Description
F	No Flex Connections between Piping and Equipment:
F1	Primary Process piping
F2	Critical Secondary piping (IA, Seal Water, Hydraulics, Lube oil)
F3	Secondary piping
F4	Fuel Gas piping
F5	Diesel piping
F6	Chemical Piping
S	Piping System with Different Support Structures:
S1	Piping system supported from 2 structures that could move differently in EQ
S2	Pipe sleeves not allowing for differential settlement
V	Valve Handles Missing:
V1	Valves missing handles that could be required during an EQ
V2	Valve/actuator support
D	Unbraced Ductwork and Ductwork with no Flex Connections:
D1	Unbraced HVAC Ductwork
D2	Unbraced OC Ductwork
D3	No Flex connection on HVAC Ductwork
D4	No Flex connection on OC Ductwork
X	Potential Flooding:
X1	Sump Pumps not braced
X2	Sump Pump Piping not braced
X3	No Sump Pump
X4	No Drain
X5	Sump Pump Level Switch not braced
E	Electrical Equipment and Conduits/Cable Tray:
E1	Tall panels, MCCs or cabinets unbraced
E2	Equipment, Panels, MCCs or Cabinets not secured at base
E3	No Flex connections to panels, MCCs or cabinets
E4	No flex connections to equipment
E5	Conduits or cable tray not braced
E6	Life Safety equipment/devices missing or that could fail
E7	Standby power or connection for temporary standby power not available
E8	Liquid piping located over electrical equipment

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Facilities were divided between small and medium/large sizes.
- Cost estimate to prepare a MEP seismic evaluation study for small facility was estimated at $12,000 per facility.
- Cost estimate to prepare a MEP seismic evaluation study for medium/large facility was estimated at $24,000 per facility.
- The number of small facilities was determined from existing KC information and included the following facilities:
  - Pump stations (less than 20 MGD): 32 facilities
  - Regulators and OC facilities: 18 facilities

MITIGATION CONCEPT SUMMARY - STRUCTURES

- The number of medium/large facilities was determined from existing KC information and included the following facilities?
  - Pump stations greater than 20MGD): 13 facilities
  - CSO Facilities: 4 facilities
  - Small WWTPs: 2 facilities
  - WPTP Facilities: 20 facilities
  - STP Facilities: 25 facilities
- The Brightwater WWTP was not included in the facilities to have MEP seismic evaluations due to the age of the facility and the seismic considerations considered in the design

Table 1. Concept-Level Cost Estimate

Estimate - AACEI Class 5							
Concept Title:	Programatic Piping, Mechanical and Electrical Upgrades			**Date:**		10/26/2017	
Location:	Multiple Locations			**Estimator:**		Eric Benton	
Description:	Perform MEP Evaluations for SPTP, WPTP, Small WWTP's, CSO Facilities, PS and Regulators			**Idea Code:**		SP-6	
DIRECT: PROGRAMMATIC ASSESSMENT COSTS							
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**		**Item Cost**	
1	Pump Stations, small, Site Evaluation and Report	32	EA	$	12,000	$	384,000
2	Pump Stations, medium/large, Site Evaluation and Report	13	EA	$	24,000	$	312,000
3	Regulators / OCU, small, Site Evaluation and Report	18	EA	$	12,000	$	216,000
4	CSO Facilities, medium/large, Site Evaluation and Report	4	EA	$	24,000	$	96,000
5	WWTP, small, Site Evaluation and Report	2	EA	$	24,000	$	48,000
6	WWTP, medium/large, Site Evaluation and Report	20	EA	$	24,000	$	480,000
	SPTP Facility, medium/large, Site Evaluation and Report	25	EA	$	24,000	$	600,000
					Subtotal Assessment Costs	***$***	***2,136,000***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES							
					Misc. Capital Costs	$	4,000
					TOTAL ASSESSMENT COSTS	***$***	***2,140,000***
INDIRECT: WTD ASSESSMENT COSTS							
					Design and Construction Consulting		n/a
					Other Consulting Services		n/a
					Permitting & Other Agency Support		n/a
					Right-of-Way		n/a
					Misc. Service & Materials		n/a
					Non-WTD Support		n/a
					WTD Staff Labor	$	361,370
					Subtotal WTD Assessment Costs	***$***	***361,370***
					Project Contingency	$	766,833
					Initiatives		n/a
					TOTAL INDIRECT WTD ASSESSMENT COSTS	***$***	***1,128,203***
					TOTAL PROJECT COST	***$***	***3,268,000***

Notes:
1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.
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MITIGATION CONCEPT SUMMARY - STRUCTURES

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - STRUCTURES

SP-7 Programmatic Glass Block Upgrades

Issue No.	Issue Title	Risk Rating
SP-7	Programmatic Glass Block Deficiencies	H
Idea Code	**Concept Title**	**Dev. Team**
SP-7	Programmatic Glass Block Upgrades	Team 1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☒ System Wide	☒ Structural	☒ Life Safety
☐ Site Specific (list site below)	☐ MEP	☐ Public Health
	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☐ Environment
	☒ Architectural	Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☐ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☒ 3 to 12 months
	☐ $5M to $10M		☐ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

There are several pre-existing glass block walls in a number of facilities that may be vulnerable to damage or collapse in an earthquake. If damaged they could be a life safety falling hazard, interrupt ingress/egress, and/or interrupt facility operations.

Risk if not Addressed:

If not addressed, a seismic event could cause the glass block walls to fall, injuring facility occupants or interrupting facility operations.

Description of Mitigation Concept:

The mitigation concept would involve the removal of glass block walls and replacement with glazing or other transparent partition wall systems that are seismically safe.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Advantages:

- Improves safety
- Reduces risk of interrupting operations due to glass block collapse during a seismic event

Disadvantages:

- May minimally interrupt operations

Main Benefit:

The main benefit is that this will allow continued operations during and following a seismic event.

Life safety is improved because the risk of a glass block wall falling and injuring WTD personnel and blocking ingress/egress routes is eliminated.

Discussion of Schedule:

This mitigation concept will require approximately 3-6 months for design. After a contractor is engaged, it will require approximately 3 month of construction per facility, which may be executed concurrently depending on how the project is contracted and the accessibility of the facilities.

Discussion of Risk:

No significant risk impacts anticipated.

Figure 33. Interurban Pump Station Glass Block Wall Example

Figure 34. West Point Treatment Plant Intermediate Pump Station Glass Block Walls at Ingress/Egress Stairway Example

Assumptions and Calculations:

1. It is assumed that glass block will be required to be removed and replaced at (14) individual facilities. The actual number of facilities with glass block will be refined by King County WTD when developing a project scope.
2. It is assumed that 200 SF of glass block will be required to be removed and replaced at each individual facility.
3. It is assumed that an architect-engineer consultant will be engaged through one contract to evaluate the glass block conditions and develop design drawings for the replacement of glass block with other forms of glazing or cladding appropriate to each facility.
4. It is assumed that a contractor will be engaged through one construction contract glass block replacement defined by the architect-engineering drawings.

MITIGATION CONCEPT SUMMARY - STRUCTURES

Table 1. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Programmatic Glass Block Upgrades			**Date:**	10/23/2017
Location:	Multiple Locations			**Estimator:**	Eric Benton
Description:	Removal of glass block walls and replacement with glazing or other transparent partition wall systems that are seismically safe			**Idea Code:**	SP-7
DIRECT: PROGRAMMATIC ASSESSMENT COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Demolition/Cut out Existing Glass Block Walls. Assuming 200 sqft of glass block wall per structure times 14 structures	2,800	SF	$ 131.40	$ 367,920
2	Disposal of Glass Block (including haul)	207	CY	$ 15.30	$ 3,173
3	Disposal Fees	104	TN	$ 81.00	$ 8,400
4	Steel Framed Windows with Glass	2,800	SF	$ 97.42	$ 272,776
5	Upgrade to Tempered Wire Glass	2,800	SF	$ 19.00	$ 53,200
6	Design of Glass Block Replacements	448		$ 200	$ 89,600
7	Mobilization	10	%	$79,507	$ 79,507
				Subtotal Assessment Costs	***$ 874,576***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				Misc. Capital Costs	$ 1,749
				TOTAL ASSESSMENT COSTS	***$ 876,000***
INDIRECT: WTD ASSESSMENT COSTS					
				Design and Construction Consulting	n/a
				Other Consulting Services	n/a
				Permitting & Other Agency Support	n/a
				Right-of-Way	n/a
				Misc. Service & Materials	$ 15,742
				Non-WTD Support	n/a
				WTD Staff Labor	$ 170,459
				Subtotal WTD Assessment Costs	***$ 186,202***
				Project Contingency	$ 320,726
				Initiatives	n/a
				TOTAL INDIRECT WTD ASSESSMENT COSTS	***$ 506,928***
				TOTAL PROJECT COST	***$ 1,383,000***

Notes:

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MITIGATION CONCEPT SUMMARY

SP-8 Seismic Standards for KC Facilities

Issue No.	Issue Title	Risk Rating
SP-8	KC Facility design standards do not address seismic resiliency	MH
Idea Code	**Concept Title**	**Dev. Team**
SP-8	Develop Seismic Standards for KC Facilities	

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☒ System Wide	☒ Structural	☒ Life Safety
☐ Site Specific (list site below)	☒ MEP	☒ Public Health
Matthews Park Pump Station	☒ SCADA	☒ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☐ Flow Volume
		☒ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☒ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☒ 3 to 12 months
	☐ $5M to $10M		☐ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

The WTD facility design standards, including specifications, standard details, and design criteria, do not adequately address the most current seismic standards or reflect the best available design technology and practices related to seismic resiliency design.

Risk if not Addressed:

The lack of having current seismic design standards for facilities will result in new projects being designed and constructed in a manner that does not reflect the best practices related to seismic design and the County's stated commitment to making all facilities seismically resilient.

Description of Mitigation Concept:

It is recommended that WTD consider review by and discussions with seismic design specialty consultants to review existing County facility design standards and documents as related to the current best practices and standards related to facility seismic design. After a thorough review of existing design standards and documents, the seismic design consultants should prepare a report outlining a program to update the County facility design standards to reflect the best practices related to seismic resiliency design and construction.

Advantages:

- Seismic design resiliency included in all future facility design.
- Seismic resiliency-related issues considered in all project planning and study reports.
- Consideration of seismic resiliency in facility design projects may result in lower insurance costs for the facility.

Disadvantages:

- Seismic resiliency design and construction may increase capital costs for new facilities.

Main Benefit:

All new County facilities would be designed and constructed to withstand damage from a major seismic event to the greatest extent practical.

Discussion of Schedule:

- Review of existing KC facility design standards is estimated to take approximately 6–9 months.
- Preparation of a report to address upgrades to the KC facility design standards for improved seismic resiliency is estimated to take 2–3 months.

Discussion of Risk:

N/A

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Direct Costs:
    - County staff participation in standards review workshops:
        - Four people for ten, 4-hour workshops = 160 hours
    - Seismic Design Consultants:
        - Two people for ten, 4-hour workshops = 80 hours
        - Prepare report: 40 hours
- Indirect Costs:
    - Miscellaneous services and materials: Assume 0.3 percent
    - Project contingency: Assume 10 percent

Table 19. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Develop Seismic Standard for King County Facilities			**Date:**	12/6/2017
Location:	Multiple Locations			**Estimator:**	Eric Benton, CPE
Description:				**Idea Code:**	SP-8
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Implementation Work Group	160	HRS	$ 150	$ 24,000
2	Seismic Specialist (Consultant)	120	HRS	$ 210	$ 25,200
3					
4					
5					
6					
7					
8					
				Subtotal Costs	***$ 50,000***
INDIRECT COSTS					
				Design and Construction Consulting	n/a
				Other Consulting Services	n/a
				Permitting & Other Agency Support	n/a
				Right-of-Way	n/a
				Misc. Service & Materials	$ 150
				Non-WTD Support	n/a
				WTD Staff Labor	n/a
				Subtotal Indirect Costs	***$ 50,150***
				Project Contingency	$ 5,015
				Initiatives	n/a
				TOTAL INDIRECT COSTS	***$ 55,000***
				TOTAL PROJECT COST	***$ 55,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY

SP-9 Seismic Standards for Conveyance Pipelines

Issue No.	Issue Title	Risk Rating
SP-9	KC conveyance pipeline design standards do not address seismic resiliency	MH
Idea Code	**Concept Title**	**Dev. Team**
SP-9	Develop Seismic Standards for KC Conveyance Pipelines	

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☒ System Wide	☒ Structural	☒ Life Safety
☐ Site Specific (list site below) Matthews Park Pump Station	☒ MEP	☒ Public Health
	☒ SCADA	☒ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☐ Flow Volume
		☒ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☒ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☒ 3 to 12 months
	☐ $5M to $10M		☐ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

The WTD conveyance pipeline design standards, including specifications, standard details, and design criteria, do not adequately address the most current seismic standards or reflect the best available design technology and practices related to seismic resiliency design.

Risk if not Addressed:

The lack of having current seismic design standards for conveyance pipelines will result in new projects being designed and constructed in a manner that does not reflect the best practices related to seismic design and the County's stated commitment to making all facilities seismically resilient.

Description of Mitigation Concept:

It is recommended that WTD consider review by and discussions with seismic design specialty consultants to review existing County conveyance pipeline design standards and documents as related to the current best practices and standards related to pipeline seismic design. After a thorough review of existing design standards and documents, the seismic design consultants should prepare a report outlining a program to update the County conveyance pipeline design standards to reflect the best practices related to seismic resiliency design and construction.

Advantages:

- Seismic design resiliency included in all future facility design.
- Seismic resiliency-related issues considered in all project planning and study reports.
- Consideration of seismic resiliency in conveyance pipeline design projects may result in lower insurance costs for the facility.

Disadvantages:

- Seismic resiliency design and construction may increase capital costs for new conveyance pipelines.

Main Benefit:

All new County conveyance pipelines would be designed and constructed to withstand damage from a major seismic event to the greatest extent practical.

Discussion of Schedule:

- Review of existing KC conveyance pipeline design standards is estimated to take approximately 6–9 months.
- Preparation of a report to address upgrades to the KC facility design standards for improved seismic resiliency is estimated to take 2–3 months.

Discussion of Risk:

N/A

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Direct Costs:
  - County staff participation in standards review workshops:
    - Four people for ten, 4-hour workshops = 160 hours
  - Seismic Design Consultants:
    - Two people for ten, 4-hour workshops = 80 hours
    - Prepare report: 40 hours
- Indirect Costs:
  - Miscellaneous services and materials: Assume 0.3 percent
  - Project contingency: Assume 10 percent

MITIGATION CONCEPT SUMMARY

Table 20. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Develop Seismic Standard for King County Conveyance Pipelines			**Date:**	12/6/2017
Location:	Multiple Locations			**Estimator:**	Eric Benton, CPE
Description:				**Idea Code:**	SP-9
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Implementation Work Group	160	HRS	$ 150	$ 24,000
2	Seismic Specialist (Consultant)	120	HRS	$ 210	$ 25,200
3					
4					
5					
6					
7					
8					
				Subtotal Costs	***$ 50,000***
INDIRECT COSTS					
				Design and Construction Consulting	n/a
				Other Consulting Services	n/a
				Permitting & Other Agency Support	n/a
				Right-of-Way	n/a
				Misc. Service & Materials	$ 150
				Non-WTD Support	n/a
				WTD Staff Labor	n/a
				Subtotal Indirect Costs	***$ 50,150***
				Project Contingency	$ 5,015
				Initiatives	n/a
				TOTAL INDIRECT COSTS	***$ 55,000***
				TOTAL PROJECT COST	***$ 55,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based on the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

D-2: Seismic Liquefaction

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MITIGATION CONCEPT SUMMARY -LIQUEFACTION

Issue No.	Concept Title
L-1	Belvoir Pump Station Liquefaction Retrofits
L-2	North Creek Pump Station Liquefaction Retrofits
L-3	63rd Avenue Pump Station Liquefaction Retrofits
L-4	West Marginal Way Pump Station Liquefaction Retrofit
L-5	30th Avenue Pump Station Liquefaction Retrofit
L-6	Interurban Pump Station Liquefaction Retrofit
L-8	Woodinville Pump Station Liquefaction Retrofit
L-9	Henderson Pump Station Liquefaction Retrofit
L-11	Rainier Avenue Pump Station Liquefaction Retrofit
L-12	East Marginal Way Pump Station Liquefaction Retrofit
LP-2	West Point Treatment Plant Liquefaction Programmatic Assessment
LP-3	South Treatment Plant Liquefaction Programmatic Assessment

MITIGATION CONCEPT SUMMARY -LIQUEFACTION

L-1 Belvoir Pump Station Liquefaction Retrofits

Issue No.	Issue Title	Risk Rating
L-1	Belvoir Pump Station Liquefaction Deficiencies	MH
Idea Code	**Concept Title**	**Dev. Team**
L-1a	Belvoir Pump Station Liquefaction Retrofits	2

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
Belvoir Pump Station	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☒ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

There are site stability deficiencies at Belvoir Pump Station related to liquefaction of the surrounding soils. The site is also adjacent to an area comprised of landfill material. Site-specific explorations and analyses are required to define liquefaction extent and are beyond the scope of this mitigation concept summary development. The mitigation concept summary is based on a cursory review of subsurface data available from the Washington State Department of Natural Resources (data reviewed provided in this summary). Assumptions regarding liquefaction extent based on the subsurface data review are indicated under “Assumptions and Calculations.”

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program there is potential that the building could float, rotate or move laterally causing pipe disconnections and system downtime.

The likely system downtime is expected to be approximately one month (as a standalone repair).

MITIGATION CONCEPT SUMMARY -LIQUEFACTION

If a failure occurs, raw sewage will be discharged into Union Bay.

Collateral damage might include the possible separation of the influent sewer from the pump station, resulting in discharge flow over land into the bay. There is a heavily used trail near the pump station that may be impacted by this discharge.

Description of Mitigation Concept:

The alternative concept includes ground improvement (compaction grouting or jet grouting) and providing pipe flexibility in and out of the pump station. The facility will require a temporary bypass to construct piping modifications.

The team assumed repair by re-piping. However, there is the potential that the building will move to the extent that the pump station will have to be rebuilt. If the pump station is rebuilt, new foundations designed to mitigate liquefaction effects (e.g., pile foundations or extending foundations down into competent soil/rock) should be included.

The pump station is located in an area determined to be susceptible to liquefaction. However, the assessment is not a site-specific study. To fully evaluate the potential for liquefaction and impacts to the facilities, a complete site-specific evaluation is needed.

Advantages:

- Supports the seismic resilience of the pump station
- Avoids raw sewage discharge into Union Bay after a major earthquake event

Disadvantages:

- Further analysis is needed to determine the cost effectiveness of repairing the pump station following a liquefaction event versus implementing this mitigation concept prior to a seismic event

Main Benefit:

The main benefit of this mitigation concept is providing mitigation for liquefiable soils at the Belvoir Pump Station.

Discussion of Schedule:

This mitigation concept will require a one-month installation window, which is not directly affected by seasonal work windows and can be accomplished year-round. The installation of ground improvements would pose little impact to facility operations.

Design and permitting may require 18 months; including contracting and construction, a total of two years.

Discussion of Risk:

This mitigation concept will address the potential impacts of liquefaction and the possible discharge of raw sewage into Lake Washington. It does not address a moderate structural vulnerability or any damage to the adjacent roadway. The CSO portion of Belvoir is not being addressed in this mitigation concept. This concept will be fully-effective provided that the 30th Avenue Pump Station (see L-5) is also addressed.

MITIGATION CONCEPT SUMMARY -LIQUEFACTION

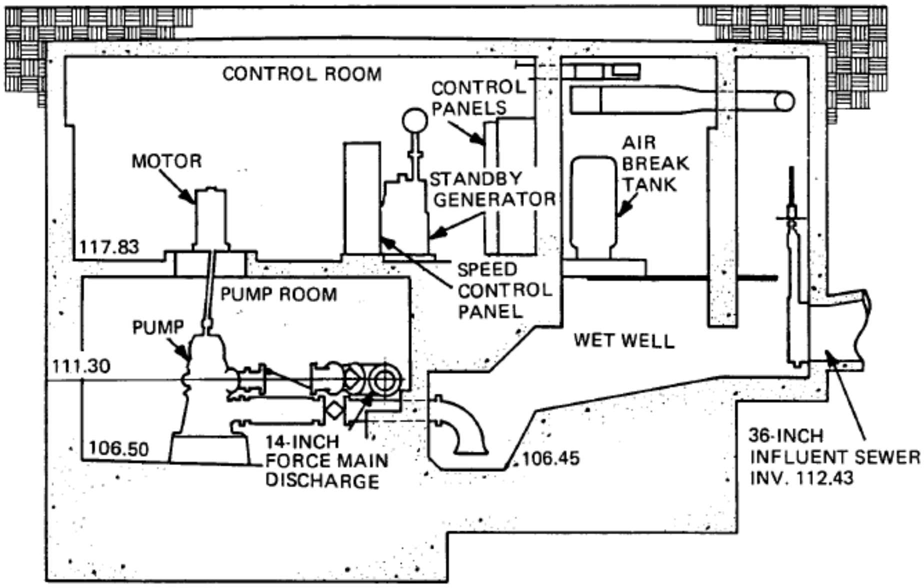

Figure 1. Station Cross Section

Figure 2. Site location with boring points identified, approximately 200 feet from the station

MITIGATION CONCEPT SUMMARY -LIQUEFACTION

Layer Data

Layer Number	Top Depth (ft)	Bottom Depth	Description	Layer Type	USCS
3	7	10	Silty sand; gray, mottled brown, fine grained, loose, saturated (sm)	Single	SM
4	10	14	Silty sand; with some gravel and trace clay, tan to brown, fine to coarse grained, loose saturated (sm)	Single	SM
5	14	17	Sandy clay; green gray to blue, coarse grained sand, very stiff, moist, medium plasticity (cl)	Single	CL

Figure 3. Boring log data

All maps and boring data obtained from: *http://www.dnr.wa.gov/geologyportal*.

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Facility size is just over 900 square feet
- Based on boring, pump station is likely on competent material or a few feet above
- Influent sewer is significantly higher, in soils that may move
- 10 feet of ground improvement assumed beneath structure

King County

HDR TEAM

MITIGATION CONCEPT SUMMARY -LIQUEFACTION

Table 1. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Belvoir Pump Station Liquefaction Retrofits			**Date:**	9/13/2017
Location:	3901 Surber Dr NE, Seattle, WA			**Estimator:**	Eric Benton
Description:				**Idea Code:**	L-1a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Ground Stabilization - Jet Grouting (941 sf)	240	LF	$ 300	$ 72,000
2	Site Demo and Restorations	2,541	SF	$ 9	$ 22,869
3	Pipe Flexibility Installation	25	LF	$ 1,850	$ 46,250
4	Mobilization / Demobilization (10%)	10	%	$ 14,112	$ 14,112
				Subtotal Construction Costs	***$ 160,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 64,000
				Construction Change Order Allowance	$ 22,400
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 246,400***
				Street Use Permit	$ -
				Construction Sales Tax	$ 24,886
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 271,286***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 493
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 272,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 184,911
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 2,864
				Right-of-Way	$ 3,200
				Misc. Service & Materials	$ 1,971
				Non-WTD Support	$ 2,094
				WTD Staff Labor	$ 62,959
				Subtotal Non-Construction Costs	***$ 258,000***
				Project Contingency	$ 159,953
				Initiatives	$ 3,397
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 421,000***
				TOTAL PROJECT COST	***$ 693,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

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Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY

L-2 North Creek Pump Station Liquefaction Retrofits

Issue No.	Issue Title	Risk Rating
L-2	North Creek Pump Station Liquefaction Deficiencies	MH
Idea Code	**Concept Title**	**Dev. Team**
L-2a	North Creek Pump Station Liquefaction Retrofits	2

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☒ Public Health
North Creek Pump Station	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☒ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

There are site stability deficiencies at the North Creek Pump Station related to liquefaction of the surrounding soils. Site-specific explorations and analyses are required to define liquefaction extent and are beyond the scope of this mitigation concept summary development. The mitigation concept summary is based on a cursory review of subsurface data available from the Washington State Department of Natural Resources (data reviewed provided in this summary). Assumptions regarding liquefaction extent based on the subsurface data review are indicated under "Assumptions and Calculations."

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program there exists the potential that the building could sink or rotate, causing the conveyance lines to fail in a substantial earthquake event and cause failure of the pump station. The North Creek Pump Station is only used when the Brightwater Treatment Plant is down. Impacts above only become critical during a Southern Whidbey Island Fault (SWIF) event that takes Brightwater offline for a period of time.

The likely system downtime is expected to be approximately two months.

MITIGATION CONCEPT SUMMARY

If the facility is not addressed, there is potential for discharge into the adjacent roadway, through wetlands and ultimately to North Creek and the Sammamish River.

Collateral damage might include impacts to the adjacent community park, the interstate and/or nearby commercial buildings.

Description of Mitigation Concept:

The alternative concept includes ground improvement (compaction grouting) and providing pipe flexibility in and out of the pump station. Given the size and age of the facility, it is likely that some liquefaction mitigation may have already been conducted and additional mitigation may not be required.

The pump station is located in an area determined to be susceptible to liquefaction. However, the assessment is not a site-specific study. To fully evaluate the potential for liquefaction and impacts to the facilities, a complete site-specific evaluation is needed.

Advantages:

- Reduces likelihood of discharge
- Provides redundancy for Brightwater Treatment Facility

Disadvantages:

- The pump station is only used as a backup to the Brightwater Treatment Facility, therefore the cost is high relative to the function

Main Benefit:

The main benefit of this mitigation concept is to provide operational flexibility and redundancy for Brightwater.

Discussion of Schedule:

This mitigation concept will require a 2-month installation window, which is not directly affected by seasonal work windows and can be accomplished year-round. The installation of ground improvements would pose little impact to facility operations.

Design and permitting may require 18 months; including contracting and construction, a total of two years.

Discussion of Risk:

This mitigation concept will address the potential impacts of liquefaction and the possible discharge of raw sewage. It does not address a moderate structural vulnerability or any damage to the adjacent roadway. The ancillary buildings (odor control and underground storage tank) at North Creek Pump Station site are not being addressed in this mitigation concept. In order for the North Creek Pump Station to be functional, the East Side Interceptor must be functional or the benefit of redundancy for the Brightwater facility is not realized.

MITIGATION CONCEPT SUMMARY

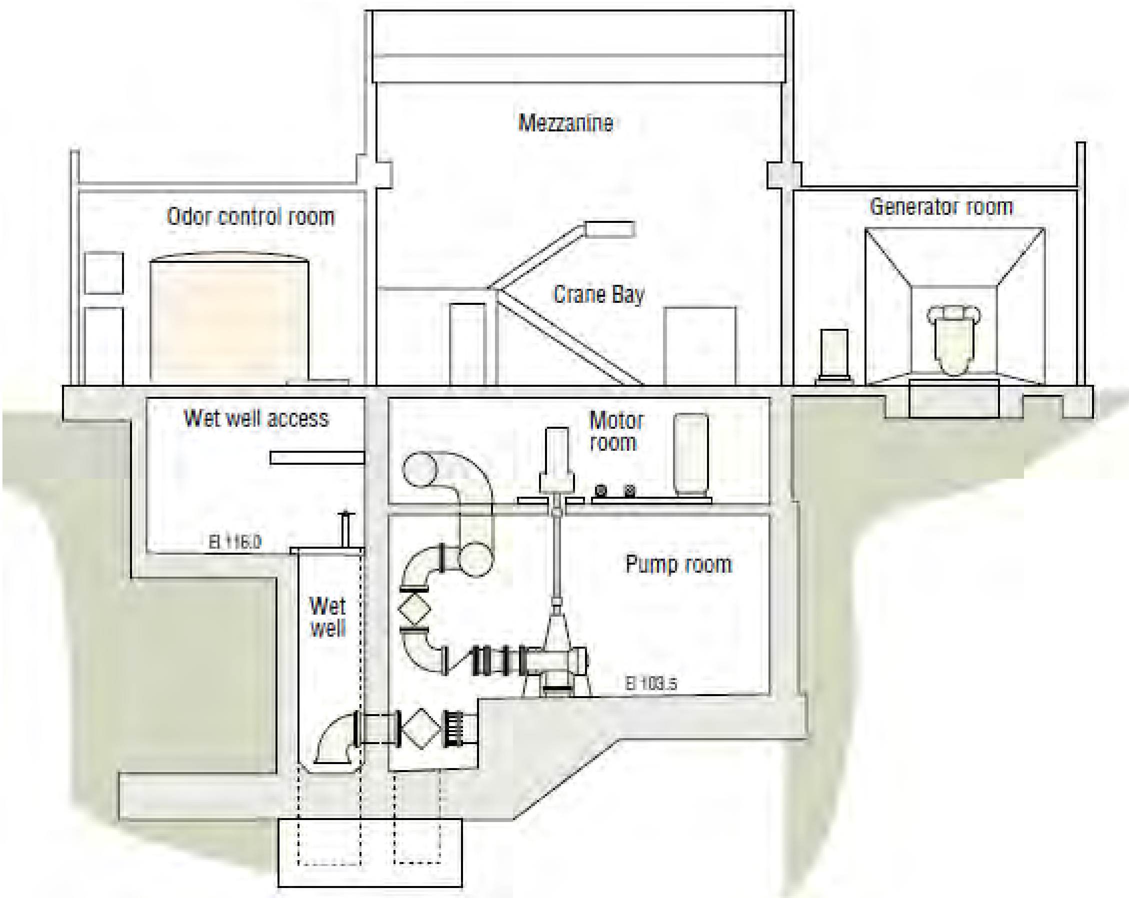


Figure 1. Station Cross Section

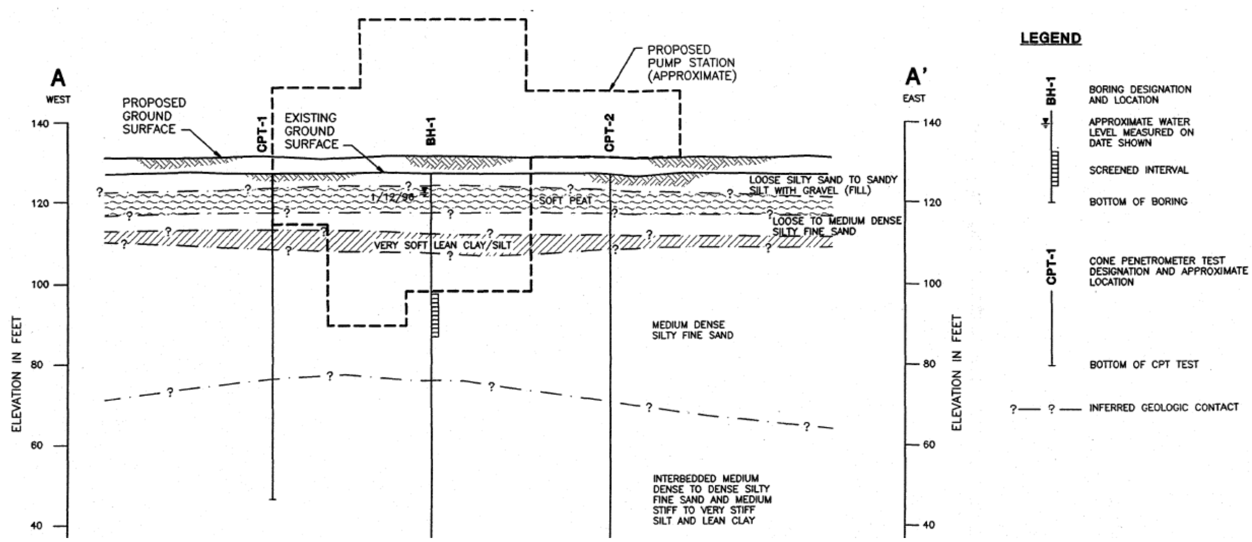


Figure 2. North Creek Subsurface Profile

Figure 3. Boring Location Map

All maps and boring data obtained from: *http://www.dnr.wa.gov/geologyportal*.

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- The facility is roughly 5,800 square feet
- Compaction grouting was used as the assumed ground improvement technique
- The bottom of the facility slab is 36 feet below grade
- Assuming 70 feet of ground improvement for the mitigation concept

MITIGATION CONCEPT SUMMARY

Table 2. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	North Creek Pump Station Liquefaction Retrofits			**Date:**	9/13/2017
Location:	18707 North Creek Pkwy, Bothell, WA			**Estimator:**	Eric Benton
Description:				**Idea Code:**	L-2a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Ground Stabilization - Compaction Grouting (5,814 sf)	10220	LF	$ 30	$ 306,600
2	Site Demo and Restorations	11,628	SF	$ 9	$ 104,652
3	Pipe Flexibility Installation	25	LF	$ 1,850	$ 46,250
4	Mobilization / Demobilization (10%)	10	%	$ 45,750	$ 45,750
				Subtotal Construction Costs	***$ 500,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 200,000
				Construction Change Order Allowance	$ 70,000
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 770,000***
				Street Use Permit	$ -
				Construction Sales Tax	$ 77,770
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 847,770***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 1,540
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 849,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 486,595
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 8,950
				Right-of-Way	$ 10,000
				Misc. Service & Materials	$ 6,160
				Non-WTD Support	$ 6,545
				WTD Staff Labor	$ 161,381
				Subtotal Non-Construction Costs	***$ 679,631***
				Project Contingency	$ 461,867
				Initiatives	$ 10,616
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 1,152,000***
				TOTAL PROJECT COST	***$ 2,001,000***

Notes:
1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.
2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY

L-3 63rd Avenue Pump Station Liquefaction Retrofits

Issue No.	Issue Title	Priority Score
L-3	63rd Avenue Pump Station Liquefaction Deficiencies	MH
Idea Code	**Concept Title**	**Dev. Team**
L-3a	63rd Avenue Pump Station Liquefaction Retrofits	2

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
63rd Avenue Pump Station	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☒ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

There are site stability deficiencies at the 63rd Avenue Pump Station related to liquefaction of the surrounding soils. Site-specific explorations and analyses are required to define liquefaction extent and are beyond the scope of this mitigation concept summary development. The mitigation concept summary is based on a cursory review of subsurface data available from the Washington State Department of Natural Resources (data reviewed provided in this summary). Assumptions regarding liquefaction extent based on the subsurface data review are indicated under “Assumptions and Calculations.”

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program there is potential that liquefaction could cause the building to sink, rotate or laterally displace in a major seismic event, causing the conveyance lines or the pump station to fail.

The likely system downtime is estimated at approximately one month.

In the event of a failure, raw and combined sewage would be discharged into the Puget Sound.

MITIGATION CONCEPT SUMMARY

Collateral damage in the event of a raw sewage discharge might include impacts to the adjacent beach, nearby residential and commercial mixed-use areas.

Description of Mitigation Concept:

The alternative concept includes ground improvement (excavation/replace, compaction grouting or jet grouting) and providing pipe flexibility in and out of the pump station.

The team assumed repair by re-piping. However, there is the potential that the building will move to the extent that the pump station will have to be rebuilt. If the pump station is rebuilt, new foundations designed to mitigate liquefaction effects (e.g., piles or extending foundation down into competent soils/rock) should be included.

The pump station is located in an area determined to be susceptible to liquefaction. However, the assessment is not a site-specific study. To fully evaluate the potential for liquefaction and impacts to the facilities, a complete site-specific evaluation is needed.

Advantages:

- Avoid raw sewage discharge after a major earthquake event
- This concept supports the seismic resilience of the pump station
- Implementing this mitigation improves the likelihood of continued operation to Alki CSO Treatment Plant

Disadvantages:

- Further analysis is needed to determine the cost effectiveness of repairing the pump station following a liquefaction event versus implementing this mitigation concept prior to a seismic event

Main Benefit:

The main benefit of this mitigation concept is to avoid raw sewage discharge into the Sound following a major earthquake event.

Discussion of Schedule:

This mitigation concept will require a one-month installation window. This work is not directly affected by seasonal work windows and can be accomplished year-round.

Design and permitting may require 18 months; including contracting and construction, a total of two years.

Discussion of Risk:

There is risk related to dependency on continued function of the force mains. If the force mains are down, 63rd Avenue would not receive flow.

MITIGATION CONCEPT SUMMARY

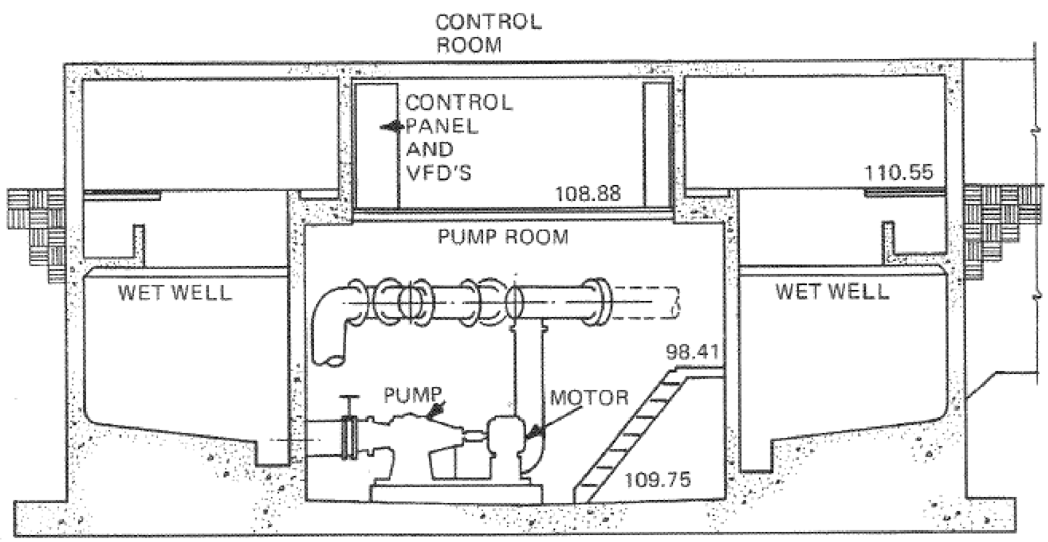


Figure 3. Station Cross Section

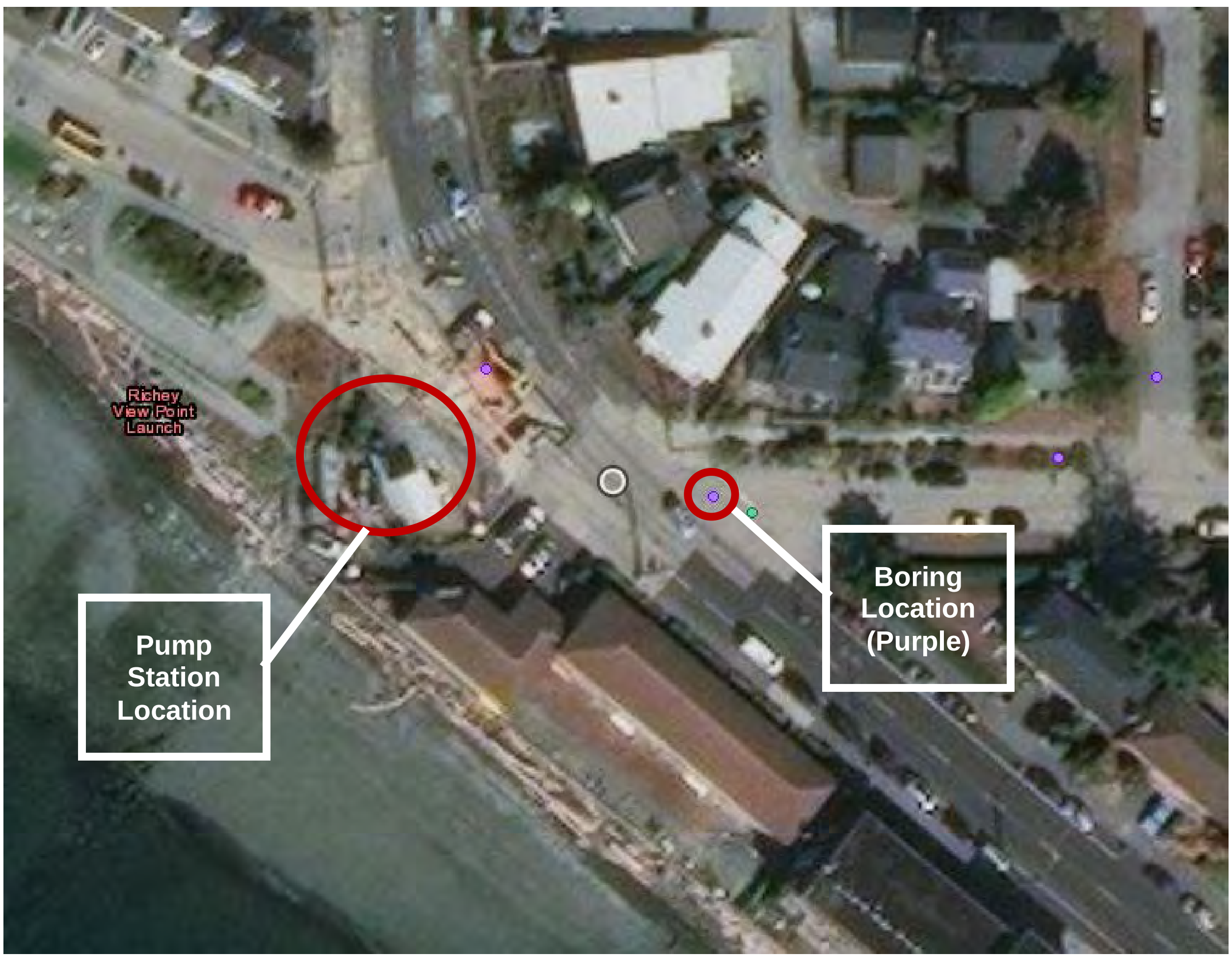


Figure 4. Pump Station and Boring Location

Layer Data

Layer Number	Top Depth (ft)	Bottom Depth (ft)	Description	Layer Type	USCS	Geologic Unit
7	16.5	17.5	Sand; black, fine to medium	Single	Unknown	U
8	17.5	20	Sand and gravel. (Beach deposits)	Single	Unknown	Qbu
9	20	29	Sand; gray, fine, trace to few silt, trace wood, trace medium to coarse sand, trace fine gravel; dense, wet	Single	Unknown	Qbu
10	29	34	Silty sand; gray-brown, fine, few medium to coarse sand and fine to coarse gravel, interbedded with fine to medium sand, trace silt	Single	Unknown	Qobc

Figure 3. Boring log data for location 100 feet from facility

All maps and boring data obtained from: *http://www.dnr.wa.gov/geologyportal*.

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- The facility is 2,600 square feet
- Cost estimate is based on the compacted grout ground improvement technique
- Soils appear liquefiable down to a depth of 20 feet
- The main facility goes to a depth of 20 feet; the 63rd Avenue Annex only goes to a depth of 12 feet (to the Alki CSO plant)
- Based on boring data, the pump station is likely on competent material or a few feet above
- Assume ground improvements to a depth of 10 feet for estimating purposes

MITIGATION CONCEPT SUMMARY

Table 3. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	63rd Avenue Pump Station Liquefaction Retrofits			**Date:**	9/13/2017
Location:	3535 Beach Drive SW, Seattle, WA			**Estimator:**	Eric Benton
Description:				**Idea Code:**	L-3a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Ground Stabilization - Compaction Grouting	660	LF	$ 38	$ 25,080
2	Site Demo and Restorations	5,216	SF	$ 9	$ 46,944
3	Pipe Flexibility Installation	25	LF	$ 1,850	$ 46,250
4	Mobilization / Demobilization (10%)	10	%	$ 11,827	$ 11,827
				Subtotal Construction Costs	***$ 130,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 52,000
				Construction Change Order Allowance	$ 18,200
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 200,200***
				Street Use Permit	$ -
				Construction Sales Tax	$ 20,220
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 220,420***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 400
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 221,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 155,047
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 2,327
				Right-of-Way	$ 2,600
				Misc. Service & Materials	$ 1,602
				Non-WTD Support	$ 1,702
				WTD Staff Labor	$ 53,117
				Subtotal Non-Construction Costs	***$ 216,395***
				Project Contingency	$ 131,993
				Initiatives	$ 2,760
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 351,000***
				TOTAL PROJECT COST	***$ 572,000***

Notes:
1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.
2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY

L-4 West Marginal Way Pump Station Liquefaction Retrofit

Issue No.	Issue Title	Risk Rating
L-4	West Marginal Way Pump Station Liquefaction Deficiencies	MH
Idea Code	**Concept Title**	**Dev. Team**
L-4a	West Marginal Way Pump Station Liquefaction Retrofit	2

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below) West Marginal Way Pump Station	☐ MEP	☐ Public Health
	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☐ Flow Volume
		☒ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

There are site stability deficiencies at the West Marginal Way Pump Station related to liquefaction of the surrounding soils. Site-specific explorations and analyses are required to define liquefaction extent and are beyond the scope of this mitigation concept summary development. The mitigation concept summary is based on a cursory review of subsurface data available from the Washington State Department of Natural Resources (data reviewed provided in this summary). Assumptions regarding liquefaction extent based on the subsurface data review are indicated under “Assumptions and Calculations.”

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program there is potential that a major seismic event could cause the pump station building to float, sink, rotate or laterally displace. Failure of the conveyance lines during a substantial earthquake event could cause failure of the West Marginal Way Pump Station.

MITIGATION CONCEPT SUMMARY

The system downtime is expected to be roughly 18 months. A temporary solution using pumps could bring the facility back online within 6 months.

In the event of a failure, raw sewage will be discharged over land or into the nearby CSO outfall, ultimately reaching the Duwamish River. Collateral damage might include raw sewage at the adjacent industrial area.

Description of Mitigation Concept:

The alternative concept includes ground improvement (compaction grouting or jet grouting) and providing pipe flexibility in and out of the pump station. The facility will require a temporary bypass to construct piping modifications.

The team assumed repair by re-piping. However, there is the potential that the building will move to the extent that the pump station will have to be rebuilt. If the pump station is rebuilt, new foundations designed to mitigate liquefaction effects (e.g., pile foundations or extending foundations down into competent soil/rock) should be included.

The pump station is located in an area determined to be susceptible to liquefaction. However, the assessment is not a site-specific study. To fully evaluate the potential for liquefaction and impacts to the facilities, a complete site-specific evaluation is needed.

Advantages:

- Avoids raw sewage discharge to the Duwamish after a major earthquake event
- This concept supports the seismic resilience of the pump station

Disadvantages:

- None noted

Main Benefit:

The main benefit of this mitigation concept is in avoiding raw sewage discharge into the Duwamish River.

Discussion of Schedule:

This mitigation concept is expected to require a two-month installation window. The proposed work is not directly affected by seasonal work windows and can be accomplished year-round. The installation of ground improvements would pose little impact to facility operations.

Design and permitting may require 18 months including contracting and construction, a total of two years.

Discussion of Risk:

Proper function of the West Marginal Way Pump Station is dependent on the functioning of the Elliott Bay Interceptor, using the Duwamish and Interbay Pump Stations. If the Elliott Bay Interceptor fails, the West Marginal Way Pump Station will discharge to the Duwamish River. Beginning in 2022, the Georgetown Wet Weather Treatment Plant may be able to accommodate partial treatment of this discharge.

MITIGATION CONCEPT SUMMARY

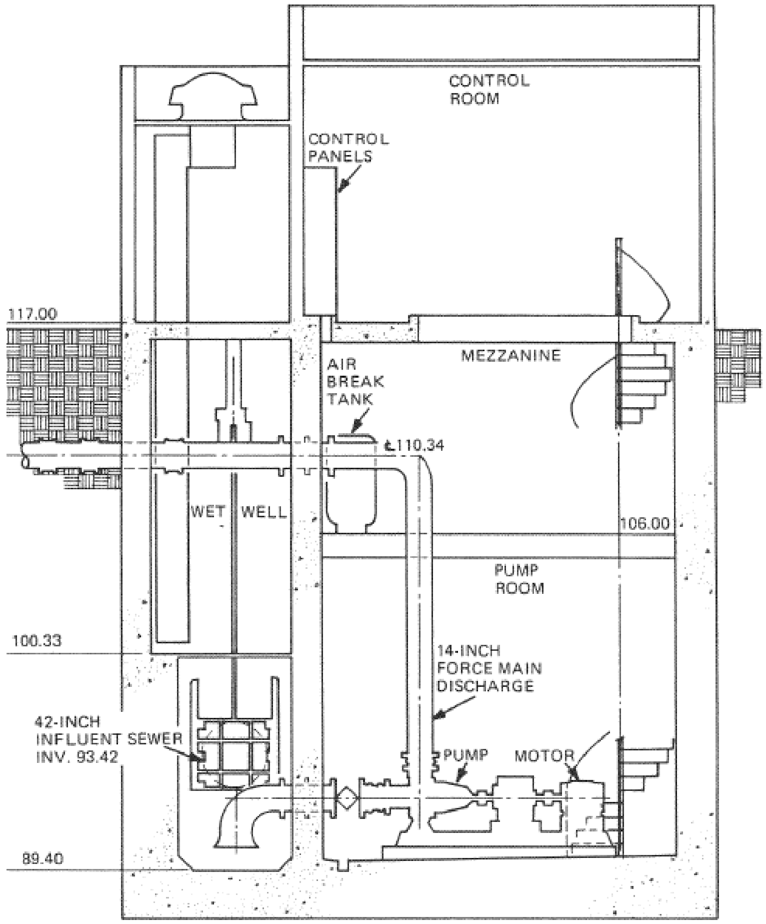


Figure 5. Station Cross Section

Figure 6. Boring Location

Layer Data

Layer Number	Top Depth (ft)	Bottom Depth (ft)	Description	Layer Type	USCS	Geologic Unit
4	16	18.5	Clayey silt (firm) blue-gray, trace fine sand, scattered roots and branches, no bedding evident (ml)	Single	ML	
5	18.5	22	Silty sand (loose) dark gray-brown, fine, scattered roots and organic fibers, thinly laminated, wet (sm)	Single	SM	
6	22	36.5	Sand (medium dense) gray, fine, little silt, scattered organic fibers, occasional beds of silt, thinly laminated, wet (sm)	Single	SM	

Figure 3: Boring Log Data

All maps and boring data obtained from: *http://www.dnr.wa.gov/geologyportal*.

MITIGATION CONCEPT SUMMARY

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Facility is roughly 1,100 square feet
- Jet grouting is the assumed ground improvement for estimating purposes
- The base of the pump station is at a depth of 30 feet
- Boring data indicates at least 40 feet of liquefaction-susceptible soil

MITIGATION CONCEPT SUMMARY

Table 4. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	West Marginal Way Pump Station Liquefaction Retrofits			**Date:**	9/13/2017
Location:	7119 W Marginal Way SW, Seattle, WA			**Estimator:**	Eric Benton
Description:				**Idea Code:**	L-4a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Ground Stabilization - Jet Grouting (1,075 sf bldg.)	1,350	LF	$ 250	$ 337,500
2	Site Demo and Restorations	2,150	SF	$ 9	$ 19,350
3	Pipe Flexibility Installation	25	LF	$ 1,850	$ 46,250
4	Mobilization / Demobilization (10%)	10	%	$ 40,310	$ 40,310
				Subtotal Construction Costs	***$ 440,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 176,000
				Construction Change Order Allowance	$ 61,600
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 677,600***
				Street Use Permit	$ -
				Construction Sales Tax	$ 68,438
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 746,038***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 1,355
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 747,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 436,506
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 7,876
				Right-of-Way	$ 8,800
				Misc. Service & Materials	$ 5,421
				Non-WTD Support	$ 5,760
				WTD Staff Labor	$ 145,102
				Subtotal Non-Construction Costs	***$ 609,464***
				Project Contingency	$ 409,860
				Initiatives	$ 9,342
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 1,029,000***
				TOTAL PROJECT COST	***$ 1,776,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY

L-5 30th Avenue Pump Station Liquefaction Retrofit

Issue No.	Issue Title	Risk Rating
L-5	30th Avenue Pump Station Liquefaction Deficiencies	MH
Idea Code	**Concept Title**	**Dev. Team**
L-5a	30th Avenue Pump Station Liquefaction Retrofit	2

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
30th Avenue Pump Station	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards (list type below)	☒ Environment
		Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

There are site stability deficiencies at the 30th Avenue Pump Station related to liquefaction of the surrounding soils. Site-specific explorations and analyses are required to define liquefaction extent and are beyond the scope of this mitigation concept summary development. The mitigation concept summary is based on a cursory review of subsurface data available from the Washington State Department of Natural Resources (data reviewed provided in this summary). Assumptions regarding liquefaction extent based on the subsurface data review are indicated under “Assumptions and Calculations.”

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program there exists the potential that during a major seismic event, the building may float, sink, rotation or experience lateral movement. The conveyance lines are susceptible to failure in a substantial earthquake event, which could result in the failure of the 30th Avenue Pump Station.

The likely system downtime is expected to be two months.

In the event of a failure, raw sewage would be discharged over land into the storm drainage system and Union Bay. The pump station is surrounded by a number of commercial facilities.

Collateral damage includes the discharge of raw sewage in the streets surrounding a number of commercial facilities (shopping center, parking garage).

Description of Mitigation Concept:

The alternative concept includes ground improvement (compaction grouting or jet grouting) and providing pipe flexibility in and out of the pump station. The facility will require a temporary bypass to construct piping modifications.

The team assumed repair by re-piping. However, there is the potential that the building will move to the extent that the pump station will have to be rebuilt. If the pump station is rebuilt, new foundations designed to mitigate liquefaction effects (e.g., pile foundations or extending foundations down into competent soil/rock) should be included.

The pump station is located in an area determined to be susceptible to liquefaction. However, the assessment is not a site-specific study. To fully evaluate the potential for liquefaction and impacts to the facilities, a complete site-specific evaluation is needed.

Advantages:

- Avoid raw sewage discharge after a major earthquake event
- This concept supports the seismic resilience of the pump station

Disadvantages:

- Further analysis is needed to determine the cost effectiveness of repairing the pump station following a liquefaction event versus implementing this mitigation concept prior to a seismic event
- The site is located in a highly congested commercial area

Main Benefit:

The main benefit of this mitigation concept is reducing the likelihood of raw sewage being discharged after a major earthquake event.

Discussion of Schedule:

This mitigation concept will require a two-month installation window. This work is not directly affected by seasonal work windows and can be accomplished year-round. The installation of ground improvements would pose little impact to facility operations.

Design and permitting may require 6-12 months, including contracting and construction, a total of up to 18 months.

Discussion of Risk:

Operation of Belvoir Pump Station system is dependent on 30th Avenue Pump Station. If 30th Avenue experiences a failure, it will discharge into the storm drain system and eventually into Union Bay.

MITIGATION CONCEPT SUMMARY

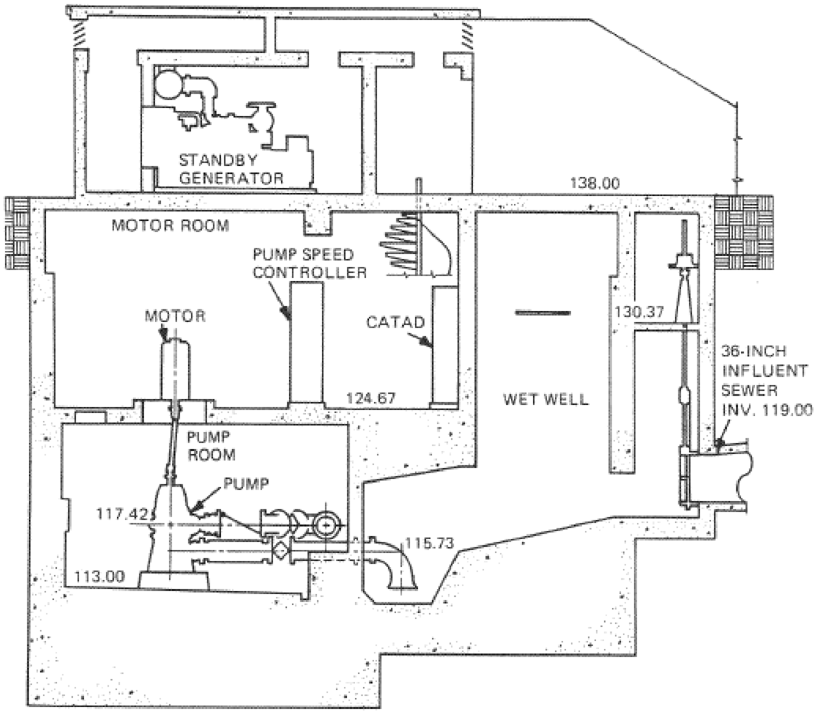


Figure 7. Station Cross Section

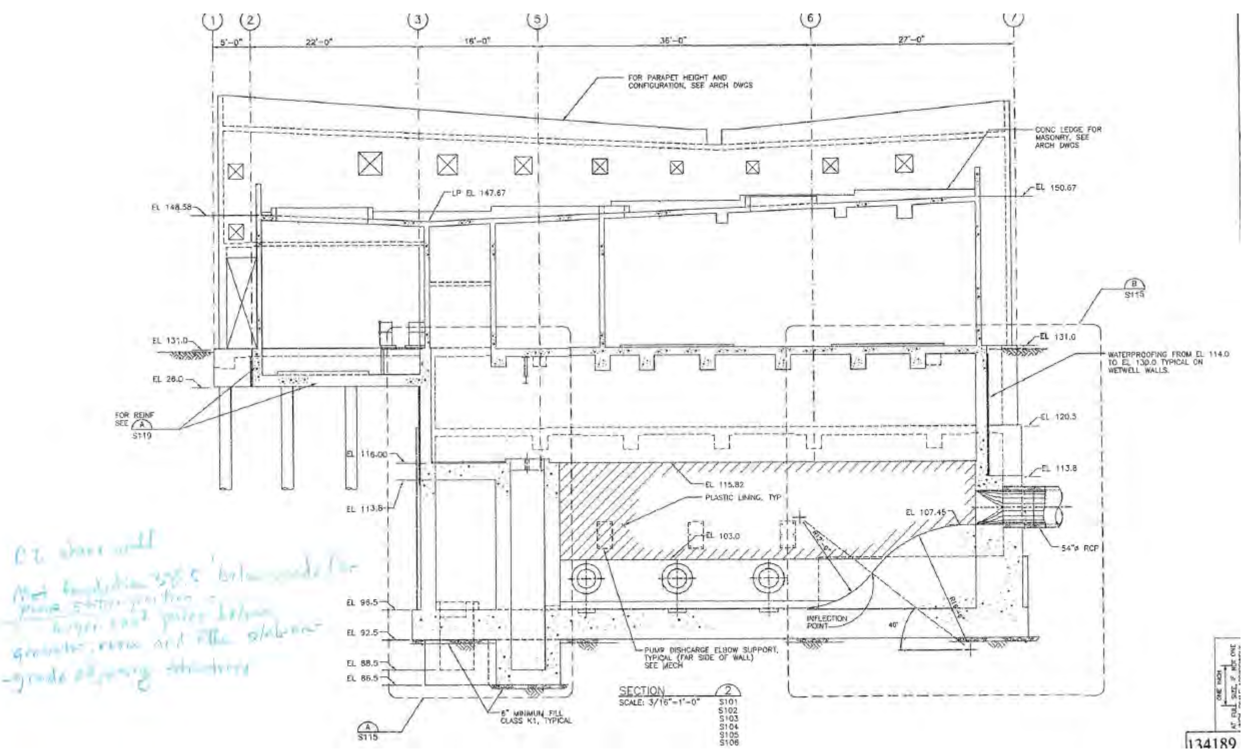


Figure 2. Structural Cross Section

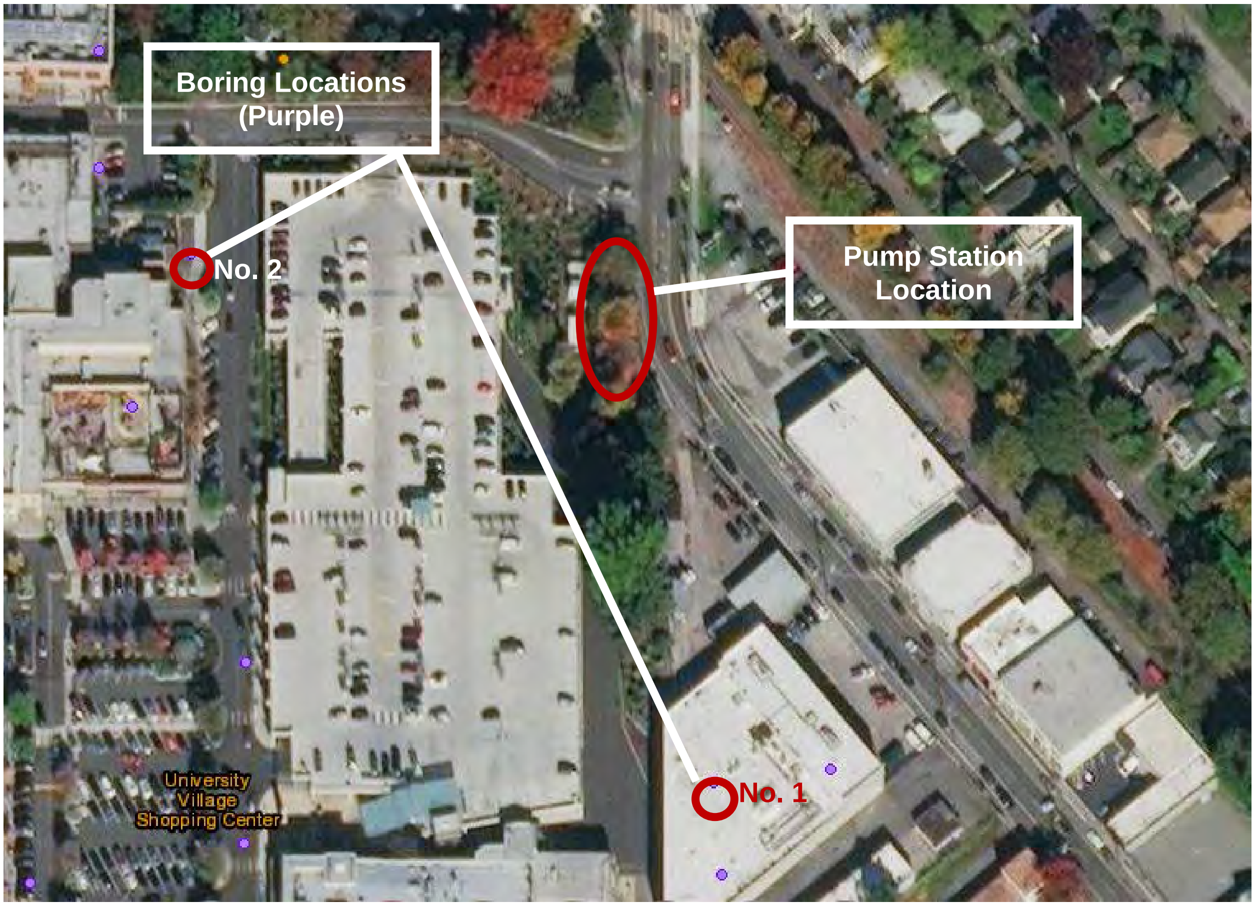


Figure 3. Boring Locations

Layer Data

Layer Number	Top Depth (ft)	Bottom Depth (ft)	Description	Layer Type	USCS	Geologic Unit
5	21	26	Soft saturated silty clay - underlain by a medium dense gravelly sand	Single	Unknown	
6	26	31	Medium gravelly sand, heave encountered	Single	Unknown	
7	31	36	Very dense coarse gray sand	Single	Unknown	
8	36	39	Very dense coarse gravelly sand	Single	Unknown	

Layer Data

Layer Number	Top Depth (ft)	Bottom Depth (ft)	Description	Layer Type	USCS	Geologic Unit
3	3	8	Very soft to soft, moist to wet, dark brown peat.	Single	Unknown	
4	8	17.5	Medium dense, wet, brown and gray, slightly silty, very gravelly, fine to medium sand.	Single	Unknown	
5	17.5	34	Dense to very dense, wet, gray, medium sand.	Single	Unknown	

Figure 4. Boring Log Data

All maps and boring data obtained from: *http://www.dnr.wa.gov/geologyportal*.

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Based on boring data, the soils may be liquefiable to a depth range of 17.5 feet to 31 feet
- The bottom of the facility is located at a depth of 31 feet
- Based on boring, pump station is likely on competent material or a few feet above
- Influent sewer is significantly higher, in soils that may move
- Assume 10 feet of ground improvement beneath structure

Table 5. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	30th Avenue Pump Station Liquefaction Retrofits			**Date:**	9/13/2017
Location:	4703 30th Ave NE, Seattle, WA			**Estimator:**	Eric Benton
Description:				**Idea Code:**	L-5a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Ground Stabilization - Jet Grouting (381 sf bldg.)	400	LF	$ 500	$ 200,000
2	Site Demo and Restorations	1,143	SF	$ 9	$ 10,287
3	Pipe Flexibility Installation	25	LF	$ 1,850	$ 46,250
4	Mobilization / Demobilization (10%)	10	%	$ 25,654	$ 25,654
				Subtotal Construction Costs	***$ 280,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 112,000
				Construction Change Order Allowance	$ 39,200
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 431,200***
				Street Use Permit	$ -
				Construction Sales Tax	$ 43,551
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 474,751***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 862
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 476,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 297,340
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 5,012
				Right-of-Way	$ 5,600
				Misc. Service & Materials	$ 3,450
				Non-WTD Support	$ 3,665
				WTD Staff Labor	$ 99,780
				Subtotal Non-Construction Costs	***$ 414,846***
				Project Contingency	$ 268,922
				Initiatives	$ 5,945
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 690,000***
				TOTAL PROJECT COST	***$ 1,165,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY

L-6 Interurban Pump Station Liquefaction Retrofit

Issue No.	Issue Title	Risk Rating
L-6	Interurban Pump Station Liquefaction Deficiencies	MH
Idea Code	**Concept Title**	**Dev. Team**
L-6a	Interurban Pump Station Liquefaction Retrofit	2

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
Interurban Pump Station	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☒ Flow Volume
		☒ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

There are site stability deficiencies at the Interurban Pump Station related to liquefaction of the surrounding soils. Site-specific explorations and analyses are required to define liquefaction extent and are beyond the scope of this mitigation concept summary development. The mitigation concept summary is based on a cursory review of subsurface data available from the Washington State Department of Natural Resources (data reviewed provided in this summary). Assumptions regarding liquefaction extent based on the subsurface data review are indicated under "Assumptions and Calculations."

Risk if not Addressed:

If these issues are not addressed by the Resiliency and Recovery Program, the building could float, sink, rotate or move laterally during liquefaction caused by a seismic event. This could result in failure of the conveyance lines and/or failure of the Interurban Pump Station.

Without mitigation, the likely system downtime in the event of failure is expected to be approximately two years. A temporary solution may require installation of a temporary wet well, and could bring the pump station back online within 6 months.

MITIGATION CONCEPT SUMMARY

Failure of this system would result in raw sewage being discharged into the Duwamish River. Collateral damage may impact the nearby golf course, commercial and residential areas.

Description of Mitigation Concept:

The alternative concept includes ground improvement (compaction grouting or jet grouting) and providing pipe flexibility in and out of the pump station. The facility will require a temporary bypass to construct piping modifications.

The team assumed repair by re-piping. However, there is the potential that the building will move to the extent that the pump station will have to be rebuilt. If the pump station is rebuilt, new foundations designed to mitigate liquefaction effects (e.g., pile foundations or extending foundations down into competent soil/rock) should be included.

The pump station is located in an area determined to be susceptible to liquefaction. However, the assessment is not a site-specific study. To fully evaluate the potential for liquefaction and impacts to the facilities, a complete site-specific evaluation is needed.

Advantages:

- Avoids raw sewage discharge to the Duwamish after a major earthquake event
- This concept supports the seismic resilience of the pump station

Disadvantages:

- None noted

Main Benefit:

The main benefit of this mitigation concept is to avoid discharge of raw sewage into the Duwamish River.

Discussion of Schedule:

This mitigation concept is expected to require a two-month installation window. The proposed work is not directly affected by seasonal work windows and can be accomplished year-round. The installation of ground improvements would pose little impact to facility operations.

Design and permitting may require 6-12 months, including contracting and construction, a total of 18 months.

Discussion of Risk:

The pump station site is in flood plain. No other risks noted.

MITIGATION CONCEPT SUMMARY

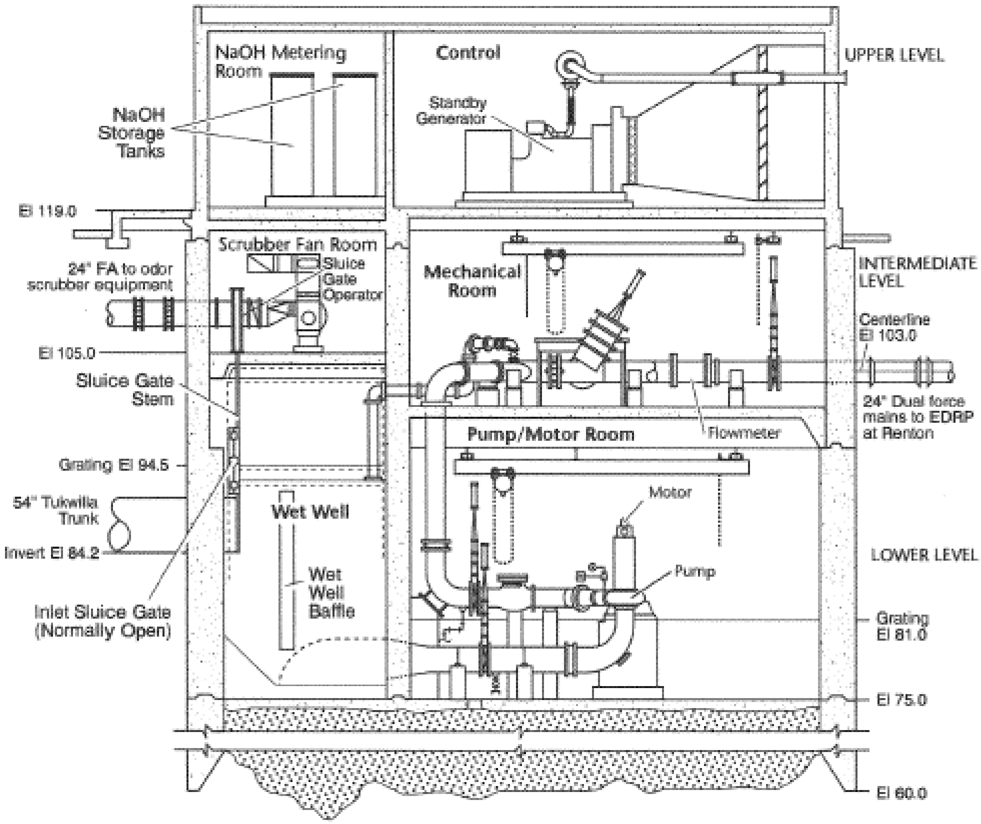


Figure 8. Station Cross Section

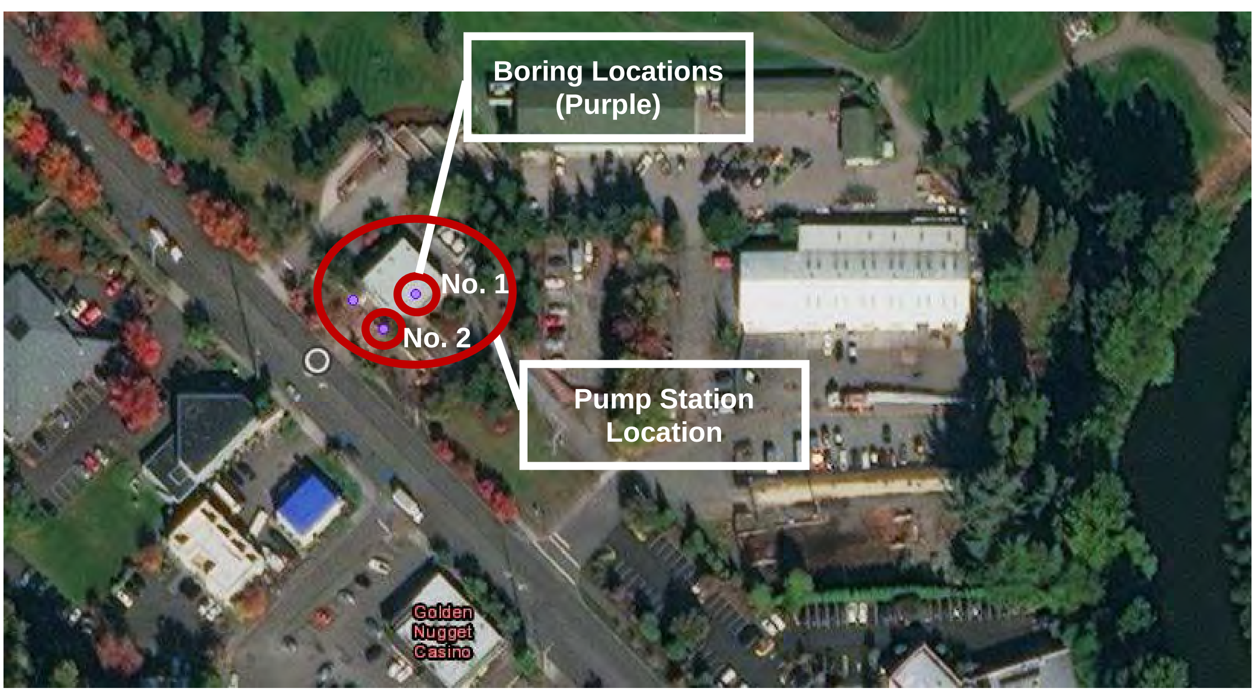


Figure 2. Pump Station and Boring Locations

Layer Data

Layer Number	Top Depth (ft)	Bottom Depth (ft)	Description	Layer Type	USCS	Geologic Unit
			et, soft			
9	58	67.5	Organic silt; dark gray, few fine sand, moderately plastic, finely laminated, f ine sandy silt interbeds up to 1/5" thi ck, wet, soft	Single	Unknown	
10	67.5	73	Silty sand and sandy silt; dark gray, f ine sand, alternating laminae up to 2" thick, trace marine shells, wet, soft	Single	Unknown	
11	73	81.5	Silty sand; dark gray, fine to medium, few shell fragments, trace brown org anic matter, wet, medium dense	Single	Unknown	

Layer Data

Layer Number	Top Depth (ft)	Bottom Depth (ft)	Description	Layer Type	USCS	Geologic Unit
			dense			
7	45	54	Silty sand and sand y silt- medium dense and firm	Single	Unknown	
8	54	60.5	Organic silt- soft	Single	Unknown	
9	60.5	67	Clayey silt- soft	Single	Unknown	
10	67	78	Silt- soft	Single	Unknown	
11	78	85	Silty sand and sand - loose to medium d ense	Single	Unknown	

Figure 3. Boring Log Data

All maps and boring data obtained from: *http://www.dnr.wa.gov/geologyportal*.

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- The facility is 2500 square feet
- Jet grouting is the assumed ground improvement used for cost estimating
- The bottom of the pump station is 40 feet deep, with caisson 15 feet deeper than this
- Per boring data, liquefaction-susceptible soils appear to be very deep at this site (greater than 80 feet)

MITIGATION CONCEPT SUMMARY

Table 6. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Interurban Pump Station Liquefaction Retrofits			**Date:**	9/13/2017
Location:	13980 Interurban Ave S, Tukwila, WA			**Estimator:**	Eric Benton
Description:				**Idea Code:**	L-6a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Ground Stabilization - Jet Grouting	3,840	LF	$ 200	$ 768,000
2	Site Demo and Restorations	2,541	SF	$ 9	$ 22,869
3	Pipe Flexibility Installation	25	LF	$ 1,850	$ 46,250
4	Mobilization / Demobilization (10%)	10	%	$ 83,712	$ 83,712
				Subtotal Construction Costs	***$ 920,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 368,000
				Construction Change Order Allowance	$ 128,800
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 1,416,800***
				Street Use Permit	$ -
				Construction Sales Tax	$ 143,097
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 1,559,897***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 2,834
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 1,563,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 817,191
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 16,468
				Right-of-Way	$ 18,400
				Misc. Service & Materials	$ 11,334
				Non-WTD Support	$ 12,043
				WTD Staff Labor	$ 268,686
				Subtotal Non-Construction Costs	***$ 1,144,123***
				Project Contingency	$ 817,916
				Initiatives	$ 19,534
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 1,982,000***
				TOTAL PROJECT COST	***$ 3,544,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY

L-8 Woodinville Pump Station Liquefaction Retrofit

Issue No.	Issue Title	Risk Rating
L-8	Woodinville Pump Station Liquefaction Deficiencies	MH
Idea Code	**Concept Title**	**Dev. Team**
L-8a	Woodinville Pump Station Liquefaction Retrofit	2

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☒ Public Health
Woodinville Pump Station	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

There are site stability deficiencies at the Woodinville Pump Station related to liquefaction of the surrounding soils. Site-specific explorations and analyses are required to define liquefaction extent and are beyond the scope of this mitigation concept summary development. The mitigation concept summary is based on a cursory review of subsurface data available from the Washington State Department of Natural Resources (data reviewed provided in this summary). Assumptions regarding liquefaction extent based on the subsurface data review are indicated under “Assumptions and Calculations.”

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program, there exists the potential that during a major seismic event, the building may float, sink, rotate or experience lateral movement. The conveyance lines are susceptible to failure in a substantial earthquake event, which could result in the failure of the Woodinville Pump Station.

MITIGATION CONCEPT SUMMARY

Without mitigation, the likely system downtime in the event of failure is expected to be approximately two years. A temporary solution, such as installation of a temporary wet well, could bring the pump station back online within 6 months.

In the event of a failure, raw sewage could be discharged into the Sammamish River, 60 feet away. If the sewer has no flow in an emergency event, collateral damage might include the possibility of sewage backing-up into nearby buildings. The area surrounding the station is commercial and park land.

Description of Mitigation Concept:

The alternative concept includes ground improvement (jet grouting) and providing pipe flexibility in and out of the pump station. The facility will require a temporary bypass to construct piping modifications.

The team assumed repair by re-piping. However, there is the potential that the building will move to the extent that the pump station will have to be rebuilt. If the pump station is rebuilt, new foundations designed to mitigate liquefaction effects (e.g., pile foundations or extending foundations down into competent soil/rock) should be included.

The pump station is located in an area determined to be susceptible to liquefaction. However, the assessment is not a site-specific study. To fully evaluate the potential for liquefaction and impacts to the facilities, a complete site-specific evaluation is needed.

Advantages:

- Avoids raw sewage discharge into the Sammamish River after a major earthquake event
- This concept supports the seismic resilience of the pump station

Disadvantages:

- Further analysis is needed to determine the cost effectiveness of repairing the pump station following a liquefaction event versus implementing this mitigation concept prior to a seismic event

Main Benefit:

The main benefit of this mitigation concept is reducing the likelihood of raw sewage being discharged into the Sammamish River after a major earthquake event.

Discussion of Schedule:

This mitigation concept will require a two-month installation window. This work is not directly affected by seasonal work windows and can be accomplished year-round. The installation of ground improvements would pose little impact to facility operations.

Design and permitting may require 18 months, including contracting and construction, a total of two years.

Discussion of Risk:

The Woodinville Pump Station has redundant discharge options and can pump either north or south. Going north – North Creek and the Brightwater Influent Pump Stations and associated gravity and pressure mains, and going south – York and the Eastside Interceptor. If all facilities fail, the Woodinville Pump Station will not function, even if the mitigation proposed above is completed.

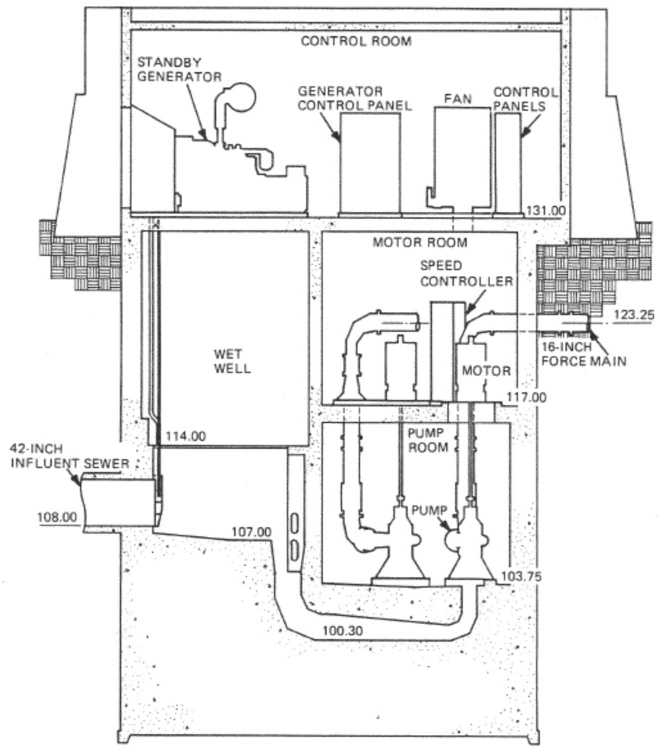


Figure 9. Station Cross Section

Figure 10. Pump Station and Boring Locations

▼ Layer Data

Layer Number	Top Depth (ft)	Bottom Depth (ft)	Description	Layer Type	USCS	Geologic Unit
			nic material in layers and with some silt pockets - loose			
2	4	6	Peat - soft	Single	Unknown	
3	6	17.5	Brown gray fine sand - med. Compact	Single	Unknown	
4	17.5	73	Gray fine - med sand with some coarse sand and pebbles in layers- med. Compact	Single	Unknown	

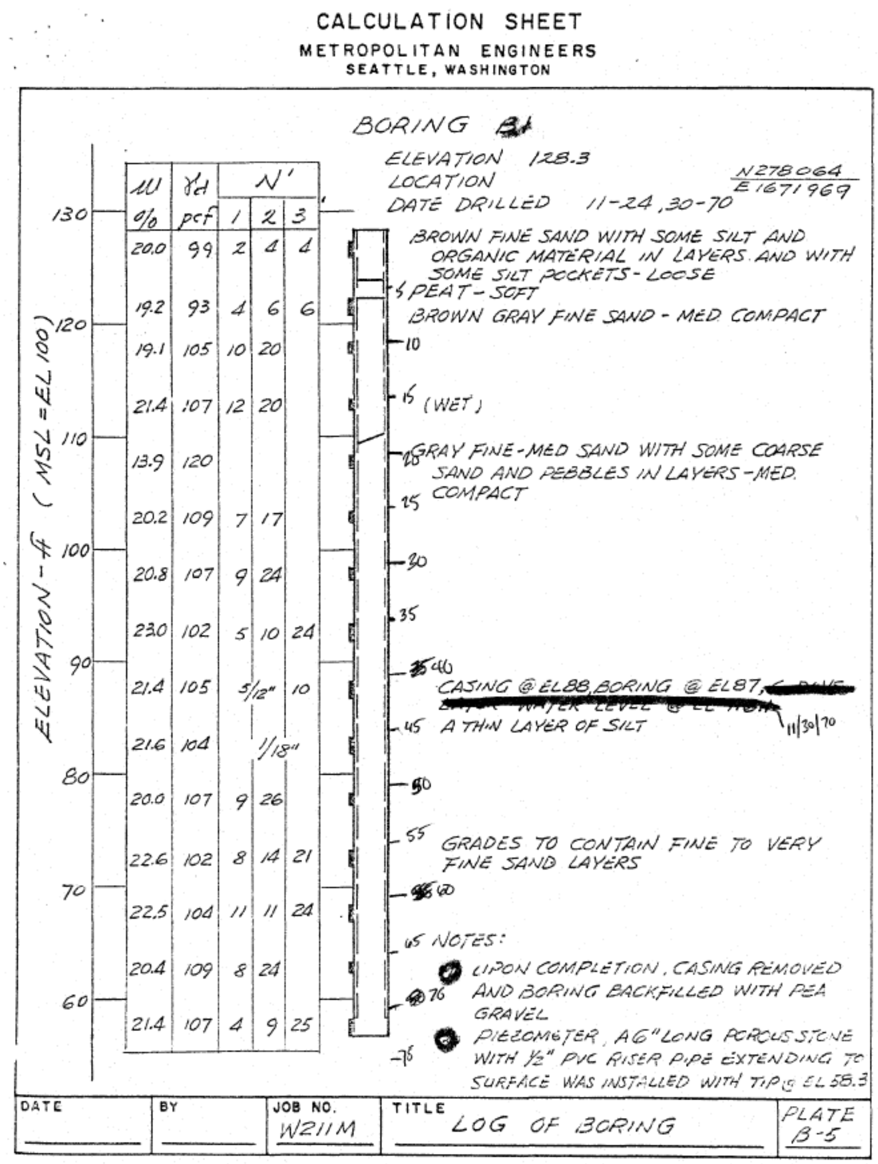


Figure 3. Boring Log Data

MITIGATION CONCEPT SUMMARY

All maps and boring data obtained from: *http://www.dnr.wa.gov/geologyportal*.

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- The facility is approximately 900 square feet
- The ground improvement technique assumed for cost estimating purposes is jet grouting
- Boring logs indicate possible liquefaction-susceptible soils to a depth of at least 50 feet
- The bottom of the pump station’s caisson is 38 feet
- Ground improvement depth is assumed at 50 feet

Table 7. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Woodinville Pump Station Liquefaction Retrofits			**Date:**	9/13/2017
Location:	12900 NE 175th St, Woodinville, WA			**Estimator:**	Eric Benton
Description:				**Idea Code:**	L-8a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Ground Stabilization - Jet Grouting	1,200	SF	$ 250	$ 300,000
2	Site Demolition and Restoration	2,799	SF	$ 9	$ 25,191
3	Pipe Flexibility Installation	25	LF	$ 1,850	$ 46,250
4	Mobilization / Demobilization (10%)	10	%	$ 37,144	$ 37,144
				Subtotal Construction Costs	***$ 410,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 164,000
				Construction Change Order Allowance	$ 57,400
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 631,400***
				Street Use Permit	$ -
				Construction Sales Tax	$ 63,771
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 695,171***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 1,263
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 696,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 411,085
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 7,339
				Right-of-Way	$ 8,200
				Misc. Service & Materials	$ 5,051
				Non-WTD Support	$ 5,367
				WTD Staff Labor	$ 136,836
				Subtotal Non-Construction Costs	***$ 573,878***
				Project Contingency	$ 383,705
				Initiatives	$ 8,705
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 966,000***
				TOTAL PROJECT COST	***$ 1,663,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY

L-9 Henderson Pump Station Liquefaction Retrofit

Issue No.	Issue Title	Risk Rating
L-9	Henderson Pump Station Liquefaction Deficiencies	MH
Idea Code	**Concept Title**	**Dev. Team**
L-9a	Henderson Pump Station Liquefaction Retrofit	2

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
Henderson Pump Station	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☐ Flow Volume
		☒ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☒ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

There are site stability deficiencies at the Henderson Pump Station related to liquefaction of the surrounding soils. It was originally thought that the pump station was constructed in liquefaction-susceptible soils. However, based on a cursory review of subsurface data available from the Washington State Department of Natural Resources (data reviewed provided in this summary), it appears highly likely that the base of the pump station is founded in competent soils. The piping into the station is likely located in liquefiable soils.

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program, there exists the potential that during a major seismic event, the conveyance lines could be susceptible to failure, which could result in the failure of the Henderson Pump Station.

The likely system downtime is expected to be two months.

Collateral damage in the event of a failure could include raw sewage backing up into the adjacent residential and commercial areas (including Rainier Beach High School). Sewage would ultimately be discharged into Lake Washington.

Description of Mitigation Concept:

The alternative concept includes providing pipe flexibility in and out of the pump station. The facility will require a temporary bypass to construct piping modifications.

The team assumed repair by re-piping. However, there is the potential that the building will move to the extent that the pump station will have to be rebuilt. If the pump station is rebuilt, new foundations designed to mitigate liquefaction effects (e.g., pile foundations or extending foundations down into competent soil/rock) should be included.

The pump station is located in an area determined to be susceptible to liquefaction. However, the assessment is not a site-specific study. To fully evaluate the potential for liquefaction and impacts to the facilities, a complete site-specific evaluation is needed.

Advantages:

- Avoids raw sewage discharge into Lake Washington after a major earthquake event
- This concept supports the seismic resilience of the pump station

Disadvantages:

- Further analysis is needed to determine the cost effectiveness of repairing the pump station following a liquefaction event versus implementing this mitigation concept prior to a seismic event

Main Benefit:

The main benefit of this mitigation concept is reducing the likelihood of raw sewage being discharged into Lake Washington after a major earthquake event.

Discussion of Schedule:

This mitigation concept will require a two-month installation window. This work is not directly affected by seasonal work windows and can be accomplished year-round.

Design and permitting may require 18 months; including contracting and construction, a total of two years.

Discussion of Risk:

Flows from Henderson Pump Station depend on Interurban Pump Station. Both facilities would need to be mitigated to ensure continued operation. If associated pipelines fail, sewage could be discharged as a result.

MITIGATION CONCEPT SUMMARY

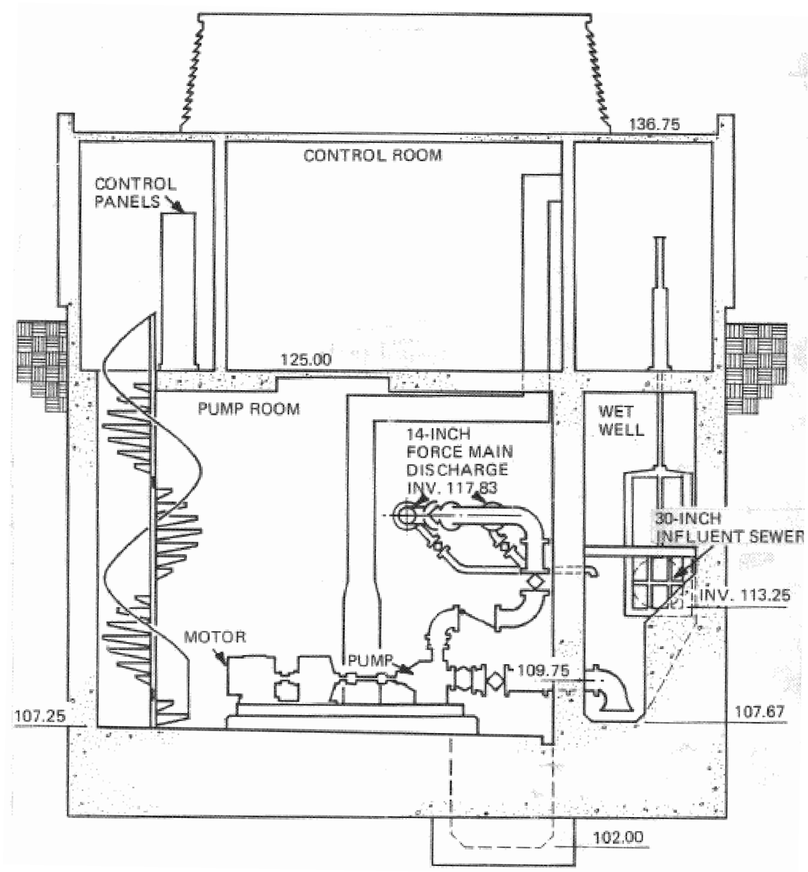


Figure 11. Station Cross Section

Figure 12. Pump Station and Boring Locations

Layer Data

Layer Number	Top Depth (ft)	Bottom Depth (	Description	Layer Type	USCS	Geologic Unit
			rounded. (Fill) sm			
2	15	20	Yellow-brown silty fine sand, occasional pockets of clayey silt; dense; moist. (Glacially overridden deposits) sm	Single	SM	
3	20	37.5	Gray, fine sandy silt; very dense; moist. Ml	Single	ML	
4	37.5	41	Blue-gray fine to medium sand, trace coarse sand and fine gravel, occasional pockets of gray silt; very dense; wet. Sp	Single	SP	

Figure 3. Boring Log Data

All maps and boring data obtained from: *http://www.dnr.wa.gov/geologyportal*.

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Based on available data, it appears the pump station is founded in competent soils
    - The bottom of the slab is roughly 25 feet deep
    - Based on boring logs, it appears the liquefaction-susceptible soils reach a depth of 16 feet

King County

HDR TEAM

MITIGATION CONCEPT SUMMARY

Table 8. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Henderson Pump Station Liquefaction Retrofits			**Date:**	9/13/2017
Location:	9829 42nd Ave S, Seattle, WA			**Estimator:**	Eric Benton
Description:				**Idea Code:**	L-9a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	*No Liquefaction Mitigation Required*				
2	Pipe Flexibility Installation	25	LF	$ 1,850	$ 46,250
3	Mobilization / Demobilization (10%)	10	%	$ 4,625	$ 4,625
				Subtotal Construction Costs	***$ 50,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 20,000
				Construction Change Order Allowance	$ 7,000
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 77,000***
				Street Use Permit	$ -
				Construction Sales Tax	$ 7,777
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 84,777***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 154
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 85,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 68,983
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 895
				Right-of-Way	$ 1,000
				Misc. Service & Materials	$ 616
				Non-WTD Support	$ 655
				WTD Staff Labor	$ 24,438
				Subtotal Non-Construction Costs	***$ 96,586***
				Project Contingency	$ 54,774
				Initiatives	$ 1,062
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 152,000***
				TOTAL PROJECT COST	***$ 237,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY

L-11 Rainier Avenue Pump Station Liquefaction Retrofit

Issue No.	Issue Title	Risk Rating
L-11	Rainier Avenue Pump Station Liquefaction Deficiencies	MH
Idea Code	**Concept Title**	**Dev. Team**
L-11a	Rainier Avenue Pump Station Liquefaction Retrofit	2

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below) Rainier Avenue Pump Station	☐ MEP	☐ Public Health
	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☐ Flow Volume
		☒ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☒ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

There are site stability deficiencies at the Rainier Avenue Pump Station related to liquefaction of the surrounding soils. It was originally thought that the pump station was constructed in liquefaction-susceptible soils; however, based on a cursory review of subsurface data available from the Washington State Department of Natural Resources (data reviewed provided in this summary), it appears highly likely that the base of the pump station is founded in competent soils. The piping into the station is likely located in liquefiable soils.

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program there exists the potential that during a major seismic event, the conveyance lines could be susceptible to failure, which could result in the failure of the Rainier Avenue Pump Station.

The likely system downtime is expected to be four months. It may be possible to provide temporary service within one month, to collect raw sewage via a barge in Lake Washington.

MITIGATION CONCEPT SUMMARY

Collateral damage in the event of a failure could include raw sewage backing up into the Genesee Tunnel (conveyance system), into the surrounding residential areas, and would ultimately be discharged into Stan Sayres Pit and Lake Washington.

Description of Mitigation Concept:

The alternative concept includes providing pipe flexibility in and out of the pump station.

The team assumed repair by replumbing.

The pump station is located in an area determined to be susceptible to liquefaction. However, the assessment is not a site-specific study. To fully evaluate the potential for liquefaction and impacts to the facilities, a complete site-specific evaluation is needed.

Advantages:

- Avoids raw sewage backup into residential areas, as well as discharge into Lake Washington after a major earthquake event
- This concept supports the seismic resilience of the pump station

Disadvantages:

- None noted

Main Benefit:

The main benefit of this mitigation concept is reducing the likelihood of raw sewage being discharged into Lake Washington and/or backup into neighboring residential areas after a major earthquake event.

Discussion of Schedule:

This mitigation concept will require a four-month installation window. This work is not directly affected by seasonal work windows and can be accomplished year-round.

Design and permitting may require 12 months; including contracting and construction, a total of 18 months.

Discussion of Risk:

Flows from Rainier Avenue Pump Station depend on the function of the inlet and discharge connecting pipes. If associated pipelines fail, sewage could be discharged as a result.

MITIGATION CONCEPT SUMMARY

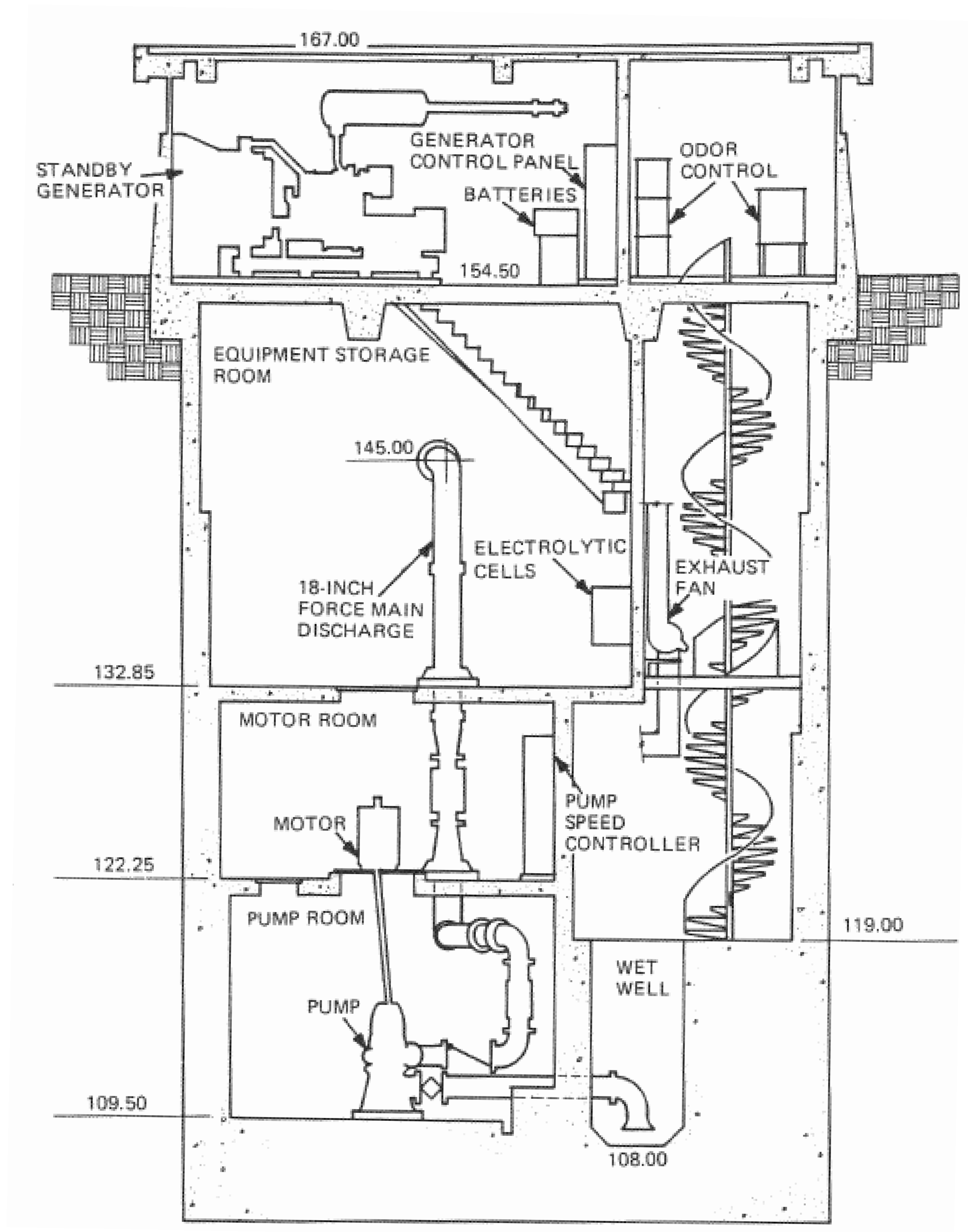


Figure 13. Station Cross Section

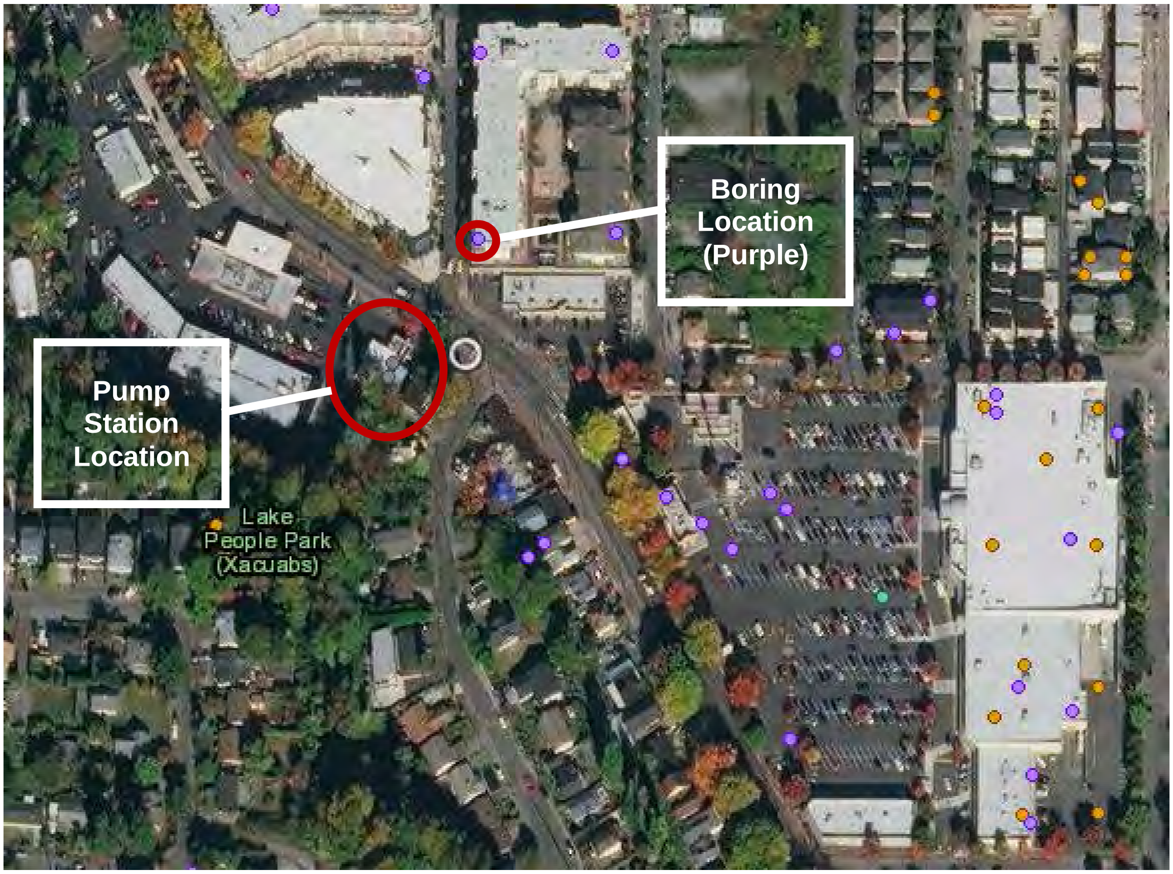


Figure 2. Station and Boring Locations

Layer Data

Layer Number	Top Depth (ft)	Bottom Depth (ft	Description	Layer Type	USCS	Geologic Unit
2	2	11	Very moist, gray silt (ml).	Single	ML	
3	11	13.5	Very moist, brow n peat (pt).	Single	PT	
4	13.5	47.5	Very moist, brow nish gray silt (ml).	Single	ML	
5	47.5	53.3	Wet, gray, silty, fi ne to medium sa nd, trace pebble gravel (sm).	Single	SM	

Figure 3. Boring Log Data

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE03268A	EB-7	1 of 2

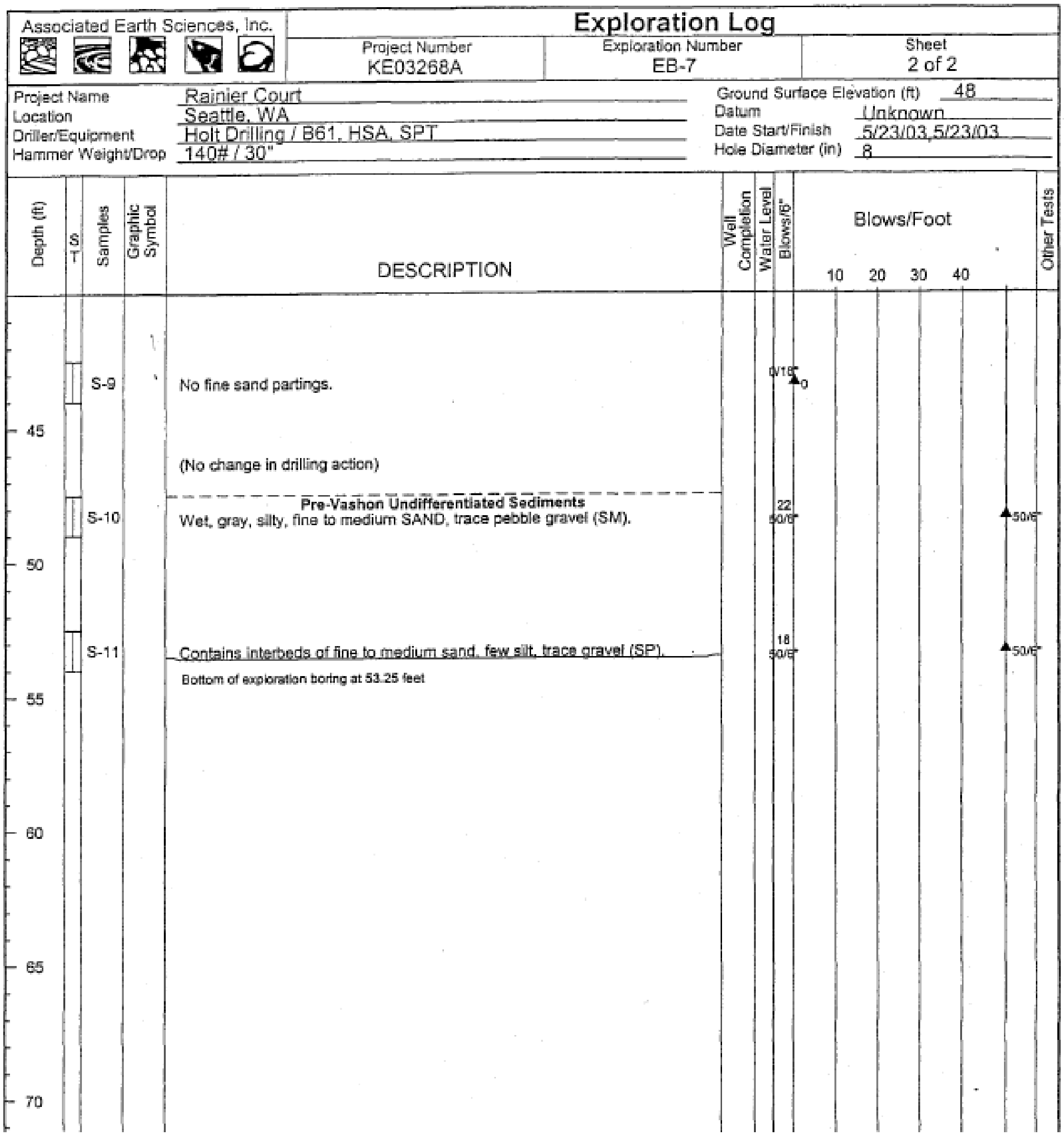
Project Name: Rainier Court
Location: Seattle, WA
Driller/Equipment: Holt Drilling / B61, HSA, SPT
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 48
Datum: Unknown
Date Start/Finish: 5/23/03,5/23/03
Hole Diameter (in): 8

Depth (ft)	Samples	DESCRIPTION	Blows/6"	Blows/Foot
		Fill		
		Very moist, dark brown, SILTY SAND with gravel (SM).		
		Holocene Lacustrine Sediments		
	S-1	Very moist, gray SILT (ML).	3 5 6	11
5				
	S-2		2 2 3	5
10				
	S-3	Very moist, brown PEAT (PT).	1 3 4	7
		Very moist, brownish gray SILT (ML).		
15				
	S-4	Becomes wet and gray with thin (< 1/2" thick) lenses of silty, fine SAND; increased moisture content.	1 1 1	2
20				
	S-5		0 0 1	1
25				
	S-6	Becomes non-plastic; dilatent; no silty, fine sand lenses present.	3 9 17	26
30				
	S-7	Becomes plastic.	0/18"	0
35				
	S-8	Contains fine sand partings.	0/18"	0

Sampler Type (ST):
2" OD Split Spoon Sampler (SPT) — No Recovery — M - Moisture
3" OD Split Spoon Sampler (D & M) — Ring Sample — Water Level ()
Grab Sample — Shelby Tube Sample — Water Level at time of drilling (ATD)

Logged by: TJP
Approved by: TJP


Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE03268A	EB-7	2 of 2

Project Name: Rainier Court
Location: Seattle, WA
Driller/Equipment: Holt Drilling / B61, HSA, SPT
Hammer Weight/Drop: 140# / 30"
Ground Surface Elevation (ft): 48
Datum: Unknown
Date Start/Finish: 5/23/03, 5/23/03
Hole Diameter (in): 8

Depth (ft)	Samples	DESCRIPTION	Blows/6"	Blows/Foot
	S-9	No fine sand partings.	0/18"	0
45		(No change in drilling action)		
	S-10	**Pre-Vashon Undifferentiated Sediments** Wet, gray, silty, fine to medium SAND, trace pebble gravel (SM).	22 50/6"	50/6"
50				
	S-11	Contains interbeds of fine to medium sand, few silt, trace gravel (SP).	18 50/6"	50/6"
		Bottom of exploration boring at 53.25 feet		
55				
60				
65				
70				

All maps and boring data obtained from: *http://www.dnr.wa.gov/geologyportal*.

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- The facility is 900 SF
- The base of the pump station structure is 50 feet deep
- Liquefiable soils extend to a depth of approximately 50 feet

Table 9. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Rainer Avenue Pump Station Liquefaction Retrofits			**Date:**	9/13/2017
Location:	3761 Rainier Ave. S, Seattle, WA			**Estimator:**	Eric Benton
Description:				**Idea Code:**	L-11a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	*No Liquefaction Mitigation Required*				$ -
2	Pipe Flexibility Installation	25	LF	$ 1,850	$ 46,250
3	Mobilization / Demobilization (10%)	10	%	$ 4,625	$ 4,625
				Subtotal Construction Costs	***$ 50,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 20,000
				Construction Change Order Allowance	$ 7,000
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 77,000***
				Street Use Permit	$ -
				Construction Sales Tax	$ 7,777
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 84,777***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 154
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 85,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 68,983
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 895
				Right-of-Way	$ 1,000
				Misc. Service & Materials	$ 616
				Non-WTD Support	$ 655
				WTD Staff Labor	$ 24,438
				Subtotal Non-Construction Costs	***$ 96,586***
				Project Contingency	$ 54,774
				Initiatives	$ 1,062
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 152,000***
				TOTAL PROJECT COST	***$ 237,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY

L-12 East Marginal Way Pump Station Liquefaction Retrofit

Issue No.	Issue Title	Risk Rating
L-12	East Marginal Way Pump Station Liquefaction Deficiencies	M
Idea Code	**Concept Title**	**Dev. Team**
L-12a	East Marginal Way Pump Station Liquefaction Retrofit	2

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below) East Marginal Way Pump Station	☐ MEP	☐ Public Health
	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☒ Flow Volume
		☒ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

There are site stability deficiencies at the East Marginal Way Pump Station related to liquefaction of the surrounding soils. Site-specific explorations and analyses are required to define liquefaction extent and are beyond the scope of this mitigation concept summary development. The mitigation concept summary is based on a cursory review of subsurface data available from the Washington State Department of Natural Resources (data reviewed provided in this summary). Assumptions regarding liquefaction extent based on the subsurface data review are indicated under “Assumptions and Calculations.”

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program there exists the potential that during a major seismic event, the building may float, sink, rotate or experience lateral movement. The conveyance lines are susceptible to failure in a substantial earthquake event, which could result in the failure of the East Marginal Way Pump Station.

System downtime is expected to be up to three years. A temporary wet well could bring the pump station back online within 6 months.

MITIGATION CONCEPT SUMMARY

In the event of a failure, raw sewage would be discharged into the Duwamish River. Collateral damage might include impacts to East Marginal Way.

Description of Mitigation Concept:

The alternative concept includes ground improvement (compaction grouting or jet grouting) to a depth of 80 feet, and providing pipe flexibility in and out of the pump station. The facility will require a temporary bypass to construct piping modifications.

The team assumed repair by re-piping. However, there is the potential that the building will move to the extent that the pump station will have to be rebuilt. If the pump station is rebuilt, new foundations designed to mitigate liquefaction effects (e.g., pile foundations or extending foundations down into competent soil/rock) should be included.

The pump station is located in an area determined to be susceptible to liquefaction. However, the assessment is not a site-specific study. To fully evaluate the potential for liquefaction and impacts to the facilities, a complete site-specific evaluation is needed.

Advantages:

- Avoid raw sewage discharge into the Duwamish River after a major earthquake event
- This concept supports the seismic resilience of the pump station

Disadvantages:

- Further analysis is needed to determine the cost effectiveness of repairing the pump station following a liquefaction event versus implementing this mitigation concept prior to a seismic event

Main Benefit:

The main benefit of this mitigation concept is reducing the likelihood of raw sewage being discharged into the Duwamish River after a major earthquake event.

Discussion of Schedule:

This mitigation concept will require a two-month installation window. This work is not directly affected by seasonal work windows and can be accomplished year-round. The installation of ground improvements would pose little impact to facility operations.

Design and permitting may require 18 months; including contracting and construction, a total of two years.

Discussion of Risk:

This pump station likely sits in or near contaminated soils of the Duwamish River EPA Superfund site.

The western side has regulators and overflows in it for CSO control. Failure in a facility that results in CSO is not anticipated to create a major public health concern.

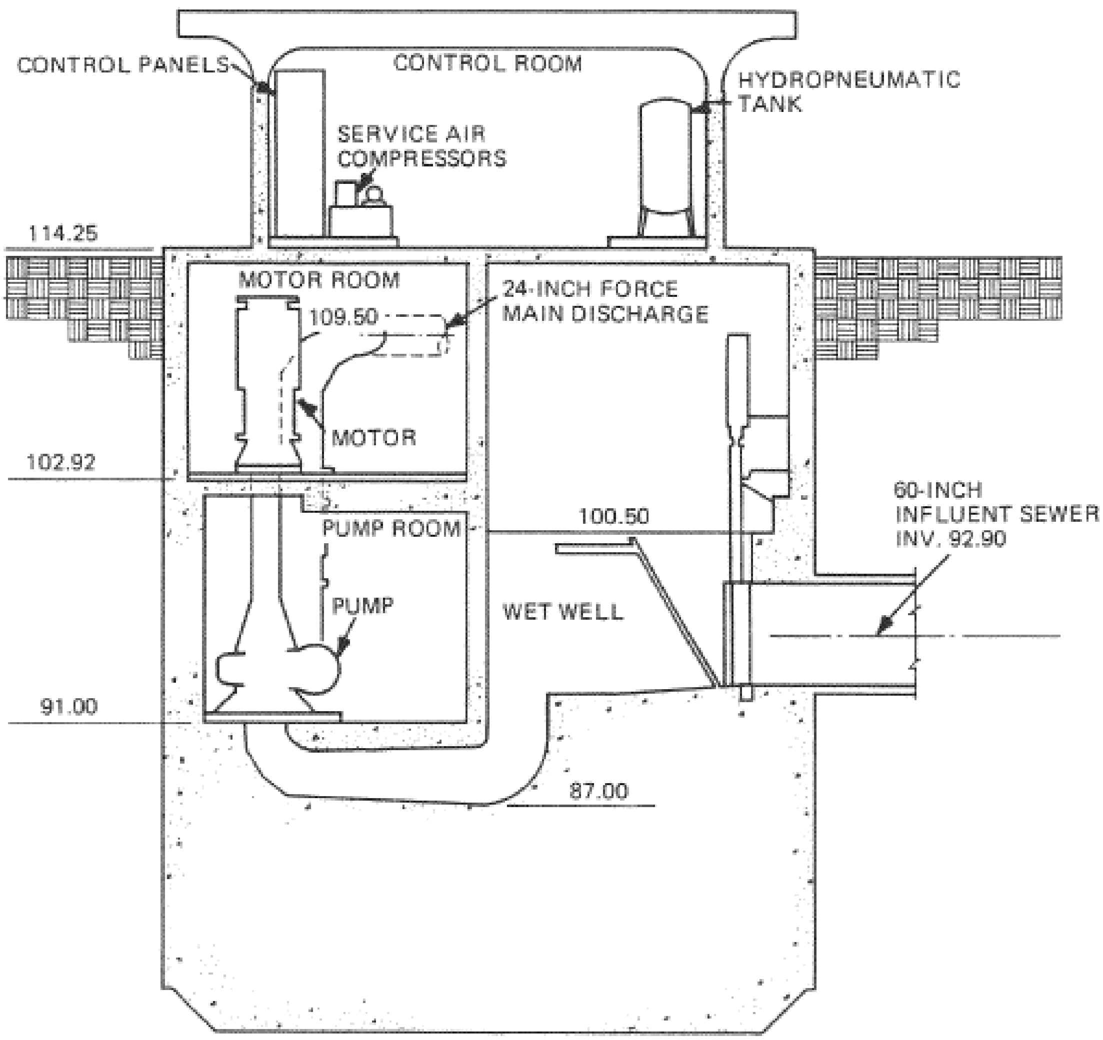


Figure 14. System Cross Section

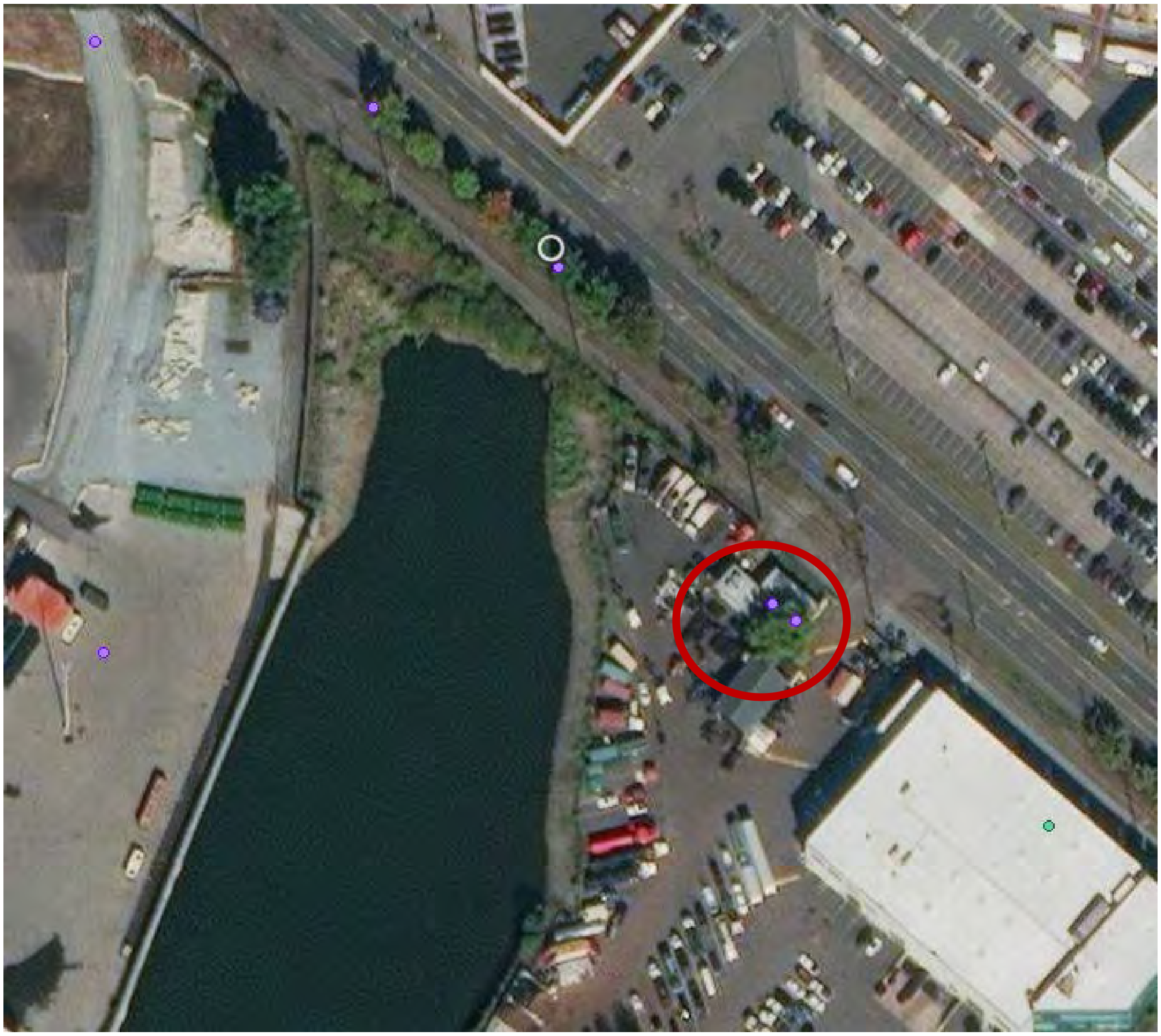


Figure 15. Station and Boring Locations

Layer Data

Layer Number	Top Depth (ft)	Bottom Depth (ft	Description	Layer Type	USCS	Geologic Unit
6	40	51	Dark gray fine-very fine sand with silty fine sand layers	Single	Unknown	
7	51	55	Gray silty fine and very fine sand	Single	Unknown	
8	55	59	Dark gray fine sand - clean, with silt laminations	Single	Unknown	

Figure 3. Boring Log Data

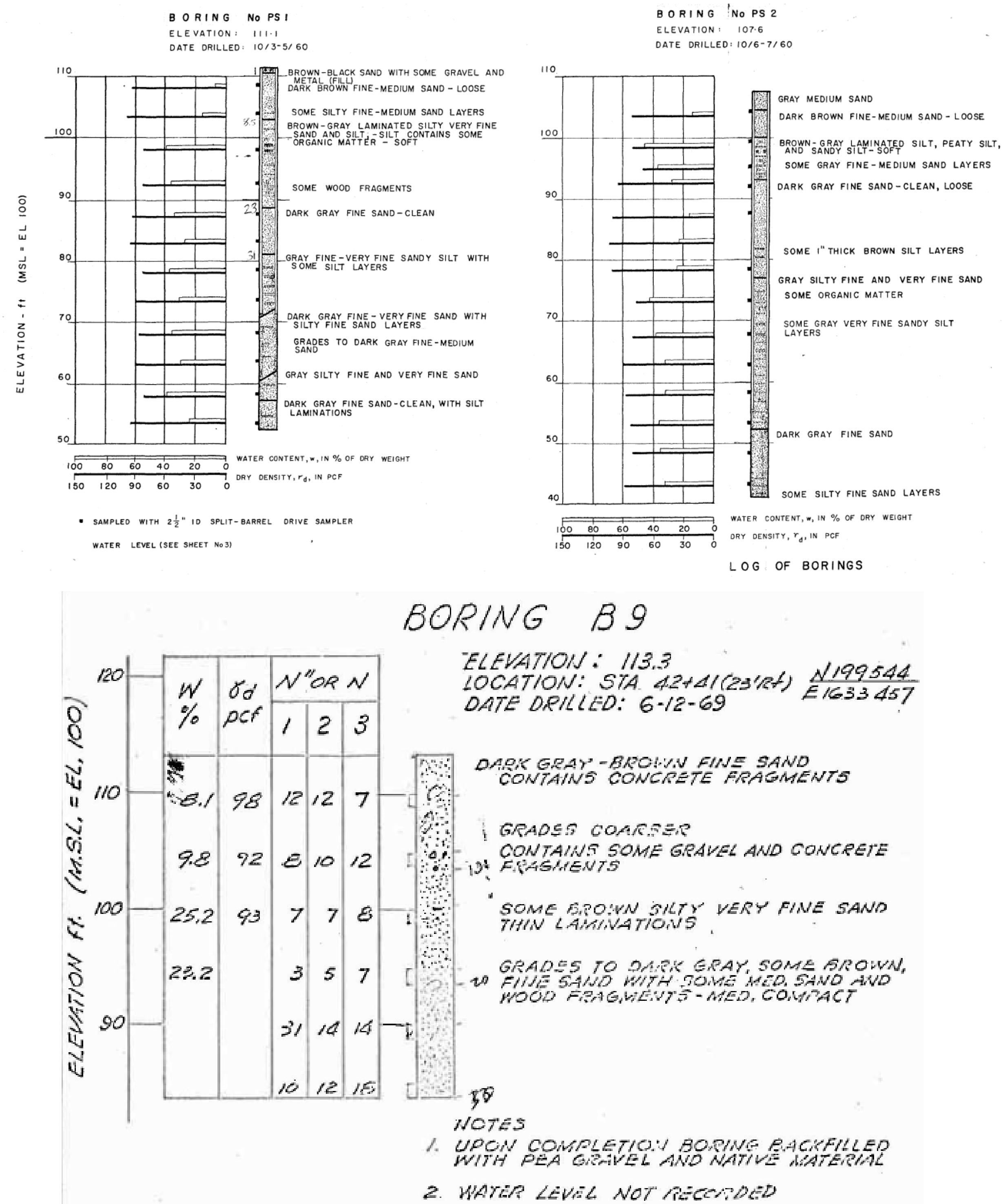


Figure 4. Additional Boring Data

All maps and boring data obtained from: *http://www.dnr.wa.gov/geologyportal*.

MITIGATION CONCEPT SUMMARY

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- The facility is 1,000 square feet
- The base of the pump station structure is 37 feet deep
- Potentially-liquefiable soils exist at this site in excess of 60 feet

MITIGATION CONCEPT SUMMARY

Table 10. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	East Marginal Way Pump Station Liquefaction Retrofits			**Date:**	9/13/2017
Location:	7319 E Marginal Way S, Seattle, WA			**Estimator:**	Eric Benton
Description:				**Idea Code:**	L-12a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Ground Stabilization - Jet Grouting	1,680	SF	$ 250	$ 420,000
2	Site Demolition and Restoration	2,406	SF	$ 9	$ 21,654
3	Pipe Flexibility Installation	25	LF	$ 1,850	$ 46,250
4	Mobilization / Demobilization (10%)	10	%	$ 48,790	$ 48,790
				Subtotal Construction Costs	***$ 540,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 216,000
				Construction Change Order Allowance	$ 75,600
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 831,600***
				Street Use Permit	$ -
				Construction Sales Tax	$ 83,992
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 915,592***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 1,663
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 917,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 519,487
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 9,666
				Right-of-Way	$ 10,800
				Misc. Service & Materials	$ 6,653
				Non-WTD Support	$ 7,069
				WTD Staff Labor	$ 172,065
				Subtotal Non-Construction Costs	***$ 725,740***
				Project Contingency	$ 496,338
				Initiatives	$ 11,466
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 1,234,000***
				TOTAL PROJECT COST	***$ 2,151,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY

LP-2 West Point Treatment Plant Liquefaction Programmatic Assessment

Issue No.	Issue Title	Risk Rating
LP-2	West Point Treatment Plant Liquefaction Deficiencies	MH
Idea Code	**Concept Title**	**Dev. Team**
LP-2	West Point Treatment Plant Liquefaction Programmatic Assessment	2

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
West Point Treatment Plant	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☒ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☒ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

There may be site stability deficiencies at the West Point Treatment Plant related to liquefaction of the surrounding soils. Liquefaction was considered previously in the design of this facility. However, this was completed under outdated building codes and ground motion estimates, and may not have considered active crustal sources such as the Seattle Fault.

Also, gravels that were previously thought to be unsusceptible to liquefaction may be susceptible to liquefaction under recent field exploration and evaluation methods.

Site-specific explorations and analyses are required to define liquefaction extent and are beyond the scope of this mitigation concept summary development. The mitigation concept summary is based on a cursory review of subsurface data available from the Washington State Department of Natural Resources (data reviewed provided in this summary).

MITIGATION CONCEPT SUMMARY

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program, there is a potential that during a major seismic event, the facilities may float, sink, rotate or experience lateral movement. This movement may result in the failure of components of the facility.

The system downtime could be from months to years if the site soils are found to be potentially liquefiable and if this liquefaction is determined to pose a significant hazard to the existing facilities.

Collateral damage includes raw sewage being discharged into the Puget Sound in the event of failure.

Description of Mitigation Concept:

The alternative concept recommends a site-specific re-evaluation of the liquefaction potential of the site soils and the potential impact to the existing structures using current design level earthquake ground motions including current field and analyses methods to evaluate the liquefaction potential of gravelly soils. The site-specific re-evaluation would include up to 4 additional subsurface explorations using techniques specifically developed to evaluate the liquefaction susceptibility of gravelly soils, associated laboratory testing, and re-evaluation of the liquefaction potential indicated by the other ~100 subsurface explorations across the site. If the results of this site-specific re-evaluation indicate liquefaction poses a significant hazard to the facility, mitigation options can be developed, such as ground improvement (compaction grouting or jet grouting), flow-shedding opportunities, and/or structural retrofits (e.g., retrofitted or rebuilt structures with pile foundations or foundations that extend down into competent soils).

Advantages:

- Improved understanding of the hazard posed by liquefaction to the facility and the need, if any, for additional liquefaction mitigation
- Avoid raw sewage discharge into the Sound after a major earthquake event
- This concept supports the seismic resilience of the facility

Disadvantages:

- None noted

Main Benefit:

The main benefits of this mitigation concept is a significantly improved assessment of the hazard posed by liquefaction to the facility and the need, if any, for additional liquefaction mitigation.

Discussion of Schedule:

Schedule is TBD.

Discussion of Risk:

The West Point Treatment Plant is underlain by geologic units that are known to be moderately susceptible to liquefaction. Major construction at the plant in the late 1980s/early 1990s considered liquefaction. However, since the latest design, the calculated ground motion hazard has increased and the methods used to evaluate the susceptibility of gravelly soils to liquefaction have improved, therefore it would be prudent to reevaluate the liquefaction susceptibility of the facilities with the most current ground motion hazard levels and gravel liquefaction susceptibility procedures.

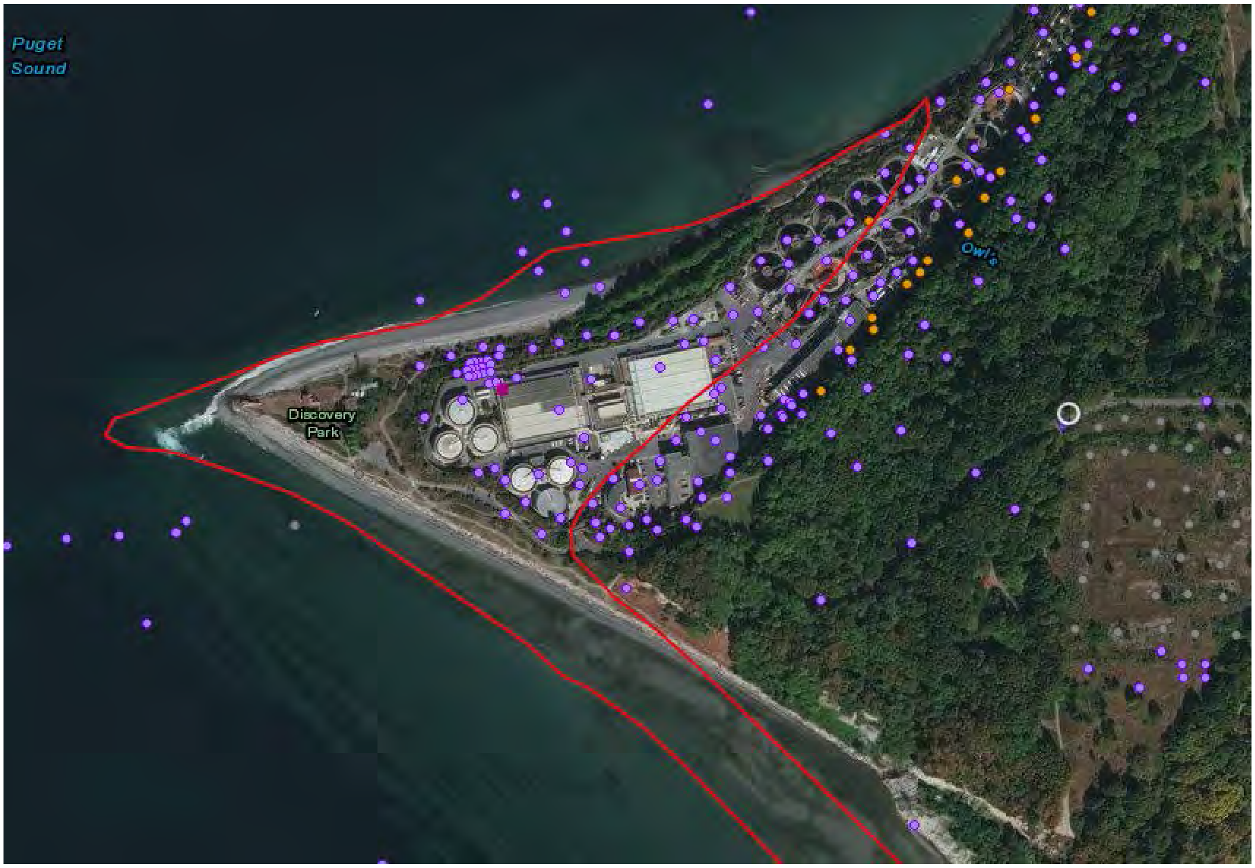


Figure 16: Liquefaction risk zone (red) and boring locations (purple)

All maps and boring data obtained from: *http://www.dnr.wa.gov/geologyportal*.

Assumptions and Calculations:

The initial mitigation concept-level cost estimate includes the following assumptions:

Assume 4 subsurface explorations specifically to evaluate the liquefaction potential for gravels are performed.

Assume 240 hours to log and analyze new explorations, re-interpret and analyze approximately 100 existing explorations, review existing foundation design and construction documents, and summarize in a site-specific geotechnical liquefaction potential report.

MITIGATION CONCEPT SUMMARY

Table 11: Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	West Point Treatment Plant Liquefaction Deficiencies			**Date:**	11/14/2017
Location:	1400 Discovery Park Blvd, Seattle, WA			**Estimator:**	Eric Benton, CPE
Description:	West Point Treatment Plant Liquefication Programmatic Assessment			**Idea Code:**	L-13a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Subsurface Explorations and Testing	4	EA	$ 25,000	$ 100,000
2	Interpret, Analyze and Summarize Existing Explorations, Foundation Designs and Construction Documents.	240	HRS	$ 210	$ 50,400
				Subtotal Assessment Costs	***$ 150,000***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				Misc. Capital Costs	$ 300
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 150,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	n/a
				Other Consulting Services	n/a
				Permitting & Other Agency Support	n/a
				Right-of-Way	n/a
				Misc. Service & Materials	n/a
				Non-WTD Support	n/a
				WTD Staff Labor	$ 39,799
				Subtotal Non-Construction Costs	***$ 39,799***
				Project Contingency	$ 89,475
				Initiatives	n/a
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 129,000***
				TOTAL PROJECT COST	***$ 280,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY

LP-3 South Treatment Plant Liquefaction Programmatic Assessment

Issue No.	Issue Title	Risk Rating
LP-3	South Treatment Plant Liquefaction Deficiencies	MH
Idea Code	**Concept Title**	**Dev. Team**
LP-3	South Treatment Plant Liquefaction Programmatic Assessment	2

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☒ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
South Treatment Plant	☐ SCADA	☐ Consequent Damages
	☐ Natural Hazards	☒ Environment
		Other: ☒ Flow Volume
		☒ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☒ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

There may be site stability deficiencies at the South Treatment Plant related to liquefaction of the surrounding soils. While liquefaction was considered previously in the design of the facility, based on the age at which portions of the facility were constructed, the design may not have considered liquefaction using the latest ground motion hazard estimates (e.g., the active crustal sources such as the Seattle Fault), and liquefaction analysis methods. Site-specific explorations and analyses are required to define liquefaction extent and are beyond the scope of this mitigation concept summary development. The mitigation concept summary is based on a cursory review of subsurface data available from the Washington State Department of Natural Resources (data reviewed provided in this summary).

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program there is a potential that during a major seismic event, the facilities may float, sink, rotate or experience lateral movement. This movement may result in failure of components of the facility.

MITIGATION CONCEPT SUMMARY

The system downtime could be from months to years if the site soils are found to potentially liquefiable and if this liquefaction is determined to pose a significant hazard to the existing facilities.

Collateral damage includes that in the event of a failure, raw sewage would be discharged into the Duwamish River.

Description of Mitigation Concept:

The alternative concept recommends a site-specific re-evaluation of the liquefaction potential of the site soils and the potential impact to the existing structures using current design level earthquake ground motions. The site-specific re-evaluation would include liquefaction potential analyses of the existing subsurface explorations across the site. If the results of this site-specific re-evaluation indicate liquefaction poses a significant hazard to the facility, mitigation options can be developed, such as ground improvement (compaction grouting or jet grouting), flow-shedding opportunities, and/or structural retrofits (e.g., retrofitted or rebuilt structures with pile foundations or foundations that extend down into competent soils/rock).

Advantages:

- Improved understanding of the hazard posed by liquefaction to the facility and the need, if any, for additional liquefaction mitigation
- Avoid raw sewage discharge into the Duwamish River after a major earthquake event
- This concept supports the seismic resilience of the facility

Disadvantages:

None noted

Main Benefit:

The main benefits of this mitigation concept is a significantly improved assessment of the hazard posed by liquefaction to the facility and the need, if any, for additional liquefaction mitigation.

Discussion of Schedule:

Schedule is TBD.

Discussion of Risk:

Much of the South Treatment Plant is underlain by geologic units that are known to have a moderate to high susceptibility to liquefaction. Since the latest design, the calculated ground motion hazard has increased and the methods used to evaluate the susceptibility of soils to liquefaction have improved, therefore it would be prudent to reevaluate the liquefaction susceptibility of the facilities with the most current ground motion hazard levels and liquefaction susceptibility procedures.

The Black River Pump Station is also in a liquefaction zone; if this facility fails, it could potentially flood the South Treatment Plant.

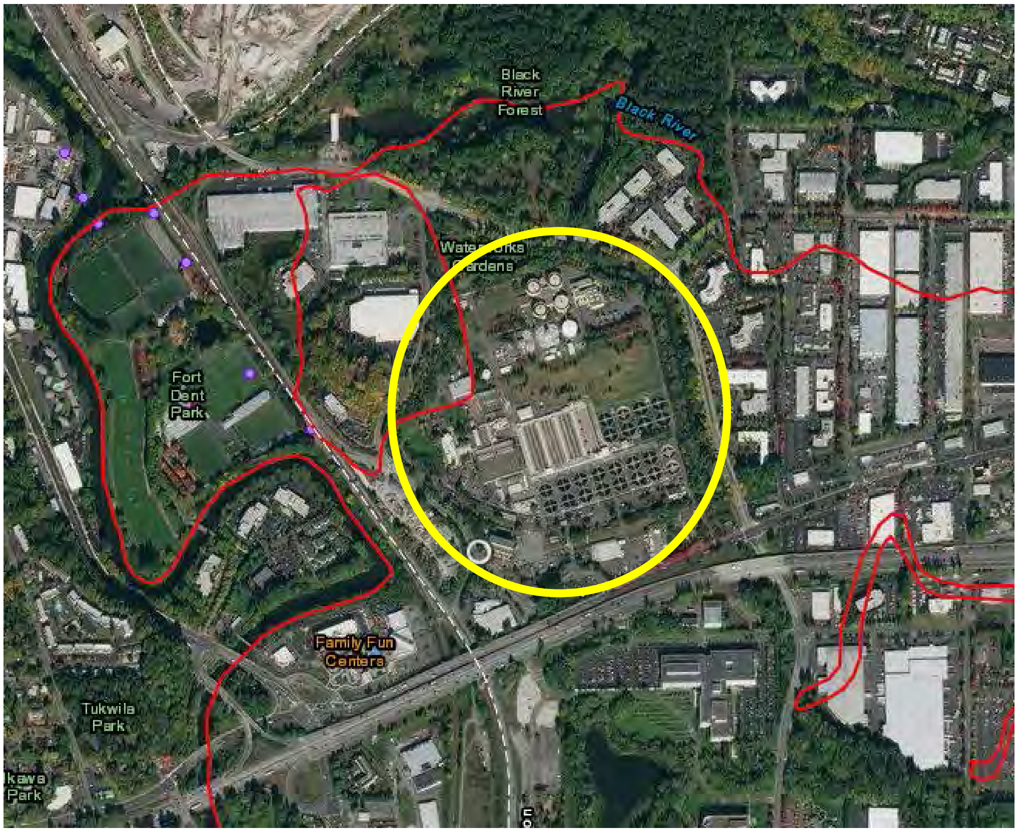


Figure 17: Liquefaction hazard zone (red) and plant location (yellow)

All maps and boring data obtained from: *http://www.dnr.wa.gov/geologyportal*.

Assumptions and Calculations:

The initial mitigation concept-level cost estimate includes the following assumptions:

Assume 200 hours to re-interpret and analyze approximately the existing site explorations, review existing foundation design and construction documents, and summarize in a site-specific geotechnical liquefaction potential report.

MITIGATION CONCEPT SUMMARY

Table 12: Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	West Point Treatment Plant Liquefaction Deficiencies			**Date:**	11/14/2017
Location:	1400 Discovery Park Blvd, Seattle, WA			**Estimator:**	Eric Benton, CPE
Description:	West Point Treatment Plant Liquefication Programmatic Assessment			**Idea Code:**	L-14a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Re-interpret and analyze approximately the existing site explorations, review existing foundation design and construction documents, and summarize in a site-specific geotechnical liquefaction potential report	200	HRS	$ 210	$ 42,000
				Subtotal Construction Costs	***$ 40,000***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				Misc. Capital Costs	$ 80
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 40,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	n/a
				Other Consulting Services	n/a
				Permitting & Other Agency Support	n/a
				Right-of-Way	n/a
				Misc. Service & Materials	n/a
				Non-WTD Support	n/a
				WTD Staff Labor	$ 13,516
				Subtotal Non-Construction Costs	***$ 13,516***
				Project Contingency	$ 26,985
				Initiatives	n/a
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 41,000***
				TOTAL PROJECT COST	***$ 81,000***

Notes:
1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.
2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

D-3: Landslides

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MITIGATION CONCEPT SUMMARY – LANDSLIDES

Issue No.	Concept Title
LS-2	South Mercer Pump Station Landslide Protection Upgrade

MITIGATION CONCEPT SUMMARY – LANDSLIDES

LS-2 South Mercer Pump Station Landslide Protection Upgrade

Issue No.	Issue Title	Risk Rating
LS-2	South Mercer Pump Station Landslide Risk	MH
Idea Code	**Concept Title**	**Dev. Team**
LS-2a	South Mercer Pump Station landslide protection upgrade	2

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☐ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
South Mercer Pump Station	☐ SCADA	☐ Consequent Damages
	☒ Natural Hazards	☒ Environment
	- Landslide	Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☐ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

The existing issue is the risk associated with potential landslides at or near the South Mercer Pump Station. The station itself is located in a landslide risk zone, and the only two land access routes also pass through an active potential landslide zone.

The boring logs show slicken-sided clays and silts that could be indicative of slope movement.

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program, there exists the potential that landslides could cause failure of either conveyance lines and/or the entire South Mercer Pump Station.

System downtime is expected to be anywhere from months to years based on the extent of the landslide.

Failure of this pump station would result in discharge of raw sewage into Lake Washington.

MITIGATION CONCEPT SUMMARY – LANDSLIDES

Description of Mitigation Concept:

The alternative concept includes soldier pile with tie-backs or secant drilled shaft walls with installed drainage system.

Advantages:

- Maintains operations of the plant
- Avoids discharging raw sewage into Lake Washington

Disadvantages:

None noted

Main Benefit:

The main benefit of this mitigation concept is to provide slope stability that will ensure ongoing operation of the pump station.

Discussion of Schedule:

This mitigation concept will require a 6-month installation window. This work is not directly affected by seasonal work windows and can be accomplished year-round.

Design and permitting may require 18 months including contracting and construction for a total of two years.

Discussion of Risk:

Following a landslide, the pump station could discharge raw sewage into Lake Washington. Land access to the pump station could also blocked for a period of time.

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumption:

- Slicken-sided clays to a depth of roughly 30 feet

MITIGATION CONCEPT SUMMARY – LANDSLIDES

Table 1. Concept-Level Cost Estimate

Estimate - AACEI Class 5						
Concept Title:	South Mercer Pump Station			**Date:**		9/13/2017
Location:	East Mercer Way & SE 72nd St., Mercer Is., WA			**Estimator:**		Eric Benton
Description:				**Idea Code:**		LS-2a
DIRECT: SUBTOTAL CONSTRUCTION COSTS						
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**		**Item Cost**
1	Drilled Shaft Retaining Wall, 80 ft deep shafts	1,600	LF	$ 130		$ 208,000
2	Concrete Wall 6 ft tall x 3 ft thick	27	CY	$ 850		$ 22,667
3	Mobilization / Demobilization (10%)	10	%	$ 23,067		$ 23,067
					Subtotal Construction Costs	***$ 250,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS						
					Mitigation Construction Contracts	$ -
					Allowance for Indeterminates (Design Allowance)	$ 100,000
					Construction Change Order Allowance	$ 35,000
					Material Pricing Uncertainty Allowance	$ -
					Subtotal Primary Construction Amount	***$ 385,000***
					Street Use Permit	$ -
					Construction Sales Tax	$ 38,885
					Owner Furnished Equipment	$ -
					Outside Agency Construction	$ -
					Subtotal KC Contribution to Construction	***$ 423,885***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES						
					KC/WTD Direct Implementation	$ -
					Misc. Capital Costs	$ 770
					TOTAL DIRECT CONSTRUCTION COSTS	***$ 425,000***
INDIRECT: NON-CONSTRUCTION COSTS						
					Design and Construction Consulting	$ 270,062
					Other Consulting Services	$ -
					Permitting & Other Agency Support	$ 4,475
					Right-of-Way	$ 5,000
					Misc. Service & Materials	$ 3,080
					Non-WTD Support	$ 3,273
					WTD Staff Labor	$ 90,870
					Subtotal Non-Construction Costs	***$ 376,760***
					Project Contingency	$ 242,017
					Initiatives	$ 5,308
					TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 624,000***
					TOTAL PROJECT COST	***$ 1,049,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

D-4: Flooding and Tsunamis

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MITIGATION CONCEPT SUMMARY - FLOODING

Issue No.	Concept Title
F-1	Interurban Pump Station flood protection upgrade
F-2	York Pump Station flood protection upgrade
F-3	Matthews Park Pump Station flood protection upgrade
F-4	Murray Pump Station flood protection upgrade
F-5	53rd Avenue Pump Station flood protection upgrade
F-6	63rd Avenue Pump Station flood protection upgrade
F-7	Bellevue Pump Station flood protection upgrade
F-8	Woodinville Pump Station flood protection upgrade
FP-1	Conduct Programmatic Flooding Evaluations – STP and BWTP
FP-2	Conduct Programmatic Flooding Evaluations – Off-site Facilities

MITIGATION CONCEPT SUMMARY - FLOODING

F-1 Interurban Pump Station flood protection upgrade

Issue No.	Issue Title	Risk Rating
F-1	Interurban Pump Station Flooding Risk	H
Idea Code	**Concept Title**	**Dev. Team**
F-1a	Interurban Pump Station flood protection upgrade	3

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☐ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
Interurban Pump Station	☐ SCADA	☐ Consequent Damages
	☒ Natural Hazards	☒ Environment
	- Flooding	Other: ☒ Flow Volume
		☒ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☒ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

This facility lies within 250 feet of the 100-year floodplain, has a low critical elevation as compared to base flood elevations, and has a substantial amount of equipment below grade. If the pump station failed due to flooding, a service disruption would occur potentially causing an overflow into the Duwamish River or possibly causing sewer back-ups into customer’s property. These factors make it susceptible to riverine flooding. The use of a 250 foot buffer is based on professional judgment to capture uncertainty about the affects of climate change on base flood elevations.

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program there exists the potential (less than 1% chance) that below-grade components of this facility (motors and pumps) could become inundated in a substantial flood event (riverine) and cause failure of the pump station.

MITIGATION CONCEPT SUMMARY - FLOODING

The likely system downtime is expected to be:

- Up to 1 month for an interim, work-around fix
- 3 – 12 months for a permanent fix (assuming emergency fast-tracking of the project)

The waterbody likely to be affected by failure of this system is the Duwamish River.

Description of Mitigation Concept:

No one has identified if water will enter the facility, but as an exercise to build resiliency at the site, the following mitigation concepts are recommended:

- Upsize submersible sump pump to at least two 10 HP pumps
- Construct a 150-foot long berm/flood wall to separate high water from the river with an inflatable baffle gate and grade site to drain to a Type 2 catch basin for use with a portable pump. The catch basin is presumed to be needed to allow routine drainage of the site during non-flooding events.
- If permits for installing a berm or floodwall prohibit using that approach, installing a hinged floodgate as shown in Figure 1 in facility could prevent flooding of the facility.
- If building is equipped with louver vents, compare their elevation with predicted water surface elevation of flooding event and adjust accordingly during preliminary design.
- It is recommended that physical testing of the “high alarm” of the sump pump occur on a regularly scheduled basis.

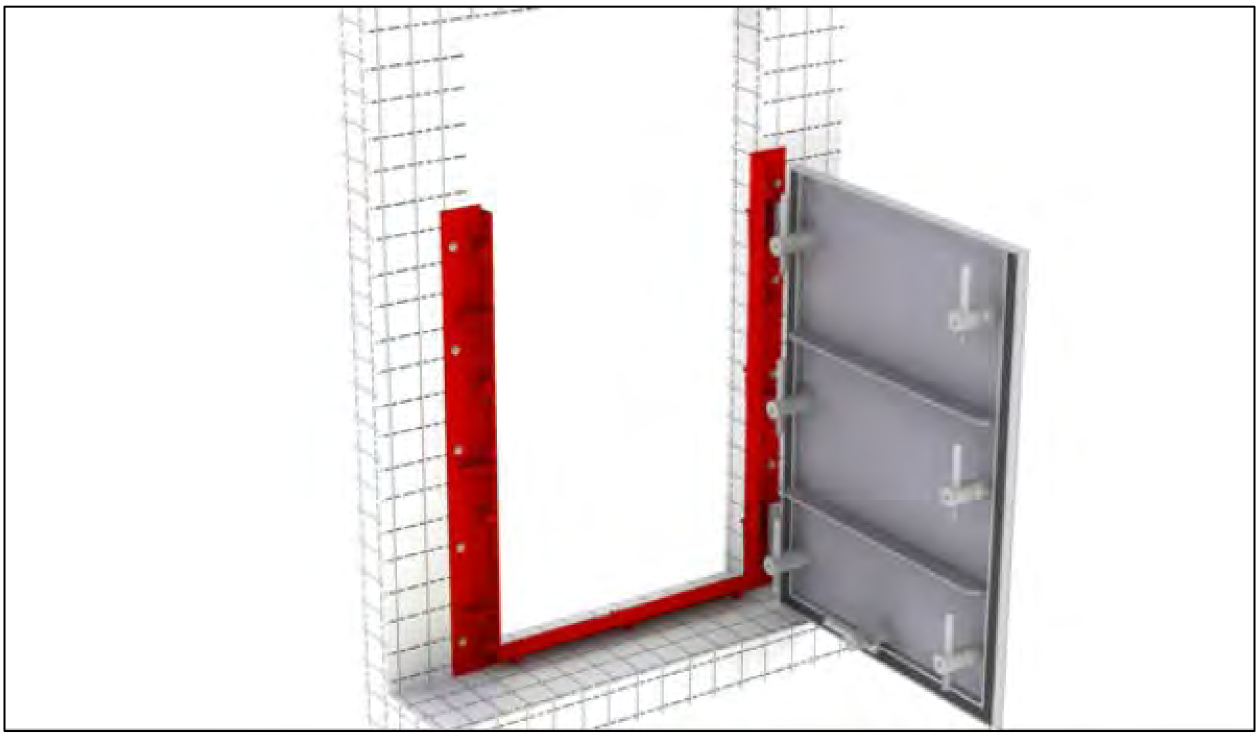

Figure 1. Example of Watertight Gate by Presray.

MITIGATION CONCEPT SUMMARY - FLOODING

Advantages:

- Wastewater operations are improved by providing additional riverine flood protection..
- Maintainability is improved slightly by enhancing the building protection against moisture through the use of watertight doors as well as by providing updated mechanical equipment.

Disadvantages:

- A berm/flood wall may negatively impact the visual aesthetics of the site.
- Maintainability is degraded slightly with the addition of the berm/flood wall and basin. Additionally, the operator will need to update operating procedures and become familiar with the use of an inflatable baffle gate.

Main Benefit:

The main benefit of this mitigation concept is that it addresses the riverine flooding risk at this facility location.

Discussion of Schedule:

This mitigation concept will require a 3-month installation window, but it is not directly affected by seasonal work windows and can be accomplished year-round.

Discussion of Risk:

This mitigation concept will address riverine flood related concerns up to a flood event of a 1 percent annual probability. It is anticipated that a riverine flood event will have a short-term collateral impact on other WTD assets (upstream sanitary sewer overflows), however, this exposure should be mitigated by temporary work-around solutions once in place. Additionally, there may be punitive environmental fines assessed by ecology regarding the overflows.

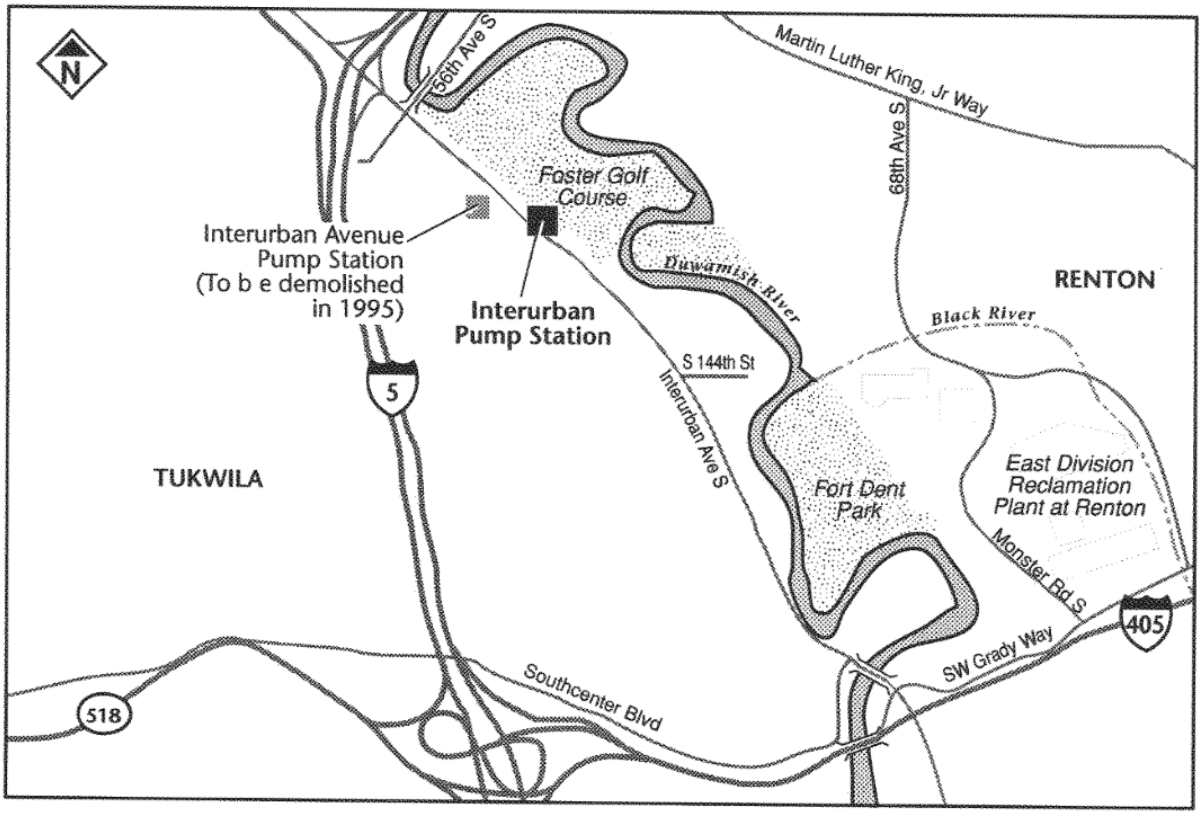

Figure 2. Location Map

MITIGATION CONCEPT SUMMARY - FLOODING

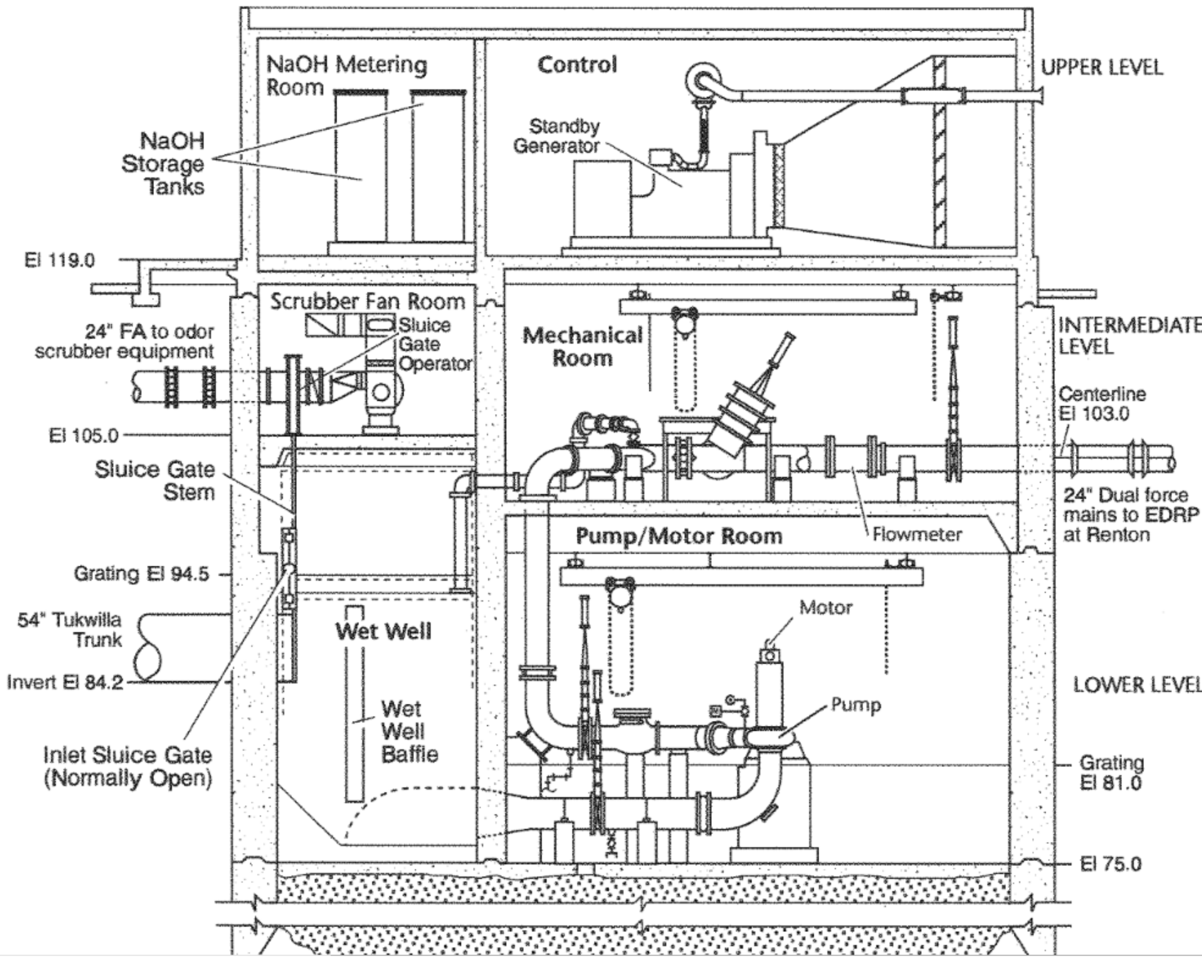

Figure 3. Station Cross Section

Assumptions and Calculations:

The initial mitigation concept-level cost estimate includes the following assumptions:

- 4-foot tall, 150-foot long berm/flood wall
- Two submersible 10 HP sump pumps, including equipment, new fittings, electrical connections, and piping as necessary
- One inflatable baffle gate
- Two watertight flood gates, frames, and hardware
- One roll up door
- Type 2 catch basin

MITIGATION CONCEPT SUMMARY - FLOODING

Table 1. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Interurban Pump Station			**Date:**	9/12/2017
Location:				**Estimator:**	Richard Greer
Description:	Flooding			**Idea Code:**	F-1a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Upsize submersible sump pumps to 10 HP (Remove & Replace)	2	EA	$ 15,000	$ 30,000
2	Install Watertight doors, frames and hardware	2	EA	$ 10,000	$ 20,000
3	Install Watertight roll updoors, frames and hardware	1	EA	$ 15,000	$ 15,000
4	4' Berm/floodwall	260	LF	$ 250	$ 65,000
5	Baffle gate for berm	40	LF	$ 500	$ 20,000
6	Install type 2 catch basin and contour grade	1	EA	$ 7,500	$ 7,500
7	Portable Pump and hoses	1	EA	$ 1,500	$ 1,500
8	Mobilization / Demobilization (10%)	10	%	$ 15,900	$ 15,900
				Subtotal Construction Costs	***$ 170,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 68,000
				Construction Change Order Allowance	$ 23,800
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 261,800***
				Street Use Permit	$ -
				Construction Sales Tax	$ 26,442
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 288,242***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 524
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 289,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 194,672
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 3,043
				Right-of-Way	$ 3,400
				Misc. Service & Materials	$ 2,094
				Non-WTD Support	$ 2,225
				WTD Staff Labor	$ 66,168
				Subtotal Non-Construction Costs	***$ 271,603***
				Project Contingency	$ 169,193
				Initiatives	$ 3,610
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 444,000***
				TOTAL PROJECT COST	***$ 733,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - FLOODING

F-2 York Pump Station flood protection upgrade

Issue No.	Issue Title	Risk Rating
F-2	York Pump Station Flooding Risk	H
Idea Code	**Concept Title**	**Dev. Team**
F-2a	York Pump Station flood protection upgrade	3

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☐ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☒ Public Health
York Pump Station	☐ SCADA	☐ Consequent Damages
	☒ Natural Hazards	☒ Environment
	- Flooding	Other: ☒ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

The existing issue is that this facility lies within 250 feet of the 100-year flood plain, has a low critical elevation as compared to base flood elevations, and has a substantial amount of equipment below grade. The below grade equipment is susceptible to failure (e.g. pump motors could burn out) if exposed to significant amounts of water. These factors make it susceptible to failure if riverine flooding were to occur.

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program there exists the potential that below grade components of this facility (motors and pumps) could become inundated in a substantial flood event (riverine) and cause failure of the pump station. Failure of the pump station would result in degraded service.

MITIGATION CONCEPT SUMMARY - FLOODING

The likely system downtime is expected to be:

- Up to 1 month for an interim, work-around fix (i.e. using temporary pumps)
- 3 - 6 months for a permanent fix to refurbish or replace the pump motors (assuming emergency fast-tracking of the project)

The waterbody likely to be affected by failure of this system is the Sammamish River.

Description of Mitigation Concept:

- Upsize existing electric pumps with three dry pit submersible pumps (600 HP). Confirm that there is sufficient room to install dry pit submersible pumps and associated equipment.
- Upgrade existing submersible sump pumps to at least two 10 HP pumps.
- Install watertight doors in facility exterior doors (three roll-up doors and four personal access doors). Note that these are only intended to protect the facility up to a few feet and are not intended to be submarine type doors. Watertight doors in addition to berm structure would increase facility resiliency and allow additional time for operator to inflate baffle gate.
- Construct a 500-foot long berm/flood wall to separate high water from the river with an inflatable baffle gate.
- Install type 2 catch basin and grade site to drain to catch basin. This would allow use of a portable pump to pump water captured between berm and facility that cannot drain naturally.
- Check for louvers around building exterior that may allow water to enter the structure. These may require mitigation if present.

It is recommended that physical testing of the “high alarm” of the sump pumps occur on a regularly scheduled basis.

Advantages:

- Wastewater Operations are improved by providing additional riverine flood mitigation and by improving upon existing pumps.
- Maintainability is improved slightly by enhancing the building protection against moisture through the use of watertight doors as well as by providing updated mechanical equipment.

Disadvantages:

- The addition of a berm/flood wall and basin near the facility may have a negative visual impact.
- Maintainability is degraded slightly with the addition of the berm/flood wall and basin. Additionally, the operator will need to update operating procedures and become familiar with the use of an inflatable baffle gate.

Main Benefit:

The main benefit of this mitigation concept is to address the riverine flooding risk at this facility location.

MITIGATION CONCEPT SUMMARY - FLOODING

Discussion of Schedule:

This mitigation concept will require a 3-month installation window, but is not directly affected by seasonal work windows and can be accomplished year-round.

Discussion of Risk:

This mitigation concept will address riverine flood related concerns up to a flood event of a 1 percent annual probability. It is anticipated that a riverine flood event will have a short-term collateral impact on other WTD assets (upstream sanitary sewer overflows). However, this exposure should be mitigated by temporary work-around solutions once in place. Additionally, there may be punitive environmental fines assessed by ecology regarding the overflows.

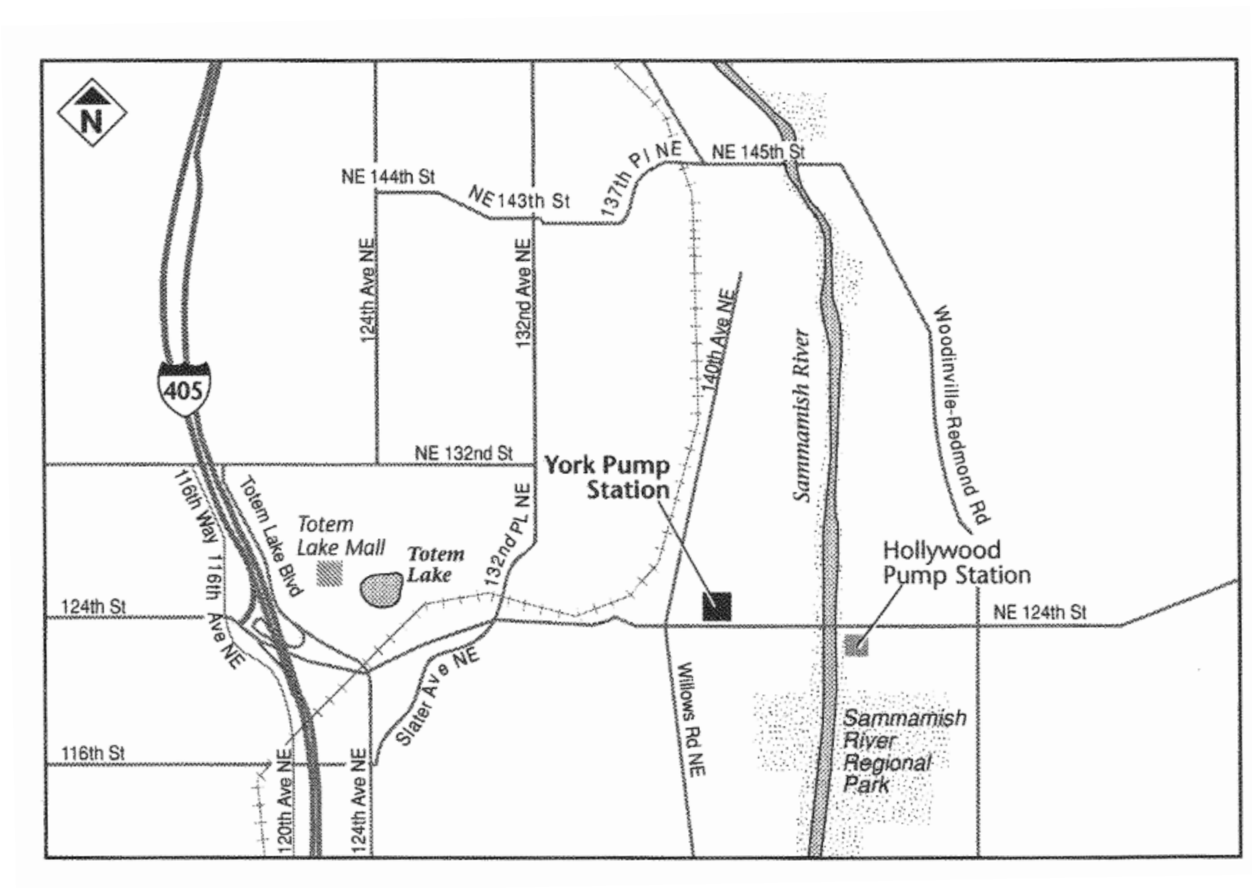

Figure 1. Location Map

MITIGATION CONCEPT SUMMARY - FLOODING

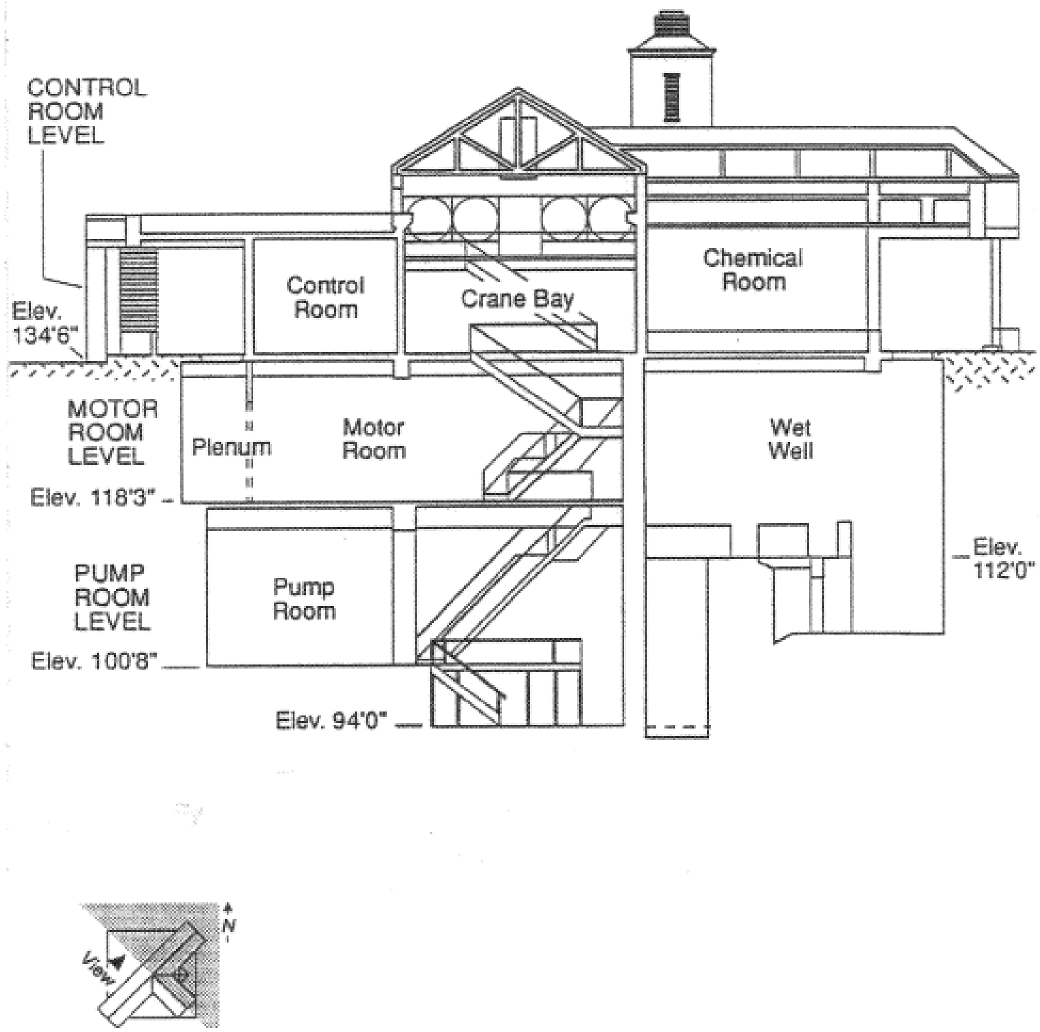

Figure 2. Station Cross Section

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Three dry pit submersible pumps (600 HP) with equipment, new fittings, electrical connections, and piping, including equipment, new fittings, electrical connections, and piping as necessary
- Two 10 HP pumps with equipment, new fittings, electrical connections, and piping
- Watertight doors – three roll up doors and four personal access doors
- 4-foot tall, 500-foot long berm/flood wall with seeding and restoration
- Inflatable baffle gate
- Type 2 catch basin and contour grade
- One portable pump with hoses

MITIGATION CONCEPT SUMMARY - FLOODING

Table 1. Concept-level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	York Pump Station			**Date:**	9/12/2017
Location:				**Estimator:**	Richard Greer
Description:	Flooding			**Idea Code:**	F-2a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Upsize electrical pumps to 600 HP (Remove & Replace)	3	EA	$ 140,000	$ 420,000
2	Upsize submersible sump pumps to 10 HP (Remove & Replace)	2	EA	$ 15,000	$ 30,000
3	Install Watertight doors, frames and hardware	4	EA	$ 10,000	$ 40,000
4	Install Watertight roll updoors, frames and hardware	3	EA	$ 15,000	$ 45,000
5	4' Berm	500	LF	$ 250	$ 125,000
6	Baffle Flood gate for berm	20	LF	$ 500	$ 10,000
7	Install type 2 catch basin and contour grade	1	EA	$ 7,500	$ 7,500
8	Portable Pump and hoses	1	EA	$ 1,500	$ 1,500
9	Mobilization / Demobilization (10%)	10	%	$ 67,900	$ 67,900
				Subtotal Construction Costs	***$ 750,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 300,000
				Construction Change Order Allowance	$ 105,000
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 1,155,000***
				Street Use Permit	$ -
				Construction Sales Tax	$ 116,655
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 1,271,655***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 2,310
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 1,274,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 686,853
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 13,425
				Right-of-Way	$ 15,000
				Misc. Service & Materials	$ 9,240
				Non-WTD Support	$ 9,818
				WTD Staff Labor	$ 226,392
				Subtotal Non-Construction Costs	***$ 960,728***
				Project Contingency	$ 675,185
				Initiatives	$ 15,925
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 1,652,000***
				TOTAL PROJECT COST	***$ 2,926,000***

MITIGATION CONCEPT SUMMARY - FLOODING

F-3 Matthews Park Pump Station flood protection upgrade

Issue No.	Issue Title	Risk Rating
F-3	Matthews Park Pump Station Flooding Risk	M
Idea Code	**Concept Title**	**Dev. Team**
F-3a	Matthews Park Pump Station flood protection upgrade	3

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☐ Structural	☐ Life Safety
☒ Site Specific (list site below) Matthews Park Pump Station	☐ MEP	☐ Public Health
	☐ SCADA	☐ Consequent Damages
	☒ Natural Hazards (list type below) - Flooding	☒ Environment
		Other: ☒ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

This facility lies within 250 feet of the 100-year floodplain of Thornton Creek, has a moderate critical elevation as compared to base flood elevations, and has a substantial amount of equipment below grade. If the pump station failed due to flooding, a service disruption would occur potentially causing an overflow into the Thornton Creek and Lake Washington or possibly causing sewer back-ups into customer's property. These factors make it susceptible to riverine flooding. Lake Washington is presumed to not be a flooding source for this planning exercise and the use of a 250-foot buffer is based on professional judgment to capture uncertainty about the affects of climate change on base flood elevations.

MITIGATION CONCEPT SUMMARY - FLOODING

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program there exists the potential that below grade components of this facility (pumps, electrical, equipment) could become inundated in a substantial flood event and cause failure of the pump station.

The likely system downtime is expected to be:

- Up to 1 month for an interim, work-around fix
- 3-12 months for a permanent fix to refurbish or replace the pump motors and electrical switch gear (assuming emergency fast-tracking of the project)

The waterbodies likely to be affected by failure of this system are Lake Washington and Thornton Creek.

Description of Mitigation Concept:

No one has identified if water will enter the facility, but as an exercise to build resiliency at the site, the following mitigation concepts are recommended:

- Replace existing electric pumps with four dry pit submersible pumps (two 400HP, one 800HP, and one 600 HP)
- Upgrade existing submersible sump pumps to at least two 10 HP pumps
- It is recommended that physical testing of the “high alarm” of the sump pumps occur on a regularly scheduled basis. If building is equipped with louver vents, compare their elevation with predicted water surface elevation of flooding event and adjust accordingly during preliminary design. Berms and/or floodwalls were presumed to not be necessary since the site is located on relatively high ground and Thornton Creek in this area is relatively steep. Flood waters from Thornton Creek might lap-up against one or two sides of the building, but likely not inundate it from all sides.

Advantages:

- Wastewater operations are improved by providing additional riverine flood mitigation and by improving upon existing pumps.
- Maintainability is improved slightly by enhancing the building protection against moisture through the use of watertight floodgates as well as by providing updated mechanical appurtenances.

Disadvantages:

- Maintainability is degraded slightly as the operator will need to update operating procedures.

Main Benefit:

The main benefit of this mitigation concept is to address the riverine flooding risk at this facility location.

MITIGATION CONCEPT SUMMARY - FLOODING

Discussion of Schedule:

This mitigation concept will require a 3-month installation window, but it is not directly affected by seasonal work windows and can be accomplished year-round.

Discussion of Risk:

This mitigation concept will address riverine flood related concerns up to a flood event of a one percent annual probability. It is anticipated that a riverine flood event will have a short-term collateral impact on other WTD assets (upstream sanitary sewer overflows). However, this exposure should be mitigated by temporary work-around solutions once in place. Additionally, there may be punitive environmental fines assessed by ecology regarding the overflows.

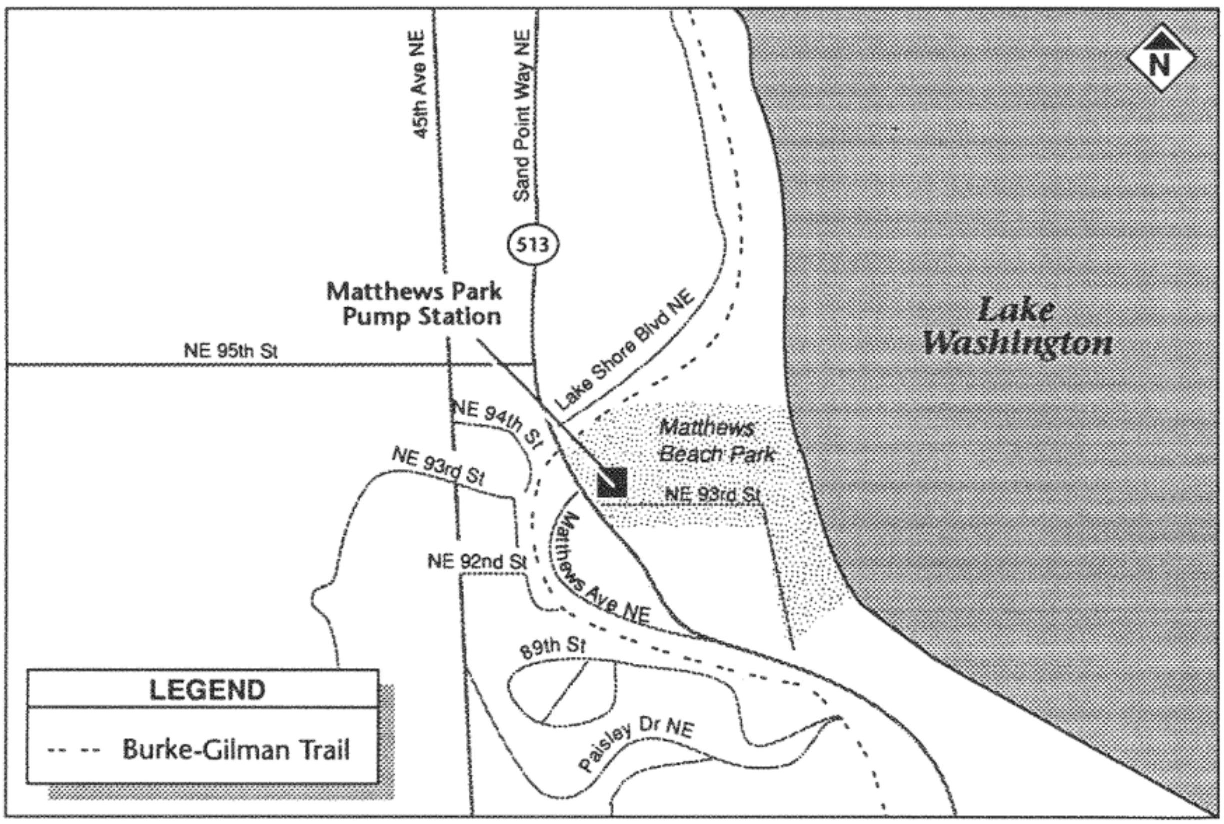

Figure 1. Location Map

MITIGATION CONCEPT SUMMARY - FLOODING

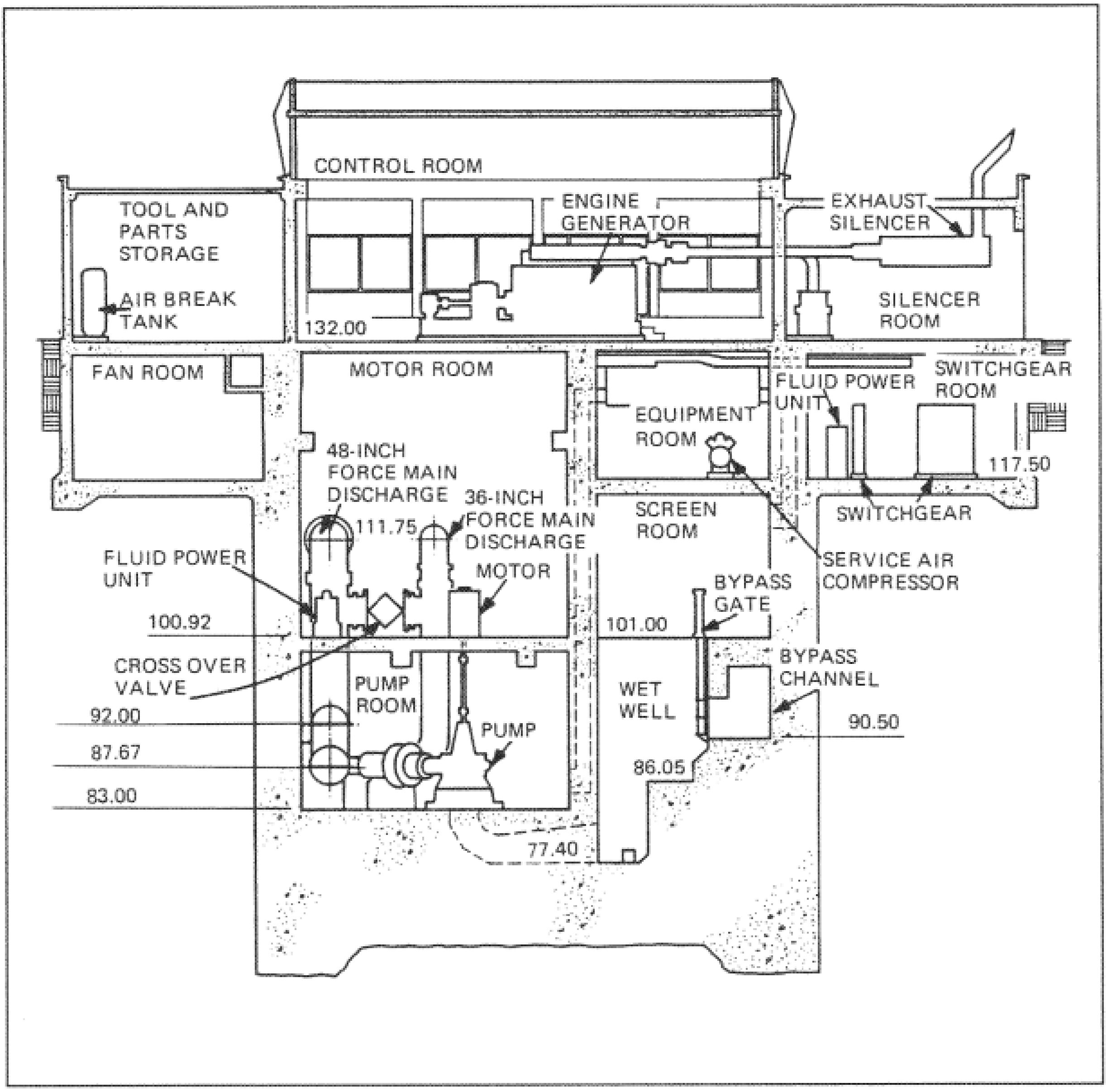

Figure 2. Station Cross Section

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Four dry pit submersible pumps (two 400HP, one 800HP, and one 600 HP), including equipment, new fittings, and piping as necessary
- Two 10 HP pumps, including equipment, new fittings, and piping as necessary

King County HDR TEAM

MITIGATION CONCEPT SUMMARY - FLOODING

Table 1. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Matthews Park Pump Station			**Date:**	9/12/2017
Location:				**Estimator:**	Richard Greer
Description:	Flooding			**Idea Code:**	F-3a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Replace electrical pump to 400 HP (Remove and Replace)	1	EA	$ 110,000	$ 110,000
2	Replace electrical pump to 500 HP (Remove and Replace)	1	EA	$ 125,000	$ 125,000
3	Replace electrical pump to 600 HP (Remove and Replace)	1	EA	$ 140,000	$ 140,000
4	Replace electrical pump to 800 HP (Remove and Replace)	1	EA	$ 175,000	$ 175,000
5	Upsize submersible sump pumps to 10 HP Remove and Replace	4	EA	$ 15,000	$ 60,000
6	Mobilization / Demobilization (10%)	10	%	$ 61,000	$ 61,000
				Subtotal Construction Costs	***$ 670,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 268,000
				Construction Change Order Allowance	$ 93,800
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 1,031,800***
				Street Use Permit	$ -
				Construction Sales Tax	$ 104,212
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 1,136,012***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 2,064
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 1,138,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 624,039
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 11,993
				Right-of-Way	$ 13,400
				Misc. Service & Materials	$ 8,254
				Non-WTD Support	$ 8,770
				WTD Staff Labor	$ 206,007
				Subtotal Non-Construction Costs	***$ 872,463***
				Project Contingency	$ 607,429
				Initiatives	$ 14,226
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 1,494,000***
				TOTAL PROJECT COST	***$ 2,632,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - FLOODING

F-4 Murray Pump Station flood protection upgrade

Issue No.	Issue Title	Risk Rating
F-4	Murray Pump Station Flooding Risk	H
Idea Code	**Concept Title**	**Dev. Team**
F-4a	Murray Pump Station flood protection upgrade	3

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)	
☐ System Wide	☐ Structural	☐ Life Safety	
☒ Site Specific (list site below)	☐ MEP	☐ Public Health	
Murray Pump Station	☐ SCADA	☐ Consequent Damages	
	☒ Natural Hazards	☒ Environment	
	- Flooding	Other:	☒ Flow Volume
			☐ Equity and Social Justice
			☒ System Downtime
			☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☒ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

This facility lies within 250 feet of the 100-year flood plain, has a moderate critical elevation as compared to base flood elevations, and has a substantial amount of equipment below grade The below grade equipment is susceptible to failure (e.g. pump motors could burn out) if exposed to significant amounts of water. These factors make it susceptible to failure coastal flooding were to occur.

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program there exists the potential that below-grade components of this facility (pumps, control panels) could become inundated in a substantial coastal flood event and cause failure of the pump station. Failure of the pump station would result in degraded service.

MITIGATION CONCEPT SUMMARY - FLOODING

The likely system downtime is expected to be:

- Up to 1 month for an interim, work-around fix (i.e. using temporary pumps)
- 1 – 3 years for a permanent fix to repair or refurbish electrical motors, MCCs, and switchgear and to construct electrical building (assuming emergency fast-tracking of the project)

The waterbody to be affected by failure of this system is the Puget Sound.

Description of Mitigation Concept:

Replace existing four electric pumps with dry pit submersible pumps (two 100 HP, two 300 HP). Confirm that there is sufficient room to install dry pit submersible pumps and associated equipment.

Upgrade existing submersible sump pumps to at least two 10 HP pumps

Add watertight hatches

Raise the electrical MCCs above grade (this will require an additional 20 x 10 outbuilding)

Check for louvers around building exterior that may allow water to enter the structure. These may require mitigation if present.

It is recommended that physical testing of the “high alarm” of the sump pump occur on a regularly scheduled basis.

Advantages:

- Wastewater operations are improved by providing additional coastal flood mitigation and by improving upon existing pumps.
- Maintainability is improved slightly by enhancing the building protection against moisture by using watertight doors and hatches, raising electrical components to above-ground level, and by providing updated mechanical equipment.

Disadvantages:

- Long-term impacts are degraded by the addition of an additional structure at the facility which may have a negative visual impact.
- Maintainability is degraded slightly with the addition of the small enclosure to house the MCC electrical equipment. Additionally, the operator will need to update operating procedures.

Main Benefit:

The main benefit of this mitigation concept is to address the coastal flooding risk at this facility location.

Discussion of Schedule:

This mitigation concept will require a 3-month installation window, but is not directly affected by seasonal work windows and can be accomplished year-round.

MITIGATION CONCEPT SUMMARY - FLOODING

Discussion of Risk:

This mitigation concept will address flood-related concerns for a coastal flood event. It is anticipated that a coastal flood event will have a short-term collateral impact on other WTD assets (upstream sanitary sewer overflows). However, this exposure should be mitigated by temporary work-around solutions once in place. Additionally, there may be punitive environmental fines assessed by ecology regarding the overflows.

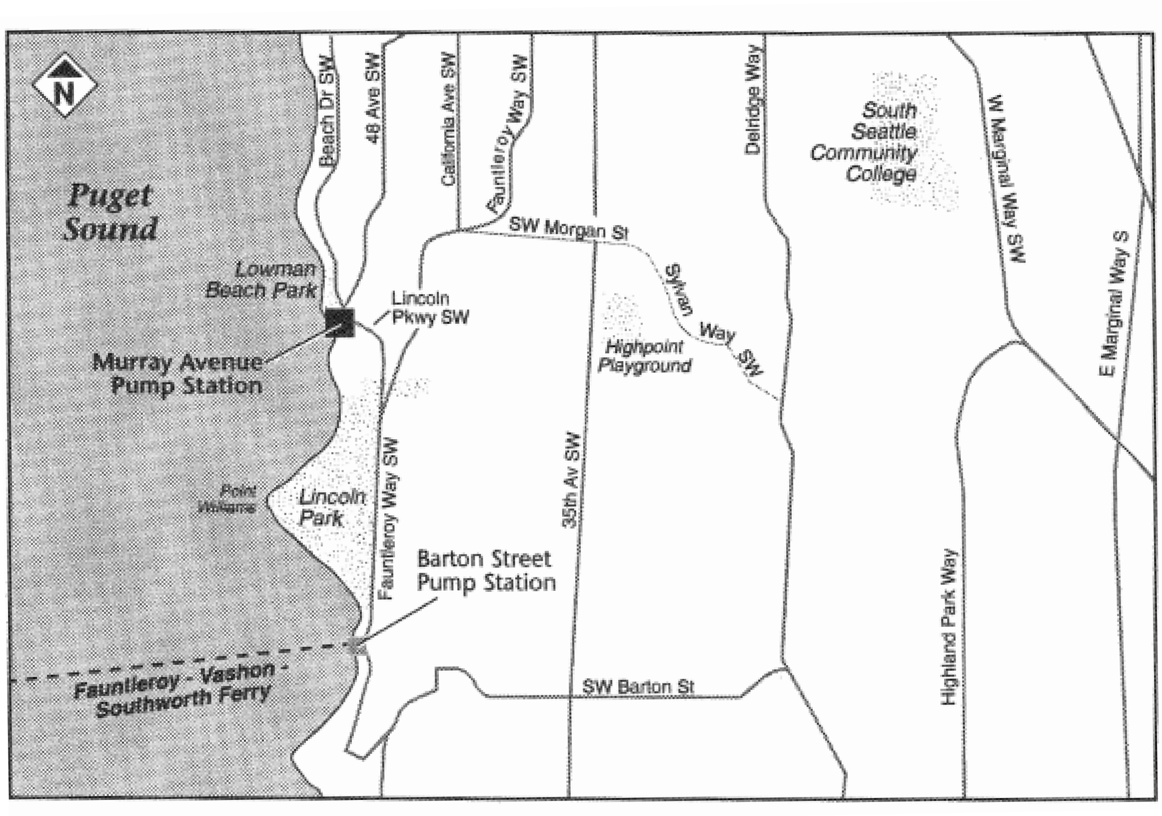

Figure 1. Location Map

MITIGATION CONCEPT SUMMARY - FLOODING

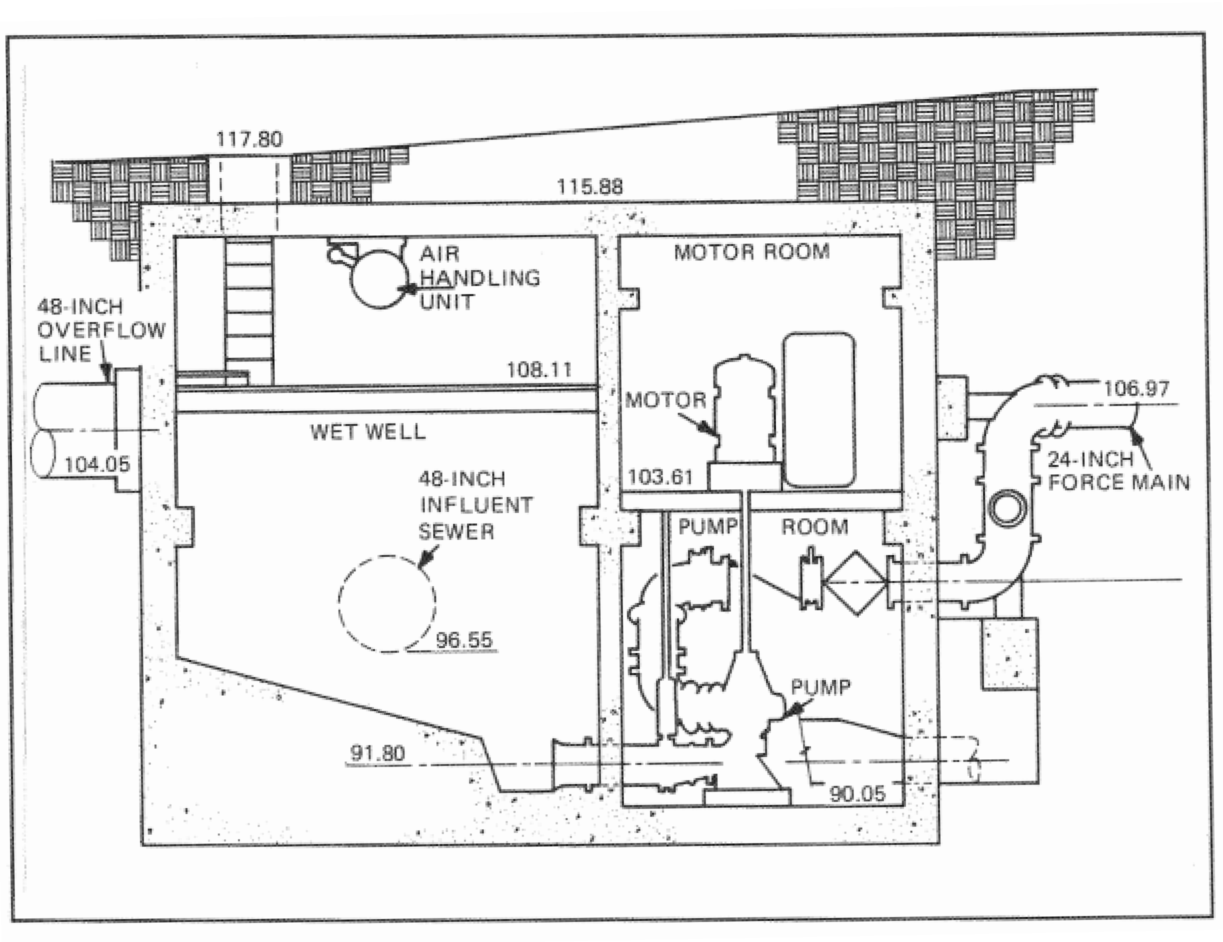

Figure 2. Station Cross Section

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Dry pit submersible pumps - two 100 HP, two 300 HP, including equipment, piping, and electrical connections as necessary
- Two 10 HP submersible sump pumps, including equipment, piping, and electrical connections as necessary
- Three watertight hatches
- 20 X 10 outbuilding to bring electrical MCCS above-grade – architectural concrete-reinforced building with HVAC and lighting

MITIGATION CONCEPT SUMMARY - FLOODING

Table 1. Concept-level Cost Estimate

Concept Title:	Murray Pump Station			**Date:**	9/12/2017
Location:				**Estimator:**	Richard Greer
Description:	Mitigate Flooding Risk			**Idea Code:**	F-4a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Water Resistant Hatches, Frames and Hardware and 10' x 4'	3	Ea	$ 15,000	$ 45,000
2	Replace electrical pump to 100 HP (Remove and Replace)	2	EA	$ 75,000	$ 150,000
3	Replace electrical pump to 300 HP (Remove and Replace)	2	EA	$ 100,000	$ 200,000
4	Raise Electrical MCC's above Grade Construct New Building	1	LS	$ 900,000	$ 900,000
5	Upsize submersible sump pumps to 10 HP Remove and Replace	2	EA	$ 15,000	$ 30,000
6	Mobilization / Demobilization (10%)	10	%	$ 132,500	$ 132,500
				Subtotal Construction Costs	***$ 1,460,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 584,000
				Construction Change Order Allowance	$ 204,400
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 2,248,400***
				Street Use Permit	$ -
				Construction Sales Tax	$ 227,088
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 2,475,488***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 4,497
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 2,480,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 1,210,544
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 26,134
				Right-of-Way	$ 29,200
				Misc. Service & Materials	$ 17,987
				Non-WTD Support	$ 19,111
				WTD Staff Labor	$ 396,432
				Subtotal Non-Construction Costs	***$ 1,699,408***
				Project Contingency	$ 1,263,118
				Initiatives	$ 31,000
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 2,994,000***
				TOTAL PROJECT COST	***$ 5,474,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - FLOODING

F-5 53rd Avenue Pump Station flood protection upgrade

Issue No.	Issue Title	Risk Rating
F-5	**53rd Avenue Pump Station Flooding Risk**	**MH**
Idea Code	**Concept Title**	**Dev. Team**
F-5a	**53rd Avenue Pump Station flood protection upgrade**	**3**

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☐ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
53rd Avenue Pump Station	☐ SCADA	☐ Consequent Damages
	☒ Natural Hazards	☒ Environment
	- Flooding	Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

This below-grade facility lies within 250 feet of the 100-year coastal floodplain, has a moderate critical elevation as compared to base flood elevations, and has a substantial amount of equipment below grade. If the pump station failed due to flooding, a service disruption would occur potentially causing an overflow into the Puget Sound or possibly causing sewer back-ups into customers' properties. These factors make this pump station susceptible to coastal flooding. The use of a 250-foot buffer is based on professional judgment to capture uncertainty about the affects of climate change on base flood elevations.

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program there exists the potential that below-grade components of this facility (pumps, control panels) could become inundated in a substantial coastal flood event and cause failure of the pump station.

MITIGATION CONCEPT SUMMARY - FLOODING

The likely system downtime is expected to be:

- Up to 1 month for an interim, work-around fix
- 3 – 12 months for a permanent fix to repair or refurbish electrical motors, MCCs, and switchgear (assuming emergency fast-tracking of the project)

The waterbody affected by failure of this system is Puget Sound.

Description of Mitigation Concept:

No one has identified if water will enter the facility, but as an exercise to build resiliency at the site, the following mitigation concepts are recommended:

- Replace two existing electric pumps with dry pit submersible pumps (two 124/1 HP)
- Upgrade existing submersible sump pumps to at least two 10 HP pumps
- Install two watertight access hatches and three watertight doors in facility

It is recommended that physical testing of the “high alarm” of the sump pump occur on a regularly scheduled basis. If building is equipped with louver vents, compare their elevation with predicted water surface elevation of flooding event and adjust accordingly during preliminary design.

Advantages:

- Wastewater operations are improved by providing additional coastal flood mitigation and by improving upon existing pumps.
- Maintainability is improved slightly by enhancing the building protection against moisture through the use of watertight doors and hatches as well as by providing updated mechanical.

Disadvantages:

- Maintainability is degraded slightly as the operator will need to update operating procedures.

Main Benefit:

The main benefit of this mitigation concept is to address the coastal flooding risk at this facility location.

Discussion of Schedule:

This mitigation concept will require a 3-month installation window, but is not directly affected by seasonal work windows and can be accomplished year-round.

MITIGATION CONCEPT SUMMARY - FLOODING

Discussion of Risk:

This mitigation concept will address flood related concerns for a coastal flood event. It is anticipated that a coastal flood event will have a short-term collateral impact on other WTD assets (upstream sanitary sewer overflows), however, this exposure should be mitigated by temporary work-around solutions once in place. Additionally, there may be punitive environmental fines assessed by ecology regarding the overflows.

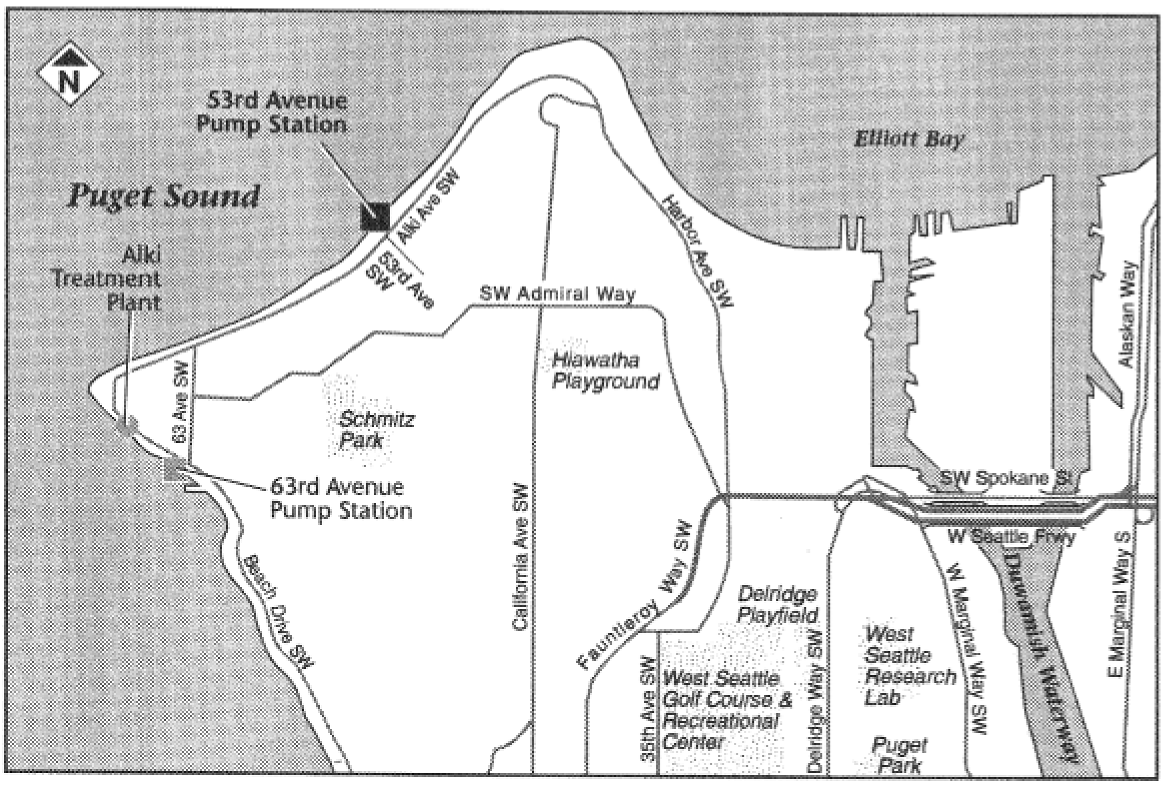

Figure 1. Location Map

MITIGATION CONCEPT SUMMARY - FLOODING

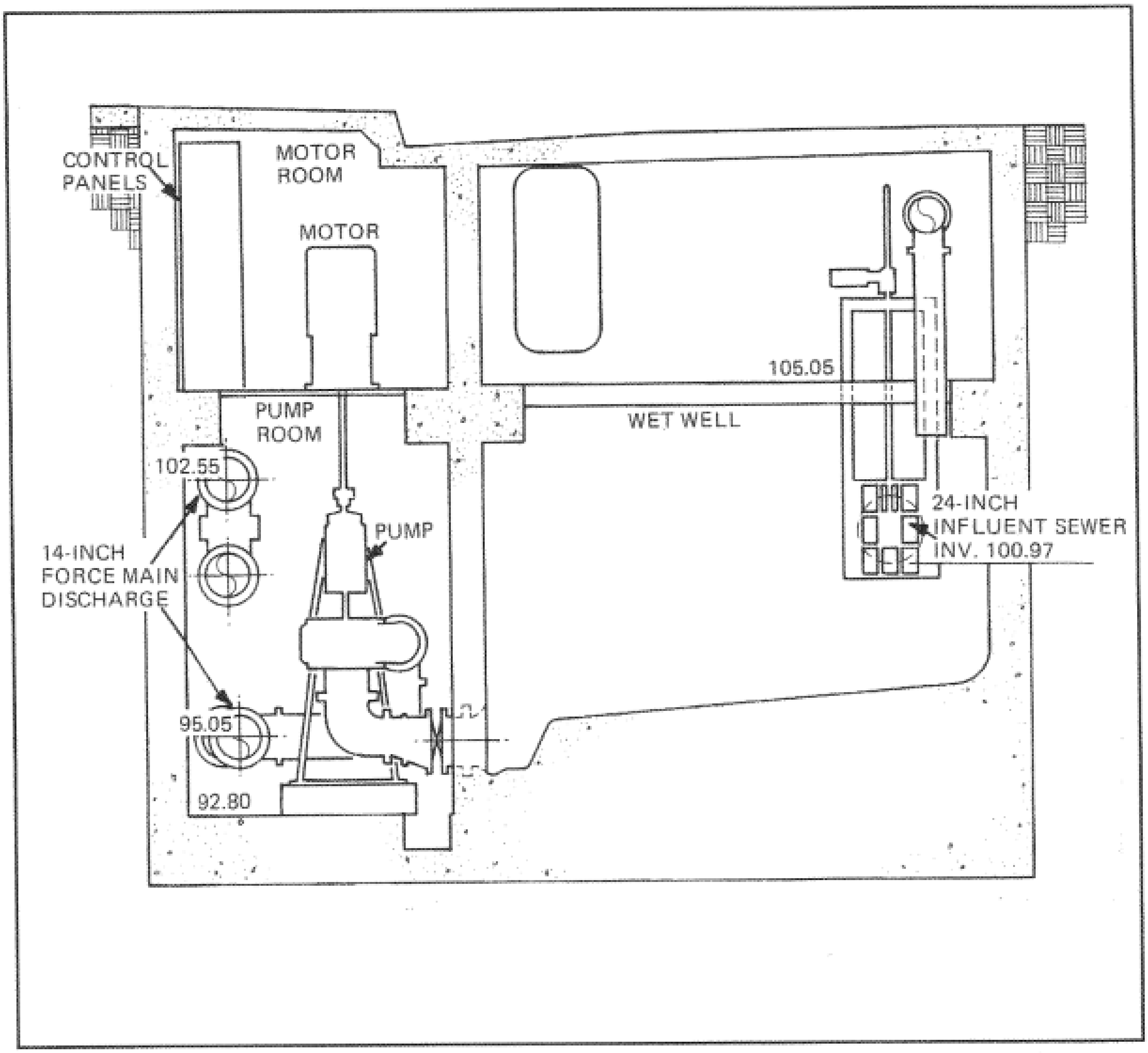

Figure 2. Station Cross Section

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Two 124/41 HP dry pit submersible pumps, including new fittings, electrical connections, and piping as necessary
- Two 10 HP submersible sump pumps, including new fittings, electrical connections, and piping as necessary
- Two watertight access hatches and three watertight doors

MITIGATION CONCEPT SUMMARY - FLOODING

Table 1. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	53rd Avenue Pump Station			**Date:**	9/12/2017
Location:				**Estimator:**	Richard Greer
Description:	Mitigate Flooding Risk			**Idea Code:**	F-5a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Water Resistant Access Hatches, Frames and Hardware 10'x4'	2	Ea	$ 15,000	$ 30,000
2	Replace electrical pump to 124/1 HP (Remove and Replace)	2	EA	$ 80,000	$ 160,000
3	Upsize submersible sump pumps to 10 HP (Remove and Replace)	2	EA	$ 16,000	$ 32,000
4	Install Watertight doors, frames and hardware	3	EA	$ 10,000	$ 30,000
5	Mobilization / Demobilization (10%)	10	%	$ 25,200	$ 25,200
				Subtotal Construction Costs	***$ 280,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 112,000
				Construction Change Order Allowance	$ 39,200
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 431,200***
				Street Use Permit	$ -
				Construction Sales Tax	$ 43,551
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 474,751***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 862
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 476,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 297,340
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 5,012
				Right-of-Way	$ 5,600
				Misc. Service & Materials	$ 3,450
				Non-WTD Support	$ 3,665
				WTD Staff Labor	$ 99,780
				Subtotal Non-Construction Costs	***$ 414,846***
				Project Contingency	$ 268,922
				Initiatives	$ 5,945
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 690,000***
				TOTAL PROJECT COST	***$ 1,165,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - FLOODING

F-6 63rd Avenue Pump Station flood protection upgrade

Issue No.	Issue Title	Risk Rating
F-6	63rd Avenue Pump Station Flooding Risk	H
Idea Code	**Concept Title**	**Dev. Team**
F-6a	63rd Avenue Pump Station flood protection upgrade	3

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☐ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
63rd Ave Pump Station	☐ SCADA	☐ Consequent Damages
	☒ Natural Hazards	☒ Environment
	- Flooding	Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

This facility lies within 250 feet of the 100-year flood plain, has a moderate critical elevation as compared to base flood elevations, and has a substantial amount of equipment below grade. The below grade equipment is susceptible to failure (e.g. pump motors could burn out) if exposed to significant amounts of water. These factors make it susceptible to failure if coastal flooding were to occur.

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program there exists the potential that below-grade components of this facility (pumps, control panels) could become inundated in a substantial coastal flood event and cause failure of the pump station. Failure of the pump station would result in degraded service.

The likely system downtime is expected to be up to 3 months.

MITIGATION CONCEPT SUMMARY - FLOODING

Up to 1 month for an interim, work-around fix (i.e. using temporary pumps)

6 – 9 months for a permanent fix to repair or refurbish electrical motors (assuming emergency fast-tracking of the project)

The waterbody affected by failure of this system is the Puget Sound.

Description of Mitigation Concept:

Replace existing three electric pumps with dry pit submersible pumps (3 X 200 HP). Confirm that there is sufficient room to install dry pit submersible pumps and associated equipment.

Upgrade existing submersible sump pumps to at least two 10 HP pumps

Install watertight door in facility entering the pump station. Note that these are only intended to protect the facility up to a few feet and are not intended to be submarine type doors.

Check for louvers around building exterior that may allow water to enter the structure. These may require mitigation if present.

It is recommended that physical testing of the “high alarm” of the sump pump occur on a regularly scheduled basis.

Advantages:

- Wastewater operations are improved by providing additional coastal flood mitigation and by improving upon existing pumps.
- Maintainability is improved slightly by enhancing the building protection against moisture through the use of watertight doors as well as by providing updated mechanical.

Disadvantages:

- Maintainability is degraded slightly as the operator will need to update operating procedures.

Main Benefit:

The main benefit of this mitigation concept is to address the coastal flooding risk at this facility location.

Discussion of Schedule:

This mitigation concept will require a 3-month installation window, but it is not directly affected by seasonal work windows and can be accomplished year-round.

Discussion of Risk:

This mitigation concept will address flood-related concerns for a coastal flood event. It is anticipated that a coastal flood event will have a short-term collateral impact on other WTD assets (upstream sanitary sewer overflows). However, this exposure should be mitigated by temporary work-around solutions once in place. Additionally, there may be punitive environmental fines assessed by ecology regarding the overflows.

MITIGATION CONCEPT SUMMARY - FLOODING

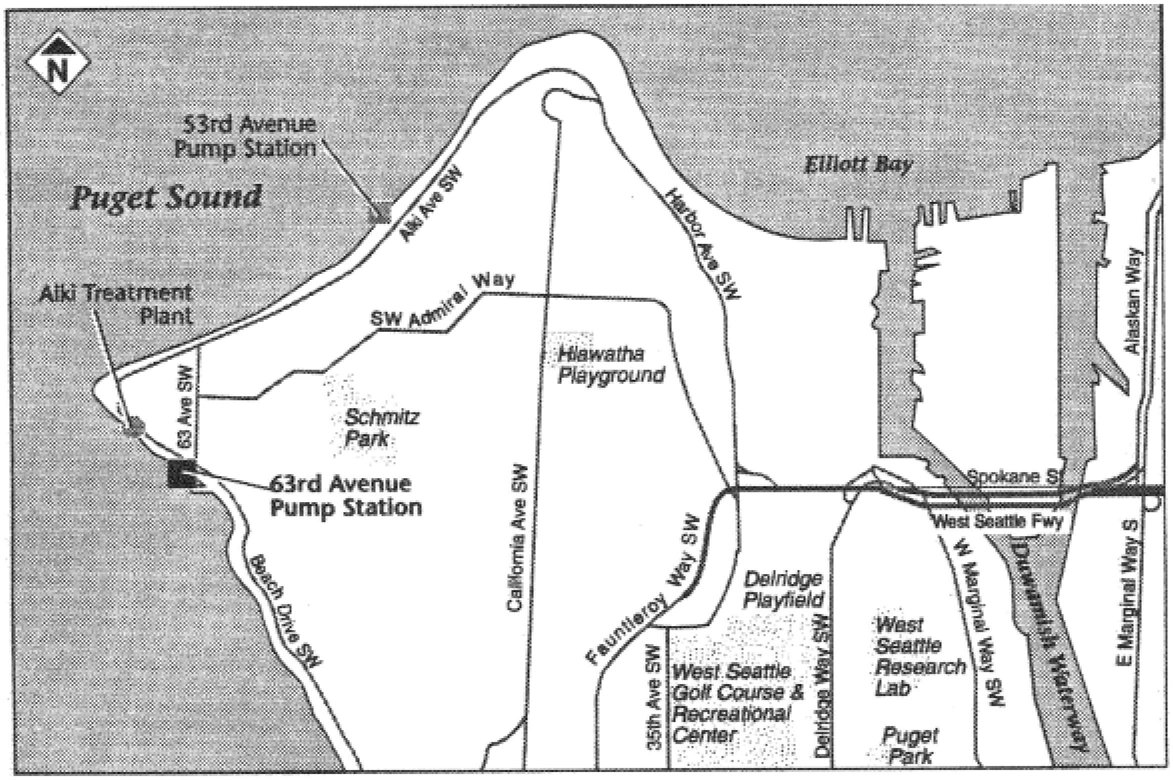

Figure 1. Location Map

MITIGATION CONCEPT SUMMARY - FLOODING

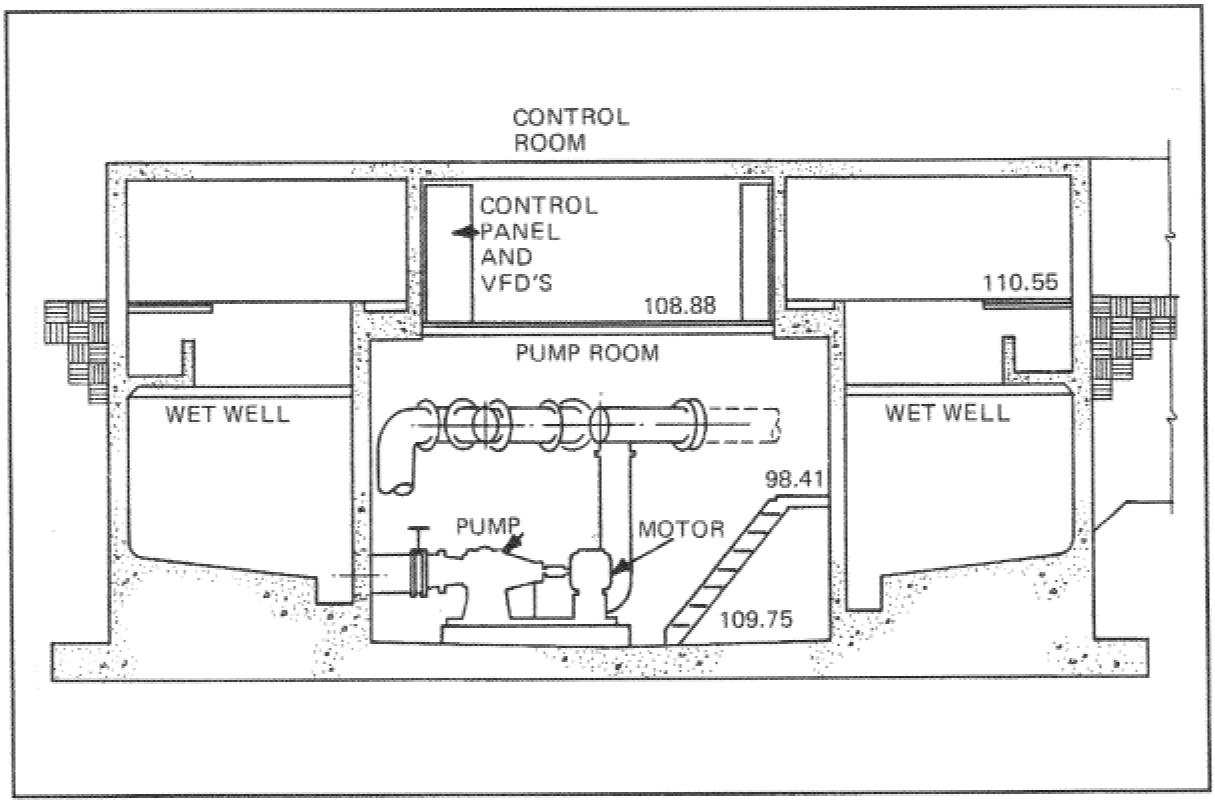

Figure 2. Station Cross Section

MITIGATION CONCEPT SUMMARY - FLOODING

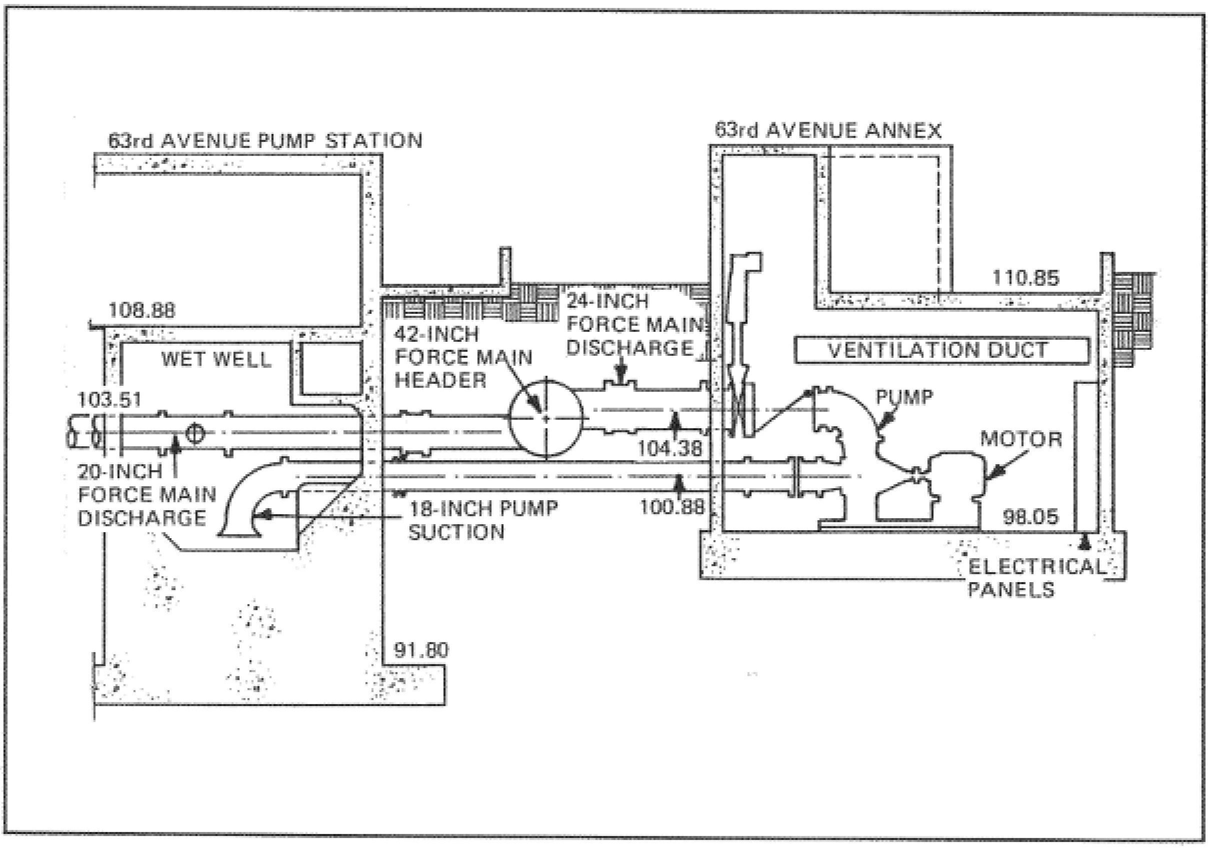

Figure 3. Station and Annex Cross Section

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Three x 200HP dry pit submersible pumps, including fittings, electrical connections, and piping as necessary
- Two x 10 HP submersible sump pumps, including fittings, electrical connections, and piping as necessary
- One watertight door

MITIGATION CONCEPT SUMMARY - FLOODING

Table 1. Concept-level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	63rd Avenue Pump Station			**Date:**	9/122017
Location:				**Estimator:**	Richard Greer
Description:	Flooding			**Idea Code:**	F-6a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Relace electrical pump to 200 HP (Remove and Replace)	3	EA	$ 75,000	$ 225,000
2	Upsize submersible sump pumps to 25 HP (Remove and Replace)	2	EA	$ 21,000	$ 42,000
3	Install Watertight doors, frames and hardware	1	EA	$ 10,000	$ 10,000
4	Mobilization / Demobilization (10%)	10	%	$ 27,700	$ 27,700
				Subtotal Construction Costs	***$ 300,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 120,000
				Construction Change Order Allowance	$ 42,000
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 462,000***
				Street Use Permit	$ -
				Construction Sales Tax	$ 46,662
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 508,662***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 924
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 510,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 315,280
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 5,370
				Right-of-Way	$ 6,000
				Misc. Service & Materials	$ 3,696
				Non-WTD Support	$ 3,927
				WTD Staff Labor	$ 105,634
				Subtotal Non-Construction Costs	***$ 439,908***
				Project Contingency	$ 286,759
				Initiatives	$ 6,370
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 733,000***
				TOTAL PROJECT COST	***$ 1,243,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

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MITIGATION CONCEPT SUMMARY - FLOODING

F-7 Bellevue Pump Station flood protection upgrade

Issue No.	Issue Title	Risk Rating
F-7	Bellevue Pump Station Flooding Risk	M
Idea Code	**Concept Title**	**Dev. Team**
F-7a	Bellevue Pump Station flood protection upgrade	3

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☐ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☐ Public Health
Bellevue Pump Station	☐ SCADA	☐ Consequent Damages
	☒ Natural Hazards	☒ Environment
	- Flooding	Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☒ < $1M		☐ 0 to 3 months
	☐ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

This facility lies within 250 feet of the 100-year floodplain, has a low critical elevation as compared to base flood elevations, and has a substantial amount of equipment below grade. If the pump station failed due to flooding, a service disruption would occur potentially causing an overflow into the Meydenbauer Creek or possibly causing sewer back-ups into customers' properties. These factors make the pump station susceptible to riverine flooding. The use of a 250-foot buffer is based on professional judgment to capture uncertainty about the effects of climate change on base flood elevations.

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program there exists the potential that below grade components of this facility (motor, pumps) could become inundated in a substantial flood event and cause failure of the pump station.

MITIGATION CONCEPT SUMMARY - FLOODING

The likely system downtime is expected to be:

- Up to 1 month for an interim, work-around fix
- 3 – 12 months for a permanent fix (assuming emergency fast-tracking of the project)
- The waterbody likely to be affected by failure of this system is Lake Washington.

Description of Mitigation Concept:

No one has identified if water will enter the facility, but as an exercise to build resiliency at the site, the following mitigation concepts are recommended:

- Install two watertight hinged floodgates to prevent flood water from entering the facility through the roll-up doors. Similarly, install two watertight flood gates to access doors, see Figure 1.
- Upgrade existing submersible sump pumps to at least two 10 HP pumps
- It is recommended that physical testing of the "high alarm" of the sump pumps occur on a regularly scheduled basis. If building is equipped with louver vents, compare their elevation with predicted water surface elevation of flooding event and adjust accordingly during preliminary design.

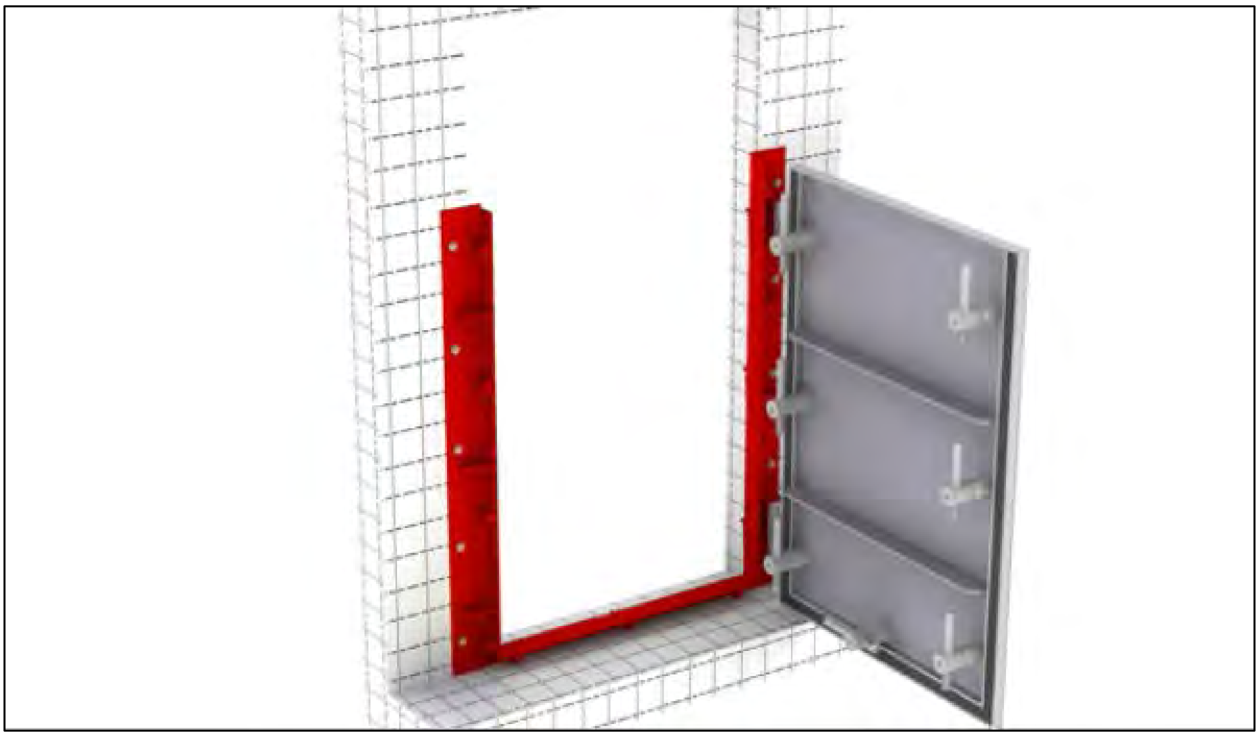

Figure 1. Example of Watertight Gate by Presray.

MITIGATION CONCEPT SUMMARY - FLOODING

Advantages:

- Wastewater Operations are improved by providing additional riverine flood protection mitigation and by improving upon existing pumps.
- Maintainability is improved slightly by enhancing the building protection against moisture through the use of watertight doors as well as by providing updated mechanical.

Disadvantages:

- Maintainability is degraded slightly as the operator will need to update operating procedures.

Main Benefit:

The main benefit of this mitigation concept is to address the riverine flooding risk at this facility location.

Discussion of Schedule:

This mitigation concept will require a 3-month installation window, but is not directly affected by seasonal work windows and can be accomplished year-round.

Discussion of Risk:

This mitigation concept will address riverine flood related concerns up to a flood event of a 1 percent annual probability. It is anticipated that a riverine flood event will have a short-term collateral impact on other WTD assets (upstream sanitary sewer overflows), however, this exposure should be mitigated by temporary work-around solutions once in place. Additionally, there may be punitive environmental fines assessed by ecology regarding the overflows.

MITIGATION CONCEPT SUMMARY - FLOODING

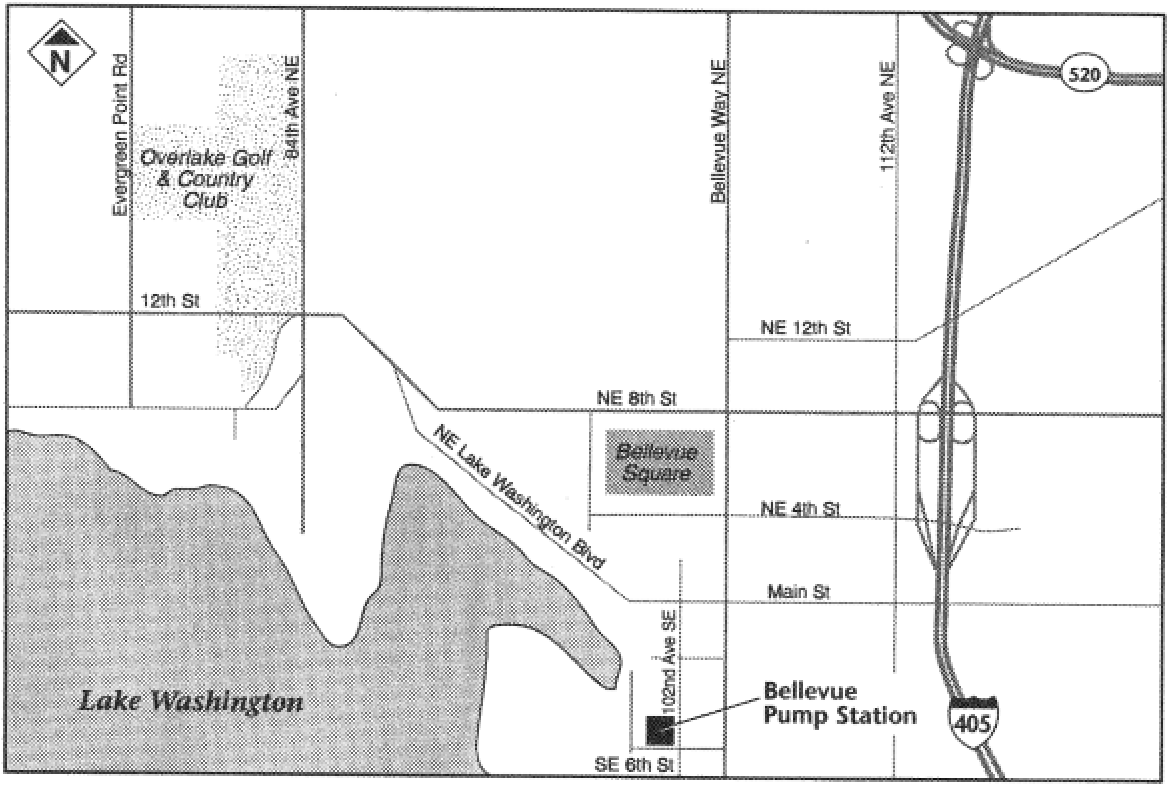

Figure 2. Location Map

MITIGATION CONCEPT SUMMARY - FLOODING

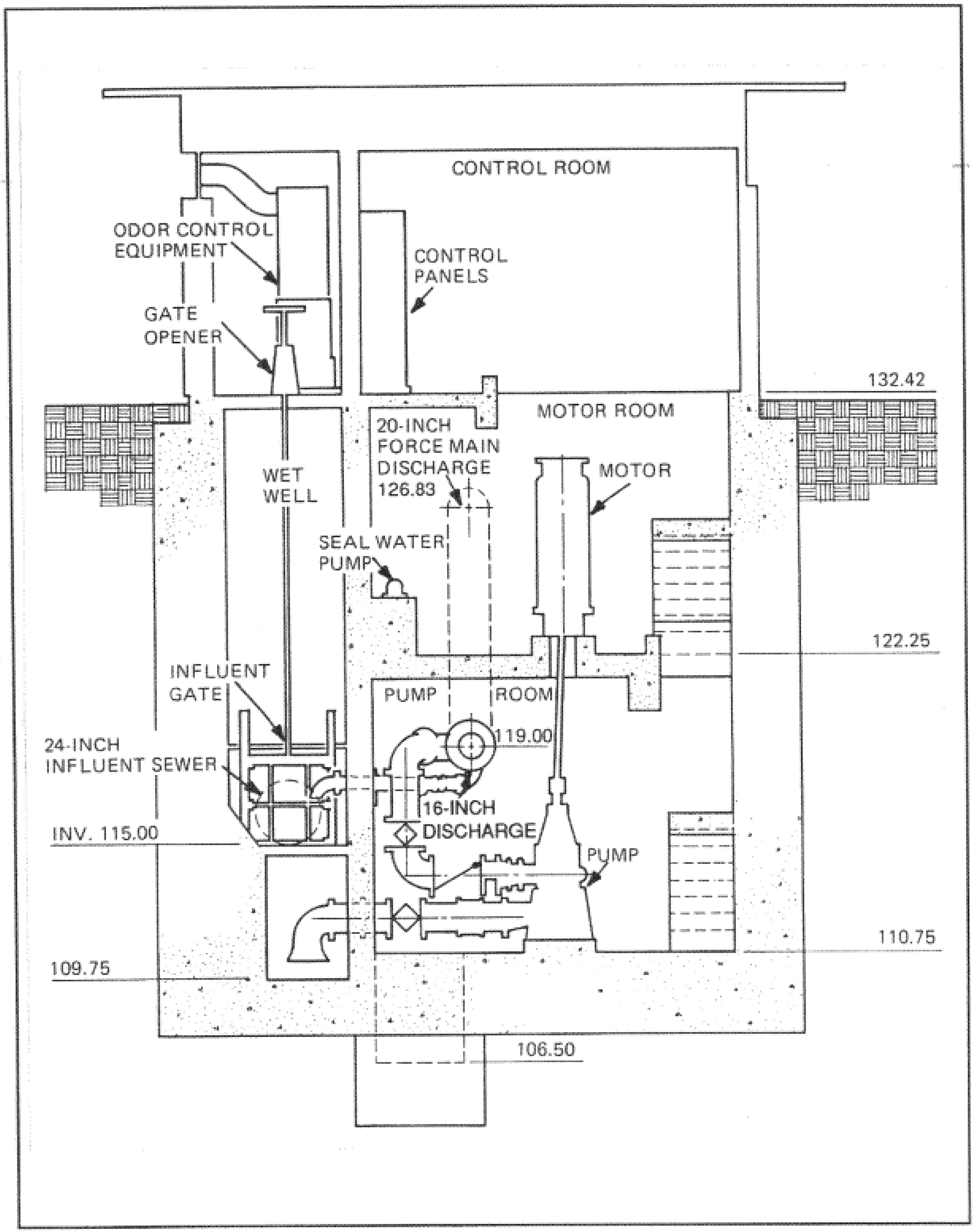

Figure 3. Station Cross Section

MITIGATION CONCEPT SUMMARY - FLOODING

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Two watertight flood gates sized to match dimensions of roll-up doors and two watertight flood gates sized to match access doors
- Two 10-HP submersible sump pumps, including electrical connections, fittings, and piping as necessary

MITIGATION CONCEPT SUMMARY - FLOODING

Table 1. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Bellevue Pump Station			**Date:**	9/12/2017
Location:				**Estimator:**	Richard Greer
Description:	Flooding			**Idea Code:**	F-7a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Upsize submersible sump pumps to 10 HP Remove & Replace	2	EA	$ 15,000	$ 30,000
2	Install Waterproof doors, frames and hardware	2	EA	$ 10,000	$ 20,000
3	Install Waterproof roll updoors, frames and hardware	2	EA	$ 15,000	$ 30,000
4	Mobilization / Demobilization (10%)	10	%	$ 8,000	$ 8,000
				Subtotal Construction Costs	***$ 90,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 36,000
				Construction Change Order Allowance	$ 12,600
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 138,600***
				Street Use Permit	$ -
				Construction Sales Tax	$ 13,999
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 152,599***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 277
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 153,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 113,513
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 1,611
				Right-of-Way	$ 1,800
				Misc. Service & Materials	$ 1,109
				Non-WTD Support	$ 1,178
				WTD Staff Labor	$ 39,354
				Subtotal Non-Construction Costs	***$ 158,564***
				Project Contingency	$ 94,005
				Initiatives	$ 1,911
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 254,000***
				TOTAL PROJECT COST	***$ 407,000***

Notes:
1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.
2 The costs represented in this document are Opinions of Probable Cost provided by the Engineering Team. The accuracy of the associated cost estimate is dependent upon the various underlying assumptions, inclusions, available information, and exclusions described herein.

Actual project costs may differ and can be significantly affected by factors such as changes in the external environment, the manner in which the project is executed and controlled, material and labor cost increases, competitive bidding methods, market conditions, and other factors that may impact the estimate basis or otherwise affect the project. Estimate accuracy ranges are only assessments based upon the cost estimating methods and data employed in preparing the estimate and are not a guarantee of actual project costs.

MITIGATION CONCEPT SUMMARY - FLOODING

F-8 Woodinville Pump Station flood protection upgrade

Issue No.	Issue Title	Risk Rating
F-8	Woodinville Pump Station Flooding Risk	MH
Idea Code	**Concept Title**	**Dev. Team**
F-8a	Woodinville Pump Station flood protection upgrade	3

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☐ System Wide	☐ Structural	☐ Life Safety
☒ Site Specific (list site below)	☐ MEP	☒ Public Health
Woodinville Pump Station	☐ SCADA	☐ Consequent Damages
	☒ Natural Hazards	☒ Environment
	- Flooding	Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

This facility lies within 250 feet of the 100-year flood plain, has a low critical elevation as compared to base flood elevations, and has a substantial amount of equipment below grade. The below grade equipment is susceptible to failure (e.g. pump motors could burn out) if exposed to significant amounts of water. These factors make it susceptible to failure if riverine flooding were to occur.

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program there exists the potential that below grade components of this facility (pumps, motors) could become inundated in a substantial flood event and cause failure of the pump station. Failure of the pump station would result in degraded service.

MITIGATION CONCEPT SUMMARY - FLOODING

The likely system downtime is expected to be:

- Up to 1 month for an interim, work-around fix (i.e. using temporary pumps)
- 6 – 9 months for a permanent fix to refurbish or replace electric motors (assuming emergency fast-tracking of the project)
- The waterbodies likely to be affected by failure of this system are Sammamish.

Description of Mitigation Concept:

Replace existing three electric pumps with dry pit submersible pumps (3 X 60 HP). Confirm that there is sufficient room to install dry pit submersible pumps and associated equipment.

Upgrade existing submersible sump pumps to at least two 25 HP pumps

Waterproof building – install one watertight roll-up door and one watertight access door. Note that these are only intended to protect the facility up to a few feet and are not intended to be submarine type doors. Watertight doors in addition to berm structure would increase facility resiliency and allow additional time for operator to inflate baffle gate.

Check for louvers around building exterior that may allow water to enter the structure. These may require mitigation if present.

Construct a 300-foot long berm/flood wall to separate high water from the river with an inflatable baffle gate

Install type 2 catch basin and grade site to drain to catch basin. This would allow use of a portable pump to water captured between berm and facility that cannot drain naturally.

It is recommended that physical testing of the “high alarm” of the sump pump occur on a regularly scheduled basis.

Advantages:

- Wastewater operations are improved by providing additional riverine flood mitigation and by improving upon existing pumps.
- Maintainability is improved slightly by enhancing the building protection against moisture through the use of watertight doors as well as by providing updated mechanical equipment.

Disadvantages:

- The addition of a berm/flood wall and basin near the facility may have a negative visual impact.
- Maintainability is degraded slightly with the addition of the berm/flood wall and basin. Additionally, the operator will need to update operating procedures and become familiar with the use of an inflatable baffle gate.

Main Benefit:

The main benefit of this mitigation concept is to address the riverine flooding risk at this facility location.

MITIGATION CONCEPT SUMMARY - FLOODING

Discussion of Schedule:

This mitigation concept will require a three-month installation window, but it is not directly affected by seasonal work windows and can be accomplished year-round.

Discussion of Risk:

This mitigation concept will address riverine flood related concerns up to a flood event of a 1 percent annual probability. It is anticipated that a riverine flood event will have a short-term collateral impact on other WTD assets (upstream sanitary sewer overflows), however, this exposure should be mitigated by temporary work-around solutions once in place. Additionally, there may be punitive environmental fines assessed by ecology regarding the overflows.

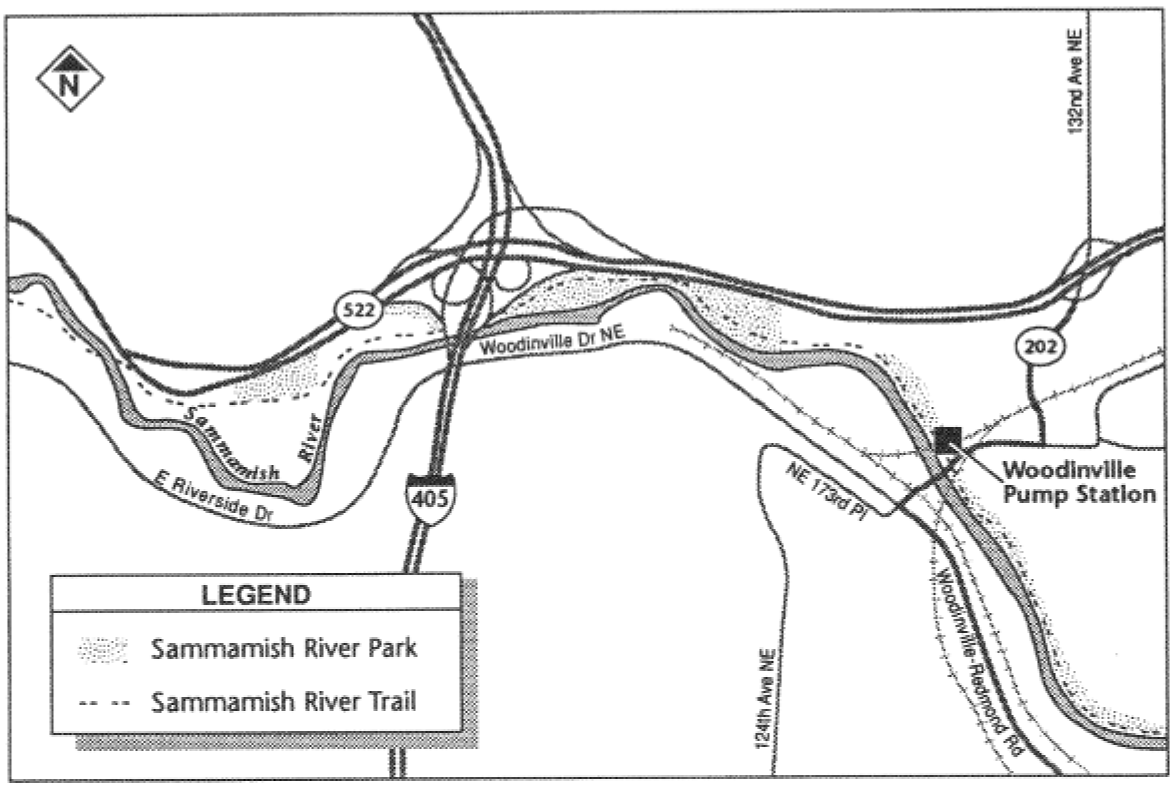

Figure 1. Location Map

MITIGATION CONCEPT SUMMARY - FLOODING

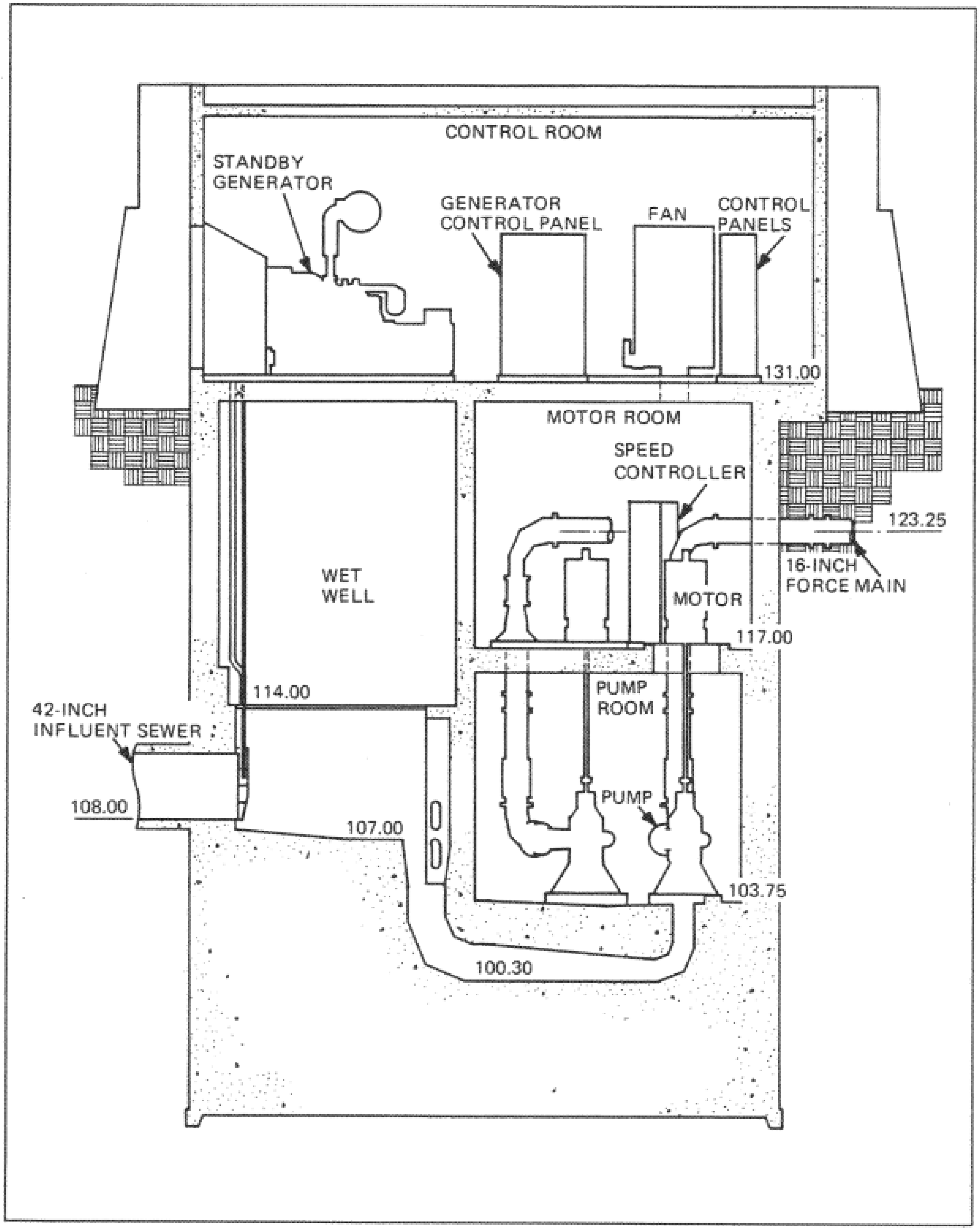

Figure 2. Station Cross Section

MITIGATION CONCEPT SUMMARY - FLOODING

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Three dry pit submersible pumps (3 X 60 HP), including fittings, electrical connections, and piping as necessary
- Two 10 HP submersible sump pumps, including fittings, electrical connections, and piping as necessary
- One watertight roll-up door and one watertight access door
- 4-foot tall, 300-foot-long berm/flood wall
- One inflatable baffle gate to be store in the station
- Type 2 catch basin and grade site to drain to catch basin for use with a portable pump, including seeding and restoration

King County

HDR TEAM

MITIGATION CONCEPT SUMMARY - FLOODING

Table 1. Concept-level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Woodinville Pump Station			**Date:**	9/12/2017
Location:				**Estimator:**	Richard Greer
Description:	Flooding			**Idea Code:**	F-8a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Relace electrical pump to 60 HP (Remove & Replace)	3	EA	$ 30,000	$ 90,000
2	Upsize submersible sump pumps to 10 HP (Remove & Replace)	2	EA	$ 18,000	$ 36,000
3	4' Berm	300	LF	$ 250	$ 75,000
4	Baffle Flood gate	20	LF	$ 500	$ 10,000
5	Install Waterproof doors, frames and hardware	1	EA	$ 10,000	$ 10,000
6	Install Waterproof roll updoors, frames and hardware	1	EA	$ 15,000	$ 15,000
7	Install type 2 catch basin and contour grade	1	EA	$ 7,500	$ 7,500
8	Portable Pump and hoses	1	EA	$ 1,500	$ 1,500
9	Mobilization / Demobilization (10%)	10	%	$ 24,500	$ 24,500
				Subtotal Construction Costs	***$ 270,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 108,000
				Construction Change Order Allowance	$ 37,800
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 415,800***
				Street Use Permit	$ -
				Construction Sales Tax	$ 41,996
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 457,796***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 832
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 459,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 288,298
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 4,833
				Right-of-Way	$ 5,400
				Misc. Service & Materials	$ 3,326
				Non-WTD Support	$ 3,534
				WTD Staff Labor	$ 96,828
				Subtotal Non-Construction Costs	***$ 402,220***
				Project Contingency	$ 259,974
				Initiatives	$ 5,733
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 668,000***
				TOTAL PROJECT COST	***$ 1,127,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

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MITIGATION CONCEPT SUMMARY - FLOODING

FP-1 Conduct Programmatic Flooding Evaluations – STP and BWTP

Issue No.	Issue Title	Risk Rating
FP-1	Programmatic Wastewater Treatment Plants Facility Flooding Assessment	H
Idea Code	**Concept Title**	**Dev. Team**
FP-1	Conduct Programmatic Flooding Evaluations for WTD Wastewater Treatment Plant Facilities.	1

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☒ System Wide	☐ Structural	☒ Life Safety
☐ Site Specific (list site below)	☐ MEP	☐ Public Health
	☐ SCADA	☐ Consequent Damages
	☒ Natural Hazards	☒ Environment
		Other: ☒ Flow Volume
		☒ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

Wet Weather Treatment Plant (WWTP) galleries/utilidors can flood catastrophically due to large influent flows coupled with pump failures and control system failure. They can also flood due to mechanical failure if pipelines in the galleries fail and discharge into the galleries. There is the potential of draining the contents of tanks into the gallery system because of a mechanical failure, pipe breaks, or tank wall damage. In some cases, the plants are susceptible to riverine flooding due to proximity to known floodplains.

WTD has conducted comprehensive facility assessments at the West Point Plant in the wake of the failure in February of 2017. The results of those assessments as well as additional comprehensive assessments should take place at other WTD treatment plants including South Plant (SPTP), Brightwater Treatment Plant (BTP), Vashon Treatment Plant (VTP), and Carnation Treatment Plant (CTP).

Risk if not Addressed:

MITIGATION CONCEPT SUMMARY - FLOODING

If this issue is not addressed by the Resiliency and Recovery Program, there exists the potential that below grade components of a given facility (electrical equipment, motors, and pumps) could become inundated by flood waters (due to riverine flooding or because of mechanical failure) and cause failure of a WWTP. Failure of a facility would result in degraded service.

Description of Mitigation Concept:

The mitigation concept would involve performing studies to evaluate potential flooding issues at all WWTP facilities. Studies would review and document potential flooding issues and mitigation strategies including:

- Recommendations made in the July 18, 2017 report "West Point treatment Plant Independent Assessment" by AECOM.
- Critical facility elevations (i.e. elevations at which external water could enter the facility during a riverine flooding event)
- Presence and condition of dikes, flood walls, inflatable baffle gates or other external flood prevention measures
- Presence and condition of existing flood mitigation equipment (sump pumps, inflatable baffle gates, water tight doors, etc.)
- Facility pump type (wet well/dry well or submersible)
- Presence below grade facilities
- Presence and amount of below grade equipment including but not limited to pumps, motors, electrical panels
- Flexibility for potential mitigation strategies or retrofit including, but not limited to:
  - Ability to move equipment above grade
  - Ability to construct additional on-site structures
  - Ability to replace pump motors
  - Ability to install large drainage pumps to drain galleries
- Ability of site to be accessed in the event of flooding
- Life safety concerns
- Ideal redundancy of flood protection measures (i.e. measures internal and external to a facility)
- Additional investigation may indicate that other mitigation concepts are required to address the issues identified across WTD facilities

Advantages:

- Avoid disruption of wastewater treatment services
- Increases system reliability and robustness
- Maintains operational capacity during and following a flooding event

- Mitigates life safety hazards
- Mitigates collateral damage

Disadvantages:

Retrofits and repairs will:

- Require shutdown of operational activities for limited periods of time depending on the nature of the repairs
- Require working around existing equipment and ongoing operations
- Requires extensive communication and coordination with operations staff to implement improvements at each facility and across WTD's system

Main Benefit:

The main benefit is that the studies and resulting repairs will allow continued operations during and following a flooding (mechanical or riverine) event. This will also minimize post-event damage to facilities and limit associated recovery costs.

Discussion of Schedule:

This mitigation concept will require 1 to 3 years for completion of the evaluations/studies. Flood mitigation strategies or retro-fits will follow evaluations based on facility priority and will be funded separately.

Discussion of Risk:

Unexpected extended downtime may be encountered during retrofitting activities. Currently, the extent of the retrofitting required at each facility is unknown.

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Facilities were divided between small and medium/large sizes.
- Cost estimate to prepare a flooding hazard evaluation study for medium/large facility was estimated at $24,000 per facility.
- The number of medium/large facilities was determined from existing KC information and included the following facilities:
    - Small WWTPs: 2 facilities
    - BWTP Facilities: 20 facilities
    - SPTP Facilities: 25 facilities
- The WPTP was not included in the facilities due to the comprehensive assessments recently completed.

MITIGATION CONCEPT SUMMARY - FLOODING

Table 1. Concept – Level Estimate

Estimate - AACEI Class 5					
Concept Title:	Programmatic Flood Risk Assessment - Small WWTP's, SPTP's, and BWTP			**Date:**	11/20/2017
Location:	Multiple Locations			**Estimator:**	Eric Benton, CPE
Description:	Perform Flooding Risk Evaluations for SPTP, BWTP, and Small WWTP's			**Idea Code:**	F-12
DIRECT: PROGRAMMATIC ASSESSMENT COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	WWTP, small, Site Evaluation and Report	2	EA	$ 24,000	$ 48,000
2	BWTP, medium/large, Site Evaluation and Report	20	EA	$ 24,000	$ 480,000
3	SPTP Facility, medium/large, Site Evaluation and Report	25	EA	$ 24,000	$ 600,000
				Subtotal Assessment Costs	***$ 1,128,000***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				Misc. Capital Costs	$ 2,256
				TOTAL ASSESSMENT COSTS	***$ 1,130,256***
INDIRECT: WTD ASSESSMENT COSTS					
				Design and Construction Consulting	n/a
				Other Consulting Services	n/a
				Permitting & Other Agency Support	n/a
				Right-of-Way	n/a
				Misc. Service & Materials	n/a
				Non-WTD Support	n/a
				WTD Staff Labor	$ 210,986
				Subtotal WTD Assessment Costs	***$ 210,986***
				Project Contingency	$ 411,002
				Initiatives	n/a
				TOTAL INDIRECT WTD ASSESSMENT COSTS	***$ 621,988***
				TOTAL PROJECT COST	***$ 1,752,000***

Notes:

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MITIGATION CONCEPT SUMMARY - FLOODING

FP-2 Conduct Programmatic Flooding Evaluations – Off-site Facilities

Issue No.	Issue Title	Risk Rating
FP-2	**Programmatic Off-site Facilities Flooding Assessment**	**H**
Idea Code	**Concept Title**	**Dev. Team**
FP-2	**Conduct Programmatic Flooding Evaluations for CSOs and Pump Stations**	**1**

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☒ System Wide	☐ Structural	☐ Life Safety
☐ Site Specific (list site below)	☐ MEP	☐ Public Health
	☐ SCADA	☐ Consequent Damages
	☒ Natural Hazards	☒ Environment
		Other: ☒ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

Pump stations and Combined Sewer Overflows (CSOs) can flood if flood waters rise above the facility flood design level. Water can come in through the doors, or backup through drain systems or ventilation systems if they were improperly designed. If pipelines inside the facility break they can discharge sewage into the drywell (such as during an earthquake) also posing a flooding risk. These issues can be classified as riverine flooding and flooding due to mechanical failure. To date, that has not been a comprehensive assessment of WTD pump stations and CSOs to evaluate flooding risks.

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program there exists the potential that below grade components of a given facility (electrical equipment, motors, and pumps) could become inundated by flood waters (due to riverine flooding or because of mechanical failure) and cause failure of a pump station or CSOs. Failure of a facility would result in degraded service.

MITIGATION CONCEPT SUMMARY - FLOODING

Description of Mitigation Concept:

The mitigation concept would involve performing studies to evaluate potential flooding issues at all offsite PS and CSOs facilities. Studies would review and document potential flooding issues and mitigation strategies including:

- Critical facility elevations (i.e. elevations at which external water could enter the facility during a riverine flooding event)
- Presence and condition of dikes, flood walls, inflatable baffle gates or other external flood prevention measures
- Presence and condition of existing flood mitigation equipment (sump pumps, inflatable baffle gates, water tight doors, etc.)
- Facility pump type (wet well/dry well or submersible)
- Presence below grade facilities
- Presence and amount of below grade equipment including but not limited to pumps, motors, electrical panels
- Flexibility for potential mitigation strategies or retrofit including, but not limited to:
    - Ability to move equipment above grade
    - Ability to construct additional on-site structures
    - Ability to replace pump motors (i.e. is a large HP submersible pump motor available)
- Ability of site to be accessed in the event of flooding
- Life safety concerns
- Ideal redundancy of flood protection measures (i.e. measures internal and external to a facility)
- Additional investigation may indicate that other mitigation concepts are required to address the issues identified across WTD facilities

Advantages:

- Avoid disruption of wastewater treatment services
- Increases system reliability and robustness
- Maintains operational capacity during and following a flooding event
- Mitigates life safety hazards
- Mitigates collateral damage

Disadvantages:

Retrofits and repairs will:

MITIGATION CONCEPT SUMMARY - FLOODING

- Require shutdown of operational activities for limited periods of time depending on the nature of the repairs
- Require working around existing equipment and ongoing operations
- Requires extensive communication and coordination with operations staff to implement improvements at each facility and across WTD's system

Main Benefit:

The main benefit is that the studies and resulting repairs will allow continued operations during and following a flooding (mechanical or riverine) event. This will also minimize post-event damage to facilities and limit associated recovery costs.

Life safety concerns are assumed to be minimal at pump station and WWTFs. These studies significantly improved because equipment and piping will be properly anchored and secured.

Discussion of Schedule:

This mitigation concept will require 1 to 3 years for completion of the evaluations/studies. Flood mitigation strategies or retro-fits will follow evaluations based on facility priority and will be funded separately.

Discussion of Risk:

Unexpected extended downtime may be encountered during retrofitting activities. Currently, the extent of the retrofitting required at each facility is unknown.

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Facilities were divided between small and medium/large sizes.
- Cost estimate to prepare a flooding hazard evaluation study for small facility was estimated at $12,000 per facility.
- Cost estimate to prepare a MEP seismic evaluation study for medium/large facility was estimated at $24,000 per facility.
- The number of small facilities was determined from existing KC information and included the following facilities:
  - Pump stations (less than 20 MGD): 28 facilities
- The number of medium/large facilities was determined from existing KC information and included the following facilities:
  - Pump stations (greater than 20MGD): 9 facilities
  - CSO Facilities: 4 facilities

MITIGATION CONCEPT SUMMARY - FLOODING

Table 1. Concept – Level Estimate

Estimate - AACEI Class 5					
Concept Title:	Programmatic Flood Risk Assessments - Offsite Facilities			**Date:**	11/20/2017
Location:	Multiple Locations			**Estimator:**	Eric Benton, CPE
Description:	Perform Flooding Risk Evaluations for CSO Facilities, and Pump Stations			**Idea Code:**	F-11
DIRECT: PROGRAMMATIC ASSESSMENT COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Pump Stations, small, Site Evaluation and Report	28	EA	$ 12,000	$ 336,000
2	Pump Stations, medium/large, Site Evaluation and Report	9	EA	$ 24,000	$ 216,000
				Subtotal Assessment Costs	***$ 552,000***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				Misc. Capital Costs	$ 1,104
				TOTAL ASSESSMENT COSTS	***$ 553,104***
INDIRECT: WTD ASSESSMENT COSTS					
				Design and Construction Consulting	n/a
				Other Consulting Services	n/a
				Permitting & Other Agency Support	n/a
				Right-of-Way	n/a
				Misc. Service & Materials	n/a
				Non-WTD Support	n/a
				WTD Staff Labor	$ 116,090
				Subtotal WTD Assessment Costs	***$ 116,090***
				Project Contingency	$ 204,981
				Initiatives	n/a
				TOTAL INDIRECT WTD ASSESSMENT COSTS	***$ 321,070***
				TOTAL PROJECT COST	***$ 874,000***

Notes:

1 Given the highly conceptual nature of the mitigation concepts, the estimating team used an AFI of 40%.

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D-5: Extreme Weather

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MITIGATION CONCEPT SUMMARY –EXTREME WEATHER

Issue No.	Concept Title
XP-1	Tree Trimming/Removal Assessment Programmatic Project

MITIGATION CONCEPT SUMMARY –EXTREME WEATHER

XP-1 Tree Trimming/Removal Assessment Programmatic Project

Issue No.	Issue Title	Risk Rating
XP-1	Extreme Weather Risk - Trees	M
Idea Code	**Concept Title**	**Dev. Team**
XP-1a	Tree Trimming/Removal Assessment Programmatic Project	3

Mitigation Type	Discipline (check as many as apply)	Criticality Concern (check as many as apply)
☒ System Wide	☒ Structural	☐ Life Safety
☐ Site Specific (list site below)	☒ MEP	☐ Public Health
	☐ SCADA	☐ Consequent Damages
	☒ Natural Hazards	☐ Environment
	- Extreme Weather	Other: ☐ Flow Volume
		☐ Equity and Social Justice
		☒ System Downtime
		☐ (Describe here)

Estimated Concept-Level Cost:		Project Duration:	
	☐ < $1M		☐ 0 to 3 months
	☒ $1M to $5M		☐ 3 to 12 months
	☐ $5M to $10M		☒ 1 to 3 years
	☐ > $10M		☐ 3 to 5 years
			☐ > 5 years

Description of Existing Issue:

The main issue affecting King County Waste Treatment Division (WTD) facilities regarding extreme weather hazards is the impact of downed trees on maintaining facility operations as well as in maintaining employee access. Many WTD facilities are in close proximity to forested parks or stands of tall trees, which could potentially impact WTD facility operation in the event of high wind gusts or extreme weather effects. Falling trees or airborne limbs/debris could affect facility operations (structures, systems, and/or power) while downed trees or power lines affected by falling limbs/trees could impede facility access for employees, resulting in operational disruption.

Risk if not Addressed:

If this issue is not addressed by the Resiliency and Recovery Program, there exists the potential that an extreme weather-related event, such as high winds (in possible combination with snow and ice) may cause trees or limbs to fall, which may in turn affect facility operation or impede employee access. Significant damage or disruption in power or access may cause operational failure of the facility and negatively impact the local area and system.

MITIGATION CONCEPT SUMMARY –EXTREME WEATHER

The likely system downtime is expected to be:

- Up to 1 month for an interim, work-around fix
- 3 – 6 months for a permanent fix (assuming emergency fast-tracking of the project)

Description of Mitigation Concept:

The mitigation concept would pursue a contract with an arborist to perform a programmatic assessment of the trees located near all WTD pump stations, regulator gates, wet weather treatment plants, and wastewater treatment plant facilities. Roughly 75 facilities would need to be assessed for this programmatic mitigation concept, with the following sites identified as "high risk" during analysis taking priority:

1. West Point Treatment Plant
2. South Treatment Plant
3. Alki CSO Plant
4. Matthews Park Pump Station
5. Carkeek CSO Plant
6. Boeing Chiller
7. Brightwater Treatment Plant

The assessment would likely result in the pursuit of additional contracts to perform tree thinning and removal as determined by the arborist's findings. This assessment may need to be performed on a periodic basis in the future. For this reason, this concept is presented as a multi-phased mitigation.

Advantages:

- Wastewater Operations are improved by reducing the potential for operational outages.
- Maintainability is improved by removing problematic trees and debris from facility grounds.

Disadvantages:

- Long-term impacts are reduced by the potential removal of trees or tree limbs that may have a net negative visual effect.

Main Benefit:

The main benefit of this mitigation concept is to address potential damage to structures and possible loss of access or power to facilities caused by trees.

Discussion of Schedule:

This mitigation concept will require a variable performance window to conduct the assessment in addition to further contracts to conduct tree removal/thinning.

Discussion of Risk:

It is not anticipated that this mitigation concept would increase risk exposure to WTD. However, local agencies may require some amount of tree removal mitigation.

MITIGATION CONCEPT SUMMARY –EXTREME WEATHER

Assumptions and Calculations:

The mitigation concept-level cost estimate includes the following assumptions:

- Phase 1: Assessment performed by licensed professional arborist of 75 facilities, assuming 8 hours per facility
- Phase 2: Tree thinning and removal at 75 facilities performed by licensed professional arborist
  - Estimate assumes costs for equipment, four-man crew, and disposal of cuttings
- Phase I and Phase II together have a concept-level cost total of $1,052,000.

MITIGATION CONCEPT SUMMARY –EXTREME WEATHER

Table 1. Concept-Level Cost Estimate

Estimate - AACEI Class 5					
Concept Title:	Extreme Weather Assessment, thinning and removal of trees			**Date:**	9/13/2017
Location:				**Estimator:**	Richard Greer
Description:				**Idea Code:**	X-1a
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
	PHASE 1 Assessment				$ -
1	Assessment 75 Facilities (8 Hours per facility)	600	Hours	$ 150	$ 90,000
2	Reports, Maps, etc. for assessment (4 Hours per facility)	300	Hours	$ 150	$ 45,000
3	Overhead and Profit	25	%	$ 33,750	$ 33,750
	TOTAL Assessment				**$ 168,750**
	PHASE 2 Thinning and Removal				$ -
4	Tree thinning/removal 75 facilities	1	LS	$ 225,000	$ 225,000
5	Overhead and Profit	25	%	$ 56,250	$ 56,250
	TOTAL Thinning and Removal				**$ 281,250**
				Subtotal Construction Costs	***$ 450,000***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Allowance for Indeterminates (Design Allowance)	$ 112,500
				Construction Change Order Allowance	$ 56,250
				Material Pricing Uncertainty Allowance	$ 13,500
				Subtotal Primary Construction Amount	***$ 632,250***
				Street Use Permit	$ -
				Construction Sales Tax	$ 62,494
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 694,744***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 1,265
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 696,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 331,434
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 4,286
				Right-of-Way	$ 9,000
				Misc. Service & Materials	$ 11,381
				Non-WTD Support	$ 5,374
				WTD Staff Labor	$ 130,768
				Subtotal Non-Construction Costs	***$ 492,243***
				Project Contingency	$ 359,085
				Initiatives	$ 8,700
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 860,000***
				TOTAL PROJECT COST	***$ 1,556,000***

Notes:

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Appendix D. King County Wastewater Treatment Division Offsite Facilities Criticality Ranking Criteria

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DRAFT
Criticality Ranking Criteria
Off-site Facilities

The following criteria were developed to assist in assigning a criticality ranking to off-site facilities.

- Peak Flow Capacity – The peak capacity of a pump station (all pumps on) or of a regulator station's outfall. Generally, the criticality of facilities increases as the peak capacity increases.
- 1-Year Event Storage Time – For facilities with offline or available upstream storage, the time available to store the 1-year storm event. Generally, the criticality of facilities increases as storage time decreases.
- Overflow Location – Distinguishes where an overflow would occur if a facility failed. For facilities without a direct outfall pipe, the overflows may occur at an upstream location, which should be considered the overflow location. Generally, the criticality of facilities is higher if overflow would result in sewer backups and/or property damage than if overflow is to deep marine outfall.
- Public Impact/Risk of Contact – The risk of human contact with sewage if an overflow occurs from a facility. Generally, the criticality of facilities is higher if overflow would result in sewer backups where the risk of human contact is higher than if overflow is to deep marine outfall.
- Receives Flow from Another Facility – A facility that receive flow from an upstream facility must be functional before it can receive flow from that upstream facility. Therefore, facilities that receive flow from other facilities are more critical than the associated upstream facilities.
- Facility Flexibility – The able to divert flow around or away from a facility. Generally, the criticality of facilities increases as flexibility decreases.

The ranking associated with each criterion follows. The numerical rankings increase with increasing criticality. The facility ranking is the sum of all 6 criteria rankings. The calculated facility ranking is to be used as a guide to assess the ranking of each facility; however, other factors may be considered to assign a higher or lower criticality to any one facility.

Peak Flow Capacity:

Flow (mgd)	Ranking
0 to 3	1
>3 to 6	3
>6 to 10	5
>10 to 20	7
>20 to 40	9
>40 to 80	11
>80	13

1-Year Event Storage Time:

Storage Time	Ranking
>8 hours	1
>3 hours to 8 hours	3
>1 hour to 3 hours	5
>20 minutes to 1 hour	7
0 to 20 minutes	9

Overflow Location:

Location	Ranking
Marine Outfall	1
Lake	2
River/Stream	3
Overland	4
Sewer Backups/Property Damage	5

Public Impact/Risk of Contact:

Consequence	Ranking
Low	1
Medium	2
High	3

Receives Flow from Another Facility (relies on another facility for flow):

Receives Flow from Another Facility	Ranking
No	0
Yes	1

Facility Flexibility (able to divert flow around or away from facility):

Flexible	Ranking
No	2
Yes	0

Criticality Ranking of Offsite Facilities
Division

Facilty Name	Section	Facility Type	Facility Number	Peak Capacity (MGD)	Rankings						Total	Comments
					Peak Capacity	Storage Time	Overflow Location	Public Impact	Serves other facilities	Flexibility	Criticality Ranking	
Matthews Park	WEST	PS	786		13	5	2	3	1	2	26	
Murray Ave	WEST	PS	484	17.2	11	9	1	1	1	2	25	
Duwamish	WEST	PS	771		13	4	3	2	1	2	25	
Interurban	EAST	PS	775	28.9	9	5	3	3	1	2	23	
York	EAST	PS	309	68	11	5	4	2	1	0	23	
Interbay PS	WEST	PS	780	133	13	5	1	1	1	2	23	
30th Avenue	WEST	PS	784	6.05	7	9	2	2	1	2	23	
63rd Avenue	WEST	PS	483	16.9	11	7	1	1	1	2	23	
East Marginal Way	WEST	PS	773	23.05	9	5	3	2	1	2	22	
Sweylocken	EAST	PS	332	31	9	5	2	2	1	2	21	
Heathfield	EAST	PS	330	15	7	5	2	3	1	2	20	
Henderson	EAST	PS	774	21.9	9	5	2	2	0	2	20	
West Marginal Way	WEST	PS	772	7.95	7	5	3	2	1	2	20	
Bellevue	EAST	PS	300	13.6	7	5	3	2	0	2	19	
Woodinville	EAST	PS	790	26.7	7	4	3	2	1	2	19	
53rd Avenue	WEST	PS	480	8.5	7	7	1	2	0	2	19	
Kenmore	WEST	PS	788	14.9	7	5	3	3	1	0	19	
Rainier Ave	WEST	PS	770	9.1	7	5	2	3	0	2	19	
North Creek PS	EAST	PS	311	23	9	2	4	3	0	0	18	Ranking is lower if IPS and BW are online
Barton Street	WEST	PS	485	23	7	7	1	1	0	2	18	
Belvoir	WEST	PS	785	5	5	7	2	2	0	2	18	
Richmond Beach	WEST	PS	550	4.9	5	7	1	2	1	2	18	
Juanita Bay	EAST	PS	306	30.6	9	3	2	1	0	2	17	
South Mercer	EAST	PS	335	11.6	7	5	2	1	0	2	17	
Lake Ballinger	WEST	PS	791	8.4	5	5	3	2	0	2	17	
North Beach	WEST	PS	540	4.8	3	9	1	2	0	2	17	
Sunset	EAST	PS	331	15	7	2	2	3	0	2	16	
East Pine Street	WEST	PS	783	3.75	3	7	2	2	0	2	16	
Kirkland	EAST	PS	304	7.7	5	4	2	2	0	2	15	
Medina	EAST	PS	301	6.55	5	5	2	1	0	2	15	
North Mercer	EAST	PS	333	6	5	4	2	2	0	2	15	
Pacific	EAST	PS	351	3.5	3	4	3	3	0	2	15	
Wilburton	EAST	PS	302	5.1	3	5	3	2	0	2	15	
West Seattle	WEST	PS	776		9	1	1	1	1	2	15	
Yarrow Bay	EAST	PS	303	3.4	3	5	2	2	0	2	14	
Lakeland Hills	EAST	PS	352	5.1	3	2	4	3	0	2	14	
Black Diamond	EAST	PS	310	1.5	1	5	4	2	0	2	14	
Carkeek	WEST	PS	520	4.6	5	3	1	1	1	0	11	
Carnation Treatment Plant	EAST	WWTP	CN	1.3	1	1	4	2	0	2	10	
Hidden Lake	WEST	PS	591	1.7	3	3	1	1	0	2	10	
8th Avenue	WEST	regulator	808				3	2	0	2	7	
Brandon Street	WEST	regulator	809				3	2	0	2	7	
Logboom	WEST	regulator	788A				3	3	1	0	7	
South Michigan Street Outfall	WEST	regulator	810A				3	2	0	2	7	
University	WEST	regulator	819				2	2	1	2	7	
Vashon Treatment Plant	EAST	WWTP	315	1.4	1	1	1	1	0	2	6	
Ballard	WEST	regulator	815				2	2	0	2	6	
Chelan Avenue	WEST	regulator	806				3	1	0	2	6	
Dexter	WEST	regulator	817				2	2	0	2	6	
Harbor Avenue	WEST	regulator	805				3	1	0	2	6	
Lake City Tunnel	WEST	regulator	818				2	2	0	2	6	
Montlake Boulevard	WEST	regulator	820				2	2	0	2	6	
Norfolk Street	WEST	regulator	811				3	2	1	0	6	
West Michigan Street	WEST	regulator	807				2	2	0	2	6	
Hanford	WEST	regulator	803				2	1	0	2	5	
Lander St	WEST	regulator	813				2	1	0	2	5	Lander II Reg assets
King Street Regulator	WEST	regulator	801				1	1	0	2	4	
Denny Way	WEST	regulator	800				1	1	0	2	4	
Kingdome	WEST	Regulator	830				1	1	0	2	4	805? (Same as Harbor)
BW IPS	EAST	PS	240	110	13	4	4	3	1	0	25	Assumes that flows would be diverted to SP or WP
Bunkertrail 2	EAST	PS	318	<1	1	1	4	3	1	2	12	
Bunkertrail 3	EAST	PS	319	<1	1	1	4	3	1	2	12	
Bunkertrail 4	EAST	PS	320	<1	1	1	4	3	1	2	12	
Beulah Park	EAST	PS	316	<1	1	1	4	3	0	2	11	
Bunkertrail 1	EAST	PS	317	<1	1	1	4	3	0	2	11	
Hollywood	EAST	PS	308	13.5	7	2	0	0	0	2	11	Can be shutdown and all flows sent to SP

Appendix E. Equity and Social Justice Approach

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Appendix E presents detailed documentation of the pro-equity considerations, analysis, and findings constructed by the HDR team and WTD during the Recommendations to Enhance the Resiliency and Recovery of King County's Regional Wastewater Treatment Facilities.

Equity and Social Justice Analysis

1 Equity and Social Justice Analysis

The Project Team (internal King County staff and consultants) conducted a pro-equity analysis guided by goals of the County's Equity and Social Justice (ESJ) Strategic Plan. The pro-equity analysis focused on finding bias or structural racism in the project recommendations, and created an ESJ Vulnerability Index to demonstrate which facilities were located in communities where there is the greatest opportunity to address the determinants of equity. This document explains the analysis and outlines how the Project Team's analysis and recommendations live squarely in King County's Equity and Social Justice Strategic Plan.

1.1 King County's ESJ Strategic Plan

1.1.1 Vision

"A King County where all people have equitable opportunities to thrive."

King County's Equity and Social Justice Strategic Plan outlines a vision for King County that "shifts the County away from policies and practices that react to crises toward investments that address root causes of inequities, ultimately leading to better quality of life and greater prosperity in all of our communities." The Project Team focused its Equity and Social Justice (ESJ) analysis on this vision – creating recommendations that build infrastructure in its historically underserved communities, preventing damage, whenever possible, from happening in the future.

1.1.2 Equity and Social Justice "Unhealthy" and "Healthy" Streams

King County's ESJ Strategic Plan notes that "race and place" matter in King County. "People of color, low-income residents and immigrants and refugees persistently face inequities in key areas, such as education, income, and health."

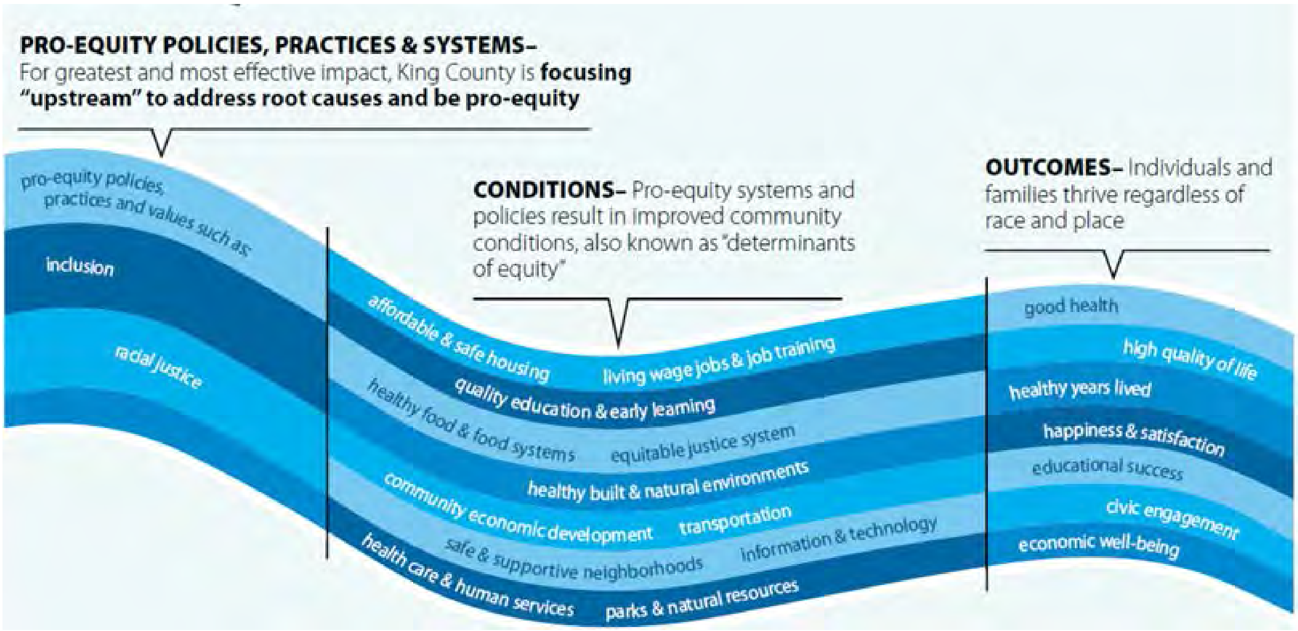


Figure D-1. King County Equity and Social Justice Healthy Stream

The Project Team recognizes the policies, practices and systems that are impacted through the Wastewater Treatment Division and ensured these were addressed through analysis and recommendations. The following table maps the Project Team's ESJ questions to the "Unhealthy Stream" and "Healthy Stream" framework in the ESJ Strategic Plan.

Table D-1. King County Equity and Social Justice Unhealthy and Healthy Stream Framework

Unhealthy Stream	Healthy Stream Considerations in Resiliency ESJ Analysis	Healthy Stream
Policies, practices, and systems	• Did the Facility and System analysis have implicit bias or structural racism? • How does system down time impact life, public health and the environment? • Can project prioritization minimize impact upstream? Can this help with loss of life, public health risks, environmental damage?	**Policies, practices, and systems focusing "upstream"**
Structural racism and discrimination	• Did the process of selecting CIPs favor any group(s) or neighborhood(s)? • Can project prioritization minimize impact upstream? • Are people of color, immigrants and refugees, or other historically underserved groups disproportionately impacted?	*Racial justice*
Class and gender bias	• Will low-income residents have access to the knowledge, language skills, and transportation to make the best decisions for themselves and their families? • Can project prioritization minimize impact upstream?	*Inclusion*

Unhealthy Stream	Healthy Stream Considerations in Resiliency ESJ Analysis	Healthy Stream
Lack of access to resources and decision-making	• Are there enough County resources to build the most-critical projects in historically underserved communities? • How will the County build staff resources to act quickly in historically underserved communities, particularly where there could be loss of life, impact to public health, and damage to the environment? • Will individuals in historically underserved communities have the information they need to act during an event? Will they have the knowledge, language skills, and transportation access to make the best decisions for themselves and their families? • Can project prioritization minimize impact upstream?	*Access and resources*
Cross-generational inequities	• Will seniors, who often lack stable transportation access, have what they need to make the best decisions for themselves and their families?	*Inclusion*
Conditions	• How can King County make the best decisions to 1.) minimize loss of life, public health risks, and environmental damage and 2.) look upstream to prevent impacts after a seismic event?	**Conditions**
Food insecurity	• Can project prioritization minimize impact upstream? Can project prioritization maintain food access?	*Healthy food and food systems*
Pollution and toxic exposures	• Can project prioritization minimize impact upstream? Can project prioritization keep people from being exposed to raw sewage?	*Healthy built and natural environments*
Unsafe neighborhoods	• Can project prioritization minimize impact upstream? Can project prioritization keep people from being exposed to raw sewage and creating a public health crisis?	*Safe and supportive neighborhoods*
Outcomes		**Outcomes**
Homelessness	• Can project prioritization minimize impact upstream? Can project prioritization keep people from being displaced after an event?	*Good health and high quality of life*
Health problems	• Can project prioritization minimize impact upstream? Can project prioritization keep people from being exposed to raw sewage?	*Healthy years lived*

1.2 Equity Impact Review: Phase I – Identify Who will be Affected

The Project Team evaluated its processes for implicit bias and structural racism, and it identified upstream opportunities to prevent loss of life, displacement, and environmental and health damage in historically underserved communities.

The 2015 Equity Impact Review Process outlines the steps needed to conduct a thorough ESJ analysis. The following analysis focuses on Phase 1 – identifying who will be affected. While the Project Team hoped it conducted its building and system analysis without bias or racism, we knew we had to analyze whether the list of potential projects impacted any communities favorably or unfavorably. This first analysis keeps WTD from continuing "Unhealthy Stream" practices. The Project Team also knew there was an opportunity to look at the project list through an ESJ lens to help prioritize projects and engage in "Healthy Stream" practices of inclusion and racial justice. This section discusses the methodology for each of these pathways.

1.2.1 King County Wastewater Treatment Division's ESJ Categories

The Project Team used the County's recommended Census categories to define ESJ populations and individuals. The table below lists the categories and their definitions.

Table D-2. King County Wastewater Treatment Division Equity and Social Justice Categories

ESJ Categories	Explanation
Average income	Uses the two figures, below, to come up with Average Income: median income divided by average household size
Income	Median household income
Household size	Average household size
Education	Percent of population over 25 years old without a Bachelor's
Poverty Level	Percent of population at 200% of the federal poverty level or below
+65 Years Old	Individuals at least 65 years old
Disabled	Percent of population with a disability who are not institutionalized
Language	Percent of population that speaks English less than "Very Well"
Non-US born	Percent of population not born in the United States
Renter	Percent of population renting
Race	Individuals who are not Hispanic or Latino and chose "white alone"

1.3 Methodology

Determining project distribution across ESJ variables

To evaluate how the projects identified in this study compared relative to KCWTD Equity and Social Justice (ESJ) indicators, the project team conducted a GIS analysis. This analysis compared each facility prioritized for a Resiliency project against the entire facility inventory. Data from the 2015 ACS 5 Year Survey results were used for this effort.

Once the ACS data was adjusted for use with the KCWTD specific geography, the attributes were associated to each of the 83 facilities analyzed in the Resiliency and Recovery effort based on the census tract within which each facility is located using a GIS spatial join.

Defining statistical significance for project distribution

The Project Team agreed the visual analysis was an excellent indicator but should be complemented with statistical analysis.

To determine whether the subset of facilities chosen for resiliency projects were representative of the entire facility inventory, a statistical analysis was conducted to compare the two groups. A Student's T-Test was performed for each of the ESJ measures above. Each comparison was performed on the entire population split into two groups, those prioritized for projects and those not prioritized. The graphs show this comparison along with a comparison of their relative mean and confidence intervals. **This analysis did not find any statistical difference across the ESJ variables.**

Moving upstream: Prioritizing projects with high ESJ populations

Continuing to focus on preventing impact to historically underserved populations, the Project Team created a process to prioritize the CIP list. By prioritizing projects located in high ESJ communities, impact (loss of life, public health consequences, and environmental damage) after an event can be minimized. In essence, if the system is fixed before an event, historically underserved communities will have a higher quality of life after an event.

Using the ESJ variables for project distribution, the Project Team created a Vulnerability Index using the following process.

1. Identify the median for each demographic variable
2. Assign a "1" if the facility is above the median and a "0" if it is at or below the median
3. Add across the variables to create a total index score

Table D-3 shows the entire WTD ESJ Vulnerability Index.

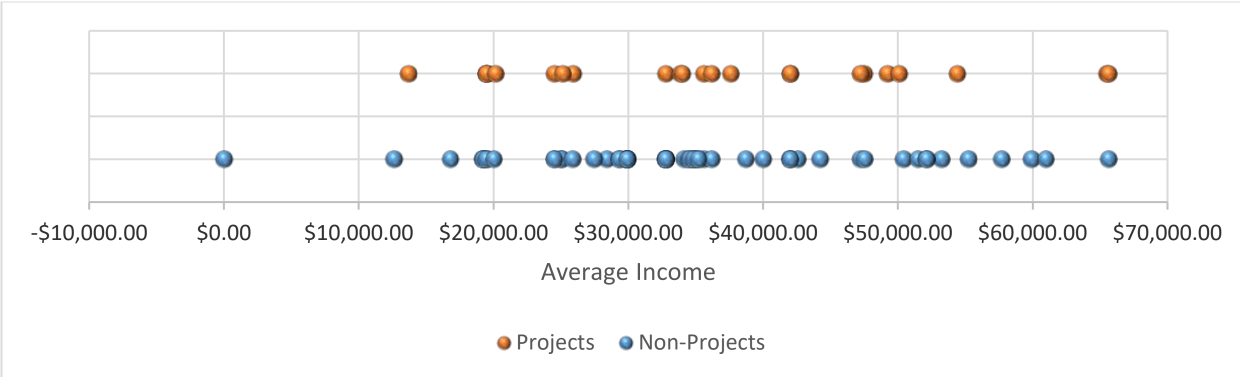
1.4 Results

1.4.1 Average Income

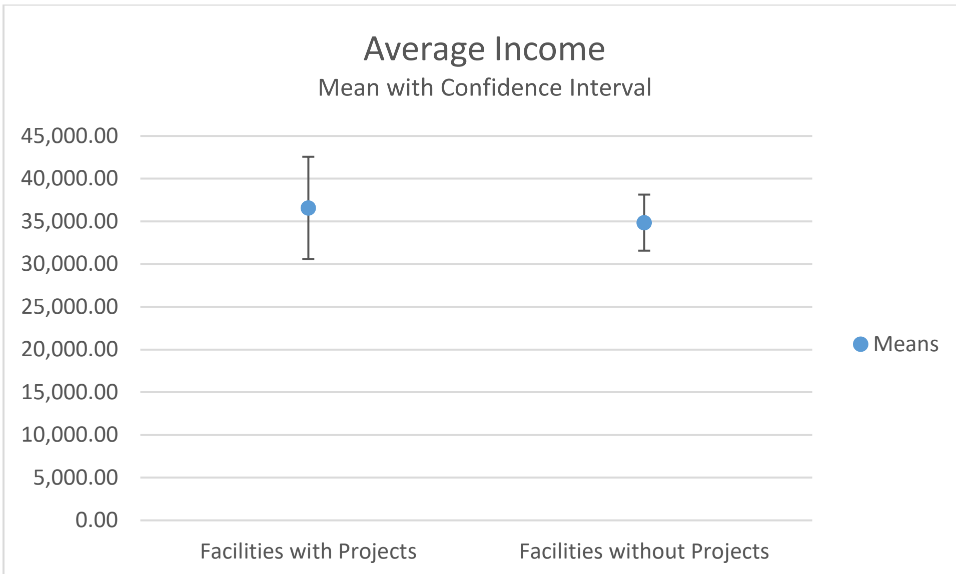
Methods: A preliminary test for the equality of variances indicates that the variances of the two groups were not significantly different F=1.30, p=0.21. Therefore, a two-sample t-test was performed that assumes equal variances.

Results: The mean score for group 1 (M=36,582.32 SD= 14,655.63, N= 23) was not significantly different than the mean score for group 2 (M=34,858.06, SD=12,858.27, N= 59.) using the two-sample t-test for equal variances, t(80) = 0.52, p = 0.60.

With regard to the percent of the population in the areas for which projects were selected when compared to areas in which projects weren't selected, there is no significant difference between the areas.



-$10,000.00
$0.00
$10,000.00
$20,000.00
$30,000.00
$40,000.00
$50,000.00
$60,000.00
$70,000.00
Average Income
Projects
Non-Projects



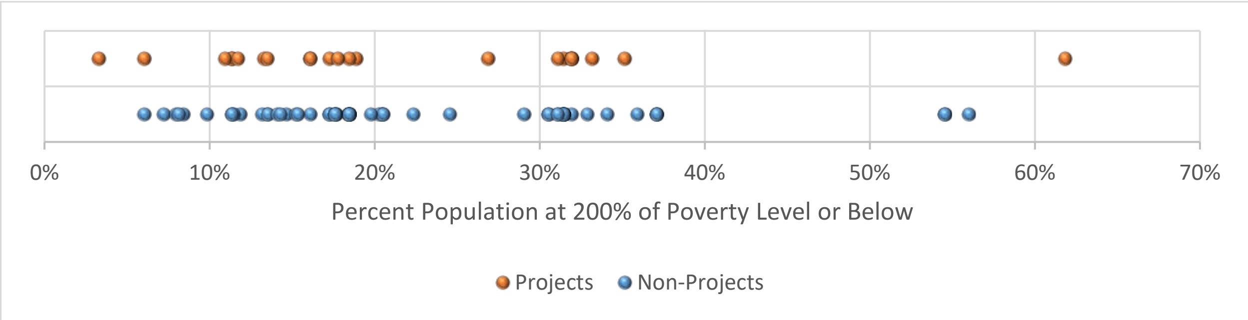
Average Income
Mean with Confidence Interval
45,000.00
40,000.00
35,000.00
30,000.00
25,000.00
20,000.00
15,000.00
10,000.00
5,000.00
0.00
Facilities with Projects
Facilities without Projects
Means

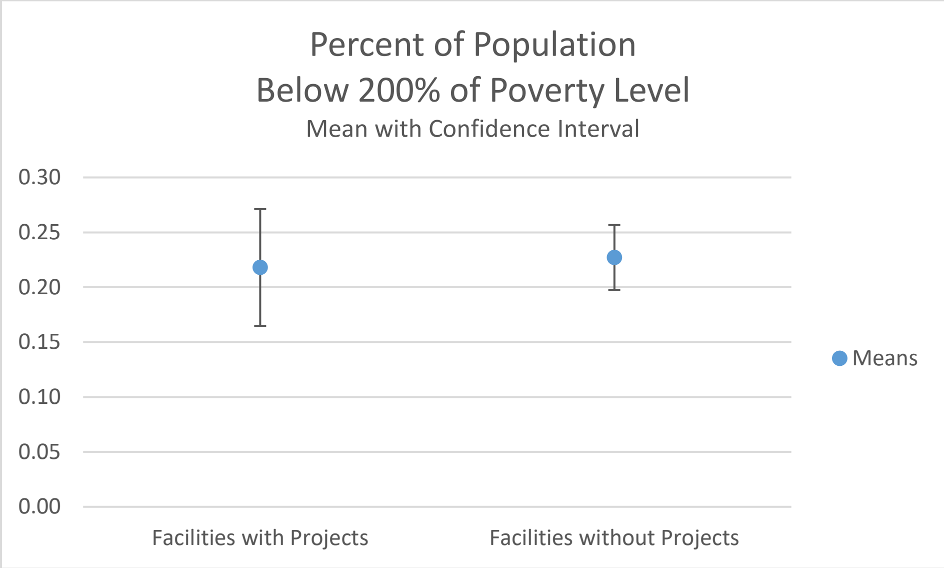
1.4.2 Poverty Level

Methods: A preliminary test for the equality of variances indicates that the variances of the two groups were not significantly different F=1.26, p=0.24. Therefore, a two-sample t-test was performed that assumes equal variances.

Results: The mean score for group 1 (M=0.22 SD= 0.13, N= 23) was not significantly different than the mean score for group 2 (M=0.23, SD=0.12, N= 59.) using the two-sample t-test for equal variances, t(80) = -0.31, p = 0.76.

With regard to the percent of the population in the areas for which projects were selected when compared to areas in which projects weren't selected, there is no significant difference between the areas.



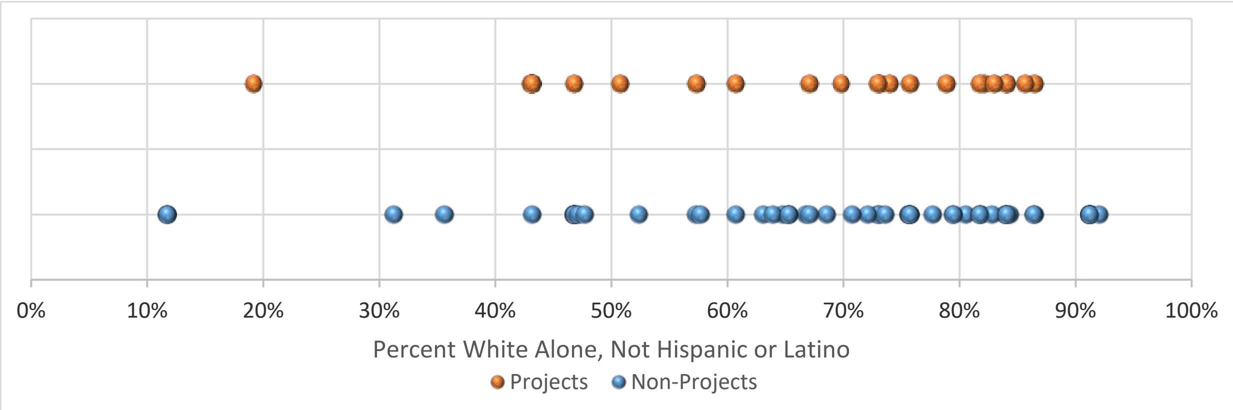


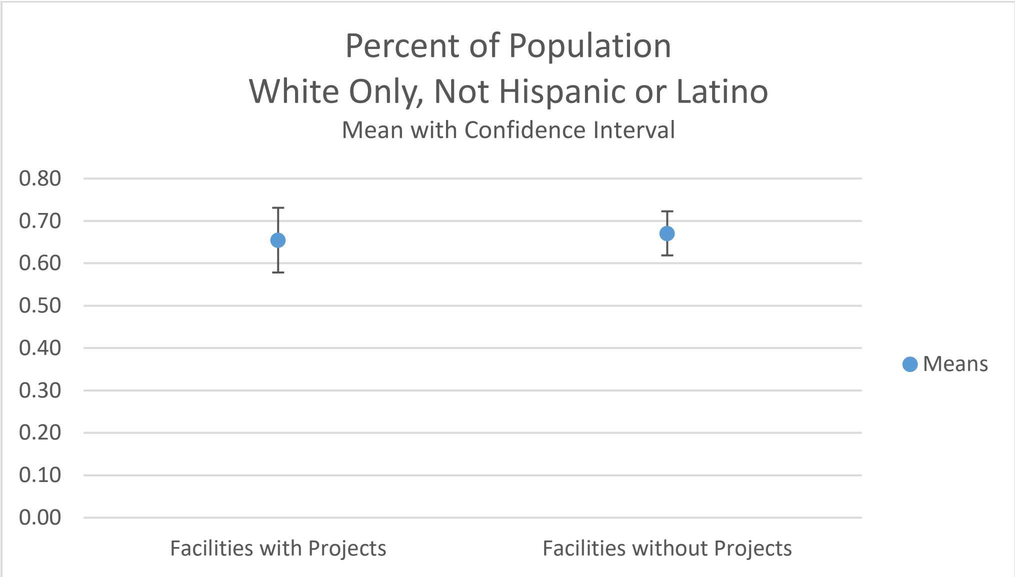
1.4.3 Race

Methods: A preliminary test for the equality of variances indicates that the variances of the two groups were not significantly different F=0.84, p=0.33. Therefore, a two-sample t-test was performed that assumes equal variances.

Results: The mean score for group 1 (M= 0.65, SD= 0.19, N= 23) was not significantly different than the mean score for group 2 (M= 0.67, SD= 0.20, N= 59.) using the two-sample t-test for equal variances, t(80) = -0.33, p = 0.74.

With regard to the percent of the population in the areas for which projects were selected when compared to areas in which projects weren't selected, there is no significant difference between the areas.



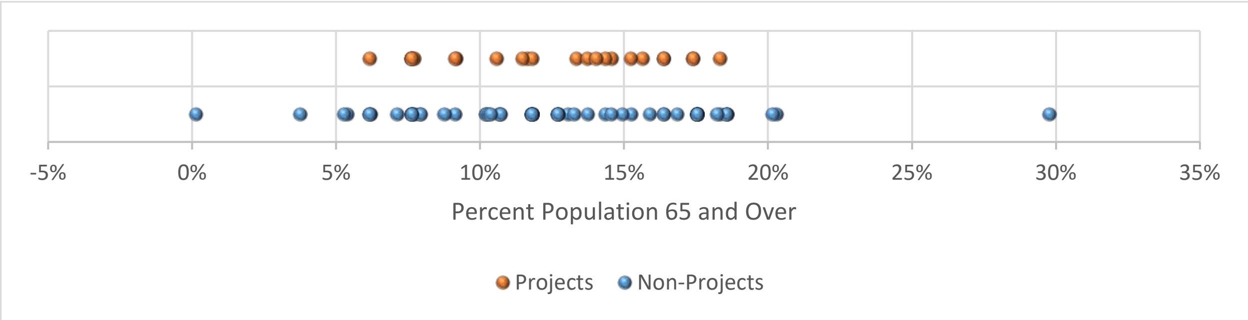


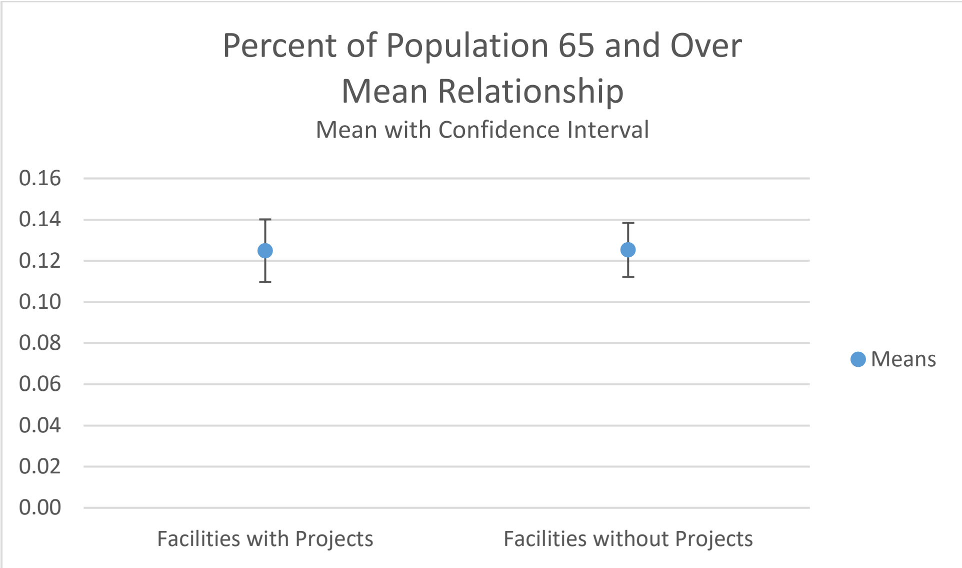
1.4.4 Age

Methods: A preliminary test for the equality of variances indicates that the variances of the two groups were not significantly different F=0.52, p=0.53. Therefore, a two-sample t-test was performed that assumes equal variances.

Results: The mean score for group 1 (M=0.12 SD= 0.04, N= 23) was not significantly different than the mean score for group 2 (M=0.13, SD=0.05, N= 59.) using the two-sample t-test for equal variances, t(80) = -0.04, p = 0.97.

With regard to the percent of the population in the areas for which projects were selected when compared to areas in which projects weren't selected, there is no significant difference between the areas.



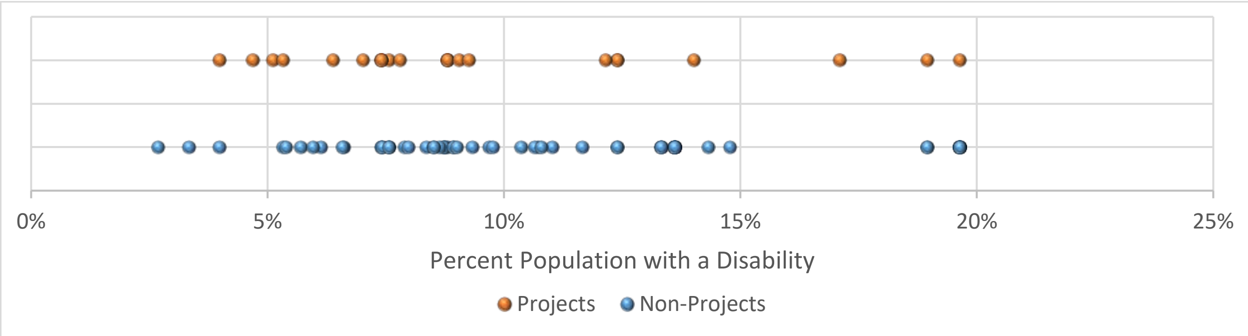


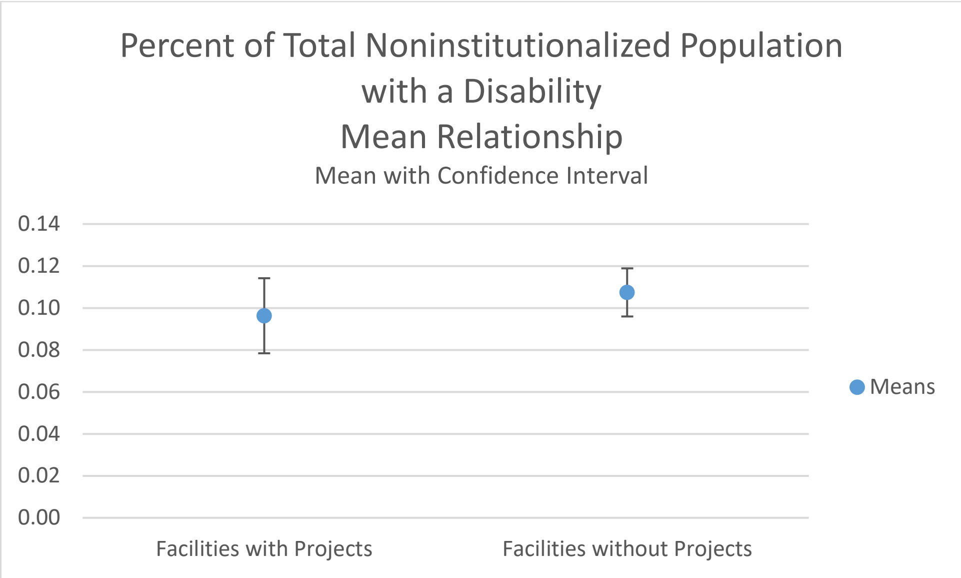
1.4.5 Disabled

Methods: A preliminary test for the equality of variances indicates that the variances of the two groups were not significantly different F=0.95, p=0.46. Therefore, a two-sample t-test was performed that assumes equal variances.

Results: The mean score for group 1 (M=0.10 SD= 0.04, N= 23) was not significantly different than the score for mean group 2 (M=0.11, SD=0.04, N= 59.) using the two-sample t-test for equal variances, t(80) = -1.01, p = 0.31.

With regard to the percent of the population in the areas for which projects were selected when compared to areas in which projects weren't selected, there is no significant difference between the areas.



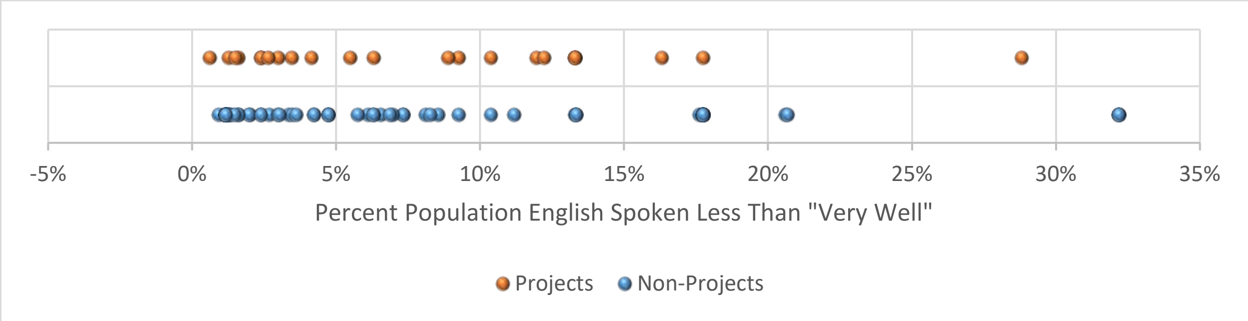


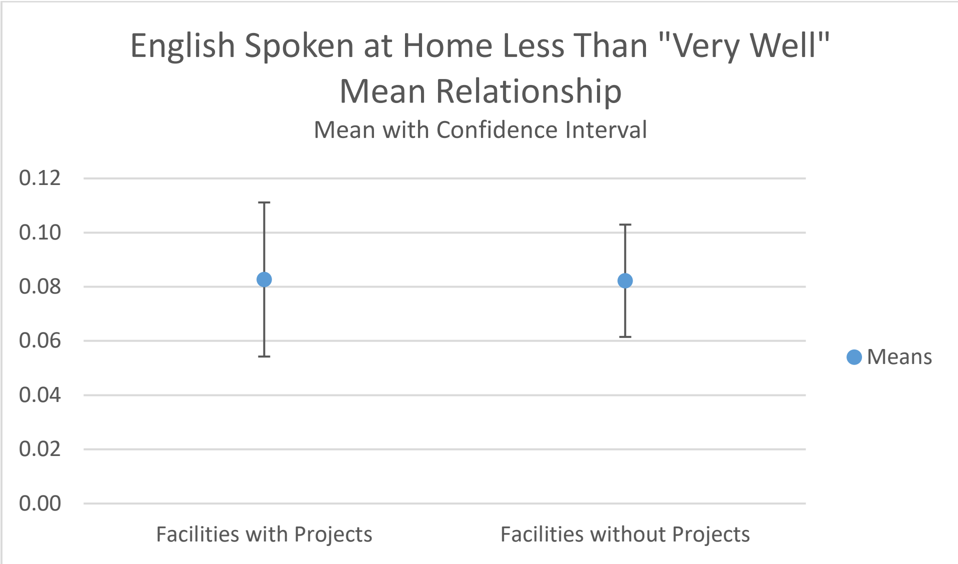
1.4.6 Language

Methods: A preliminary test for the equality of variances indicates that the variances of the two groups were not significantly different F=0.73, p=0.21. Therefore, a two-sample t-test was performed that assumes equal variances.

Results: The mean score for group 1 (M=0.08 SD= 0.07, N= 23) was not significantly different than the mean score for group 2 (M=0.08, SD=0.08, N= 59.) using the two-sample t-test for equal variances, t(80) = 0.02, p = 0.98.

With regard to the percent of the population in the areas for which projects were selected when compared to areas in which projects weren't selected, there is no significant difference between the areas.



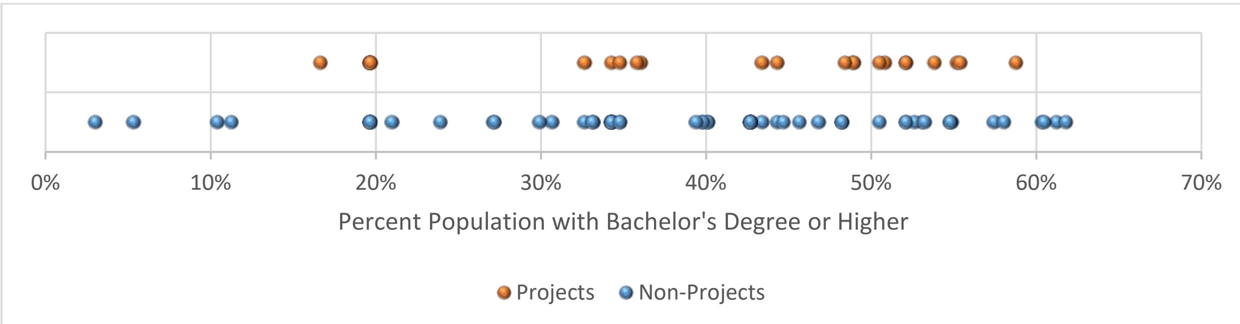


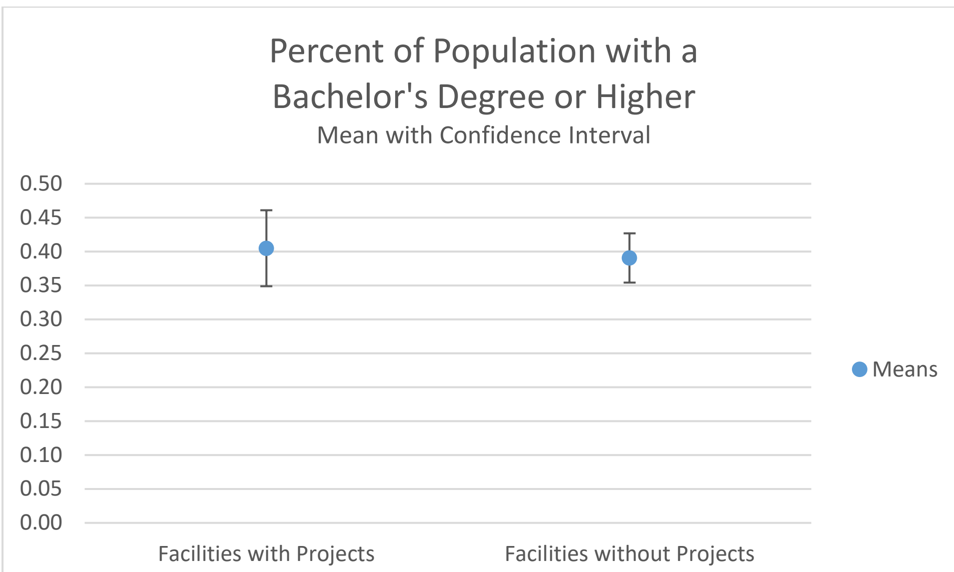
1.4.7 Education

Methods: A preliminary test for the equality of variances indicates that the variances of the two groups were not significantly different F=0.93, p=0.44. Therefore, a two-sample t-test was performed that assumes equal variances.

Results: The mean score for group 1 (M=0.40 SD= 0.14, N= 23) was not significantly different than the mean score for group 2 (M=0.39, SD=0.14, N= 59.) using the two-sample t-test for equal variances, t(80) = 0.41, p = 0.68.

With regard to the percent of the population in the areas for which projects were selected when compared to areas in which projects weren't selected, there is no significant difference between the areas.



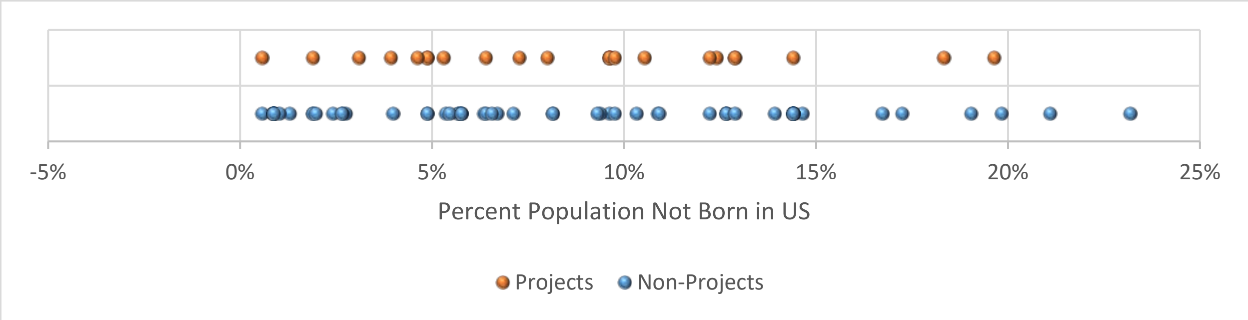


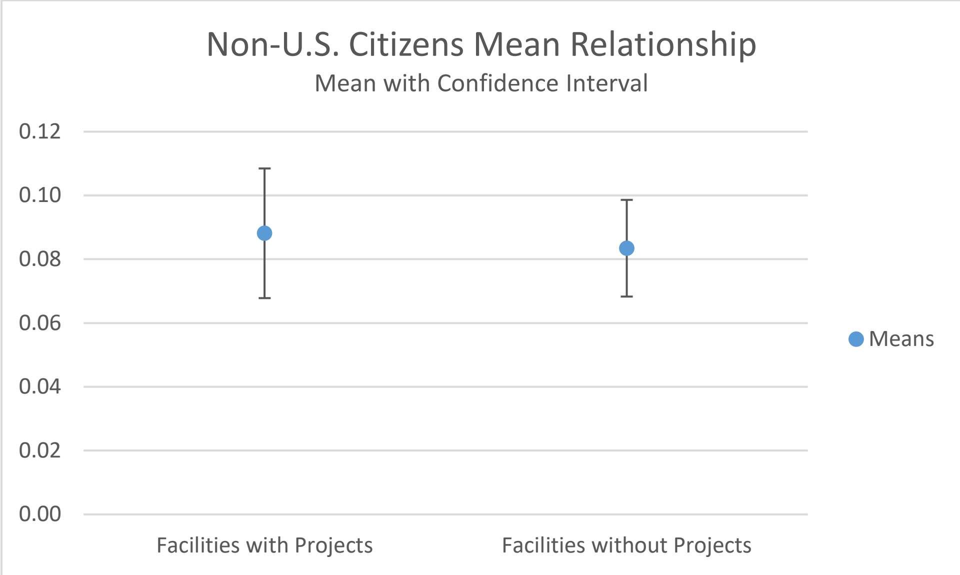
1.4.8 Non-U.S. Citizens

Methods: A preliminary test for the equality of variances indicates that the variances of the two groups were not significantly different F=0.70, p=0.18. Therefore, a two-sample t-test was performed that assumes equal variances.

Results: The mean score for group 1 (M=0.09 SD= 0.05, N= 23) was not significantly different than the mean score for group 2 (M=0.08, SD=0.06, N= 59.) using the two-sample t-test for equal variances, t(80) = 0.33, p = 0.74.

With regard to the percent of the population in the areas for which projects were selected when compared to areas in which projects weren't selected, there is no significant difference between the areas.



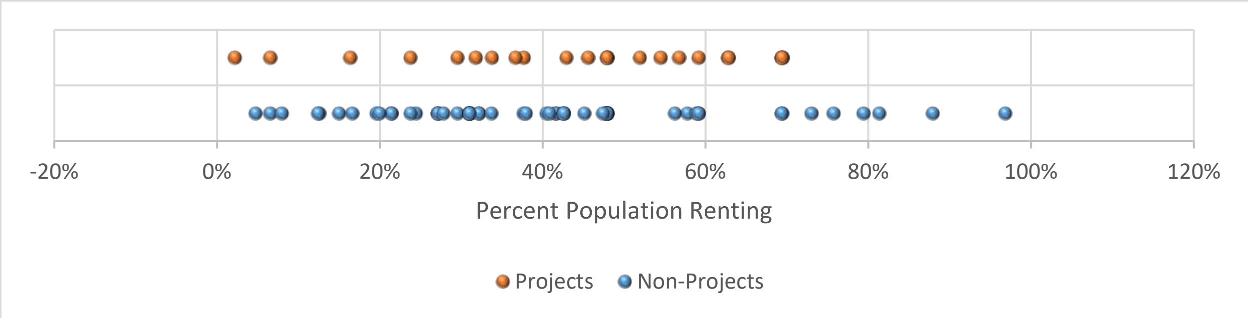


1.4.9 Rentals

Methods: A preliminary test for the equality of variances indicates that the variances of the two groups were not significantly different F=.87, p=.37. Therefore, a two-sample t-test was performed that assumes equal variances.

Results: The mean score for group 1 (M=0.44 SD= 0.19, N= 23) was not significantly different than the mean score for group 2 (M=0.41, SD=0.21, N= 59.) using the two-sample t-test for equal variances, t(80) = 0.63, p = 0.53.

With regard to the percent of the population in the areas for which projects were selected when compared to areas in which projects weren't selected, there is no significant difference between the areas.



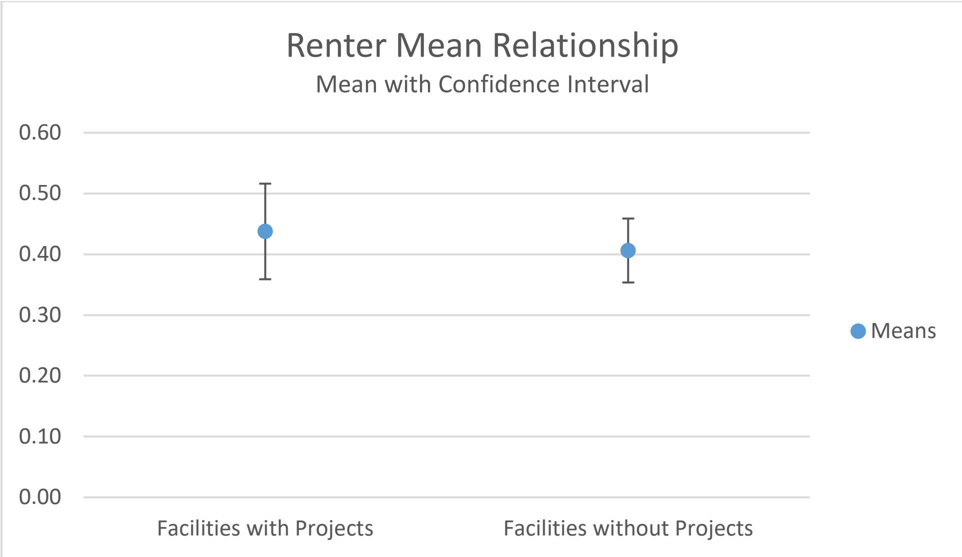


Table D-3. ESJ Vulnerability Index

Facility Name	ESJ Vulnerability Index	Avg. Income Index	Race Index	Education Index	Poverty Index	Over 65 Index	Disabled Index	ESL Index	Non-US Index	Renter Index
West Marginal Way	**9**	1	1	1	1	1	1	1	1	1
Duwamish	**8**	0	1	1	1	1	1	1	1	1
Henderson	**8**	1	1	1	1	0	1	1	1	1
Effluent Pump Station	**7**	1	1	1	1	0	0	1	1	1
Interurban	**7**	1	1	1	1	0	0	1	1	1
Rainier Av.	**7**	1	1	1	1	1	1	0	0	1
South Treatment Plant - Primary System	**7**	1	1	1	1	0	0	1	1	1
East Marginal Way	**5**	1	0	1	1	0	1	0	0	1
30th Av. NE	**4**	1	0	0	1	0	0	0	1	1
Sweyolocken	**4**	0	1	0	0	0	0	1	1	1
53rd Av.	**3**	0	0	0	0	1	1	0	0	1
63rd Av.	**3**	0	0	0	0	1	1	0	0	1
Bellevue	**3**	0	0	0	0	1	0	1	1	0
Sunset	**3**	0	0	1	0	1	0	0	1	0
Woodinville	**3**	0	0	1	0	1	0	0	0	1
Murray	**2**	0	0	1	0	1	0	0	0	0
Northcreek	**2**	0	0	1	0	0	0	0	1	0
York	**2**	0	1	0	0	0	0	0	1	0
Belvoir	**1**	0	0	0	0	1	0	0	0	0
Interbay	**1**	0	0	0	0	0	0	0	0	1
Matthews Park	**1**	0	0	0	0	1	0	0	0	0
South Mercer Island	**1**	0	0	0	0	1	0	0	0	0
West Point Treatment Plant - Primary System	**1**	0	0	0	0	1	0	0	0	0

1.5 ESJ Recommendation: Equity Impact Review Process Phase 2

The Project Team is confident in its statistical analysis, but that is only the first step in moving the CIP project list forward. The Team recommends advancing with the Equity Impact Process Phase 2 – assess equity and community context. WTD should consider the following as it moves to Phase 2.

1.5.1 Assess equity and community context

WTD should convene community members, leaders, and stakeholders to review the statistical analysis and understand the community's needs and priorities. The analysis will only become better when community members add context. For example, a project might have a high Vulnerability Index score but is not located in a highly residential area, and community members might prefer to prioritize one that has higher residential density or access to services. At this moment, the overall Vulnerability Index scores in Table D-4 are the starting place for a community conversation. They are not intended to be and should not be used as a final list of recommendations.

Table D-4. Wastewater Treatment Division Equity and Social Justice Summary Vulnerability Index

Facility Name	ESJ Vulnerability Index
West Marginal Way	**8**
Duwamish	**7**
Henderson	**7**
Effluent Pump Station	**6**
Interurban	**6**
Rainier Av.	**6**
South Treatment Plant – Primary System	**6**
E. Marginal Way	**5**
30th Av. NE	**4**
53rd Av.	**3**
63rd Av.	**3**
Bellevue	**3**
Sunset	**3**
Sweyolocken	**3**
Woodinville	**3**
Murray	**2**
Northcreek	**2**
Belvoir	**1**
Interbay	**1**
Matthews Park	**1**
South Mercer Island	**1**
West Point Treatment Plant - Primary System	**1**
York	**1**