

# Shaking Things Up – Innovative Seismic Risk Planning

City of Bellevue

February 25, 2021 – Doug Lane, PE, and Matt Maring, PE, PMP

# Presentation Overview

- Project Background and Seismic Threat Characterization
- Post-Event Level of Service (PE-LOS) Goals
- Seismic Resilience Improvement Alternatives
- Prioritizing Improvements to Achieve PE-LOS Goals
- Questions and Discussion

# Project Team and Contributors



# Jacobs

 SHANNON & WILSON

 Optimatics  
PLAN SMARTER

# Background and Seismic Threat Characterization

## Project Goals and Priorities

Characterize water system seismic event threats



Identify system vulnerabilities and potential service area customer impacts



Determine system and operational improvements needed to mitigate seismic risks

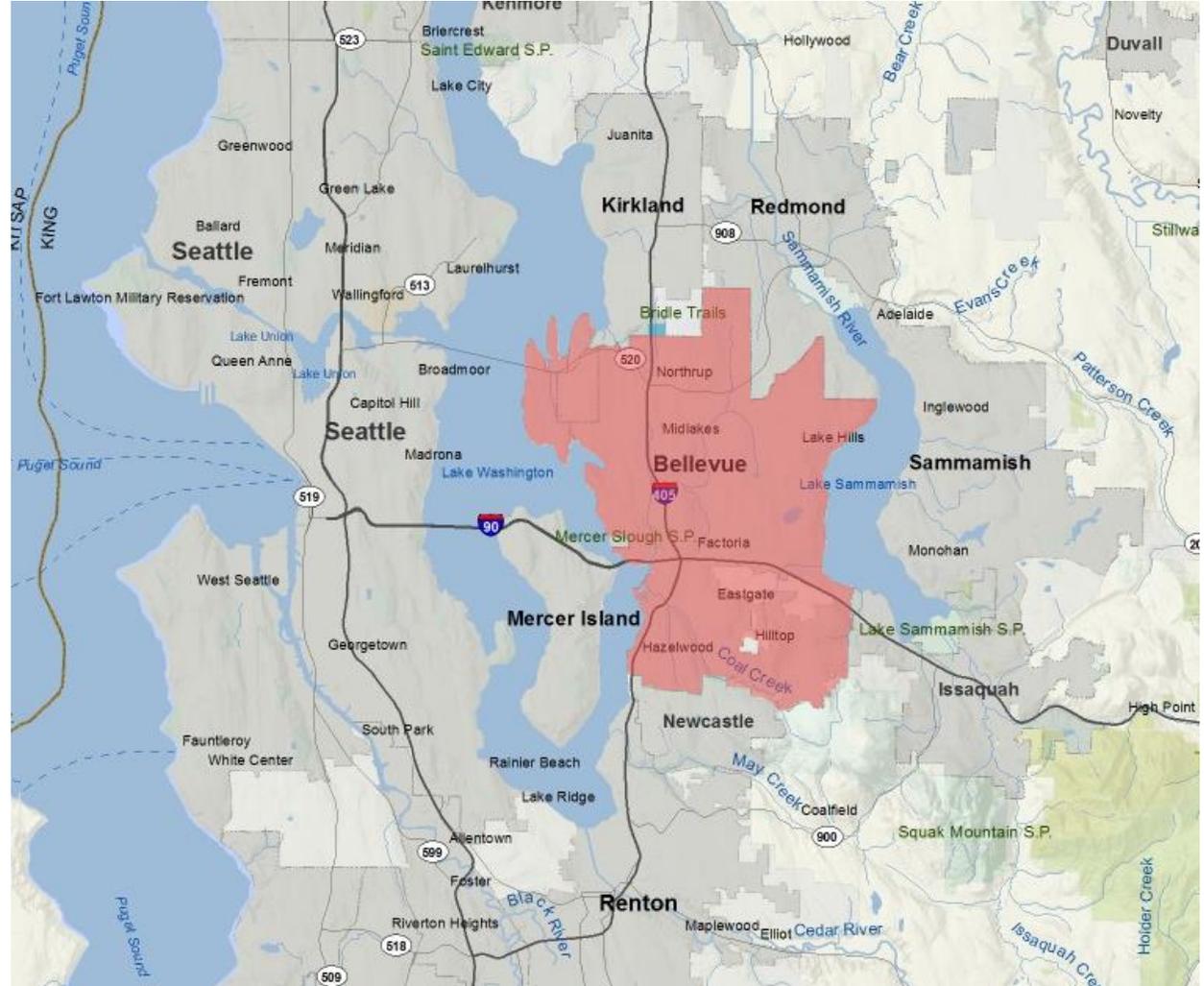


Develop level of service goals and improvement implementation plans

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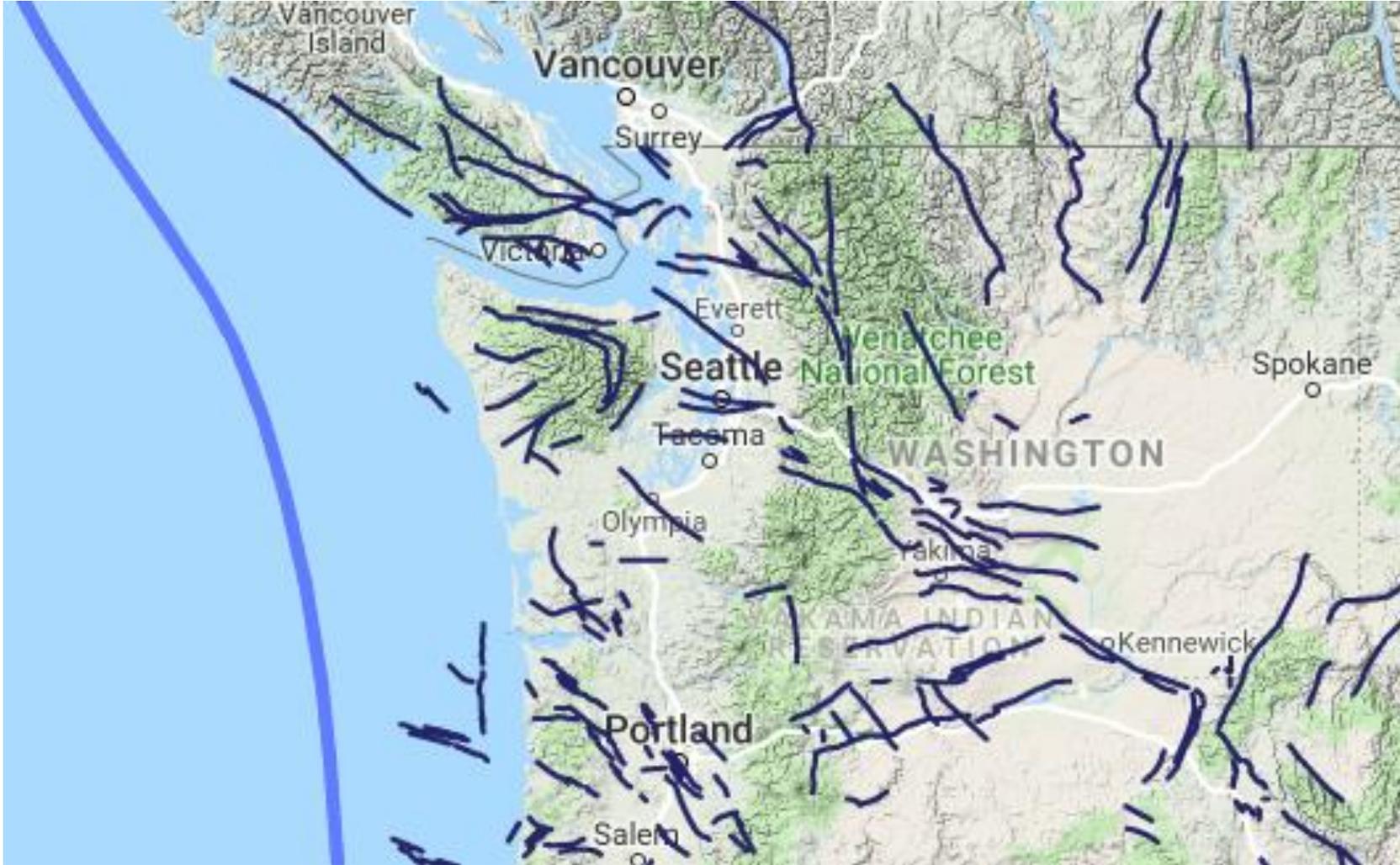
# Bellevue Service Area and Water System

- 150,000+ Population
- 140,000+ Jobs
- 14 Regional Water Supply Inlet Stations
- 72 Pressure Zones
- 24 Storage Tanks
- 22 Pump Stations
- 148 PRV Stations
- 620 Miles of Water Mains
- 20-1440 ft Surface Elevations





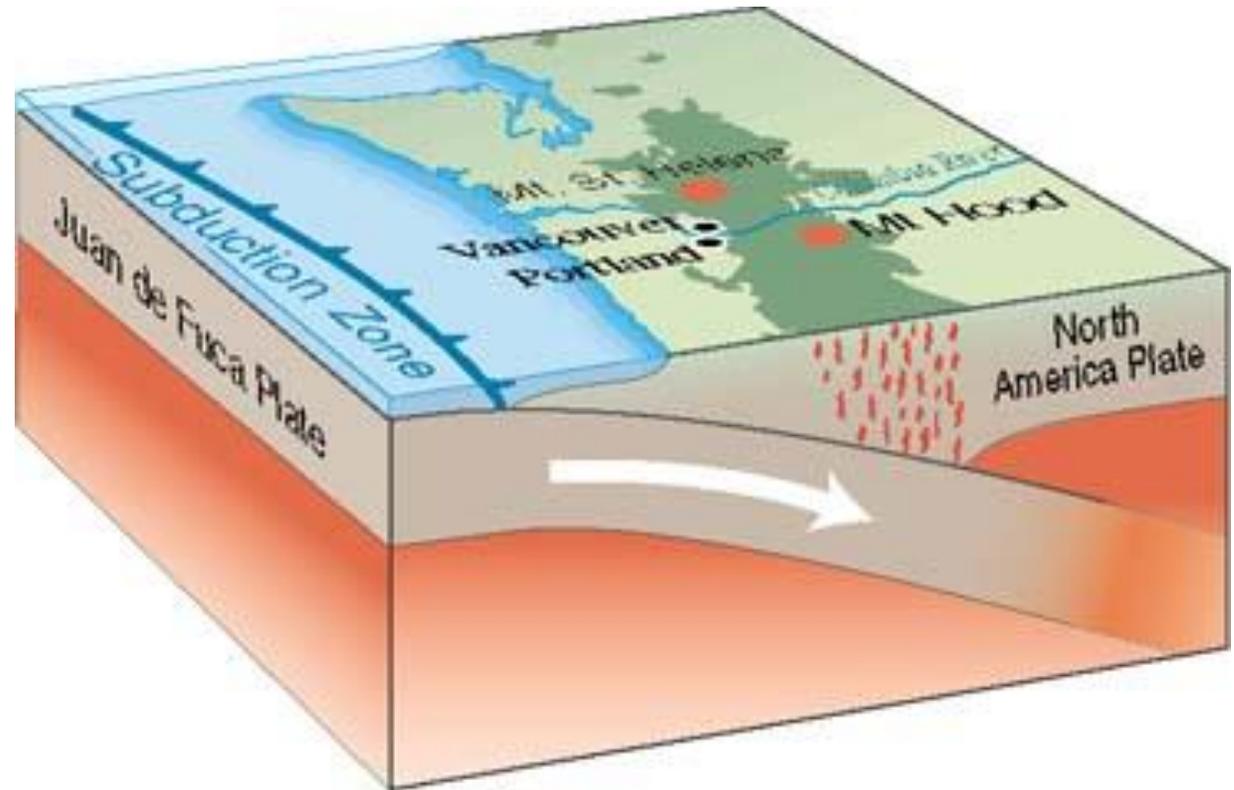
# Pacific Northwest Faults and Bellevue Seismic Risks



- Cascadia Subduction Zone (CSZ)
- Seattle Fault Zone (SFZ)
- South Whidbey Island Fault (SWIF)

# Cascadia Subduction Zone Earthquake

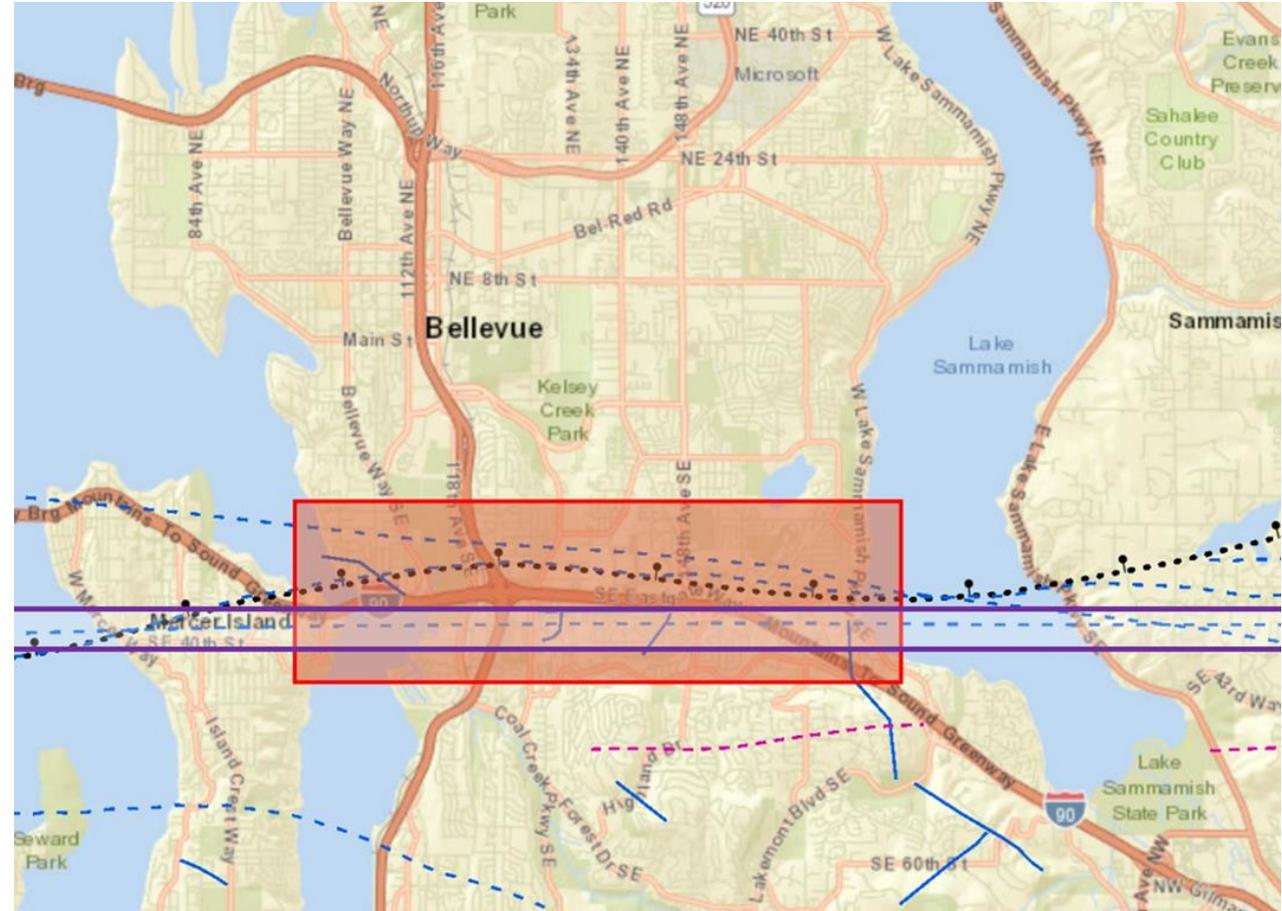
- Ostensibly “The Big One”
- Magnitude 9.0
- ~500 year event
- Longer (~3 minutes) duration
- Pacific Ocean epicenter
- Broad regional impacts



*(U.S. Geological Survey)*

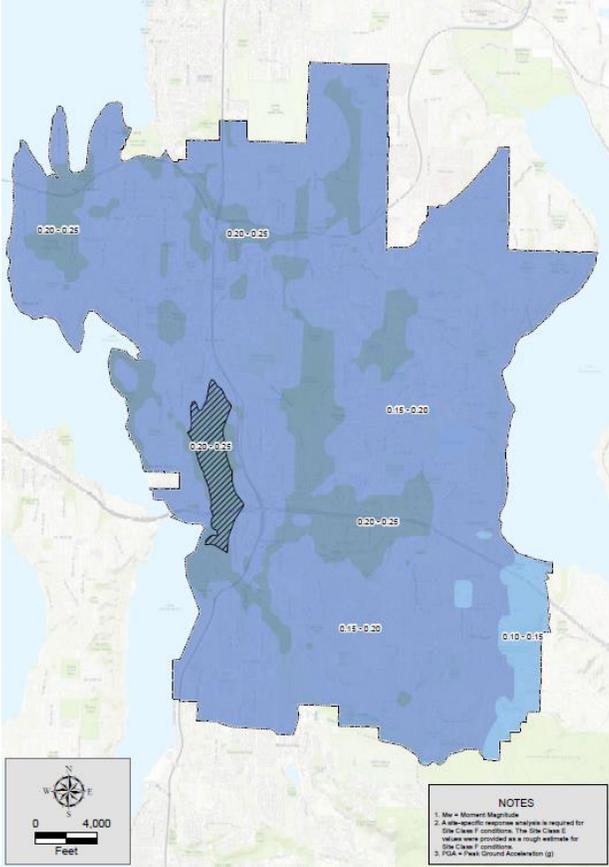
# Seattle Fault Zone Earthquakes

- The actual “Big One”
- Magnitude 6.6 (800+ year) to Magnitude 7.2 (4,000+ year)
- Short duration
- Shallow fault
- Epicenter near or under Bellevue
- Severe localized impacts

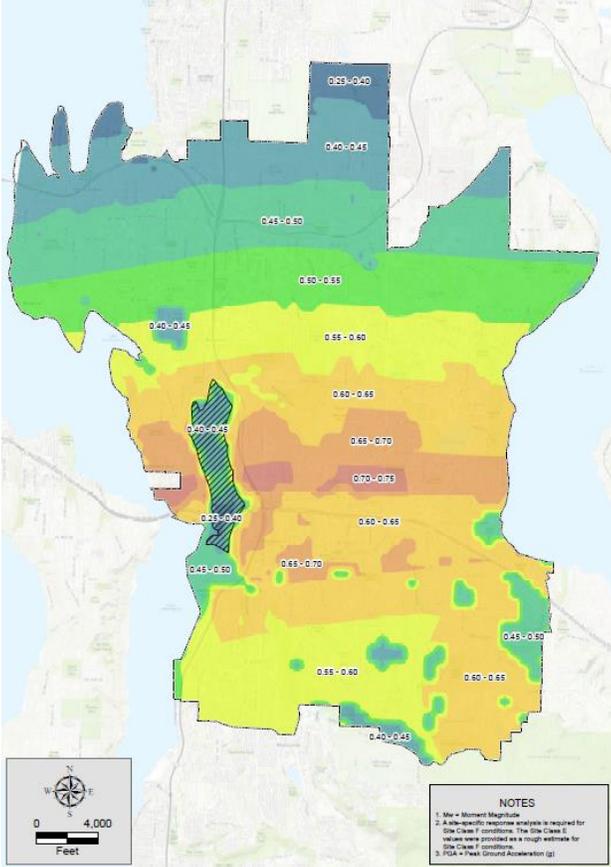


# Seismic Event Peak Ground Acceleration (PGA)

## Cascadia Subduction Zone (CSZ) Mw 9.0



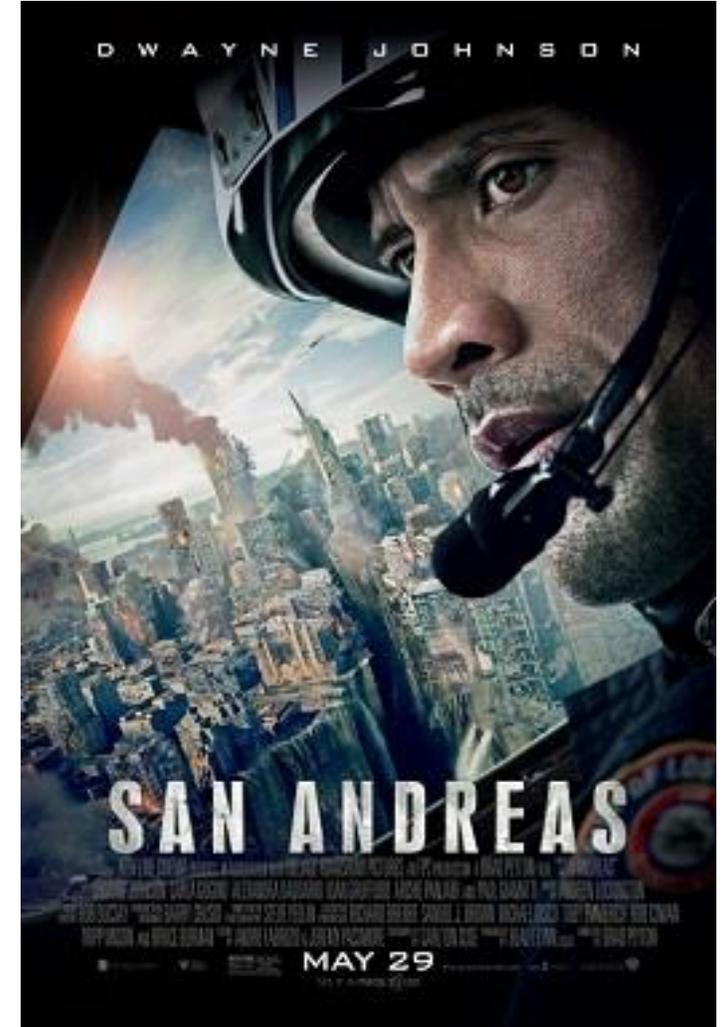
## Seattle Fault Zone East (SFZE) Mw 6.6



## CEU Virtual Attendance Poll Question 1 of 2

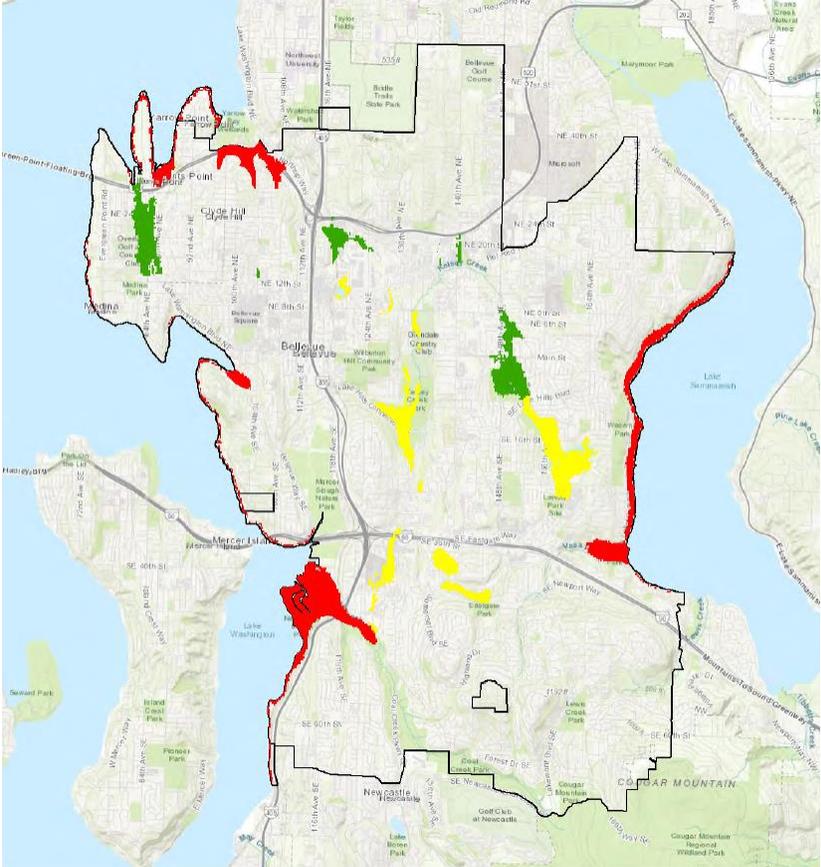
The **greatest** apparent seismic threat for Bellevue is:

1. Cascadia Subduction Zone (CSZ)
2. South Whidbey Island Fault (SWIF)
3. Seattle Fault Zone (SFZ)
4. San Andreas Fault (THE ROCK!)

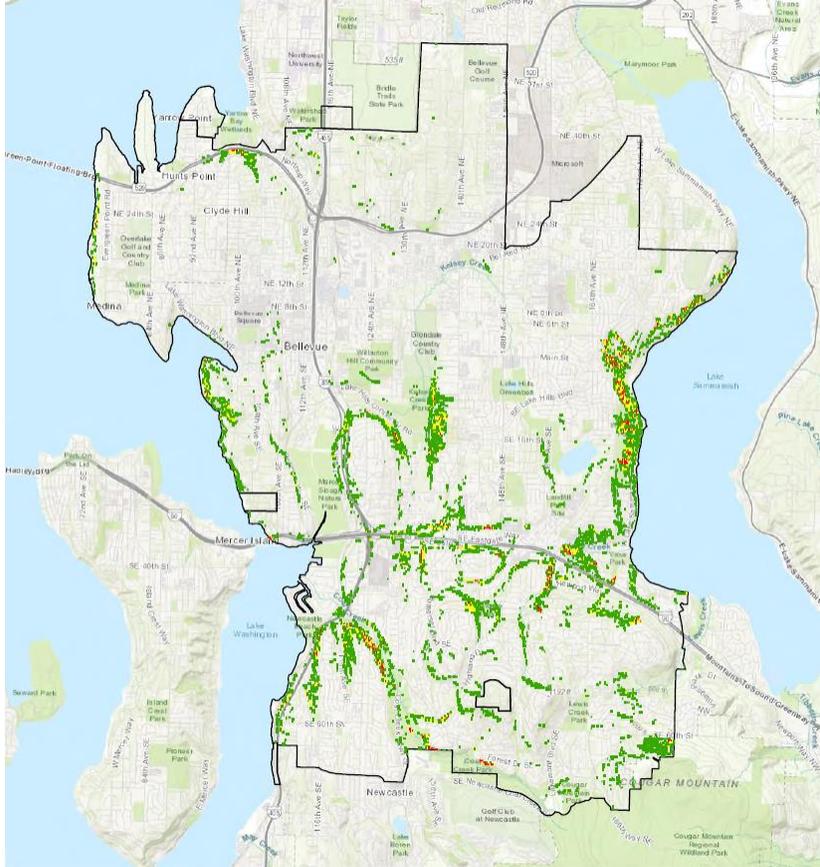


# Geotechnical Vulnerabilities – Seattle Fault Zone East

## Liquefaction and Subsidence Hazards

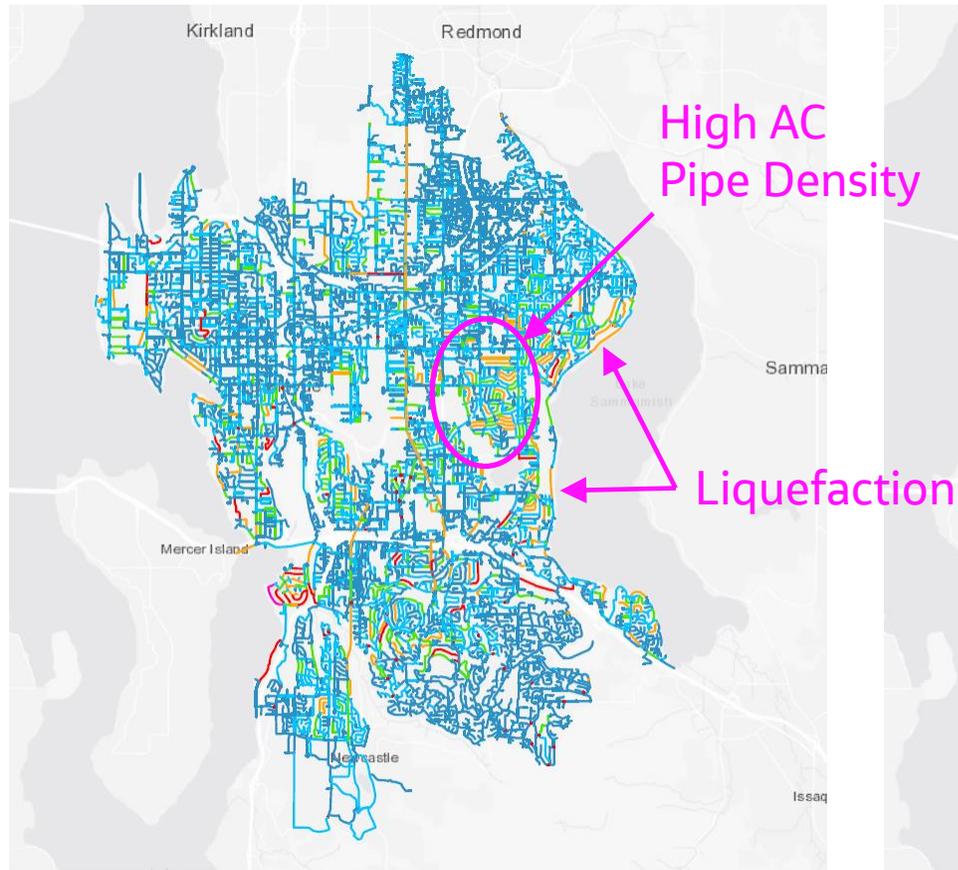


## Landslide and Slope Stability Hazards

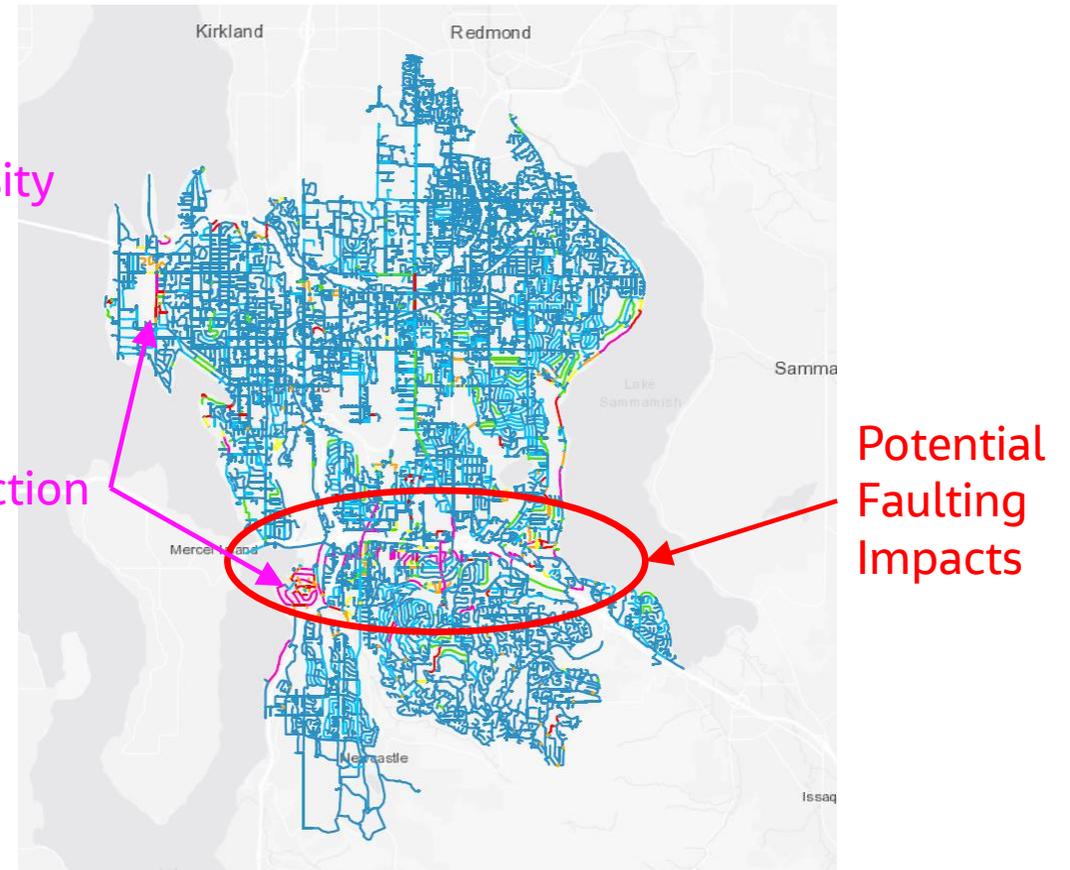


# ALA Pipe Failure Probabilities - Existing System, Seattle Fault Zone East

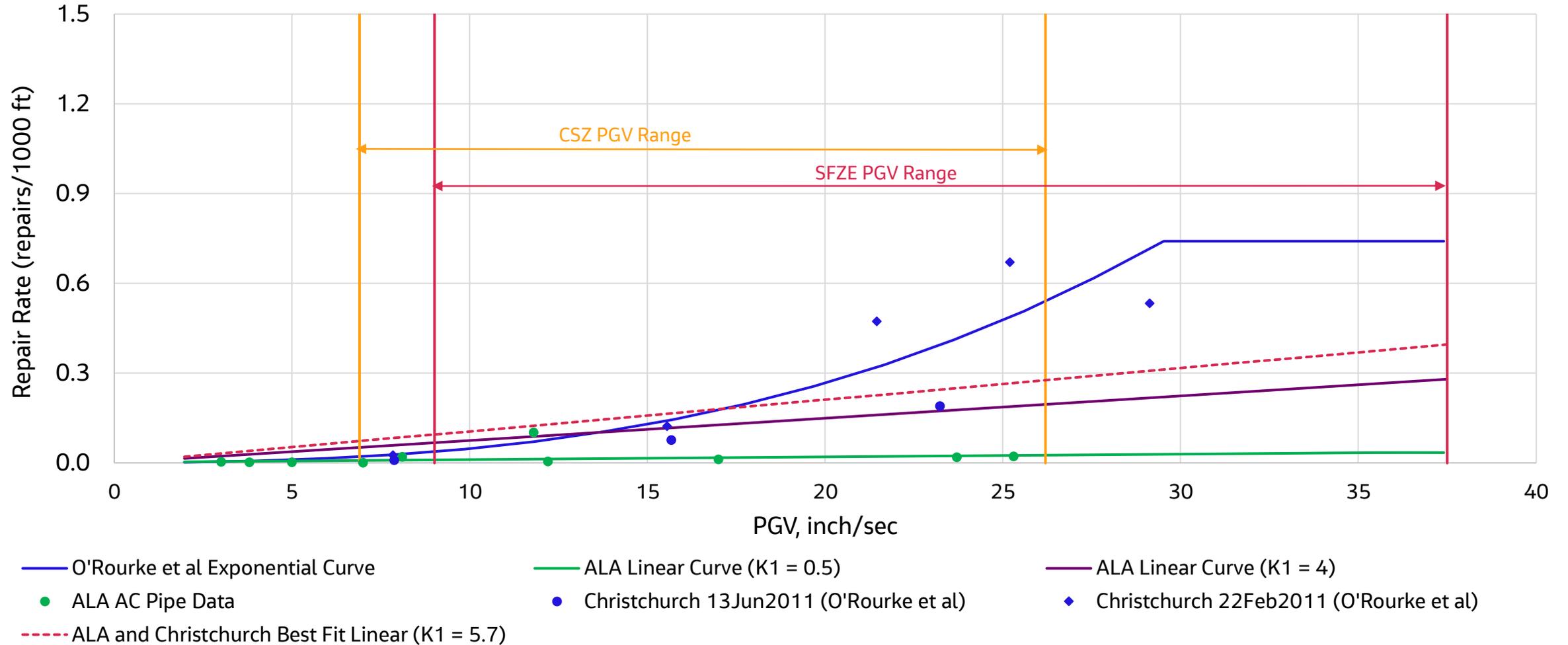
## Leak Probability and Distribution



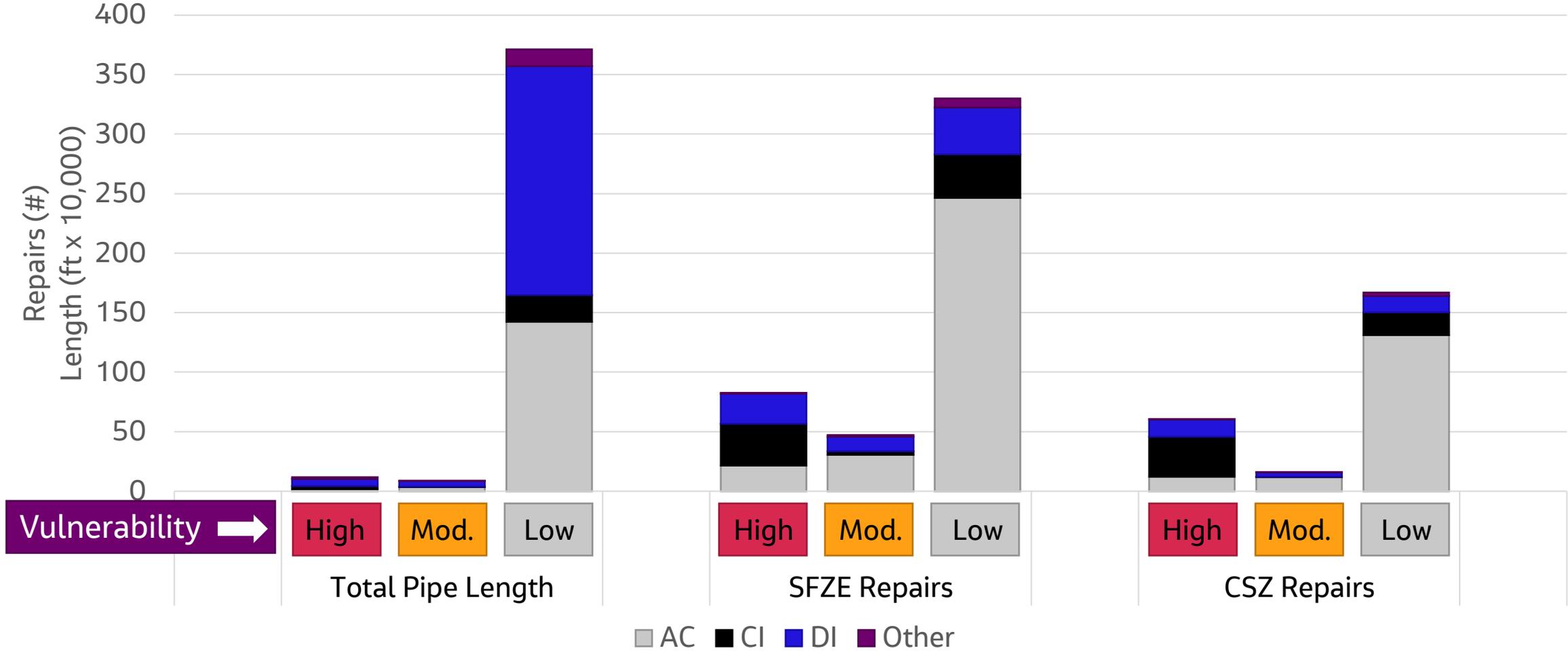
## Break Probability and Distribution



# AC Pipe Fragility Factors Updated based on 2011 Christchurch NZ Data



# Pipe Repairs by Material and Vulnerability Rating – Existing System



# Hazus Facility Damage and Failure Probabilities – Existing System

- Probability of extensive facility damage or complete failure under:
  - Cascadia Subduction Zone (CSZ) Scenario
  - Seattle Fault Zone East (SFZE) Scenario

Reservoirs	CSZ M9	SFZ East
Cherry Crest	0.34%	12.37%
Clyde Hill 465	0.19%	6.40%
Clyde Hill 390	0.38%	11.87%
Clyde Hill 335 Rd	4.46%	33.40%
Clyde Hill 335 Sq	0.38%	8.12%
Cougar Mt. 1	0.19%	22.84%
Cougar Mt. 2	0.13%	23.17%
Cougar Mt. 3	2.08%	44.67%
Cougar Mt. 3A	2.08%	44.15%
Factoria	5.51%	45.69%
Forest Hills	0.37%	21.10%
Horizon View 1 - NEW	0.18%	13.25%
Horizon View 2	4.26%	42.58%
Horizon View 3	0.13%	13.43%
Horizon View 3A	0.34%	21.92%
Lake Hills North	0.18%	10.27%
Lake Hills South	0.17%	10.37%
Meydenbauer N	0.39%	21.51%
Meydenbauer S	0.39%	21.51%
N.E. 40th	0.36%	8.16%
Newport	0.17%	21.84%
Parksite	4.66%	46.94%
Pikes Peak		
Sammamish		
Somerset 2	0.04%	21.93%
Woodridge	0.20%	17.32%
Kirkland 545 - South		
Kirkland 545 - North		
CCUD 580 East		
CCUD 580 West		
CCUD 440		

Pump Stations	CSZ M9	SFZ East
Cherry Crest	6.36%	54.67%
Clyde Hill	23.99%	75.50%
Cougar Mt. 1	4.24%	61.90%
Cougar Mt. 2	3.44%	62.29%
Cougar Mt. 3	2.79%	62.09%
Forest Hills	6.94%	61.00%
Horizon View 1 - NEW	0.63%	25.11%
Horizon View 2	20.06%	83.11%
Horizon View 3	0.03%	19.92%
Lake Hills (Crossroads)	6.22%	55.80%
Meydenbauer	0.82%	25.55%
NE 8th Inlet	0.06%	14.46%
NE 40th	6.42%	37.96%
Newport	4.27%	62.30%
Parksite	21.70%	86.22%
Pikes Peak		
SE 28th Inlet	0.04%	32.80%
Somerset Inlet	0.03%	25.85%
Somerset 2	0.04%	21.93%
Woodridge	6.75%	68.28%
161st Ave Inlet	0.03%	25.08%
670/NE 40th	23.37%	66.85%
CCUD 475/580		

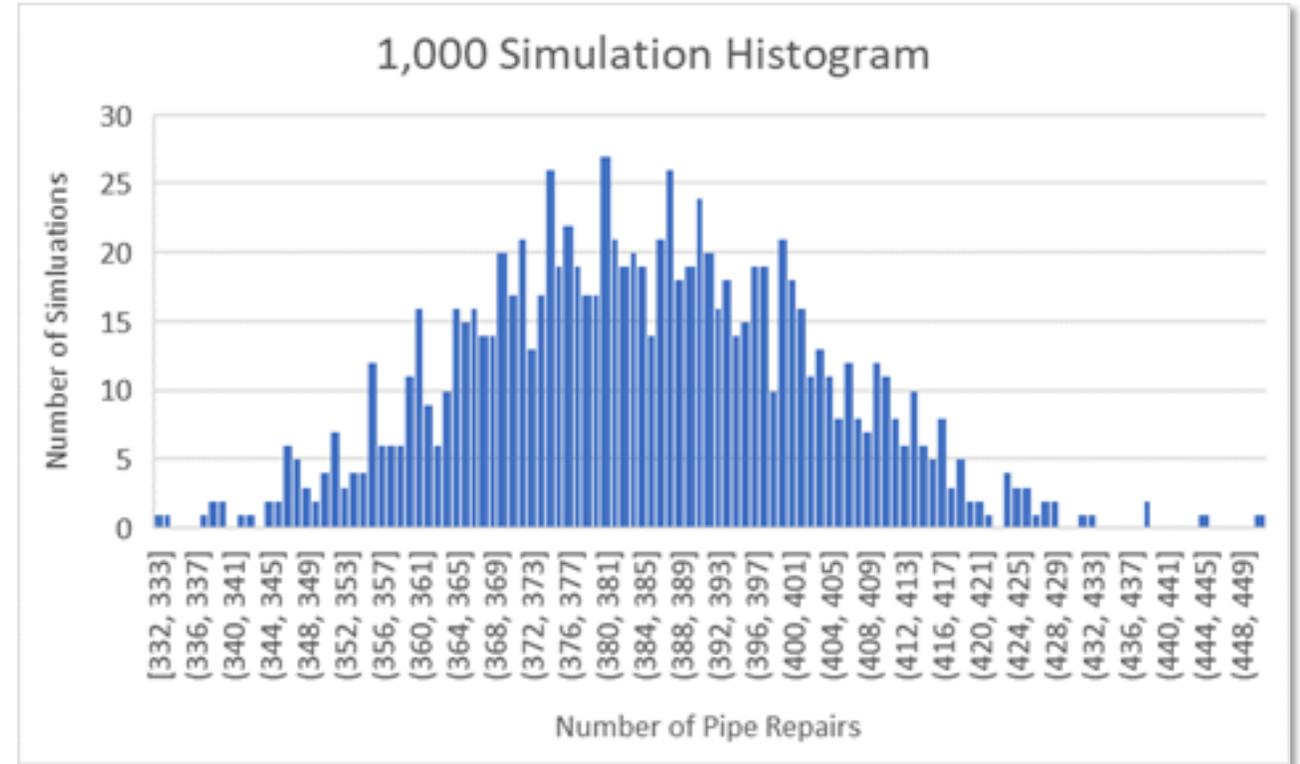
  

Wells	CSZ M9	SFZ East
WD97 Well No. 3	1.68%	41.29%
WD97 Well No. 5	1.90%	33.83%
WD97 Well No. 6	1.90%	33.83%
WD97 Well No. 7	1.90%	33.83%



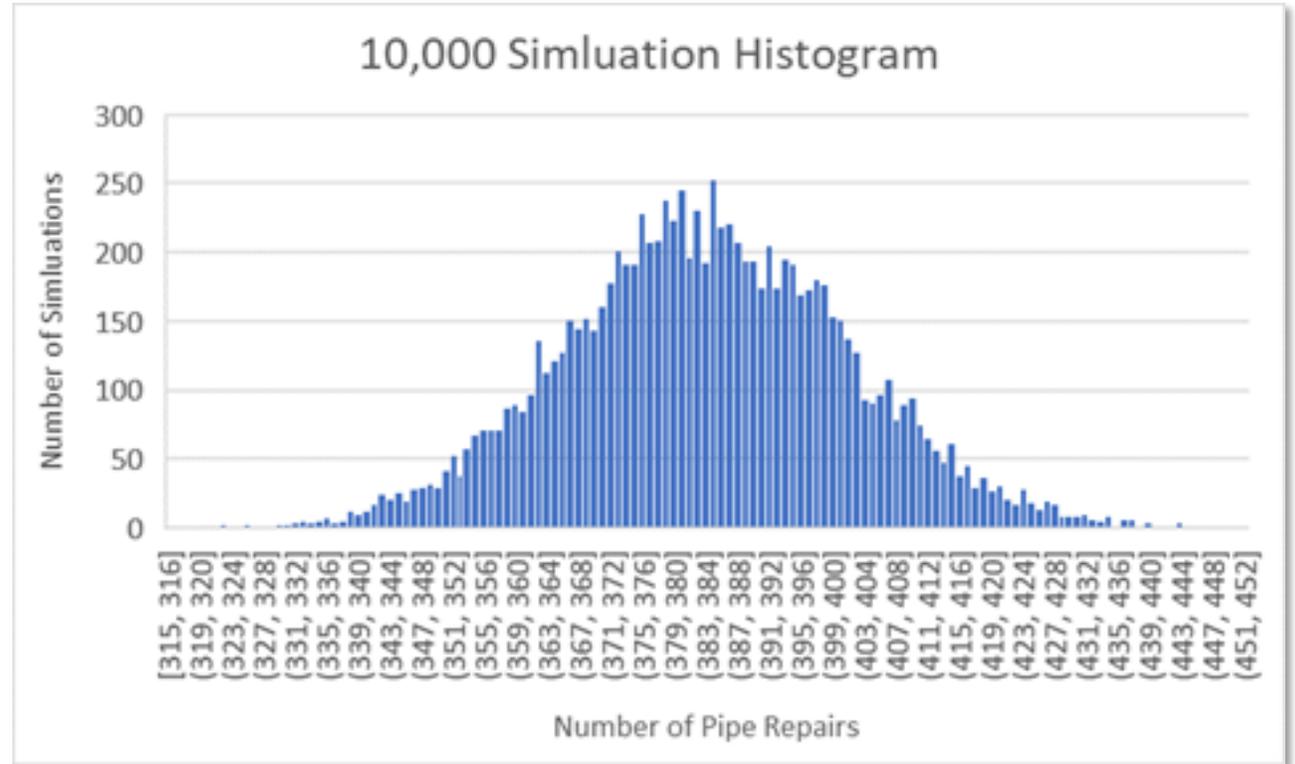
# Monte Carlo Failure Analysis Modeling

- System performance modeled based on ALA and Hazus failure probabilities estimated according to:
  - Projected seismic event severity
  - Materials and condition
  - Geotechnical factors
- Initial 1,000 simulation analysis approached typical “normal” statistical distribution
- 10,000 simulation analysis provides smoother distribution for use in multi-break system modeling analysis



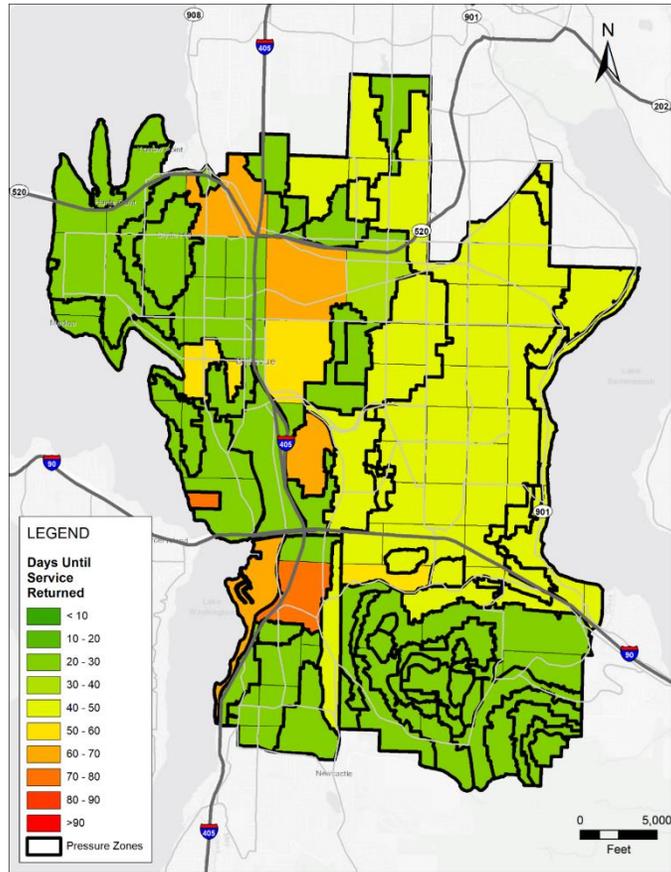
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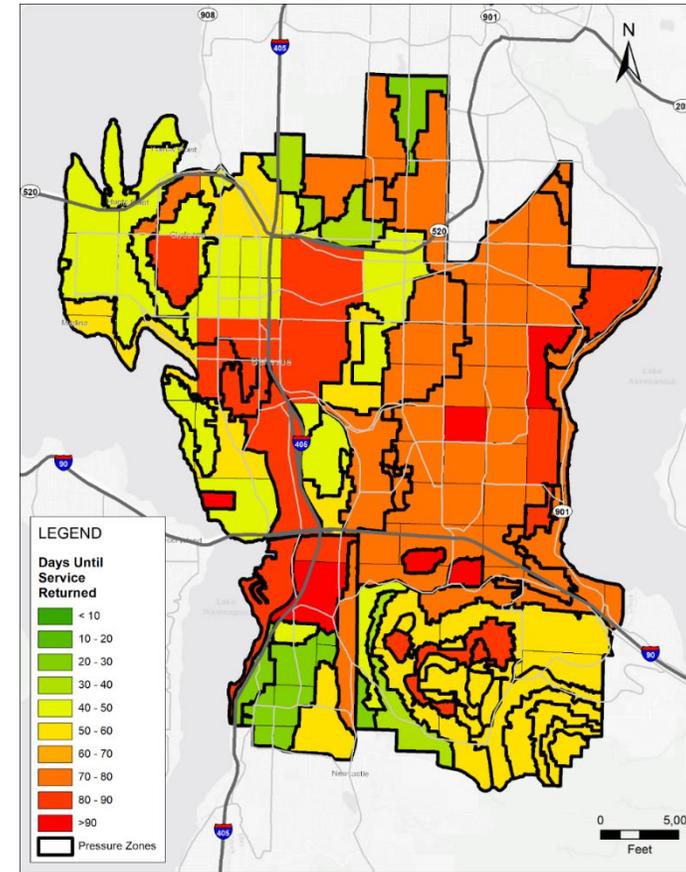


# Estimated Water Service Restoration Times – Existing System

Cascadia Subduction Zone  
Mw 9.0

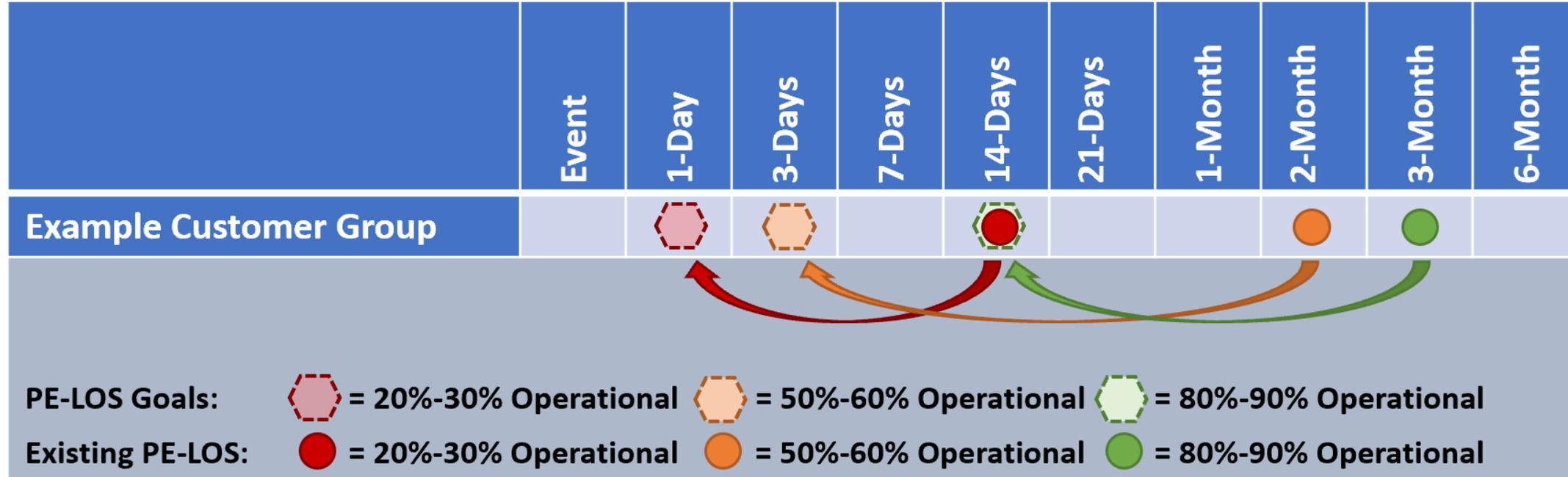


Seattle Fault Zone East  
Mw 6.6



# PE-LOS Goal “Targets”

# Post-Event Level of Service (PE-LOS) Goal "Target" Charts



# Bellevue Water System: Long-Term PE-LOS for SFZE

SFZE	Event	1-Day	3-Days	7-Days	14-Days	21-Days	1-Month	2-Month	3-Month	6-Month
Emergency Room Hospitals										
Designated Resilient Supply Points <sup>1</sup>										
Community Recovery Facilities <sup>2</sup>										
Essential Businesses <sup>3</sup>										
Basic Domestic Service to All Customers										
Existing Service Restored										

Bellevue PE-LOS Goals:  = 20%-30% Operational  = 50%-60% Operational  = 80%-90% Operational

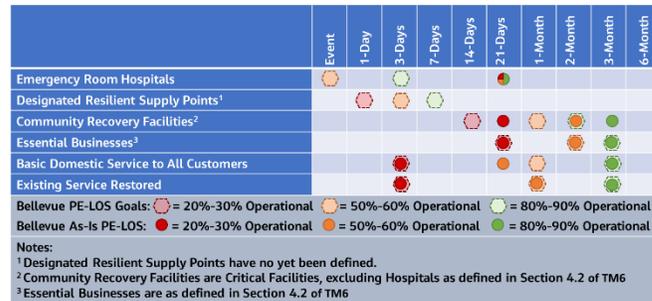
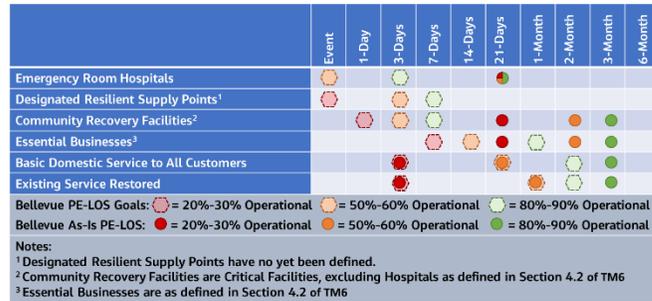
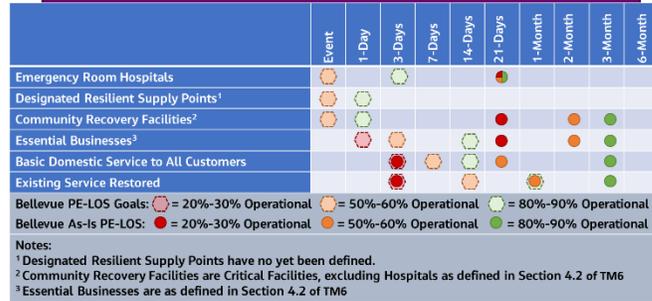
Bellevue As-Is PE-LOS:  = 20%-30% Operational  = 50%-60% Operational  = 80%-90% Operational

**Notes:**  
<sup>1</sup> Designated Resilient Supply Points have not yet been defined.  
<sup>2</sup> Community Recovery Facilities are Critical Facilities, excluding Hospitals as defined in Section 4.2 of TM6  
<sup>3</sup> Essential Businesses are as defined in Section 4.2 of TM6

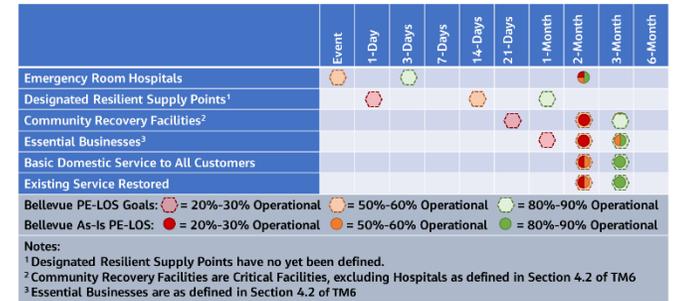
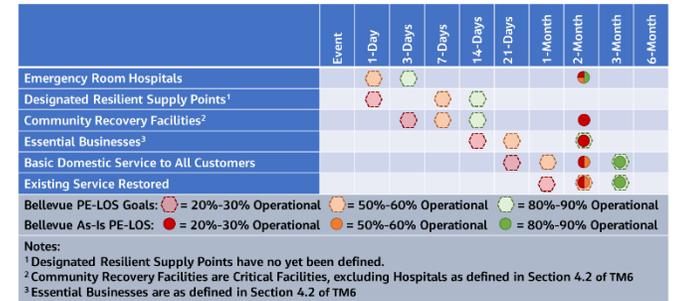
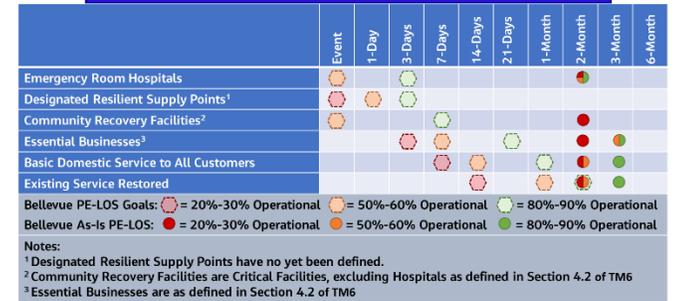
# PE-LOS Goal and Planning Development Process



## Cascadia Subduction Zone



## Seattle Fault Zone East



Long-Term

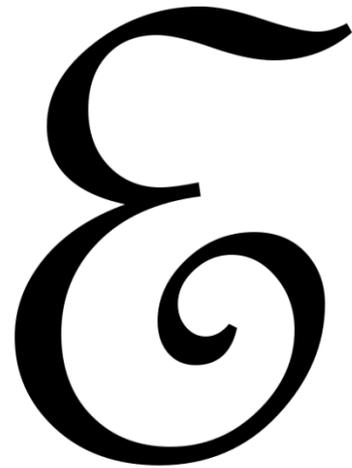
Mid-Term

Short-Term

# CEU Virtual Attendance Poll Question 2 of 2

PE-LOS is short for:

1. Pre-Emergent Liquefaction Of Soils
2. Performance Evaluations: Limited Optimized Solutions
3. Post-Event Level of Service



of



# Seismic Resilience Improvements Alternatives

# Regional Water Supply System Resilience Improvements

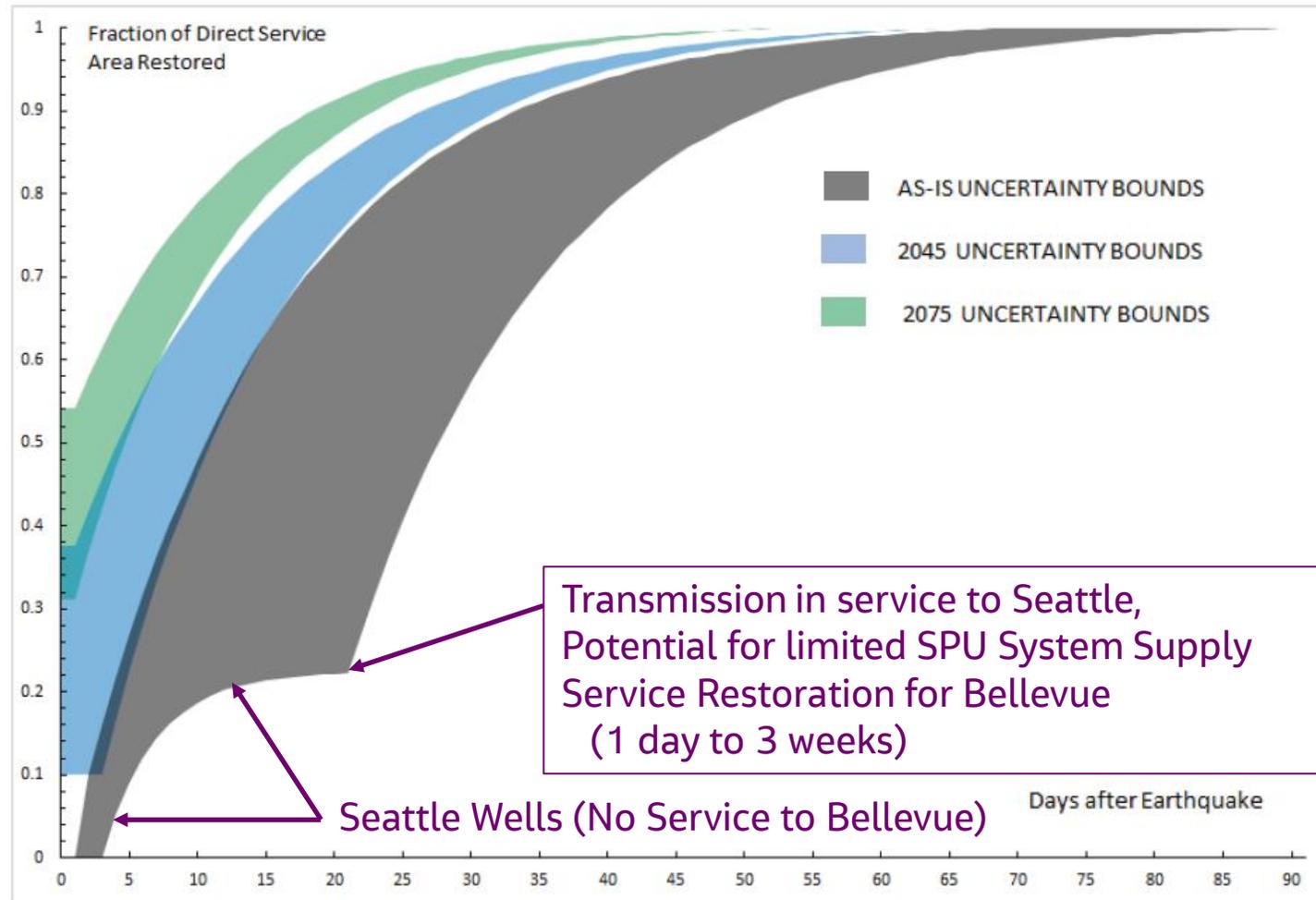


Figure ES-3. Retail service area restoration estimates after catastrophic earthquakes: current condition, after 20+ years of seismic upgrades, and after 50+ years of seismic upgrades

Source:  
SPU 2018  
Seismic Study

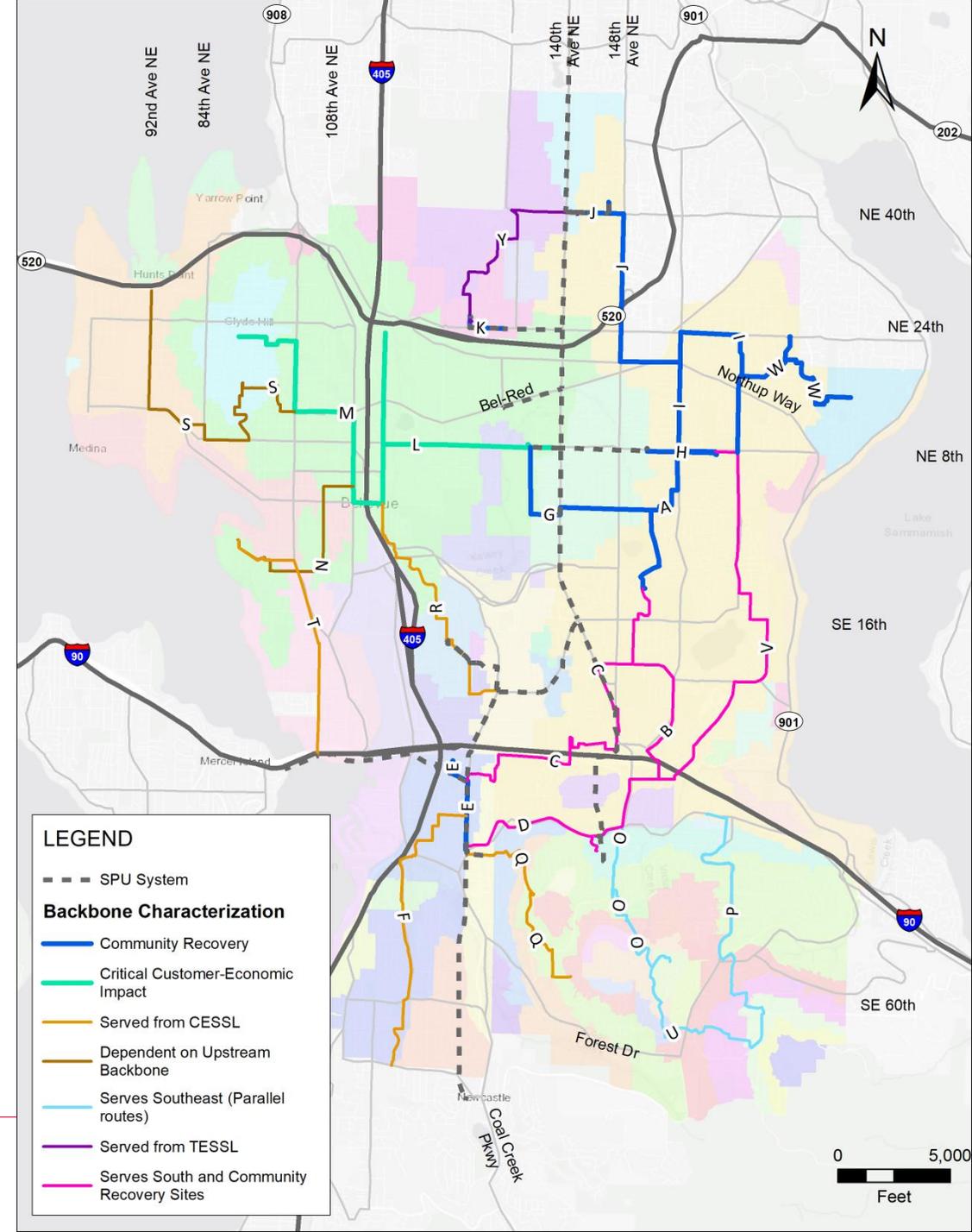
## Other Water Supply Improvements

- Develop Emergency City of Bellevue Supply Well Sources
- Interconnections with Adjacent Water System Groundwater Supplies
- Emergency Water Treatment of Surface Water Sources



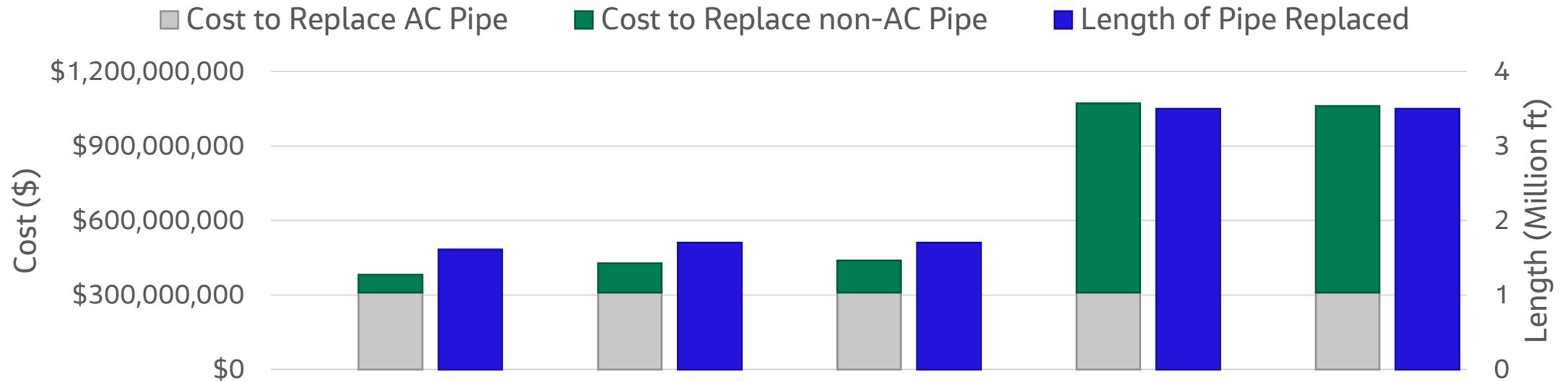
# Resilient Seismic Backbone Pipelines

- Supply source connections and delivery
  - Regional Supply System
  - Local Emergency Wells and Supplies
- Supply to critical customers
- Connections/customers served
- Coordinate with facility improvements to support delivery between pressure zone service areas



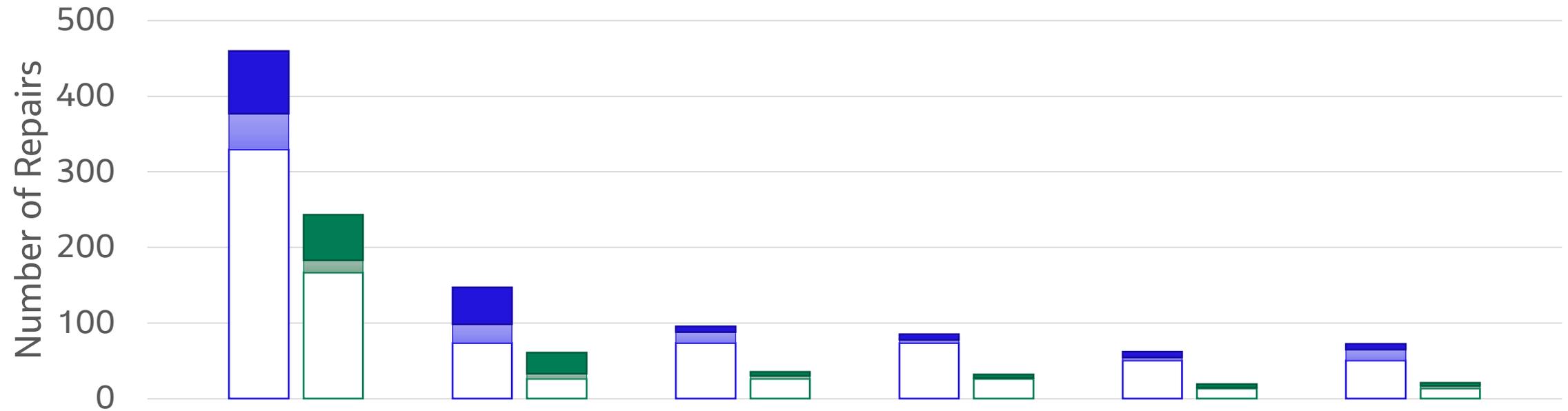


# Pipe Replacement Alternatives - Costs



	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Vulnerability	Pipe Materials				
High	Unrestrained DI	ERDIP	ERDIP	ERDIP	ERDIP
Moderate	Unrestrained DI	Restrained DI	ERDIP	ERDIP	Restrained DI
Low	Unrestrained DI	Unrestrained DI	Unrestrained DI	Restrained DI	Restrained DI

# Pipe Replacement Alternatives – Effects on Post-Event Pipe Repairs



Legend		Exist. System	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
SFZE	CSZ	Vulnerability	Pipe Materials				
Blue	Green	High	Unrestrained DI	ERDIP	ERDIP	ERDIP	ERDIP
Light Blue	Light Green	Moderate	Unrestrained DI	Restrained DI	ERDIP	ERDIP	Restrained DI
White	White	Low	Unrestrained DI	Unrestrained DI	Unrestrained DI	Restrained DI	Restrained DI

# Operational Mitigation Strategies

- Surface Water Drafting for Fire Protection
  - Already practiced by fire department, significant reduction in fire suppression response
- Personal Preparedness Education
  - Can help reduce impact to residents
- Fire Hydrant Jumper Hoses
  - This is a potential option to bypass breaks to serve critical customers
- Community Distribution Points
  - Resilient locations to serve water
  - Start with wells and tanks with seismic valves
- Blivets
  - Potentially valuable to support emergency water distribution in south Bellevue
- Spare Parts
  - Maintain adequate inventories

# **Prioritizing Improvements to Achieve PE-LOS Goals**

# Using LOS to Drive Improvement Identification: SFZE Long Term

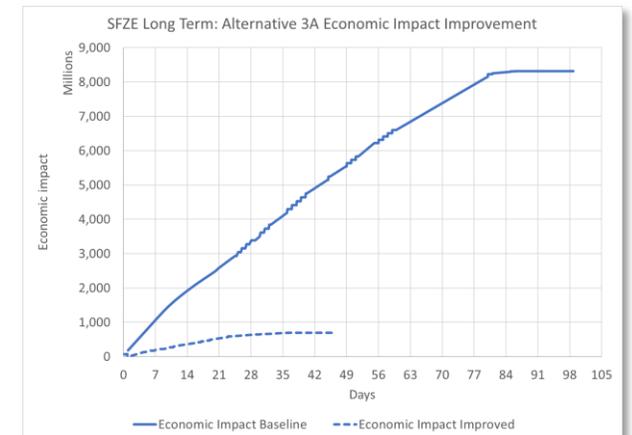
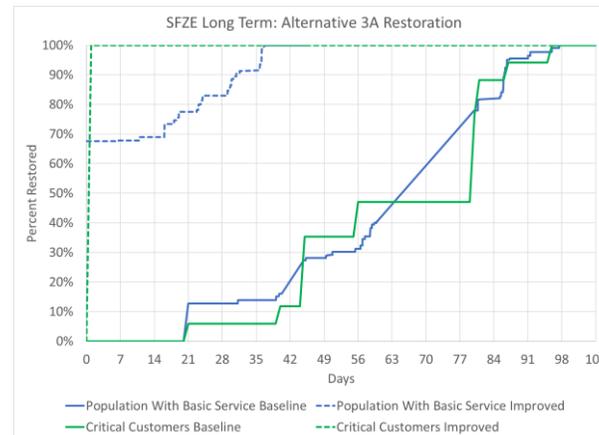
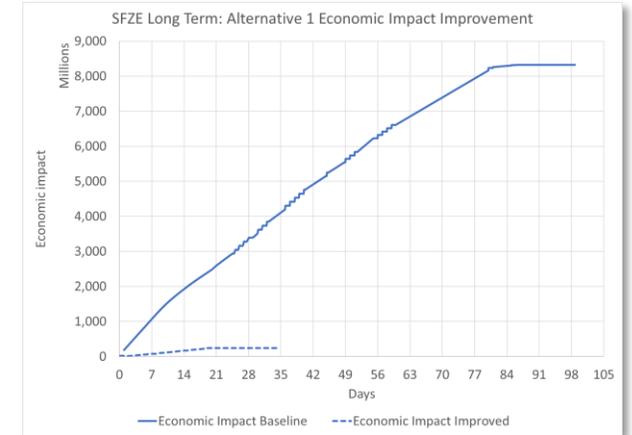
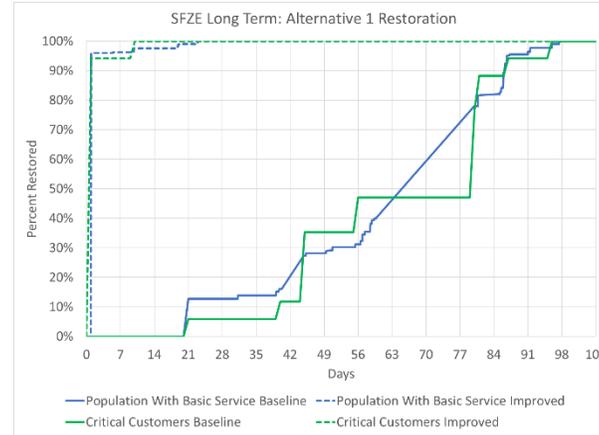
SFZE	Event	1-Day	3-Days	7-Days	14-Days	21-Days	1-Month	2-Month	3-Month	6-Month
Emergency Room Hospitals	●		●					●		
Designated Resilient Supply Points <sup>1</sup>	●	●	●							
Community Recovery Facilities <sup>2</sup>	●			●				●		
Essential Businesses <sup>3</sup>			●	●		●		●	●	
Basic Domestic Service to All Customers				●	●		●	●	●	
Existing Service Restored					●		●	●	●	
Bellevue PE-LOS Goals: ● = 20%-30% Operational   ● = 50%-60% Operational   ● = 80%-90% Operational Bellevue As-Is PE-LOS: ● = 20%-30% Operational   ● = 50%-60% Operational   ● = 80%-90% Operational										

Supply Immediacy  
 Hardened Supply to Community  
 Recovery and Critical Facilities

Supply Improvements  
 Hardened Pressure Zones  
 (broad coverage)

# SFZE Long Term Restoration Options – PE-LOS and Economic Benefit

Alt.	Supply Improvements	Pipe and Facility Upgrades	Relative Cost
L1	SPU Supply Resilience Improvements	Hardening Systemwide	\$\$\$\$\$
...	...	...	...
L3A	Emergency Well Supplies, SPU Supply available in 7 days	Key Pressure Zone Hardening, Partial Resilient Backbone	\$\$\$
...	...	...	...



## Questions?

- Doug Lane, City of Bellevue – [dlane@bellevuewa.gov](mailto:dlane@bellevuewa.gov)
- Matt Maring, Jacobs – [matt.maring@jacobs.com](mailto:matt.maring@jacobs.com)

Thank You

**Jacobs**

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Reinventing tomorrow.

