8. SEISMIC DESIGN STANDARDS FOR NEW FACILITIES AND PIPELINES

One of the most important and cost-effective long-term seismic improvement strategies SPU can adopt is to ensure that all new facilities are designed to be earthquake-resistant. Almost all types of structures are covered under current seismic building codes and standards. Existing national building codes can be used to construct seismic-resistant facilities that are likely to meet desired performance requirements. However, buried water pipelines are not currently addressed in United States seismic standards and codes. A few water utilities, such as the East Bay Municipal Utility District and Los Angeles Department of Water and Power in California, have or are developing utility-specific seismic standards for all facilities.

8.1 New Nonpipeline Facilities

In the future, SPU may supplement established codes and standards with utility-specific requirements. For now, making sure that existing codes and standards are followed will enable SPU to gradually develop a seismic-resistant water system. There may be instances, such as for buried reservoir seismic upgrades, when facility-specific criteria that go beyond the building codes are needed. Because appropriate criteria will typically be project-specific, development of specialized analysis, design, and performance criteria will be prepared on a case-by-case basis.

8.2 Occupancy Category for Nonpipeline Facilities

In current codes and standards, determination of the appropriate occupancy category for a new facility is defined in ASCE 7. There are four occupancy categories that range from I for the least critical facilities to IV for facilities that need to remain functional after a seismic event. Any facility that is needed to supply fire suppression water is categorized as Occupancy Category IV, Essential Facilities. Consequently, most SPU water system facilities are considered essential facilities. Even administration and warehousing facilities may be considered essential facilities if they are needed to ensure the flow of firefighting water. By default, all new SPU facilities should be defined as essential facilities providing there is a mechanism to lower the occupancy category if warranted:

> All new facilities, including but not limited to water storage facilities, pump stations, emergency response facilities and office spaces, shall be designed as Essential Facilities, Occupancy Category IV in accordance with the latest edition of ASCE 7, Minimum Design Loads for Buildings and Other Structures, and the Seattle Building Code. The Transmission and Distribution Planning Section Manager may grant waivers that allow design to a lesser occupancy category on a case-by-case basis if the Transmission and Distribution Planning Manager believes the facility does not need to remain functional/operational after a seismic event.

8.3 Existing Facilities

Seismic upgrade design standards for existing facilities are not covered in this section. Facility criticality and function, remaining facility life, and financial costs are some of the considerations that must be considered when determining the appropriate upgrade criteria. The appropriate performance level design criteria should be determined on a case-by-case basis. ASCE 41 (American Society of Civil Engineers 2017) is an industry standard that can be used to guide existing facility upgrade analysis and design.

8.4 Seismic Design Standards for New Buried Pipelines

SPU's approximately 1900 miles of transmission and distribution pipelines constitute SPU's most valuable (in terms of replacement cost) asset class. With a total replacement cost that is in the billions of dollars, only the most critical and vulnerable (highest risk) pipelines can be considered for proactive replacement. Most pipelines will not be considered for seismic improvement until they are replaced for age, obsolescence or capacity reasons.

8.4.1 Pipeline Classifications

SPU's pipelines have been categorized/defined as follows:

Primary Backbone Pipelines: transmission pipelines that convey water from the Tolt Reservoir or Lake Youngs Treatment Plant to the terminal reservoirs.

Secondary Backbone Pipelines: Transmission pipelines that convey water from the terminal reservoirs to distribution reservoirs or large service areas. Because Lake Youngs can supply the Cedar system for approximately four weeks, the transmission pipelines from the Landsburg Diversion to Lake Youngs are defined as secondary backbone pipelines.

Hospital/Critical Facility Watermains: watermains that are needed to supply hospitals or other critical facilities that must remain operational after an earthquake.

Firefighting Mains: mains needed to supply water to within 2,500 feet of any location in the City of Seattle.

Ordinary Mains: all watermains that are not classified as backbone, hospital/critical facility, or firefighting mains.

A map of the backbone pipelines and hospital/critical watermains is shown on Figure 8-1. As upgrade opportunities arise and discussions with the fire department continue, some watermain classifications may change.

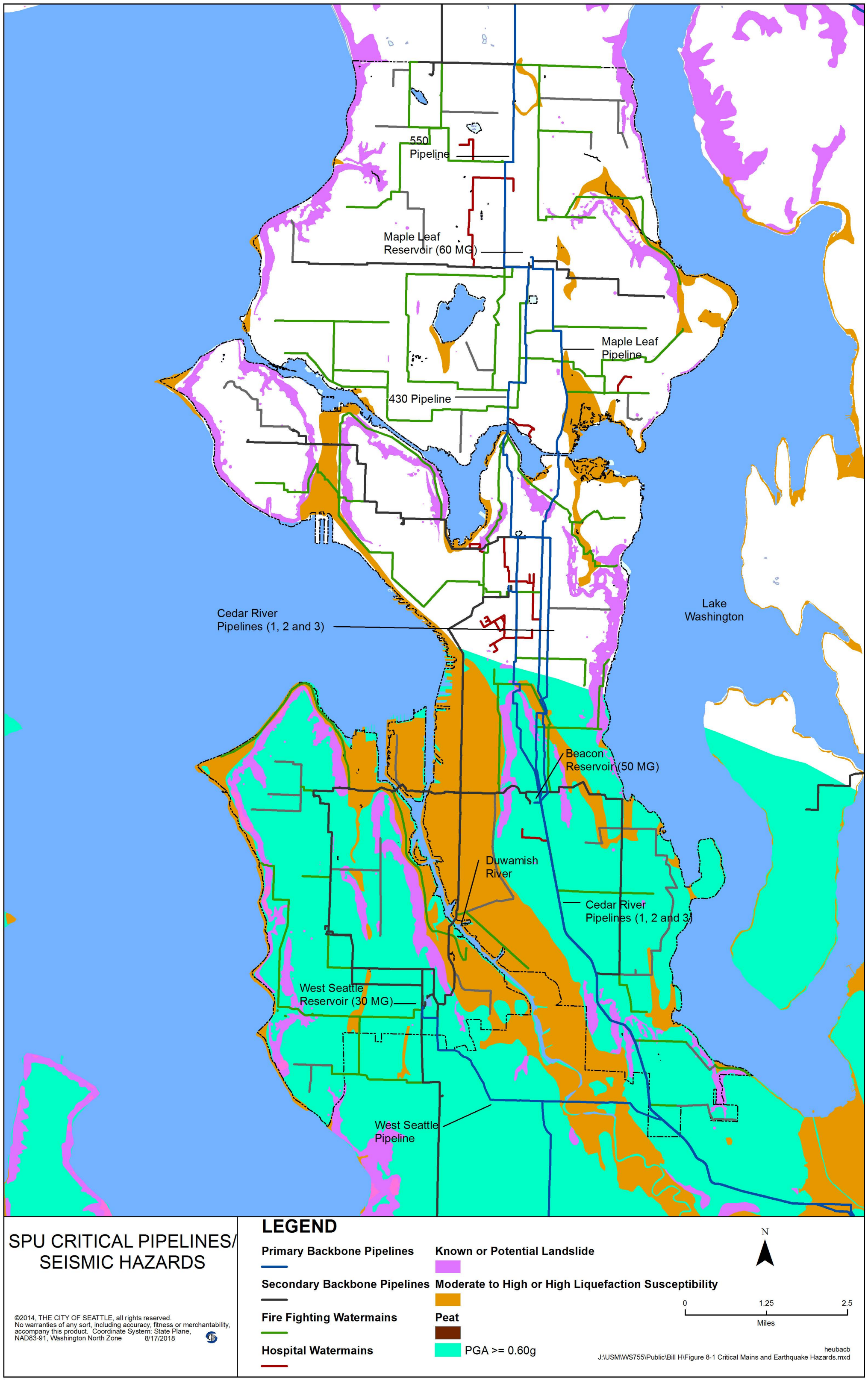

Figure 8-1. SPU critical pipeline map

8.4.2 Pipeline Standards Background

As discussed in Section 4, pipeline failures can be attributed to either failures caused by PGDs or transient effects caused by seismic wave propagation. Most pipeline damage is attributed to PGD.

Although ASCE is currently developing a manual of practice to address seismic design of buried water pipelines, there are no official standards that govern seismic design of water pipelines in the United States. The American Lifelines Alliance (ALA) published a set of pipeline guidelines in 2001 that are sometimes used, but they are nearly 20 years old and have never been officially recognized or adopted by organizations that publish standards. The standards presented in this section are based on ISO 16134, *Earthquake- and Subsidence Resistant-Design of Ductile Iron Pipe* (International Organization for Standardization 2006) and practices used in Japan for seismic-resistant watermains. Currently, there are no equivalent seismic standards for other types of pipe materials.

ISO 16134 defines three performance criteria, with performance levels for each criterion:

- The ability of the pipe joint to allow longitudinal expansion or contraction:
  - S-1: joint can expand or contract at least ±1% of each pipe segment length
  - S-2: joint can expand or contract at least ±0.5% of each pipe segment length
  - S-3: joint can expand or contract less than ±0.5% of each pipe segment length
- The tensile force that would be required to pull the pipe joint apart:
  - A: the force required to pull the joint apart, expressed in kilonewtons, is at least 3 multiplied by the pipe diameter expressed in millimeters
  - B: the force required to pull the joint apart, expressed in kilonewtons, is at least 1.5 multiplied by the pipe diameter expressed in millimeters
  - C: the force required to pull the joint apart, expressed in kilonewtons, is at least 0.75 multiplied by the pipe diameter expressed in millimeters
  - D: the force required to pull the joint apart, expressed in kilonewtons, is less than 0.75 multiplied by the pipe diameter expressed in millimeters
- The ability of the pipe joint to rotate:
  - M-1: joint can deflect at least ±15˚
  - M-2: joint can deflect at least ±7.5˚
  - M-3: joint can deflect less than ±7.5˚

Earthquake-resistant ductile-iron pipe (ERDIP) that meets the IS0 16134 S-1, A, and M-2 performance criteria has been in use for over 40 years in Japan. There have only been a few earthquake-related failures of ERDIP in Japan, and these failures have been attributed to improper installation. Recently, United States ductile-iron pipe manufacturers have developed, validated through testing and are marketing ERDIP that meets the ISO 16134 standards. Recent earthquakes have demonstrated that butt-welded steel pipe and fusion welded high-density polyethylene (HDPE) pipe provide superior ductility and robust performance during earthquakes. Polyvinyl chloride (PVC) pipe manufacturers have also developed, validated through large-scale testing, and are marketing PVC pipelines with restrained joints that are able to accommodate significant earthquake-induced ground deformation.

The ultimate intentions of the seismic pipeline standards developed by SPU are to:

1. Maximize the likelihood that backbone, hospital/critical facility, and firefighting mains remain functional after a major earthquake. It is recognized that although PGDs are most likely in those areas that have already been identified, PGDs can occur in other areas that may not yet have been identified as being susceptible to PGD. Consequently, earthquake-resistant pipe is required for all backbone, hospital/critical facility, and firefighting mains, regardless of whether or not the alignment lies in an area that has been identified as susceptible to PGD. Because backbone pipelines are the most critical pipelines, site-specific analysis is required for backbone pipelines.
2. Eliminate most, but not necessarily all, pipeline breaks in ordinary distribution system mains. Past earthquake experience has shown that by using earthquake-resistant pipe, almost all failures will be eliminated. Wave propagation effects and unexpected PGDs will result in some additional failures in areas that have not been identified as susceptible to PGD. Even if earthquake-resistant pipe is not used in these areas, the number of failures is expected to be manageable.
3. Acknowledge that if surface ruptures occur in the SFZ, there will be ordinary (noncritical) watermain failures in the SFZ. Require earthquake-resistant transmission pipelines in fault zones that will withstand small fault rupture displacements but that may not withstand displacements of several meters if they occur. Because the SFZ and SWIF fault zones are so wide and there is uncertainty in the location and size of potential abrupt surface displacements, pipelines within the fault zones would need to be designed for large abrupt displacements for miles and would likely be prohibitively expensive.

Because most distribution pipe damage is expected within areas that are susceptible to PGD, ERDIP, butt-welded steel or HDPE pipe should be required in all areas that are subject to PGD. In areas of intense ground-shaking, transient waves can also damage pipelines. To reduce pipe damage in the areas of intense ground-shaking, pipeline joints should be restrained.

The most vulnerable area of water service is often at the service connection to the main. To allow for differential movement between the main and the service, the proposed standards will require a steel sleeve be placed around the main cock and HDPE sleeves around the service. The service should be constructed with flexible tubing that allows for gradual deformation.

Hydrant runs are less vulnerable than service runs, but can still be damaged if PGDs are large enough. However, accommodating all possible PGD is expensive. The minimal amount of differential displacement provided in the standards may prevent most failures, but not all. American Pipe has developed a seismic-resistant fire hydrant assembly. However, SPU has had mechanical problems with these hydrants.

8.4.3 Proposed Standards for Incorporation Into SPU's Design Standards and Guidelines

The proposed standards for new buried watermains are presented in Appendix D. Before these standards can be officially included in SPU's Design Standards and Guidelines, they need to go through a formal review and acceptance process. After the ASCE manual of practice on the seismic design of water and wastewater pipelines is completed, the SPU standards may be updated so they are better coordinated with these guidelines.