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REPORT ON

ENGINEERING RESEARCH SUMMARY FOR THE OREGON DEQ SEISMIC RULES DEVELOPMENT

by
Haley & Aldrich, Inc.
Portland, Oregon

for
Oregon Department of Environmental Quality
Portland, Oregon

File No. 0206559-000
August 2023

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29 August 2023
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Oregon Department of Environmental Quality
700 NE Multnomah Street, Suite 600
Portland, Oregon 97232

Attention: Svetlana Lazarev

Subject: Oregon DEQ Seismic Rules Development

The enclosed engineering research summary report presents the results of our engineering code, standard, and regulation review and evaluation to support the Oregon DEQ Seismic Rule Development process. Haley & Aldrich, Inc. (Haley & Aldrich) conducted this research analysis and comparison in accordance with our work plan dated January 2023.

Sincerely yours,
HALEY & ALDRICH, INC.

Della Graham

Della M. Graham, R.G., PMP
Senior Project Manager

Enclosures

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PREPARED FOR
OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY
PORTLAND, OREGON

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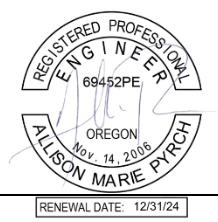

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List of Abbreviations

Abbreviation	Definition
AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
AHJ	Authority Having Jurisdiction
ALA	American Lifelines Alliance
ANSI	American National Standards Institute
API	American Petroleum Institute
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
Assessment	Seismic Vulnerability Assessment
AWWA	American Water Works Association
CEI	Critical Energy Infrastructure
CCR	California Code of Regulations
CFR	Code of Federal Regulations
CSZ	Cascade Subduction Zone
DBE	Design-Basis Earthquake
DEQ	(Oregon) Department of Environmental Quality
DOD	United States Department of Defense
FEMA	Federal Emergency Management Agency
Haley & Aldrich	Haley & Aldrich, Inc.
I	Seismic Importance Factor
IBC	International Building Code
ICS	Incident Command System
M	Magnitude
MCE	Maximum Considered Earthquake
MCE_R	Risk-Adjusted Maximum Considered Earthquake
MOTEMS	Marine Oil Terminal Engineering and Maintenance Standards
NIMS	National Incident Management System
OAR	Oregon Administrative Rule
O&M	Operations and Maintenance
OC	Occupancy Category
ODOT	Oregon Department of Transportation
ORS	Oregon Revised Statutes
OSS	Oregon Standard Specifications (Construction)
OSSC	Oregon Structural Specialty Code
PBEM	City of Portland Bureau of Emergency Management

Plan	Seismic Risk Assessment Mitigation Implementation Plan
PSHA	Probabilistic Seismic Hazard Analysis
PSU	Portland State University
RC	Risk Category
SB	Senate Bill
SUG	Seismic Use Group
TCLEE	ASCE Technical Council of Lifeline Earthquake Engineering
UFC	Unified Facilities Criteria
USACE	United States Army Corp of Engineers
USGS	United States Geological Survey
USVA	United States Veterans Affairs

1. Introduction

1.1 PROJECT BACKGROUND

In early 2020, Multnomah County's Office of Sustainability and the City of Portland Bureau of Emergency Management (PBEM) commissioned a study of the Critical Energy Infrastructure (CEI) Hub located along the Willamette River in Portland, Oregon. ECONW and Salus Resilience, a trademark of Haley & Aldrich, Inc. (Haley & Aldrich), completed the study to quantify the costs associated with the anticipated damage to the fossil fuel infrastructure located in the CEI Hub following a Cascadia Subduction Zone (CSZ) earthquake. At the time of the study, there was estimated to be a 37 percent chance of a major seismic event (greater than Magnitude 8 [>M8]) occurring on the CSZ within the next 50 years (Goldfinger, 2012). The study, which was released in January 2022, found that:

- The average year the tanks were built at the CEI Hub is 1954.
- Total potential release of materials stored at the CEI Hub as a result of a CSZ earthquake was estimated to range from 94.6 million to 193.7 million gallons.
- The resulting monetized costs could range up to $2.6 billion.
- Releases from the tanks at the CEI Hub could potentially spread downstream through the Willamette and Columbia rivers to the Pacific Ocean.

Following the release of this study in 2022, Senator Michael Dembrow of Oregon State Senate District 23 sponsored Senate Bill 1567 (SB 1567) which:

> *Requires owners or operators of bulk oils and liquid fuel terminals to conduct and submit to the Department of Environmental Quality seismic vulnerability assessments. Requires department to review and approve seismic vulnerability assessments. Requires owner or operator of existing bulk oil or liquid fuels terminal to submit seismic vulnerability assessment by June 1, 2024. Requires department to submit report on seismic vulnerability assessment to interim committees of Legislative Assembly by November 1, 2024.*
>
> *Requires owner or operator of bulk oils or liquid fuels terminal to properly implement seismic risk implementation plan approved by department. Directs Environmental Quality Commission to, by rule, adopt seismic risk mitigation program for bulk oils or liquid fuels terminals.*
>
> *Requires State Department of Energy to develop energy security plan and report plan to interim committees of Legislative Assembly by January 1, 2024.*

On 1 March 2022, the Oregon Legislature passed SB 1567 by a 23 to 2 vote, which gave the Department of Environmental Quality (DEQ) the authority to develop the program that will require evaluation and mitigation of the seismic vulnerability of bulk oils or liquid fuels terminals in Columbia, Lane, and Multnomah counties. The program will require facilities that have the capacity to store more than 2 million gallons of oil and/or fuel to assess risk and develop a plan to mitigate the seismic vulnerability risks as summarized in SB 1567.

1.2 PROJECT CONTRIBUTORS

This background report was prepared by Haley & Aldrich and was produced in tandem with research conducted by Portland State University (PSU). The research team consisted of scientists and geotechnical, civil, and structural engineers that performed a review of regulatory requirements and engineering standards relevant to earthquake risk, design, and resilience for fuel tanks (and similar systems) and appurtenant components. PSU completed an environmental justice study and a review of policy-relevant requirements from select jurisdictions, other states, and other countries. Haley & Aldrich complemented PSU's research by reviewing additional regulatory requirements from U.S. cities, counties, states, and federal agencies. The purpose was to identify model policies for reducing risk of fuel releases and provide best practices for mitigation planning and design for earthquake-induced fuel releases to outline a framework for emergency response and mitigation plans for large fuel terminals.

Haley & Aldrich and their structural engineering subconsultant (Degenkolb Engineers) completed a review of local, national, and international engineering standards and technical guidance pertinent to the design of fuel tanks and similar systems to withstand earthquakes and other extreme events. The goal of this review was to provide DEQ with pertinent engineering considerations, including engineering approaches to make facilities more resistant to an earthquake, earthquake hazard definitions, performance criteria, and other relevant engineering considerations.

1.3 PROJECT INTERESTED PARTIES

The DEQ established a rules advisory committee to represent various interests and provide input and suggestions during the development of the new rules. The committee represents perspectives from neighborhood, local emergency response, impacted neighborhoods, community groups, and regulated parties. The committee members were asked to provide input on DEQ proposals for the program, including equity and potential impacts to underrepresented communities. Members were expected to participate in Advisory Meetings, which included DEQ-facilitated discussions. The committee met four times via Zoom meetings. These meetings were open to the public. Haley & Aldrich supported DEQ for these meetings.

Committee Members:

- Amit Kumar, City of Portland Bureau of Development Services, Engineering Supervisor
- Andrew Holbrook, Kinder Morgan Pipeline, NW Region Director
- Chris Voss, Multnomah County Director of Emergency Management
- Doug Lenz, Columbia Pacific Bio-Refinery, Plant Manager
- Holli Johnson, Western States Petroleum Association, Senior Manager Local Government Affairs
- Jacque Wurster, Ready NW Eugene, Committee Chair
- Lindsey Hutchison, Willamette Riverkeeper, Staff Attorney
- Nancy Hiser, Linnton Neighborhood Association, Environmental Committee
- Paul Edison-Lahm, NAACP Environmental Justice Committee, Co-founder
- Peter Dusicka, Portland State University, Professor of Civil Engineering
- Randy Groves, City of Eugene, City Council
- Sterling Stokes, Campaign Manager, Portland Harbor Community Coalition
- Warren Seely, Beaver Drainage District, President

2. Regulatory Policies Review

PSU completed a review of policy-relevant requirements from select jurisdictions, states, and countries. Their review included, but was not limited to an environmental justice study, Japan's Law Framework, and the Seveso III Directive. Haley & Aldrich reviewed PSU's research summaries and incorporated their findings into Table 1, which includes a summary of all policies and engineering standards reviewed by the Haley & Aldrich research team, including:

- disaster resilience, risk management, and emergency response requirements;
- spill release, containment, prevention, and reporting requirements;
- design scenarios and procedures for seismic performance; and
- vulnerability assessment and engineering tank design requirements.

Results from Haley & Aldrich's review of PSU's policy research are summarized in Section 3.2.

3. Standards for Design Criteria and Magnitude Thresholds Review

3.1 REVIEW OF POLICIES AND STANDARDS FOR DESIGN CRITERIA AND MAGNITUDE THRESHOLDS

3.1.1 Methodology

Haley & Aldrich performed a review of engineering (industry) standards and guidance. All of these documents were reviewed with the objective of identifying key international, federal, state, and local requirements in codes and other relevant rules for fuel tanks and similar systems during earthquakes and other extreme events.

For the purposes of this background report, the types of documents reviewed included:

- **Regulatory**: documents that are adopted as law
- **Codes**: rules adopted by agencies that convey policy, protocol, guidance, or implementation requirements
- **Proposed regulations or codes**: rules or regulations that have not yet been enacted
- **Guidance documents**: engineering or industry standards that are developed and peer-reviewed by a professional organization, such as the American Society of Civil Engineers (ASCE) and are voluntarily accepted by an organization's membership as the best management approaches. The documents are often adopted by local and state agencies as code.

A full listing of the reference documentation reviewed is provided in Tables 1 and 2. The references include standards that address extreme risk scenarios (e.g., nuclear disaster) and more typical hazards, such as flood and seismic events, guidance that addresses risk reduction, and design standards for various types of tanks, pipes, buildings, and other structures. The sources of standards vary across discipline and site application, and include civil, electrical, mechanical, and nuclear engineering; civilian and military applications; and local, national, and international applications. The approach used across the different standards includes both prescriptive and performance-based approaches.

Table 1 – Research Summary summarizes the policies, codes, and engineering (industry) standards and specifies how those references apply to fuel facilities, earthquake risks, and policies or design criteria standards that aim to reduce the risk of fuel releases. Several codes (e.g., California Code of Regulations [CCR] 2022) contain multiple entries with summaries that address different sections of the code.

Table 2 – Comparison Matrix of Regulations, Policies, and Engineering Standards organizes the information collected on the policies and engineering standards based on criteria relevant to seismic risk reduction of bulk oils or liquid fuels terminals, including the following:

- risk categories;
- disaster resilience requirements (which includes risk management and emergency response plan requirements), spill, release, containment, prevention, and reporting requirements;
- design scenario and performance requirements and procedures (including geotechnical, seismicity, and structural requirements and tank design and seismic vulnerability assessment requirements);

- building code and seismic load requirements;
- tank and pipe parameters, such as capacity, fluid contents, construction material, and whether aboveground or buried; and
- anchorage, connections, and freeboard requirements.

These tables are attached at the end of the report.

3.2 KEY OBSERVATIONS

3.2.1 General Design Requirements

Based on the references reviewed, there is a diversity of regulations, codes, and policy requirements that vary from state to state and/or program by program, particularly with regard to containment requirements, spill requirements, and prevention.

Based on the documents and policies we reviewed, seismicity requirements and design scenarios vary across the engineering standards. However, the engineering references are typically meant to be used in conjunction with the building codes or other regulations. As such, the codes rarely dictate a prescriptive approach to seismicity or required performance for various systems. With the exception of building codes or the Uniformed Facilities Criteria (UFC) documents, all of the engineering references are guidelines until they are adopted into the building code. The adopted building codes and UFC documents are regulations to be followed during design, though waivers of some requirements may be allowed through an approval process with the Authority Having Jurisdiction (AHJ).

The standards vary widely from industry to industry. Most engineers and public agencies rely on the current standards developed by specialty industry groups, such as the ASCE for new and existing buildings or structures; American Water Works Association (AWWA), American Concrete Institute (ACI), and American Petroleum Institute (API) for tanks; American Society of Mechanical Engineers (ASME) for mechanical equipment and aboveground process piping; and AWWA, ASME, and ASCE for buried pipes and equipment. While many of the standards focus on different design and procedural elements, many also reference the same standards, such as ASCE 7, ASCE 41, ACI 650, API 620, API 650, or AWWA D110 and build on one another. Industry standards are guidance documents, voluntarily adhered to, except when referenced or adopted by an AHJ as code. For example, the Oregon Structural Specialty Code (OSSC) references ASCE 7-16 and International Building Code (IBC) 2021; therefore, in Oregon they are part of the Oregon Building Code.

American National Standards Institute (ANSI)-approved standards are ones that have undergone an accreditation process that is accepted by a consensus of reviewers. An ANSI-adopted standard may bear both the original organization’s designation and the ANSI designation, for instance ASME/ANSI B31E-2008.

A common thread across the design procedures and performance requirements is to apply whichever requirement is more stringent when requirements conflict. Some jurisdictions call out specific standards (IBC 2021 and ASCE 7) to apply when a building or other permit is triggered. This is especially true for retrofitting or rehabilitating existing facilities (ASCE 41 and UFC 3-301-05a).

Rarely do tanks or process piping systems require building permits if there is no building or structure involved. However, the City of Portland does require a structural permit review of new tank construction on private property. Some jurisdictions (including City of Portland) require a plumbing permit or site (zoning) permit instead of a building permit that could address the tanks and process piping when there is no structure involved. Piping or tanks that are located in a public right-of-way are subject to transportation street opening permits or right-of-way permits that focus on the site location and impacts on the public and transportation system. The building codes typically do not apply to the public right-of-way, as building permitting departments do not have jurisdiction. However, different standards, such as the American Association of State Highway and Transportation Officials (AASHTO) and the Oregon Standard Specifications for Construction (OSS), may be applicable for work within a right-of-way.

3.2.2 Seismic Design Risk Categories

Risk categories (RCs) are assigned to communicate the consequences and risk to human life or infrastructure in the event of failure, using a scale from I to V. The assigned RC determines a seismic importance factor (I) in most codes and standards. The seismic importance factor is used "to determine earthquake design lateral forces" and to "provide additional strength to critical facilities." (Charney et al., 2020)

Table 3 shows the relationship between the RC and seismic importance factor as used in the commonly adopted building codes and industry standards, such as ACI, API, ASCE 7, AWWA, IBC, OSSC, and UFC.

Table 3 – Relationship Between Risk and Occupancy Category to Seismic Importance Factor

Risk Category (RC)	Description*	Seismic Importance Factor (I_e)
I	Buildings and other structures that represent low risk to human life in the event of failure. Facilities can be taken out of service while repairs are performed.	1.0
II	All buildings and other structures except those listed in Risk Categories I, III, and IV. These facilities can be taken out of service while repairs are performed.	1.0
III	Buildings and other structures, the failure of which could pose a substantial risk to human life. Buildings and other structures, not included in RC IV, with the potential to cause substantial economic impact or mass disruption to day-to-day civilian life. Buildings and other structures, not included in RC IV (including, but not limited to facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing toxic or explosive substances where the quantity of the material exceeds a threshold quantity established by the AHJ and is sufficient to pose a threat to the public if released. Essential facilities that can remain in service or operational while repairs are made.	1.25
IV	Buildings and other structures designated as essential. Buildings and other structures, the failure of which could pose a substantial hazard to the	1.5

Risk Category (RC)	Description*	Seismic Importance Factor (I_e)
	community. Buildings and other structures, not included in RC IV (including, but not limited to facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, or hazardous waste) containing sufficient quantities of highly toxic substances where the quantity of the material exceeds a threshold quantity established by the AHJ and is sufficient to pose a threat to the public if released. Buildings and other structures (i.e., critical facilities) required to maintain functionality of other RC IV structures, must remain in service or operational during and following a seismic event with insignificant damage.	
V	Used in military-sensitive (national strategic defense assets – such as, but not limited to missile control systems) applications only where these facilities are required to remain elastic and operational.	1.0**

**Table 3 Footnote 1: Risk Category (RC) I through IV are defined in ASCE 7.*
***Table 3 Footnote 2: UFC 1-200-0 Change 1, 2022; Risk Category (RC) V is not used in the IBC or ASCE 7. UFC 301-01 defines RC V and requires a separate set of seismic design requirements included in UFC 301-02. These facilities are designed to remain elastic in a Maximum Considered Earthquake (MCE)-level event, so importance factors are not applied separately.*

API 650 Appendix E requires tank owners specify a Seismic Use Group (SUG) of I, II, or III. In API 650, commentary says "It is unlikely that petroleum storage tanks in terminals, pipeline storage facilities and other industrial sites would be classified as SUG III (RC IV) unless there are extenuating circumstances," meaning it is likely that most existing tanks are designed as SUG I or II (RC II or III).

AWWA recommends using RC IV for water tanks unless otherwise identified. ACI 350.3 recommends RC IV (I = 1.5) for hazardous material tanks, RC III (I = 1.25) for emergency response tanks, and RC I or II (I = 1.0) for all other tanks. Most other technical guidelines prepared by other professional organizations defer to local codes and regulations to determine the RC. At the discretion of the engineer or owner, higher RCs may be used even if not required by regulations.

The definition of what facilities and structures are assigned to which Risk Category varies by code and standard. Based on our research, there are examples where fuel tanks and facilities could be considered either RC III or RC IV as summarized in Table 4. Relevant language is in *italics*.

Table 4 – Comparison of Risk Category Definitions

Risk Category III (I=1.25)	Risk Category IV (I=1.5)
ASCE 7 defines RC III as structures *with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure*. ACI 350.3 defines RC III as tanks with *potential to cause a substantial economic impact, mass disruption*	ASCE 7 defines RC IV as essential facilities, buildings, and other structures that could pose a *substantial hazard to the community*, and those that *store hazardous fuels* containing sufficient quantities of highly toxic substances, where the *quantity of material exceeds a threshold quantity established by the AHJ*

Risk Category III (I=1.25)	Risk Category IV (I=1.5)
of day-to-day civilian life, or both, in the event of failure. API 620 defines (RC III) as *tanks storing toxic or explosive substances in areas where accidental release could be dangerous to public safety.* API 650 defines Seismic Use Groups using different numerals than Risk Categories. SUG II is similar to RC III (I = 1.25) and is defined as tanks storing material that may *pose a substantial public hazard and lack secondary controls to prevent public exposure* or those tanks providing direct service to major facilities.	*and is sufficient to pose a threat to the public if released*. ACI 350.3 defines RC IV as *hazardous material tanks* and tanks required to maintain water pressure for fire suppression. API 620 does not require I > 1.25 for any tanks. API 650 defines Seismic Use Group III similarly to RC IV (I = 1.5) as tanks providing necessary service to facilities that are *essential for post-earthquake recovery and essential to the life and health of the public*; or, *tanks containing substantial quantities of hazardous substances that do not have adequate control to prevent public exposure*.

3.2.3 Ground Motion Intensity Measures

Earthquake ground motions are characterized by various ground motion intensity measures which take into account amplitude, frequency, and duration of the ground motions. For building design using ASCE 7 (new), ASCE 41 (existing), and related standards, the key intensity measures are seismically induced ground accelerations at the site in question, calculated for a range of structural frequencies or periods. ASCE 7 and 41 and the building codes contain requirements for how the design accelerations are calculated. The design accelerations consider magnitude of various earthquakes, the distance from the earthquake source to the site in question, local soil characteristics, and the frequencies that impact a particular structure.

Building code seismic design ground motions are based primarily on Probabilistic Seismic Hazard Analysis (PSHA). PSHA incorporates multiple fault sources and ranges of magnitudes that could impact a particular site. Code-based building design can be based on overall PSHA results from the United States Geological Survey (USGS) or site-specific PSHA results performed by a geotechnical engineer. Design considers the ground shaking (measured by acceleration) felt due to multiple sources and various magnitudes at various structural periods. Several ground motion models are used to predict the response at a given site for each of the sources and magnitudes under consideration, with the results combined probabilistically. For the Portland area, key sources include the CSZ, with magnitudes ranging from approximately M8.4 to M9.3, and the Portland Hills Fault, with magnitudes ranging from approximately M6.4 to M7.1. For the broader, three-County area covered by SB 1567, the key seismic sources similarly include the CSZ, though may have different local fault hazards.

In ASCE 7, the PSHA is computed for a return period of 2,475 years and is referred to as the Maximum Credible Earthquake (MCE). In the most recent versions of ASCE 7 adopted by the OSSC and the IBC, the PSHA results are adjusted by a risk adjustment factor that is intended to provide a uniform hazard of collapse of buildings across areas with different seismic sources.

ASCE 7 also includes provisions for using deterministic ground motions for sites near faults. These ground motions are based on evaluation of individual scenario events (e.g., a specific earthquake event such as a M9.0 earthquake on the CSZ). Several scenario earthquakes are used in the evaluation, because the controlling event can vary depending on the structure and soil characteristics. Ground motion models provide a range of ground motion values for any given event and distance, and ASCE 7 uses the 84th percentile motions (near the upper end of the range). ASCE 7 also defines a lower limit to deterministic ground motions, such that probabilistic ground motions determined from PSHA control most sites not near a fault. Given the distance to the CSZ, probabilistic ground motions govern the building code's seismic hazard for sites in the three counties covered by the rule.

For design using ASCE, the PSHA and deterministic MCE ground motion accelerations results are further modified by a two-thirds factor to develop the Design-Basis Earthquake (DBE). These factored accelerations developed for the DBE are used in design equations that are calibrated to this level of seismicity while maintaining the overall goal of a limited probability of collapse over the lifespan of the structure.

3.2.4 Emergency Planning

Nearly all policies and rules related to tank design require some form of disaster resilience planning (typically referred to as risk management and emergency response planning). Risk management plans may include a site-level vulnerability assessment. Emergency response and preparedness requirements vary greatly, with some organizations using Federal Emergency Management Agency's (FEMA's) National Incident Management System/Incident Command System (NIMS/ICS) process. Few engineering standards address emergency response. Some standards include spill, release, containment, and reporting requirements.

The American Lifelines Alliance (ALA) recommends that a cost-benefit analysis be included in the engineering planning or feasibility phase of seismic improvement projects (ALA, 2005). This may include comparing cost factors, such as the capital costs of seismic improvements, loss of revenue to the owner and their tenants, and the liability cost of physical and environmental damage. However, cost based on ALA's recommendation should not be the only consideration. The benefits of continuous operations (at least as long as necessary for safe shutdown) include minimal damage or repairs following a seismic event.

3.3 RESEARCH FINDINGS

In Table 5 we summarize the findings from the information collected and presented in Table 2 – Comparison Matrix.

Table 5 – Summary of Findings and Recommendations

Criteria	Definition	Findings	Commentary
RISK CATEGORY (RC)	A categorization of buildings and other structures for determination of flood, wind, tornado, snow, ice, and earthquake loads based on the risk associated with unacceptable performance (ASCE-7). Typically ranges from I to IV, with IV being the most critical and expected to be functional during and after a catastrophic event. (An exception is RC V used by the military for sensitive strategic military assets.)	Risk categories are scaled from I to IV according to ASCE 7. RC III has a seismic importance factor (I = 1.25) and RC IV has I = 1.5. U.S. Department of Defense (DOD) Building Code (UFC –1-200-01u, C1) uses categories I through IV and an additional category V (I = 1.0) which is for sensitive strategic military assets with additional requirements. ASCE 7 defines RC IV as critical buildings, facilities, and lifelines (including utilities) that are expected to be fully operational during and following an emergency, or operational long enough to safely shut down facilities, though slight insignificant damage is allowed. ASCE 7 defines RC III as essential buildings, facilities, and lifelines that are expected to remain functional while damages are being repaired. ASCE 7 indicates RC I and II are non-essential and can be taken out of service or closed while repairs are implemented. OSSC uses risk categories identified in the IBC. When related to a building, the risk category is related to occupancy. On a fuel facility site, there may be multiple risk categories for different structures or components. AWWA recommends using RC IV for water tanks unless otherwise identified.	Code-based building design relies on controlled structural damage as an earthquake energy dissipation mechanism. The building design importance factors are applied to structure designs to reduce the amount of allowable damage in design-basis ground motions. Higher importance factors are used to reduce the amount of allowable damage, resulting in stronger structures. Codes generally specify minimum design values, which can be increased if desired by the owner. API 650 commentary says "It is unlikely that petroleum storage tanks in terminals, pipeline storage facilities, and other industrial sites would be classified as SUG III unless there are extenuating circumstances," meaning it is likely that most existing tanks are designed as SUG I or II.

Criteria	Definition	Findings	Commentary
		ACI 350.3 recommends RC IV (I = 1.5) for hazardous material tanks, RC III (I = 1.25) for emergency response tanks, and RC I and II (I = 1.0) for all other tanks. API 620 uses an Importance Factor I = 1.25 for tanks storing toxic or explosive substances in areas where accidental release could be dangerous to public safety. API 650 relies on ASCE 7 but uses Seismic Use Groups (SUGs) instead of Risk Categories (RCs). API 650's SUG III corresponds to RC IV. SUG I = RC II.	
DISASTER RESILIENCE/RISK MANAGEMENT PLAN AND/OR EMERGENCY RESPONSE REQUIREMENTS	Identifies if there is a disaster resilience plan, risk management plan, or emergency response plan required – and any specific criteria mentioned.	Generally, disaster resilience plans are written emergency response plans and/or risk management plans that are recommended. In some cases, a resilience plan specific to the facility infrastructure will be prepared. Details of what is expected to be included are vague. The most detailed and prescriptive facility emergency response requirement is found in the 40 Code of Federal Regulations (CFR) 112.20 for protection of the environment.	
SPILL, RELEASE, CONTAINMENT, PREVENTION, AND REPORTING REQUIREMENTS	Identifies whether there are any cited spill, release, containment, prevention, and/or reporting requirements.	CCR 2022, Title 24 Marine oil Terminal Engineering and Maintenance Standards (MOTEMS) appear to be the most prescriptive when considering spill containment requirements. If mentioned at all, the other documents reviewed identify a performance approach to prevent spills or to protect the environment. ASCE Technical Council of Lifeline Earthquake Engineering (TCLEE) Monograph 12	

Criteria	Definition	Findings	Commentary
		recommends spill containment facilities be seismically designed and notes that historically, these have failed and have been overlooked in design. API and AWWA include inspection and maintenance requirements for tanks. ASME requires written operations and maintenance (O&M) plans (or manuals). California MOTEMS requires risk and hazard evaluations be included in their O&M manuals and inspections. Oregon Administrative Rule (OAR) 340 -141-0160 includes spill prevention, containment, and maintenance requirements.	
DESIGN SCENARIOS AND PROCEDURES, SEISMIC PERFORMANCE, VULNERABILITY ASSESSMENTS, AND TANK DESIGN REQUIREMENTS	Identifies seismic design scenarios, procedures, performance, or assessment requirements.	ASCE 7 describes the MCE as an earthquake which has a 2 percent exceedance in 50 years (or roughly a return interval of 2,500 years). (This is the most commonly referenced design earthquake by other standards). The latest versions of ASCE 7 use a risk-adjustment factor related to building performance and the overall seismic hazard, such that new building design is related to the risk-adjusted Maximum Considered Earthquake (MCE_R). ASCE 7 building design is based on two-thirds of these ground motion acceleration values, referred to as the Design Earthquake Ground Motions. ASCE 41 – Design level shaking for retrofit of existing buildings is identified at two levels: 5	For Oregon, ASCE 7 and 41 use ground motions that consider several earthquake sources, including the CSZ (range including M9.0) earthquake and site-applicable crustal faults. Ground motions for design of retrofits of existing structures such as those governed by ASCE 41 are generally lower than those for new structures such as those governed by ASCE 7. These lower design values allow existing buildings to meet a lower standard, given that they may have a shorter remaining use and that fully meeting new building codes may not be technically or economically feasible.

Criteria	Definition	Findings	Commentary
		percent in 50 years and 20 percent in 50 years depending on the desired performance level. Seismic design values are either identified on maps within technical standards (e.g., ASCE 7) and codes (e.g., IBC) or are developed by engineers through site-specific response spectra analyses. These values are based on guidance and values developed by the USGS. ASCE 7 also includes provisions for using deterministic ground motions for sites near faults. These ground motions are based on scenario events. Several scenario earthquakes are used in the evaluation because the controlling event can vary depending on the structure and soil characteristics. The ground motions are computed at the 84th percentile. Tank design requirements vary by material, contents, and use. Industry standards by AWWA and API are commonly used for steel and concrete water tanks, and steel petroleum tanks, respectively. API 650 and other similar standards reference ASCE 7 to assess the minimum seismic design loading requirements. Both API and AWWA design procedures assume some damage to tanks as the result of design-basis earthquake ground motions. The amount of acceptable damage is lower for the higher RCs/SUGs. Oregon Department of Transportation (ODOT) and AASHTO consider a 1,000-year earthquake return interval as the design for	ASCE 7 defines a lower limit to deterministic ground motions, such that probabilistic ground motions determined from PSHA control for most sites near a fault. For example, given the distance to the CSZ, probabilistic ground motions govern the building code's seismic hazard for sites in Portland.

Criteria	Definition	Findings	Commentary
		the no-collapse scenario and the 500-year (CSZ for ODOT) return interval as operational criteria.	
APPLICABLE TANK OR STORAGE CAPACITY	Identifies any cited threshold for storage capacity where the code or standard applies.	Only two references list a capacity threshold or requirement – OSSC and the City of Escondido, California. OSSC 2022 Section 2802.1.1 – applies aggregate tank capacity restrictions for fuel oil, flammable, and combustible liquid storage tanks within buildings. Capacity limits range between 660 and 3,000 gallons based on fire prevention systems.	For discussion of sloshing, see *Anchorage, Connections, and Freeboard* below
TANK AND PIPE CONTENTS	Identifies specific design requirements based on the intended contents of the tank, storage, or piping system where codes or standard applies.	References reviewed include different content types in storage tanks and piping systems from water, liquid hydrocarbons, crude oil, petroleum, gasoline, chemical, paper, processing, liquid natural gas, liquified anhydrous ammonia, produced water, injection water, brine, biofuels and slurries, and semi-conductors. The contents of the tank or piping system dictate which regulation or industry standard applies and the degree of stringency of the design requirements (for instance AWWA D100, API 625, API 650, etc.) Radioactive contents had the most stringent design requirements, with water and natural gas somewhat less stringent, and most other materials having the least stringent design criteria.	

Criteria	Definition	Findings	Commentary
PIPELINE REQUIREMENTS	Identifies aboveground and buried piping systems, including any attached valves, metering, or instrumentation.	Aboveground piping systems (also called process piping) are located on site and covered by ASME standards or under ALA guidance. (i.e., ASME/ANSI B31E-2008 – Standard for the Seismic Design and Retrofit of Above-Ground Piping Systems.) Buried piping systems are typically located in the public rights-of-way or areas with traffic or railroad crossings. ALA provides guidelines for the Seismic Design and Retrofit of Piping Systems. ASCE has no specific seismic standards for piping systems that are not inside a building or structure covered by ASCE 7 but references several conference papers with seismic design suggestions. (Spyras et al., 2014; Mahotram, 2013) Pipes and piping systems located inside a building or structure are covered by ASCE 7.	
BUILDING AND FACILITY REQUIREMENTS	Identifies specific building and facility standards.	Most codes and standards for building have adopted IBC and ASCE 7 for seismic requirements. ASCE 41 is referenced for seismic retrofitting of existing buildings. Building codes tend to be the most prescriptive and generally only apply to new buildings or existing buildings that require a permit due to change of occupancy, addition of square footage, building alterations, or repairs. In Portland, the City Code Chapter 24.85 Seismic Design Requirements for Existing	

Criteria	Definition	Findings	Commentary
		Buildings requires permits for repair of catastrophic damage or mandatory or voluntary seismic strengthening.	
ANCHORAGE, CONNECTIONS, AND FREEBOARD	Identifies anchorage for tanks or connection requirements for pipes, conducts, or ducts attached to tanks and buildings and piping systems. Identifies the distance between the fluid and the inside roof of a tank.	Generally, API, ACI, ASCE, AWWA, and IBC require tanks in seismic zones to be anchored to their foundations. These references also require or recommend flexible connections and couplings to absorb differential movements from earthquakes. Tank standards (API, ACI, ASCE, AWWA, and IBC) indicate that tanks should have freeboard allowance, and roof structures should resist uplift pressures from sloshing force. In ASCE 7, the minimum requirements for freeboard are higher in RCs III and IV.	

4. Engineering Recommendations

4.1 SEISMIC CRITERIA

The bulk oil and liquid fuel storage and distribution facilities represent a high risk for public and environmental safety in a seismic event. SB 1657 requires such facilities to assess their seismic vulnerability and minimize the risk to their employees and the surrounding communities via mitigation of the seismic risks.

Based on the result of this research, a combination of a specified seismic hazard with a targeted performance level is judged to provide performance objective that design professionals can use for seismic assessments and mitigation planning.

Based on the research completed and DEQ's stated goals, the use of the ASCE 7 2,475-year return period design earthquake is recommended over lesser earthquake hazards identified by some other standards. Incorporating this design-level earthquake with a "Maximum Uncontained Spill" performance level as the target performance objective for the facilities provides a target for developing seismic mitigation schema. This approach represents a seismic performance target that is not directly defined by the applicable codes and standards, so seismic assessment and mitigation design will require performance-based principles, in that engineers will need to evaluate structures using the seismic criteria from the applicable codes and standards and interpret the results to determine the likelihood of an exceedance of a Maximum Uncontained Spill.

The engineering requirements to implement this approach are described below.

4.1.1 Seismic Hazard Level

To provide a seismic shaking design level for fuel tanks that is consistent with industry standards, meets local code requirements, and addresses site-specific seismic requirements, we recommend that DEQ refer to ASCE 7 for seismic design criteria, and specifically the DBE. ASCE 7 is updated regularly in a rigorous peer-reviewed process, references USGS data that is also reviewed and updated on a regular basis, and is adopted into OSSC on a regular schedule. ASCE 7 includes seismic design values calculated by the USGS that can be used directly, and procedures by which a geotechnical engineer can calculate site-specific ground motions. Further, many of the design guidelines for tanks and other structures already reference ASCE 7 for seismic design criteria. Use of the DBE is consistent with building design and with current design requirements for new tanks. As discussed in Section 3.2.3, the DBE is defined as two-thirds of the ground accelerations of the MCE_R. The earthquake data used to develop the design shaking level includes estimated shaking from all earthquakes expected at the site. For sites in Oregon, this includes the M9.0 CSZ earthquake and relevant local crustal faults.

4.1.2 Limiting Performance Level

The seismic performance level will consist of Maximum Uncontained Spill criteria, given the ground motions for the seismic hazard described above. For a tank, those ground motions are roughly equivalent to the performance expected for a SUG III (RC IV) tank designed per the current version of API 650.

By establishing performance criteria for fuel tanks, DEQ is allowing the owners and their engineers flexibility in mitigation design, the ability to use state-of-the-art practices to reduce seismic risk, and flexibility to develop a mitigation plan that meets the needs of the facility. From a structural engineering perspective, this is not intended to require performance based nonlinear seismic analysis in all cases, though it does not preclude such an analysis. However, this approach requires an engineer to use the applicable standards, such as API 650, to assess the damage given the rule required design-level ground motions and the likelihood of a spill as result of that damage.

4.1.3 New Construction vs. Existing Construction

Based on our research, design of seismic retrofits of existing facilities often targets a lower seismic standard than design of new facilities. Retrofit criteria in ASCE 41 and other design methods often allow a higher probability shaking level (lower ground acceleration) and/or lower structural performance level requirements that allow for additional damage in existing buildings versus new, such as designing for "non-collapse" instead of "life safety." Some building codes do require existing buildings to meet new building standards when substantial changes are implemented.

We understand that for consideration of public health, life safety, and environmental safety, DEQ proposes to hold the design of seismic mitigation of existing storage facilities to a standard equivalent to the design of new structures.

4.2 REQUIREMENTS FOR SEISMIC RISK ASSESSMENTS AND RISK MITIGATION IMPLEMENTATION PLANS

As indicated in SB 1567, Section 3, the owner or operator of a bulk fuel terminal must "…properly implement a seismic risk mitigation implementation plan that has been approved by the Department of Environmental Quality." At a minimum, SB 1567 requires owner or operators to identify actions with timelines to protect public health, life safety, and environmental safety within the facility, areas adjacent to the facility, and in other areas that may be affected by damage to the facility. DEQ has identified two steps to this process. The first is a Seismic Vulnerability Assessment (Assessment) and the second is a Seismic Risk Mitigation Implementation Plan (Plan). Based on our document review for assessment and mitigation designs of this nature, the following are standard tasks that should be completed and sections that should be included in these documents.

4.2.1 Seismic Vulnerability Assessment

The first step in this process is for owners or operators to prepare and submit to DEQ a facility-wide Assessment. The critical elements that must be included in the Assessment are defined in the Draft Fuel Tank Seismic Stability Rules, OAR 340-300-0003 (DEQ, 2023a). As part of our work, we reviewed requirements for seismic assessments, including both structural and geotechnical aspects. Based on our review and discussions with DEQ, typical elements of an Assessment should include geotechnical, structural, and safety assessments. Following is a general description of the guidelines for those assessments:

- The geotechnical and structural assessments should be prepared and stamped by professional engineers of record licensed in Oregon that specialize in geotechnical and structural engineering, respectively. The safety assessment should be prepared by a qualified safety professional.

- Geotechnical Assessment
  - Site Condition Assessment
    - Description of project site surface conditions, topography, and bathymetry (if adjacent to a body of water).
    - Description of regional and site geology, including soil stress history, deposition/erosion environment, and bedrock and soil geologic units.
    - Description of field explorations, including methods, standards, numbers, and types of explorations, testing, and instrumentation. Description of results including final exploration logs, field data, and profiles.
      - Field explorations (number, types, and depth) should be sufficient to categorize subsurface conditions at the site, including extent and properties of subsurface geologic strata of compressible, liquefiable, soft or loose soils, and bearing layers.
      - Field explorations should be sufficient to define the Site Class per OSSC. Both geotechnical and geophysical methods of investigation may be required.
    - Summary of laboratory testing performed and results.
    - Description of site subsurface conditions, including soil and rock units encountered, extents and properties of those layers, and groundwater conditions (include subsurface profiles).
  - Seismic Hazard Evaluation
    - Description of active seismic sources relevant to the site.
    - Description of seismic hazards at the site, including seismic evaluation criteria (expected ground shaking), liquefaction, settlement, surface effects, loss of strength, lateral spread, and slope stability, as appropriate.
    - Evaluate global stability of and anticipated ground deformations at storage tanks, associated containment structures (e.g., berms and walls), and other appurtenances which could affect the potential for fuel or oil spills.
    - Describe methods of analysis, assumptions, and results of analysis.
    - Description of the resulting effects on the structures on site.
  - Geotechnical Evaluation Criteria
    - Develop geotechnical criteria required for structural evaluation of existing facilities, including but not limited to seismic design parameters, estimated vertical settlement and lateral ground deformation, foundation bearing and lateral capacity (including reduced capacities for liquefied soils, if appropriate), and wall design parameters.
- Structural Assessment
  - Description of all onsite structures *where damage would result in a potential uncontained release of fuel,* including but not limited to above or underground tanks, pipes, foundations of structures, buildings, structures, ancillary components, spill

containment structures, transloading facilities, wharves, piers, moorings and retaining structures, loading racks, control equipment, and any other structures within the property line or properties operated together.

  - Description to Include the age, type of construction, and other relevant characteristics of each structure.
  - Description of expected seismic performance of each onsite structure included above. Use appropriate engineering standards such as ASCE 41, ASCE 61, API 650, etc., as the basis for each evaluation.
  - Structural assessment shall include consideration of all limit states that could result in a spill exceeding the specified performance.
  - Structural assessment shall include consideration of the existing and anticipated condition of the structure. A corrosion evaluation per API standards would meet the intent of this requirement for tanks.
  - Where the geotechnical evaluation finds that significant soil settlement or lateral spread is expected, include the effects of soil displacement in the structural analysis.
- Safety Assessment
  - Description of fire control and suppression systems and procedures and the potential impacts of seismic hazards on these systems.
  - Description of spill containment systems, equipment, and procedures in the event of an earthquake and their vulnerabilities to the identified seismic hazards at the site.
  - Description of onsite emergency equipment, operational safety measures, and personnel policies/availability and their vulnerabilities to the identified seismic hazards at the site.
- All assessments should provide a list of technical references used in completion of the assessment.

Based on our experience, a seismic assessment as described above would typically require between six to 18 months to complete. This would include site investigations, engineering evaluation and modeling, and report preparation. This timeline estimate does not include the contracting and procurement process for engineering design and support or review and response to DEQ's review of the assessment.

4.2.2 Seismic Risk Mitigation Implementation Plan

Following the Assessment, owners or operators will be required to prepare and submit to DEQ a facility-wide Plan. The Plan requirements, timelines, and approval criteria will be listed in the Draft Fuel Tank Seismic Stability Rules, OAR 340-300-004 (DEQ, 2023b). Based on our review, we anticipate Plans should include the following elements:

- Description of proposed mitigation measures, including but not limited to slope stabilization, ground improvement, foundation upgrades, structural improvements, containment stabilization, connection and piping improvements, and containment improvements and/or replacement.

- Description of engineering standards, analysis methods, and assumptions used in the development of mitigation measures.
- Description of expected seismic performance of the mitigated facility, including structures, containment, seismically induced ground and structure deformations, and ground improvement, as appropriate.
- Description of any potential fuel release based on expected seismic performance.
- Description of safety improvements, including but not limited to improvement, replacement or retrofit of spill containment and firefighting systems, personnel and operational changes, and emergency equipment and supply additions.

Based on our experience, mitigation plan development meeting the criteria described above would typically require between six to 24 months to complete. This would include any additional required site investigations, engineering design, calculation, and modeling, and plans and specification preparation. This timeline estimate does not include the contracting and procurement process for engineering design and support or review and response of DEQ's review of the plan.

5. Financial Impact Estimates

At the request of DEQ, Haley & Aldrich has developed a Class/Level 5 "order-of-magnitude" conceptual cost estimate range for the following items:

- Investigation, modeling, and preparation of an Assessment for a typical fuel facility;
- Engineering design, modeling, and preparation of a Plan for a typical fuel facility;
- Geotechnical and structural peer review of a typical Assessment; and
- Geotechnical and structural peer review of a typical Plan.

The cost estimates above are outlined in Table 6 – Fiscal Impacts (attached).

In addition to the costs above, implementation of the plan will incur significant cost for facilities that have been designed prior to current seismic design requirements. Mitigation costs will range based on facility size, age of infrastructure, and soil conditions. These costs could be minimal for newer facilities on good soils that only require minimal and operational upgrades to full replacement costs for facilities where ground improvement is required, and tank and containment design requires significant updates or full replacement.

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TABLES

TABLE 1 - RESEARCH SUMMARY TABLE
DEQ FUEL TANK SEISMIC STABILITY RULES DEVELOPMENT PROJECT

Regulatory Authority	Code/Policy	Summary of Policy/Code	Criteria/Requirement	Application to Fuel Facilities in Oregon
Federal				
Natural Hazard				
Environmental	40 CFR 112.20 - Title 40 Protection of Environment, Chapter 1 EPA, Subchapter D Water Programs, Part 112 Oil Pollution Prevention, Subpart D § 112.20 Facility response plans.	Facility Response Plan is required if the facility has the potential to cause "substantial harm" to the environment.	Plan must include: (1) Emergency Response Action Plan (ERAP); (2) demonstrate the facility has the resources to respond to a worst-case scenario discharge. Substantial harm is determined by any of the following: amount of storage (≥ 42,000 gallons and operations include over-water transfers of oil to or from vessels); a facility with a maximum oil storage capacity ≥ 1,000,000 gallons; a facility without secondary containment for each aboveground storage tank; a facility located at a distance such that discharge could injure fish, wildlife, or the environment or would shut down a drinking water intake; a facility that has reportable spill in past 5 years ≥ 10,000 gallons. A response plan shall follow the format of the model facility-specific response plan included in Appendix F to this part, unless an equivalent response plan has been prepared to meet state or other federal requirements. All facility response plans shall be consistent with the requirements of the National Oil and Hazardous Substance Pollution Contingency Plan (40 CFR Part 300) and applicable Area Contingency Plans prepared pursuant to Section 311(j)(4) of the Clean Water Act. The facility response plan should be coordinated with the local emergency response plan developed by the local emergency planning committee under Section 303 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (42 U.S.C. 11001 et seq.). §112.21 Facility response training and drills/exercises. (a) The owner or operator of any facility required to prepare a facility response plan under § 112.20 shall develop and implement a facility response training program and a drill/exercise program that satisfy the requirements of this section.	Emergency Response plan needs: facility response plans, area continency plans, facility response, drills, and exercises. Defines "substantial harm" based on amount of storage, maximum storage capacity, facility without secondary containment, distance to sensitive species, wildlife habitat, or drinking water sources, and history of spills.
Environmental	Clean Air Act, Section 112(r) - General Duty Clause - Risk Management Program (RMP) Rule, Chapter 2 Applicability of Program Levels	The RMP rule implements Section 112(r) of the 1990 Clean Air Act amendments, and requires facilities that use extremely hazardous substances to develop a Risk Management Plan and revise/resubmit every five years.	Program 1: Processes which would not affect the public in the case of a worst-case release (in the language of Part 68, processes “with no public receptors within the distance to an endpoint from a worst-case release”) and with no accidents with specific offsite consequences within the past five years are eligible for Program 1, which imposes limited hazard assessment requirements and minimal prevention and emergency response requirements. Program 2: Processes not eligible for Program 1 or subject to Program 3 are placed in Program 2, which imposes streamlined prevention program requirements, as well as additional hazard assessment, management, and emergency response requirements. Program 3: Processes not eligible for Program 1 and either subject to Occupational Safety and Health Administration's (OSHA's) PSM standard under federal or state OSHA programs or classified in one of 10 specified North American Industrial Classification System (NAICS) codes are placed in Program 3, which imposes OSHA’s PSM standard as the prevention program, as well as additional hazard assessment, management, and emergency response requirements.	Criteria used for defining worst-case scenarios based on the program level, as processes that would or would not affect public health and are subject to prevention programs.
State				
Natural Hazard				

TABLE 1 - RESEARCH SUMMARY TABLE
DEQ FUEL TANK SEISMIC STABILITY RULES DEVELOPMENT PROJECT

Regulatory Authority	Code/Policy	Summary of Policy/Code	Criteria/Requirement	Application to Fuel Facilities in Oregon
California	California Code Regulations (CCR) 2022 Title 24, Part CA. Building Code Ch. 31F - Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS)	The Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS) serves to fulfill the requirements of the Lempert-Keen-Seastrand oil spill prevention and response act of 1990. The code established "minimum engineering, inspection and maintenance criteria" for Marine Oil Terminals (MOTs) to prevent oil spills and to protect public health, safety, and the environment.	MOTs regulated by MOTEMS must undergo inspections (conducted annually), audits (conducted every four years unless otherwise recommended), and post-event inspections to ensure compliance with this code. These audits and inspections are a form of vulnerability analysis which then set forward mitigation requirements to which facilities must respond with a mitigation plan. Methodology for determining the seismic requirements at a given facility based on Design Peak Ground Acceleration (DPGA), Design Spectral Acceleration, and Design Magnitude, which will include site amplification effects and site liquefaction assessments. DPGA and Design Spectral Acceleration will be obtained from either the USGS Seismic Design Maps tool using ASCE/SEI 41 with the probability of exceedance in 50 years and appropriate site soil classifications. Or, DPGA and Design Spectral Acceleration will be determined by a site-specific probabilistic seismic hazard analysis conducted by a qualified California-registered civil engineer with a California authorization as a geotechnical engineer. The design earthquake is determined by the recurrence rate probability as provided in the text, or the design earthquake may be selected as the largest earthquake magnitude associated with a critical seismic source, taken as the closest distance from the source to the facility site. If the largest earthquake magnitude is selected, it "shall be associated with all DPGA values for the site, irrespective of probability levels." The minimum seismic performance for facilities is evaluated at two criteria levels. Level 1 defines a performance criterion to ensure MOT functionality following an earthquake and requires minor or no structural damage and temporary or no interruption in operations. Level 2 defines a performance criterion to safeguard against major damage, collapse, or major oil spill. Level 2 includes controlled inelastic behavior with reparable damage, the prevention of collapse, a temporary loss of operations that is restorable within months, and the prevention of major spills. Major spills are defined as greater than 1,200 barrels—it is worth noting here that MOTEMS applies to berthings and marine oil terminals, so this metric for major spills may not be transferable to the CEI Hub.	Risk Management Plan involves inspections, audits, and post-event inspections. Seismic requirements methodology - has two levels. Prevention Plan criteria - use up-to-date Risk and Hazards Analysis per Center for Chemical Process Safety (CCPS) "Guidelines for Hazard Evaluation Procedures" to identify external events likely to cause a spill. Oil Spill Exposure Classification Seismic Performance Criteria for existing MOTS Seismic Performance Criteria for new MOTS Seismic analytical procedure requirements for displacement capacity of elements of the structure vs. displacement demand.

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DEQ FUEL TANK SEISMIC STABILITY RULES DEVELOPMENT PROJECT

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California	California Code Regulations (CCR) 2022 Title 24, Part CA. Building Code Ch. 31F - Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS)	The Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS) serves to fulfill the requirements of the Lempert-Keen-Seastrand oil spill prevention and response act of 1990. The code established "minimum engineering, inspection and maintenance criteria" for Marine Oil Terminals (MOTs) to prevent oil spills and to protect public health, safety, and the environment.	3101F.5 Spill prevention. Each MOT shall utilize up-to-date Risk and Hazards Analysis results developed per Center for Chemical Process Safety (CCPS) "Guidelines for Hazard Evaluation Procedures" [1.1] and [1.2], to identify the hazards associated with operations at the MOT, including operator error, the use of the facility by various types of vessels (e.g., multi-use transfer operations), equipment failure, and external events likely to cause an oil spill. 3101F.6 Oil Spill exposure classification - Table 31F-1-1: High, Moderate, or Low based on exposed total volume of oil, maximum number of transfers per berth per year, and maximum vessel size. 3104F.2.1 Seismic Performance Criteria for existing MOTS (Table 31F-4-1) - defined as probability of exceedance and return period based on two levels of seismic performance: Level 1 Seismic Performance: · Minor or no structural damage · Temporary or no interruption in operations; Level 2 Seismic Performance: · Controlled inelastic behavior with repairable damage · Prevention of collapse · Temporary loss of operations, restorable within months · Prevention of major spill (≥ 1,200 bbls) AND based on Spill Exposure Classification (defined in above 3101F.6). 3104F.3 New MOTs - The analysis and design requirements described in Section 3104F.2 shall also apply to new MOTs. However, new MOTs shall comply with the seismic performance criteria for high spill classification, as defined in Table 31F-4-1. Additional requirements are as follows: 1. Site-specific response spectra analysis (see Section 3103F.4.2.3). 2. Soil parameters based on site-specific data and new borings (see Section 3106F.2.2). 3104F.2.3 Seismic Analytical procedure requirements for displacement capacity of elements of the structure vs. displacement demand. The displacement capacity shall be calculated using the nonlinear static (pushover) procedure; Methods used to calculate the displacement demand are linear modal, nonlinear static, and nonlinear dynamic and are based on spill classification, configuration, and substructure material. The required analytical procedures are summarized in Table 31F-4-2.	Risk Management Plan involves inspections, audits, and post-event inspections. Seismic requirements methodology - has two levels. Prevention Plan criteria - use up-to-date Risk and Hazards Analysis per CCPS "Guidelines for Hazard Evaluation Procedures" to identify external events likely to cause a spill. Oil Spill Exposure Classification Seismic Performance Criteria for existing MOTS Seismic Performance Criteria for new MOTS Seismic analytical procedure requirements for displacement capacity of elements of the structure vs. displacement demand.
California	Caltrans 2019 Seismic Design Criteria	Seismic Design Criteria of bridges	Seismic Design Criteria (SDC) - includes classifications of bridges and soil types. Provides performance criteria based on bridge type. Important bridges are expected to be available for use immediately following event for emergency response. Recovery bridges are necessary for the economic recovery of the impacted area. Ordinary bridges are those that are not Important or Recovery. Bridges within 300 feet of fault must be designed for fault crossing hazard. Evaluation and performance levels are dictated by bridge importance - for example - ordinary bridges have the lowest evaluation and performance requirements, while Important bridges have highest level of safety evaluation and performance requirements (Section 1.3).	Seismic design standards
MOTEMS	California Code Regulations (CCR) 2022 Title 24, Part 2 - CA Building Code, Chapter 31F). MOTEMS	Building code	Section 3103F.4 - Earthquake Loads Earthquake ground motion parameters should be obtained from USGS Seismic Design Maps or a Probabilistic Seismic Hazard Analysis under a CA civil engineer. Site amplification effects can be calculated using the simplified evaluation procedure from Ch.1 of FEMA 356 or a site-specific evaluation. Directivity effects must be considered when the site is within 15 km of a seismic source that can significantly affect the site. Deterministic earthquake motions can be used for comparison purposes. Section 3104F - Seismic Analysis and Structural Performance Section 3106F - Geotechnical Hazards and Foundations Provides requirements for liquefaction, slope/embankment stability, and lateral spreading.	Building code - Seismic design parameters that could apply to fuel sites.

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Oregon	Oregon Building Code ORS 455.447 Regulation of certain structures vulnerable to earthquakes and tsunamis	Requires new building sites to be evaluated on a site-specific basis for vulnerability to seismic geologic hazards if the sites are for structures that are: Major structures; or Designated under subsection (5) of this section as Tsunami Risk Category III or IV for design.	"Major structure" means a building over six stories in height with an aggregate floor area of 60,000 square feet or more, every building over 10 stories in height, and parking structures as determined by Department of Consumer and Business Services rule. Requires that a site-specific evaluation be conducted when a tank is installed exterior to and not attached to a building in specific situations. Tanks that are deemed containing, housing, or supporting water or fire-suppression materials, or equipment required for the protection of essential or hazardous facilities, or special occupancy structures (whether interior or exterior to a building) and: - Those that are housing, supporting, or containing sufficient quantities (exceeding maximum allowable quantities per control area, See table 307.1(1) or 307.1(2)) of toxic or explosive substances to be of danger to the safety of the public if released. - Does not provide a minimum design standard or instructions for permit issuance for tanks, only that sites for defined tanks are subject to the site evaluation requirements. The division believes that at a minimum, the evaluation should be provided to property owners and the Building Official of record and, that as a best practice recommendation, the evaluation procedures found in OSSC Section 1803 be followed.	Site-specific evaluation for tanks installed exterior, not attached to building. Specifies tanks that contain different materials, including hazardous materials. No design standard for tanks, only site evaluation requirements OSSC Section 1803.
Environmental				
Oregon	Oregon Administrative Rule (OAR) 340 -141-0160 Department of Environmental Quality Oil Spill Contingency Planning	The owner/operator of onshore and offshore facility must develop spill prevention strategies that will, when implemented, provide the best achievable protection from damages caused by the discharge of oil into the waters of the state.	The strategies may be in the form of: Appendices to oil spill prevention and emergency response plans required under this chapter; or a stand-alone prevention plan that meets all requirements of OAR 340-141-0100 to 340-141-02; or Spill Prevention, Control, and Countermeasures Plans (SPCCs), Operation Manuals, and other prevention documents prepared to meet federal requirements under 33 CFR 154, 33 CFR 156, 40 CFR 109, 40 CFR 112, or the Federal Oil Pollution Act of 1990. Evidence of a maintenance and inspection program that includes: Summary of frequency and type of regularly scheduled inspection and preventative maintenance procedures for tanks, pipelines, key storage, transfer or production equipment, safety and prevention equipment; description of integrity testing of storage tanks and pipelines using hydrostatic testing and visual inspection; external and internal corrosion detection and repair; damage criteria for equipment repair or replacement; and maintenance and inspection records.	Spill prevention and emergency response plan requirements. Routine maintenance requirements.

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Oregon	OSSC 2022 - Oregon Structural Specialty Code OSSC 1803.3.2 - Site-specific seismic hazard investigation	Site-specific seismic hazard investigation. Sites for structures and facilities defined by ORS 455.447 as major structures or Risk Category III or IV buildings and other structures evaluated on a site-specific basis for vulnerability to seismic-induced geologic hazards and reported in a site-specific seismic hazard report, in accordance with Section 1803.6.1.	1803.3.2.1 Design earthquake. Building sites required to be investigated as provided in Section 1803.3.2 shall, at a minimum, address earthquakes from: 1. A shallow crustal earthquake on real or assumed faults near the site, subject to evaluation. Minimum design earthquake shall in no case be considered less than a moment magnitude of 6.0 or the design earthquake ground motion acceleration determined in accordance with Section 1613. 2. A deep earthquake with a moment magnitude greater than 7.0 on the seismogenic part of the subducting plate of the Cascadia Subduction Zone. 3. An earthquake on the seismogenic part of the interface between the Juan de Fuca Plate and the North American Plate on the Cascadia Subduction Zone with a minimum moment magnitude of 8.5. (p. 234). 1803.6.1 Site-specific seismic hazard report. In addition to the reporting requirements of Section 1803.6, for building sites requiring a site-specific seismic hazard investigation per Section 1803.3.2. 1803.6.1.1 Site-specific seismic hazard report review. Provision shall be made by the municipality for qualified review of the site-specific seismic hazard report for conformance with Section 1803. Persons approved to do such review shall have qualifications deemed equivalent to the person who prepared the report. This review may be by the municipality's staff, a consultant firm, or a committee established by the municipality. With the approval of the building official, the owner may provide a peer review. Where the review is provided by a party other than the municipality's staff, the review shall consist of a written summary of the reviewer's assessment of the overall adequacy of the site report and a listing of additional questions or factors that need to be addressed.	Design earthquake requirements. Site-specific seismic hazards report and report review requirements.
Oregon	OSSC 2022 - Oregon Structural Specialty Code	Chapter 4 Special Detailed Requirements Based on Occupancy and Use	406.7.3 Aboveground tanks located inside buildings. Aboveground tanks for the storage of Class I, II, and IIIA liquid fuels are allowed to be located in buildings. 406.7.3.1 Special enclosures. Where installation of tanks underground is impractical, or because of property or building limitations, tanks for liquid motor fuels are allowed to be installed in buildings in special enclosures: The special enclosure shall be liquid-tight and vapor-tight. 2. The special enclosure shall not contain backfill. 3. Sides, top, and bottom of the special enclosure shall be of reinforced concrete not less than 6 inches (152 mm) thick, with openings for inspection through the top only. 4. Tank connections shall be piped or closed such that neither vapors nor liquid can escape into the enclosed space between the special enclosure and any tanks inside the special enclosure. 5. Means shall be provided whereby portable equipment can be employed to discharge outdoors any vapors that might accumulate inside the special enclosure, should leakage occur. 6. Tanks containing Class I, II, or IIIA liquids inside a special enclosure shall not exceed 6,000 gallons (22,710 L) in individual capacity or 18,000 gallons (68,130 L) in aggregate capacity. 7. Each tank within a special enclosure shall be surrounded by a clear space of not less than 3 feet (910 mm) to allow for maintenance and inspection. 406.7.5 Secondary containment. Aboveground tanks shall be provided with drainage control or diking in accordance with this chapter. Drainage control and diking are not required for listed secondary containment tanks.	Design Requirements for Tanks inside buildings in Special enclosures. Secondary containment requirements. Ancillary equipment requirements.

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Regulatory Authority	Code/Policy	Summary of Policy/Code	Criteria/Requirement	Application to Fuel Facilities in Oregon
Oregon	OSSC 2022 - Oregon Structural Specialty Code	Chapter 4 Special Detailed Requirements Based on Occupancy and Use	Section 440 Compressed Gases 440.3.3 Securing compressed gas containers, cylinders, and tanks. Compressed gas containers, cylinders, and tanks shall be secured to prevent falling caused by contact, vibration, or seismic activity. 1613.4.13 ASCE 7, Section 15.4.3. Modify ASCE 7, Section 15.4.3, Loads, to read as follows: The seismic effective weight, W, for non-building structures shall include the dead load and other loads as defined for structures in Section 12.7.2. For purposes of calculating design seismic forces in non-building structures, W also shall include all normal operating contents for items such as tanks, vessels, bins, hoppers, and the contents of piping. W shall include 20 percent of snow or ice loads where the flat roof snow load, Pf, or weight of ice, Di, exceeds 30 psf (1.44 kN/m2), regardless of actual roof or top of structure slope.	Routine Maintenance. Structural design
Oregon	OSSC 2022 - Oregon Structural Specialty Code OSSC 2802 Fuel Oil Storage Systems	OSSC 2802 2802.1 Fuel oil storage systems. Fuel oil storage systems shall be installed in accordance with this code. Fuel oil piping systems shall be installed in accordance with the Mechanical Code.	2802.1.1 Fuel oil storage inside buildings. Fuel oil storage inside buildings shall comply with Section 444 or Sections 2802.1.1.1 through 2802.1.1.7. 2802.1.1.1 Quantity limits. One or more fuel oil storage tanks containing Class II or III combustible liquid shall be permitted in a building. The aggregate capacity of all tanks shall not exceed the following: 1. 660 gallons (2,498 L) in unsprinklered buildings, where stored in a tank complying with UL 80, UL 142 or UL 2085. 2. 1,320 gallons (4,997 L) in buildings equipped with an automatic sprinkler system in accordance with Section 903.3.1.1, where stored in a tank complying with UL 142. The tank shall be listed as a secondary containment tank, and the secondary containment shall be monitored visually or automatically. 3. 3,000 gallons (11,356 L) in buildings equipped with an automatic sprinkler system in accordance with Section 903.3.1.1, where stored in protected aboveground tanks complying with UL 2085 and Section 444.4.1.7.5. The tank shall be listed as a secondary containment tank, as required by UL 2085, and the secondary containment shall be monitored visually or automatically." ([p. 28]) "2802.1.1.6 Spill containment. Tanks exceeding 60 gallon (227 L) capacity or an aggregate capacity of 1,000 gallons (3,785 L) that are not provided with integral secondary containment shall be provided with spill containment sized to contain a release from the largest tank." ([p. 28])	Capacity limits for storage inside buildings. Spill containment requirements.
Oregon	OSSC 2022 - Oregon Structural Specialty Code OSSC 444 Flammable and Combustible Liquids	444.1 Prevention, control, and mitigation of dangerous conditions related to storage, use, dispensing, mixing, and handling of flammable and combustible liquids shall be in accordance with Sections 414 and 415 and this section. 444.4 Storage. The storage of flammable and combustible liquids in containers and tanks inside buildings shall be in accordance with this section and the applicable provisions of Sections 414 and 415.	444.4.1 Tank storage. The provisions of this section shall apply to: 1. The storage of flammable and combustible liquids in fixed aboveground tanks. 444.4.1 Tank storage. The provisions of this section shall apply to: 1. The storage of flammable and combustible liquids in fixed aboveground tanks. 2. The storage of flammable and combustible liquids in fixed aboveground tanks inside of buildings. 3. The storage of flammable and combustible liquids in portable tanks whose capacity exceeds 660 gallons (2,498 L). 4. The installation of such tanks and portable tanks. ([p. 131]) 444.4.1.5 Design, fabrication, and construction requirements for tanks. The design, fabrication, and construction of tanks shall comply with NFPA 30. 444.4.1.8 Drainage and diking. The area surrounding a tank or group of tanks shall be provided with drainage control or shall be diked to prevent accidental discharge of liquid from endangering adjacent tanks, adjoining property, or reaching waterways.	Design requirements for tanks. Spill prevention: Drainage and diking requirements in areas surrounding tanks.

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California	CCR (California Code of Regulations) 2022, Title 19, Division 2, Chapter 4.5, Article 1 to 11, Sections 2735.1 to 2785.1	Chapter 4.5 - California Accidental Release Prevention (CalARP) Program Detailed Analysis	PSU Summary - Requires that facilities assess for the risk of an earthquake in their process hazard assessment; however, the severity of the earthquake is not determined by the regulation. - No set performance standards at the state level. Require that facilities and ongoing processes are made “safe” and comply with recognized and generally accepted good engineering practices (RAGAGEP). - Local regulatory authority and the facility determine the most appropriate methodology for this assessment. - No cost limitations. Mitigation recommendations should be implemented unless they are deemed infeasible, but that determination of infeasibility will not be based solely on cost. - Requirements for off-site impact analysis which account for impacts to public receptors, defined as “offsite residences, institutions (e.g., schools, hospitals), industrial, commercial, and office buildings, parks, or recreational areas inhabited or occupied by the public at any time,” and environmental receptors, defined as “natural areas such as national or state parks, forests, or monuments; officially designated wildlife sanctuaries, preserves, refuges, or areas; and federal wilderness areas, that could be exposed at any time."	Site Assessment/Hazard Assessment requirement. Prevention Program: No cost limitations. Site Assessment - Requirement for off-site impact analysis.
California	CCR (California Code of Regulations) 2022, Title 19, Division 2, Chapter 4.5, Article 1 to 11, Sections 2735.1 to 2785.1	Chapter 4.5 - California Accidental Release Prevention (CalARP) Program Detailed Analysis	Section 2750.3 - Defines Worst-Case Release Scenario Analysis for Risk Management Plan (RMP) (1) For Program 1 processes (see definition in Federal Section 112r Clean Air Act), one worst-case release scenario, including an offsite consequence analysis, for each Program 1 process using the offsite consequence analysis parameters in Section 2750.2; (2) For Program 2 and 3 processes and Program 4 stationary sources: (A) One worst-case release scenario that is estimated to create the greatest distance in any direction to an endpoint as defined in Section 2750.2(a) resulting from an accidental release of regulated toxic substances from covered processes under worst-case conditions defined in Section 2750.2(b) through (g); (B) One worst-case release scenario that is estimated to create the greatest distance in any direction to an endpoint defined in Section 2750.2(a) resulting from an accidental release of regulated flammable substances from covered processes under worst-case conditions defined in Section 2750.2; and, (C) Additional worst-case release scenarios for a hazard class if a worst-case release from another covered process at the stationary source potentially affects public receptors different from those potentially affected by the worst-case release scenario developed under Sections (a)(2)(A) or (a)(2)(B). (b)Determination of worst-case release quantity. The worst-case release quantity shall be the greater of the following: (1) For substances in a vessel, the greatest amount held in a single vessel, taking into account administrative controls that limit the maximum quantity; or (2) For substances in pipes, the greatest amount in a pipe, taking into account administrative controls that limit the maximum quantity.	Risk Management Plan: defines worst-case release scenario analysis based on program level as defined by EPA Section 112r Clean Air Act. Program 1 use offsite consequence analysis parameters; For Program 2 and 3 processes and Program 4 stationary sources. Risk Management Plan: Determination of worst-case release quantity.
California				
Local Jurisdiction				
Natural Hazard				
City of Escondido, California	City of Escondido, CA - Guideline 22 Installation Requirements for Aboveground Storage and Dispensing Tanks (2009)	Applies to building permits for aboveground tanks, 5,000 gallons or more and height to diameter or width ratio of 2:1. Covers what is required for the permit and the plan submittal.	Requires structural design; overflow tanks/reservoirs based on size of tank and fluid contents; includes set-back requirements. City of Escondido building code requirements for aboveground storage tanks (2009). Exempt from screening requirements, tanks with less than 5,000 gallons or under 5 feet.	Design requirements for tanks that require a building permit. Minimum capacity application.

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City of Portland, Oregon	City of Portland (COP) City Code Chapter 24.85 Seismic Design Requirements for Existing Buildings	Seismic Design Requirements for Existing Buildings only applies to building seeking permit that change occupancy, adds square footage, alters, or repairs a building. Also includes requirements for catastrophic damage or mandatory or voluntary seismic strengthening.	Seismic Design Requirements for Existing Buildings only applies to building seeking permit that change occupancy, adds square footage, alters, or repairs a building. Also includes requirements for catastrophic damage or mandatory or voluntary seismic strengthening.	Design requirements for any existing building seeking a building permit or that does seismic strengthening.
City of Portland, Oregon	City of Portland Mitigation Action Plan (2016), Portland Bureau of Emergency Management	City Hazard Mitigation Plan	Includes policy discussion and requirements. Also discusses and references the Critical Energy Infrastructure Hub report.	Informational
Engineering Standards				
Natural Hazard				
American Association of State Highway and Transportation Officials (AASHTO)	AASHTO LRFD Bridge Design Specifications, Ninth Edition 2020	Applies to the design and construction of bridges. Updated in 2020.	Applies to design and construction of bridges and highway structures. Requires the seismic hazard to be characterized by the acceleration response spectrum for the site and site factors for the relevant site class (defined in Section 3.10.3.1). This can be completed by following the general procedure outlined in Section 3.10.2.1 or by following a site specific procedure outlined in Section 3.10.2.2. except in cases where a) site is within 6 miles of an active fault, b) site is classified as Site Class F, c) long-duration earthquakes are expected, or d) bridge is identified as high importance.	Comparable design and seismic requirements for bridges.
American Concrete Institute (ACI)	ACI 350.3 Seismic design of liquid-containing concrete structures and ACI 350.3-20 Commentary	Applies to the design and construction of reinforced concrete structures. Updated in 2020.	Applies to the design and construction of reinforced concrete structures. Updated in 2020. Includes procedures for seismic design in accordance with ACI350.3-20, chapter 13 and uses ASCE 7-10; contains minimum requirements for design and construction. Recommends using Risk category (Importance Factor) I = 1.5 for horizontal tanks, I = 1.25 for emergency response tanks, and I = 1.0 for all other tanks. Includes requirements for analysis and design of liquid-containing concrete structures - covers rectangular and circular ground-supported tanks/structures. Relies on AWWA D110-13 and D115-17, IBC 2012, and ASCE/SEI 7-16 for specific design parameters. Recommends accommodating sloshing to prevent roof and structural damage.	Design and construction requirements for reinforced concrete tanks.
American Concrete Institute (ACI)	ACI 372R-13 Guide to design and construction of circular wire- and strand-wrapped prestressed concrete structures	Applies to the design and construction of circular wire- and strand-wrapped prestressed concrete structures	Has provisions for seismic-induced forces. Criteria provided in ACI 350.3, ACI 350, US NRC (1963), AWWA D110. Design should accommodate the maximum wave oscillation (sloshing) induced by seismic acceleration. Design considerations for seismic restraint cables. Tank should have freeboard allowance, and roof structure should resist uplift pressures from sloshing force.	Design and construction requirements for circular wire- and strand-wrapped prestressed concrete structures.
American Lifelines Alliance (ALA)	ALA - Guide for Seismic Evaluation of Active Mechanical Equipment (2004)	Seismic evaluation of mechanical equipment	Should consult ASCE 7, AISC Steel Manual, ACI 318, API 650, AWWA D100, BNL-52361 (1995). Aboveground piping should consult ASME Boiler and Pressure Vessel Code, Section III, Dev 1, Nuclear Components Subsections NB/NC/ND-3600 ALA - Seismic Design and Retrofit of Piping Systems, ASME B31, NFPA-13. Buried piping should consult ALA - Guide for the Design of Buried Steel Pipe ASCE 4.	Analysis procedures for seismic evaluating of mechanical equipment.
American Lifelines Alliance (ALA)	ALA Guideline for the Design of Buried Steel Pipe (2001)	Design guideline for buried steel pipelines	Provides wave propagation strain design guidelines for different types of potential earthquake hazards (e.g., what to consider for permanent ground displacement vs. lateral earth spreading).	Design of buried steel pipelines on site and serving the fuel facilities.

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American Lifelines Alliance (ALA)	ALA Guidelines for the Seismic Design and Retrofit of Piping Systems (2002)	Seismic design and retrofit guidelines for aboveground pipelines	Applies to aboveground piping systems only. Uses risk category, I= 1 to 1.5. Seismic analysis can be static or dynamic. Design pressure and temperature are the highest pressure and corresponding temperature (p.8). Allowable stress in gas and oil pipes is based on 72% of minimum specified yield stress and the population density. Max bending stress = 0.5 SY; where SY = material yield stress at operating temperatures. Limit midspan bending to 2-inches. Deformation under seismic loading is ≤ to 1/8-inches. Assumes 4 ≤ FOS ≤ 5.	Design of aboveground pipelines serving the fuel facilities.
American Lifelines Alliance (ALA)	ALA Guideline for Assessing the Performance of Electric Power Systems in Natural Hazard and Human Threat Events (April 2005)	Applies to the electric power system and how to assess hazards and performance	Guideline for vulnerability and hazard assessments of natural and man-made disasters. Phase 1 - qualitative. Phase 2 quantitative. Earthquake hazard considered the worst case. Recommends 4 key performance criteria: 1) protect public and worker safety; 2) maintain system reliability; 3) prevent monetary loss; and 4) prevent environmental damage. Offers variety of analysis methods depending on facility type.	Vulnerability and hazard assessments for electrical systems on-site and serving the fuel facilities.
American Petroleum Institute (API)	API 620 - Design and Construction of Large, Welded, Low-pressure Storage Tanks (2002)	Design and construction standards for aboveground tanks	Seismic zone factor for horizontal seismic acceleration is determined by purchaser or governmental authority based on mapped values. The response spectra for a specific site shall be established by considering the active faults within the region, the types of faults, the magnitude of the earthquake that could be generated by each fault, the regional seismic activity rate, the proximity of the site to the potential source faults, the attenuation of the ground motion between the faults and the site, and the soil conditions at the site. Importance factor I = 1.25 for tanks storing toxic or explosive substances in areas where accidental release could be dangerous to public safety. The thickness of the bottom plate under the shell shall not exceed the thickness of the bottom shell course or 1/4 in., whichever is greater. Suitable flexibility shall be provided in the vertical direction for all piping attached to the shell or bottom of the tank. On unanchored tanks that are subject to bottom uplift, piping connected to the bottom should be free to lift with the bottom or located so that the horizontal distance measured from the shell to the edge of the connecting reinforcement is equal to the width of the bottom hold-down plus 12 inches.	Design and construction of fuel and miscellaneous storage tanks.
American Petroleum Institute (API)	API Standard 650 - Welded Tanks for Oil Storage (2007) plus addendums through Feb 2012)	Industry standard guideline for design of welded tanks used for oil storage	Performance based on Seismic Use Groups (SUGs) which are similar to IBC/ASCE7 Risk Categories, but with different designations. (SUG I is similar to RC II; SUG III is similar to RC IV). Commentary on SUG I implies that some loss of product (as determined by the purchasers) is acceptable performance in Design Basis Earthquake (DBE). Site-specific ground motions should be considered if the tank is located within 10 km of a fault, the structure is designed with a base isolation or energy dissipation system, or is required by owner. The 5% damped site-specific MCE_R spectral response acceleration for any period shall be the lesser of the probabilistic and deterministic MCE_R ground motion spectral response accelerations.	Design and construction of fuel and miscellaneous storage tanks.
American Society of Civil Engineers (ASCE)	ASCE/SEI 4-16 Seismic analysis of safety-related nuclear structures	Seismic analysis of nuclear facilities	Focus is analysis methods. Demands refer back to ASCE 43. Goal to predict seismic demands in DBE shaking at 80th percentile nonexceedance probability (ASCE 43 Sec 1.3). Ch 9 includes requirements for vertical, liquid-storing tanks. Ch 10 includes distribution piping.	Seismic analysis of critical facilities.

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Regulatory Authority	Code/Policy	Summary of Policy/Code	Criteria/Requirement	Application to Fuel Facilities in Oregon
American Society of Civil Engineers (ASCE)	ASCE/SEI 7-16 - Minimum Design Loads and Associated Criteria for Building and Other Structures	Minimum seismic design guidelines for buildings and other structures	This version is adopted in IBC 21. IBC 24 is expected to adopt ASCE 7-22. - Seismic Ground Motions & Design Response Spectrum: Section 11.4 & Beyond - Seismic Design Requirements for Building Structures - Ch. 12 - Seismic Design for Nonstructural Components - Ch. 13 - Soil-Structure Interaction for Seismic Design - Ch. 19 - Site Class Defined - Ch. 20 - Site-Specific Ground Motion Procedures - Ch. 21 - MCE_R, DBE_R. Risk categories for different performance levels. Performance targets discussed in commentary or other sources (RC II: 1% collapse in 50 years, 10% collapse given MCE_R) - Potential for industrial buildings to be classified as nonbuilding structures per Chapter 15. Ch 13 references ASME B31 for pressure piping. Ch 15 has sloshing/impulsive loads for tanks. - API 620 and 650, AWWA D115 are referenced.	Design guidelines for buildings and other structures on the fuel sites.
American Society of Civil Engineers (ASCE)	ASCE/SEI 7-22 - Minimum Design Loads and Associated Criteria for Building and Other Structures	Minimum seismic design guidelines for buildings and other structures	IBC 24 is expected to adopt ASCE 7-22. - Seismic Ground Motions & Design Response Spectrum: Section 11.4 & Beyond - Seismic Design Requirements for Building Structures - Ch. 12 - Seismic Design for Nonstructural Components - Ch. 13 - Soil-Structure Interaction for Seismic Design - Ch. 19 - Site Class Defined - Ch. 20 - Site-Specific Ground Motion Procedures - Ch. 21 - MCE_R, DBE_R. Risk categories for different performance levels. Performance targets discussed in commentary or other sources (RC II: 1% collapse in 50 years, 10% collapse given MCE_R) - Potential for industrial buildings to be classified as nonbuilding structures per Chapter 15. Ch 13 references ASME B31 for pressure piping. Ch 15 has sloshing/impulsive loads for tanks - API 620 and 650, AWWA D115 are referenced.	Design guidelines for buildings and other structures on the fuel sites.
American Society of Civil Engineers (ASCE)	ASCE/SEI 41-17 - Seismic Evaluation and Retrofit of Existing Buildings	Primarily applies to existing buildings including tanks inside a building	Primarily applies to existing buildings. Tanks included in Ch 13 are intended for tanks within buildings. (cf ASCE7-22 15.7 that points to other sections for "supported" tanks). Technically any hazard can be used. In addition to ASCE 7 DBE_R and MCE_R (BSE-1N and -2N), any additional defaults are 5%/50 (BSE-2E) and 20%/50 (BSE-1E) which are generally used for existing buildings and lower than ground motions used for new design. For seismic retrofit of existing buildings; mostly structural based.... In Sec. 13.3....indicates retrofit shall be augmented with ASCE 7 for components with Ip = 1.5 Performance Objectives & Seismic Hazards - Ch. 2 - requirements based on performance objective & buildings risk category Tanks are considered "acceleration sensitive" (Sec. 13.7.2.2) and should be retrofitted with appropriate anchorage or bracing (see Section 13.5) - evaluated to achieve Performance Objective (Sec. 2.2) - calc Level of Seismicity from Table 13.1 - calc Seismic forces in accordance with Sec. 13.4.3 - calc Seismic Deformations in accordance w/ Sec. 13.4.4 - Life Safety Performance Levels from Sec. 13.6 - 13.8 - calc forces on bracing and connections Sec. 13.4	Seismic retrofit of existing buildings and tanks inside or attached to buildings.

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American Society of Civil Engineers (ASCE)	ASCE/SEI 43-19 Seismic design criteria for Structures, Systems and Components in Nuclear Facilities	Seismic design criteria of nuclear facilities	Values of damping for steel-plate composite members and HVAC are not addressed in ASCE 4-16 but are included for ASCE 43. Other design references ASCE 4-16.	Seismic design criteria for critical facilities.
American Society of Civil Engineers (ASCE)	ASCE Pipelines 2014 Proceedings - "Seismic Design of Buried Steel Water Pipelines" by Spyras A. Karamanos, Brent Keil, Robert J Card	Seismic design of buried steel water pipelines	This paper presented "tools and provisions for structural analysis and design of buried welded (continuous) steel water pipelines in seismic areas, subjected to earthquake action." Goals - minimize seismic risk to pipes, safeguard water supply, minimize earthquake damage, maintain structural integrity, and prevent leakage. Concerned about transient and permanent ground deformation. For oil and gas, also concerned about accidental (environmental) leakage.	Design guidelines for buried pipe on site or serving fuel facilities.
American Society of Civil Engineers (ASCE)	ASCE/SEI - "Seismic Design Criteria for Pipelines and other Long Structures" by Pravecnk Mahotram, Strong Motions, Inc. Article in SEI May 2013	Seismic design of pipelines	Site-specific analysis generally underestimates risks to pipes. Proposes using aggregate (accumulative) analysis for whole length to assess risk. Uses ASCE 7-10 for loads. Used 475 years for return period and PGA of 0.4 g. Design criteria dependent on level of acceptable risk.	Design guidelines for pipelines on site or serving fuel facilities.
American Society of Civil Engineers (ASCE)	ASCE Seismic Evaluation and Design of Petrochemical and Other Industrial Facilities (2020)	Guideline for seismic evaluation and design of petrochemical and other industrial facilities	Liquefaction triggering analyses can be evaluated using the simplified procedure outlined by Seed & Idriss (1982) - evaluated based on the geometric mean PGA from the MCE with applied site amplification factor - also need to analyze the consequences of liquefaction (down drag, uplift, increased lateral loads, bearing failures, settlement, lateral spread). See sections 3.5.2.1 through 3.5.2.3. MCE (Maximum considered earthquake) = 2% in 50 yrs. (2475-year) - can obtain ground motions using ASCE 7 online Hazard Tool - must adjust ground motions for correct site class determined by Vs30 for the top 100 ft or the SPT blow counts (Vs30 is preferred).	Seismic evaluation and design of fuel facilities and related structures.
American Society of Civil Engineers (ASCE)	ASCE TCLEE Monograph 12 - Seismic Guidelines for Ports (March 1998)	General guideline for seismic performance, design and evaluation of port facilities	General guideline for seismic performance, design, and evaluation of port facilities - from waterfront areas, cranes, tank and container storage, site utilities, and site buildings. Manual is based on evaluation of seismic performance of port facilities from 26 earthquakes from 1923 to 1995. Recommends design performance criteria for each type of facility on site be established in advance for both new and existing facilities. No specific code applies to all port facilities. In some cases, building codes apply to specific buildings. In general designs use best management practices based on what has been decided as the acceptable seismic risks. Recommends emergency response and recovery plans be developed. Acknowledges that things will fail so being prepared is critical. Weighs cost of doing seismic design and retrofits with loss of revenue, physical and environmental damage, region economic impact, etc. Recommends in advance identifying what is critical or essential to function continuously without interruption. Introduces "acceptable seismic risk" in terms of operational level earthquake (OLE) motions versus contingency level earthquake (CLE) motions. In case of OLE, this is the maximum level of horizontal ground motions the port facilities can withstand and still be fully useable without damage or needing repairs. CLE acknowledges some damage, but the port facilities can still be used. Recommends spill containment facilities be seismically designed. Historically these have failed too and usually overlooked in design.	General guideline for seismic performance, design, and evaluation of port facilities - from waterfront areas, cranes, tank and container storage, site utilities, and site buildings.

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American Society of Mechanical Engineers (ASME)	ASME B31.3 - Process Piping (2006)	Standard for aboveground piping or in structures	Standard for petroleum and natural gas facilities, tanks, piping, and controls. Uses ASCE 7 for minimum seismic loading requirements in design. Includes design provisions for metallic and pipes lined with non-metallic materials. Excludes gravity pipe, pipes under 15 psi that are non-flammable, non-toxic and not harmful to human tissue. Requires new pipe and all related facilities to be labeled: - Category D - normal fluid service pipe (nonflammable, nontoxic, and not damaging to human tissues, the design pressure does not exceed 150 psig (1035kPa), the design temperature is from -20 degrees F to 366 degrees F. (Per ASME B31.3 Appendix A) - Category M - safety class piping systems subject to severe cyclic conditions, "a fluid service in which both of the following conditions apply: highly toxic fluid such that a single exposure to a very small quantity of the fluid, caused by leakage, can produce serious irreversible harm to persons on breathing or bodily contact, even when prompt restorative measures are taken." (per ASME B31.3 Appendix O) - High-Pressure - owner defined, though typically applies to pressures higher than ASME B16.5 Class 2500, "a fluid service for which the owner specifies the use of Chapter IX for piping design and construction", see Appendix M. - High-Purity Fluid - "a fluid service that requires alternative methods of fabrication, inspection, examination, and testing not covered elsewhere in the Code, with the intent to produce a controlled level of cleanness. The term thus applies to pipe systems defined for other purposes as high purity, ultra-high purity, hygienic, or aseptic."	Seismic design of onsite piping.
American Society of Mechanical Engineers (ASME)	ASME B31.4 - Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids (2006)	Standard for Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids	Uses ALA Guidelines for Design of Buried Pipelines and ASME B31.1 for design of soil forces on buried pipelines. Applies to process piping at and from refineries to production facilities, processing facilities, and related plants and/or terminals. Applies to new aboveground and buried pipe only. Pertains to pipes transporting hazardous products that are predominantly liquid fuels between facilities and production. Recommends written emergency response plan. Seismic loading is an occasional load that is included in strength design and includes: - Direct effects due to ground vibration - Induced effects from liquefaction and landslides - Crossing active faults at surface	Seismic design of piping for liquid fuel and other liquids.
American Society of Mechanical Engineers (ASME)	ASME B31.8 - Gas Transmission and Distribution Piping Systems (2022)	Standard for Gas Transmission and Distribution Piping Systems	Applies to steel and plastic piping transporting natural gas products between sources and terminals including compressors, regulators, and metering stations. Requires written emergency response plan. Section 841.1.10 - contains no specific seismic design. Just calls for "protection of pipelines from hazards" and to "take reasonable precautions to protect the pipe."	Seismic guidelines of piping for gas systems, no specific design recommendations
American Society of Mechanical Engineers (ASME)	ASME/ANSI B31E-2008 - Standard for the Seismic Design and Retrofit of Above-Ground Piping Systems	Seismic Design and Retrofit of Above-Ground Piping Systems	Establishes guidance method for seismic design and retrofit of aboveground piping systems in the scope of ASME B31. Critical piping must remain leak-tight during and following earthquake. Pipe must remain operable to deliver contents, control (throttle) or shut down flow during or after the design earthquake as determined by the engineer and owner. Seismic loading may be horizontal or vertical or both using static coefficients; or use response spectra with ASCE 7; or use site-specific response spectra. “Design earthquake is considered the level of earthquake that the piping system is designed for to perform a seismic function – position retention, leak tightness, or operability.” Retrofits require condition assessment.	Seismic design of onsite piping.

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Regulatory Authority	Code/Policy	Summary of Policy/Code	Criteria/Requirement	Application to Fuel Facilities in Oregon
American Society of Mechanical Engineers (ASME)	ASME International Pipelines, "Guidelines for seismic design and assessment of natural gas and liquid hydrocarbon pipelines" by Douglas G. Honegger, Richard W. Gailing and Douglas J. Nyman	Guidelines for seismic design and assessment of natural gas and liquid hydrocarbon pipelines	Discusses historical practice and seismic design process developed in 1998-2000 by Pipeline Research Council International (PRCI). Emphasizes balanced design between cost, safety, regional economic impacts, imposed loads, and risk assessment. Primary Earthquake load is the PGD. Recommends using finite element analysis. Also see “PRCI - Honegger, D.G. and D.J. Nyman (2004) - Guidelines for the Seismic Design and Assessment of Natural Gas and Liquid Hydrocarbon Pipelines” below for same topic.	Seismic design of piping for gas and fuel systems.
American Water Works Association (AWWA)	AWWA D100-21 Welded Carbon Steel Tanks for Water Storage	Design and construction of water tanks	This is a standard/guidance document adopted by water industries for design of welded carbon steel tanks for water storage. Use risk category IV unless otherwise specified. Do not use risk category I. Refers to ASCE 7 for MCE (2% exceedance in 50 years). Includes site coefficient tables similar to ASCE 7-10. Scaled down by 2/3 factor to get to Design Earthquake. Considers vertical acceleration at different values depending on controlling failure mode. Uses allowable stress design, except for the design of the reinforced concrete foundation. References using ACI 318, API 620, and API 650. Includes provisions for alternative design basis for ground-supported tanks and reservoirs (chapter 14). R-factors included for Impulsive component of loading up to R=3. Requires consideration of flexibility, with prescriptive table for values of design movements (Table 26). Requires freeboard for RC IV tanks and RC III where Sds>=0.33g (moderate seismicity or higher). Recommends annual inspection and maintenance of exterior tank shell to bottom connection. Three-year interval for inspection and maintenance of the entire internal and external tank.	Design and construction of fuel, water and miscellaneous steel storage tanks.
American Water Works Association (AWWA)	AWWA D110-18 Wire- and Strand-Wound; Circular; Prestressed Concrete Water Tanks	Design and construction of water tanks	This is a standard/guidance document adopted by water industries for Wire- and Strand-Wound; Circular; Prestressed Concrete Water Tanks. Section 3 uses allowable stress design and allows alternative analysis with adjustments for response spectrum. References IBC, ASCE 7, and ACI 350. Section 4 has provisions for earthquake induced forces. R-factors vary for loading and structure type, up to 3.5 for some anchored tanks. R-factors are based on working-stress design. Use ASCE 7 for the MCE. Design earthquake is 2/3 of MCE. Probabilistic MCE is defined as 2% exceedance in 50 years. Allows deterministic, probabilistic calculation of MCE or site-specific response spectra. If deterministic EQ used, MCE defined as 150% of the median response from controlling characteristic earthquake. Vertical accelerations considered. Risk category (RC) IV: Tanks that must remain usable to provide emergency service for fire suppression, with slight structural damage and insignificant leakage after an earthquake. Risk category III: Tanks that must remain usable, but may suffer repairable structural damage, and can be taken out of service ... Water tightness criteria - generally the net liquid loss shall be less than 0.05% of the tank capacity in 24 hours. Requires consideration of sloshing forces against roof if insufficient freeboard height is not maintained. Requires that water stops sustain "relative displacement between the tank shell and foundation caused by the combined effects of earthquake-induced base shear, gravity loads and vertical accelerations ... without leakage when subjected to design seismic load." (Sec 4.8.2). Anchorage required for higher seismicity (Sds >= 0.5g). (Sec 4.2.2) Additionally recommends certain types of base joints (radially freed but anchored) for larger (>2 mil gallon) tanks in higher seismicity areas. Requires consideration of sloshing forces at tank roof if minimum freeboard is not maintained. (Sec 4.10).	Design and construction of fuel and miscellaneous storage tanks.

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American Water Works Association (AWWA)	AWWA D115-20 Tendon-Prestressed Concrete Water Tanks	Design and construction of water tanks	This is a standard/guidance document adopted by water industries for design of Tendon-Prestressed Concrete Water Tanks. Design basis: 2/3 of MCE. Vertical accelerations considered refers to ACI 350.3 for values. Uses allowable stress design. Refers to ACI 350.3 for general design equations, with some exceptions. Design earthquake loads to ACI 350.3 as modified R-factors are given based on type of base, and whether the base is above grade or below grade. They range from 1.5 (unanchored on/above grade), to 4.5 (fixed base, below grade). Fixed base on/above-grade R = 3.5. These are based on 'working loads' for seismic design. For LRFD, multiply the load effects by 1.4. 4.8.2 requires consideration of water stop integrity to "accommodate radial and tangential movement without leakage" which is "caused by the combined effects of earthquake-induced base shear, gravity loads, and vertical accelerations." Anchorage required for higher-seismicity areas (Sds>0.5). Use flexible connections to accommodate differential settlement and seismic activity. Requires consideration of freeboard per ACI 350.3 and resulting uplift forces on the roof if sufficient freeboard is not provided. (Sec 4.10)	Design and construction of fuel and miscellaneous storage tanks.
Federal Emergency Management Agency (FEMA)	FEMA Region 10 CSZ Response Plan (2022)	Federal emergency response plan	FEMA's Emergency response plan for Oregon, Washington, Idaho and Alaska post-Cascadia Subduction Zone.	Informational emergency response plan.
Federal Emergency Management Agency (FEMA)	FEMA 233 Earthquake resistant construction of gas and liquid fuel pipeline systems	Seismic design and construction of gas and liquid fuel pipelines	Provides performance summaries of various components of a fuel pipeline system (pipes, storage tanks, aboveground facilities) during historical earthquakes. Highlights failure mechanisms and lists some remedial recommendations. References API 650, AWWA D100 for above-ground tanks. Notes that API 650 and AWWA D100 (at the time of this publishing) does not address siting and secondary containment requirements for storage tanks.	Seismic design and construction of gas and liquid fuel pipelines.
Federal Emergency Management Agency (FEMA)	FEMA P-2090 Recommended options for improving the Built Environment for Post-Earthquake Re-occupancy and Functional Recovery Time	Emergency recovery post-earthquake	Guideline for post-disaster recovery. Defines 3 levels of recovery - re-occupancy, functional recovery, and full recovery. For lifelines - functional is subdivided into operability and functionality.	Emergency preparedness for emergency recovery post-earthquake.
Federal Emergency Management Agency (FEMA)	FEMA P-414 Installing seismic restraints for duct and pipe	Installation of seismic restraints for ducts and pipes	Installation guidelines of seismic restraints for ducts, pipes, and equipment attached to buildings.	Seismic design and construction of mechanical equipment.

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IBC	International Building Code (IBC)	Building Code	IBC 21 is currently being used - IBC 24 is expected to be adopted. Following its adoption a year or two later local jurisdictions are expected to be adopted . New IBC seismic provisions adopt ASCE 7 and only provide a few exceptions or alternatives to ASCE 7. Risk Category (RC) II is typical, IV is for higher performance, III is in-between. See seismicity for performance targets. RC IV includes "Power-generating stations and other public utility facilities required as emergency backup facilities for Risk Category IV structures." RC III includes other power generation and public utilities not captured in RC IV. References ASCE 7 for seismic design of building structures. NEHRP Recommended Seismic Provisions for New Buildings and Other Structures discuss intent/basis of risk targeting adopted in IBC/ASCE7, including (for RC II), 10% probability of collapse given a "very rare ground motion" and 1% overall chance of collapse in 50 years. "The combination of these two probabilities defines the Risk Targeted Maximum Considered Ground Motion (MCE_R)". (Except for near-fault sites where deterministic motions control MCE_R). Includes table that notes RC IV -- 2.5% probability of collapse in MCE_R motions and <1% probability of collapse in 50 years. NEHRP commentary notes that in most places the MCE_R is slightly lower than 2%/50 ground motions, including Oregon.	Building codes.
National Association of State Energy Officials (NASEO)	NASEO Electricity-Water Critical Infrastructure Interdependencies: How states can enhance resilience and reduce risks	Assessments of Infrastructure Interdependencies	Provides a 3 step approach to assess interdependencies (p. 7). This doc is more policy related - no engineering standard though.	Procedures for assessing infrastructure interdependencies at the fuel sites.
National Academies of Sciences, Engineering and Medicine	National Academies of Science, Engineering and Medicine - State of the Art and Practice in the Assessment of Earthquake-Induced Soil Liquefaction and Its Consequences	State of the Art and Practice in the Assessment of Earthquake-Induced Soil Liquefaction and Its Consequences	This document provides a discussion of various methods used for evaluating liquefaction but does not require one over the other.	Procedures for evaluating liquefaction and liquefaction induced settlement which seismic conditions may apply at the fuel sites.
Oregon Department of Transportation (ODOT)	ODOT Geotechnical Design Manual (GDM)	Geotechnical design	Specifies procedures for evaluation of liquefaction & liquefaction induced settlement Design using life-safety & operational design criteria: 1. Life Safety = 1,000-year return period EQ using USGS seismic hazard maps or the ODOT ARS spreadsheet 2. Operational = 500-year return period east of Hwy 97, west of Hwy 97, design using full rupture of CSZE If liquefaction triggers Site Class F, site specific ground response analyses is required. References AASHTO LRFD Seismic Bridge Design.	Design procedures for evaluating liquefaction and liquefaction induced settlement which seismic conditions may apply at the fuel sites.

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Oregon Department of Transportation (ODOT)	ODOT Bridge Design Manual (BDM)	Geotechnical and structural design standards and practices	References AASHTO LRFD Bridge Design Specifications (BDS) Requires all bridges to be designed for full seismic loading according to the AASHTO BDS and the ODOT requirements of: - New bridges on or West of US97 should be designed for a two-level performance criteria: Life Safety and Operational. - Bridge widenings are designed using the same criteria as new bridges - Seismic retrofit should reference FHWA's Seismic Retrofitting Manual for Highway Structures (FHWA-HRT-06-032) but at a minimum achieve Life Safety performance Life Safety = 1,000-year return period earthquake using USGS Hazard Maps and Response Modification Factors from AASHTO LRFD Table 3.10.7.1-1, and importance category of "other"...can also use the ODOT developed design spreadsheet or CSZ program. Operational = assumes a full rupture of CSZ; uses Response Modification Factors from AASHTO LRFD Table 3.10.7.1-1, importance category of "essential". CSZ is a deterministic event so a deterministic Design Response Spectrum should be generated using the Design Response Spectra developed by Portland State University (PSU) in conjunction with a site specific VS30 and site latitude/longitude.	Seismic design standards
Oregon Seismic Safety Policy Advisory Commission (OSSPAC)	Oregon Resilience Plan - Section 6 Energy Sector	Target states of recovery	Provides suggested target states of recovery for energy sector - use as performance goals - there was no evaluation of the liquid fuel tanks - no target state of recovery. However, for the natural gas pipelines the target state is 1 to 2 weeks. Again this is a guidance document though some jurisdictions / agencies may have adopted it as code.	Target states of recovery for the energy sector which applies to the fuel sites.
PRCI	PRCI - Honegger, D.G. and D.J. Nyman (2004) - Guidelines for the Seismic Design and Assessment of Natural Gas and Liquid Hydrocarbon Pipelines	Guidelines for seismic design and assessment of natural gas and liquid hydrocarbon pipelines	Also see "ASME- Honegger, D.G. and D.J. Nyman (2004) - Guidelines for the Seismic Design and Assessment of Natural Gas and Liquid Hydrocarbon Pipelines." Assuming this is the same document (titles are same) this discusses historical practice and seismic design process developed in 1998-2000 by Pipeline Research Council International (PRCI). Emphasizes balanced design between cost, safety, regional economic impacts, imposed loads, and risk assessment.	Seismic design of piping for gas and fuel systems.
State of California Department of Industrial Relations	California Department of Industrial Relations Section 532 Installation of Aboveground Storage Tanks	Seismic design and construction of aboveground tanks	Applies to Aboveground Tanks - requires secure anchorage on firm masonry on concrete foundations. Includes load requirements for seismic, wind, and vibration.	Design and construction of fuel and miscellaneous storage tanks.
Unified Facilities Criteria (UFC)	UFC 1-200-0, change 1, DOD Building Code	Building code	This is the overarching document and directs the use of the code for buildings and facilities owned by Department of Defense. Directs the use of IBC as well as other seismic standards as modified for military purposes. UFC 3-301-01 and UFC 3-301-02 for new and existing facilities. Applies to permanent and temporary construction. Limits temporary to 180 days, though that can be extended up to 5 years max. References other codes for seismic design - UFC 3-301-01, 3-301-05a, 3-301-02, 3-310-04, and IBC and ASCE 7.	Building code that may apply to some of the fuel sites.
Unified Facilities Criteria (UFC)	UFC 3-301-01, chapter 1, 2022 - Structural Engineering w/ Change 1	Seismic evaluation of existing buildings	Directs the use of IBC and ASCE 7 as modified for military purposes. UFC 3-301 and UFC 3-301-02 for new and existing facilities. Use table 3-1 instead of ASCE 7.16 Table 12.2-1 for earthquake loads. Most facilities I = 1.0; essential facilities I = 1.5; National defense facilities are category V, I = 1.0.	Seismic evaluation of existing buildings that might apply to some of the fuel facilities.

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Unified Facilities Criteria (UFC)	UFC 3-301-05a Seismic Evaluation and Rehabilitation of Existing Buildings	Seismic evaluation of existing buildings	Seismic Evaluation and Rehabilitation of Existing Buildings was written for USACE, and other military organizations - references ASCE 41-13, and ASCE 7-10, outdated with ASCE 41-17. Superseded by UFC 3-301-01, Ch 1, 2022.	Seismic evaluation of existing buildings that might apply to some of the fuel facilities.
Unified Facilities Criteria (UFC)	UFC 3-310-04 Seismic Design of Buildings	Seismic design of buildings	Used IBC 2012, ASCE 7-10 and ASCE/SEI 41-13 as basis of their seismic standard with minor changes or additions for military specific type of facilities. Includes special inspection criteria. Uses Risk Category instead of Occupancy Category. Designs to resist progressive collapse. Most facilities I = 1.0; essential facilities I = 1.5; National defense facilities are category V, I = 1.0. Designs to resist progressive collapse. Superseded by UFC 3-301-01, Chapter 1, 2022.	Design and construction of fuel and miscellaneous storage tanks that might apply to some of the fuel facilities.
Unified Facilities Criteria (UFC)	UFC 3-460-01 Design of Petroleum Fuel Facilities (Change 2)	Design of petroleum fuel facilities	These have expectation of continuous operation. Requires spill prevent control and countermeasures plan in accordance with 40 CFR Part 112; requires onsite containment. Containment must equal the greater of 24-hour, 25-year event, or 1 foot over entire containment area. Use API 650 except as modified for military purposes. Aboveground tanks may be single-wall, double-wall, horizontal, or vertical. Underground tanks must be double-walled. General design criteria and standard procedures for the design and construction of military-land based facilities which receive, store, distribute, or dispense liquid petroleum fuels. Includes tank design, anchoring, support, and foundation requirements. Includes requirements for concrete ring wall thickness, fuel impermeable liner, leak detection system, flexible connections, piping, and appurtenances to accommodate movement. References using the UFC 3-301-05 and UFC 3-3-310-04 for seismic design. Pipes and tanks require cathodic protection. When there is a conflict between requirements Use the most stringent criteria. Contains design standards based on tank type and fuel type. Anchoring and supports are expected to be designed for earthquake, hurricane and flood restraint tie downs.	Design and construction of fuel and miscellaneous storage tanks that might apply to some of the fuel facilities.
US Department of Veterans Affairs (USVA)	USVA H-18-8 Seismic Design Requirements	Seismic design requirements	Required incorporation of hazards assessment review and in design to ensure systems safety. References ASCE 7 for most seismic design, some limitations on types of buildings, drifts. As noted, critical and essential buildings are assigned ASCE 7 Risk Categories for seismic design. Some modifications to nonstructural provisions in ASCE 7. States that all new critical and essential facilities shall be designed with earthquake design and detailing requirements from the IBC.	Design and construction of fuel and miscellaneous storage tanks that might apply to some of the fuel facilities.
US Department of Veterans Affairs (USVA)	13 05 41 Seismic Restraint Requirements for Non Structural Components	Seismic design requirements	Use UFGS Section 13 05 41 Seismic Restraint Requirements for Non Structural Components, dated 1/1/2021 - construction specifications. Specification includes deferred design requirements that are passed on to contractor and subcontractor for design-build distribution systems. Executive Order 13717 requires federal agencies to adopt RP8 and exceed minimum seismic safety standards. H-18-8 is aligned with the RP8 requirements.	Design and construction of fuel and miscellaneous storage tanks that might apply to some of the fuel facilities.
Unified Facilities Criteria (UFC)	UFC 33 16 13.16 Wire-wound Circular prestressed Concrete Water Tank	Design and construction of water tanks	Includes standards for the design and construction -- uses AWWA D110.	Design and construction of fuel and miscellaneous storage tanks.
Washington Department of Transportation (WSDOT)	WSDOT Geotechnical Design Manual (GDM)	Assessment and mitigation of liquefaction	Specifies procedures for evaluation of liquefaction & liquefaction induced settlement. Design using safety evaluation & functional evaluation earthquakes: 1. Safety Evaluation = 1,000-year return period EQ; 2. Functional Evaluation = 210-year return period EQ Limits liquefaction consideration depth to 80 feet bgs References AASHTO LRFD Seismic Bridge Design	Assessment and mitigation of liquefaction practices that could be applied to the fuel sites.

TABLE 2 - COMPARISON MATRIX OF REGULATIONS, POLICIES, AND ENGINEERING STANDARDS
DEQ FUEL TANK SEISMIC STABILITY RULES DEVELOPMENT PROJECT

Reference	Category	Regulatory, Code, Guidance?	Risk Category (RC)	Disaster Resilience/ Risk Management Plan/ Emergency Response Requirements	Spill/ Release/ Containment/ Prevention & Reporting Requirements	Design Scenarios & Procedures / Seismic Performance / Assessment/ Engineering & Tank Design Requirements	Applicable Tank or Storage Capacity	Tank & pipe contents	Pipelines	Buildings & Facilities	Anchorage, Connections & Freeboard
40 CFR 112.20 - Title 40 Protection of Environment, Chapter 1 EPA, Subchapter D Water Programs, Part 112 Oil Pollution Prevention, Subpart D § 112.20 Facility response plans.	Federal	Regulatory		- Facility Response Plan is required if the facility has the potential to cause "substantial harm" to the environment. Plan must include: facility response plans, area continency plans, facility response, drills and exercises. - A response plan shall follow the format of the model facility-specific response plan included in Appendix F to this part, unless an equivalent response plan has been prepared to meet State or other Federal requirements. All facility response plans shall be consistent with the requirements of the National Oil and Hazardous Substance Pollution Contingency Plan (40 CFR part 300) and applicable Area Contingency Plans prepared pursuant to section 311(j)(4) of the Clean Water Act. The facility response plan should be coordinated with the local emergency response plan developed by the local emergency planning committee under section 303 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (42 U.S.C. 11001 et seq.). §112.21 Facility response training and drills/exercises. (a) The owner or operator of any facility required to prepare a facility response plan under § 112.20 shall develop and implement a facility response training program and a drill/exercise program that satisfy the requirements of this section.	Demonstrate the facility has the resources to respond to a worst case scenario discharge.	- Defines "substantial harm" based on amount of storage, maximum storage capacity, facility without secondary containment, distance to sensitive species, wildlife habitat, or drinking water sources, and history of spills - Worst case scenario is defined as "Program Levels" , specified in the Clean Air Act Section 112r					
ACI 350.3 Seismic design of liquid-containing concrete structures and ACI 350.3-20 Commentary	Industry Standard	Guidance	Tanks with "hazardous fuels" = RC III or IV. Tanks for emergency response tanks, RC = III or IV			Probabilistic based on ASCE 7-16. (Although other seismic design values can be used consistently with this standard as it focuses on analysis and response to the seismic inputs.) Vertical accelerations (as a % of horizontal) are included in design. Response modification factors (R) are relatively low, so provisions should result in limited damage to tanks under design ground motions. (ref ACI 350 Ch 21.2.1.1: "For liquid-containing structures, serviceability considerations preclude significant excursions into the nonlinear range under unfactored loads"). MCE spectral response. Includes requirements for analysis and design of liquid-containing concrete structures - covers rectangular and circular ground supported tanks/structures. Refers to AWWA D110-13 and D115-17, IBC 2012, and ASCE/SEI 7-16 for specific design parameters. Allows dynamic analysis. Includes methods to determine sloshing forces, combination with impulsive forces. Considers uplift on tank lid due to sloshing.		Liquid			Recommends freeboard to accommodate sloshing to prevent roof and structural damage
ACI 372R-13 Guide to design and construction of circular wire- and strand-wrapped prestressed concrete structures	Industry Standard	Guidance	Use ACI 350.3			Has provisions for seismic-induced forces. Criteria provided in ACI 350.3, ACI 350, US NRC (1963), AWWA D110 Design should accommodate the maximum wave oscillation (sloshing) induced by seismic ground motion.					Design considerations for seismic restraint cables. Tank should have freeboard allowance, and roof structure should resist uplift pressures from sloshing force.
ALA - Guide for Seismic Evaluation of Active Mechanical Equipment (2004)	Industry Standard	Guidance				Should consult ASCE 7, AISC Steel Manual, ACI 318, API 650, AWWA D100, BNL-52361 (1995)			Aboveground piping should consult ASME Boiler and Pressure Vessel Code, Section III, Dev 1, Nuclear Components Subsections NB/NC/ND-3600 ALA - Seismic Design and Retrofit of Piping Systems **ASME B31,** NFPA-13 Buried piping should consult ALA - Guide for the Design of Buried Steel Pipe ASCE 4		In-line and in-structure spectrum amplification should be considered. Valves with cast iron bodies more prone to stress failure than steel. If the valve is connected to the piping through non-welded mechanical joints other than pipe flanges, the nozzle joints could deform and leak If the valve operator is braced directly to the wall but the pipe span is flexible, the operator could fail from large reaction loads developed as the pipe span tries to swing and is held back by the brace on the operator.
ALA Guideline for Assessing the Performance of Electric Power Systems in Natural Hazard and Human Threat Events (April 2005)	Industry Standard	Guidance				Recommends 4 key performance criteria: 1) protect public and worker safety; 2) maintain system reliability; 3) prevent monetary loss; and 4) prevent environmental damage. Guideline for vulnerability and hazard assessments of natural and man-made disasters. Primarily prepared for winter storms, wind, snow, ice, localized flooding, and vandalism. Utilities generally not prepared for larger, rarer events like earthquakes, major flooding or terrorism. Phase 1 - qualitative. Phase 2 quantitative. Earthquake hazard considered the worst case.					
ALA Guideline for the Design of Buried Steel Pipe (2001)	Industry Standard	Guidance				Provides guidelines on pipe strains due to transient wave propagation. Also provides guidance on ground deformations and associated strains for different types of potential earthquake hazards (e.g., what to consider for permanent ground displacement vs. lateral earth spreading).					
ALA Guidelines for the Seismic Design and Retrofit of Piping Systems (2002)	Industry Standard	Guidance	RC = I to IV depending on application and content			Applies to above ground piping systems only. Seismic analysis can be static or dynamic. Max bending stress = 0.5 S_Y; where S_Y = material yield stress at operating temperatures. Limit midspan bending to 2-inches. Deformation under seismic loading is ≤ to 1/8-inches. 4 ≤ FOS ≤ 5			Design pressure and temperature are the highest pressure and corresponding temperature (p.8). Allowable stress in gas and oil pipes is based on 72% of minimum specified yield stress and the population density. Calls for restrain stiffness so that pipe deformation under seismic load is less than or equal to 1/8" (p. 33); Factor of safety in pipe capacity design ranges from 4 to 5 (p.51). Brace pipes against large side sway and large vertical earthquake movement.		Verify adequacy of vertical supports and anchorage and tie-downs for earthquake movements. Provide flexible connections and couplings to absorb differential movements from earthquakes

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API 620 - Design and Construction of Large, Welded, Low-pressure Storage Tanks (2002)	Industry Standard	Guidance	RC = III (I=1.25) or RC = IV (I = 1.5) are used for tanks storing hazardous, toxic or explosive substances in areas where accidental release could be dangerous to public safety.			Seismic zone factor for horizontal seismic acceleration is determined by purchaser or governmental authority based on mapped values. The response spectra for a specific site shall be established by considering the active faults within the region, the types of faults, the magnitude of the earthquake that could be generated by each fault, the regional seismic activity rate, the proximity of the site to the potential source faults, the attenuation of the ground motion between the faults and the site, and the soil conditions at the site. The thickness of the bottom plate under the shell shall not exceed the thickness of the bottom shell course or 1/4 in., whichever is greater.					Annex L.7 addresses vertical flexibility of piping. Suitable flexibility shall be provided in the vertical direction for all piping attached to the shell or bottom of the tank. On unanchored tanks that are subject to bottom uplift, piping connected to the bottom shall be free to lift with the bottom or shall be located so that the horizontal distance measured from the shell to the edge of the connecting reinforcement is equal to the width of the bottom hold-down plus 12 in. Annex L.8 allows purchaser to specify freeboard and provides an equation for sloshing wave.
API Standard 650 - Welded Tanks for Oil Storage (2007) plus addendums through Feb 2012)	Industry Standard	Guidance	Performance based on Seismic Use Groups (SUG) which are similar to IBC/ASCE7 Risk Categories, but with different designations. (SUG I is similar to RC II; SUG III is similar to RC IV). Commentary: "It is unlikely that petroleum storage tanks in terminals, pipeline storage facilities and other industrial sites would be classified as SUG III unless there are extenuating circumstances." However there could be a path to SUG III using E.3.1.1: "those providing necessary service to facilities that are essential for post-earthquake recovery an essential to the life and health of the public; or, tanks containing substantial quantities of hazardous substances that do not have adequate control to prevent public exposure."	API 653 addresses condition assessment including inspection frequency. Includes internal and external inspections.	Section E.7.2 Freeboard, says the purchasers determines in there is any freeboard desired for SUG 1 to prevent spillage. Freeboard is required for SUG II and III to prevent spillage.	Site-specific ground motions should be considered if the tank is located within 10 km of a fault, the structure is designed with a base isolation or energy dissipation system or is required by owner. Vertical ground motions are included. (E6.1.3) The 5% damped site-specific MCE_R spectral response acceleration for any period shall be the lesser of the probabilistic and deterministic MCE_R ground motion spectral response accelerations. Design method includes response reduction for ductility (ref EC.5) , implying damage to tank or anchor bolts. E.1 discusses possibility of damage to tanks when designed per these provisions. Commentary on SUG I (EC7.2) implies that some loss of product is acceptable performance in DBE.		Oil			Allows for "self-anchored" tanks in some areas. For practical purposes, tanks in seismic zones will require anchorage. Commentary EC7.3 discusses flexibility of connections and pipe breaks. Notes that it may be more cost effective to improve pipe connection flexibility rather than anchoring the tanks. Table E.8 includes a displacement table for flexibility design. Section E.7.2 Freeboard, says the purchasers determines in there is any freeboard desired for SUG 1 to prevent spillage. Freeboard is required for SUG II and III to prevent spillage.
ASCE/SEI 4-16 Seismic analysis of safety-related nuclear structures	Industry Standard	Guidance				Focus is analysis methods. Demands refer back to ASCE 43. Goal to predict seismic demands in DBE shaking at 80th percentile no exceedance probability (ASCE 43 Sec 1.3). Ch 9 includes requirements for vertical, liquid-storing tanks. Ch 10 includes distribution piping.		Primarily coolant	Ch 7 includes buried pipe and conduit analysis methods.		
ASCE/SEI 7-16 - Minimum Design Loads and Associated Criteria for Building and Other Structures	Industry Standard	Guidance except when referenced from OSSC, IBC, etc. Note OSSC 2022 references ASCE 7-16 so in Oregon it is Code.	Risk categories (RC = I to IV) with RC = IV the highest. RC are established to limit damage for more important structures. Definitions from IBC, OSSC, etc. usually control RC assignment. RC IV is assigned to utility-scale power generation, hospitals, emergency facilities, emergency response facilities, etc.		See notes on Freeboard.	Defines MCE as 2% exceedance in 50 years (about 2,500-year interval). Design level ground motions (DBE_R) are 2/3 of MCE_R Design methods include R-factors that allow for controlled damage of structure. Risk targeting concept is based on an acceptable level of collapse in 50 years, which varies by risk category. Chapter 15 includes standards for design but also references API 650 and API 620 for design of welded tanks. Foundations not allowed to lose strength capacity to support vertical reactions to prevent BC failures in shallow foundations & axial load failure in deep foundations IBC 2021 uses ASCE 7-16. - Site Class based on shear wave or SPT-N in upper 100 feet - Ground motions for MCE (2% exceedance in 50 years) & design response spectrum using ASCE 7 online Hazard tool - Liquefaction evaluation required for MCE PGA minimum FS for sliding = 1.5 minimum FS for buckling = 1.0			Piping systems typically designed for pressure containment with min FS = 3 against rupture		Commentary (C15.7.3) notes that stretching of anchor bolts is a desirable energy absorption mode. Requires flexible connections between structurally separate components (15.7.6.1.3). Table 15.7.1 provides minimum design displacements. Freeboard sloshing of liquid shall be determined by Eq. 15.6-1. Minimum freeboard in higher seismic areas (SDS>0.33g) requires freeboard for RC III and RC IV tanks but not RC II.
ASCE/SEI 7-22 - Minimum Design Loads and Associated Criteria for Building and Other Structures	Industry Standard	Guidance, except when referenced by Code or Proposed Code like IBC or OSSC	Risk categories (RC = I to IV) with RC = IV the highest. RC are established to limit damage for more important structures. Definitions from IBC, OSSC, etc. usually control RC assignment. RC IV is assigned to utility-scale power generation, hospitals, emergency facilities, emergency response facilities, etc.		See notes on Freeboard.	Defines MCE as 2% exceedance in 50 years (about 2,500-year interval) Design level ground motions (DBE_R) are 2/3 of MCE_R Design methods include R-factors that allow for controlled damage of structure. Risk targeting concept is based on an acceptable level of collapse in 50 years, which varies by risk category. Chapter 15 includes standards for design but also references API 650 and API 620 for design of welded tanks. Foundations not allowed to lose strength capacity to support vertical reactions to prevent BC failures in shallow foundations & axial load failure in deep foundations ASCE 7-22 is expected to be adopted in IBC 24, which means it should be adopted into Oregon Structural code in 2025 or later - Site Class based on shear wave or SPT-N in upper 100 feet - Ground motions for MCE (2% exceedance in 50 years) & design response spectrum using ASCE 7 online Hazard tool - Liquefaction evaluation required for MCE PGA minimum FS for sliding = 1.5 minimum FS for buckling = 1.0			Piping systems typically designed for pressure containment with min FS = 3 against rupture		Commentary (C15.7.3) notes that stretching of anchor bolts is a desirable energy absorption mode. Requires flexible connections between structurally separate components (15.7.6.1.3). Table 15.7.1 provides minimum design displacements. Freeboard sloshing of liquid shall be determined by Eq. 15.6-1. Minimum freeboard in higher seismic areas (SDS>0.33g) requires freeboard for RC III and RC IV tanks but not RC II.

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ASCE/SEI 41-17 - Seismic Evaluation and Retrofit of Existing Buildings	Industry Standard	Guidance except when referenced by a code like OSSC, IBC, etc.	References ASCE 7.			Probabilistic seismic hazard. Damage to building components is part of the design methodology. Allowable amount of damage is dependent on desired performance level. All standard performance objectives allow for some damage (m-factors >1.0) Technically any hazard can be used. In addition to ASCE 7 DBE,r and MCE,r (BSE-1N and -2N), additional defaults are 5%/50 (BSE-2E) and 20%/50 (BSE-1E) which are generally used for existing buildings and lower than ground motions used for new design.				Applicable to seismic evaluation and retrofit of existing buildings.	
ASCE/SEI 43-19 Seismic design criteria for Structures, Systems and Components in Nuclear Facilities	Industry Standard	Guidance				Ground motions are risk-targeted to probabilities of failure for different components and systems. Acceptable probabilities of failure vary, with 4 different Seismic Design Categories (SDCs) (4E-4 to 1E-5). Overall goal of 1% probability of failure given DBE ground motions AND less than 10% probability of failure given 150% DBE shaking. (Sec 1.3, 1.5). Evaluation at two annual probabilities of exceedance: one at 4E-4 to 1E-5 (Table 1-1) and one at 10x (Sec 2.2) Ch 2 method starts with a Uniform Hazard Spectrum (based on exceedance probability above) and a frequency-dependent scale factor in turn based on the shape of the UHS. Requires site-specific soil evaluation (Sec 2.3) for transforming bedrock motions to surface. Section 1.4: "Selection of the appropriate SDC and LS for a givens structure or usage is beyond the scope of this standard, which provides design requirements for a given SDB, once selected" Evaluation is component and system-based, rather than building-level approach used in ASCE 7. (Commentary C1.3)					
ASCE Pipelines 2014 Proceedings - "Seismic Design of Buried Steel Water Pipelines" by Spyras A. Karamanos, Brent Keil, Robert J Card	Industry Standard	Guidance						Water	Goals - minimize seismic risk to pipes, safeguard water supply, minimize earthquake damage, maintain structural integrity and prevent leakage. Concerned about transient and permanent ground deformation. For oil and gas, also concerned about accidental (environmental) leakage.		
ASCE Seismic Evaluation and Design of Petrochemical and Other Industrial Facilities (2020)	Industry Standard	Guidance	References ASCE 7			Defines MCE as 2% exceedance in 50 years (2475 years). Evaluate ground deformation due to liquefaction on buried tanks, vaults, and pipelines. Must use ASCE 7 vertical seismic load (exception is large flat bottom tank. Obtain ground motions based on risk category and site class using ASCE 7 online Hazard tool Must adjust ground motions for correct site class determined by Vs30 for the top 100 ft or the SPT blow counts (Vs30 is preferred) Liquefaction, lateral spreading, and slope stability must be incorporated into analysis and design of tanks - lateral spread evaluated empirically as outlined in Khoshnevisan et al. 2015 or nonlinear effective stress model programs - liquefaction can be evaluated using the Simplified Procedure FS for sliding = 1.0 FS for Overturning = 1.0 (min)		Petrochemical			Freeboard to account for seismic shaking sloshing wave calculated by ASCE 7 and API 650 App. E
ASCE TCLEE Monograph 12 - Seismic Guidelines for Ports (March 1998)	Industry Standard	Guidance		Recommends emergency response and recovery plans be developed. Acknowledges that deformations and damage may occur so being prepared is critical. Weighs cost of doing seismic design and retrofits with loss of revenue, physical and environmental damage, region economic impact, etc. Recommends in advance identifying what is critical or essential to function continuously without interruption. Introduces "acceptable seismic risk" in terms of operational level earthquake (OLE) motions versus contingency level earthquake (CLE) motions. In case of OLE, this is the maximum level of horizontal ground motions the port facilities can withstand and still be fully useable without damage or needing repairs. CLE acknowledges some damage but the port facilities can still be used.	Recommends spill containment facilities be seismically designed. Historically these have failed too and usually overlooked in design.	General guideline for seismic performance, design and evaluations of port facilities - from waterfront areas, cranes, tank and container storage, site utilities and site buildings. Manual is based on evaluation of seismic performance of port facilities from 26 earthquakes from 1923 to 1995. Recommends design performance criteria for each type of facility on site be established in advance for both new and existing facilities. No specific code applies to all port facilities. In some cases, building codes apply to specific buildings. In general, designs use best management practices based on what has been decided as the acceptable seismic risks.					
ASCE/SEI - "Seismic Design Criteria for Pipelines and other Long Structures" by Pravecnk Mahotram, Strong Motions, Inc. Article in SEI May 2013	Industry Standard	Guidance				Site-specific analysis generally underestimates risks to long pipelines. Proposes using aggregate (a cumulative) analysis for whole length to assess risk. Uses ASCE 7 for minimum seismic loading requirements. Used 475 years for return period and PGA of 0.4 g. Design criteria dependent on level of acceptable risk.					

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ASME B31.3 - Process Piping (2006)	Industry Standard	Guidance except when referenced by a code or adopted by a jurisdiction as code	See ASCE 7	Standard for petroleum and natural gas facilities, tanks, piping, and controls. Uses ASCE 7 for minimum seismic loading requirements in design. Includes design provisions for metallic and pipes lined with non-metallic materials. Excludes gravity pipe, pipes under 15 psi that are non-flammable, non-toxic and not harmful to human tissue. Requires new pipe and all related facilities to be labeled: • Category D - normal fluid service pipe (nonflammable, nontoxic, and not damaging to human tissues, the design pressure does not exceed 150 psig (1035kPa), the design temperature is from -20 degree F to 366 degrees F. (Per ASME B31.3 Appendix A) • Category M - safety class piping systems subject to severe cyclic conditions, "a fluid service in which both of the following conditions apply: highly toxic fluid such that a single exposure to a very small quantity of the fluid, caused by leakage, can produce serious irreversible harm to persons on breathing or bodily contact, even when prompt restorative measures are taken." (per ASME B31.3 Appendix O) • High Pressure - owner defined, though typically applies to pressures higher than ASME B16.5 Class 2500, "a fluid service for which the owner specifies the use of Chapter IX for piping design and construction", (ASME B31.3 Appendix M) • High Purity Fluid - "a fluid service that requires alternative methods of fabrication, inspection, examination, and testing not covered elsewhere in the Code, with the intent to produce a controlled level of cleanness. The term thus applies to pipe systems defined for other purposes as high purity, ultra-high purity, hygienic, or aseptic."		Standard for petroleum and natural gas facilities, tanks, piping and controls. Uses ASCE 7 for minimum seismic loading requirements in design. Includes design provisions for metallic and pipes lined with non-metallic materials. Excludes gravity pipe, pipes under 15 psi that are non-flammable, non-toxic and not harmful to human tissue.		Petroleum, gasoline, chemical, paper, processing, semiconductor.			
ASME B31.4 - Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids (2006)	Industry Standard	Guidance except when referenced by a code or adopted by a jurisdiction as code		Requires written emergency plan - to include: •remedial action for providing safety of public and operations staff, •minimize property damage, •protect the environment, •limit accidental discharge from piping system, •coordination with federal, state and local jurisdictions and the public •staff training		Uses ALA Guidelines for Design of Buried Pipelines and ASME B31.1 for design of soil forces on buried pipelines. Applies to new pipe only. Pertains to pipes transporting hazardous products that are predominately liquid fuels between facilities and production. Seismic loading is an occasional load that is included in strength design" and includes •Direct effects due to ground vibration •Induced effects from liquefaction and landslides •Crossing active faults at surface		Liquid hydrocarbons, crude oil, liquid natural gas, liquified anhydrous ammonia, produced water, injection water, brine, biofuels and slurries	Applies to process piping at and from refineries to production facilities, processing facilities and related plants and/or terminals. Applies to new aboveground and buried pipe only.		
ASME B31.8 - Gas Transmission and Distribution Piping Systems (2022)	Industry Standard	Guidance except when referenced by a code or adopted by a jurisdiction as code		Requires written emergency plan but vague on details. Requires written operations and maintenance manual (O&M)		Steel and plastic pipe design. This guidance is for design, fabrication and installation. Section 841.1.10 - contains no specific seismic design. Just calls for "protection of pipelines from hazards… Take reasonable precautions to protect the pipe."		Gas	Applies to piping transporting natural gas products between sources and terminals including compressors, regulators, and metering stations. Does not apply to pressure vessels, pipes over 450 degrees F, or passed the customer's meter.		
ASME/ANSI B31E-2008 - Standard for the Seismic Design and Retrofit of Above-Ground Piping Systems	Industry Standard	Guidance except when referenced by a code or adopted by a jurisdiction as code	Uses ASCE 7		Critical piping must remain leak tight during and following earthquake. Pipe must remain operable to deliver contents, control (throttle) or shut down flow during or after the design earthquake as determined by the engineer and owner.	Establishes guidance method for seismic design and retrofit of aboveground piping systems in the scope of ASME B31. Seismic loading may be horizontal or vertical or both using static coefficients; or use response spectra with ASCE 7; or use site specific response spectra. "Design earthquake is considered the level of earthquake that the piping system is designed for to perform a seismic function – position retention, leak tightness, or operability." Retrofits require condition assessment. Critical piping must remain leak tight during and following earthquake. Pipe must remain operable to deliver contents, control (throttle) or shut down flow during or after the design earthquake as determined by the engineer and owner.			Applies to aboveground piping systems. "minimum elongation at rupture not to exceed 15% at temperature concurrent with the seismic load"		
ASME International Pipelines, "Guidelines for seismic design and assessment of natural gas and liquid hydrocarbon pipelines" by Douglas G. Honegger, Richard W. Gailing and Douglas J. Nyman	Industry Standard	Guidance				Primary Earthquake load is the PGD. Recommends using finite element analysis.		Gas, liquid hydrocarbons	Discusses historical practice and seismic design process developed in 1998-2000 by Pipeline Research Council International (PRCI). Emphasizes balanced design between cost, safety, and imposed loads and risk assessment.		
AWWA D100-21 Welded Carbon Steel Tanks for Water Storage	Industry Standard	Guidance	Risk categories - similar to ASCE 7. Specifies using Rc = IV unless otherwise specified. Advises against using RC = I.	Recommends annual inspection and maintenance of exterior tank shell to bottom connection. Three year interval for inspection and maintenance of the entire internal and external tank.		Refers to ASCE 7 for MCE (2% exceedance in 50 years). Includes site coefficient tables similar to ASCE 7-10. Scaled down by 2/3 factor to get to Design Earthquake. Considers vertical acceleration at different values depending on controlling failure mode. R-factors included for Impulsive component of loading up to R=3. This is a standard/guidance document adopted by water industries for design of welded carbon steel tanks for water storage. Uses allowable stress design, except for the design of the reinforced concrete foundation. References using ACI 318, API 620, and API 650. Includes provisions for alternative design basis for ground supported tanks and reservoirs (chapter 14).		Water			Requires consideration of flexibility, with prescriptive table for values of design movements (Table 26). Requires freeboard for RC IV tanks and RC III where Sds>=0.33g (moderate seismicity or higher). Freeboard not required for RC II tanks.

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DEQ FUEL TANK SEISMIC STABILITY RULES DEVELOPMENT PROJECT

Reference	Category	Regulatory, Code, Guidance?	Risk Category (RC)	Disaster Resilience/ Risk Management Plan/ Emergency Response Requirements	Spill/ Release/ Containment/ Prevention & Reporting Requirements	Design Scenarios & Procedures / Seismic Performance / Assessment/ Engineering & Tank Design Requirements	Applicable Tank or Storage Capacity	Tank & pipe contents	Pipelines	Buildings & Facilities	Anchorage, Connections & Freeboard
AWWA D110-18 Wire- and Strand-Wound; Circular; Prestressed Concrete Water Tanks	Industry Standard	Guidance	RC IV: Tanks that must remain usable to provide emergency service for fire suppression, with slight structural damage and insignificant leakage after an earthquake. RC III: Tanks that must remain usable, but may suffer repairable structural damage, and can be taken out of service... (note no specific reference to leakage for RC III) (Table 2)		Water tightness criteria - net liquid loss shall be less than 0.05% of the tank capacity in 24 hours. Requires consideration of sloshing forces against roof if insufficient freeboard height is not maintained. Requires that water stops sustain "relative displacement between the tank shell and foundation caused by the combined effects of earthquake-induced base shear, gravity loads and vertical accelerations ... without leakage when subjected to design seismic load" (Sec 4.8.2)	Use ASCE 7 for the MCE. Design earthquake is 2/3 of MCE. Probabilistic MCE is defined as 2% exceedance in 50 years. Allows deterministic, probabilistic calculation of MCE or site-specific response spectra. If deterministic EQ used, MCE defined as 150% of the median response from controlling characteristic earthquake. Vertical accelerations considered. This is a standard/guidance document adopted by water industries for Wire- and Strand-Wound; Circular; Prestressed Concrete Water Tanks. Section 3 uses allowable stress design and allows alternative analysis with adjustments for response spectrum. References IBC, ASCE 7, and ACI 350. Section 4 has provisions for earthquake induced forces. R-factors vary for loading and structure type, up to 3.5 for some anchored tanks. R-factors are based on working-stress design.		Water	Section 3.11.1.3 recommends concrete encasement of pipes under tanks and flexible joints outside of the footing to accommodate differential settlement and seismic activity		Anchorage required for higher seismicity (Sds >= 0.5g). (Sec 4.2.2) Additionally recommends certain types of base joints (radially freed but anchored) for larger (>2 mil gallon) tanks in higher seismicity areas. Requires consideration of sloshing forces at tank roof if minimum freeboard is not maintained. (Sec 4.10)
AWWA D115-20 Tendon-Prestressed Concrete Water Tanks	Industry Standard	Guidance			4.8.2 requires consideration of water stop integrity to "accommodate radial and tangential movement without leakage" which is "caused by the combined effects of earthquake-induced base shear, gravity loads, and vertical accelerations"	This is a standard/guidance document adopted by water industries for design of Tendon-Prestressed Concrete Water Tanks. Design basis: 2/3 of MCE. Vertical accelerations considered refers to ACI 350.3 for values. Uses allowable stress design. Refers to ACI 350.3 for general design equations, with some exceptions. Design earthquake loads to ACI 350.3 as modified R-factors are given based on type of base, and whether the base is above grade or below grade. They range from 1.5 (unanchored on/above grade), to 4.5 (fixed base, below grade). Fixed base on/above-grade R = 3.5. These are based on 'working loads' for seismic design. For LRFD, multiply the load effects by 1.4.		Water			Anchorage required for higher-seismicity areas (Sds>0.5). Use flexible connections to accommodate differential settlement and seismic activity. Requires consideration of freeboard per ACI 350.3 and resulting uplift forces on the roof if sufficient freeboard is not provided. (Sec 4.10)
California Code Regulations (CCR) 2022 Title 24, Part CA. Building Code Ch. 31F - Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS)	State	Code		MOTs regulated by MOTEMS must undergo inspections (conducted annually), audits (conducted every 4 years unless otherwise recommended), and post-event inspections to ensure compliance with this code. These audits and inspections are a form of vulnerability analysis which then set forward mitigation requirements to which facilities must respond with a mitigation plan.	3101F.5 Spill prevention. Each MOT shall utilize up-to-date Risk and Hazards Analysis results developed per CCPS "Guidelines for Hazard Evaluation Procedures" [1.1] and [1.2], to identify the hazards associated with operations at the MOT, including operator error, the use of the facility by various types of vessels (e.g., multi-use transfer operations), equipment failure and external events likely to cause an oil spill. Minimum maintenance criteria for the Marine Oil Terminals (MOTs) Minimum inspection criteria for MOTs including: - Annual inspections - Audits conducted every 4 years unless otherwise recommended - Post-event inspections 3101F.6 Oil Spill exposure classification - Table 31F-1-1: High, Moderate, Low based on exposed total vol of oil, max number of transfers per berth per year; max vessel size.	Design earthquake - determined by the recurrence rate probability, or the design earthquake may be selected as the largest earthquake magnitude associated with a critical seismic source, taken as the closest distance from the source to the facility site. If the largest earthquake magnitude is selected, it "shall be associated with all DPGA values for the site, irrespective of probability levels. 3104F.2.1 Seismic Performance Criteria for existing MOTS (Table 31F-4-1) - defined as probability of exceedance & return period based on two levels of Seismic performance: Level 1 Seismic Performance: · Minor or no structural damage · Temporary or no interruption in operations Level 2 Seismic Performance: · Controlled inelastic behavior with repairable damage · Prevention of collapse · Temporary loss of operations, restorable within months · Prevention of major spill (≥1200 bbls) AND based on Spill Exposure Classification (defined in above 3101F.6) 3104F.3 New MOTs - The analysis and design requirements described in Section 3104F.2 shall also apply to new MOTs. However, new MOTs shall comply with the seismic performance criteria for high spill classification, as defined in Table 31F-4-1. Additional requirements are as follows: 1. Site-specific response spectra analysis (see Section 3103F.4.2.3). 2. Soil parameters based on site-specific and new borings (see Section 3106F.2.2). Seismic Analytical procedure requirements for displacement capacity of elements of the structure vs. displacement demand. The displacement capacity shall be calculated using the nonlinear static (pushover) procedure; Methods used to calculate the displacement demand are linear modal, nonlinear static and nonlinear dynamic and based on spill classification, configuration, and substructure material. The required analytical procedures are summarized in Table 31F-4-2. Minimum engineering criteria for MOTS: - methodology for determining the seismic requirements at a given facility based on Design Peak Ground Acceleration (DPGA), Design Spectral Acceleration, and Design Magnitude, which will include site amplification effects and site liquefaction assessments. DPGA and Design Spectral Acceleration will be obtained from either the USGS US Seismic Design Maps tool using ASCE/SEI 41 with the probability of exceedance in 50 years and appropriate site soil classifications. Or, DPGA and Design Spectral Acceleration will be determined by a site-specific probabilistic seismic hazard analysis conducted by a qualified California registered civil engineer with a California authorization as a geotechnical engineer.		Oil	All pressure piping, pipelines, and all supports and attachments for oil service shall comply with provisions of API Standard 2610, ASME B31.3, or ASME 31.4 as appropriate. Pipeline stress analysis should be performed in accordance with ASME 31.4 considering the loads and corresponding displacements determined from the structural and/or geotechnical analysis		
California Department of Industrial Relations Section 532 Installation of Aboveground Storage Tanks	State	Regulatory				Applies to Aboveground Tanks - requires secure anchorage on firm masonry on concrete foundations. Includes load requirements for seismic, wind, vibration.					Aboveground Tanks are supposed to be securely anchored on firm masonry on concrete foundations.
Caltrans 2019 Seismic Design Criteria	State	Regulatory				Seismic Design Criteria (SDC) - includes classifications of bridges and soil types. Provides performance criteria based on bridge type. Important bridges are expected to be available for use immediately following event for emergency response. Recovery bridges are necessary for the economic recovery of the impacted area. Ordinary bridges are those that are not Important or Recovery. Bridges within 300 feet of fault must be designed for fault crossing hazard. Evaluation and performance levels are dictated by bridge importance - for example - ordinary bridges have the lowest evaluation and performance requirements, while Important bridges have highest level of safety evaluation and performance requirements (Section 1.3)					

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CCR (California Code of Regulations) 2022, Title 19, Division 2, Chapter 4.5, Article 1 to 11, Sections 2735.1 to 2785.1	State	Code		Requires that facilities assess for the risk of an earthquake in their process hazard assessment, however the severity of the earthquake is not determined by the regulation. Local regulatory authority and the facility determine the most appropriate methodology for this assessment. Risk Management Plan defines worst case release scenario analysis based on program level as defined by EPA Section 112r Clean Air Act. Program 1 use offsite consequence analysis parameters; For Program 2 and 3 processes and Program 4 stationary sources. Requires that facilities assess for the risk of an earthquake in their process hazard assessment, however the severity of the earthquake is not determined by the regulation. Local regulatory authority and the facility determine the most appropriate methodology for this assessment. Risk Management Plan defines worst case release scenario analysis based on program level as defined by EPA Section 112r Clean Air Act. Program 1 use offsite consequence analysis parameters; For Program 2 and 3 processes and Program 4 stationary sources. Mitigation recommendations should be implemented unless they are deemed infeasible, but that determination of infeasibility will not be based solely on cost.	The worst-case release quantity shall be the greater of the following: 1.For substances in a vessel, the greatest amount held in a single vessel, taking into account administrative controls that limit the maximum quantity 2.For substances in pipes, the greatest amount in a pipe, taking into account administrative controls that limit the maximum quantity	Require that facilities and ongoing processes are made "safe" and comply with recognized and generally accepted good engineering practices (RAGAGEP), as defined by OSHA's process safety management standard (29 CFR 1910.119). Requirements for off-site impact analysis which account for impacts to public receptors, defined as "offsite residences, institutions (e.g., schools, hospitals), industrial, commercial, and office buildings, parks, or recreational areas inhabited or occupied by the public at any time," and environmental receptors, defined as "natural areas such as national or state parks, forests, or monuments; officially designated wildlife sanctuaries, preserves, refuges, or areas; and federal wilderness areas, that could be exposed at any time."					
City of Escondido, CA - Guideline 22 Installation Requirements for Aboveground Storage and Dispensing Tanks (2009)	Local	Regulatory				City of Escondido building code requirements for aboveground storage tanks (2009). Exempts from screening requirements, tanks with less than 5000 gallons or under 5 feet tall. Covers what is required for the permit and the plan submittal Applies to building permit with on-grade (aboveground) tanks 5,000 gallons or more and height to diameter or width ratio of 2:1. Requires structural design; overflow tanks/reservoirs based on size of tank and fluid contents; includes set back requirements	5000 gallons or more, or under 5 feet tall				
City of Portland (COP) City Code Chapter 24.85 Seismic Design Requirements for Existing Buildings	Local	Code								Seismic Design Requirements for Existing Buildings only applies to building seeking permit that change occupancy, adds square footage, alters or repairs a building. Also includes requirements for repair of catastrophic damage or mandatory or voluntary seismic strengthening.	
City of Portland Mitigation Action Plan (2016), Portland Bureau of Emergency Management	Local	Guidance		Includes policy discussion and requirements. Also discusses and references the Critical Energy Infrastructure Hub report.							
FEMA Region 10 CSZ Response Plan (2022)	Federal	Guidance		FEMA's Emergency response plan for Oregon, Washington, Idaho and Alaska post-Cascadia Subduction Zone.							
FEMA 233 Earthquake resistant construction of gas and liquid fuel pipeline systems	Federal	Guidance			Notes that API 650 and AWWA D100 (at the time of this publishing in 1992) don't address secondary containment requirements for storage tanks.	References API 650, AWWA D100 for above-ground tanks. Notes that API 650 and AWWA D100 (at the time of this publishing) don't address siting and secondary containment requirements for storage tanks.		Gas & liquid fuel	Provides performance summaries of various components of a fuel pipeline system during historical earthquakes. Highlights failure mechanisms and lists some remedial recommendations.		
FEMA P-2090 Recommended options for improving the Built Environment for Post-Earthquake Re-occupancy and Functional Recovery Time	Federal	Guidance		Guideline for post disaster recovery. Defines 3 levels of recovery - re-occupancy, functional recovery and full recovery. For lifelines - functional is subdivided into operability and functionality							
FEMA P-414 Installing seismic restraints for duct and pipe	Federal	Guidance				Installation guidelines of seismic restraints for ducts, pipes and equipment attached to buildings.					
International Building Code (IBC)	International	Model Code, except when adopted by jurisdictions, then it becomes code	Risk Category (RC) II is typical, IV is for higher performance, III is in between. RC IV includes "Power-generating stations and other public utility facilities required as emergency backup facilities for Risk Category IV structures." RC III includes other power generation and public utilities not captured in RC IV.			References ASCE 7 for seismic design of building structures. NEHRP Recommended Seismic Provisions for New Buildings and Other Structures discuss intent/basis of risk targeting adopted in IBC/ASCE7, including (for RC II), 10% probability of collapse given a "very rare ground motion" and 1% overall chance of collapse in 50 years. "The combination of these two probabilities defines the Risk Targeted Maximum Considered Ground Motion (MCE_R)". (Except for near-fault sites where deterministic motions control MCE,r). Includes table that notes RC IV -- 2.5% probability of collapse in MCE,r motions and <1% probability of collapse in 50 years. NEHRP commentary notes that in most places the MCE,r is slightly lower than 2%/50 ground motions, including Oregon.					

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IEEE 693 - Recommended Practice for Seismic Design of Substations (April 2005)	Industry Standard	Guidance	Three categories are established for earthquake performance: low, moderate, and high qualification levels. (Sect 1.3) RC I to IV			A goal of the documented recommended practice is to allow the user to secure substation equipment that will have no significant structural damage and maintain electrical functionality at nominal operating conditions during and after a seismic event as specified. (1.3, 5.2.2). Some damage is tolerated, provided that it is not 'significant' (5.2.2). Significant damage is classified as (1) Failure to maintain functionality; or (2) Excessive yielding or fracture. Does not account for subduction zone earthquake (5.8.3.2) because historical performance shows good behavior during these events. To reduce the risks of unfavorable performance associated with uncertainty as to the true performance level, the user may wish to assign the high qualification level to sites with a PGA less than but close to 0.5g. (5.12.1). High qualification level - horizontal 'ZPA' (zero period acceleration) is 1.0g Moderate qualification level - 0.5g Low level - no ZPA. (5.7.1) Site-specific: Based on mean + 1 SD PGA and Spectrum for the MCE_G. Or as an alternative, use the 2% exceedance in 50-years PGA < 0.1g - LOW PGA 0.1-0.5 - MODERATE PGA 0.5+ - HIGH (5.12.2) There are two qualification approaches, the 'performance level approached' (5.3.4) and the 'design level qualification approach (5.3.5). The response spectra accelerations for the design level approach at moderate/high are half of the spectra at the performance level. This is based on a minimum allowable stress ratio of 2 for ductile materials. Design level = Half of performance level. (5.3.2)					Foundation support requirements are in 6.6.6. High qualifications for flex equip: Fp_h = 0.75*Ip*Wp Fp_v = 0.6 * Wp Moderate = half the above. High qualifications for rigid equip: Fp_h = 0.5*Ip*Wp Fp_v = 0.4 * Wp Moderate = half the above.
NASEO Electricity-Water Critical Infrastructure Interdependencies: How states can enhance resilience and reduce risks	Industry Standard	Guidance		Provides a 3 step approach to assess interdependencies (p. 7). This doc is more policy related - no engineering standard though.		Provides a 3 step approach to assess interdependencies (p. 7). This doc is more policy related - no engineering standard though.					
Oregon Administrative Rule (OAR) 340 -141-0160 Department of Environmental Quality Oil Spill Contingency Planning	State	Regulatory			Prevention requirements: The owner/operator of onshore and offshore facility must develop spill prevention strategies that will, when implemented, provide the best achievable protection from damages caused by the discharge of oil into the waters of the state. - Appendices to oil spill prevention and emergency response plans required under this chapter; or A standalone prevention plan that meets all requirements of OAR 340-141-0100 to 340-141-02;. or Spill Prevention Countermeasure and Control Plans (SPCC), Operation Manuals and other prevention documents prepared to meet federal requirements under 33 C.F.R. 154, 33 C.F.R. 156, 40 C.F.R. 109, 40 C.F.R. 112, or the Federal Oil Pollution Act of 1990. Evidence of an inspection program includes: Summary of frequency and type of regularly scheduled inspection and preventative maintenance procedures for tanks, pipelines, key storage, transfer, or production equipment, safety and prevention equipment Evidence of a maintenance program that includes: Description of integrity testing of storage tanks and pipelines using hydrostatic testing and visual inspection; External and internal corrosion detection and repair; Damage criteria for equipment repair or replacement; Maintenance and inspection records.						
ODOT Geotechnical Design Manual (GDM)	State	Guidance				Design using life-safety & operational design criteria: 1. Life Safety = 1000 yr. return period EQ using USGS seismic hazard maps or the ODOT ARS spreadsheet 2. Operational = west of Hwy 97, design using full rupture of CSZE If liquefaction triggers Site Class F, site specific ground response analyses is required References AASHTO LRFD Seismic Bridge Design					
Oregon Building Code - Seismic criteria for building standards vs. critical buildings	State	Regulatory				Site Class based on Ch. 20 of ASCE 7 Section 1613 2022 OSSC covers earthquake loads for structural design					

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Oregon Senate Bill 1567	State	Proposed Regulatory				Include a seismic risk assessment, or a series of seismic risk assessments, conducted by qualified professionals using the most recent industry standards for assessing seismic risk to: (A) Buildings, structures and ancillary components (B) Bulk storage tanks (C) Spill containment structures (D) Transloading facilities, including wharves, piers, moorings and retaining structures (E) Loading racks (F) Control equipment (G) Any other structures and related or supporting facilities that constitute the bulk oils or liquid fuels terminal					
Oregon Building Code ORS 455.447 Regulation of certain structures vulnerable to earthquakes and tsunamis	State	Regulatory				Requires that a site-specific evaluation be conducted when a tank is installed exterior to and not attached to a building in specific situations. Tanks that are containing: containing, housing or supporting water or fire-suppression materials, or equipment required for the protection of essential or hazardous facilities, or special occupancy structures (whether interior or exterior to a building) and, -Those that are housing, supporting or containing sufficient quantities of toxic or explosive substances to be of danger to the safety of the public if released. - does not provide a minimum design standard or instructions for permit issuance for tanks, only that sites for defined tanks are subject to the site evaluation requirements. the division believes that at a minimum, the evaluation should be provided to property owners and the Building Official of record and, that as a best practice recommendation, the evaluation procedures found in OSSC Section 1803 be followed.				Following Department of Consumer and Business Services consultation with the Seismic Safety Policy Advisory Commission and the State Department of Geology and Mineral Industries, the Department can adopt rules (set forth in ORS 183.325 to 183.410) to amend the state building code to require new building sites to be evaluated on a site specific basis for vulnerability to seismic geologic hazards if the sites are for structures that are: Major structures; or Designated under subsection (5) of this section as Tsunami Risk Category III or IV for design. "Major structure" means a building over six stories in height with an aggregate floor area of 60,000 square feet or more, every building over 10 stories in height and parking structures as determined by Department of Consumer and Business Services rule.	
OSSC 2022 - Oregon Structural Specialty Code	State	Regulatory	Chapter 16 definitions match IBC for power/public utilities. RC I to IV with IV being highest		406.7.5 - Secondary containment. Above-ground tanks shall be provided with drainage control or diking in accordance with this chapter. Drainage control and diking are not required for listed secondary containment tanks. 444.1 Prevention, control and mitigation of dangerous conditions related to storage, use, dispensing, mixing and handling of flammable and combustible liquids shall be in accordance with Sections 414 and 415 and this section.	444.4.1 Tank storage. The provisions of this section shall apply to: 1. The storage of flammable and combustible liquids in fixed above-ground tanks." 444.4.1 Tank storage. The provisions of this section shall apply to: 1. The storage of flammable and combustible liquids in fixed above-ground tanks. 2. The storage of flammable and combustible liquids in fixed above-ground tanks inside of buildings. 3. The storage of flammable and combustible liquids in portable tanks whose capacity exceeds 660 gallons (2498 L). 4. The installation of such tanks and portable tanks. 444.4.1.8 Drainage and diking. The area surrounding a tank or group of tanks shall be provided with drainage control or shall be diked to prevent accidental discharge of liquid from endangering adjacent tanks, adjoining property or reaching waterways.444.4 Storage. The storage of flammable and combustible liquids in containers and tanks inside buildings shall be in accordance with this section and the applicable provisions of Sections 414 and 415. 1613.4.13 ASCE 7, Section 15.4.3. Modify ASCE 7, Section 15.4.3, Loads, to read as follows: The seismic effective weight, W, for nonbuilding structures shall include the dead load and other loads as defined for structures in Section 12.7.2. For purposes of calculating design seismic forces in nonbuilding structures, W also shall include all normal operating contents for items such as tanks, vessels, bins, hoppers and the contents of piping. W shall include 20 percent of snow or ice loads where the flat roof snow load, Pf, or weight of ice, Di, exceeds 30 psf (1.44 kN/m2), regardless of actual roof or top of structure slope.		Fuel Oil, flammable and combustible liquids		406.7.3 - Above-ground tanks located inside buildings. Above-ground tanks for the storage of Class I, II and IIIA liquid fuels are allowed to be located in buildings. 406.7.3.1 - Special enclosures. Where installation of tanks underground is impractical, or because of property or building limitations, tanks for liquid motor fuels are allowed to be installed in buildings in special enclosures: 1. The special enclosure shall be liquid tight and vapor tight. 2. The special enclosure shall not contain backfill. 3. Sides, top and bottom of the special enclosure shall be of reinforced concrete not less than 6 inches (152 mm) thick, with openings for inspection through the top only. 4. Tank connections shall be piped or closed such that neither vapors nor liquid can escape into the enclosed space between the special enclosure and any tanks inside the special enclosure. 5. Means shall be provided whereby portable equipment can be employed to discharge outdoors any vapors that might accumulate inside the special enclosure should leakage occur. 6. Tanks containing Class I, II or IIIA liquids inside a special enclosure shall not exceed 6,000 gallons (22 710 L) in individual capacity or 18,000 gallons (68 130 L) in aggregate capacity. 7. Each tank within a special enclosure shall be surrounded by a clear space of not less than 3 feet (910 mm) to allow for maintenance and inspection.	Section 440 Compressed Gases 440.3.3 Securing compressed gas containers, cylinders and tanks. Compressed gas containers, cylinders and tanks shall be secured to prevent falling caused by contact, vibration or seismic activity.

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OSSC 2022 - Oregon Structural Specialty Code	State	Regulatory	Chapter 16 definitions match IBC for power/public utilities. RC I to IV with IV being highest		2802.1.1.6 Spill containment. Tanks exceeding 60-gallon (227 L) capacity or an aggregate capacity of 1,000 gallons (3785 L) that are not provided with integral secondary containment shall be provided with spill containment sized to contain a release from the largest tank.	1803.3.2.1 - Building sites required to be investigated shall, at a minimum, address earthquakes from: (not verbatim) 1. A shallow crustal earthquake on real or assumed faults near the site, subject to evaluation. Minimum design earthquake - no less than a moment magnitude of 6.0 or the design earthquake ground motion acceleration. 2. A deep earthquake (Benioff Zone, intraslab) with a moment magnitude greater than 7.0 on the seismogenic part of the subducting plate of the Cascadia Subduction Zone (CSZ). 3. A CSZ earthquake on the seismogenic part of the interface between the Juan de Fuca Plate and the North American Plate with a minimum moment magnitude of 8.5. 1803.3.2 - Site-specific seismic hazard investigation. Sites for structures and facilities defined by ORS 455.447 as major structures or Risk Category III or IV buildings and other structures evaluated on a site-specific basis for vulnerability to seismic-induced geologic hazards. 1803.6.1 - Site-specific seismic hazard report for building sites requiring a site-specific seismic hazard investigation. ... 2802.1- Fuel oil storage systems shall be installed in accordance with this code. Fuel oil piping systems shall be installed in accordance with the Mechanical Code. 444.4.1.5 Design, fabrication and construction requirements for tanks. The design, fabrication and construction of tanks shall comply with NFPA 30.	2802.1.1 - ... The aggregate capacity of all tanks shall not exceed the following: 1. 660 gallons (2498 L) in unsprinklered buildings, (UL 80, UL 142 or UL 2085) 2. 1,320 gallons (4997 L) in secondary containment tank, buildings equipped with an automatic sprinkler system ... 3. 3,000 gallons (11 356 L) in secondary containment in buildings equipped with an automatic sprinkler system ...	Fuel Oil, flammable and combustible liquids			
Oregon Resilience Plan - Section 6 Energy Sector	State	Guidance		Section 6 Energy Sector - Provides suggested target states of recovery for energy sector - use as performance goals - there was no evaluation of the liquid fuel tanks - no target state of recovery. However, for the natural gas pipelines the target state is 1 to 2 weeks. Again this is a guidance document though some jurisdictions / agencies may have adopted it as code							
PRCI - Honegger, D.G. and D.J. Nyman (2004) - Guidelines for the Seismic Design and Assessment of Natural Gas and Liquid Hydrocarbon Pipelines	Industry standard	Guidance				Also see "ASME- Honegger, D.G. and D.J. Nyman (2004) - Guidelines for the Seismic Design and Assessment of Natural Gas and Liquid Hydrocarbon Pipelines" below for same above Emphasizes balanced design between cost, safety, regional economic impacts, imposed loads and risk assessment. Primary Earthquake loads		Natural gas and liquid hydrocarbon	Assuming this is the same document (titles are same) this discusses historical practice and seismic design process developed in 1998-2000 by Pipeline Research Council International (PRCI).		
Clean Air Act, Section 112(r) - General Duty Clause - Risk Management Program (RMP) Rule, Chapter 2 Applicability of Program Levels	Federal	Regulatory		Program 2 requires management, and emergency response requirements.	The rule defines three Program levels based on processes' relative potential for public impacts and the level of effort needed to prevent accidents with criteria used for defining worst-case scenarios. Program 2 requires streamlined prevention program requirements	Criteria used for defining worst-case scenarios based on program level as processes that would or would not affect public health, and are subject to prevention programs. Criteria used for defining worst-case scenarios based on program level as processes that would or would not affect public health, and are subject to prevention programs. Program 1 imposes limited hazard assessment requirements and minimal prevention and emergency response requirements. Program 2 (additional hazard assessments)					
UFC 1-200-0, change 1, DOD Building Code	Federal Armed Services	Code	RC = I to V. Most facilities RC II or III; essential facilities RC IV; national defense assets facilities use a special category RC = V. RC V are used with military sensitive (national strategic defense assets – such as, but not limited to, missile control systems) applications only where these facilities are required to remain elastic and operational.	Required incorporation of hazards assessment review and in design to ensure systems safety.		"Provides common requirements across DOD for safety, sustainability, durability, and functionality for DoD facilities. " Applies to new and retrofitted facilities. Expected to design for at least 25-yr design life. Design for life safety and habitability. Uses IBC 21 as modified. This is the overarching document and directs the use of the code for buildings and facilities owned by Department of Defense. Directs the use of IBC as well as other seismic standards as modified for military purposes. UFC 3-301 and UFC 3-301-02 for new and existing facilities. Applies to permanent and temporary construction. Generally limits temporary to 180 days, though that can be extended up to 5 years max. Use UFC 3-301-01 Seismic Evaluation and Retrofit of Existing Buildings for seismic design and retrofit. References other codes for seismic design.				Applies to permanent and temporary construction. Generally limits temporary to 180 days, though that can be extended up to 5 years max. References other codes for seismic design	
UFC 3-301-01, chapter 1, 2022 - Structural Engineering w/ Change 1	Federal Armed Services	Code	RC = I to V. Most facilities RC II or III; essential facilities RC IV; national defense facilities use a special category RC = V	Incorporate a hazards review in regular design process. Incorporate safety engineering practices.		Specifies additional design loads for vertical earthquake ground motions. Uses ASCE 7-16 except as modified. Combines UFC 3-301-01 structural engineering and UFC3-110-04 Seismic Design, except for category V which now uses UFC3-301-02 Directs the use of IBC 2018 as well as other seismic standards as modified for military purposes. UFC 3-301 and UFC 3-301-02 for new and existing facilities. Use table 3-1 instead of ASCE 7.16 Table 12.2-1 for earthquake loads.		Chapter 5 covers liquid storage, petroleum storage tanks, and water treatment facilities		Chapter 5 covers non=building structures including "bridges, storage tanks, water treatment plants, transmission towers and poles, antenna towers, etc.	

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Reference	Category	Regulatory, Code, Guidance?	Risk Category (RC)	Disaster Resilience/ Risk Management Plan/ Emergency Response Requirements	Spill/ Release/ Containment/ Prevention & Reporting Requirements	Design Scenarios & Procedures / Seismic Performance / Assessment/ Engineering & Tank Design Requirements	Applicable Tank or Storage Capacity	Tank & pipe contents	Pipelines	Buildings & Facilities	Anchorage, Connections & Freeboard
UFC 3-301-05a Seismic Evaluation and Rehabilitation of Existing Buildings	Federal Armed Services	Code	RC = I to V. Most facilities RC II or III; essential facilities RC IV; national defense facilities use a special category RC = V	Incorporate a hazards review in regular design process. Incorporate safety engineering practices.		Seismic Evaluation and Rehabilitation of Existing Buildings was written for US ACE, and other military organizations - references ASCE 41-13, and ASCE 7-10, outdated with ASCE 41-17. Superseded by UFC 3-301-01, Ch 1, 2022				Seismic Evaluation and Rehabilitation of Existing Buildings was written for US ACE, and other military organizations - references ASCE 41-13, and ASCE 7-10, outdated with ASCE 41-13	
UFC 3-310-04 Seismic Design of Buildings	Federal Armed Services	Code	RC = I to V. Most facilities RC II or III; essential facilities RC IV; national defense facilities use a special category RC = V			Used IBC 2012, ASCE 7-10 and ASCE/SEI 41-13 as basis of their seismic standard with minor changes or additions for military specific type of facilities. Includes special inspection criteria. Designs to resist progressive collapse. Superseded by UFC 3-301-01, chapter 1, 2022				Uses IBC 2012, ASCE 7-10 and ASCE/SEI 41-13 as basis of their seismic standard with minor changes or additions for military specific type of facilities. Includes special inspection criteria. Uses Risk Category instead of Occupancy Category. Designs to resist progressive collapse.	
UFC 3-460-01 Design of Petroleum Fuel Facilities (Change 2)	Federal Armed Services	Code	Expectation of continuous operation, RC = IV		Requires spill prevent control and countermeasures plan in accordance with 40 CFR Part 112; requires onsite containment. Containment must equal the greater of 24-hour, 25-year event or 1 foot over entire containment area.	Use API 650 except as modified for military purposes. Aboveground tanks may be single -wall, double wall, horizontal or vertical. Underground tanks must be double walled. General design criteria and standard procedures for the design and construction of military-land based facilities which receive, store, distribute, or dispense liquid petroleum fuels. Includes tank design, anchoring, support and foundation requirements. Includes requirements for concrete ring wall thickness, fuel impermeable liner, leak detection system, flexible connections, piping, and appurtenances to accommodate movement. References using the UFC 3-301-05 and UFC 3-3-310-04 for seismic design. Pipes and tanks require cathodic protection. When there is a conflict between requirements Use the most stringent criteria. Contains design standards based on tank type and fuel type.		Petroleum, liquid natural gas (LNG), and compressed natural gas (CNG)			Anchoring and supports are expected to be designed for earthquake, hurricane and flood restraint tie downs. Requires flexible connections
US Department of Veterans Affairs (USVA) 13 05 41 Seismic Restraint Requirements for Non Structural Components	Federal Armed Services	Code	Based on H-18-8			Use UFGS Section 13 05 41 Seismic Restraint Requirements for Non Structural Components, dated 1/1/2021 - construction specifications. Specification includes deferred design requirements that are passed on to contractor and subcontractor for design-build distribution systems. Executive Order 13717 requires federal agencies to adopt RP8 and exceed minimum seismic safety standards. H-18-8 is aligned with the RP8 requirements,					
USVA H-18-8 Seismic Design Requirements	Federal Armed Services	Code	Uses ASCE 7 with modifications. RC for VA-specific facility types - RC II (ancillary facilities, non-essential); RC III (essential facilities) and RC IV (Critical facilities). RC IV must remain operation, with insignificant damage. RC III remain functional but can be damaged. RC II can be taken out of service and repaired.	Have a seismic safety coordinator.		Adopted IBC 2018. References ASCE 7 for most seismic design, some limitations on types of buildings, drifts. As noted, critical and essential buildings are assigned ASCE 7 Risk Categories for seismic design. Some modifications to nonstructural provisions in ASCE 7. States that all new critical and essential facilities shall be designed with earthquake design and detailing requirements from the IBC				References ASCE 7 for most seismic design, some limitations on types of buildings, drifts. As noted, critical and essential buildings are assigned ASCE 7 Risk Categories for seismic design. Some modifications to nonstructural provisions in ASCE 7. States that all new critical and essential facilities shall be designed with Earthquake design and detailing requirements from the IBC	
USACE EM-1110-1-1804 Geotechnical Investigations	Federal Armed Services	Guidance				Presents criteria & guidance for geotech investigations - discusses good sampling and drilling procedures - recommends geologic & seismicity history of site for EQ's >4.5 M					
USGS 33 16 13.16 Prestressed Concrete Water Tank	Federal Armed Services	Code				Includes standards for the design and construction -- uses AWWA D110		Water			
WSDOT Geotechnical Design Manual (GDM)	State	Guidance				Specifies procedures for evaluation of liquefaction & liquefaction induced settlement. Design using safety evaluation & functional evaluation earthquakes: 1. Safety Evaluation = 1000 yr. return period EQ; 2. Functional Evaluation = 210 yr. return period EQ Limits liquefaction consideration depth to 80 feet bgs References AASHTO LRFD Seismic Bridge Design					

TABLE 6 - FISCAL IMPACTS
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Assessment				
Element	***Low***	***Assumptions***	***High***	***Assumptions***
Geotechnical Assessment (per site)	$25k	Small site with existing geotechnical site characterization indicating consistent soil conditions; therefore, limited exploration needs. Soil conditions and/or structural assumptions do not require significant seismic evaluation. Seismic hazard assessment can be made using current updates of the USGS NSHMP PSHA with site-specific vs_30. Deterministic SHA, if required, can be made using the magnitude-distance pairs from PSHA deaggregation for the return period of interest. Soil and site conditions are favorable such that limited geotechnical analysis is required (e.g., Plaxis, Flac, or other 2D/3D modeling not required).	$250k	Large site, differing soil conditions, and/or soil vulnerable to cyclic degradation may require extensive, deep, and varied types of explorations, including advanced in-situ and laboratory testing. Soil conditions and/or structural considerations (e.g., type, configuration, age of design, current condition, and fragility) require additional seismic analysis and design for new or existing facilities in need of retrofit to satisfy seismic performance objectives. Extensive geotechnical analysis likely required, including 2-dimensional nonlinear displacement analysis (e.g., Plaxis, Flac, or other 2D/3D modeling).
Structural Assessment (per element[1])	$5k	Simple structure	$50k	Larger or more complicated structure[2]
Example Total	$40k	Simple geotechnical site with three simple structures	$750k	Large, geotechnically complex site with 10 large and/or complicated structures.
Mitigation Design and Plan				
Element	***Low***	***Assumptions***	***High***	***Assumptions***
Geotechnical Design (per site)	$25k	Minimal foundation analysis and simplified ground improvement design parameter recommendations.	$200k	Includes several different foundation types, iterative ground improvement/foundation design process, and additional 2D/3D modeling employed.
Site-wide Structural Design to 30% Design	$10k	Facility-wide design with limited simple structures.	$100k	Facility-wide design with several different element designs required.
Site-wide Structural Design to construction documents	$10k	Facility-wide design with limited simple structures.	$100k	Facility-wide design with several different element designs required.
Example Total	$55k	Simple geotechnical site with three simple structures	$400k	Large geotechnically complex site with 10 large and/or complicated structures.
DEQ Design Review Services - 10-15 percent of the plan preparation cost ($8.5k) up to $100k.				

1. Structural elements include tanks, buildings, pipe racks, containment walls and slabs, piers etc.

2. Assuming no structure will require nonlinear analysis. Nonlinear analysis could be up to $250k per structure.