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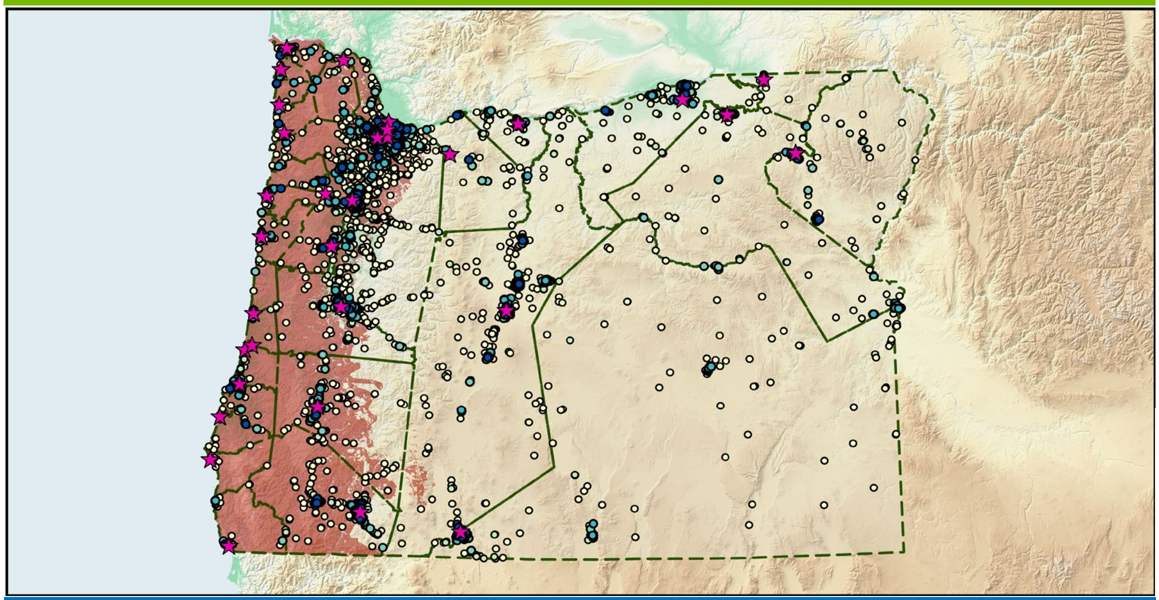

Diversification of Oregon's liquid fuel storage: A screening tool

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Abstract

Under the Infrastructure Investment and Jobs Act, the United States Department of Energy (USDOE) directed state departments of energy to complete state energy security plans that bring together relevant energy information into a single plan to evaluate energy systems' security status and a roadmap to improve energy security over time. The Oregon Department of Energy (ODOE) in 2023 hired CNA and its subcontractor Haley and Aldrich to support development of the Oregon Energy Security Plan. This report contributes to the Oregon Energy Security Plan by proposing a methodology and completing analysis to help ODOE evaluate locations to increase fuel storage at public and private sites to improve the state's resilience to the Cascadia Subduction Zone (CSZ) earthquake. The analysis considers the islanding effects stemming from transportation damage during the earthquake, considers hazard exposure as screening factors, and uses a multi-indicator weighted scoring assessment to prioritize sites best-suited to siting additional fuel storage.

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Executive Summary

Oregon Senate Bill 1567 (2022) updates seismic resilience requirements within the liquid fuel industry and directs the Oregon Department of Energy (ODOE) to create an energy security plan that identifies fuel storage sites capable of providing fuel after a Cascadia Subduction Zone (CSZ) earthquake event. The storage sites should be able to survive the initial impacts of the event, be geographically distributed across the state, and account for potential islanding effects caused by infrastructure damage. This report summarizes the structured process used to identify, screen, and prioritize sites for additional fuel storage, and offers additional considerations for ODOE, its state agency partners, and other stakeholders to consider as they recommend sites to build and maintain the additional fuel storage.

Oregon's fuel infrastructure is currently extremely vulnerable to a major seismic event because the major storage fuel facilities are highly concentrated geographically and vulnerable to earthquake damage, and most fuel is imported and moved within the state on very few transportation links (pipelines, rail lines, the Columbia River, and some highways). Even if the major fuel storage locations survived a major seismic event, fuel distribution would be a major challenge due to the road and highway damage that will functionally divide the state into population islands (where movement is possible within the area, but not to other parts of the state). The analysis uses modeled population island boundaries for the CSZ 9.0 magnitude event, with the goal of finding potentially viable sites in each of them.

To help the state increase its capability to provide fuel after major seismic event, the research team executed a four-step process (identify, screen, prioritize, recommend) to help ODOE identify sites best-suited to position additional fuel storage and recommend them for implementation. The first step in the process was to identify all potential site candidates. The research team used nearly all fuel storage locations in state underground storage tank (UST) and aboveground storage tank databases as the starting point, for a total of 4,324 potential sites. The next step in the process was to analyze which sites may need to be screened out due to exposure to hazards that may render them non-viable. The research team identified whether each site would fall into high-risk zones due to hazards related to the CSZ 9.0 earthquake event, including: earthquake shaking intensity, landslides, soil liquefaction, and tsunamis. The sites were also evaluated for flooding and wildfire exposure, which could happen before the CSZ event. Of the sites, only 201 were not at risk of any of the hazards, indicating the need to plan for appropriate hazard mitigations at fuel storage sites.

After screening, the research team completed a site prioritization analysis that uses indicators to rank sites that have features that make them well-suited as locations for fuel storage. The analysis uses a weighted average of indicator scores to rank the site candidates within each island. The indicators reflect four major groupings: proximity to major fuel transportation routes, site ownership, fuel storage at the site, and proximity to fuel users that may need fuel during a seismic incident response. The transportation routes considered include designated seismic lifeline routes (roadways), major freight routes, and rail segments that currently carry fuel products. Closer proximity to the routes receives a higher score. The site ownership type indicator uses a scoring rubric, with public sector sites (particularly state government) receiving higher scores, private sector sites receiving lower scores, and sites with a conflicting use (e.g., medical sites, telecommunications, private sector distribution or industrial sites) receiving even lower scores. Each site's total storage and diesel storage capacity is used as an indicator of the site's ability to store and manage additional fuel reserves at the site. Finally, the site's proximity to government, government partners (utilities, transportation providers, waste management, etc.), and medical and telecommunications are evaluated as indicators because these users may require fuel after an incident, and being closer to them will make it easier to distribute the fuel.

All results have been provided to ODOE for review as it considers which sites it may recommend for additional fuel storage. The research team has also provided some additional considerations that could not be included directly in the site prioritization analysis, and some discussion of potential next steps for sites that ODOE will recommend for additional fuel storage. Note that all results and discussion of additional considerations is solely the opinion of the research team (CNA and Haley & Aldrich) and does not reflect the views of ODOE or the State of Oregon. The research team does not provide formal recommendations for any individual sites; those decisions are left solely to ODOE and its coordinating partners.

In accordance with the requirements of SB1567, ODOE will continue to work with other state agencies and other stakeholders to recommend fuel storage locations at both public and private-sector candidate sites. After these sites have been identified and the additional storage constructed and made operationally ready, the state will very likely achieve greater resilience to the CSZ 9.0 event, as well as to seismic events of lesser magnitude, and other types of hazards.

Contents

Abbreviations and Acronyms

AST	Aboveground storage tank
B20	Fuel blend of 20 percent biodiesel, 80 percent diesel
CSZ	Cascadia Subduction Zone
E-85	Fuel blend of 85 percent ethanol, 15 percent gasoline
UST	Underground storage tank
CISA	Cybersecurity and Infrastructure Security Agency
DOGAMI	(Oregon) Department of Geology and Mineral Industries
DEQ	(Oregon) Department of Environmental Quality
FAF	Freight Analysis Framework
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FMI	Fire Modeling Institute (within US Forest Service)
ODOE	Oregon Department of Energy
ODOT	Oregon Department of Transportation
OEM	(Oregon) Office of Emergency Management
OSFM	Office of the State Fire Marshal
SB1567	Senate Bill 1567 (from 2022 session)
SLIDO42	Oregon Statewide Landslide Inventory Database

Introduction

Objective and approach

Senate Bill 1567 (SB1567), as enrolled in 2022, requires the Oregon Department of Energy (ODOE) to create an energy security plan, and as part of the plan, to include, from Section 12(2)(e):

(B) Strategies for expanding storage capacities at public facilities with existing capability to store and dispense unleaded, diesel or aviation fuel, including an evaluation of whether fuel storage sites contain properly installed seismically certified generators and adequate on-site fuel storage capacity to power backup generators so that independent operations can be maintained for three or more weeks after a Cascadia Subduction Zone earthquake.

(C) Partnerships with private-sector companies to build fuel storage capacity at identified, prioritized locations, especially private-sector companies that provide an emergency or essential service mission to save or sustain life or support the restoration of critical lifelines and services in support of the state's overall response and recovery effort.

(D) Strategies for increasing geographically distributed fuel storage that prioritize areas of this state that are expected to be most vulnerable to a Cascadia Subduction Zone earthquake, including local or regional islanding effects that would isolate a region from the rest of this state as a result of road or bridge damage.

This objective of this report is to develop a methodology and complete analysis to identify, screen, and prioritize candidate sites for increasing fuel storage capacity in Oregon that can serve critical lifelines' fuel demands after a Cascadia Subduction Zone (CSZ) earthquake.

In so doing, this report supports identification of both public and private-sector sites (described in sections 12(2)(e)(B) – (C)) that could serve to house the fuel storage, and prioritizes those sites. In the screening step, this analysis explicitly considers exposures of sites to hazards related to the CSZ event as a way to partially "mitigate the barriers to implementing a geographically distributed fuel network" (from 12(2)(e)). To meet the requirement to consider "local or regional islanding effects that would isolate a region from the rest of this state as a result," the analysis team uses modeled *population islands*[1] generated by Haley & Aldrich as the foundation of the recommended site selection analysis.

[1] Population islands use modeled road and bridge damage as an input to a geospatial routing model that determines contiguous areas that can be reached by vehicle, but the boundaries can't be crossed.

This report does not directly examine generators at the sites, but the next steps section includes a discussion of generators and other considerations as ODOE moves from site recommendation to implementation of the additional fuel storage.

Need for distributed fuel storage

The challenge that SB1567 and this report seeks to partially address is Oregon's vulnerability to impacts from a catastrophic earthquake occurring along the CSZ megathrust fault zone about 70-100 miles off the coast of Oregon, which has been estimated to be capable of producing shaking intensity of at least 9.0 magnitude. (Oregon OEM, 2024) Although the shaking intensity decreases somewhat with distance from the fault, the entire Western portion of the state is vulnerable to intense shaking that could severely damage infrastructure.

This shaking may cause damage to infrastructure systems of all kinds, but the liquid fuel system is at high risk of potentially catastrophic damage. SB1567 provisions on seismic resilience of fuel storage tanks and infrastructure at petroleum terminals and bulk storage facilities seek to address some of the risk. Even with changes to increase resilience, the overall system would remain at high risk because of the way Oregon sources its supplies of liquid fuels. Oregon has no refineries to produce petroleum-derived fuels (diesel, gasoline, jet fuel, aviation gasoline), and limited capacity to produce renewable fuels like biodiesel, renewable diesel, and ethanol. All these fuel products are imported on a variety of transportation modes from other states (or countries).

The seismic event would very likely damage infrastructure used to move fuel into Oregon. The Olympic Pipeline is the dominant source of most petroleum derived fuels imported to Oregon and brings fuel form Washington refineries south across the Columbia River to Portland-area fuel terminals. It is likely to be damaged or at minimum cease operations during damage assessment. Some products arrive by barge or tanker ship from the Pacific and up the Columbia River to arrive at piers at the Portland-area terminals and further upriver to Umatilla and Pasco, WA. Bridge failures due to the earthquake or damage to piers would very likely block flow by the maritime mode. Several products (e.g., biodiesel, renewable diesel, ethanol) are imported by rail from the North, South, and East, but all the main rail lines delivering fuel to Portland and Eugene pass through areas of very strong or severe shaking. Some products are driven by truck from either production facilities (such as biofuel production facilities in Washington), or petroleum terminals in neighboring states. Trucks from Washington terminals in Vancouver, Longview, Tacoma, or Pasco would all have to cross the Columbia River. Trucks from Boise, ID may be able to enter the state, but would likely not be able to bring fuel all the way to Western Oregon or serve all demand in the state.

Furthermore, even if fuel could be delivered by one or more modes, and terminals survived the event sufficiently to continue operations filling trucks to distribute fuel, the trucks would not be able to reach most areas of the state due to damage to roadway infrastructure. The earthquake can damage roadways through direct ground deformation or soil liquefaction caused by the shaking, bridge collapses, landslides triggered by the shaking, blocking roads with debris, and tsunami inundation near the coast. Collectively, the damage to roadways will create islanded areas (population islands) that will limit the ability of vehicles to travel out of the area. (Travel within the areas could still be extremely difficult.) Oregon has very limited geographic diversity with respect to where it stores fuel, with major petroleum terminals only located in the Portland area, Eugene, and minor storage at a few other places including Umatilla and Clatskanie. If the terminals survive, the population islands that house them may be able to use the fuel, but the rest of the state would not have any access to them. Although there are fuel distributors with bulk storage and other users have some fuel storage in underground and aboveground storage tanks, most of the fuel storage in the state is at the terminals.

For the reasons discussed above (lack of production facilities, seismic vulnerability of fuel terminals, vulnerability of infrastructure used to bring fuel into the state, extensive roadway damage across the State, concentration of fuel storage in relatively few locations), there is a well-supported case to be made for the SB1567 goal of increasing geographic distribution of fuel storage in the state.

Methods and Results

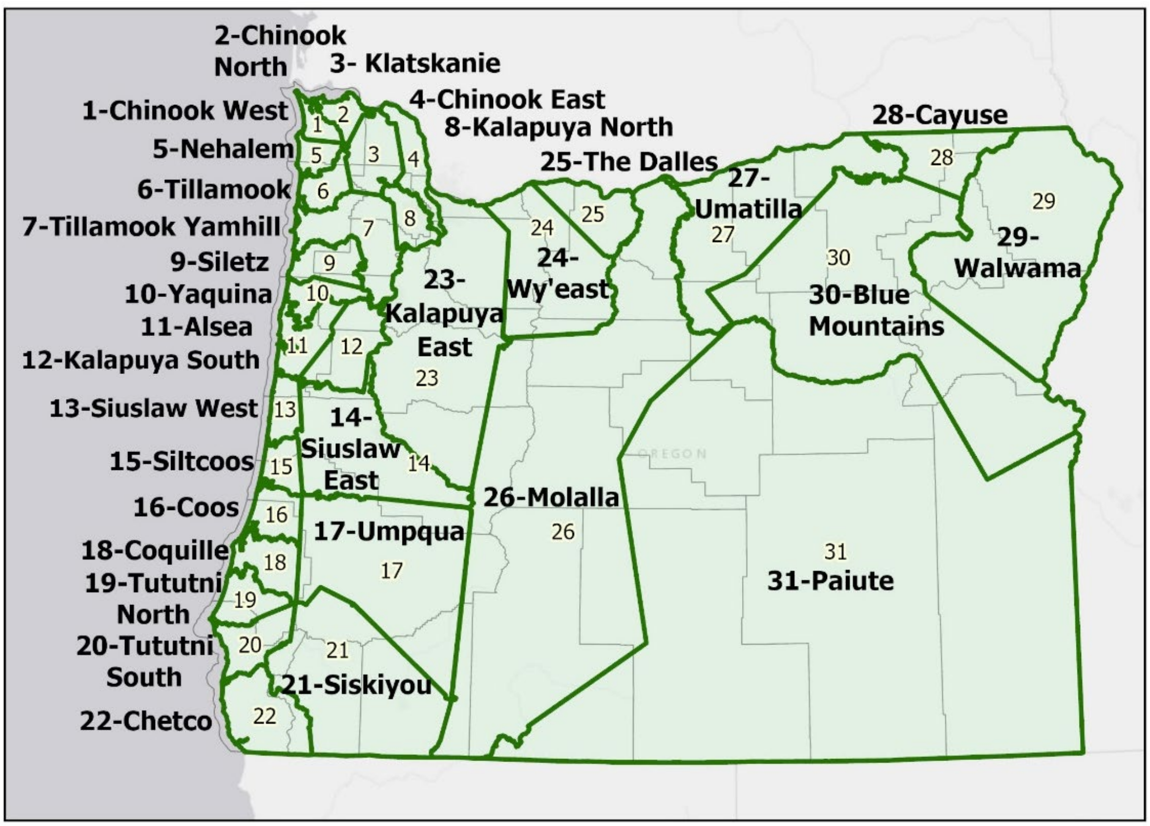
The selection of sites recommended for building additional fuel storage requires a multi-step process to identify potential locations, confirm the locations are likely to survive relevant hazards, and are preferred relative to other comparable sites based on objective evaluation criteria. This site recommendation process can be described as Identify, Screen, Prioritize, and Recommend. These steps are described as follows:

- **Identify –** Locate potential fuel sites in each population island that could serve as fuel storage locations.
- **Screen –** The CSZ earthquake (9.0 magnitude) is a significant hazard event that may cause severe shaking, soil liquefaction, landslides, and tsunamis. The screening step evaluates each site in view of these hazards and others (flooding, fire) and removes from consideration sites that are not likely to survive and be viable as a fuel distribution location.
- **Prioritize –** The characteristics of the sites and their location relative to emergency fuel demand locations make some sites better suited than others to the intended purpose. Prioritization uses several quantitative indicators and scores them to help rank sites against others in the same islanded area. Each indicator will allow selecting a preference for one site over another (all other variables being equal). Indicators include metrics such as existing fuel storage, proximity to transportation routes, site ownership, and proximity to potential demands. After weighting and averaging all indicators together for each site, final site scores and rankings are developed to enable site selection.
- **Recommend –** While the prioritization process identifies a preliminary subset of sites, ODOE and relevant state partners will use this analysis and other information to recommend sites that should move forward to planning and implementation. The process may involve several additional considerations not included in prioritization, such as spacing between sites, centrality of the site in the island, effects on or proximity to vulnerable populations or site-specific factors that could not be assessed in prioritization with available data.

Following recommendation of a top site, the site operators or the designers of the additional fuel storage infrastructure may need to complete site-specific investigations and confirm that each selected site can meet the intended purpose as a fuel storage site. The “Next steps” section at the end of this report discusses several relevant considerations as the process moves from site recommendations to implementation.

SB1567 has specific goals to provide fuel after a CSZ earthquake or similar event to meet need for fuel in a "geographically distributed" network. This assessment process uses the CSZ earthquake 9.0 magnitude event's "population islands" as the basic unit of planning for prioritizing sites. The modeled population islands define areas isolated by infrastructure damage to bridges and roadways caused by the earthquake event itself or other hazards triggered by the event such as landslides. Travel within the population islands will be difficult but possible; travel between islands will require road repairs or debris clearing. As a result, the SB1567 intent to create a geographically distributed fuel network will necessitate using population islands as a guide for identifying fuel storage sites.

Figure 1. Map of population islands for the CSZ 9.0 earthquake event based on modeled transportation infrastructure damage. Sources: Haley and Aldrich, 2023; CISA, 2021;



Identify

Candidate sites include nearly all sites that have fuel storage in the state and appear in government databases, including the Department of Environmental Quality's (DEQ) Underground storage tanks (UST) database (Oregon DEQ, 2023) and Office of the State Fire Marshall's (OSFM) aboveground storage tanks (AST) database (OSFM, 2024). Each site has at least some existing storage of diesel fuel (including various biodiesel blends or renewable diesel), gasoline (or gasoline-ethanol blends), or aviation fuels including Jet fuel (Jet-A) and 100-Low Lead aviation gasoline. ODOE also provided to the research team as list of state fuel storage at sites operated by a variety of state agencies as well as airports. (ODOE, 2023)

Note that petroleum product terminals are *not* included because they are the typical source of fuel distributed in the state and this effort seeks to diversify the locations of stored fuel reserves. Most of the fuel storage in the state is concentrated in the Portland area fuel terminals, which are vulnerable to the CSZ event. Much of the language of SB1567 is focused on investigating and increasing the resilience of these fuel terminals. It is clear that requirements for "increasing the geographic diversity of fuel storage facilities" (SB1567 Sec. 12(2)(b)) are intended to identify alternate locations to store fuel.

In total, there are roughly 4,300 potential fuel storage sites identified and included in the analysis. Table 1 lists the number of sites identified by population island, with a preliminary breakdown by site owner type. Figure 2 maps the sites by population island. The owner type categories include:

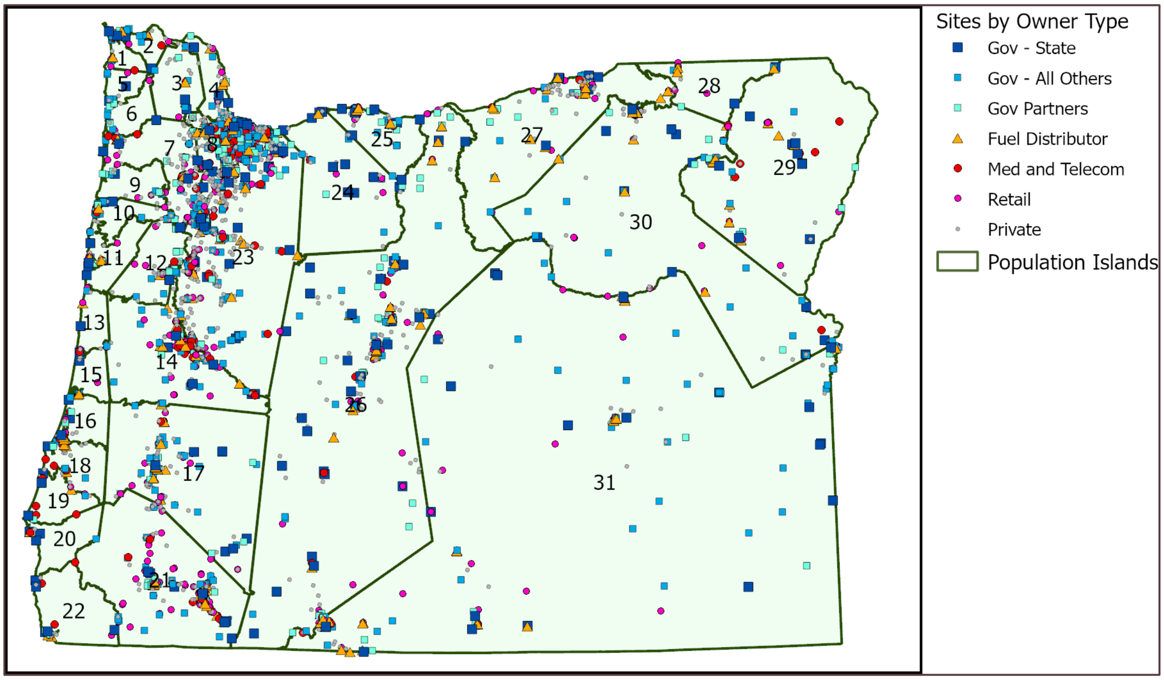
- **State Government –** Sites owned by State Government agencies, or closely managed by state agencies, notably airports.
- **Other Government –** All other government entities, including federal, military, county, local, and most government owned first responder and special service districts. (Tribal facilities were not included in this analysis.)
- **Government Partners –** Quasi-public sector entities or private entities providing public services. Includes independent and investor-owned utility providers (water, sewer, power, irrigation), waste management, education (e.g., community colleges, school bus transportation providers), and transportation (ports and railroads).
- **Fuel Distributors –** Private sector bulk fuel distributors and wholesaling companies.
- **Others** (not listed in Table 1) –
    - **Medical facilities –** Hospitals, long-term care facilities, clinics, rehab centers.
    - **Telecommunications –** Relay and switching stations, antenna, server facilities, among others.
    - **Retail fuel –** Retail fuel stations such as gas stations and truck stops.

- **Other private sites –** Industrial facilities, independent transportation providers, commercial facilities, private clubs and associations, accommodations, etc.

Table 1. **Number of identified sites by owner type for each population island. Source: Oregon DEQ, 2023; Oregon OSFM, 2024; Oregon DOE, 2024; Haley and Aldrich, 2023;**

Population Island	**Total sites**	**State Gov.**	**Other Gov.**	**Gov. Partners**	**Fuel Distributors**
1 - Chinook West	40	4	6	2	7
2 - Chinook North	32	2	11	1	2
3 - Klatskanie	23	1	3	1	2
4 - Chinook East	197	5	26	18	9
5 - Nehalem	12	2	4	0	0
6 - Tillamook	18	0	6	4	0
7 - Tillamook Yamhill	150	5	17	12	6
8 - Kalapuya North	372	5	32	32	14
9 - Siletz	24	3	2	2	0
10 - Yaquina	38	0	11	2	3
11 - Alsea	40	4	5	5	4
12 - Kalapuya South	91	2	13	13	2
13 - Siuslaw West	24	2	4	1	2
14 - Siuslaw East	239	6	39	14	10
15 - Siltcoos	6	1	0	0	0
16 - Coos	26	2	4	2	3
17 - Umpqua	160	7	29	6	10
18 - Coquille	79	3	11	6	11
19 - Tututni North	24	2	2	2	2
20 - Tututni South	14	3	1	1	4
21 - Siskiyou	315	7	40	12	16
22 - Chetco	36	5	3	3	2
23 - Kalapuya East	1298	43	130	87	51
24 - Wy'east	44	12	5	3	1
25 - The Dalles	80	5	12	6	4
26 - Molalla	350	32	40	28	34
27 - Umatilla	140	7	10	12	18
28 - Cayuse	18	2	2	1	2
29 - Walwama	98	11	8	8	11
30 - Blue Mountains	126	10	25	8	9
31 - Paiute	210	21	40	16	25
Total	**4,324**	**214**	**541**	**308**	**264**

Figure 2. Locations of all candidate fuel storage sites, displayed by owner type categories. Source: Oregon DEQ, 2023; Office of the State Fire Marshall, 2023; ODOE, 2024;



Screen

To be a viable choice as a fuel storage location, each site should theoretically be able to survive the CSZ 9.0 earthquake event and other major hazards such as floods that could occur in the time before a major earthquake hits. The process of screening overlays a variety of hazards with the site locations and flags the sites that are in high-risk areas. This information can be used in the selection process to screen out sites unlikely to survive in favor of other sites.

The screening criteria are derived from authoritative geospatial layers on hazard risk based on scientific investigations completed for the whole state or country. In many cases, the entire state is classified into various risk zones, so a threshold level is needed to identify areas at high enough risk to be screened out of the analysis. Table 2 summarizes the types of hazards included in the screening process, and the threshold levels that determine the high-risk areas. The hazards are grouped into those that are directly related to the CSZ 9.0 event (or similar strong seismic events) and all other hazards (flooding and wildfire).

Table 2. Major hazards included as screening factors with screening threshold levels. Hazards related to the CSZ 9.0 event are shaded in light blue. Flooding (dark blue) and wildfire (orange) are also included in the screening analysis for completeness.

Hazard	Description	Screening Level	Source
CSZ Earthquake Shaking intensity	Shaking intensity rating for CSZ 9.0 earthquake event	Very Strong Shaking or higher shaking intensity	DOGAMI, Madin et al., 2021
Liquefaction	Liquefaction susceptibility of soil	High (or higher) risk	Madin and Burns, 2013; CISA RRAP, 2021;
Landslide	Modeled landslide susceptibility for the CSZ 9.0 event	High and Very High susceptibility	DOGAMI SLIDO42, 2021;
Tsunami	Modeled tsunami inundation area for CSZ Event and other nearer shore scenarios	In any modeled tsunami inundation area	DOGAMI, 2013; CISA, 2021;
Flooding	FEMA National Flood Hazard Layer flood risk zones	In 100-yr (1% annual chance) flood risk zone	FEMA, 2022
Wildfire	Areas of high burn probability	Wildfire Risk of 5 (High) or greater	USDA Forest Service FMI, 2020

Figure 3 shows maps of each screening criteria's high-risk areas and the sites that fall within them, including panels for: A. Earthquake shaking intensity, B. Liquefaction, C. Landslides, D. Tsunami, E. Flood, and F. Wildfire. Sites that would not pass screening for each criterion are shown in red, and other sites in gray.

Figure 3. Maps of high-risk zones and affected sites for the six screening criteria: A. Earthquake shaking intensity, B. Liquefaction, C. Landslides, D. Tsunami, E. Flood, and F. Wildfire.

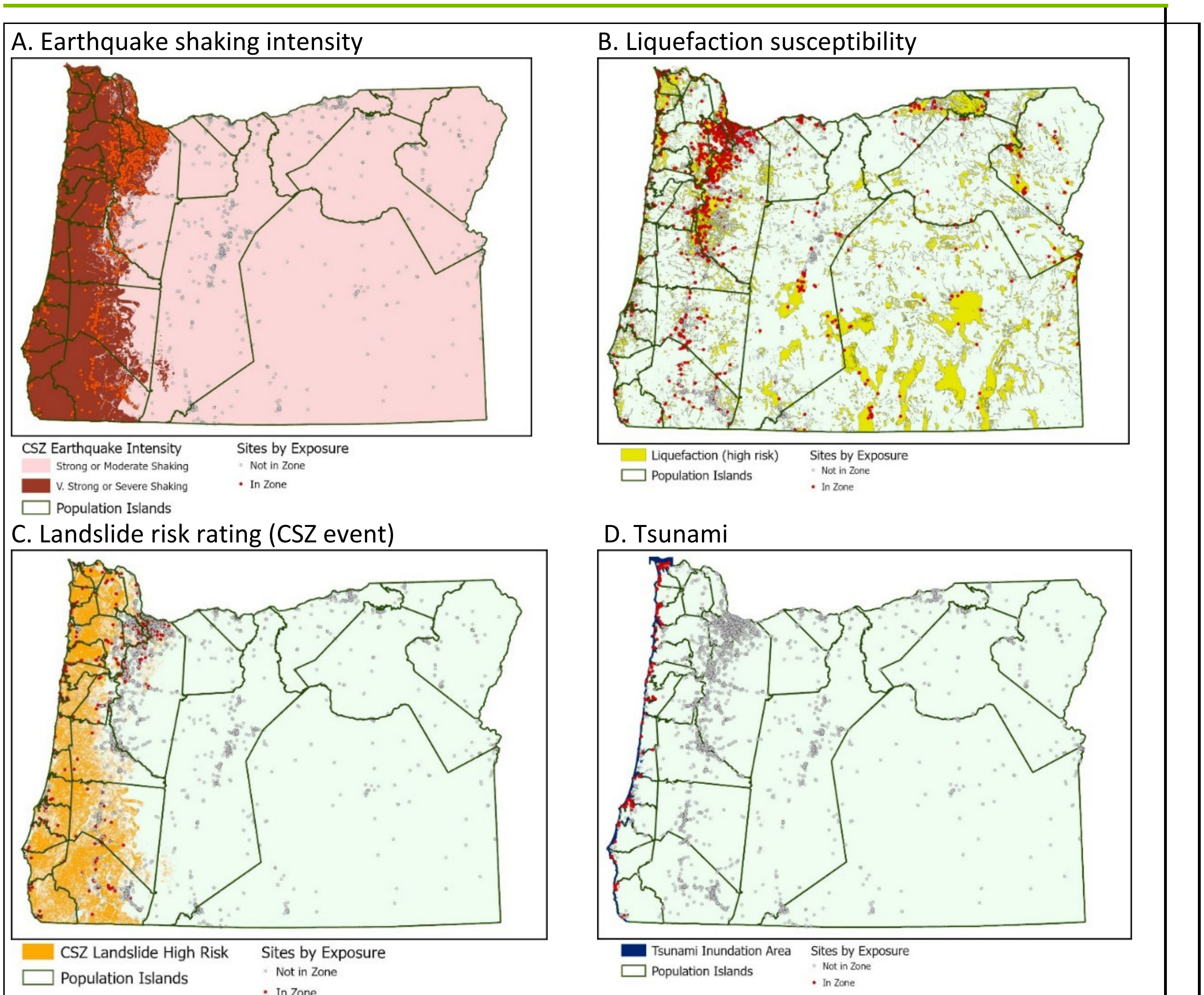
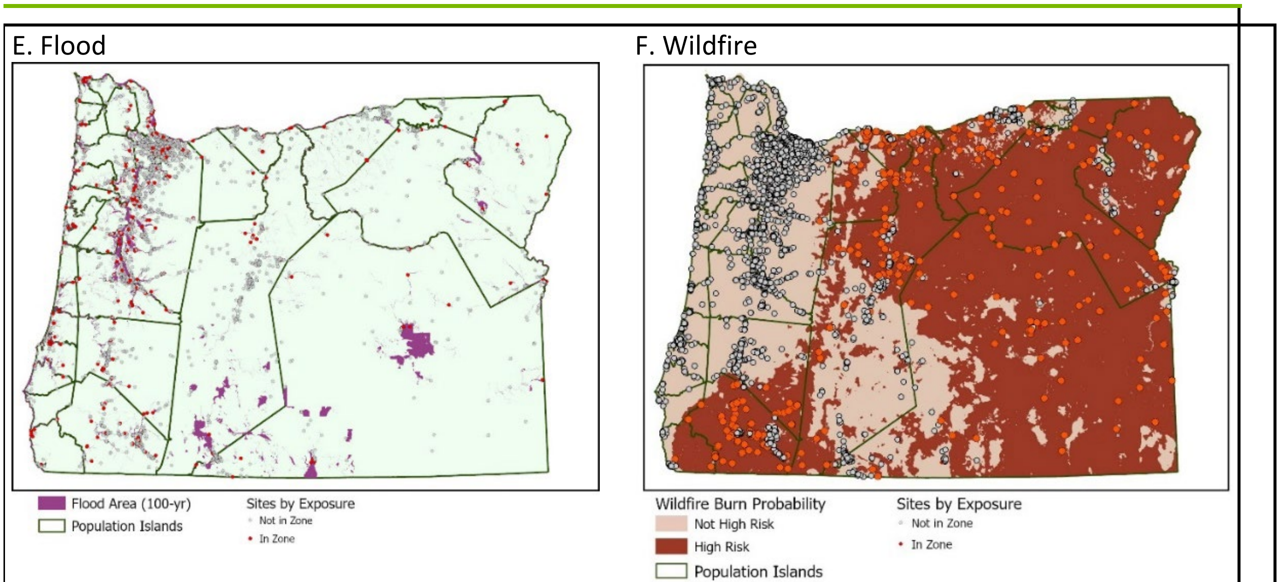


Figure 3. Maps of high-risk zones and affected sites for the six screening criteria: A. Earthquake shaking intensity, B. Liquefaction, C. Landslides, D. Tsunami, E. Flood, and F. Wildfire. (continued)



The geospatial "intersect" method was used to determine the exposure of each site (represented by a single point) with the relevant polygon layer with the risk levels for each hazard. Note that on sites with larger parcels, some of the site's area may be in a high-risk area but the site will not be screened out if the single point representing the site fell outside the high-risk area. (Parcel data was not available for all sites, so could not be used in the analysis.)

Table 3 summarizes the number of candidate sites remaining after screening out several hazards or combinations of hazards. There are only 201 sites statewide in this analysis that are not vulnerable to any of the hazards included in the screening analysis. The CSZ earthquake itself screens out over 800 sites. Limiting the analysis to all hazards except the earthquake leaves 1,022 sites. The landslide, liquefaction, and tsunami all have their risk closely tied to the CSZ event. When combined (but ignoring the CSZ earthquake shaking itself), these "CSZ Hazards" leave 1,701 potentially viable sites after screening. Riverine flooding and wildfire risk are not tied to the CSZ event. No population islands have all sites in flood zones, but at least three population islands have all sites in zones of high wildfire risk.

Table 3 can assist during the recommendation process by identifying hazards that will screen out all or nearly all sites for particular population islands. (Zero values indicating no viable sites are shown in pink.) In these cases, the selection process may need to ignore one or more screening criteria see the Recommend section for more discussion). In the process of implementation planning, additional mitigation measures such as higher seismic design standards or fire protection measures may be warranted in lieu of simply screening out these sites.

Table 3. Total sites remaining after screening out sites affected by listed hazards. Population islands with zero sites remaining after screening is applied are flagged in light red.

Population Island	All hazards	All except Earthquake	Landslide, Tsunami, and Liquefaction	Wildfire	Total Sites
1 - Chinook West	0	0	0	40	40
2 - Chinook North	0	4	4	32	32
3 - Klatskanie	4	6	10	23	23
4 - Chinook East	4	24	25	197	197
5 - Nehalem	0	0	0	12	12
6 - Tillamook	0	0	0	18	18
7 - Tillamook Yamhill	0	4	9	94	150
8 - Kalapuya North	0	17	17	372	372
9 - Siletz	0	4	6	22	24
10 - Yaquina	0	13	15	38	38
11 - Alsea	0	11	11	40	40
12 - Kalapuya South	2	17	22	88	91
13 - Siuslaw West	0	0	0	24	24
14 - Siuslaw East	11	107	143	204	239
15 - Siltcoos	0	0	0	6	6
16 - Coos	0	6	8	26	26
17 - Umpqua	8	87	90	160	160
18 - Coquille	0	11	11	79	79
19 - Tututni North	0	10	10	24	24
20 - Tututni South	0	2	3	12	14
21 - Siskiyou	23	214	234	283	315
22 - Chetco	0	1	4	10	36
23 - Kalapuya East	80	415	438	1210	1298
24 - Wy'east	16	16	35	20	44
25 - The Dalles	0	0	40	0	80
26 - Molalla	46	46	286	58	350
27 - Umatilla	0	0	81	0	140
28 - Cayuse	0	0	6	0	18
29 - Walwama	4	4	22	7	98
30 - Blue Mountains	1	1	64	1	126
31 - Paiute	2	2	107	5	210
Total	**201**	**1,022**	**1,701**	**3,105**	**4,324**

Prioritize

The screening step allows *avoiding* sites that have a high likelihood of being rendered non-viable by the CSZ 9.0 event or other hazards, or flagging where additional mitigation measures may be need. By contrast, prioritization seeks to identify a range of factors that would make the site *attractive* for storing emergency fuel reserves. After prioritization analysis, the locations *best suited to serve as fuel storage sites* (given currently available information) will rise to the top of a rank-ordered list for each population island.

Prioritization is a multi-indicator, weighted scoring process in which indicator values are computed for each site, converted to score values in a common 0-1 range, and then averaged together (using a weighted average) into a final score value. Each indicator should allow selecting one site over another if all other variables were equal. Indicators must be calculable for the full range of potential sites, meaning that data must be equally available at all sites.

Indicators are selected based factors that would make the site attractive as a fuel storage location. Some of these qualities and their rationale for inclusion follow:

- **Proximity to routes used for fuel transport** – Within Oregon, fuel is overwhelming transported by truck, and having sites close to major truck routes helps reduce delivery times and increase efficiency of transport. Notably, proximity to routes that are more likely to survive seismic events (or be repaired quickly) is even more preferred.
- **Site ownership** – Sites that are owned by public sector entities are preferred given the intent of the fuel storage program to supply fuel for disaster response. Furthermore, some types of sites have incompatible uses (e.g., some industrial sites) that would cause additional hazards, or hinder the site from completing its own role during the recovery. ODOE has existing relationships with other State agencies and some of their sites have already been pre-identified as potential fuel storage locations.
- **Existing fuel use at site** – Many fuels including diesel, biodiesel, and ethanol and gasoline-ethanol blends, are prone to fouling and degradation over time, often as algae and microbes grow in small amounts of water that get into fuel tanks. Maintenance and periodic filtering can keep the fuel viable, but it is preferable if the fuel is regularly used and replenished with fresh fuel. It is difficult to obtain reliable data on fuel usage at individual sites, but storage capacity is often positively correlated with usage. That is, storage sites that have a larger storage volume on site are likely to use more fuel. Thus, larger tank storage capacity of fuels (particularly diesel) is preferable to smaller storage capacities.

- **Proximity to other fuel users** – After a CSZ event, fuel for vehicles and emergency back-up generators will be a large component of initial demand. A candidate fuel site is more favorable if it is close to where these demands are located. Given that demand is difficult to estimate directly, storage capacity at relevant site types (e.g., hospitals, government vehicle fleet parking areas) within a specified radius can be an indicator of proximity to priority users. Specifically, some of the relevant types of sites (note that these groupings mirror the owner types in the Identification section) include:
  - ***Government sites*** – The envisioned scenario will require a whole of government response, so all valid government fuel storage sites could potentially need fuel. This includes all state, county, local, federal, and military sites, as well as first responders that are part of local governments.
  - ***Government "partners"*** – Many quasi-governmental organizations, public utilities, and other types of service organizations provide commodities and services such as electric power, water, sewer, and sanitation services (including debris management). Transportation sites not already included in the government categories are also included as potential government partners. These types of partners will be active in a response and may require fuel to restore or continue providing service to the residents in their population islands. Education sites like colleges and universities, private school, or contracted school bus operators are also included with government partners.
  - ***Health & medical and telecommunications*** – Hospitals and other medical locations must continue operating during a major disaster scenario, and although they have generators and fuel storage, will require sustained fuel deliveries to stay operational during a sustained power outage. Telecommunications sites like antennas, transmitters, cell phone towers, data centers, and relay stations require electric power to operate, and have backup generators if grid power is not available. These sites will also need fuel to keep operating and carry telecommunications traffic for the emergency response and the entire population.
  - ***General fuel users*** – Fuel storage sites tend to cluster where there are large populations and/or large fuel demands. The proximity to storage of all fuel types can help identify whether the candidate site is close to substantial fuel needs. And to some degree, fuel needs are likely to be concentrated in densely populated areas, which typically also have many existing fuel storage sites.

These qualities can be translated into indicators that can be calculated using data intrinsic to each site, data from other sources, and geospatial analysis. Table 4 lists each of the indicators, a brief description of how they are calculated (including units), and any relevant notes. The following section provides much more detail on how the individual indicators were computed. The site selection analysis is geared toward selecting from among sites in the same population island. Therefore, the "score" values for each indicator are the percentile of the indicator value relative to all the sites in the same population island, on a scale from 0 to 1. Score values of '1' are most preferred, and '0' least preferred. (Note that the score values are inverted when a lower indicator value is more preferred.) To compute the final score, the score values are combined using a weighted average in which each indicator receives a relative weight. The weights are listed and described in Table 4 (see the following section for a detailed description of computation methods and rationale for weighting).

Table 4. Prioritization indicators, descriptions and default weights used for score calculation.

Indicator	Description	Weight	Note
1a. Seismic Route Distance	Distance (miles) from nearest ODOT Seismic Route in same population island.	*60% of Indicator 1 total, ~18% of overall total*	Percentile rankings inverted to prioritize sites with lower distances
1b. Freight Route Distance	Distance (miles) from nearest freight route in same population island.	*30% of Indicator 1 total, ~9% of overall total*	
1c. Energy Rail Distance	Distance (miles) from nearest rail line that currently carries energy products.	*10% of Indicator 1 total, ~3% of overall total*	
1. Transportation Route distance	Weighted average of 1a, 1b, and 1c.	**30%**	
2a. Total Storage	Total fuel storage at site (gallons).	**10%**	
2b. Gasoline Storage	Total gasoline or ethanol blend storage at site (gallons).	**0%**	Not used because subsumed by 2a and 2c
2c. Diesel Storage	Total diesel or biodiesel blend storage at site (gallons).	**10%**	
3. Site Type	Site Type scored by rubric.	**10%**	
4. Fuel Proximity – All 2 miles	Total fuel storage at other sites within 2 miles and in same population island.	**10%**	
5. Fuel Proximity diesel – Gov. 5 miles	Total diesel storage at government sites within 5 miles and in same population island.	**10%**	
6. Fuel Proximity Diesel – Gov. Partners 5 miles	Total diesel storage at government partner sites within 5 miles and in same population island.	**10%**	
7. Fuel Proximity Diesel – Medical and Telecom. 10 miles	Total diesel storage at medical and telecommunications facilities within 10 miles of site.	**10%**	

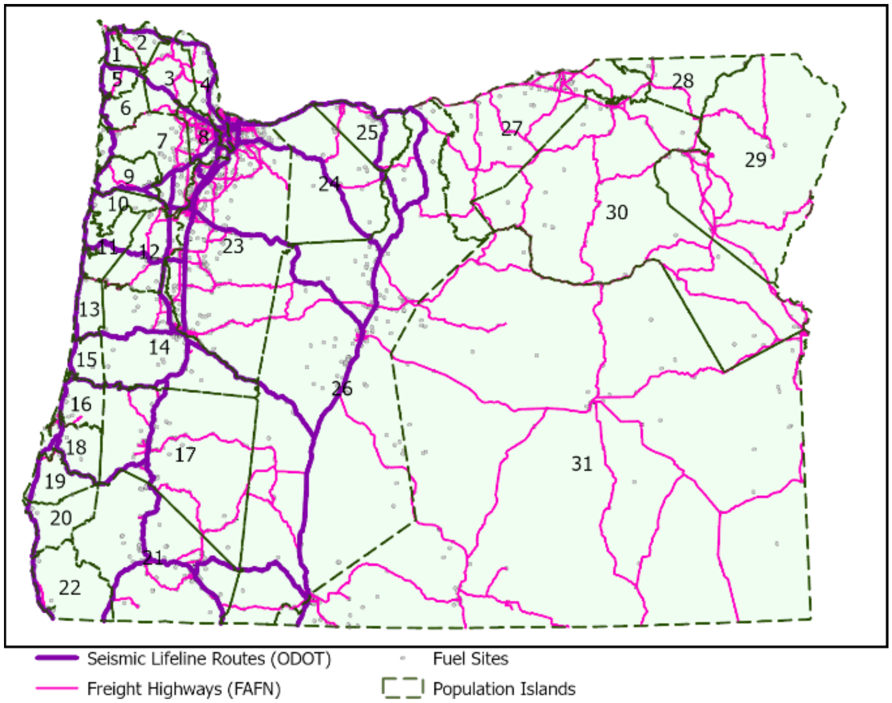
Methods for computation of indicators

Table 4 presented a list of indicators and the associated weights used in computing the final score values. In general, equal weighting is used across most indicators, except for indicators 1a, 1b, and 1c. These indicators are not uniformly available across islands, so they are combined through their own set of weightings into a consolidated indicator 1. The following discussion explains the rationale and methods for doing so.

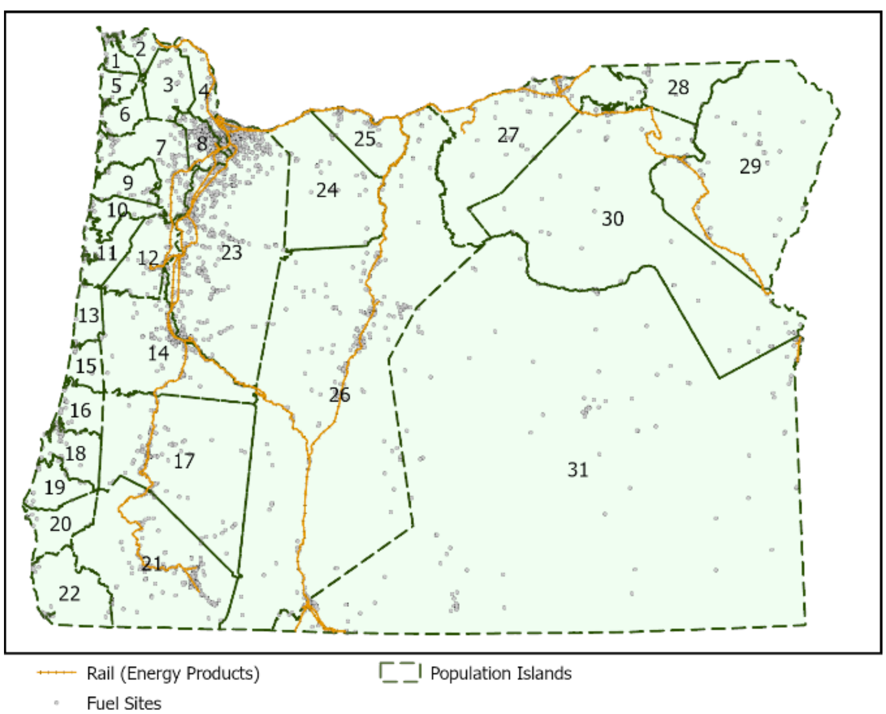
The distance from transportation route indicators (1a, 1b, 1c) use geospatial analysis to measure the distance from each site to the nearest route of the relevant type *within the same population island*. The three types of routes include ODOT designated seismic routes (ODOT, 2013) for indicator 1a; Freight Analysis Framework (FAF) routes (FHWA, 2022) for indicator 1b, which include all major highways and secondary routes with significant truck traffic; and rail segments that currently carry energy products (ODOT, 2023) for 1c. Not all these routes are equally important and not all are present in all population islands. Figure 4 maps the three types of infrastructure over the population island boundaries. The ODOT Seismic Routes have been pre-identified as particularly important for transport after a CSZ earthquake but are only designated in the Western portion of the State. The FAF network is available statewide and has a slightly greater density of roadways in most population islands. Although most fuel is moved to end users (including most candidate sites in the analysis) by truck, railroads carry a significant amount of certain fuel types like ethanol and renewable diesel into and within the state. In normal circumstances, the rail shipments primarily go to fuel terminals, but after a CSZ event, rail offers an alternate mode for delivery of fuel to places with a surviving rail line. Several of the fuel distributors in the state have verified they can offload fuel from rail cars to trucks if needed. As a result, proximity to rail lines that currently carry fuel (according to staff at the ODOT Rail Regulatory Programs Branch) are a third indicator for proximity to transportation infrastructure.

Figure 4. Transportation routes used in seismic route and freight routes indicators (A), and energy rail indicator (B). Source: ODOT, 2013; FHWA, 2022; ODOT, 2022;

A.



B.



The three indicators are not uniformly available across the population islands, so this study developed a weighted indicator approach to combine the three into a single transportation indicator. As noted in Table 4, the ODOT seismic routes receive a 60 percent weight, FAF Freight routes 30 percent, and Energy rail routes 10 percent. In population islands without one of the indicators, the relative weights are maintained for the remaining indicators. That is, if no Seismic routes are present, the FAF routes have a 75 percent (30/40) weight, and energy rail 25 percent (10/40).

The site storage indicators include 2a – Total storage, 2b – Gasoline storage, and 2c – Diesel storage. Site storage capacity by fuel type is included in Oregon DEQ underground storage tank records, or Office of the State Fire Marshall (OSFM) aboveground storage tank records as applicable. For the aboveground storage tanks, tank capacity is specified only as range, so the estimated storage capacity is calculated as the midpoint of the range. Both databases had multiple fuel type classifications. Total storage includes all types of finished fuels (except heating oil), but not any lube oils or similar products, crude oil, waste oils, or unspecified hazardous materials. The calculated gasoline storage for each site includes all grades of on-road gasoline and gasoline-ethanol blends of E-85 or lower. The calculated diesel storage includes all types of diesel except heating oil, as well all diesel-biodiesel blends B20 and lower, and renewable diesels. In the indicator weightings, the diesel storage capacity is far more important than gasoline storage. Furthermore, total storage, gasoline storage, and diesel storage taken together would have significant cross correlation. Thus, only total storage and diesel storage are included in the final weighted score.

The site type indicator (3) is unique in that it is a qualitative indicator that requires a scoring rubric instead of percentile rank for a numeric indicator value to be scored. The rubric for site type prioritizes sites that are public sector based on the input of ODOE and other coordinating partners. The primary rationale is that public sector sites have a role in the emergency response (which will certainly require a whole of government approach) and have far lower barriers to signing agreements with the site owner. The scores by category of owner type, and additional comments on rationale for the rating follow:

- **State government sites – 0.9.** Sites earn a bonus of 0.09 (for a total of 0.99) if pre-identified as a candidate fuel site by ODOT, Oregon Parks and Recreation, Office of Emergency Management, Oregon Department of Aviation, Department of Administrative Services, or Department of Corrections. (ODOE, 2023)
- **Other government sites – 0.8.** These public sector sites including federal and local government sites are attractive due to their role in response, and ease of developing agreements (as compared with private sector sites.)

- **Government partner sites – 0.7.** Similar to other government sites, but some are private companies and may have functions that could interfere with operating fuel dispensing during a disaster.
- **Fuel distributor sites – 0.6.** Nearly all fuel distributors or wholesaler are private sector companies, but they have significant existing fuel storage, fuel dispensing and distribution capabilities and often access control at their sites. Additionally, many of these distributors already provide fuel to governments under statewide fuel contracts or independent contracts with individual government agencies.
- **Fuel retail sites – 0.4.** Many fuel retail sites do have existing fuel storage and ability to dispense fuel. But as private sector locations that are widely open to the public, they are less highly scored for this indicator.
- **Other private sector sites – 0.2.** These sites include industrial, commercial and association sites. These users likely have their own emergency functions during a disaster, such as a grocery distributor trying to deliver food, and are scored lower as a result.
- **Medical and telecommunications sites – 0.1.** These sites are ranked lower because they are often storing fuel for generators and do not have capacity to dispense fuel. Furthermore, medical sites need clear access to fulfill their primary medical service function and a queue of fuel trucks could block access. Telecom sites are frequently remote and small, do not have dispensing equipment, and may require the providers have access to restore service. Queues of trucks would interfere with operations for either of these owner types

The last four indicators have different uses but are calculated in a similar manner. Each represents a sum of fuel storage capacity within a given distance of the site. A simple buffer analysis was used in GIS to create a circle around the site of the specified distance. The circular buffer shape was then clipped to the same population island as the site at the center of it because travel between islands would not be possible. The process for computing indicator 4 uses a "spatial join" to sum all fuel storage at sites falling within the 2-mile buffer of the site. To do so, the total storage attribute value and the location of all the candidate sites is used.

Indicators 5-7 represent categories of potential users of (diesel) fuel during a CSZ 9.0 event. Storage capacity is assumed to be a reasonably proxy indicator for fuel demand. For indicators 5-7, the computational process is the same as for indicator 4, but different buffer distances, site types, and attributes are used. Indicators 5 and 6 use a 5-mile buffer and Indicator 7 a 10-mile buffer. All three use diesel storage instead of total storage as the fuel attribute that is summed. Indicator 5 selects only the government sites before completing the spatial join with the buffer areas, and Indicator 6 the Government partner sites. Finally, Indicator 7 selects the medical and telecommunications sites. These sites primarily use diesel for generators and are among the most important recipients of fuel during a major emergency, so a slightly larger buffer is used to help identify sites that can serve multiple of these facilities.

Prioritization results

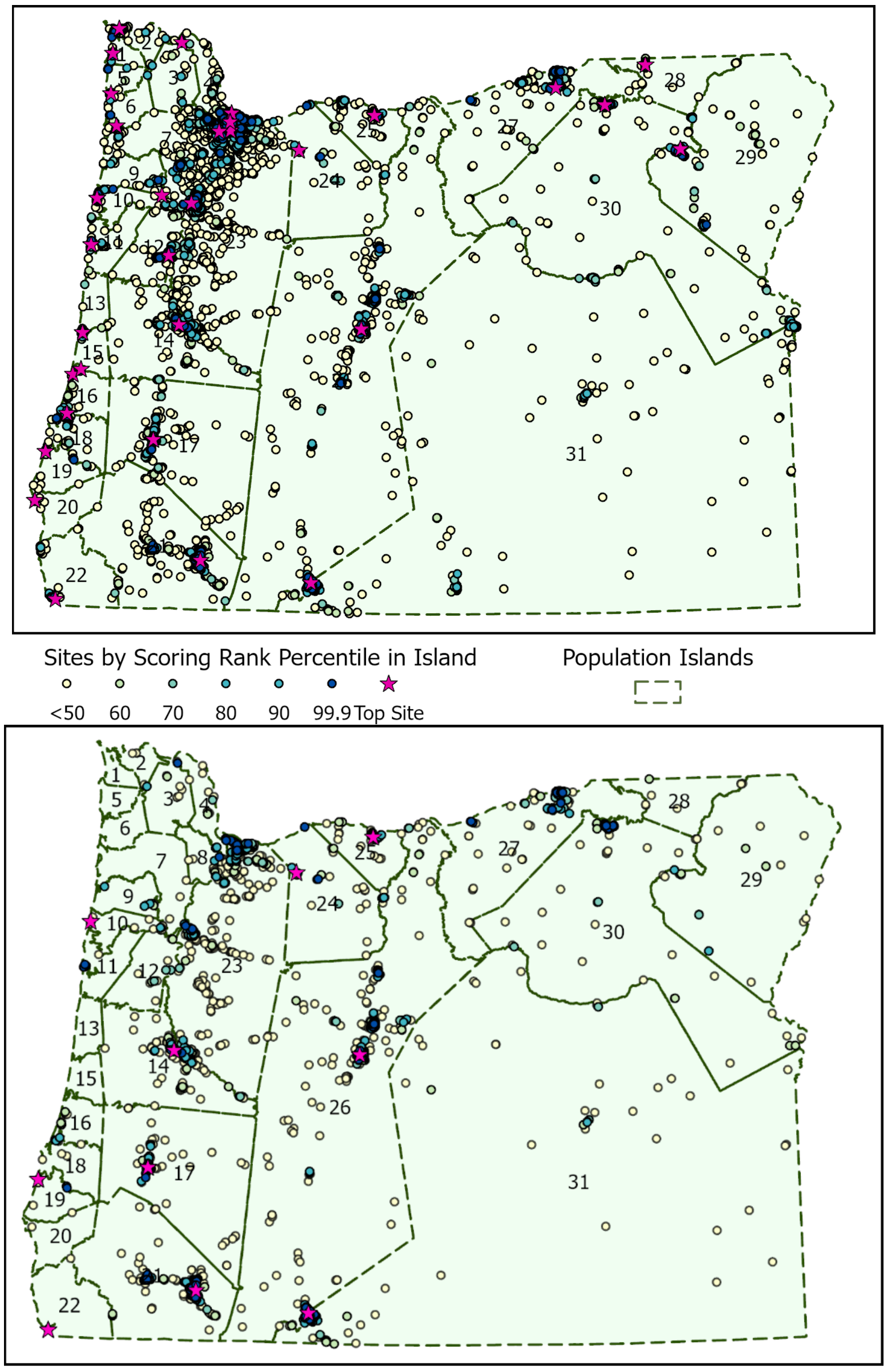
The prioritization results include a total score for each site which includes the weighted average score of all the indicators, using the weights in Table 4. Due to the averaging across several indicators, the scores are clustered around the middle of the range. (It is unlikely for any site to have the highest or lowest rank across all seven indicators.) To rescale the results to a 0 to 1 range, the percentile rank is computed for site scores within each population island. (The top site in each island will have percentile rank score of 1, and the bottom ranked site, 0.)

Figure 5 shows two maps of the prioritization results. The first has all sites and shows the top site in each island as a star. The second shows the same results, but screens out all sites at high-risk for liquefaction, landslide, or tsunami in the screening analysis.

Figure 5. Prioritization results by site ranking percentile in population island for all sites (A), only sites not screened out by landslide, liquefaction, and tsunami (B).

A.

B.



Dissemination of results

Full results of the screening and prioritization analysis have been provided to ODOE for internal use only to enable site selection. Results have been provided in tabular and geospatial forms to allow staff to quickly review all screening and prioritization indicator values and scores. Geospatial data and map products allow reviewers to see the site in relationship to other sites and hazard layers.

With these results and analysis datasets, ODOE is equipped to lead the site selection process.

Recommend

Recommendation of sites is not completed in this report, but this section provides a discussion of some relevant considerations for the completing the process. The combination of screening and prioritization results provide tools to enable finding and recommending viable sites well-suited to building additional fuel storage. But the process is not as simple as screening out all sites in high-risk areas and selecting the top scoring sites remaining in each population island. Screening results may require more nuanced examination on the scale of individual population islands. Prioritization results may not consider all relevant information, or the ability to serve overall fuel need in the population islands. Site recommendation is an active decision-making process. A generalized process for effective recommendation might include the following steps:

1. Determination of targets for the number of sites to be recommended in each population island and overall, across the State.

Then, within each population island:

2. Consideration of screening results' applicability in the population island.
3. Consideration of additional factors not included prioritization results.
4. Final recommendation and balancing of objectives.

The first step requires knowing the target number of sites per population island and in aggregate if there is a limitation on number of sites that can move forward to implementation. The process is very different if only one site can be recommended per population island versus having the number of sites adjust based on fuel needs or the population in each island. A multi-site recommendation is more difficult because site spacing becomes important (since high ranked sites are typically closely clustered geographically, as, shown in Figure 5).

In the second step, screening results should be scrutinized carefully before removing sites in each island. Table 3 shows that several population islands have zero (or one) viable sites, which would end the site selection process. Instead, those completing the site recommendation process may choose to disregard certain screening criteria or re-evaluate whether individual sites may be kept in the selection pool. When screening criteria are disregarded, additional mitigation measures may be warranted during implementation, such as more stringent seismic design criteria. Finally, a site-level look at each screening data layer may identify additional issues. For instance, a site's only access road may be blocked by landslides, or the point representing the site may only be slightly outside the high-risk area while the majority of the site's overall parcel is at risk. At the conclusion of this step, the final list of sites that passed through the screening can be considered for recommendation.

In the third step, ODOE and its partners completing the site recommendation process consider the prioritization results to determine the top ranked sites in each island. But the process does not end with simply recommending the top ranked site for each island. The prioritization results do not consider all relevant factors for decision making.

Some of the relevant considerations include:

- Ability of the site to handle truck traffic,
- Whether hazards block key transportation routes connecting the site to priority demand locations (even if the site itself is not at risk),
- Ability of the site to store enough additional fuel to meet target projected demands in the population island,
- Centrality of the site within the population island or proximity to known cities or population centers,
- Type or types of fuel to be stored, and needs of surrounding high-priority fuel users for those fuel types, [2]
- Incompatible land uses or facilities (e.g., certain industrial uses, level 1 trauma hospitals, sensitive environmental resources) near the site,
- Willingness of the site owner to sign an agreement to store fuel,
- Features already present on the site that would otherwise need to be added (fuel dispensing pumps, emergency back-up generators, fencing, etc.), and
- Potential impacts to vulnerable populations and ability to serve vulnerable populations' fuel need.[3]

As ODOE and its coordinating partners consider these factors, they may find even more factors that affect the decision, or identify opportunities. When the screening results, prioritization results, and additional considerations have been evaluated, the process reaches the final selection step to identify the recommended sites. In this step, the number of target sites

[2] Oregon's transition to renewable fuels usage and electrification may result in changes to the types of fuel (e.g., more renewable diesel) stored or anticipated demands of critical facilities if they build resilience that shift them away from needing fuel. An analysis for aviation fuel storage may be very different than one for diesel.

[3] Note that this consideration is required by the SB1567 legislation

identified in step one becomes particularly important. Selecting two or three sites may require distributing the sites effectively across the geographic area and population concentrations within the island. Or in some cases, an opportunity to build a site with larger storage may reduce the number of sites needed in population islands requiring several sites to meet need.

Finally, as some sites may have viability concerns that do not appear until visiting, it is more efficient if the recommendation process identifies one or more alternate sites for each population island as a contingency. If alternate sites are identified, the decision process will not have to be revisited if the top site is found to be non-viable.

Next Steps

After the recommendation has been made, additional steps will support preparation for building the new fuel storage on the recommended sites.

This report does not prescribe the steps that will occur but offers some ideas and considerations. All recommendations and considerations are presented for discussion only and reflect the opinions of the analytic team – CNA and Haley & Aldrich – and do not represent the position of ODOE or the state of Oregon. Some of the next steps could include: **Site visits and confirmation**, **approvals and design**, and **construction and operations plans**.

The recommended sites will have completed initial screening for viability and desirability as a site but may have site-level factors not visible on maps or discernable in data that argue against selection. Visiting each site and meeting the owner can confirm the site is viable, or if not, help identify potential issues that would preclude using the site or make an alternate site more attractive.

If the site visit finds no issues, the process of approval and design starts. In addition to any approvals required by the legislature or state agencies, the site owner will likely need to sign an agreement or memorandum of understanding to begin site level planning work.

The design process will have to consider all the relevant infrastructure and capabilities needed to operate the site, and where they will be located. Some of the relevant facilities include, but are not limited to:

- Seismically resilient storage tanks with appropriate spill containment, optionally with tank level monitors that can be read without electric power,
- Fuel dispensing devices,
- Emergency back-up generator present and capable of providing sufficient power for necessary lighting, communications, and pumping capability,
- Paving, signs, and markings needed for truck traffic direction,
- Site security measures including fencing, lighting, vehicle barriers, and security personnel staffing plan, and
- Mitigation measures against hazards near the site such as flood barriers, vegetation management, or reinforcement of bridges or culverts on the site.

The site design process will also require a significant number of plans for construction and operation. Some of the possible plan items may include:

- Seismic design approvals and design and construction plan,

- Other environmental approvals as needed (erosion and sediment control plan, air quality permits, etc.),
- Plan for truck access and traffic flow through site,
- Basic site operational plans including access control and security, standard (non-CSZ event) emergency operations plans, site inspection and maintenance plans, etc.,
- Fuel and tank maintenance plans, back-up generator maintenance plans, and
- Plans and documents for the CSZ event response, including:
  - Prioritized list of customers to be served by site,
  - Plan for fuel distribution and delivery and contact information for transporters of fuel authorized to use the facility,
  - Storage location for physical copies of all relevant contracts, plans, procedures, and area maps needed to run the site during an incident that requires activation of the fuel site stored on site,
  - Responsibilities in the event of site ownership change, and
  - Required fuel tank storage reserve levels during normal site operation.

To reiterate, this section provides a starting list of potential next steps for information and discussion purposes only. Further guidance and decisions on next steps will be forthcoming and the responsibility of the state legislature and relevant state agencies including ODOE and as applicable, federal, tribal, and local authorities.

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