Liquid Storage Tanks at the CEI Hub

Seismic Assessment of Tank Inventory

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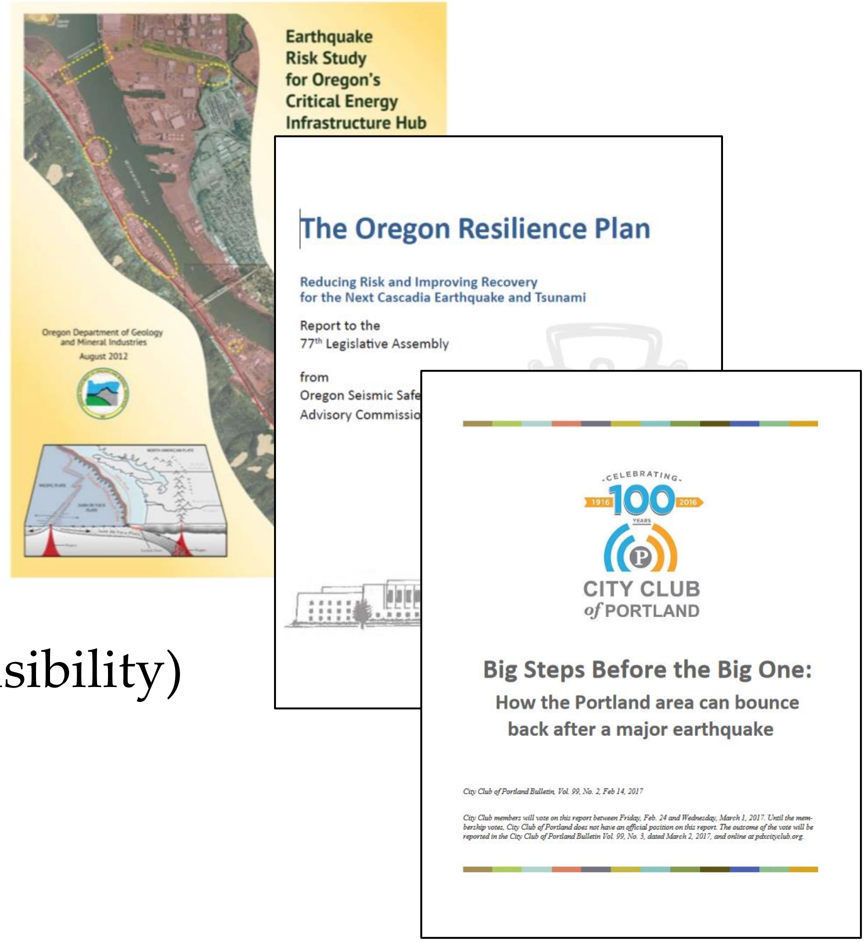
CEI (Critical Energy Infrastructure) Hub

- DOGAMI 2012
  - Earthquake Risk Study for Oregon's CEI Hub
- OSSPAC 2013
  - The Oregon Resilience Plan
- City Club of Portland 2017
  - Big Steps Before the Big One: How the Portland area can bounce back after a major earthquake



- This study – focus on liquid storage tanks (risk of failure & visibility)
  - review storage tank failures in past EQs
  - gather available data on CEI hub tanks
  - review potential mitigation options
  - recommend next steps

General Liquid Storage Tank Types

- fixed roof – atmospheric or pressurized (propane, butane, kerosene …)
- floating roof – atmospheric (crude oil, gasoline, diesel, …)

- size varies

smaller storage

cone fixed roof

roof

riveted or
welded steel shell

soil supported
base plate

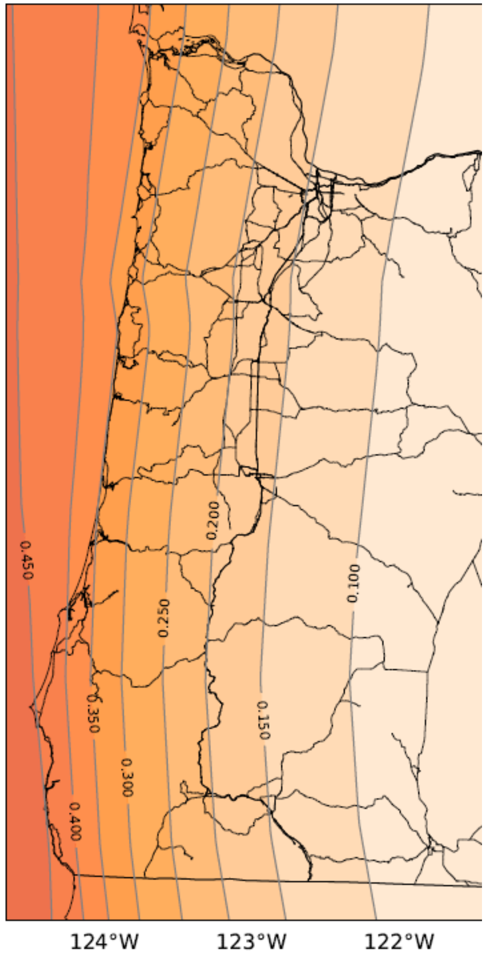
ring conc.
foundation

Floating roof (internal / external)

Past EQs and Tank Damage

Location	Magnitude	Date
Long Beach, California	6.4	March 10, 1933
Kern County, California	7.3	July 21, 1952
Alaska	9.2	March 27, 1964
Niigata, Japan	7.6	June 16, 1964
San Fernando, California	6.5	February 9, 1971
Managua, Nicaragua	6.3	December 23, 1972
Miyagi-Ken-Oki, Japan	7.7	June 12, 1978
Imperial County, California	6.5	October 15, 1979
Greenville, California	5.9	January 24, 1980
Central Greece	6.7	February 24, 1981
Coalinga, California	6.2	May 2, 1983
Marmara, Turkey	7.6	August 17, 1999
Tōhoku, Japan	9.0	March 11, 2011

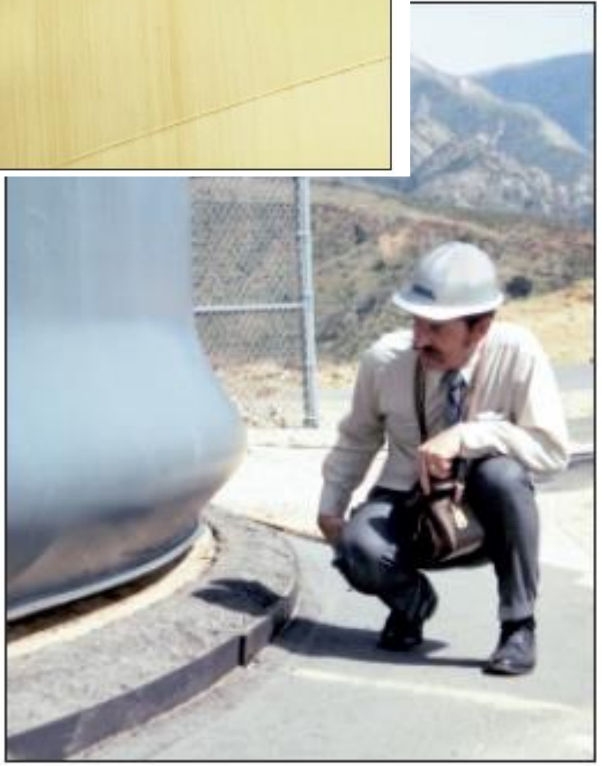
fault type
amplitude
duration

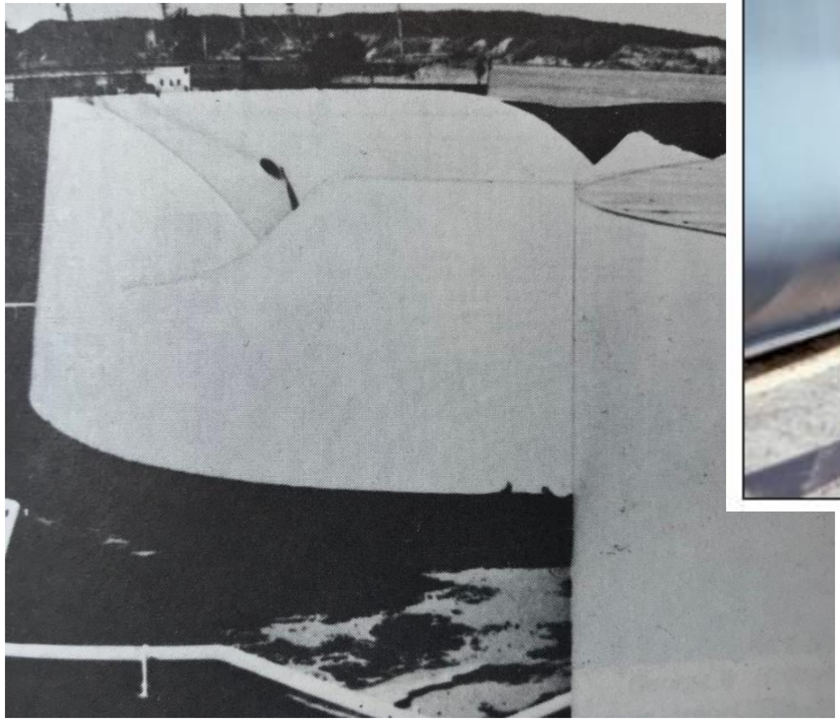


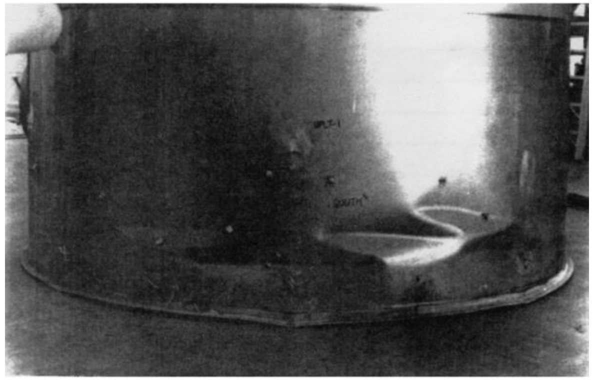
Oregon
Anticipated Full Rupture CSZ
Spectral Accel. @ 1.0sec (units: g)

Structural Damage

- buckling of tank wall
  - top – sloshing, low pressure
  - bottom – compression stresses
- roof collapse/sinking
- bottom plate rupture – uplift
- sliding of tank

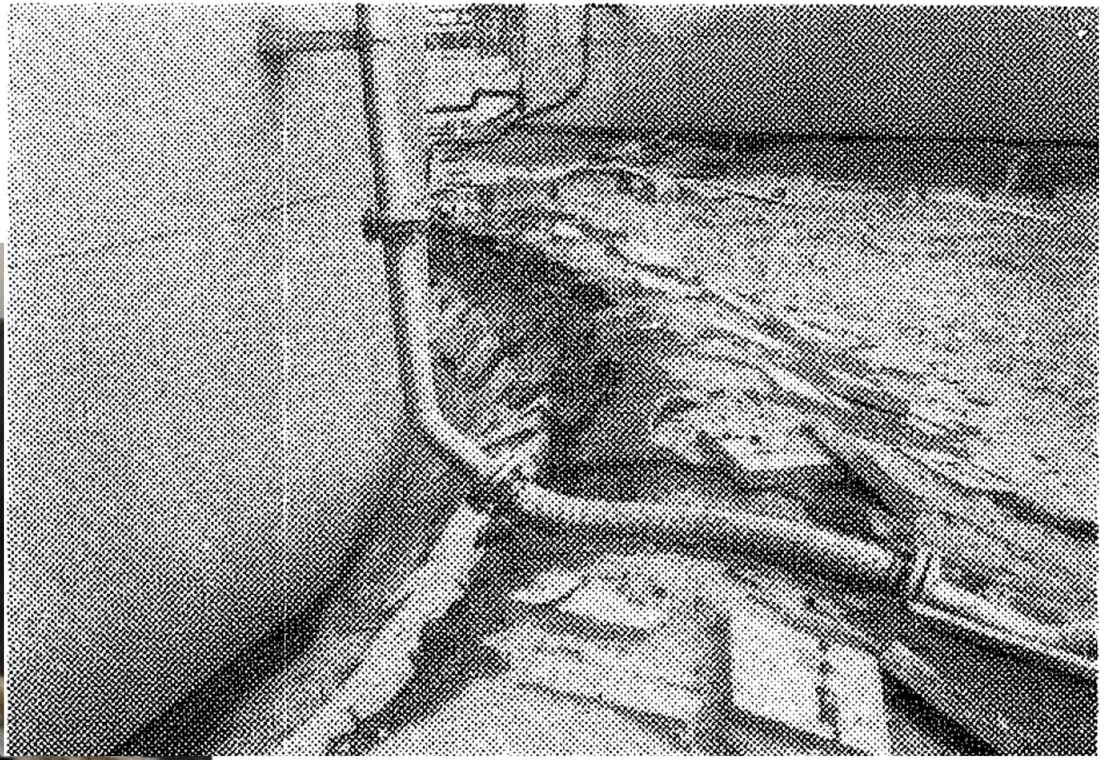


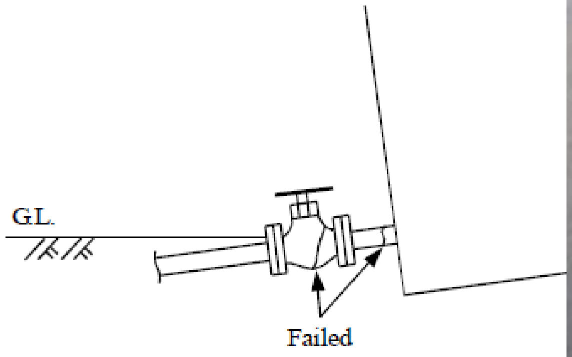




Soil Induced Damage

- liquefaction settlement
- liquefaction lateral spread



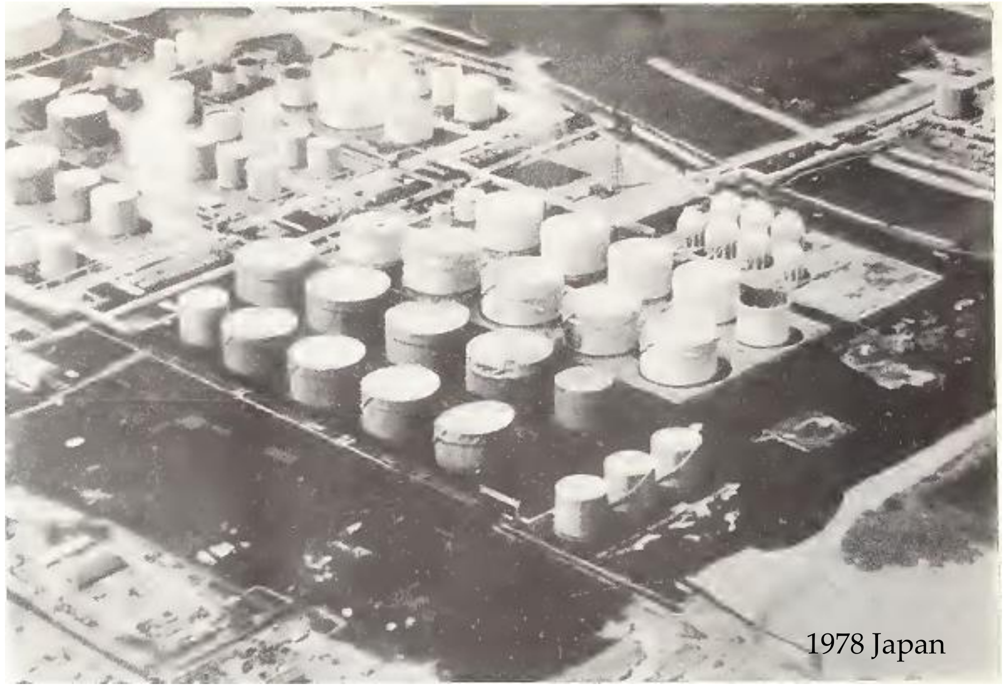


Consequences of Failure

- Limit access to fuel during recovery
- Spilled contents
- Fire – volatile gasses, floating roof collision

1964 Great Alaska

1999 Turkey

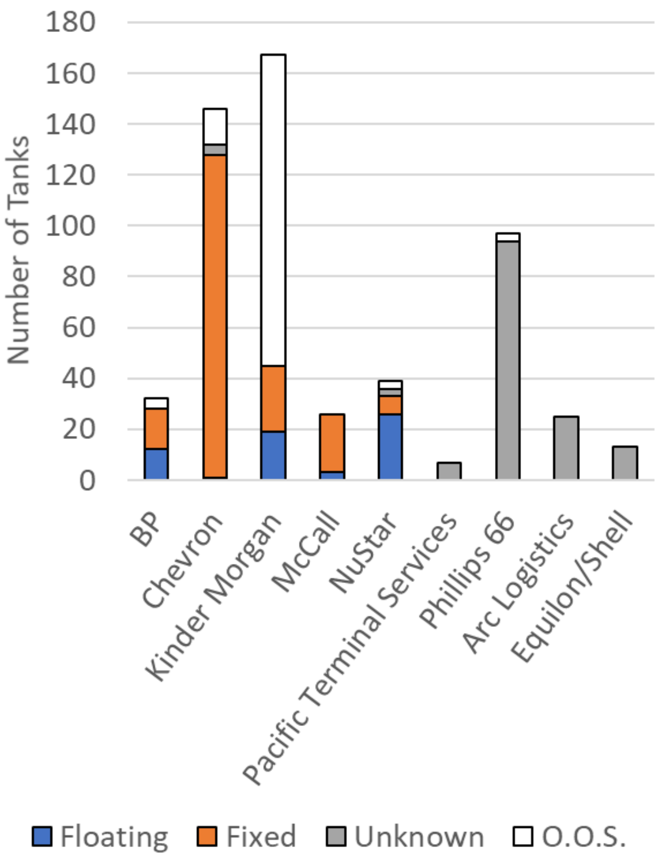


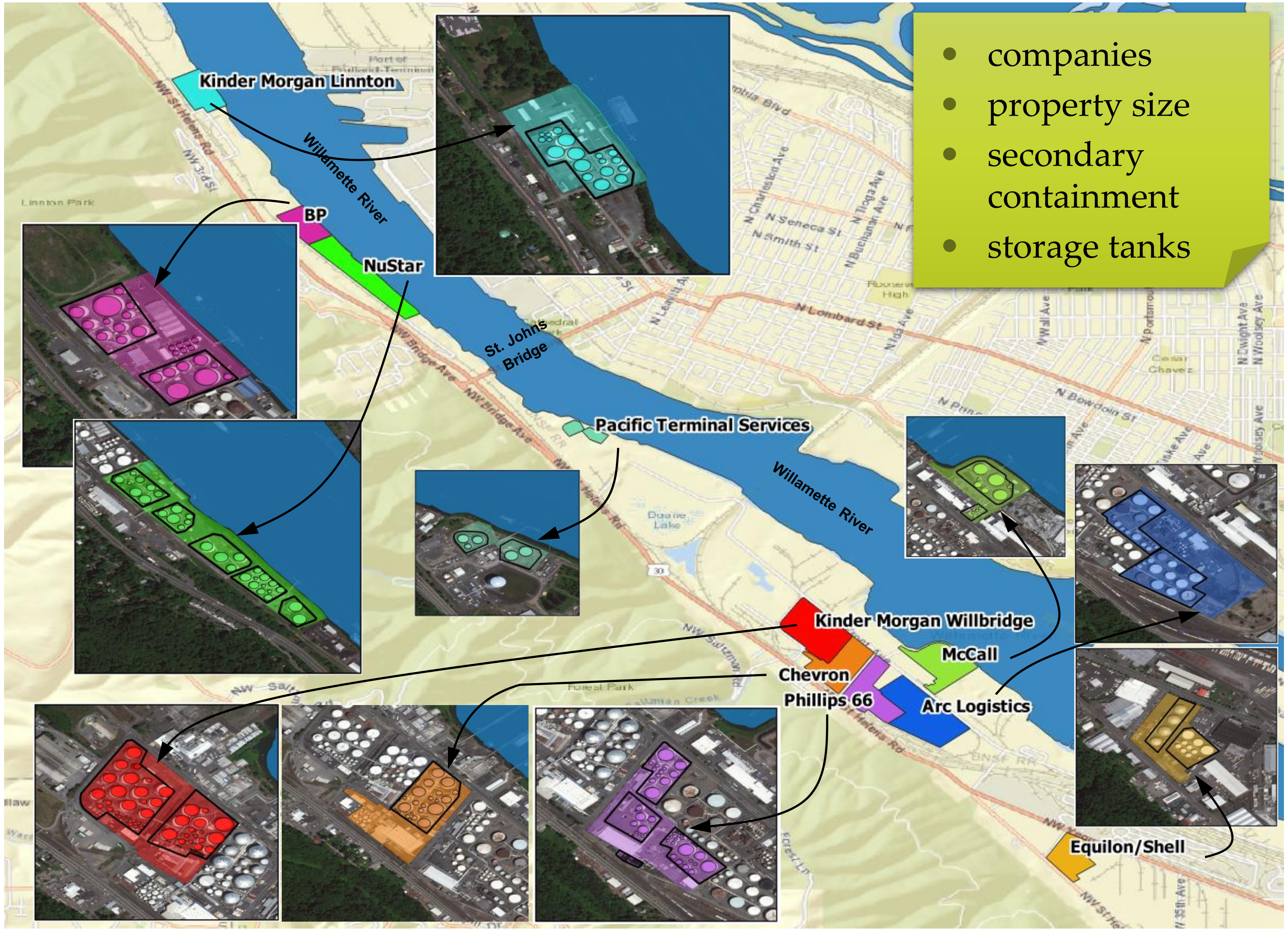
1978 Japan

2011 Japan

Fuel at Hub

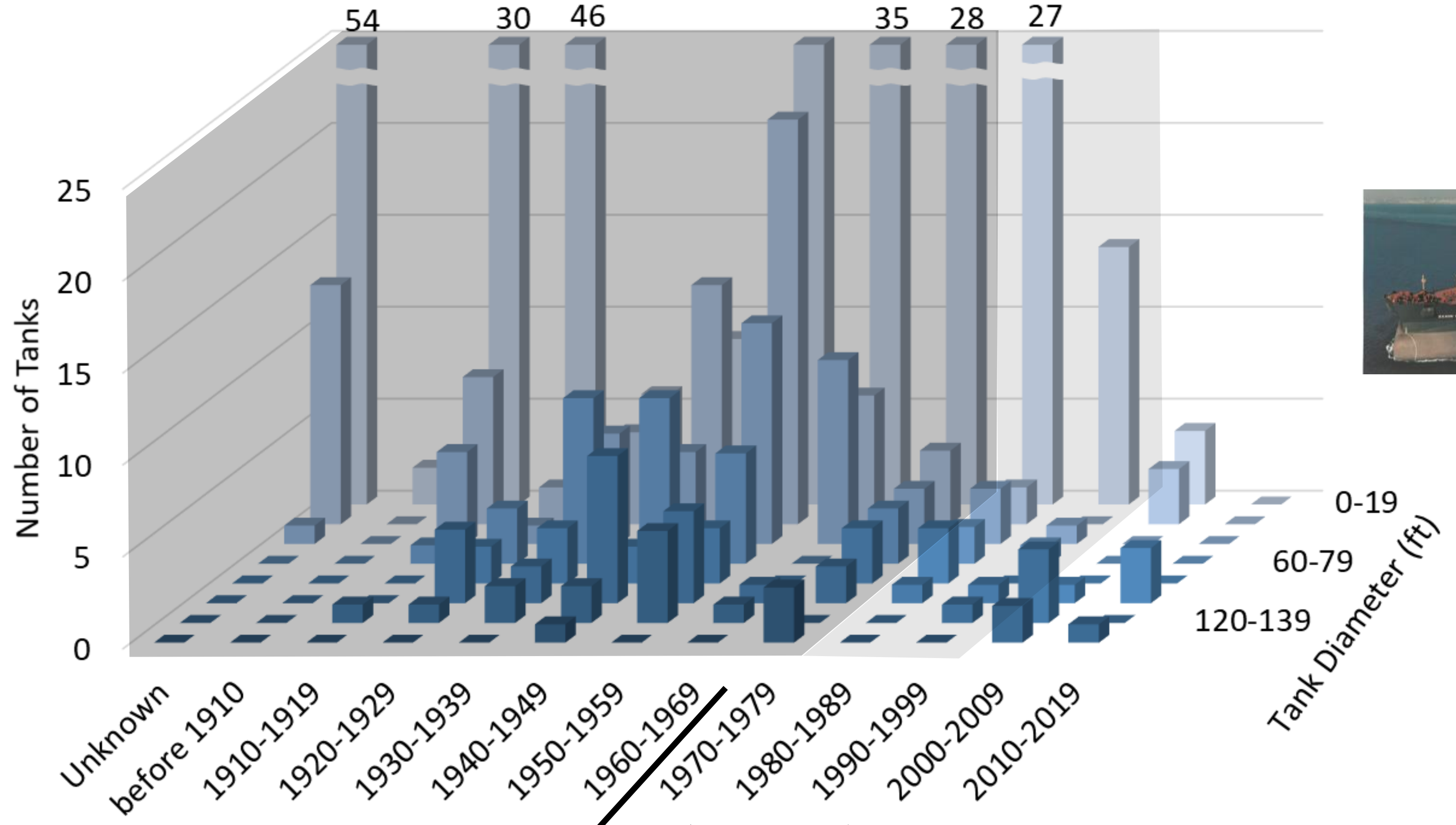
- e.g. number of tanks





- companies
- property size
- secondary containment
- storage tanks

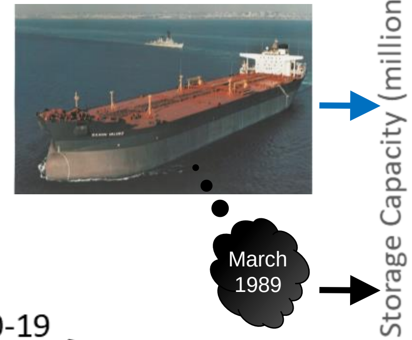
Tank Age and Size



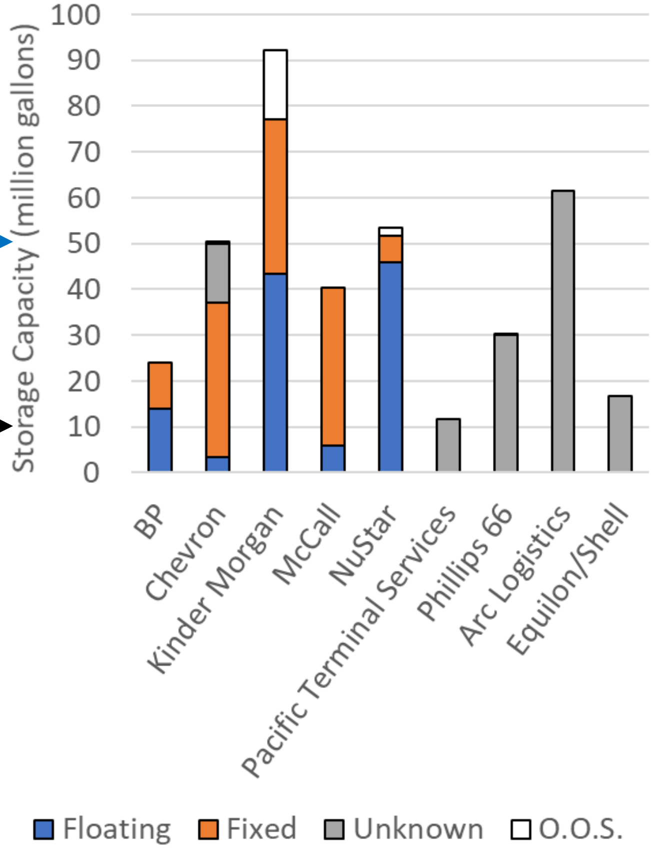
Alaska EQ (1964)

building code increases hazard in OR

building code increases hazard in OR

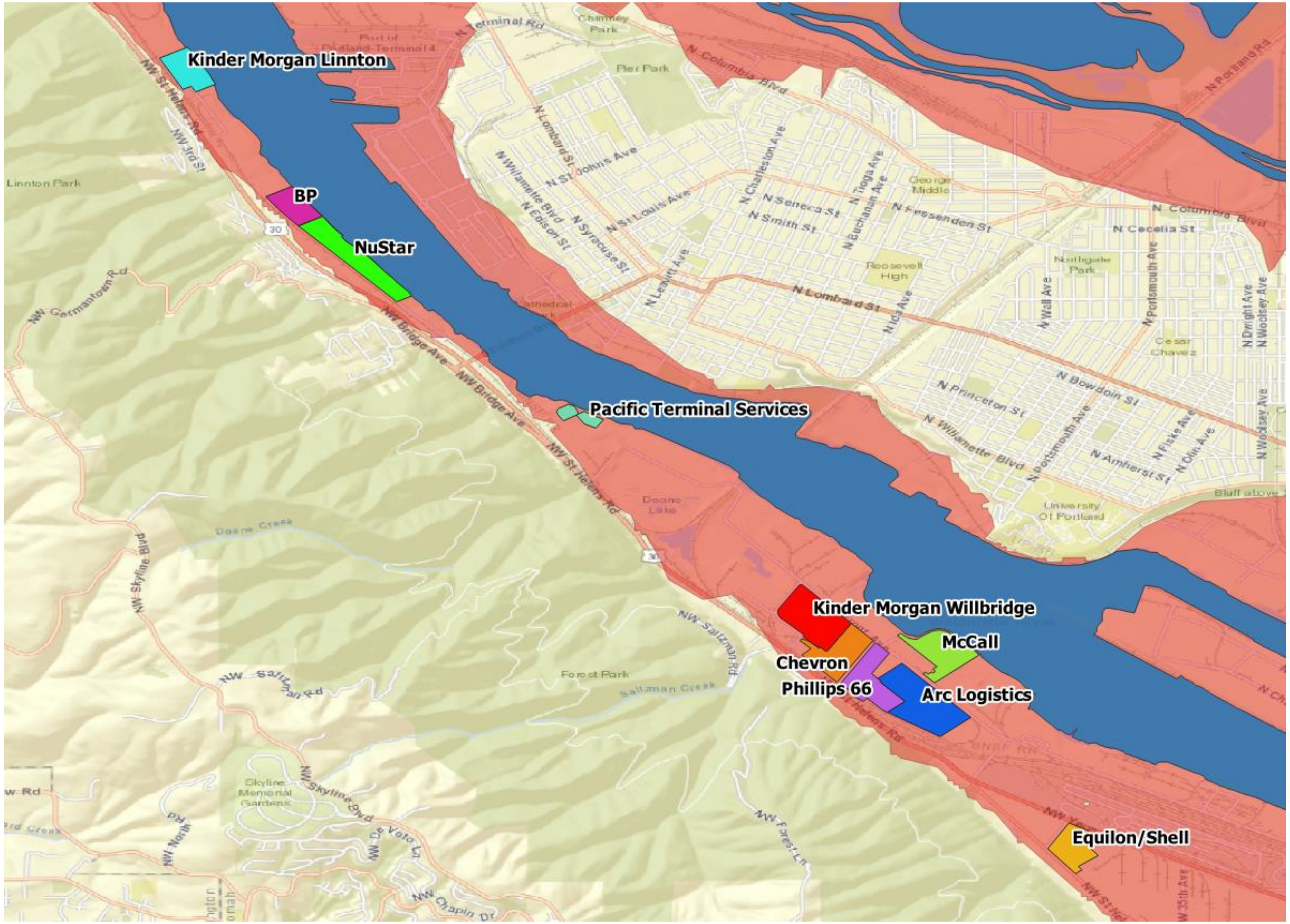


Liquid Storage Capacity



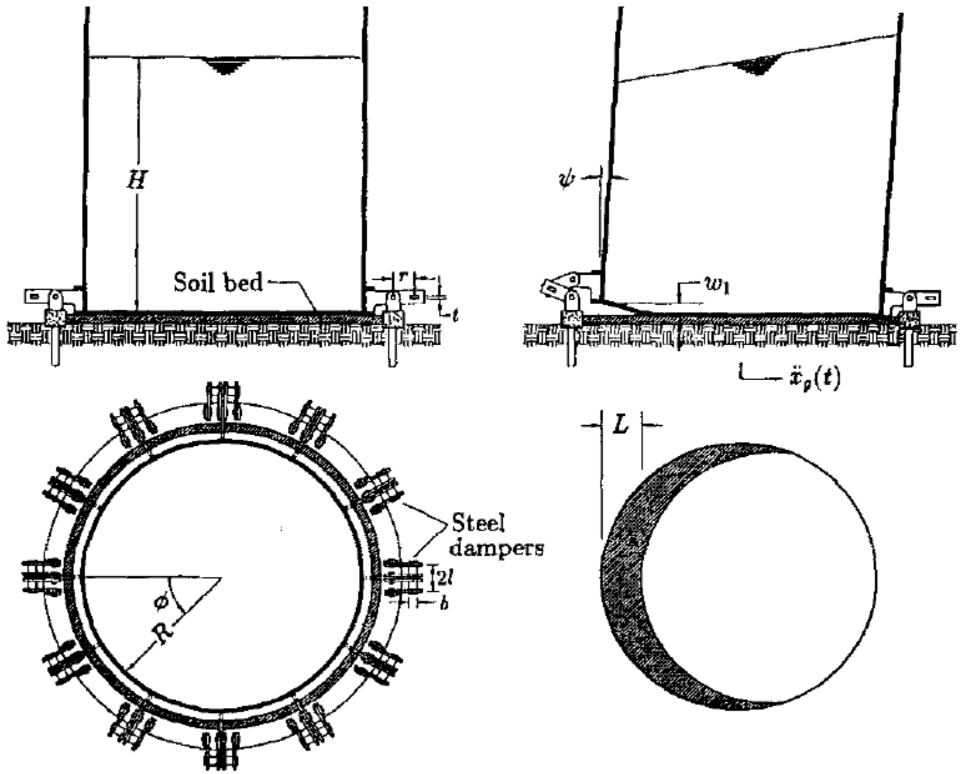
Soil at CEI

- data is lacking, but loose to medium-loose sands and high water table.
- permanent ground deformations (DOGAMI)



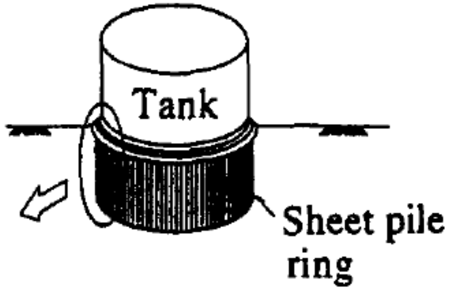
Mitigation - Structural

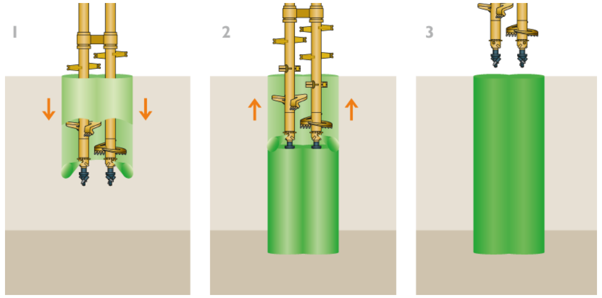
- Anchoring of tank walls
  - sliding, uplift, wall buckling
- Strengthening of walls
  - thickness or perimeter rings
- stabilization of roofs
- reduction of liquid storage

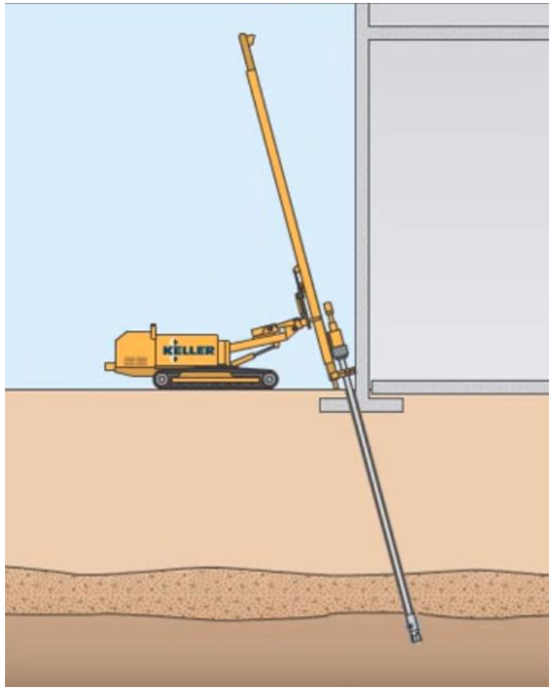


Mitigation - Soil

- Sheet pile ring around perimeter
- Deep soil mixing
- Jet grouting
- Lowering of ground water table







Mitigation Considerations Past Tanks

- secondary containment
- connections to/from tanks
- distribution systems
- support equipment
- site access

Kinder Morgan Willbridge Terminal
(via Google Earth)

Recommendations for Next Steps

- Goal of quantifiable scientific evaluation of risk and mitigation

- <u>More physical information</u>
  - conduct subsurface geotechnical data
  - obtain more detailed structural tank data
  - assess mitigation options for fuel distribution

→ refine cost estimates & understand resiliency

- <u>New scientific knowledge</u>
  - quantify seismic fragility of tanks (pre & post mitigation)
  - develop seismic performance criteria
  - prioritize tank importance

→ remediation selection
seismic risk analysis
cost/benefit

→ strategically approach preparation & mitigation