The Impacts of the Cascadia Subduction Zone Earthquake on Oregon

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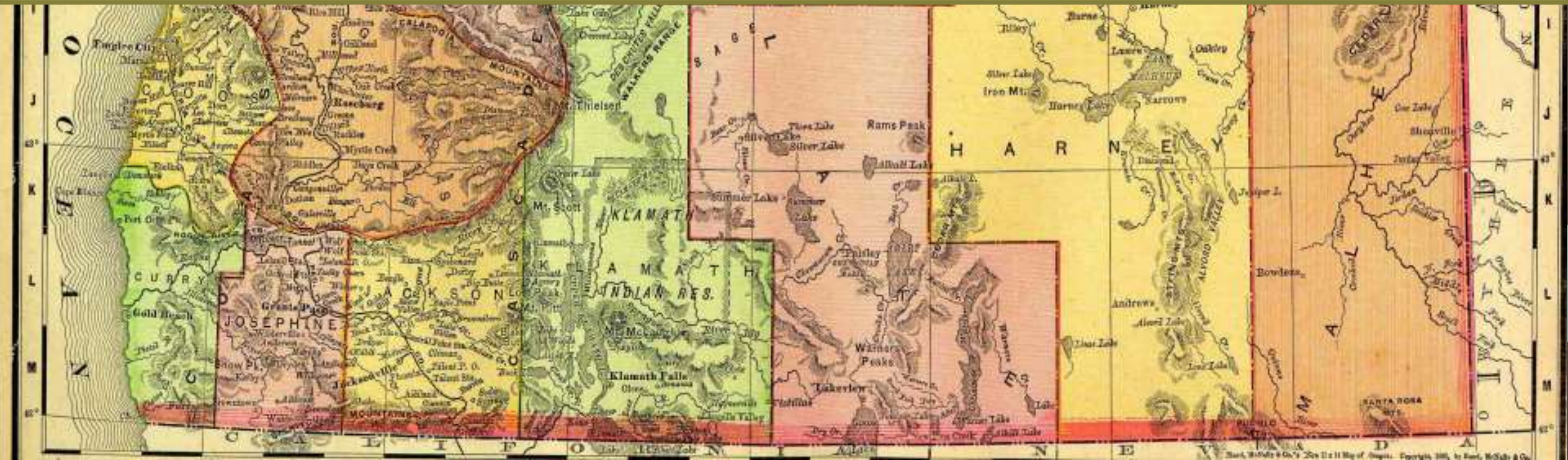
Oregon Military Department
Office Of Emergency Management

What are the Implications for Oregon if Cascadia happened today?



Oregon is at risk

from an earthquake and tsunami that can significantly **impact our people and economy for decades.**

Impacts to Built Environment

Impacts to People

Impacts to Economy

Cascadia Planning Assumption

Three metropolitan cities in impact zone

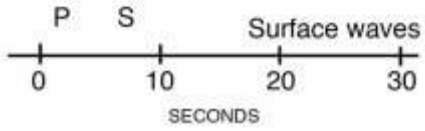
- Portland
- Seattle
- Vancouver, B.C.

15 million people live in the impact zone

- No power for weeks/months/years
- No fuel for weeks/months/years
- No deliveries of food/water for weeks/months
- No running water for weeks/months/years
- No sewer system for weeks/months/years

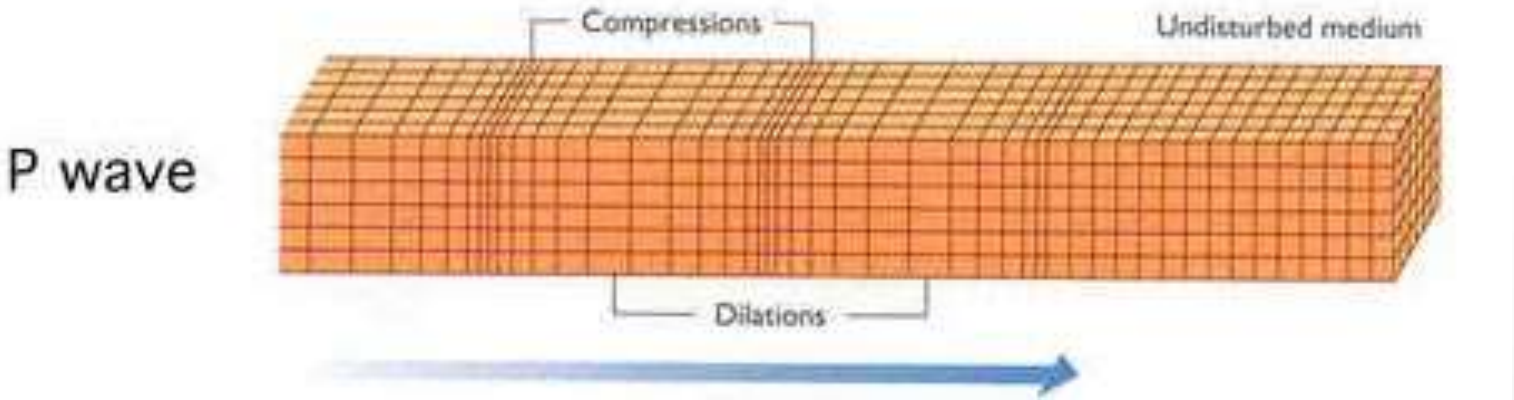
Seismic Waves

- P Waves (Primary Waves)
- S Waves (Secondary or Shear Waves)
- Surface Waves



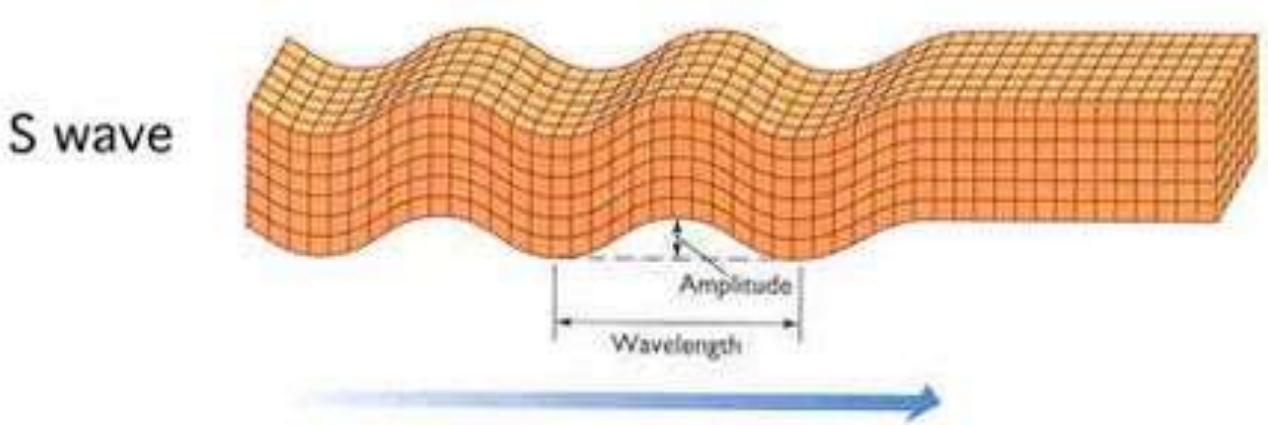
P Waves

- A P wave, or **compressional wave**, is a seismic body wave that shakes the ground back and forth in the same direction and the opposite direction as the direction the wave is moving.



S Waves

- An S wave, or **shear wave**, is a seismic body wave that shakes the ground back and forth perpendicular to the direction the wave is moving.



Surface waves

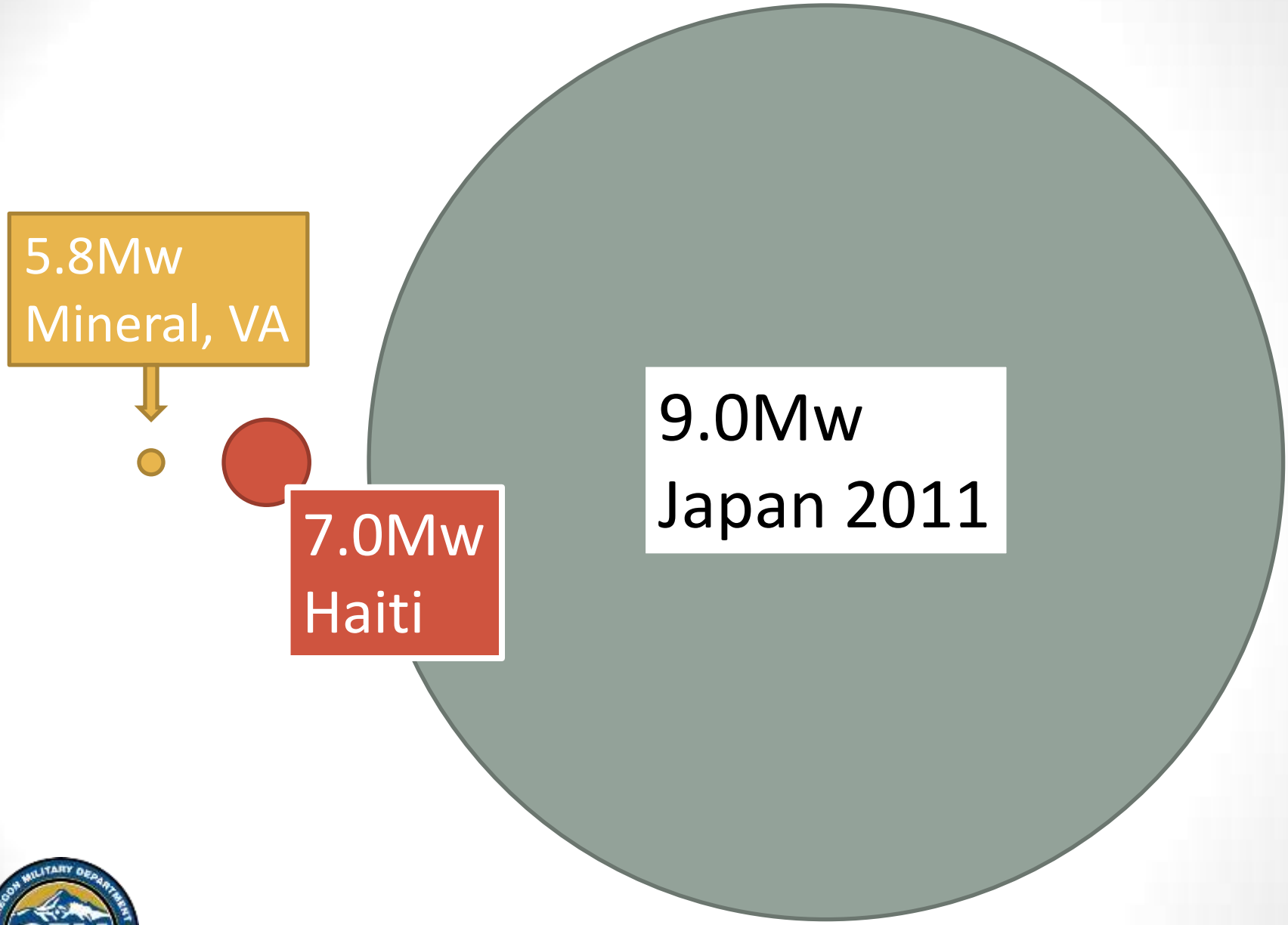
- A surface wave is a seismic wave that is trapped near the surface of the earth.
- Travel along the Earth's surface.
- Slower than body waves.
- Because of their low frequency, long duration, and large amplitude, they can be the most **destructive type of seismic wave**.
- There are two types of surface waves.

How big is big?

- **Richter Scale**
  - Developed by Charles F. Richter in 1934
  - Amplitude of the largest wave recorded on a specific type of seismometer and the distance between the earthquake and the seismometer.
  - Specific to California earthquakes.

Moment Magnitude

- Moment is a product of the distance a fault moved and the force required to move it.
- Proportional to the fault area multiplied by the average displacement on the fault.
  - The **SHAKING** of a 6.0 Magnitude quake is 10x greater than a 5.0 Mw
  - The **AMOUNT of ENERGY RELEASED** is 32x greater


5.8Mw
Mineral, VA
7.0Mw
Haiti
9.0Mw
Japan 2011

Modified Mercalli Scale

- This scale, composed of increasing levels of intensity that range from imperceptible shaking to catastrophic destruction, is designated by Roman numerals. It does not have a mathematical basis; instead it is an arbitrary ranking based on observed effects

I	Instrumental	Not felt.
II	Just Perceptible	Felt by people sitting or on upper floors of buildings.
III	Slight	Felt by almost all indoors. Hanging objects swing. May not be recognized as an earthquake..
IV	Perceptible	Vibration felt like passing of heavy trucks. Windows, dishes, doors rattle. In the upper range of IV, wooden walls and frames creak.
V	Rather Strong	Felt outdoors. Sleepers wakened. some spilled. Pictures move.
VI	Strong	Felt by all. People walk unsteadily. Windows crack. Weak buildings cracked.
VII	Severe	Difficult to stand or walk. Damage to poorly built masonry buildings. Some cracks in better masonry buildings.
VIII	Destructive	Extensive damage to unreinforced masonry buildings. Fall of some masonry walls. Wood-frame houses moved on foundations if not bolted
IX	Violent	General panic. Damage to masonry buildings ranges from collapse to serious. Wood-frame structures rack, and, if not bolted, shifted off foundations. Underground pipes broken.
X	Very Violent	Poorly built structures destroyed with their foundations. Even some well-built wooden structures and bridges heavily damaged and needing replacement.
XI	Extreme	Rails bent greatly. Underground pipelines completely out of service.
XII	Catastrophic	Damage nearly total.

Great
Can cause major destruction over areas several 100 kms across

Major
Serious damage over larger areas

Strong
Affects areas up to 100km across

Moderate
Affects small regions, causing slight damage

Light
Often felt, rarely causes damage

Minor
Recorded though not generally felt

Micro
Only recorded locally

9.0
8.0
7.0
6.0
5.0
4.0
3.0

9.3
7.9
7.0
6.3

Sumatra 2004 (triggered Asian tsunami)

China 2008

Haiti 2010

Italy 2009

Understanding Ground Motion

- The strength of ground shaking is measured in
  - the **velocity of ground motion**,
    - Rate of motion
  - the **acceleration of ground motion**,
    - Change in rate of speed
  - the **frequency content of the shaking** and
  - **how long the shaking continues** (the "duration").

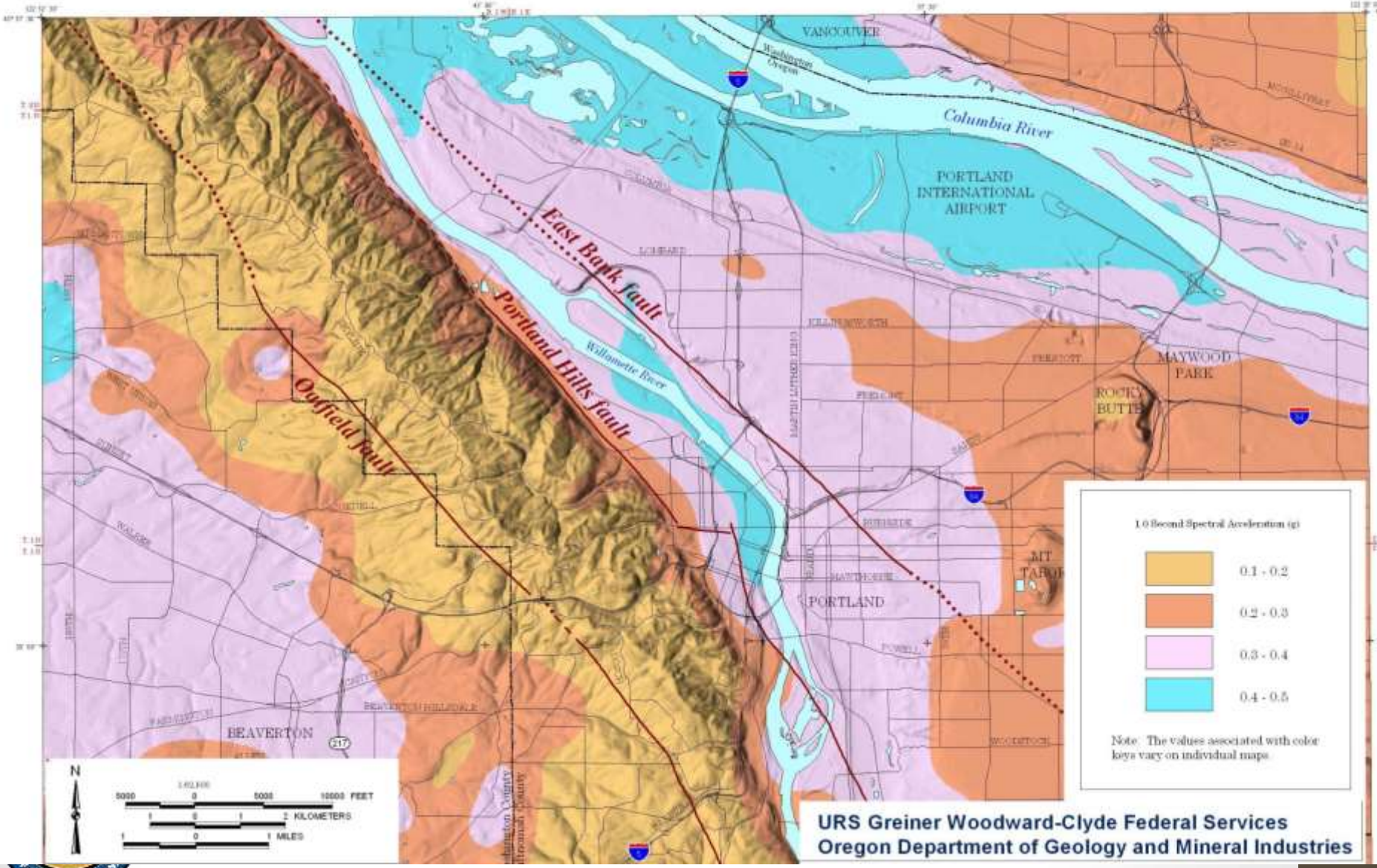
Measuring seismic forces

- Acceleration
  - 0.001 g (0.01 m/s^2)
    - perceptible by people
  - 0.02 g (0.2 m/s^2)
    - people lose their balance
  - 0.50 g – very high
    - well-designed buildings can survive if the duration is short.

Earthquake Scenario Ground Shaking Map for the Portland, Oregon, Metropolitan Area

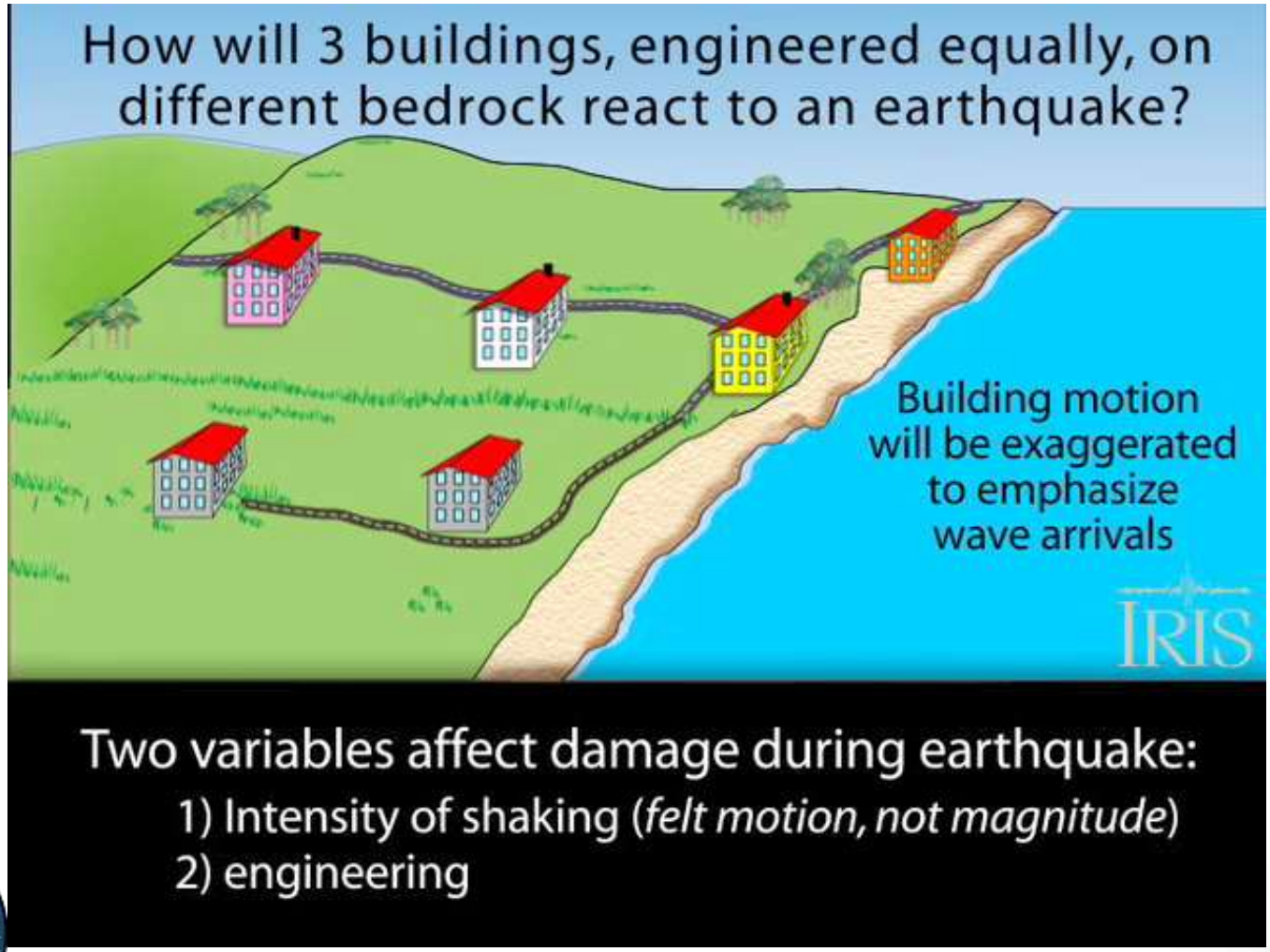
Cascadia Subduction Zone M 9.0 Earthquake
1.0 Second Spectral Acceleration (g) at the Ground Surface

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
JOHN D. BEAULIEU, STATE GEOLOGIST



URS Greiner Woodward-Clyde Federal Services
Oregon Department of Geology and Mineral Industries

Amplification and Liquefaction



Understanding how earthquakes impact the built environment

Role of Building Codes

- Building codes
  - sets of regulations governing the
    - design,
    - construction,
    - alteration and
    - maintenance of structures.

- They specify the minimum requirements to adequately safeguard the health, safety and welfare of building occupants.

Role of Building Codes

- Most states and local jurisdictions adopt the model building codes maintained by the International Code Council (ICC)
  - **International Building Code (IBC):** Applies to almost all types of new buildings
  - **International Residential Code (IRC):** Applies to new one- and two-family dwellings and townhouses of not more than three stories in height
  - **International Existing Building Code (IEBC):** Applies to the alteration, repair, addition or change in occupancy of existing structures

How Are the Codes Enforced?

- Adopting the latest building codes is only part of the solution.
- Codes must also be effectively enforced
- Code enforcement is the responsibility of local government building officials who review design plans, inspect construction work and issue building and occupancy permits.

What about Older Buildings?

- Except in certain circumstances, such as when a building is significantly renovated or altered or there is a change in its use that triggers the IBC or IEBC, the code requirements for existing buildings are those that were in effect when the structure was designed and constructed.
- Your community probably has many older structures that are not protected against earthquakes. This is because buildings are often used for decades before being replaced or substantially altered.
- These existing buildings are the single biggest contributor to seismic risk in the United States today.

FEMA Earthquake Publications: Building Codes and Seismic Rehabilitation

- https://www.fema.gov/earthquake-publications/earthquake-publications-building-codes-and-seismic-rehabilitation

NEHRP Recommended Seismic Provisions for New Buildings and Other Structures. 2009 Edition

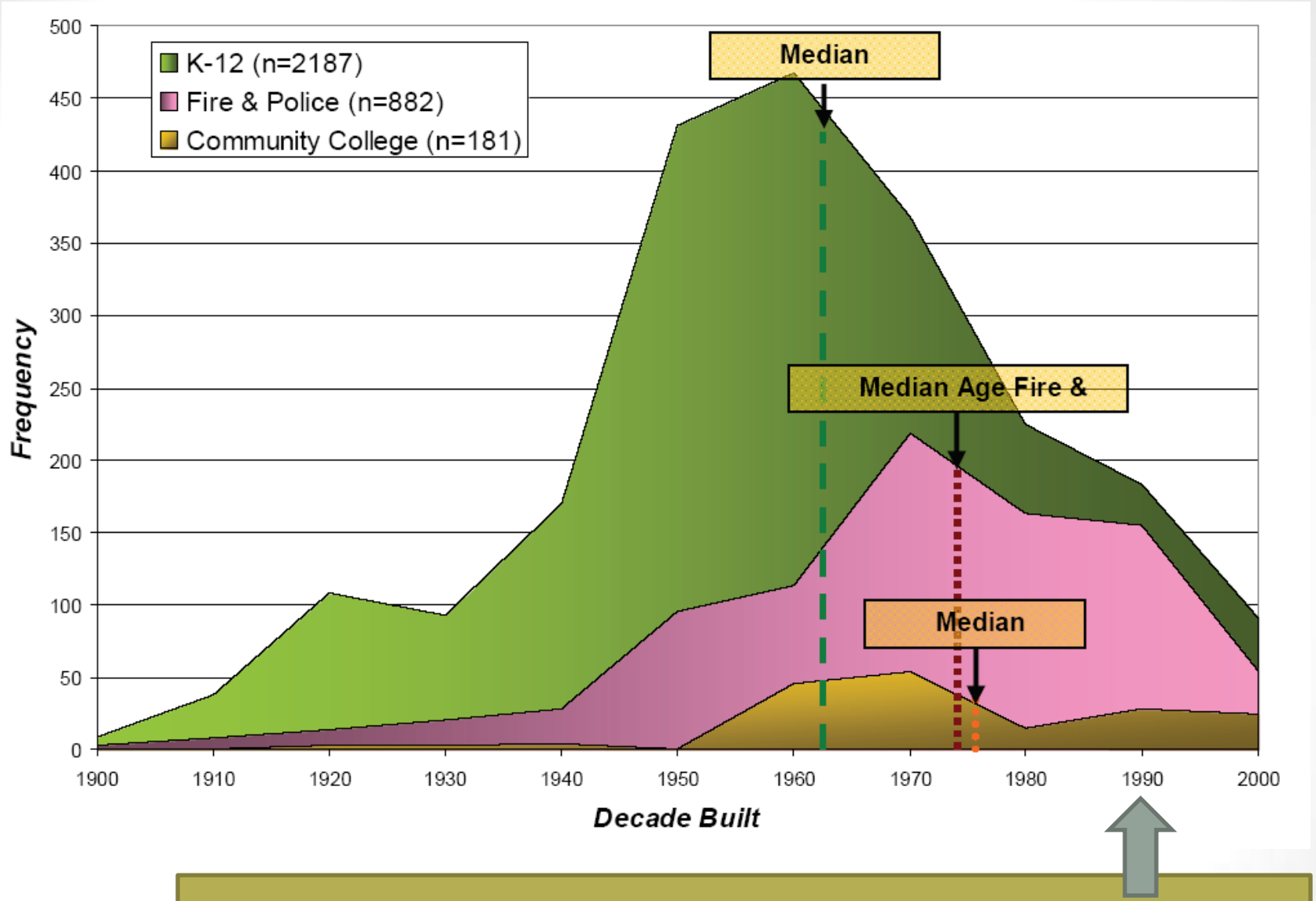
https://www.fema.gov/media-library/assets/documents/18152?id=4103

Seismic Building Codes in OR

- First Oregon building codes in 1974
  - 1973 Uniform Building code
  - Seismic criteria weak
- 1990 Oregon Structural Specialty Code (OSSC)
  - 1988 UBC – Significant shift
- 2004 OSSC
  - 2003 IBC – new EQ models upgrade to 2,500 year return from 500
- 2014 Oregon Structural Specialty Code (OSSC)
  - 2012 IBC

Seismic Building Codes in OR

- Planning for Natural Hazards: Seismic TRG
  - http://www.oregon.gov/LCD/HAZ/docs/earthquakes/08_seismic.pdf
- City of Medford Seismic Ordinance: www.ci.medford.or.us/Code.asp?CodeID=3643
- City of Portland Seismic Ordinance: www.portlandonline.com/auditor/index.cfm?c=28673



First significant seismic building codes in Oregon

Impacts on Built Environment

- Transportation
- Energy
- Critical and Essential Buildings
- Water and Wastewater
- Business and Workforce Continuity

Transportation

- Road
- Rail
- Water
- Ports
- Air

State of Oregon's bridges

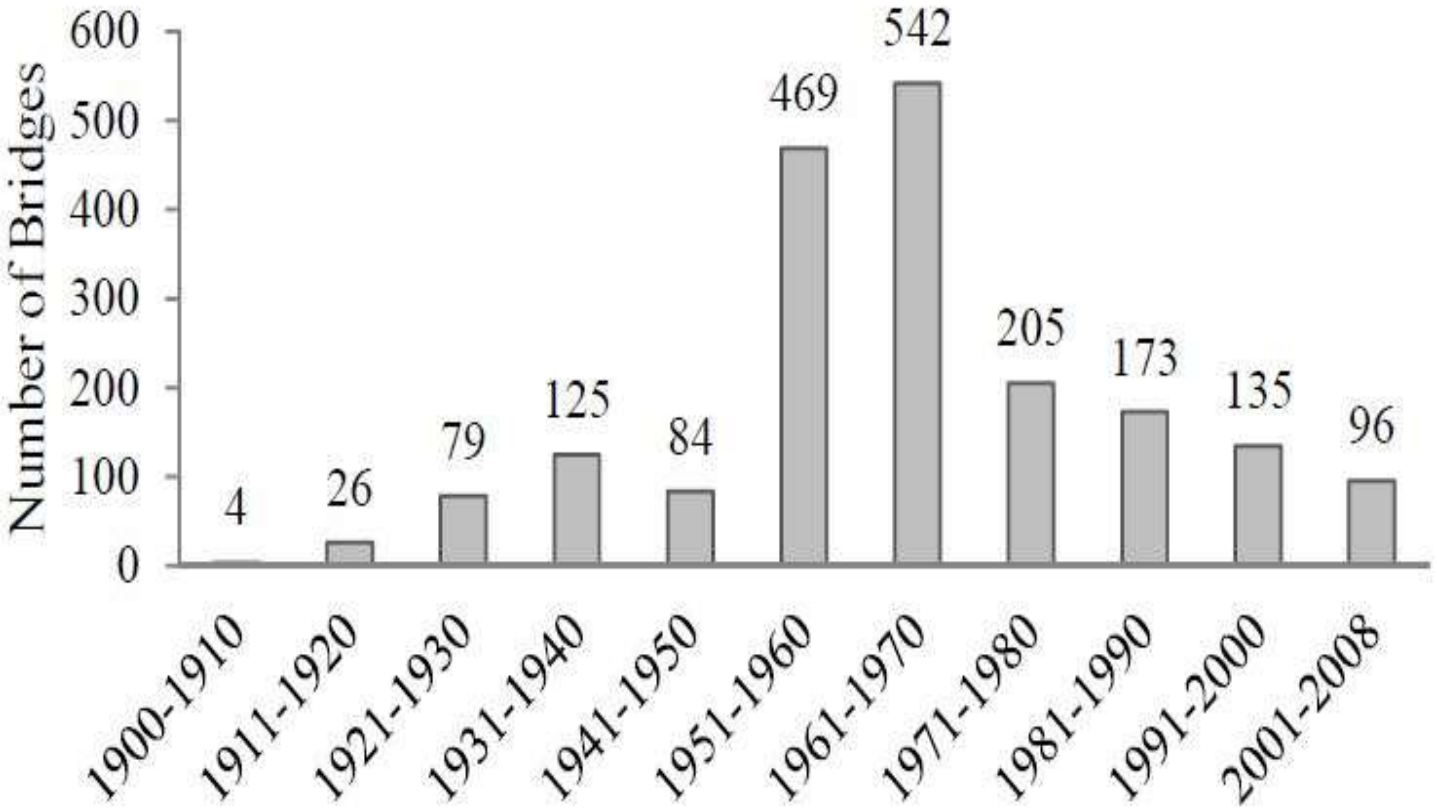
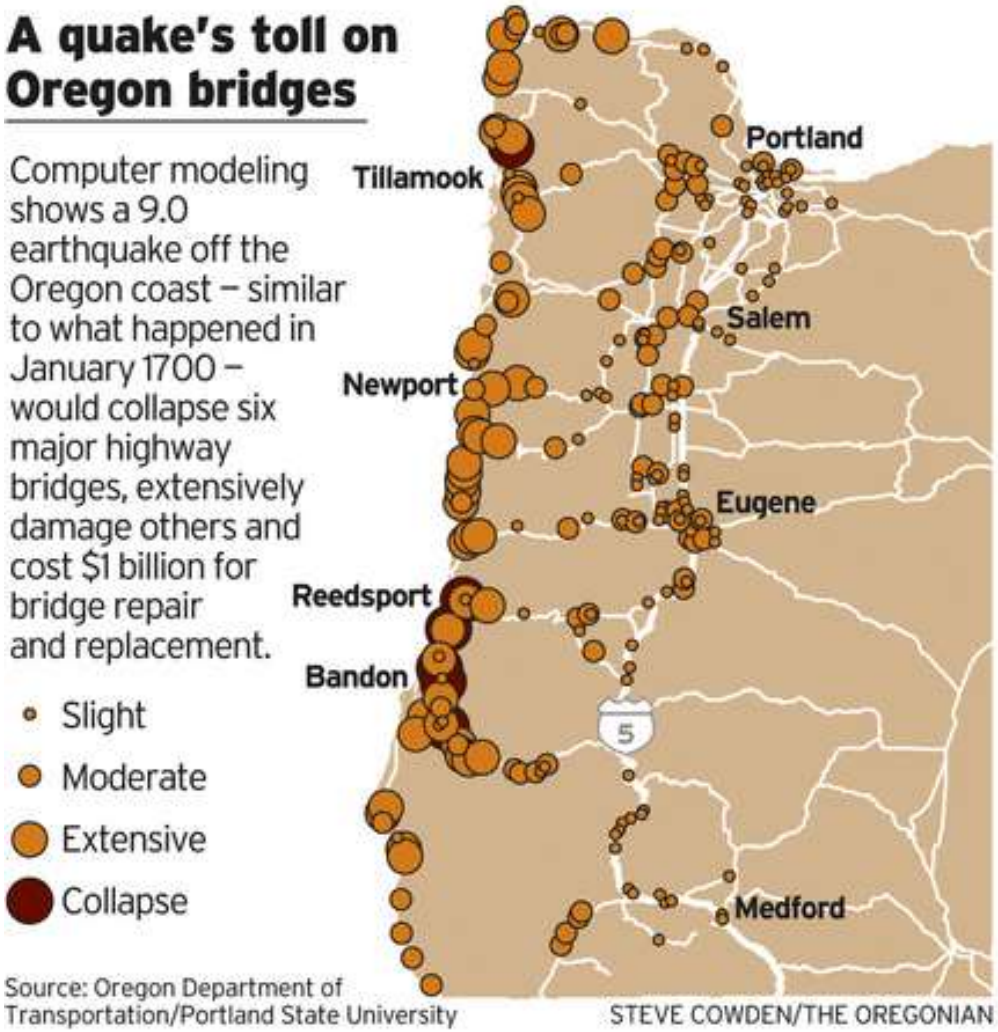


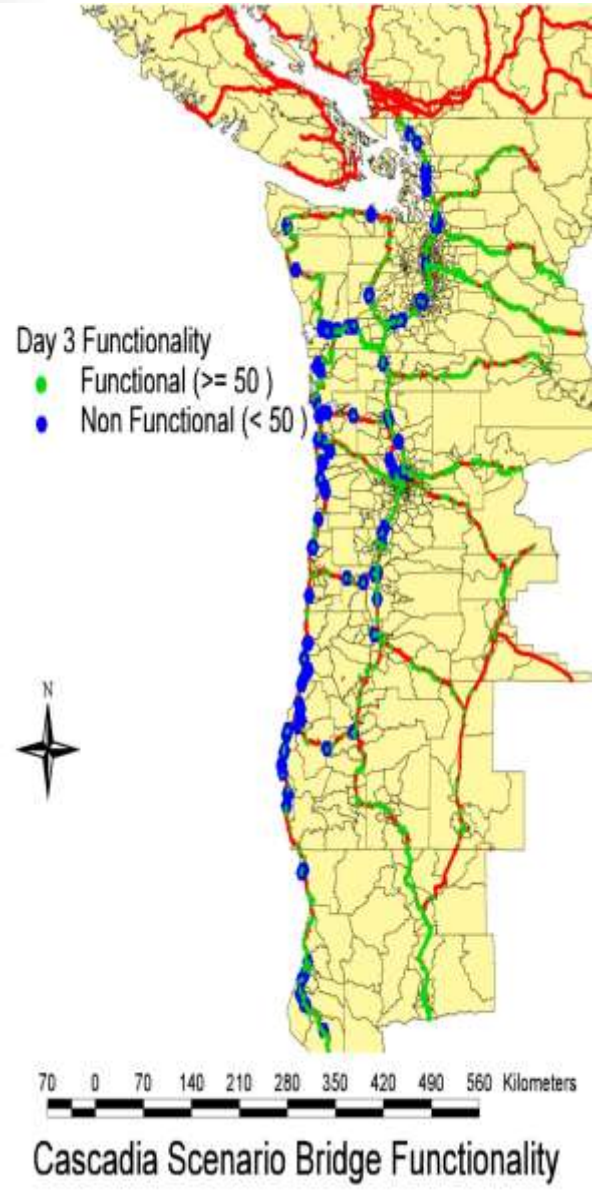
Figure 3: Distribution of year of construction completion

State of Oregon's bridges



Roads Damaged

Bridge Damage



621 bridges heavily damaged.

399 bridges totally or partially collapsed

Routes connecting Interstate I-5 with the HWY 101 would be closed.

Closure could be **3 to 12 months**.

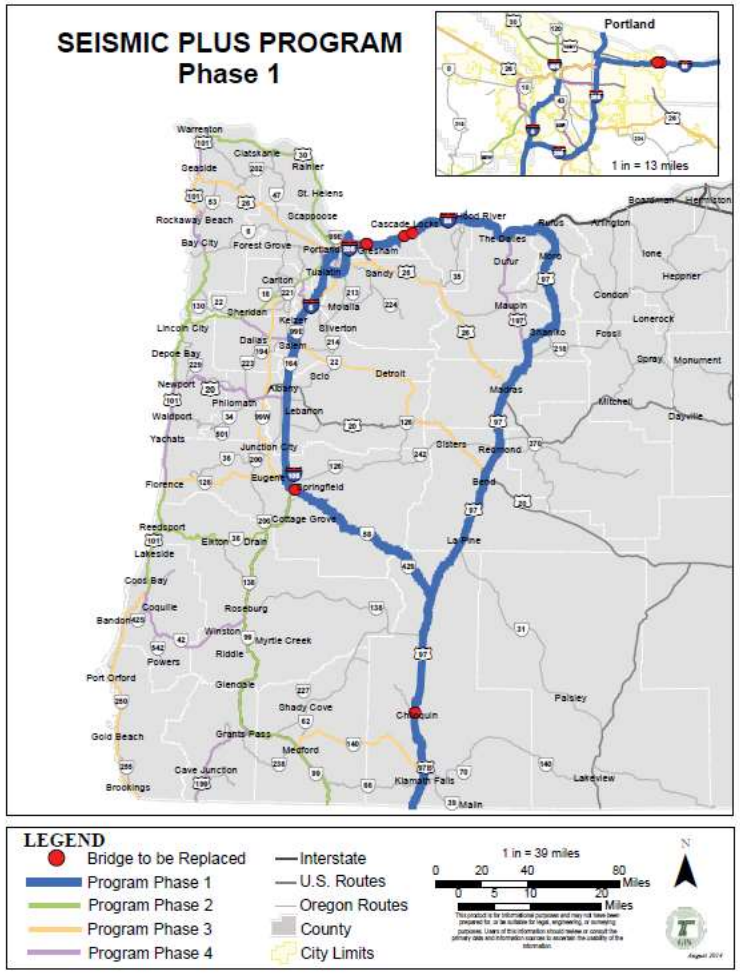
Restoration could take **3 to 5 years**

$5.1 Billion to seismically retrofit bridges

ODOT Seismic Plus Program

138	• Bridges to be replaced
390	• Bridges to be retrofitted
190	• Bridges to be rehabilitated and retrofitted
1185	• Landslides and rock falls to be mitigated

ODOT Seismic Plus Program



Recommendation 1

- Investment package

Recommendation 2

- Five phases over several decades

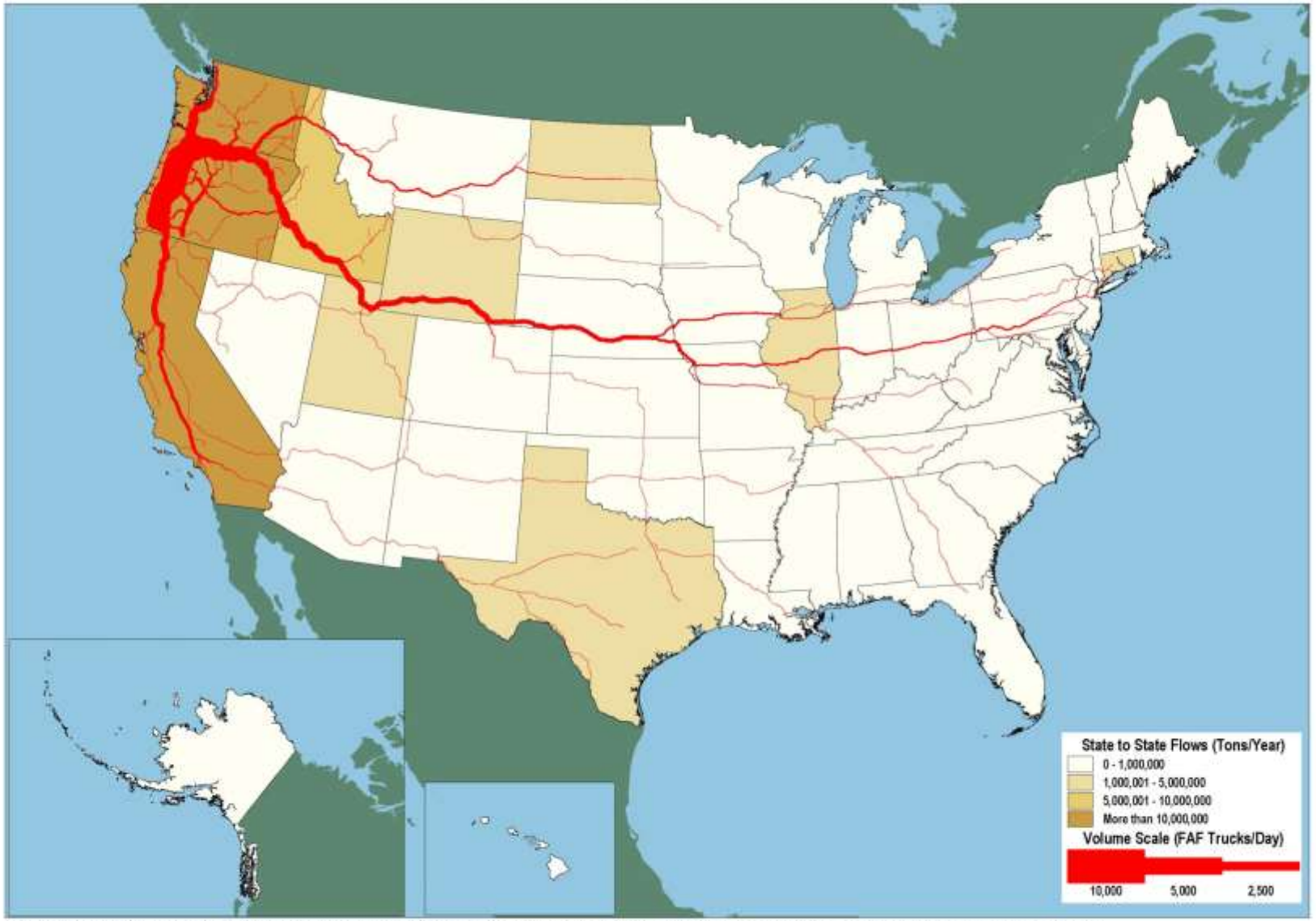
SOURCE:
http://www.oregon.gov/ODOT/HWY/BRIDGE/docs/2014_Seismic_Plus_Report.pdf

Cost benefits of retrofits

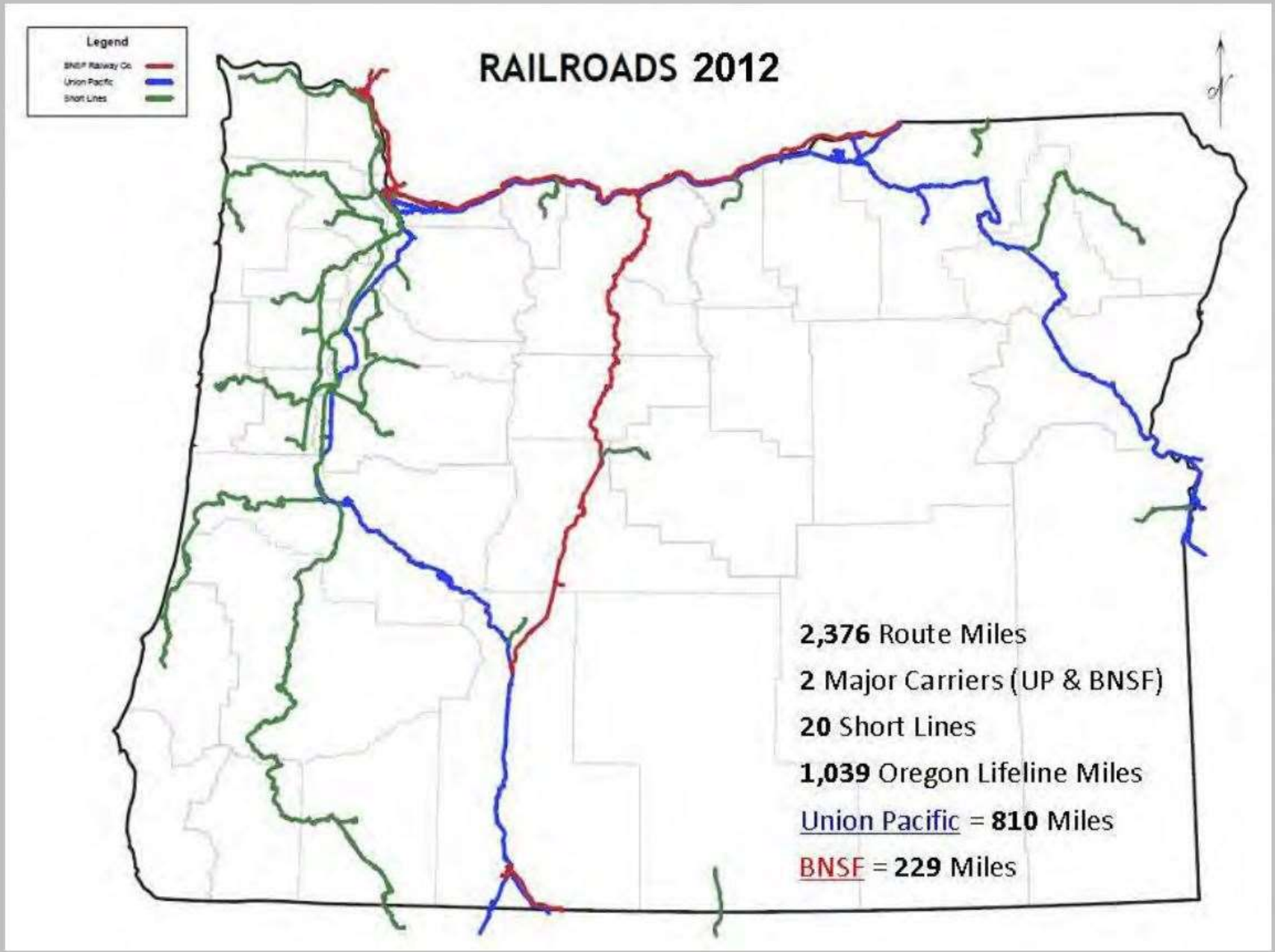
Seismic retrofitting could lessen economic losses by 24%

Cost benefit could be up to $84B

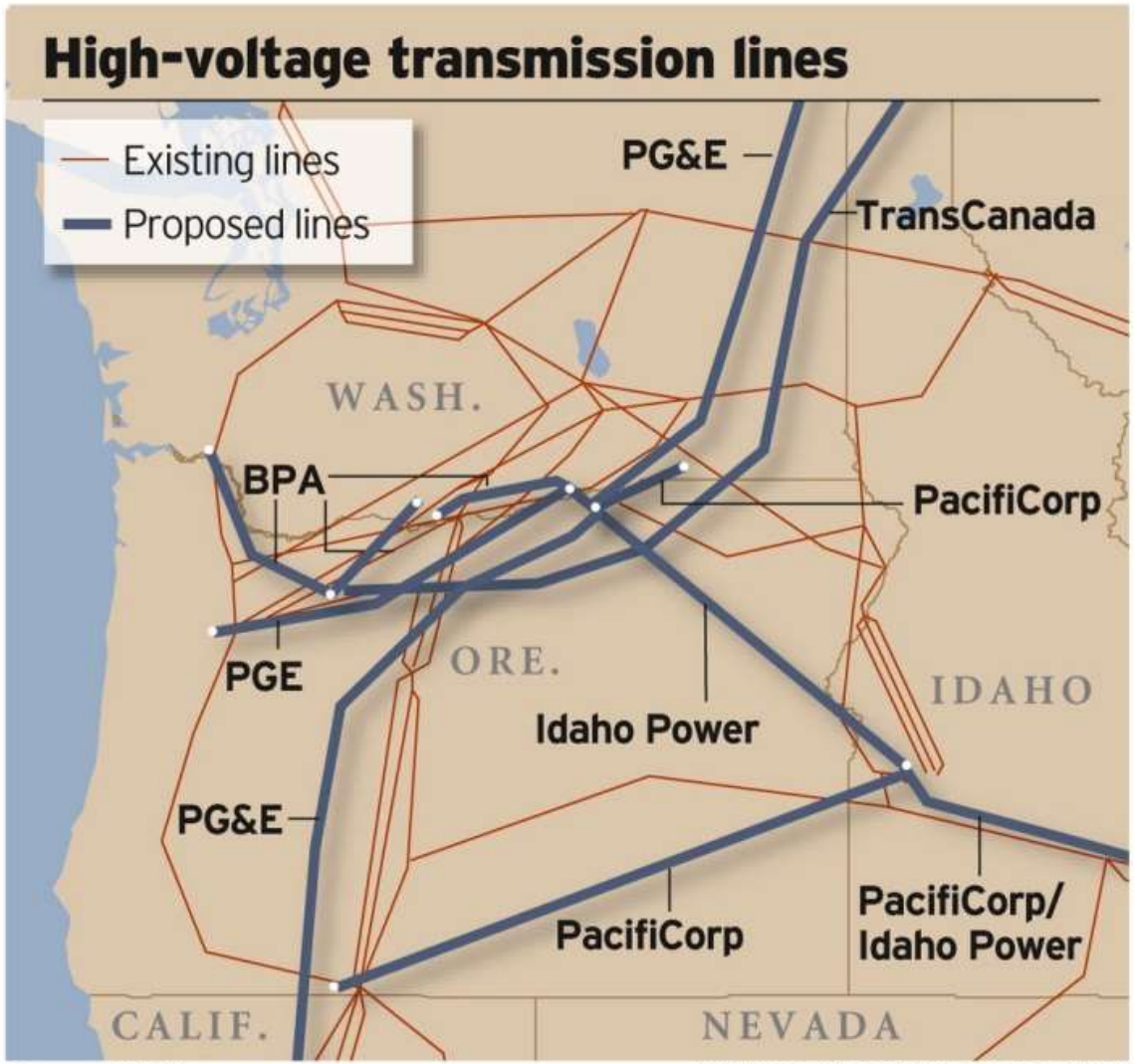
Major Flows by Truck To, From, and Within Oregon: 2007

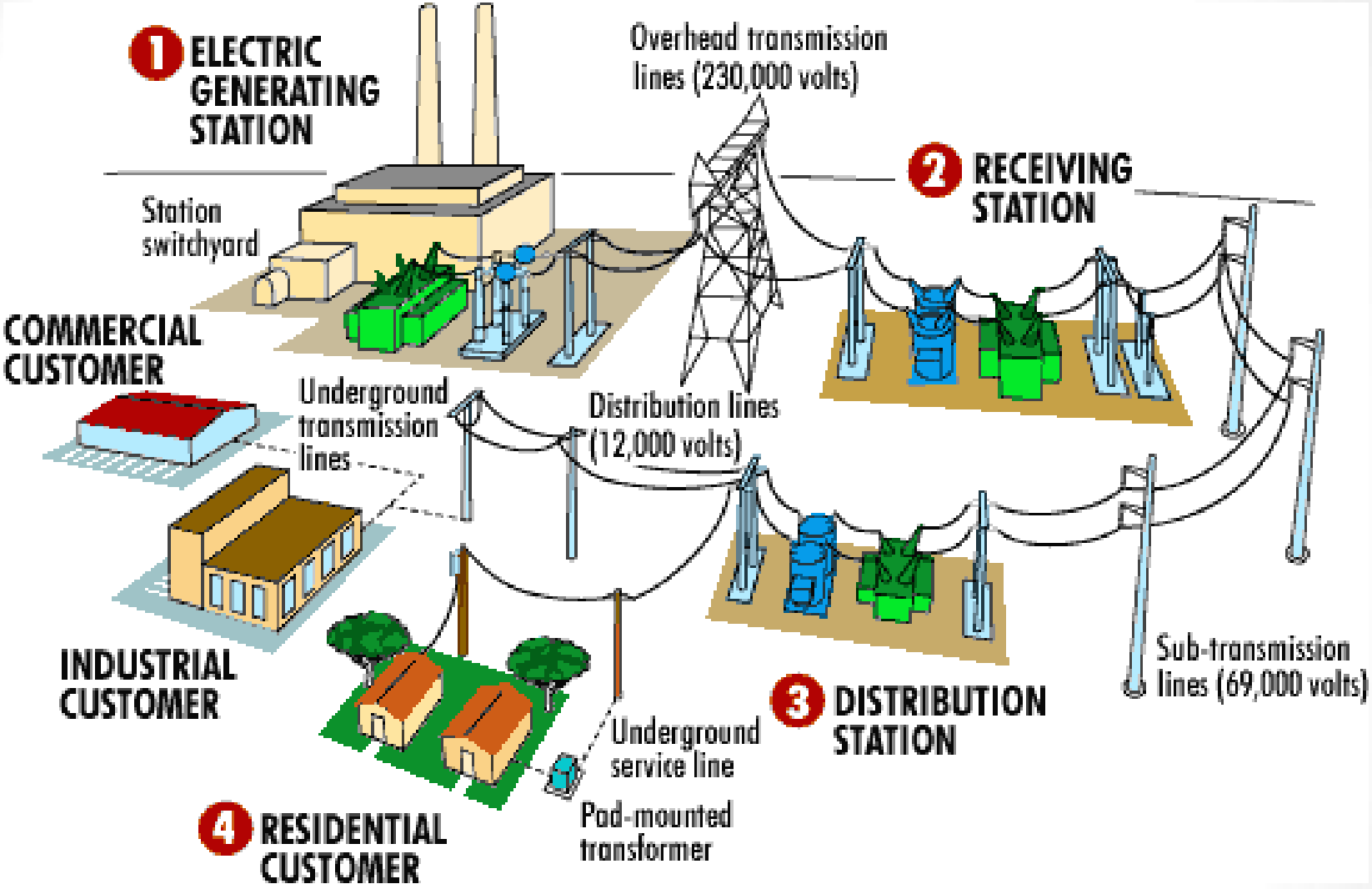


Note: Major flows include domestic and international freight moving by truck on highway segments with more than twenty five FAF trucks per day and between places typically more than fifty miles apart.
Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework, version 3.1.2, 2011.


Legend
BNSF Railway Co.
Union Pacific
Short Lines
RAILROADS 2012
2,376 Route Miles
2 Major Carriers (UP & BNSF)
20 Short Lines
1,039 Oregon Lifeline Miles
Union Pacific = 810 Miles
BNSF = 229 Miles

Energy


High-voltage transmission lines
Existing lines
Proposed lines
PG&E
TransCanada
WASH.
BPA
PacifiCorp
PGE
ORE.
IDAHO
Idaho Power
PG&E
PacifiCorp
PacifiCorp/
Idaho Power
CALIF.
NEVADA
Source: Utilities
MICHAEL MODE/THE OREGONIAN


1 ELECTRIC GENERATING STATION
Overhead transmission lines (230,000 volts)
Station switchyard
2 RECEIVING STATION
COMMERCIAL CUSTOMER
Underground transmission lines
Distribution lines (12,000 volts)
INDUSTRIAL CUSTOMER
Sub-transmission lines (69,000 volts)
3 DISTRIBUTION STATION
Underground service line
Pad-mounted transformer
4 RESIDENTIAL CUSTOMER

Electricity Target Timeframe for Recovery

Willamette Valley	0-24hrs	1-3 days	3-7 days	1-3 weeks	3+ weeks
Transmission					X
Substation					X
Distribution					X

Coast (Non-Tsunami)	0-24hrs	1-3 days	3-7 days	1-3 weeks	3+ weeks
Transmission					X
Substation					X
Distribution					X

Oregon Resilience Plan
http://www.oregon.gov/OMD/OEM/osspac/docs/Oregon_Resilience_Plan_Final.pdf

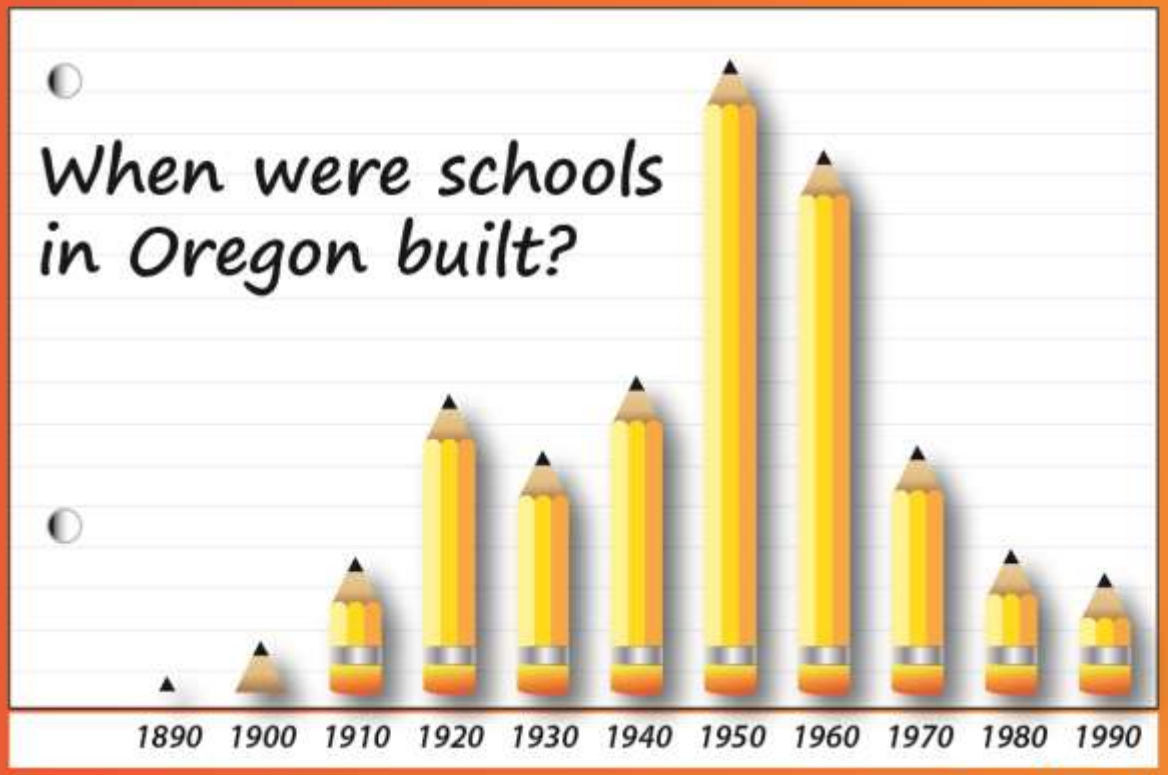
School Buildings

- Oregon population (2010)
  - 3,930,065
- Percentage under 18
  - 21.8%

3,930,065 x .218 = 856,754.17

When were the first sesimic codes adopted in Oregon?

1990



Source: DOGAMI

How many school kids go to school in buildings that could collapse in a Cascadia earthquake?

300,000

It doesn't take a building collapsing to cause injury

Pendant light fixtures failed in this elementary school library during the 1983 M6.5 Coalinga, California earthquake. If the room had been occupied, this could have caused injuries.
Bracing nonstructural elements in homes, schools, and offices can often be done easily and relatively inexpensively. (Source: NOAA/NGDC, Earthquake Engineering Research Institute)


Break Time

Effects on People

Sheltering Needs & Mass Care

1.7 M	• Housing units
62.5%	• Home ownership rate
23.2%	• Multi-family housing
1.5 M	• Households
15.5%	• Below poverty level

	Population (2013 Estimate)	Homeownership rate, 2009-2013	Residential Rental rate (%)	# of Individuals Residential Rental
OREGON	3,930,065	64.9	35	1,379,453
Region 1				
	Population (2013 Estimate)	Homeownership rate, 2009-2013		
Benton County	86,591	57.9	42	36,455
Lincoln County	46,350	65.5	34	15,991
Linn County	118,765	66.8	33	39,430
Polk County	76,794	65.4	34	26,571
Yamhill County	100,725	68.8	31	31,426
	429,225			

Medical Needs

- Less than 30% U.S. trained in first aid
  - 90% in Norway
  - 80% in Germany

First Aid & Medications

Water

	Population (2013 Estimate)	Daily water needs (3gal/day)
OREGON	3,930,065	
Region 1		
	Population (2013 Estimate)	
Benton County	86,591	259,773
Lincoln County	46,350	139,050
Linn County	118,765	356,295
Polk County	76,794	230,382
Yamhill County	100,725	302,175
	429,225	

Food


ヨークベニマル


MAYDAY
EMERGENCY FOOD RATIO
RATION D'URGENCE
3600
MAYDAY
EMERGENCY FOOD RATIONS
RATION D'URGENCE
2400
MAYDAY
EMERGENCY FOOD RATIONS
RATION D'URGENCE
3600


ヨークベニマル

Sanitation

Economic Impact

- $219M Oregon GDP (2013)
  - Decades to rebuild

Economic Output Costs

1	• Business interruptions
2	• Production losses directly due to asset loss
3	• Supply-chain disruptions
4	• Macro-economic feedbacks
5	• Long-term adverse consequences on economic growth

Impacts to marine industries

- Oregon's four major fishing ports:
  - Astoria,
  - Coos Bay,
  - Brookings,
  - and Newport.
- These four ports handled nearly 90 percent of Oregon commercial fish landings by value.

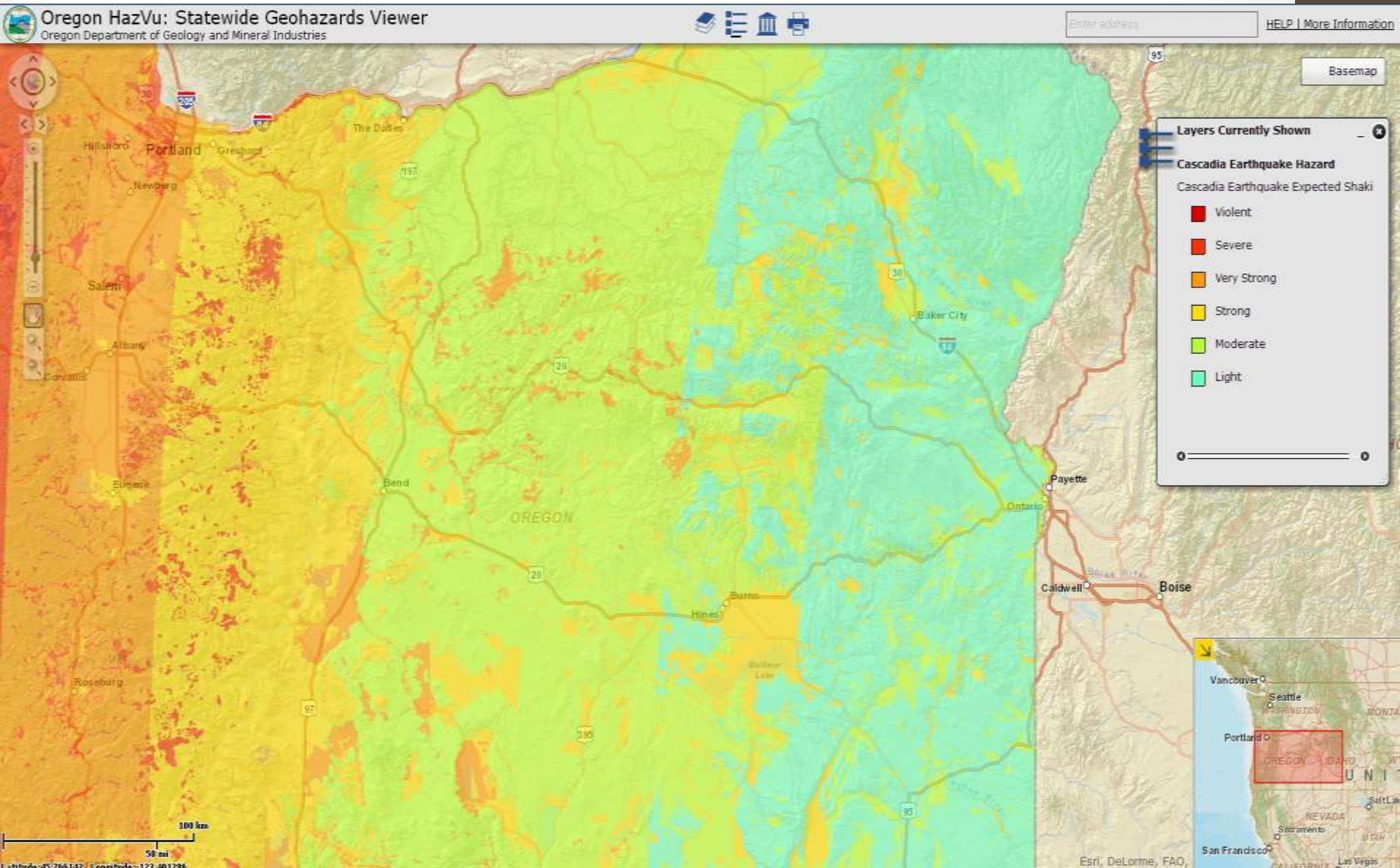
What does this mean to Eastern Oregon?

- Physical impact on built environment?
- Impact on the people of Eastern Oregon?
- What will be the economic impact?

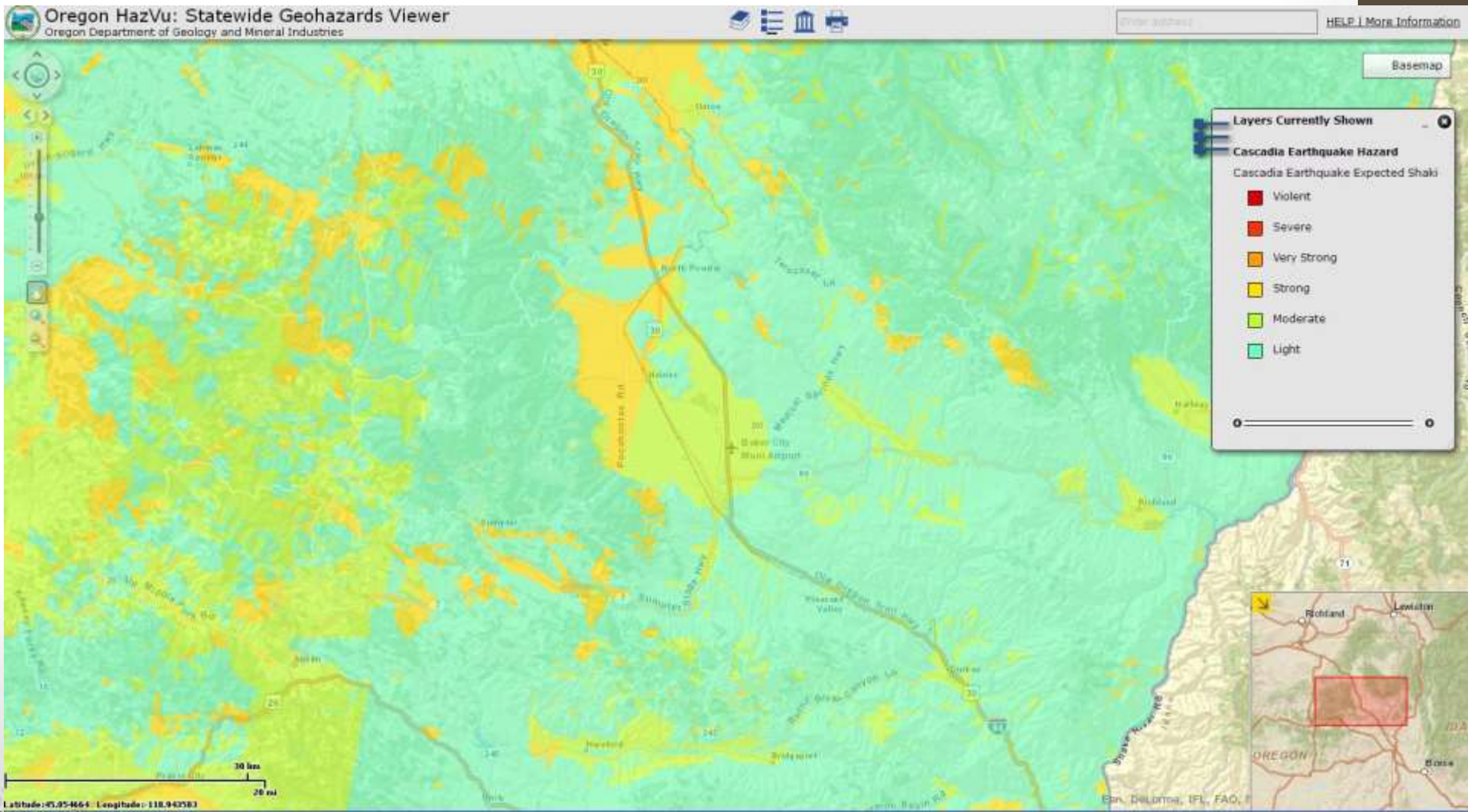
Impacts on Western Oregon

- Earthquake deaths ranging from 650 to 5,000, with another 600 to 5,000 deaths due to the tsunami.
- 24,000 buildings completely destroyed, and another 85,000 with extensive damage requiring months to years of repair.
- 27,600 displaced households.
- Approximately $32 billion in economic losses.
- Almost 10 million tons of debris (1 million dump truck loads).

Shaking Intensity in Eastern Oregon from CSZ



Shaking Intensity in Baker City



Conclusion: Light Physical effects

- Shaking Intensity
  - Light to moderate, with pockets of strong shaking
  - Modified Mercalli Scale I to VI
    - Felt by all
    - Some damage to plaster, chimneys
    - Significant damage unlikely

But …

- Buildings in eastern Oregon will experience ground shaking levels similar to or greater than those that URM buildings experienced during two previous Oregon earthquakes: Scotts Mills and Klamath Falls.
- Because the Cascadia subduction zone earthquake will likely be of much longer duration than these two previous events, it has the potential to cause even more damage.
- For this reason, the expected recovery duration for vulnerable buildings in eastern Oregon was determined to be 30 days.

Most impacts will be secondary

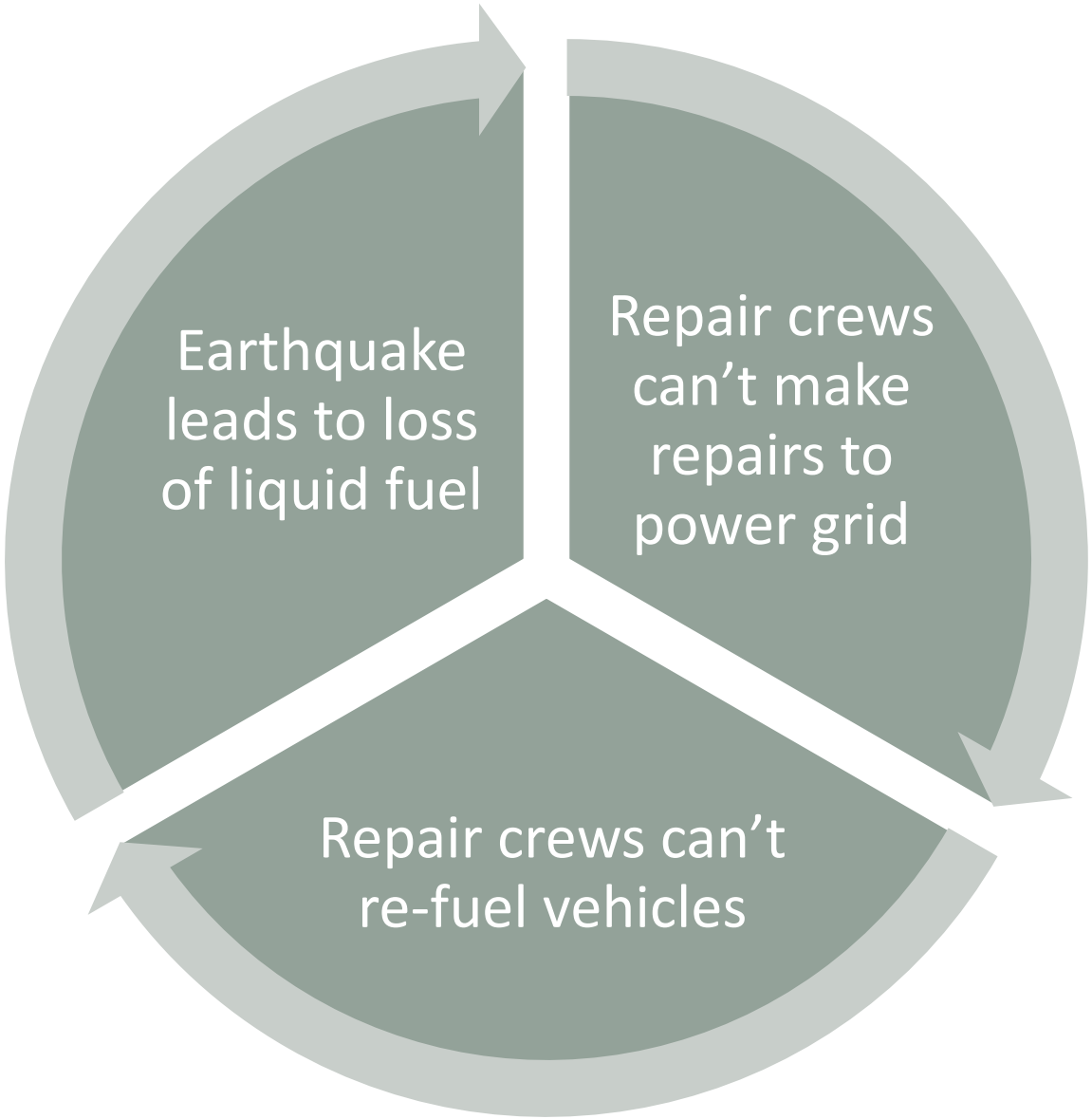
Transportation & Energy

Relief & Response

Economy

Energy Interruption

- Electricity
- Natural Gas
- Liquid Fuel


Earthquake leads to loss of liquid fuel
Repair crews can't make repairs to power grid
Repair crews can't re-fuel vehicles

Relief and Response

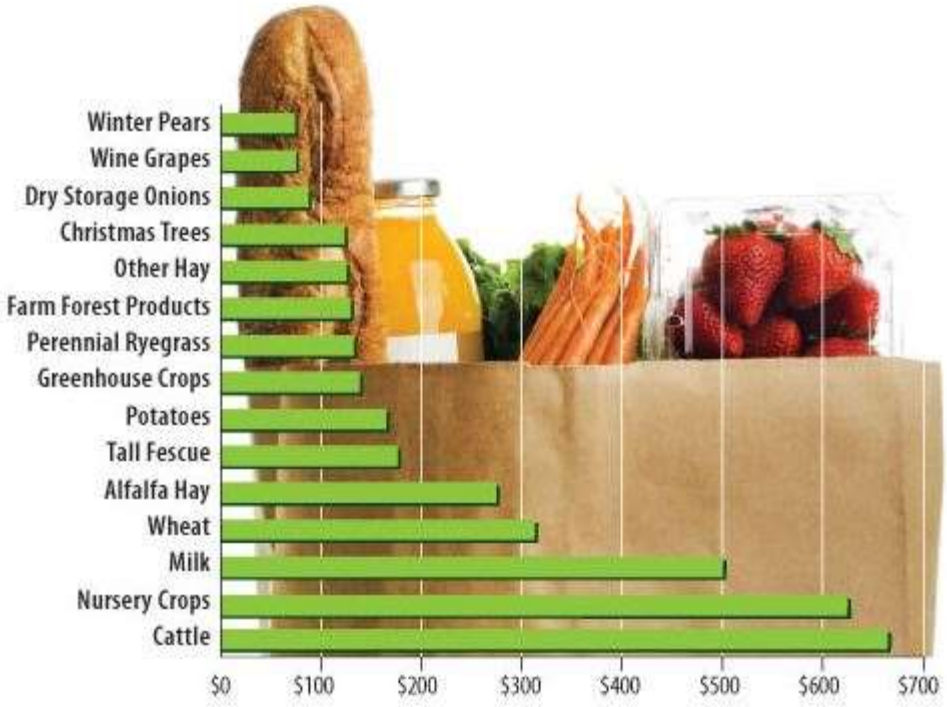
- Eastern Oregon will become the main area of support functions
- Supply side chain distribution (including fuel, food, and natural gas)
- Demand for logistics and staging areas
- Shelter, and relocation of individuals and animals from the impacted areas.

- Massive staging areas are likely to be required in various areas of Central and Eastern Oregon with the primary location of relief supplies
  - Roberts Field Airport in Redmond, Oregon, Deschutes County.
- River traffic on the Columbia River will be an important response and recovery lifeline.

- Mutual aid from Eastern Oregon local jurisdictions will be sought to the maximum degree possible.
- Many building inspectors, police, firefighters, medical personnel, engineers, and public works personnel may deploy to the impacted areas of Western Oregon

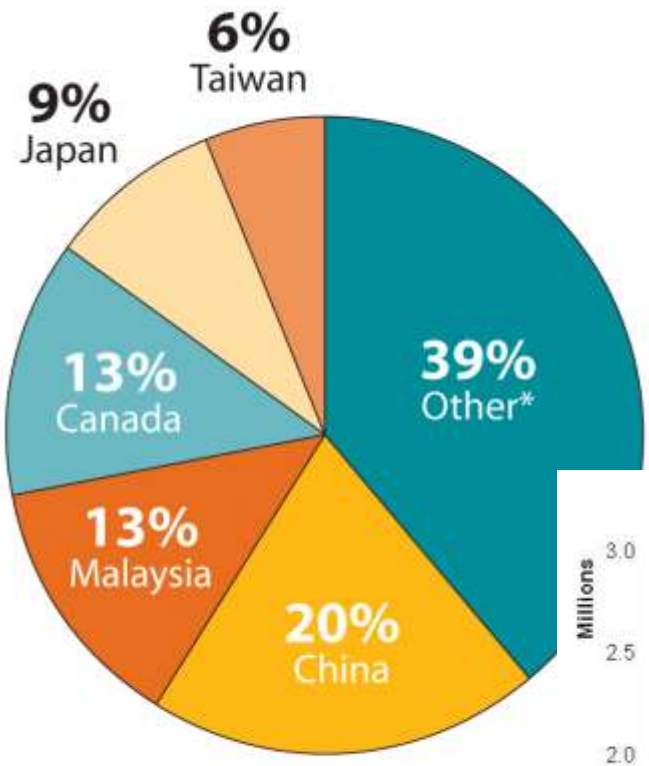
Impact on Economy

- Probably the longest lasting impact for Eastern Oregon

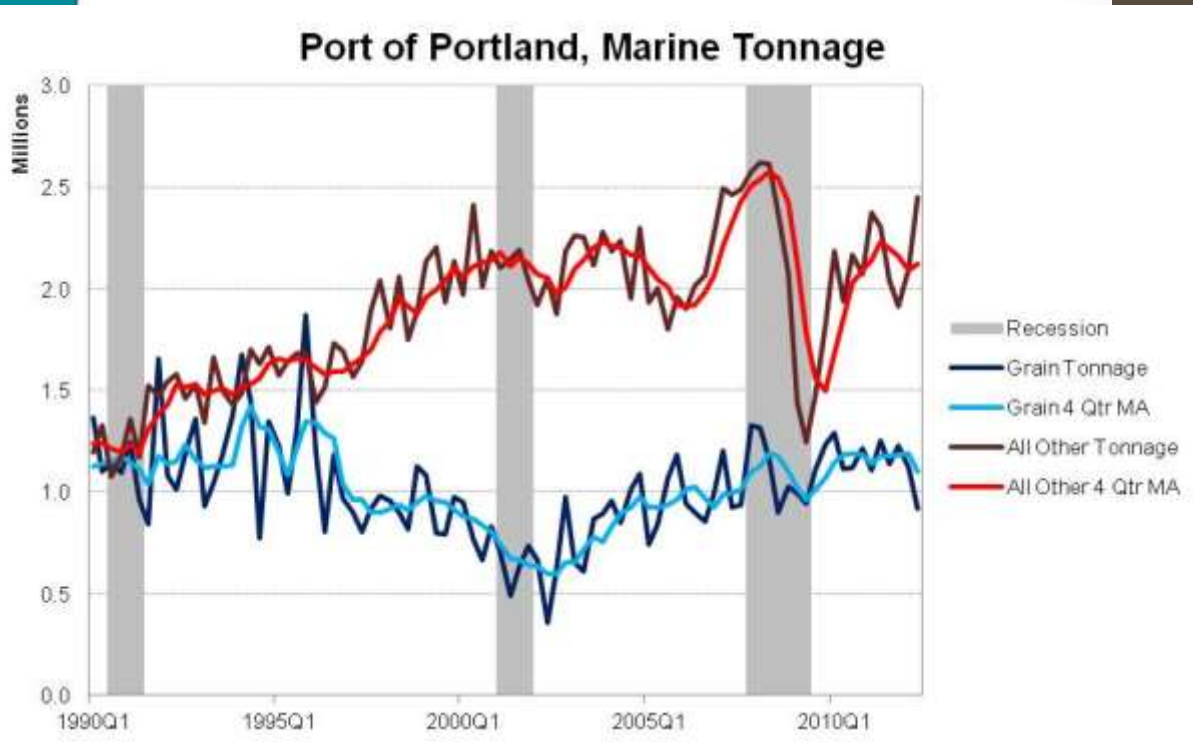


Oregon Farm Gate Sales (In Millions) 2008, OSU Extension Service

Top Oregon Exports Markets, 2009

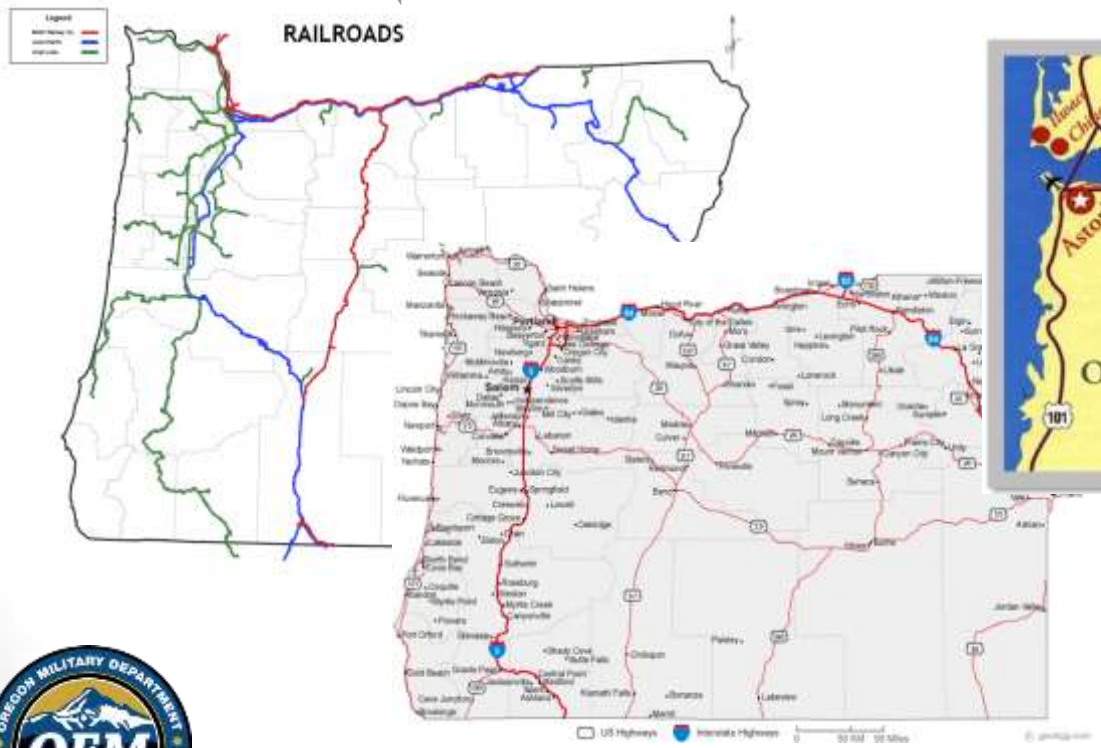


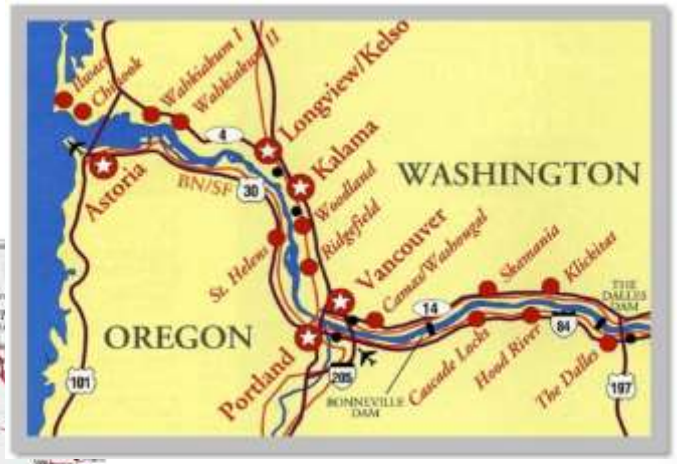
* Other category includes more than 230 count
the largest markets including South Korea, C
The Netherlands and Germany.



Exports

Imports





A new normal?

Benefits of Seismic Retrofitting

- Economic Benefits
- Social Benefits
- Financial burden to retrofit URMS is significant.
  - cost to owners can range from $20 to $50 per square foot

Retrofitting URMS

- Three alternative approaches to seismic retrofits for unreinforced masonry (URM) buildings in the City of Seattle.
- The three alternatives being considered are:
  - 1. Business-as-usual
  - 2. Bolts-Plus: Moderate seismic retrofit to protect life safety of building inhabitants
  - 3. Reinforced: More extensive retrofit that would be more likely to preserve the building and inhabitants

Alternative 1: Business-as-usual

- Currently, the only significant City of Seattle code requirement relating to seismic upgrades for URM buildings outside of substantial alterations relates to parapet bracing.
- Parapets on URMs must be anchored to the building in such a way that they can sustain the design loads specified in the building code.
- Unreinforced parapets are considered “unsafe building appendages” and regulated as a public nuisance.
- inconsistently enforced as it relates to parapets on existing buildings that are not otherwise in disrepair.

Alternative 2: Bolts-Plus– Moderate seismic retrofit to protect life safety of building inhabitants

- The “Bolts-Plus” method of seismic retrofit for URMs refers to the program that was adopted by the City of San Francisco in 1992 as part of Ordinance 225-92, completed in 2006.
- It is generally viewed as the least intrusive program for property owners, and provides some meaningful reduction of risk of building collapse in an earthquake.
- California’s “Bolts-Plus” standard essentially involves the installation of shear and tension anchors at the roof and floors, and, when required, the bracing of the unreinforced masonry bearing walls.

Alternative 3: Reinforced –More extensive retrofit that would be more likely to preserve the building and inhabitants

- Adding seismic bracing or strengthening walls
  - by coating the unreinforced walls with a reinforced concrete layer, placing reinforced concrete “ribs” or structural plating within the wall, or by using other materials such as a reinforced carbon fiber composite to one or both sides of the walls.
- Add substantial strength to masonry walls and increase the overall structural integrity of a building during a seismic event.
- Can help save lives and reduce damages that can impact the economic use of buildings.
- Typically require an extensive (and often expensive) effort to retrofit affected buildings.

Potential Costs and Benefits Associated with URM Retrofits

- Costs Associated with Seismic Event.
- Costs Associated with Seismic Retrofits.
- Benefits Associated with Seismic Retrofits.
- Benefits and Costs Associated with A Mandatory Retrofit Policy.

Costs Associated with Seismic Event.

- building damage (reflecting costs to repair),
- earthquake damage to building contents,
- displacement and loss-of-business costs for residential and commercial tenants during the repair/reconstruction period,
- loss of community benefits provided by visually distinctive URMs, and
- costs associated with casualties to building occupants

Costs Associated with Seismic Retrofits.

- displacement and loss-of business costs in this case, during the period the building was closed for retrofit installation.

Benefits and Costs Associated with A Mandatory Retrofit Policy

- Benefits
  - Redevelopment value stimulated (a benefit to owners through partial offset of retrofit costs)
  - Improved seismic protection
  - Historic preservation and community cohesion
  - Fine Revenues
- Costs
  - Net costs of seismic retrofits or full redevelopment
  - Loss of historically significant buildings and community cohesion
  - Fines

Benefits Associated with Seismic Retrofits

- savings in terms of building damage,
- damage to contents,
- displacement and loss-of-business,
- and casualties.
- There would also be reduced probabilities of lost URM buildings and their historic and neighborhood definition values.

Resilience by Design

- Implemented by Los Angeles Mayor Eric Garcetti
  - Require retrofitting of two types of vulnerable buildings. Retrofits would be required within 5 years at “soft-first-story” buildings built prior to 1980, and retrofits would be required within 25 years at “non-ductile reinforced concrete” buildings built prior to 1980.

Resilience by Design

- investments in fortifying water supply, including developing an alternative water system for firefighting, protecting our aqueducts that cross the San Andreas Fault, increasing local water sources, and developing a network of resilient pipes.

Resilience by Design

- Upgrades to our city's telecommunications network to enable Internet and mobile connectivity after an earthquake.
  - http://www.lamayor.org/earthquake

Resiliency CAN be achieved

After the February 27, 2010 M8.8 Maule Earthquake, Chile

- 90% communication services and 95% power supply within two weeks, and re-start commercial flights after ten days.

After the March 11, 2011 M9.0 Tohoku Earthquake,

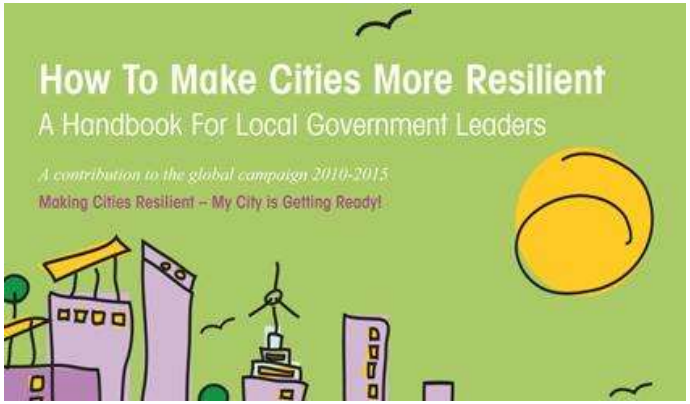
- 90% power supply in ten days, 90% telephone lines in two weeks, and 90% cellular base stations in 19 days.

Pathway to resilience

Resilience

- *The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self- organization, and the capacity to adapt to stress and change.*

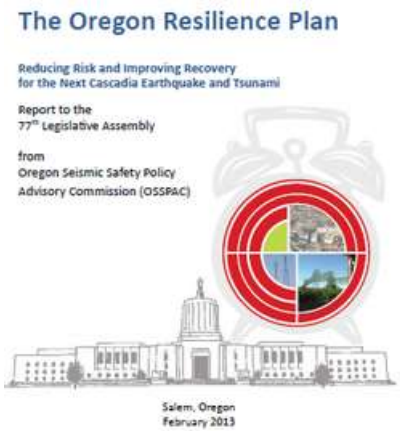
Local control of resilience efforts



- http://www.unisdr.org/archive/26728

BUILDING RESILIENT REGIONS
INSTITUTE OF GOVERNMENTAL STUDIES
THE UNIVERSITY OF CALIFORNIA BERKELEY

- http://brr.berkeley.edu/economic-resilience/



- http://www.oregon.gov/OMD/OEM/osspac/docs/Oregon_Resilience_Plan_Final.pdf

OREGON MILITARY DEPARTMENT
OEM
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