

Date: January 11<sup>th</sup>, 2013

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**FROM:** Becky Knudson, Senior Transportation Economist and  
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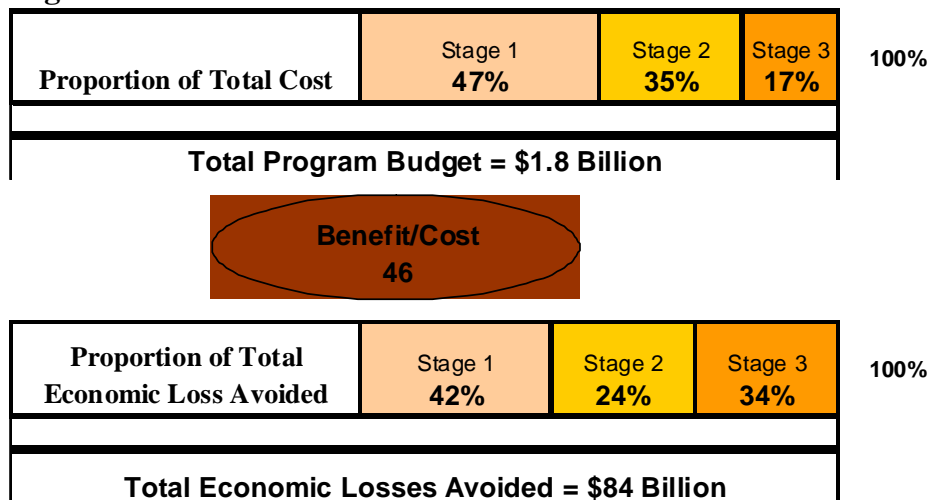
**Cc:** Paul Mather P.E., Albert Nako P.E., Brian Dunn, P.E.

**SUBJECT:** Estimated Economic Impact Analysis Due to Failure of the Transportation  
 Infrastructure in the Event of a 9.0 Cascadia Subduction Zone Earthquake

**OVERVIEW**

A major seismic event will significantly impact the Oregon economy immediately after and in the longer run. Results of this analysis indicate strengthening corridors before a major seismic event will enable the state to avoid a significant amount of economic loss. This analysis evaluated four alternative scenarios in order to gain a sense of the potential loss in production activity we could expect due to the damage to the transportation system after a major seismic event. Four scenarios representing seismic preparation and repair demonstrate the value added (impacts avoided) to the Oregon economy. Significant economic losses in production activity can be avoided by preparing for a major earthquake ahead of time. With no preparation ahead of time, Oregon could lose up to \$355 billion in gross state product in the 8 to 10 year period after the event. Proactive investment in bridge strengthening and landslide mitigation reduces this loss between 10% and 24% over the course of the eight years simulated for this analysis. **Figure 1** presents the estimated cost of the preventive seismic work along side the economic benefits, as measured by avoided loss of state production activity. This results in a benefit-cost ratio of 46 for the full seismic program.

**Figure 1.**



## *Real World Experience*

Major events, such as a 9.0 Cascadia subduction zone earthquake, significantly impact an economy beyond short term emergency management issues. Several recent case studies from Japan, Turkey and New Zealand reveal a predictable pattern of economic disruption.<sup>1</sup> Generally speaking, the patterns are as follows:

- Very large proportion of small to medium sized firms fail the first few months after a major earthquake
- Firms attempt to adapt to post-event conditions to maintain business activity:
  - Maintain access to selling markets by choosing new routes and modes if necessary;
  - Maintain access to production inputs by using firms able to provide what is needed, if local firms are unavailable, shift to next best supplier;
  - Maintain access to workers;
  - Relocate firm if access to necessary resources are constrained for a period long enough to threaten the firm's position in the competitive market
  - Once a firm relocates, there is little incentive to return to the previous location. Small and medium firms supporting production activity are likely to relocate near the new location area as well.

Every industry has a unique mix of production activity, logistical needs, and market presence driving their business decisions. The long range impact of major damage to transportation infrastructure has the potential to significantly alter the industrial mix of an area. In turn, such changes will alter the characteristics of the economy, such as wages, population growth and land use.

## *Oregon Interpretation*

Analysis conducted using the Statewide Integrated Model suggests the impacts of a major seismic event results in significant reduction in production activity for the western region of the state. This study evaluated four scenarios representing multiple stages of strengthening corridors to withstand the impacts of a seismic event. The effects of a seismic event after a three staged pre-emptive program is implemented are compared to the effects of the event without seismic strengthening. The difference in the impact on production activity represented in the statewide model enabled the estimation of the avoided economic losses to Gross State Product (GSP).

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<sup>1</sup> Small business failure/Port of Kobe losing demand permanently:  
<https://www.rms.com/publications/natural-catastrophes>; Loss of small businesses, skilled labor flight/firm loss in Turkey (under Economic and Business Losses section):  
<http://www2.ce.metu.edu.tr/~ce467/DOWNLOADS/erdik.pdf> ; Association of Bay Area Governments on Turkey quake: <http://resilience.abag.ca.gov/wp-content/documents/TurkeyFinal.pdf> ; Tourism loss in Christchurch, area cordoned off from workers (50,000+ jobs relocated/lost):  
[http://mceer.buffalo.edu/quakesummit2011/program/presentations/00-Thursday%20Plenary\\_d-Peek.pdf](http://mceer.buffalo.edu/quakesummit2011/program/presentations/00-Thursday%20Plenary_d-Peek.pdf); Population flight in Christchurch: ):  
[http://mceer.buffalo.edu/quakesummit2011/program/presentations/00-Thursday%20Plenary\\_d-Peek.pdf](http://mceer.buffalo.edu/quakesummit2011/program/presentations/00-Thursday%20Plenary_d-Peek.pdf)

Conducting seismic strengthening before the event occurs enables Oregon to avoid significant economic loss as measured by GSP alone. The losses avoided are larger than the cost of the repair programs, resulting in a good return on the investment. Particularly at risk of impacts to production is the Oregon manufacturing sector, since this industry is export oriented and depends heavily on the transportation system to get goods to market and maintain access to the factors of production.

**Table 1** describes the manufacturing industry by firm size and employment. Given patterns observed in areas hit by major earthquakes in recent history, Oregon’s manufacturing industry has the potential to lose a large proportion of firms and jobs in the first year, since small and medium firms are the most likely to fail shortly after a major event. This increases the likelihood of dependent firms relocating to areas unaffected by the earthquake. Repair and strengthening of the system before the seismic event will reduce the rate of firm failure, mitigating the economic impacts in the short and long run.

| <b>Table 1. Manufacturing Sector, First Quarter 2011, Statewide<br/>Number of Firms by Size and Employment (in thousands)</b> |                            |                 |                   |              |         |
|---|----------------------------|-----------------|-------------------|--------------|---------|
| % of State  | NAICS 31-33 Manufacturing  | 1 to 19 workers | 20 to 249 workers | 250+ workers | TOTAL   |
| 5%  | Establishments             | 4,062           | 1,108             | 98           | 5,268   |
|   | % of sector establishments | 77              | 21                | 2            | 100     |
| 13%   | Employment                 | 21,086          | 70,561            | 76,604       | 168,251 |
|   | % of sector employment     | 13              | 42                | 46           | 100     |
|   | % of sector wages          | 6               | 29                | 65           | 100     |

Source: Oregon Employment Department

It is important to note that the impacts reported in this analysis are likely to be lower than anticipated impacts occurring after a major earthquake. The dynamic relationship between the transportation system’s support of everyday households and business activity, accommodating emergency services and rebuilding Oregon in the wake of such a devastating event are only partially accounted for in this analysis. Fully accounting for all the impacts to infrastructure and the interactions of the resulting failures requires much more detailed analysis, involvement from experts for other subject areas, and refined assumptions regarding the magnitude of the earthquake, system failures, repair and recovery, etc. This analysis only evaluates impacts and failures on the highway transportation infrastructure.

## TECHNICAL ANALYSIS

The purpose of this analysis is to provide high level estimates of avoidable economic impacts caused by damage to the transportation system from a major seismic event (a 9.0 Cascadia Subduction Zone Earthquake, where the fault breaks along the entire subduction zone – a worst case earthquake scenario). Four alternative scenarios were used to evaluate the impacts of pre-emptive mitigation. This analysis was prepared for the ODOT Bridge Engineering Section, which is evaluating risks and identifying strategies to mitigate seismic vulnerabilities of the state highway system. The scenario approach was designed to provide a general sense of the magnitude and direction of avoidable economic impacts to Oregon from damage occurring on the highway/street transportation system alone (non-transportation losses were not accounted for). This analysis focuses on the western portion of the state, defined as the area to the west of the Oregon Cascade Range.

### Methodology

The analysis was conducted using the Oregon Statewide Integrated Model (SWIM). SWIM is a state-of-the-art model that integrates the Oregon economy, land use and transportation system into one dynamic interactive environment. This model design characterizes the synergies between these three major components of Oregon's economic activity.<sup>2</sup>

Only the roadway network was altered for the modeled scenarios. Corridors expected to experience damage from a major seismic event were represented as "failing." The points of failure were identified by the ODOT Bridge Engineering Section for high-use state-owned facilities. For lower use corridors and non-state owned facilities in the SWIM network, adjacent parallel routes within these corridors needed to be altered to maintain consistency in network coding. Therefore, the full network was reviewed and altered for consistency. Nearby facilities with similar proximity and characteristics of those identified to fail were represented to fail in the same manner.

Representing loss of commercial buildings or housing, damage to utilities, other damage or loss of life resulting from an earthquake was outside the scope and purposes of this analysis. This analysis was to determine the isolated impacts of the failure of the transportation system, not to create an estimate of the overall economic impact of a major seismic event. No changes were made to the regional forecast of economic activity by industry sector. The purpose of this analysis is to evaluate the effects of impacts to transportation on economic activity separately, apart from the other economic responses to a seismic event to the Oregon system. Because the interaction between land use, the economy and the transportation system is dynamic, the modeling results provide a good estimate of the magnitude and direction of the effects of the seismic reinforcement to Oregon's economy. Changes in spatial location of economic activity resulting in the transportation limitations were evaluated. The model acuity is very informative at a regional level. Regional aggregation of modeling results provides reliable indication of the relative economic impacts of preparing the transportation infrastructure for a seismic event.

Economic impacts were measured by evaluating the model output values for industry production activity, employment and population. The model outcomes do not represent the full economic impacts from seismic event, but this is appropriate given the intentional design of the scenarios to separate the impact of transportation system damage from the other effects, as well as identify the differences between the alternative levels of investment.

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<sup>2</sup> Further information on SWIM is available online here: <https://www.oregon.gov/ODOT/Planning/Pages/Technical-Tools.aspx#SWIM>

## Caveats

The results presented in this memo derive from hypothetical scenarios where only highways and adjacent local routes fail and all other infrastructure continue to operate as if no earthquake occurred. The analysis is designed to provide a general sense of high-level impacts avoided if proactive measures for the highway infrastructure were taken. Given that the analysis focused only on transportation infrastructure and did not account for loss of commercial buildings or housing, damage to utilities, other damage, or loss of life, these estimates are likely lower than what would actually occur when such a disruptive event occurs. A larger analysis effort is required to account for the impacts to people, infrastructure, and businesses that a 9.0 earthquake would cause. *All consideration and use of the analysis results must reflect this context.*

This analysis does not account for:

- loss of life and injuries,
- loss of worker productivity as an input to industrial production,
- savings from improved emergency service accessibility,
- shifts of resources to provision of basic needs/services,
- shifts of resources to re-construction from other industries,
- loss in productivity due to lost capital, floor space, equipment, utilities and commodity flows,
- damage to and failure of dams,
- loss of electricity, water, telephone (cell and land lines), natural gas, and fuel pipeline

It is important to note that true complete isolation is not represented in the model run, SWIM will not run if this were the case; in order to mimic conditions after a large event like this, damaged segments were assigned a new speed of 1 mph or a fixed travel time of up to a day to represent the difficulty of crossing the damaged segment. This is a reasonable simulation approach for aggregate analysis. Focused analysis would require specific locations be evaluated for likely solutions, such as floating bridges, ferries, and other countermeasures taken at each closure point, which is far beyond the scope of this analysis.

A sophisticated tool such as SWIM is designed to simulate the interactive nature of the economy, population, households, industry location, freight movement, access to skilled workers, spatial relationships and the transportation system that connects them all together. To fully assess the economic impacts of an earthquake of this magnitude, the features bulleted above should be accounted for in the modeling specifications. The work completed for this analysis endeavors to isolate and estimate the avoidable economic impacts solely due to the loss or retention of sections of the highway system. While these scenarios are strictly hypothetical, they provide a broad sense of the benefit of investing in a seismic mitigation program and are appropriate for the question being addressed.

## **Description of Scenario Alternatives Evaluated**

The Bridge Engineering Section provided TPAU with a list of bridges and highway sections that “fail” after a major seismic event. For each scenario, a list of bridges repaired and opened was provided by the Bridge Section for five years after the seismic event. Repair schedules for lower functional class roads not identified by the Bridge Section were generated by TPAU to be consistent with the state repair schedule. The model simulation includes eight years, beginning with the seismic event (year 0), five years of repair activity (years 1-5) and two years of continued economic activity (years 6-7) with a fully functioning

highway system.<sup>3</sup> All highway sections in the model were assumed to be open and operating as usual within five years. Thus, network characteristics modeled were the same for all scenarios for years 6 and 7.

*Reference Scenario:* This is the baseline comparison scenario with current highway conditions, no earthquake or major shocks to the transportation network, and economic growth consistent with current forecasts for the state for eight years.

*Major Seismic Event:* This scenario represents highway conditions after a 9.0 subduction zone earthquake occurs. This scenario serves as a hypothetical worst-case example representing the greatest level of highway damage. The scenario represents the list of state-owned bridges and sections of highway that “fail” and “repairs” them according to an estimated schedule provided by the Bridge Section.

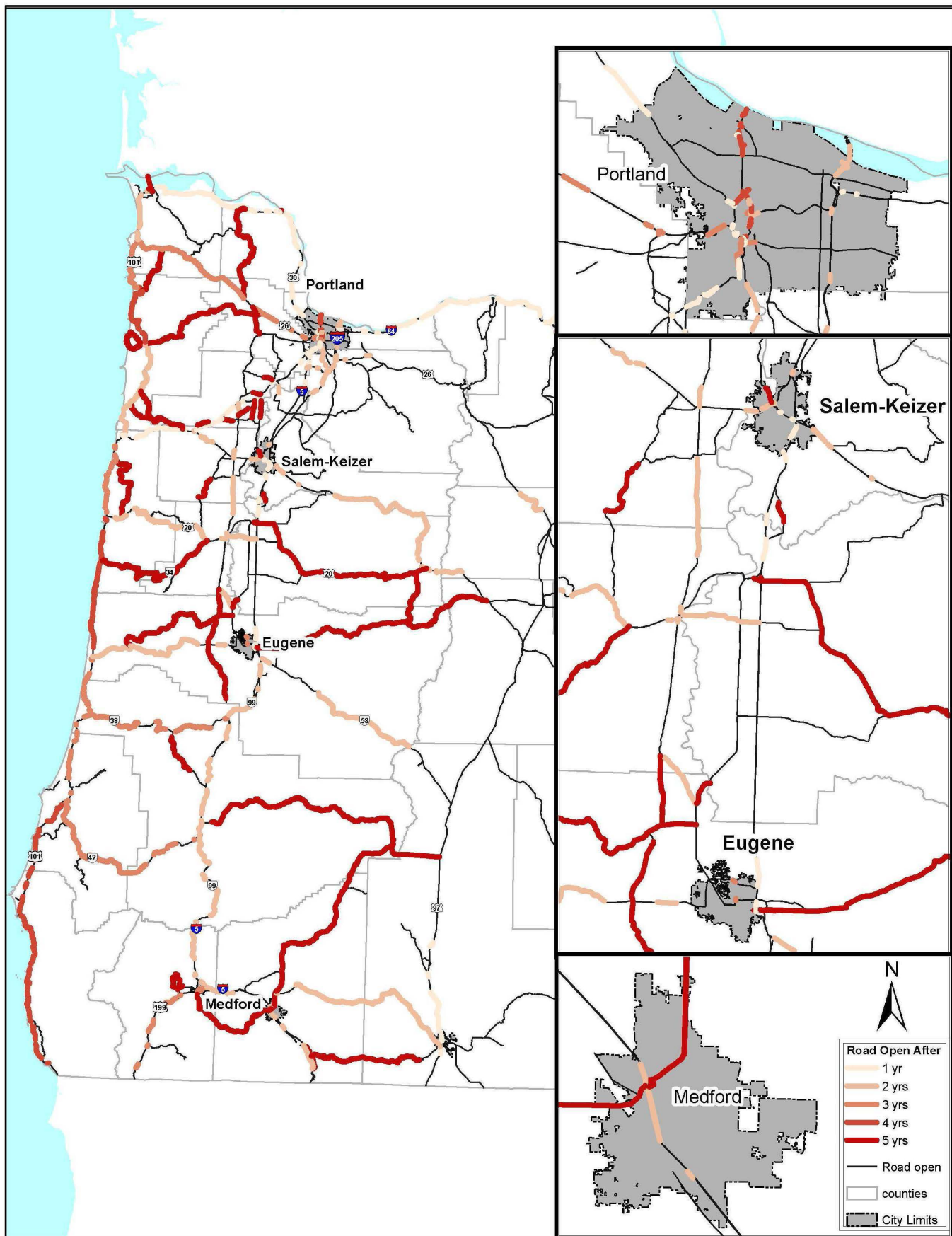
In order to produce a modeled scenario with consistent post-earthquake routing, multiple lower functional class state highways and non-state-owned roads were coded to “fail”. Many of these bridges are off the state system, but included in the SWIM network. Thus, they were not specifically identified by the Bridge Section to fail. For example, OR 20 to the coast was identified to fail, but OR 34 was not (because it is a lower function road). In order to represent consistent effects from a major earthquake, OR 34 was coded to fail as well. All the lower functional class roads and off-system roads were coded to be rebuilt within 5 years to remain consistent with the state facility assumptions.

The sections of highways affected by failures are illustrated in **Figure 2**. The roadway network is color coded to illustrate when corridors would be repaired and returned to pre-earthquake conditions. The time of completion ranges from 1 to 5 years. **Figure 3** provides further illustration of the duration of area isolation due to damaged roads and bridges. Areas coded with the lightest color regain access to the highway system within one year, where the darkest red areas remain isolated for the full five year repair period. Isolation and damage due to loss of power, water, building collapses, fire and other causes are not included in **Figure 3** or this analysis. Isolation means severely limited (day(s) of travel) access to markets for the local economy, causing delay in economic recovery.

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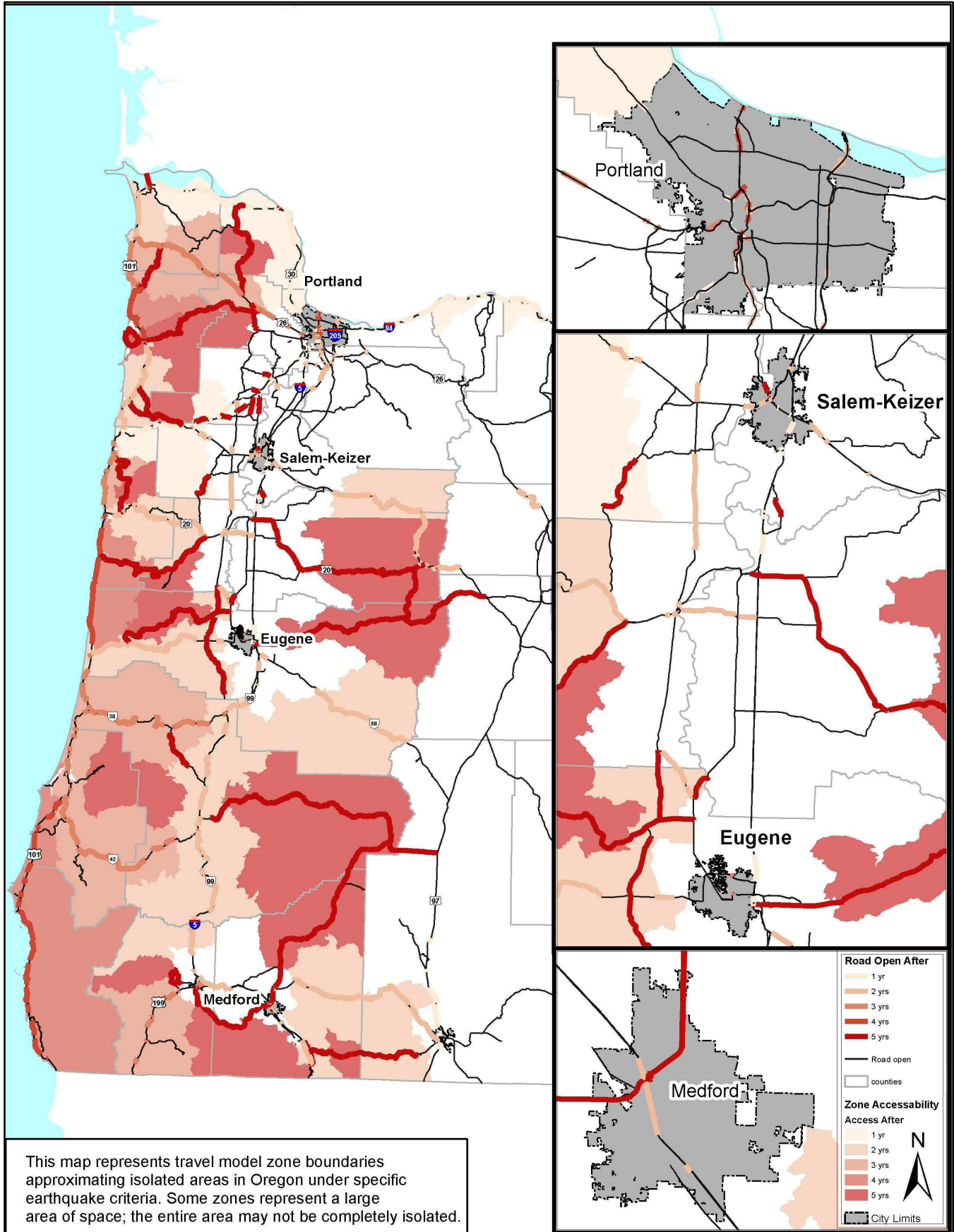
<sup>3</sup> The original intent was to run eleven years in order to evaluate a five year period post repairs. In order to meet the analysis schedule, the simulation period was reduced to eight years. The objective of determining at which point the economy would recover to normal levels was not met given the shorter simulation period, but no other findings are affected by the shorter simulation period.

**Figure 2. Failures and Repair Schedule: Major Seismic Event**





**Figure 3. Isolated Zones and Repair Phasing: Major Seismic Event Scenarios**





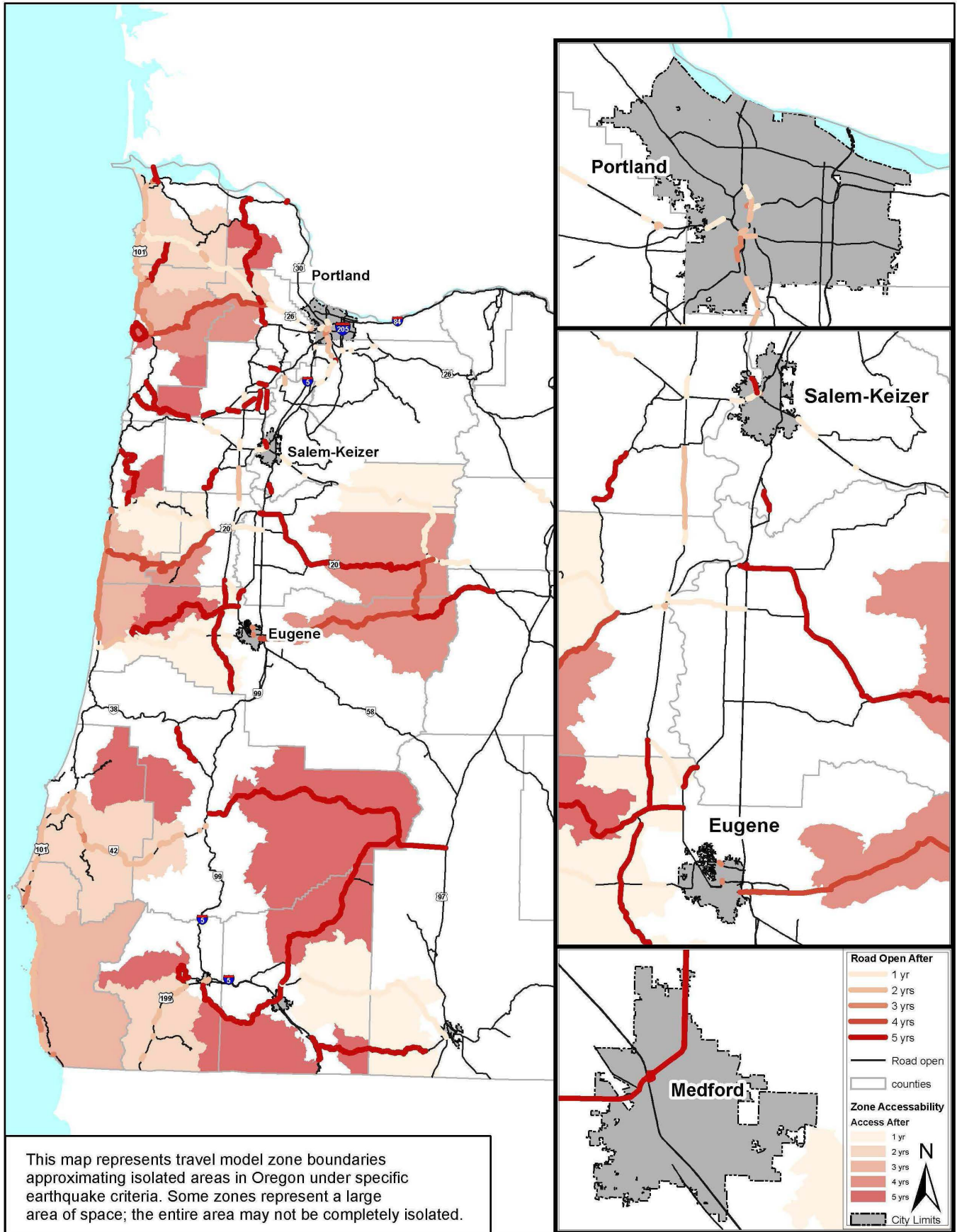
A seismic retrofitting, rockfall and landslide stabilization program budget was provided for three separate stages. Scenarios were designed to capture the effects of the individual stages in order to gain a sense of the economic benefits associated with each stage.

*Stage 1:* This scenario represents conditions after a 9.0 subduction zone earthquake, given the completion of seismic fortification for corridors identified stage 1. **Figure 4** illustrates the repair completion schedule and isolation timelines for this scenario. This scenario is represented in SWIM in the same manner as the Major Seismic Event scenario; the only difference is the presence of reinforced bridges and landslide/rockfall mitigation through a seismic improvement program. This program enables Oregon to avoid major earthquake damage to several key corridors, allowing faster and larger scale access to emergency services and supplies necessary to rebuild, as well as accelerated repair damaged sections of the transportation system.

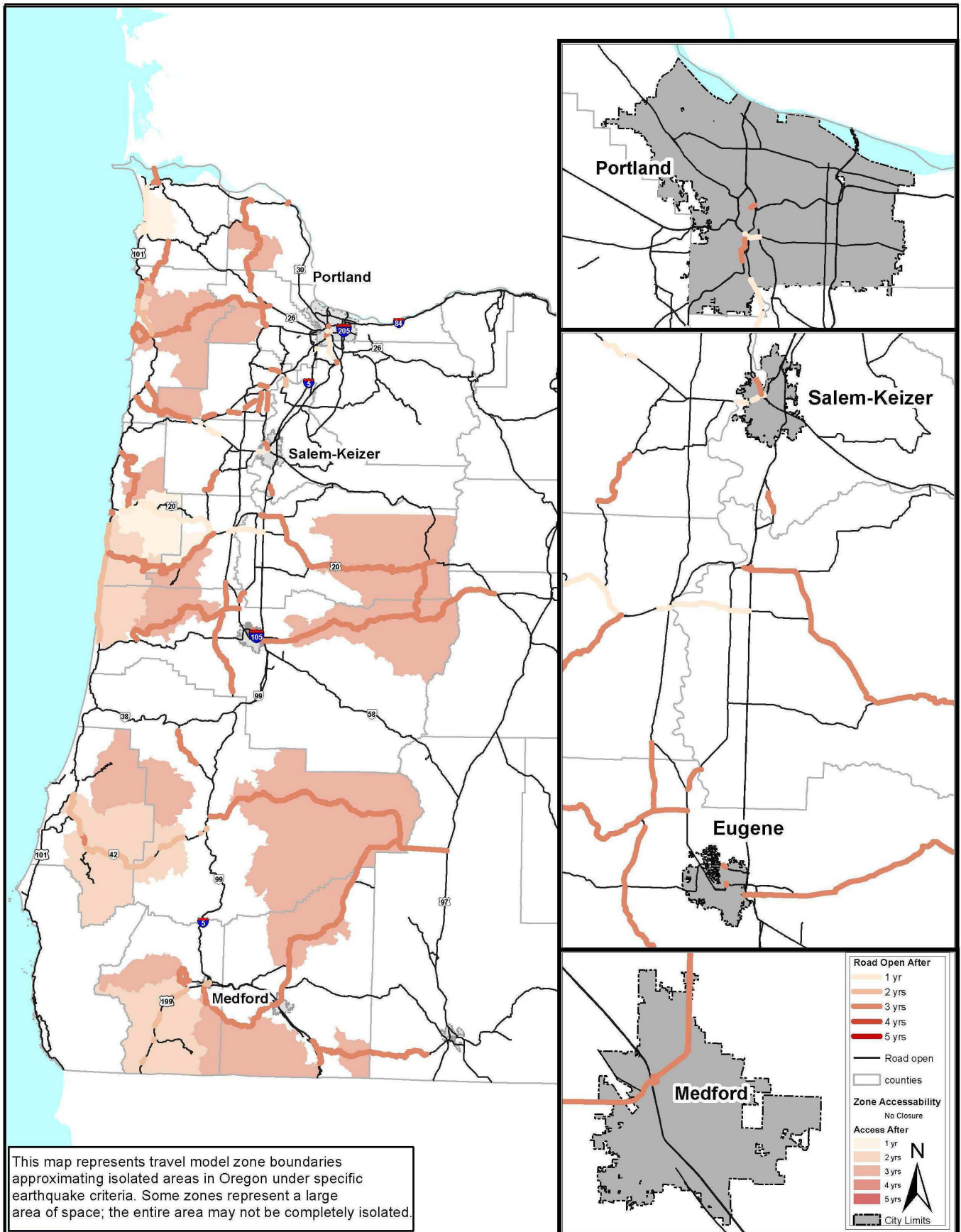
*Stages 1 & 2 Scenario:* This scenario represents investing at the Stage 1 level and adding Stage 2 improvements, as illustrated in **Figure 5**. This figure also reports the level of isolation by geographical location associated with this level of investment.

*Full Seismic Program (Stages 1, 2, & 3):* This scenario is the level of investment for all three stages of the program, as illustrated in **Figure 6**. This figure also reports the level of isolation by geographical location associated with the full seismic program.

**Figure 4. Isolated Zones and Repair Phasing: Stage 1 Scenario**

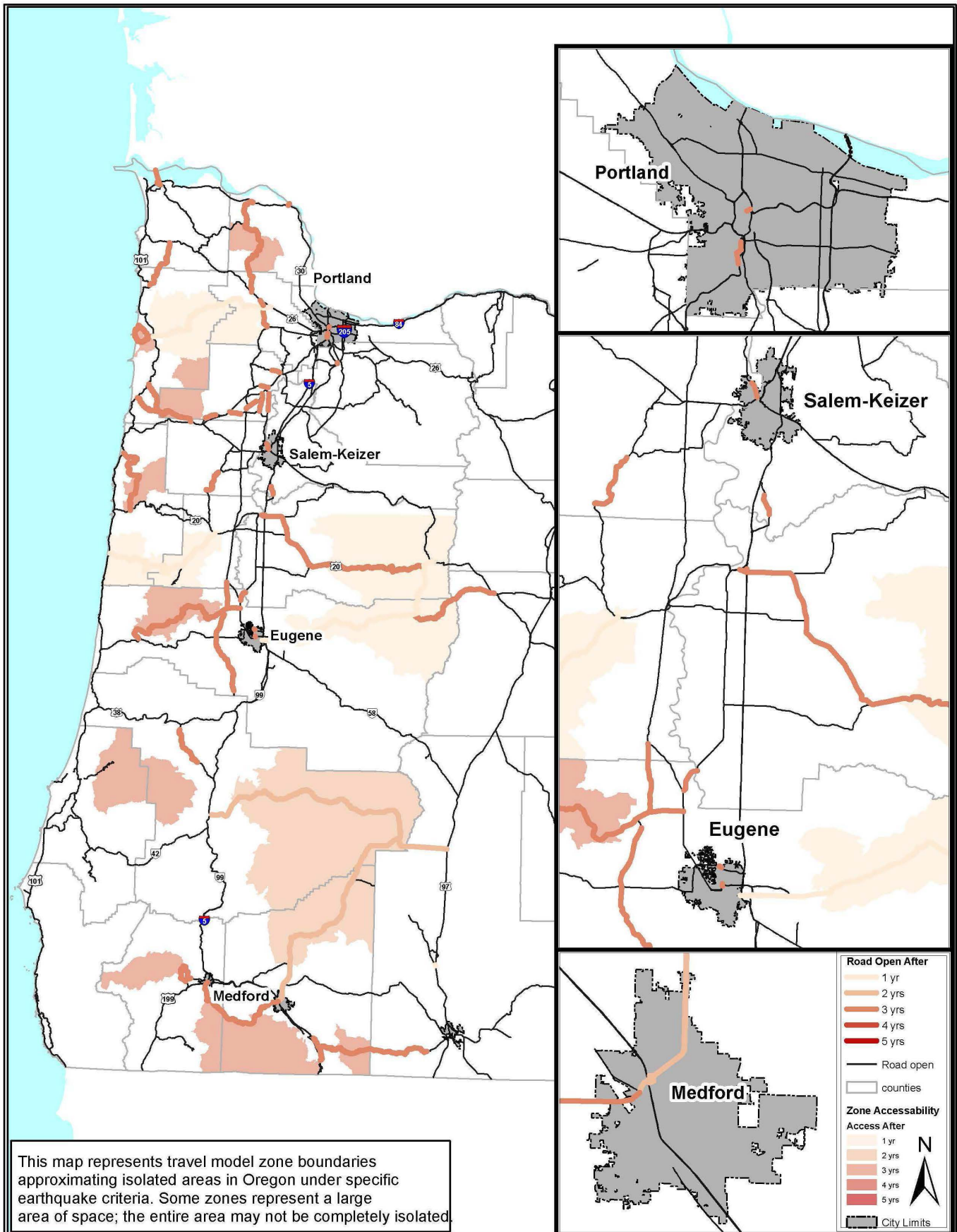


**Figure 5. Isolated Zones and Repair Phasing: Stage 1 and 2 Scenario**





**Figure 6. Isolated Zones and Repair Phasing: Full Seismic Program Scenario (Stages 1, 2, & 3)**



## Findings

### Western Oregon Impacts

Western Oregon would be significantly affected by a major seismic event. This region of the state generates over eighty percent of the statewide Gross State Product (GSP). In order to gain a general sense of the economic impacts avoided by strengthening of the highway system before the major event occurs, SWIM was used to produce estimates of the value of avoiding reductions to state production levels. This is an appropriate reporting approach because SWIM outputs for production activity closely relate to GSP.

The US Bureau of Economic Analysis reported Oregon’s 2011 Gross State Product (GSP) as \$194,700 million. **Table 2** presents the western region share of GSP, including the shares for four sub-regions of the state using results from SWIM. This information is used as the basis for forecasting the state GSP for this analysis. Assuming the Oregon economy has slow growth<sup>4</sup> over the next ten years (1.5% annually) and the western region’s share of GSP remains at 86%, GSP is estimated for the years modeled for this analysis and presented in **Table 3**. The modeled year of the earthquake is 2014. These are fairly conservative economic assumptions for growth that can be altered to represent more refined economic forecast for the state if desired. However, these estimates are sufficient in order to gain a general sense of the benefits associated with the seismic program relative to no preliminary preparations.

| State GSP 2011               | \$ 194,700 |
|------------------------------|------------|
| Coast Share (6%)             | \$ 11,700  |
| Greater Portland Metro (46%) | \$ 89,600  |
| Mid-Willamette Valley (24%)  | \$ 46,730  |
| Southern Valley (10%)        | \$ 19,500  |
| Western Region share (86%)   | \$ 167,400 |

| Year After Event | Scenario      |        |        |        |
|------------------|---------------|--------|--------|--------|
|                  | Seismic Event | Tier 1 | Tier 2 | Tier 3 |
| 1                | 38            | 32     | 31     | 27     |
| 2                | 31            | 28     | 27     | 23     |
| 3                | 29            | 28     | 24     | 21     |
| 4                | 26            | 26     | 20     | 17     |
| 5                | 24            | 23     | 19     | 17     |
| 6                | 22            | 18     | 20     | 20     |
| 7                | 22            | 18     | 21     | 21     |

<sup>4</sup> Generalized growth rate based on DAS OEA forecast:  
<https://www.oregon.gov/das/OEA/Pages/Index.aspx> November 20, 2012

| <b>Table 4. Estimated Reduction in Economic Activity Relative to Reference Scenario<br/>(2011 dollars, millions)</b> |                      |                |                |                |
|--|----------------------|----------------|----------------|----------------|
|  | <b>Scenario</b>      |                |                |                |
| <b>Year After Event</b>  | <b>Seismic Event</b> | <b>Tier 1</b>  | <b>Tier 2</b>  | <b>Tier 3</b>  |
| 1  | 67,500               | 56,900         | 55,100         | 48,000         |
| 2  | 55,900               | 50,500         | 48,700         | 41,500         |
| 3  | 53,100               | 51,300         | 43,900         | 38,500         |
| 4  | 48,300               | 48,300         | 37,200         | 31,600         |
| 5  | 45,300               | 43,400         | 35,800         | 32,100         |
| 6  | 42,100               | 34,500         | 38,300         | 38,300         |
| 7  | 42,700               | 35,000         | 40,800         | 40,800         |
| <b>TOTAL</b>   | <b>354,900</b>       | <b>319,900</b> | <b>299,800</b> | <b>270,800</b> |

**Table 4** provides the modeled year-to-year reduction in production activity for the western region of the state for the four alternative scenarios. The value of lost production activity under each scenario is estimated using the information presented in **Tables 3 and 4**. The results are compared side-by-side and presented in **Table 5**. Over the course of the modeled years, the greatest loss to production activity occurs under the Major Seismic Event scenario. The seismic improvement program reduces these losses by billions of dollars.

| <b>Table 5. Estimated Reduction in Economic Activity Relative to Reference Scenario<br/>(2011 dollars, millions)</b> |                      |                |                      |                     |
|--|----------------------|----------------|----------------------|---------------------|
|  | <b>Scenario</b>      |                |                      |                     |
| <b>Year After Event</b>  | <b>Seismic Event</b> | <b>Stage 1</b> | <b>Stage 1&amp;2</b> | <b>Full Program</b> |
| 1  | 67,500               | 56,900         | 55,100               | 48,000              |
| 2  | 55,900               | 50,500         | 48,700               | 41,500              |
| 3  | 53,100               | 51,300         | 43,900               | 38,500              |
| 4  | 48,300               | 48,300         | 37,200               | 31,600              |
| 5  | 45,300               | 43,400         | 35,800               | 32,100              |
| 6  | 42,100               | 34,500         | 38,300               | 38,300              |
| 7  | 42,700               | 35,000         | 40,800               | 40,800              |
| <b>TOTAL</b>   | <b>354,900</b>       | <b>319,900</b> | <b>299,800</b>       | <b>270,800</b>      |

**Table 6** presents the dollar value of the avoided GSP reduction by scenario for the first three full years of recovery followed by the last four years. The first three years of construction for the different stage scenarios provide more than half of the economic benefit over the course of the eight year recovery modeled. This demonstrates how important a speedy recover is to the economy of Oregon.



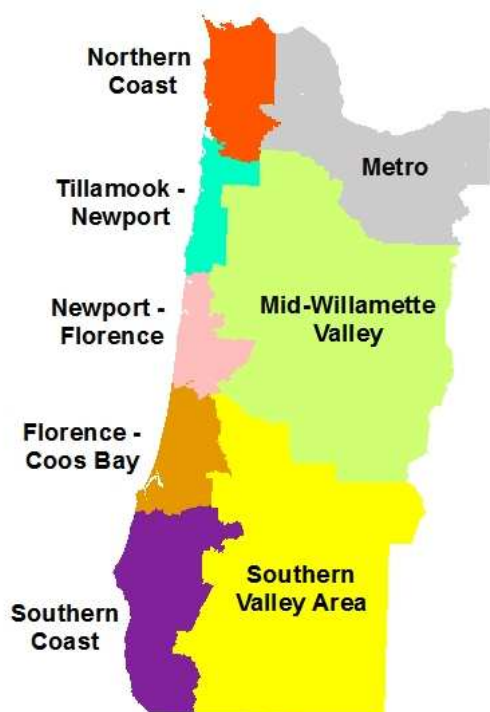
| <b>Table 6. Avoided Reduction in Production Activity by Scenario</b><br>(2011 dollars, millions) |                 |               |               |               |
|--|-----------------|---------------|---------------|---------------|
|  | <b>Scenario</b> |               |               |               |
|  | Seismic Event   | Stage1        | Stage 1&2     | Full Program  |
| First Three Years Loss   | 176,500         | 158,700       | 147,700       | 128,000       |
| <b>Loss Avoided</b>  |                 | <b>17,800</b> | <b>28,800</b> | <b>48,500</b> |
| Last Four Years Loss   | 178,400         | 161,200       | 152,100       | 142,800       |
| <b>Loss Avoided</b>  |                 | <b>17,200</b> | <b>26,300</b> | <b>35,600</b> |
| <b>TOTAL AVOIDED LOSS</b>  |                 | <b>35,000</b> | <b>55,100</b> | <b>84,100</b> |

### Economic Impacts by Region

For this analysis, western Oregon was divided into several sub-regions. **Figure 7** illustrates the sub-regions used for this analysis:

- The Coast (split into five parts)
- The Metro Area (Portland)
- The Mid-Willamette Valley (MWV) including Salem, Corvallis and Eugene; and
- The Southern Valley area (SV) including the area south of Eugene and north of California, bordered by the Cascade and Coastal mountain ranges.

**Figure 7. Areas of Analysis**



**Table 7** provides a brief summary of the economic impacts on regional production activity for all four seismic scenarios relative to the reference scenario. The western region of Oregon generates about 86% of the total statewide production activity. The Coastal region represents 6% of statewide production activity, Portland Metro 46%, Mid-Willamette Valley 24% and the Southern Valley 10%. Additional details discussed in the following text are provided in **Table 8** at the end of this report.

**Table 7. Percent Reduction in Economic Production With Respect to Reference Scenario**

| Region<br>(percent share of state) | Seismic Event |      |      | Stage 1 |      |      | Stage 1&2 |      |      | Full Program |      |      |
|------------------------------------|---------------|------|------|---------|------|------|-----------|------|------|--------------|------|------|
|                                    | Yr 1          | Yr 3 | Yr 7 | Yr 1    | Yr 3 | Yr 7 | Yr 1      | Yr 3 | Yr 7 | Yr 1         | Yr 3 | Yr 7 |
| Coast Total (6)                    | 63            | 49   | 11   | 53      | 38   | 10   | 49        | 30   | 11   | 34           | 24   | 11   |
| Portland Metro (46)                | 32            | 25   | 28   | 28      | 26   | 21   | 26        | 24   | 26   | 25           | 21   | 26   |
| Mid-Willamette Valley (24)         | 38            | 26   | 16   | 34      | 24   | 15   | 33        | 23   | 16   | 25           | 22   | 14   |
| Southern Valley (10)               | 49            | 37   | 12   | 39      | 33   | 11   | 42        | 30   | 11   | 39           | 24   | 11   |
| Western Total (86)                 | 38            | 29   | 22   | 32      | 28   | 18   | 31        | 24   | 21   | 27           | 21   | 21   |

### Oregon Coast

Under the Major Seismic Event scenario, the Oregon coast economy is significantly impacted, with production initially dropping over 60% and employment over 70%. Within a couple of years the economy continues to perform at a significantly lower level with 49% less production activity than forecast in the reference scenario and employment 63% lower. By the end of the seventh year after the seismic event, production activity recovers to a level 11% lower than the reference scenario and employment 10% lower.

Initial impacts along the coast vary among sub-regions, with the largest drop in production activity in the southern coast section (71% drop) and the smallest drop in the Newport to Florence section (55% drop). The effects on employment range between an 81% reduction in the southern coast to a 66% reduction in the Newport to Florence section.

The three stage scenarios reduce the impact of the seismic event. The Stage 1 initial drop in production activity is 73%, Stage 1&2 is 50% and the Full Program is 37%. The Stage 1 initial drop in employment is 64%, Stage 1&2 is 59% and the Full Program is 40%. Within a couple of years the economy continues to perform at a lower level, production activity for Stage 1 is 38% less, Stage 1&2 is 30% less and the Full Program is 24% less than the reference scenario. Employment for Stage 1 is 51% less, Stage 1&2 is 42% less, and the Full Program is 35% less. By the end of the seventh year after the seismic event, production activity recovers to a level 10% lower for Stage 1 and 11% lower for Stage 1&2 and the Full Program. Employment levels are 10% lower for all three scenarios.

### Portland Metro

The Portland Metro economy is significantly impacted under the Major Seismic Event scenario, with production initially dropping by about 32% and employment about 24%. Within a couple of years the economy continues to perform at a significantly lower level with 25% less production activity than forecast in the reference scenario and employment 16% lower. By the end of the seventh year after the seismic event, production activity is 28% lower than forecast and employment 20% lower.

The three stage scenarios reduce the impact of the seismic event. The Stage 1 initial drop in production activity is 28%, Stage 1&2 is 26% and the Full Program is 25%. The Stage 1 initial drop in employment is 14%, Stage 1&2 is 9% and the Full Program is 8%. Within a couple of years the economy continues to perform at a lower level, production activity for Stage 1 is 26% less, Stage 1&2 is 24% less and the Full Program is 21% less than the reference scenario. Employment for Stage 1 is 9%, Stage 1&2 is 10% and the Full Program is 10% less. By the end of the seventh year after the seismic event, production activity recovers to a level 21% lower for Stage 1 and 26% lower for Stage 1&2 and the Full Program. Employment levels are 15% lower for Stage 1 and 19% lower for Stage 1&2 and the Full Program.

## Mid-Willamette Valley

Under the Major Seismic Event scenario, the Mid-Willamette Valley is significantly impacted, with production initially dropping 38% and employment 32%. Within a couple of years the economy continues to perform at a significantly lower level with 26% less production activity than forecast in the reference scenario and employment 24% lower. By the beginning of the eighth year after the seismic event, production activity recovers to a level 16% lower than the reference scenario and employment 14% lower.

The three stage scenarios reduce the impact of the seismic event. The Stage 1 initial drop in production activity is 34%, Stage 1&2 is 33% and the Full Program is 25%. The Stage 1 initial drop in employment is 31%, Stage 1&2 is 30% and the Full Program is 26%. Within a couple of years the economy continues to perform at a lower level, production activity for Stage 1 is 24% less, Stage 1&2 is 23% less and the Full Program is 22% less than the reference scenario. Employment for Stage 1 is 23%, Stage 1&2 is 21% and the Full Program is 20% less. By the end of the seventh year after the seismic event, production activity recovers to a level 15% lower for Stage 1, 16% lower for Stage 1&2 and 14% lower for the Full Program. Employment levels are 13% lower for Stage 1 and the Full Program, 11% lower for the Stage 1&2 scenario.

## Southern Valley

Under the Major Seismic Scenario, the Southern Valley is significantly impacted, with production initially dropping 49% and employment 56%. Within a couple of years the economy continues to perform at a significantly lower level with 37% less production activity than forecast in the reference scenario and employment 50% lower. By the end of the seventh year after the seismic event, production activity and employment recover to a level 12% lower than the reference scenario.

The three stage scenarios reduce the impact of the seismic event. The Stage 1 initial drop in production activity is 39%, Stage 1&2 is 42% and the Full Program is 39%. The Stage 1 initial drop in employment is 52%, Stage 1&2 is 54% and the Full Program is 48%. Within a couple of years the economy continues to perform at a lower level, production activity for Stage 1 is 33% less, Stage 1&2 is 30% less and the Full Program is 24% less than the reference scenario. Employment for Stage 1 is 45%, Stage 1&2 is 43% and the Full Program is 39% less. By the end of the seventh year after the seismic event, production activity recovers to a level 11% lower for all three stage scenarios and employment levels are 12% lower for Stage 1 and 10% lower for Stage 1&2 and the Full Program.

**Table 8. Estimated Percent Reduction in Production, Employment and Population Relative to Reference Scenario by Region of Western Oregon, Scenario and Year After Seismic Event**

| PRODUCTION ACTIVITY |        |             |                          |                            |                             |             |             |                        |                       |                 |               |
|---------------------|--------|-------------|--------------------------|----------------------------|-----------------------------|-------------|-------------|------------------------|-----------------------|-----------------|---------------|
| Scenario            | Region | North Coast | Coast: Tillamook-Newport | Coast: Newport to Florence | Coast; Florence to Coos Bay | South Coast | Coast Total | Greater Portland Metro | Mid-Willamette Valley | Southern Valley | Western Total |
| Seismic Event       | Yr 1   | 58          | 61                       | 55                         | 67                          | 71          | 63          | 32                     | 38                    | 49              | 38            |
|                     | Yr 3   | 31          | 50                       | 46                         | 58                          | 64          | 49          | 25                     | 26                    | 37              | 29            |
|                     | Yr 7   | 9           | 8                        | 11                         | 16                          | 7           | 11          | 28                     | 16                    | 12              | 22            |
| Stage 1             | Yr 1   | 48          | 49                       | 52                         | 46                          | 73          | 53          | 28                     | 34                    | 39              | 32            |
|                     | Yr 3   | 28          | 44                       | 40                         | 40                          | 41          | 38          | 26                     | 24                    | 33              | 28            |
|                     | Yr 7   | 9           | 6                        | 9                          | 16                          | 8           | 10          | 21                     | 15                    | 11              | 18            |
| Stage 1&2           | Yr 1   | 43          | 52                       | 54                         | 48                          | 50          | 49          | 26                     | 33                    | 42              | 31            |
|                     | Yr 3   | 21          | 34                       | 29                         | 38                          | 29          | 30          | 24                     | 23                    | 30              | 24            |
|                     | Yr 7   | 9           | 8                        | 11                         | 16                          | 8           | 11          | 26                     | 16                    | 11              | 21            |
| Full Program        | Yr 1   | 19          | 46                       | 30                         | 43                          | 37          | 34          | 25                     | 25                    | 39              | 27            |
|                     | Yr 3   | 14          | 25                       | 25                         | 33                          | 24          | 24          | 21                     | 22                    | 24              | 21            |
|                     | Yr 7   | 9           | 7                        | 11                         | 16                          | 8           | 11          | 26                     | 14                    | 11              | 21            |
| EMPLOYMENT          |        |             |                          |                            |                             |             |             |                        |                       |                 |               |
| Scenario            | Region | North Coast | Coast: Tillamook-Newport | Coast: Newport to Florence | Coast; Florence to Coos Bay | South Coast | Coast Total | Greater Portland Metro | Mid-Willamette Valley | Southern Valley | Western Total |
| Seismic Event       | Yr 1   | 67          | 74                       | 66                         | 78                          | 81          | 73          | 24                     | 32                    | 56              | 35            |
|                     | Yr 3   | 35          | 72                       | 64                         | 72                          | 81          | 63          | 16                     | 24                    | 50              | 27            |
|                     | Yr 7   | 8           | 8                        | 9                          | 14                          | 9           | 10          | 20                     | 14                    | 12              | 16            |
| Stage 1             | Yr 1   | 54          | 65                       | 67                         | 55                          | 83          | 64          | 14                     | 31                    | 52              | 29            |
|                     | Yr 3   | 31          | 65                       | 55                         | 51                          | 64          | 51          | 9                      | 23                    | 45              | 23            |
|                     | Yr 7   | 8           | 7                        | 9                          | 14                          | 9           | 10          | 15                     | 13                    | 12              | 14            |
| Stage 1&2           | Yr 1   | 47          | 68                       | 69                         | 56                          | 61          | 59          | 9                      | 30                    | 54              | 28            |
|                     | Yr 3   | 23          | 53                       | 37                         | 49                          | 52          | 42          | 10                     | 21                    | 43              | 21            |
|                     | Yr 7   | 8           | 7                        | 8                          | 12                          | 9           | 10          | 19                     | 11                    | 10              | 15            |
| Full Program        | Yr 1   | 11          | 66                       | 32                         | 52                          | 51          | 40          | 8                      | 26                    | 48              | 23            |
|                     | Yr 3   | 12          | 50                       | 26                         | 47                          | 49          | 35          | 10                     | 20                    | 39              | 19            |
|                     | Yr 7   | 9           | 7                        | 9                          | 10                          | 9           | 10          | 19                     | 13                    | 10              | 15            |
| POPULATION          |        |             |                          |                            |                             |             |             |                        |                       |                 |               |
| Scenario            | Region | North Coast | Coast: Tillamook-Newport | Coast: Newport to Florence | Coast; Florence to Coos Bay | South Coast | Coast Total | Greater Portland Metro | Mid-Willamette Valley | Southern Valley | Western Total |
| Seismic Event       | Yr 1   | 65          | 76                       | 59                         | 73                          | 80          | 70          | 15                     | 28                    | 53              | 29            |
|                     | Yr 3   | 35          | 74                       | 56                         | 67                          | 80          | 61          | 11                     | 20                    | 48              | 23            |
|                     | Yr 7   | 7           | 6                        | 9                          | 14                          | 9           | 9           | 19                     | 12                    | 11              | 15            |
| Stage 1             | Yr 1   | 55          | 69                       | 60                         | 49                          | 81          | 63          | 10                     | 27                    | 49              | 26            |
|                     | Yr 3   | 30          | 68                       | 48                         | 43                          | 62          | 49          | 10                     | 19                    | 44              | 21            |
|                     | Yr 7   | 3           | 5                        | 9                          | 32                          | 10          | 9           | 11                     | 10                    | 11              | 10            |
| Stage 1&2           | Yr 1   | 44          | 72                       | 62                         | 52                          | 59          | 57          | 6                      | 25                    | 50              | 25            |
|                     | Yr 3   | 22          | 56                       | 27                         | 42                          | 50          | 39          | 10                     | 17                    | 42              | 19            |
|                     | Yr 7   | 1           | 5                        | 8                          | 35                          | 6           | 8           | 18                     | 5                     | 8               | 14            |
| Full Program        | Yr 1   | 13          | 71                       | 23                         | 49                          | 47          | 39          | 6                      | 23                    | 45              | 21            |
|                     | Yr 3   | 12          | 55                       | 19                         | 41                          | 45          | 34          | 9                      | 17                    | 39              | 17            |
|                     | Yr 7   | 7           | 6                        | 10                         | 35                          | 8           | 9           | 17                     | 11                    | 7               | 13            |

## APPENDIX: ANALYSIS TEAM

This technical memo is included in the final report “Oregon Highways Seismic Options Report” March 2013 as Appendix F.

This analysis required a team of people working closely together in order to meet the objectives of this analysis within the ambitious timeline:

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