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GEOLOGIC HAZARDS STUDY FOR THE COLUMBIA RIVER TRANSPORTATION CORRIDOR

By

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EXECUTIVE SUMMARY

The Columbia River Transportation Corridor serves as a significant east-west transportation artery for the Pacific Northwest. The transportation corridor includes U.S. Interstate Highway 84, two transcontinental rail lines, inland water navigation on the Columbia River, major electric power and gas lines, and lines of communication. This study covers a stretch of approximately 150 miles of corridor and three large hydroelectric facilities. Each of the hydroelectric facility has over 1,000 megawatt electrical generating capacity and includes a navigational lock for river commerce.

Freight is carried by highway, rail, barge, and intermodal (a combination of modes) means through the Columbia River Transportation Corridor. Highway transport is the dominant transportation method and carries half the weight and over two-thirds the value of freight through the corridor. Each mode has advantages and disadvantages, depending on the freight characteristics (e.g., bulk, size, containers), travel time needs, cost to transport, location of sources and destination, and so on. For example, for moving small-volume, high value cargo, trucking is the dominant method of transportation; whereas for moving high-volume, low-value commodities, barge may be a more cost-effective method. Water-borne traffic through Bonneville Lock moved 9.4 million tons in 1996, which is equivalent to 940 100-car unit trains or over 180,000 trucks. The freight flow is bound for domestic and international destinations and continues to increase. In 1997, the freight value that was moved through this corridor to the Portland-Vancouver region is estimated at about $95 billion. This estimate does not include a substantial amount of "through freight" (e.g., rail freight that continues directly to or from the Seattle region ports without stopping).

The risk to this transportation corridor from severe geologic hazards is relatively low but poses a real and significant threat because of the potential consequences. In the past, this area has been subjected to glacial outburst floods, which steepened the Columbia River Gorge, leaving landslide-prone cliffs. Heavy winter storms often cause landslides and local flooding. Earthquake hazards are from shallow, crustal earthquakes and Cascadia Subduction Zone earthquakes, which occur at intervals ranging from decades to hundreds and even thousands of years. Potentially costly coseismic geohazards include seiches, landslides, lateral spreading, liquefaction, and fault rupture. Volcanic hazards in the Cascade Range, including eruptions and lahars (fast-moving mudflows or debris avalanches triggered by volcanic activity), occur at intervals ranging from decades to hundreds of years. Two low-probability worst-case scenarios that could occur between near Hermiston in Morrow County and the Portland area have been developed.

Scenario one is a natural recurrence of a large-scale failure of steep canyon walls similar to past occurrences known as the Cascade Landslide Complex. The Cascade Landslide Complex includes two distinctly separate megalandslide events. Of these, the Bonneville landslide is the westernmost and youngest (possibly less than 1,000 years). It blocked and diverted the Columbia River to the south by over one mile. At the toe of this landslide, the Bonneville Project is located. This project includes two powerhouses, spillway, navigation lock, fish facilities, and the Bonneville Power Administration's (BPA) electrical switchyards and would probably require over 10 years and $2 billion to replace today. Recurrence of such a landslide event could result in the complete disruption of transportation through the Gorge and heavy damage to, perhaps complete destruction of, major population areas and facilities downstream and upstream including low lying parts of Portland, small cities, dams, and commercial and industrial sites.

The second scenario is a catastrophic dam failure and water release from the John Day Lock and Dam or from any other major water storage dam upstream in the Columbia basin. Such a release has a very low probability and would require an extreme or infrequent event, such as a strong earthquake on a nearby fault. Significant damage would extend downstream to the Pacific Ocean. Damage due to overtopping of dikes and levees would probably cause disruption to cities, including significant portions of downtown Portland, The Dalles, other smaller cities, power generation facilities, and the transportation infrastructure, such as the Port of Portland, Portland International Airport, and Union Pacific terminals.

The study results indicate that geologic hazards in the Columbia River Transportation Corridor can have a severe, long lasting impact on the economy of Oregon, affect productive capacity, and slow the pace of economic growth and development. Catastrophic damage is possible by a large landslide, such as an earthquake-triggered landslide, earthquake shaking, flooding, and volcanic activity. Due to the severe consequences to the regional economy and local communities, additional studies and mitigation should be implemented to better evaluate the risks and to lower the vulnerability of this transportation corridor.

1.0 INTRODUCTION

The Columbia River Transportation Corridor stretches for 150 miles along Oregon's Interstate Highway 84 from near Hermiston in Morrow County on the east to Portland on the west (Figure 1.1). What is known as the "Oregon Project" covers most of the transportation corridor and includes three parallel systems: U.S. Interstate Highway 84, the inland waterway of the Columbia River, and transcontinental railroad lines, all of which are economic lifelines for the Pacific Northwest.

The study region is characterized by extreme climatic conditions ranging from heavy rainfall to high-desert aridity. It includes diverse geology settings ranging from flat river valleys to steep Gorge slopes. Damaging earthquakes, volcanic eruptions, heavy winter storms, and destructive landslides have been experienced in this region. The study area also includes stretches of the Columbia River, a major river and dam system that is critical for flood control and power generation. It is located in the lower reaches of a large watershed, which includes part of the Province of British Columbia and the States of Washington, Oregon, Wyoming, Nevada, Idaho, Montana, and Utah (Figure 2).

preliminary findings with selected key members and stakeholders of the community.

The goal is to highlight the interdependencies among existing lifelines, geologic hazards and the economy and promote awareness on the community's major vulnerabilities. In areas where risks are shown to be unacceptably high, mitigation and public policies should be pursued by stakeholders and study partners.

This transportation corridor is vital to Oregon's economy. The study results help illustrate the reliability of the region's different modes of transportation. Because transportation reliability is invaluable to business continuity, the expected damage and economic impact of the geologic hazards considered would be high. This information can be used to develop mitigation strategies to lower the economic impact, improve the emergency response, recovery, and mitigation plans and business continuity plans.

Since the main purpose of the project was to serve as a pilot study to better understand the complex relations among different modes of transportation and geologic hazards and to assess their importance for the community, we exam-

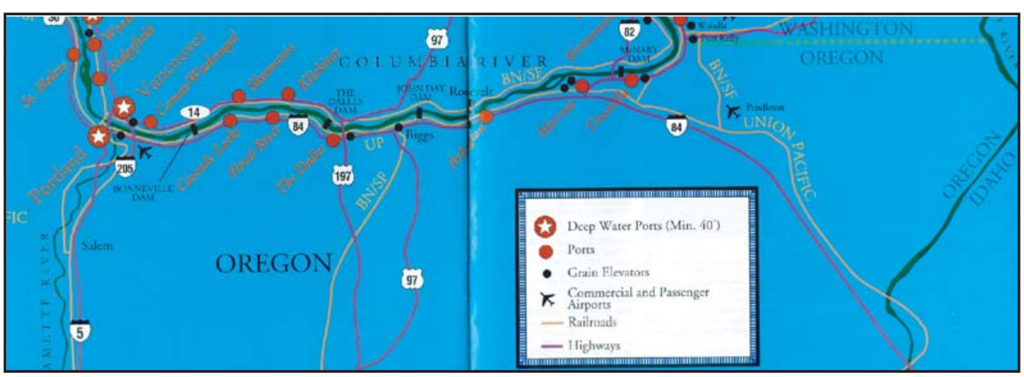

Figure 1. 1. Map of the greater study area showing multimodal transportation corridors, including the Columbia River Transportation Corridor along the Oregon-Washington border (The Great Waterway, 1998).

ined engineered systems (bridges, roads, dams, and railroads) along with geologic hazards (rockfall landslides, debris-flow landslides, volcanic landslides, earthquake ground shaking, floods, and dam stability hazards) and limited economic and commerce data to determine the overall vulnerability and interdependencies in the region. As we integrated our data with existing data from other agencies, we shared our preliminary findings with selected key members and stakeholders of the community.

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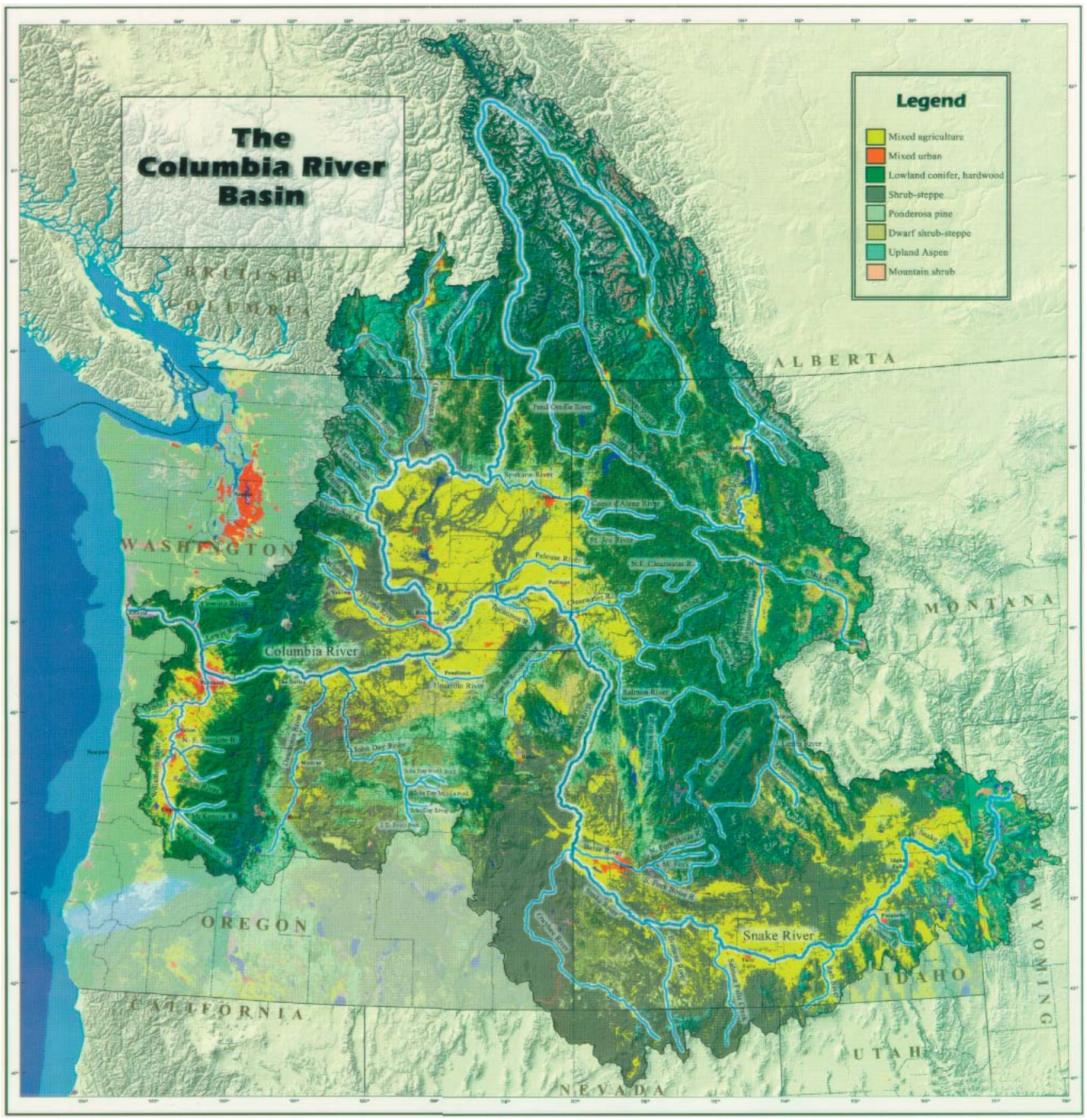

Figure 1.2. The Columbia River watershed includes part of British Columbia, Washington, Oregon, Wyoming, Nevada, Idaho, Montana, and Utah.

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2.0 STUDY PARTNERS

The project included many partners in order to obtain pertinent data and share the findings with them and other stakeholders. We developed significant partnerships with the Oregon Department of Transportation(ODOT), the U.S. Army Corps of Engineers (USACE), the Port of Portland, the U.S. Geological Survey (USGS), Oregon Emergency Management (OEM), and others.

Geologic data on landslides, faults, and bedrock shaking were obtained from the Oregon Department of Geology and Mineral Industries (DOGAMI), the USGS, and other sources. Data on the Bonneville, The Dalles, and John Day locks and dams were obtained from the USACE. Commerce data were obtained from the Port of Portland, USACE, and ODOT.

During the course of this study, DOGAMI shared information that was developed as part of this study, including:

- Presenting preliminary study results to a State Commission at the State Capitol (June 11, 2002). The Commission included legislators, OEM, ODOT, and others.
- Hosting a landslide hazards workshop and field trip for the landslide committee of the National Academies (March 14-16, 2002).
- Leading a field trip on geologic hazards and transportation for the Geological Society of America (May 16, 2002) and publishing a field guide; (Wang and others, 2002).
- Presenting and publishing a paper at a conference of the American Society of Civil Engineers on the risks to the Columbia River Gorge waterway (presented August 29, 2003; published as Wang and Scofield, 2003).

The damage impact results are being shared with planners at the Port of Portland and the City of Portland. The Port of Portland handles domestic and international cargo to the Pacific Rim nations and conducts significant business along this transportation corridor.

We also shared our findings with Multnomah County, Hood County, Wasco County, Sherman County, Gilliam County, Morrow County, Umatilla County, the Washington Department of Transportation, and the Washington State Department of Natural Resources Geology Division and will do so in a forthcoming field trip from Portland to the John Day Dam, which is being sponsored by the American Society of Civil Engineers and the Association of Engineering Geologists (on March 22, 2004).

3.0 NATIONAL DISASTERS AND TRANSPORTATION

Geologic hazards such as major earthquakes or landslides can develop into natural disasters that have far-reaching impacts on communities, including slow recovery and long-lasting socioeconomic difficulties. Not surprisingly, the transportation infrastructure is exposed to such hazards as well. In view of the critical role of transportation systems in emergency response and disaster recovery and of the large direct and indirect losses that can be incurred, it is essential that the vulnerability of the transportation infrastructure be understood.

Natural disasters frequently result in significant damage, loss and disruption of urban and regional transportation systems. The failures of the Cypress Viaduct and the Oakland-San Francisco Bay Bridge during the 1989 Loma Prieta earthquake, of major freeway interchanges during the 1994 Northridge earthquake, and of the Hanshin Expressway during the 1995 Kobe earthquake provide striking examples (Figure 3.1).

Figure 3.1. The Hanshin Expressway collapse in the 1995 Kobe, Japan earthquake (photo credit: Paul Sommerville).

or earthquakes, the causes of such disruptions are many, among them bridge collapse, landslide, impending collapse of an adjacent structure, bursting of a nearby water or natural gas pipe, settlement or compaction, liquefaction, lateral spreading, surface rupture, rock falls, and more. In these instances, one or more links or nodes of the transportation network are rendered unusable, the transportation system's capacity is reduced, gridlock may occur, and when access remains possible, travel distances and times are greatly increased. Damage to one critical link can have impacts far beyond the local area. Although we do not address technological and other man-made disasters in this study, these can have much the same effect on transportation systems.

Transportation systems provide an essential function to society by allowing the movement of people and goods and are the key to commerce and economic activity. They provide the mobility that allows us to conduct business, commute, travel, enjoy recreation. They are lifelines without which citizens and businesses could not function. Transportation represents a substantial share of a country's gross domestic product: it amounts to 11 % for the United States.

The transportation systems considered herein include waterways, roads, and railroads.
The more visible part of these systems is the built infrastructure: roads, runways, airports, terminals, railways, stations, canals, ports, traffic control centers, and maintenance and operation facilities. The infrastructure of these transportation systems can be represented as complex, multiply connected networks of nodes and links. While less visible, the operations side (i.e., transportation operators, vehicles, traffic safety, power, command control and communications centers, and maintenance) is just as essential for the transportation systems to function properly. Although the importance of the operations side is recognized, this study does not address it.

What are the dimensions of a major disruption caused by geologic hazards to the Columbia River Transportation Corridor? Geologic hazards, such as from a great Cascadia Subduction Zone earthquake, can impact a large region of Oregon. Statewide, direct losses would be on the order of $12 billion and 5,000 casualties (Wang, 1999; Wang and Clark, 1999). Prolonged disruption of the Columbia River Transportation Corridor from such an earthquake could lead to major economic losses to Oregon and slow recovery efforts. Both direct losses, such as dollar loss for repairs of structures, and indirect losses, such as impact on the flow of freight by businesses, can be incurred. Damage to the facilities dependent on the transportation corridor, such as ports and intermodal terminals, would be likely.

The primary features of the transportation system that are relevant to disaster resiliency, the effects of disasters on the transportation system with examples, intermodal impacts and losses are discussed in the next two sections.

3.1 Transportation Infrastructure Features Relevant to Disaster Resiliency

Assessing the vulnerability of the transportation infrastructure is needed to determine the overall risk to the system. Our current understanding of the seismic response of structures and their modes of failure are based on the principles of structural dynamics, the results of recent research and the findings of post-earthquake investigations. As examples, possible causes for failure of transportation infrastructure include

- Severe shaking from amplification of the ground motion due to local site conditions.
- Fault rupture at bridge and dam sites (Figure 3.2)
- Oscillations due to significant influence of the spatial variation of ground motion on the response of long structures (bridges)
- Liquefaction of loose, saturated sands and silts – often found at bridge and dam sites along rivers.
- Settlement of the abutment fill material; possibly slumping and abutment rotation.
- Pounding between adjacent structures coming in contact during earthquake shaking because they are too close together.

Figure 3.2. Failure of Shigang Dam in the 1999 Chichi Taiwan earthquake (Okunishi, K.).

The primary features of transportation networks, which in some way are relevant to their resiliency to disasters, are listed below:

- They are decentralized and typically extended over wide geographic areas, and so is their vulnerability.
- Failure at one point along a link often means failure of the link.
- Transportation infrastructure frequently follows river valleys, where population centers are located and it is often easier and cheaper to build.. However, such siting makes the infrastructure prone to flooding and, in seismic areas, susceptible to liquefaction damage.
- Utilities, including pipelines, often follow transportation infrastructure right-of-ways, and cross valleys using bridges of the road system. Due to the physical proximity of these lifeline systems and to their functional interdependency, interaction between them can be significant.

- Transportation systems usually have redundancy so that, most often, a variety of transportation options and alternate routes are available when components of the network are damaged.
- It is rare for a single national entity to have responsibility or oversight over the entire transportation system.
- Different geographic units have responsibility over the transportation infrastructure of different regions.
- It is usual for different transportation modes to be managed by different administrations or legal entities.
- Transportation infrastructure is very costly, and each year a substantial share of a nation's resources is required to maintain the existing system and to build and expand the system for the future.
- Although private ownership of transportation infrastructure exists (e.g., railroads), the majority of such infrastructure is owned by public entities and publicly funded (hence the expression "public works").
- Transportation infrastructure is usually not insured (or the owner is self-insured). Some public agencies seek the financial protection provided by re-insurance.
- Transportation planning needs to consider many issues such as financing, traffic congestion, air quality, the environmental impact, and scenic and historic preservation. It seldom considers the overall effect of the planned infrastructure on the vulnerability of the larger transportation system, particularly since disaster events tend to be infrequent.

3.2 Effects of Disasters on Transportation infrastructure

Transportation systems are exposed to hazards that can cause events with devastating consequences. These events results from natural hazards such as geologic hazards (e.g., earthquakes, volcanoes, tsunamis) and climatic hazards (e.g., floods, windstorms, snow storms, ice storms, hail storms, avalanches, mudslides), or from man-made hazards (e.g., accidents, explosions, tunnel fires, discharge of hazardous materials, intentional damage). This study focuses primarily on natural hazards.

These events produce a number of primary and secondary effects that can lead to the failure of portions of the transportation networks. For example, the primary effect of an earthquake is ground shaking, which can cause the failure of bridge structures or the compaction of fill at bridge abutments. Its secondary effects include surface fault rupture, tectonic deformation, ground subsidence, lateral spreading, soil liquefaction, landslides, rock falls, flooding, fire, and even tsunamis. The primary effect of hurricanes is high-velocity winds, which can be accompanied by hurling of debris and flooding as secondary effects. Note that these events become disasters only if there are vulnerable elements exposed to the hazard.

Earthquakes are a major source of disasters that affect urban and regional transportation systems. Events of recent years offer striking examples of disasters impacting transportation systems.

The earthquakes of Loma Prieta, California (October 17, 1989), Northridge, California (January 17, 1994) and Kobe, Japan (January 17, 1995), dramatically demonstrated the devastating impact earthquakes could have on highway bridges not adequately protected against seismic forces. So did the bridge collapses observed during the 1999 earthquakes in Kocaeli, Turkey and in Chi-Chi, Taiwan.

During the Loma Prieta earthquake, the U.S. Interstate Highway I-880 Cypress Street Viaduct in Oakland and the east crossing of the Oakland-San Francisco Bay Bridge both collapsed, killing 43 people. The earthquake also caused the collapse of the Truve Slough

Bridge near Monterey and damaged 94 other bridges. In addition, the Embarcadero Freeway Viaducts suffered damage so severe they had to be demolished. The most serious disruption resulted from the collapse of the bridge deck of the San Francisco-

Oakland Bay Bridge and the Cypress Street Viaduct in Oakland. The quake led to142 road closures.

During the Northridge earthquake, 286 state highway bridges suffered damage, and five bridges collapsed, one on Interstate Highway 5 (Golden State Freeway), one on Interstate Highway10 (Santa Monica Freeway), two on State Route SR 14 (Antelope Valley Freeway), and one on SR 118 (Simi Valley Freeway). Road closures amounted to 140.

During the Kobe earthquake, a number of major bridge collapses occurred, as well as collapse of numerous spans of the Hanshin expressway.

During the San Fernando (Sylmar) earthquake of February 9, 1971, two persons died on the California State Highway System. A number of bridges in the interchanges of Interstate Highway 5 with Route 210 and Route 14collapsed or had severe damage.

The 1964 earthquake at Anchorage, Alaska, caused the collapse of nearly all bridges on a newly completed highway.

As the above examples indicate, bridges are among the most vulnerable components of highway systems, which in turn are the backbone of the transportation system. While disruptions of the highway system are the most frequent, railroads, ports, terminals, airports, waterways, utilities, and the interaction among these modes can also be affected by earthquakes. .

The 2001 earthquake at Nisqually, Washington, caused damage to the Seattle airport control tower, which forced closure of the airport. During the same earthquake, liquefaction rendered the pavement of the Boeing airfield and a section of the railroad unusable (Figure 3.3).

Figure 3.3. Damage to railway from liquefaction in the 2001 Nisqually, Washington earthquake (photo credit: William Byers).

The overturned Oran-Algiers train that was crossing the fault at the time of main shock during the 1980 earthquake at El Asnam, Algeria, and the bent rails of the railroad between Guatemala City and Puerto Barrios left by the 1976 earthquake in Guatemala are extreme examples of railway system disruptions. The port of Kobe, Japan, suffered extensive damage due to liquefaction during the 1995 earthquake (Figure 3.4).

Pipelines are not immune to earthquakes either. The motion on the Oued Fodda fault during the 1980 earthquake at El Asnam sheared a major water pipeline. Gas pipelines in the San Francisco Marina district were ruptured during the 1989 Loma Prieta earthquake, causing major fires. During the 1999 earthquake at Chi-Chi, Taiwan, natural gas pipelines were damaged due to liquefaction.

Figure 3.4. Failure of the port gantry cranes caused by liquefaction and lateral spreading during the 1995 earthquake at Kobe, Japan (photo: Ian Austin).

Interaction among different modes of transport and of transport modes with utilities can affect the actual vulnerability of transportation systems. It can be complex and difficult to predict, as discussed below:

- Damage to a highway bridge crossing over a railroad can interrupt railway traffic.
- The capacity of an airport can be reduced because air traffic controllers and passengers have difficulty reaching the airport when they need surface transportation. In such a case, the highway and air modes of transport are "in series." Airport facilities are examples of intermodal interfaces, the damage of which can have major consequences far beyond their immediate location.
- In some cases, when different modes of transportation are "in parallel," one mode with little or no damage (e.g., transit) may have to assist another mode (e.g., highway system) which may have suffered extensive damage, and then function only in degraded fashion.
- Utility lines, colocated or in the vicinity of transportation infrastructure, can affect it as well. For example, a water main break, a gas pipe leak or downed power lines can all lead to road closures (Figure 3.5). Loss of traffic signals can impair the operation of the transportation infrastructure and hamper relief efforts.

Figure 3.5. Co-located water and gas pipelines that failed in a California quake.

It should be realized, however, that disruptions of the transportation systems do not always lead to a complete breakdown. To some extent, transportation networks can adapt to the loss of a link or node. In some cases, the flow capacity is reduced, but access remains possible (Figures 3.6 and 3.7). Unless a link is the only way to access a given area, the redundancy usually present in transportation networks provides alternate routes. In some cases, it may be possible to rely on the substitution of one mode for another. For example, following the span collapse on the San Francisco Oakland Bay Bridge during the 1989 Loma Prieta earthquake, many motorists used the Bay Area Rapid Transit (BART) and the ferry. The ability of individuals to make a variety of short-term adjustments can also help alleviate the problem. As a result, disruptions of components of the transportation systems do not always constitute an on-or-off situation. It is often possible for the system as a whole to continue to function at a reduced capacity or in a degraded mode (e.g., reduced capacity, longer travel distances and times). Some degradation can be tolerated in most cases. This consideration is a key feature for the disaster resiliency of transportation systems.

Figure 3.6. One of two parallel bridges failed in the 2003 Zemmouri, Algeria earthquake causing traffic to be rerouted to the undamaged bridge (Photo credit: Mark Yashinsky).

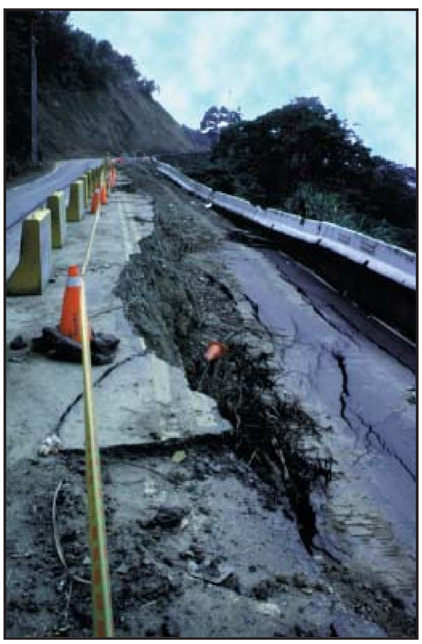


Figure 3.7. Outside edge of roads, which include fill material, commonly fail and limit the traffic flow to fewer lanes (Photo credit: David K Keefer).

3.3 Losses

Natural disasters can cause tens of thousands of casualties. Thus, for example, the 1985 Subduction Zone earthquake at Mexico City killed about 10,000 people; and the quakes of 1990 in northwestern Iran and of 2003 at Bam, Iran, each killed between 35,000 and 50,000 people. Fortunately, the number of direct casualties resulting from disaster-induced damage to transportation infrastructure is usually less, although the examples of the motorists trapped under the upper part of a double-deck bridge (Nimitz Freeway in Oakland, California), others killed because of the collapse of a bridge span (Oakland Bay Bridge), or yet others caught in tunnel fires are no less terrible. More devastating effects of disasters occur usually in the built infrastructure itself, with damage to nodes and links of the transportation network, and to the utilities located in the right-of-way.

The direct loss (cost of restoring the damaged node or link) is compounded by additional indirect losses. Since transportation systems are critical to disaster response and recovery, delays in the arrival of emergency vehicles and the evacuation of casualties may result in increased fatalities. A transportation system functioning in degraded mode impedes the arrival of food, supplies, and heavy equipment on site and thus delays recovery. While the transportation system is functioning in degraded mode, additional losses are incurred because, as travel distances and times are lengthened, debris-removal, reconstruction, repair, and retrofitting activities are slowed down. In some cases the maximum transportable load is reduced. Such disruptions in transportation systems can have a severe impact on the economy of a region for months or even years, affect productive capacity, and slow the pace of economic recovery.

4.0 MULTIMODAL COLUMBIA RIVER TRANSPORTATION CORRIDOR

4.1 Statewide Transportation

Statewide in Oregon, the largest percentage of tonnage is moved by truck, rail, and barge. Figure 4.1 shows the freight flows on the rail, highway, and waterway modes. The statewide freight movements by modes for tonnage and dollar value are shown in Table 4.1. The top five commodities shipped to, from, and within Oregon by all modes in 1998 are shown in Table 4.2. Most of Oregon's rail and barge freight—and, of course a great portion of all other transportation traffic—moves through the Portland area and the Columbia River Gorge Transportation Corridor.

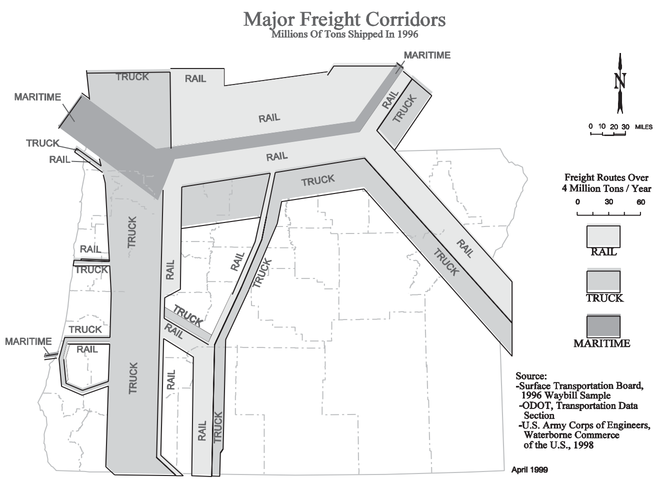


Figure 4.1. Map showing the modal share and distribution in Oregon (ODOT web).

TABLE 4.1. FREIGHT SHIPMENTS TO, FROM AND WITHIN OREGON IN 1998 (US DOT)

Mode	Weight (Million tons)	Value ($ Billions)
Highway	220	165
Rail	53	18
Water	16	3
Total	289	186

TABLE 4.2. COMMODITIES SHIPPED TO, FROM AND WITHIN OREGON IN 1998 (US DOT)

Commodity	Weight (Million Tons)	Value ($ Billions)
Lumber/Wood Products	105	41
Farm Products	38	39
Secondary Traffic	38	23
Freight All Kinds*	18	16
Clay/Concrete/Glass/Stone	18	13
Total	217	132

* All Kinds refers to "Single freight, which is charged irrespective of the commodity" (www.eyefortransport.com/glossary/ab.shtml).

4.2 Corridor Transportation

The Columbia River Transportation Corridor includes a major Interstate Highway, I-84, two transcontinental rail lines, Union Pacific (UP) and Burlington Northern Santa Fe (BNSF), the Columbia River inland water navigation, major electric power and gas lines, and communication conduits. The main terminus of the corridor is Portland. Also, the Portland International Airport (PDX) and trucking play major roles in the transportation system of the region.

Thus, the Columbia River Gorge is a multimodal transportation corridor in that there is more than one mode to serve transportation needs. Some of the modal share is "intermodal," which refers to connecting different modes of transportation and/or transferring freight from one mode to another at facilities such as ports, terminals, stations, or airports. For example, a portion of lumber harvested in Oregon and bound for inland markets by rail travels to the rail reload facilities by truck. Grain and potash rail shipments, on the other hand, travel to the Port of Portland for export by ship. The modal share, or percentage of freight moved by barge, rail and truck, is schematically shown on Figure 4.1. Freight movements can also take place at non-intermodal facilities, such as distribution centers and warehouses, manufacturing plants, truck reload facilities, and terminals (ODOT, website).

The Portland region has a high concentration of freight activity that includes intermodal operations at ports, rail yards (or terminals), trucking and industrial yard facilities. The Port of Portland, Port of Vancouver, and other private Portland-Vancouver regional ports handle most of the barged goods. However, some barged freight, such as corn, passes through the Columbia River Gorge and Portland-Vancouver region on rail without stopping to Kalama, downstream of Portland.

A considerable amount of "through freight" passes through the Portland-Vancouver region, linking, e.g., Puget Sound and inland markets. Estimates indicate that more than 15 million tons of rail freight moved between markets east and north of the Portland-Vancouver region without stopping (Scott Drumm, oral communication, December 10, 2003).

In the Columbia River Transportation Corridor, trucking is the most used transportation mode, followed by rail, intermodal transport, then barge. Tables 4.3 and 4.4 provide the top five commodities that are transported through the corridor both to and from the Portland-Vancouver metropolitan area, including all modes of transportation by value and by weight. Table 4.5 shows commodity flow through this corridor. It is possible that the barge values are actually higher than shown on this table. The data from Tables 3 to 5 are from the 2002 "Commodity Flow Forecast Update and Lower Columbia River Waterborne Cargo Forecast" report by DRI-WEFA, Cambridge Systematics, and BTS Associates.

4.3 Waterway and Federal Hydroelectric Facilities

The entire Columbia River system carries about $14 billion worth of goods each year, provides the means to ship goods to over 1,000 companies

TABLE 4.3. TOP 5 COMMODITIES BY VALUE

COMMODITIES	Short Tons (in thousands)	$ Value (in millions)
Vehicles	1,960	$24,053
Textiles, leather, and articles	569	$9,1612
Foodstuffs and alcoholic beverages	5,332	$7,7835
Cereal grains	10,870	$6,649
Mixed freight	2,770	$5,506

TABLE 4.4. TOP 5 COMMODITIES BY WEIGHT

COMMODITIES	Short Tons (in thousands)	$ Value (in millions)
Cereal grains	10,870	$6,649
Gas, fuel, petroleum/coal products	5,711	$1,928
Base chemical	5,471	$3,744
Foodstuffs and alcoholic beverages	5,332	$7,785
Wood products	3,621	$1,240

in Portland, and, ranks fourth in the nation and first in the West Coast in agricultural export tonnage (Port of Portland website). Oregon's ports near the study region include Umatilla, Morrow, Arlington, The Dalles, Hood River, Cascade Locks, and the Port of Portland. Grain elevators are located near Umatilla, Morrow, Arlington, Biggs, The Dalles and in Portland.

Three major hydroelectric facilities exist in this study region. Each of the hydroelectric facility consists of a dam, powerhouse, spillway, navigational lock, and fish passages. Bonneville Lock and Dam, which is located 40 miles east of Portland at the head of tidal influence from the Pacific Ocean, has a 1,059-MW electricity generating capacity. The Dalles and John Day facilities upriver have electricity generating capacities of 1,636 MW and 2,160 MW, respectively. Barge traf-

Table 4.5 Commodity Flow through the Columbia River Transportation Corridor

	Barge	Tr	uck		Rail		Intermodal		Totals	
Commodity Description	**Short Tons** (in 1,000's)	**$ Value** (in 1,000,000's)	**Short Tons** (in 1,000's)	**$ Value** (in 1,000,000's)	**Short Tons** (in 1,000's)	**$ Value** (in 1,000,000's)	**Short Tons** (in 1,000's)	**$ Value** (in 1,000,000's)	**Short Tons** (in 1,000's)	**$ Value** (in 1,000,000's)
Agricultural products, except live animals, cereal grains and forage products	39.00	5.57	949.62	135.51	79.86	11.40	20.97	2.99	1,089.46	155.47
Animal feed and feed ingredients, cereal, straw, and eggs and other products of animal origin, n.e.c.	0	0	149.86	152.66	9.87	10.05	0.34	0.35	160.07	163.05
Articles of base metal	0	0	915.39	2,726.28	0.42	1.25	30.32	90.31	946.13	2,817.84
Base chemical	0	0	1932.00	1,322.08	3006.47	2,057.34	532.57	364.44	5,471.04	3,743.86
Base metal in primary or semifinished forms and in finished basic shapes	0	0	962.18	742.86	163.33	126.10	354.76	273.89	1,480.27	1,142.85
Cereal grains	4,639.12	2,837.74	516.24	315.78	5714.62	3,495.63	0	0	10,869.98	6,649.15
Chemical products and preparations, n.e.c.	0	0	528.41	1,585.87	0.00	0	0	0	528.41	1,585.87
Coal	0	0	0.05	0.01	0	0	0	0	0.05	0.01
Crude Petroleum Oil and Oil from Bituminous Materials	0	0	0.03	0.00	0	0	0	0	0.03	0.00
Electronic and other electrical equipment and components, and office equipment	0	0	179.51	4,719.49	8.47	222.55	0	0	187.98	4,942.05
Fertilizer and fertilizer materials	0	0	141.04	36.11	716.49	183.43	0	0	857.54	219.54
Foodstuffs and alcoholic beverages	0	0	4643.30	6,779.23	569.58	831.59	118.99	173.73	5,331.87	7,784.54
Furniture, mattresses and mattress supports, lamps, lighting fittings, and illuminated signs	0	0	144.20	723.53	12.58	63.10	0.90	4.49	157.68	791.12
Gas, fuel, petroleum/coal products	2,567.81	867.05	2769.92	935.30	373.51	126.12	0	0	5,711.24	1,928.47
Gravel and crushed stone	0	0	1.52	0.02	0	0	0	0	1.52	0.02
Live animals and live fish	0	0	61.50	38.98	11.45	7.25	0	0	72.94	46.24
Logs and other wood in the rough	0	0	2060.66	183.02	0	0	0	0	2,060.66	183.02
Machinery	0	0	299.62	3,376.68	50.12	564.84	9.72	109.57	359.46	4,051.09
Mail and Express Traffic	0	0	15.05	14.53	0	0	0	0	15.05	14.53
Meat, fish, seafood, and preparations	0	0	173.15	39.14	1.71	0.39	10.97	2.48	185.83	42.00
Metallic ores	0	0	0.04	0.00	517.47	24.87	0	0	517.51	24.87
Milled grain products and preparations and bakery products	0	0	978.74	2,551.14	363.70	948.01	13.24	34.50	1,355.68	3,533.65
Miscellaneous manufactured products	0	0	279.28	1,409.94	0.24	1.20	19.47	98.30	298.99	1,509.44
Mixed freight	0	0	336.96	669.89	0.00	0.00	2432.84	4,836.50	2,769.80	5,506.39
Monumental or building stone	0	0	22.24	258.02	134.08	1,555.46	0	0	156.32	1,813.48
Natural sands	0	0	0	0	0	0	0	0	0.00	0.00
Nonmetallic mineral products	0	0	2689.30	344.44	232.63	29.79	314.42	40.27	3,236.36	414.51
Nonmetallic minerals, n.e.c.	0	0	39.00	0.28	0.00	0.00	0	0	39.00	0.28
Paper or paperboard articles	0	0	758.68	981.39	0.00	0.00	0	0	758.68	981.39
Pharmaceutical products	0	0	70.57	2,198.30	0.00	0.00	0	0	70.57	2,198.30
Plastics and rubber	0	0	375.65	971.29	37.34	96.56	1.22	3.16	414.22	1,071.01
Precision instruments and apparatus	0	0	43.02	3,153.57	0	0	0	0	43.02	3,153.57
Printed products	0	0	202.19	874.91	16.12	69.75	1.49	6.44	219.80	951.11
Pulp, newsprint, paper, and paperboard	0	0	1010.93	505.98	0.67	0.33	839.46	420.15	1,851.05	926.46
Textiles, leather, and articles	0	0	555.45	8,942.74	12.96	208.70	0.64	10.38	569.06	9,161.82
Tobacco products	0	0	117.35	139.28	0.76	0.90	0	0	118.11	140.19
Transportation equipment, n.e.c.	0	0	324.33	1,618.68	0	0	0	0	324.33	1,618.68
Vehicles	0	0	1307.38	16,042.33	397.20	4,873.87	255.63	3,136.69	1,960.21	24,052.89
Waste and scrap	0	0	1776.93	330.10	0	0	355.48	66.04	2,132.41	396.14
Wood products	0	0	1643.72	562.88	0	0	1976.92	676.98	3,620.64	1,239.86
TOTAL 7,245.92		**3,710.36**	**28,975.06**	**65,382.24**	**12,431.65**	**15,510.48**	**7,290.34**	**10,351.68**	**55,942.97**	**94,954.77**

fic through Bonneville Lock moved 9.4 million tons in 1996, which is equivalent to 940 100-car unit trains or over 180,000 trucks. Predominant exports include wheat, soda ash, potash and hay to Japan, South Korea, Brazil, and Taiwan. Major imports are automobiles, petroleum products, steel, and limestone from Japan, South Korea, China, and Australia.

The Port of Portland, Port of Vancouver and smaller private ports handle some of the barged commodities. In 2000, the Port of Portland handled over $10 billion in imports and exports (Port of Portland website, 2003). According to the commodity flow study on 1997 data, about $4 billion was from barged commodities (Scott Drumm, Port of Portland, oral communication, December 2003). The waterborne commodity flow handled by the Port of Portland alone for 2000 is shown on Table 4.6.

4.4 U.S. Interstate Highway I-84 and Railways

The I-84 transportation infrastructure is dependent on roads, bridges, tunnels, and clear passages to transportation hubs, such as Portland International Airport (PDX) and intermodal industrial parks. Many portions of the roads and rails are subject to landslides and, in places, overpass collapses. I-84 has approximately 130 bridges between Portland and Hermiston

TABLE 4.6. WATERBORNE COMMODITY FLOW BY PORT OF PORTLAND

Cargo (2000 actual volumes)	
Containers (TEUs)[1]	290,000
Breakbulk (MT)[2]	585,000
Automobiles (units)	385,000
Bulk Grains (MT)	2,919,000
Bulk Minerals (MT)	3,827,000

Notes: Breakbulk refers to specific commodities (other than automobiles, bulk grains and bulk minerals) that are not containerized , such as long or heavy objects like logs, lumber and stacked steel plates.
[1]TEUs = twenty-foot equivalent units
[2]MT = metric tons

The rail infrastructure is dependent on railways, bridges, tunnels, and facilities. The strength of rail transport is that it can move high volumes over longer distances at a lower cost relative to truck transport. For this reason, less time-sensitive bulk commodities traveling several hundred miles or more generally are transported by rail. Much of the rail freight terminating in Portland originates in Washington, California, Idaho, Montana, Wyoming and Illinois. Portland is at the western end of both the UP and BNSF railway lines through the Columbia River Gorge. The two railroads moved a combined 128 million gross tons over their lines in the Gorge in 1999—67.5 million on UP and 61 million on BNSF. These main lines are the most heavily used rail system in the Pacific Northwest.

The Union Pacific terminal is an assemblage of facilities provided by a railway at a terminus and/or intermediate point for freight and the receiving, classifying, assembling, and dispatching of trains. UP has major terminal facilities at Brooklyn Yard in southeast Portland, Albina Yard in northeast Portland and Barnes Yard in north Portland. UP also has intermodal ramps at both Brooklyn and Albina.

The Burlington Northern Santa Fe major facility is located in Vancouver, Washington. In Portland, BNSF terminals include Willbridge in northwest Portland, which is intermodal, and Rivergate in north Portland, which is the largest receiver and shipper of freight in the region.

UP and BNSF jointly own the Portland Terminal Railroad with a major terminal at Lake Yard in northwest Portland. It serves the Port of Portland facilities along the west shore of the Willamette River and industries located in northwest Portland.

5.0 Geologic History of the Columbia River Gorge

This section on the geologic history of the Columbia River Gorge was first published in a Geological Society of America field trip guide in Wang and others (2002). It has been slightly modified for this report.

The formation of the Columbia River Gorge can be associated with two violent processes that are often labeled with the terms, fire and ice. All of the geologic history exposed by the Columbia River in the Gorge and the adjacent area is limited to the Tertiary and Quaternary (Figure 5.1).

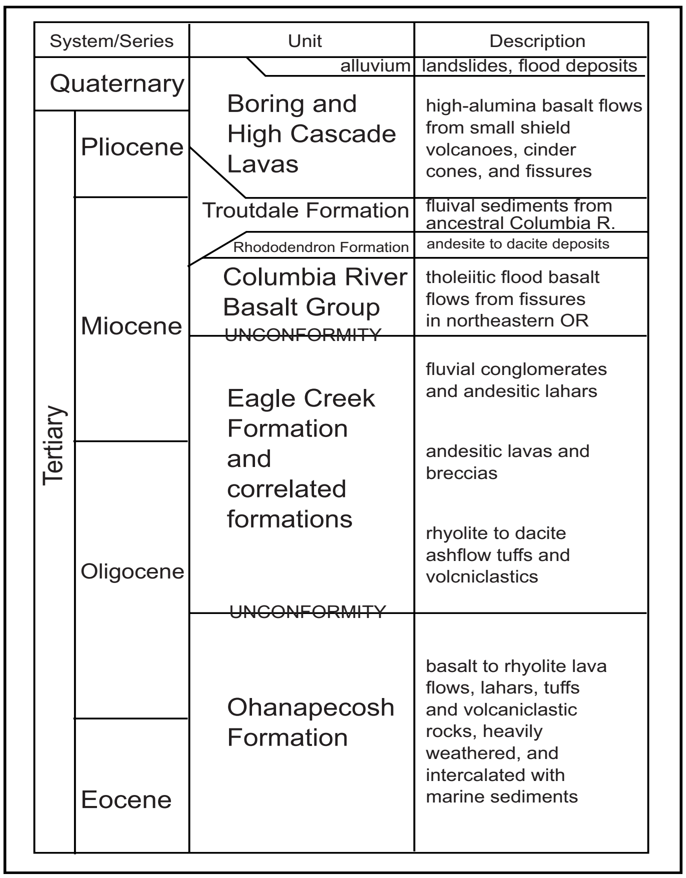


Figure 5.1. Generalized geologic stratigraphy of the Columbia River Gorge (modified from Tolan and Beeson, 1984).

The spectacular stratigraphy that is exposed within the Gorge is mostly volcanic. The geomorphology of the Gorge has been modified by flooding associated with the catastrophic emptying of Pleistocene glacial Lake Missoula.

During Eocene and Oligocene time, subduction of the Farallon Plate beneath the North American Plate produced a broad belt of volcanism that formed the ancestral Western Cascade Range. Rhyolite to basalt lava flows, lahars, tuffs, and volcaniclastic rocks formed a volcanic highland trending roughly north (Tolan and Beeson, 1984). Up to 6,000 m of volcanic rocks and volcaniclastic and marine sediment define the Ohanapecosh Formation (Figure 5.1). Volcanic activity was intermittent with times of erosion and intense weathering of the deposits.

The Ohanapecosh Formation is the oldest rock unit exposed in the Gorge. The rocks are basalt to rhyolite lava flows and volcaniclastic rocks (including tuff and lahars), heavily weathered and intercalated with marine sediment (Tolan and Beeson, 1984) (Figure 5.1). The most striking feature is their uniform and widespread zeolitic and argillic alteration. Due to this alteration, the primary joints, vesicles, and other cavities are commonly filled, which results in very low permeability (Waters, 1973). Numerous large slides move on the upper surface of the unit where water collects.

In late Oligocene and early Miocene time, rotation of the subducting plate boundary or the steepening of the angle of the subducting plate resulted in renewed volcanism and a retreat of the ocean shoreline to the west. Primarily andesitic lava and lahars with interstratified laharic breccia and fluvial conglomerate make up the nearly 1,500-m-thick Eagle Creek Formation and correlative formations above the Ohanapecosh Formation (Tolan and Beeson, 1984). The top of the Eagle Creek Formation is marked by an erosional unconformity most likely associated with temporary cessation of volcanic activity and subsequent weathering and soil development (Suchanek, 1974).

The Eagle Creek Formation unconformably overlies the Ohanapecosh with a pervasive saprolitic layer, in places, up to 30 m (100 ft) thick. The Eagle Creek Formation is characterized by fluvial conglomerate and andesitic lahars, andesitic lava and breccia, and rhyolite to dacite ash-flow tuff and other volcaniclastic rocks (Figure 5.1). Much of it was deposited from mudflows and slurry floods washed from nearby volcanoes. Consequently, the thickness is highly variable. In the headscarp scar of the Cascade Landslide Complex near Red Bluffs, over 300 m (1,000 ft) of bedded volcanic conglomerate and tuffaceous sandstone are exposed. On the Oregon shore of the Columbia River Gorge, the thickest deposit observed is 250 ft in McCord Creek about 5 mi west of Cascade Locks (Waters, 1973).

Volcanic activity originating in what is now northeastern Oregon was to dramatically change the processes at work. There, voluminous and low-viscosity flows of basalt and basaltic andesite lava of the Columbia River Basalt Group began flowing westward from fissures at approximately 17 Ma, blanketing the landscape and forming a level plateau (Figure 5.2). By 15 Ma, these flood basalts had advanced down the ancient river channels to reach the sea more than 750 km away (Tolan and others, 1989). It is estimated that the total volume of Columbia River Basalt Group flows approaches 175,000 km3 (Tolan and others, 1989).

Although not all the Columbia River Basalt flows made it as far west as the Gorge, enough of them did to form a flow-on-flow landscape that is now marked by thick-layered, columnar-jointed walls of the present-day Gorge. These lava flows uncomformably overlie the weathered Ohanapecosh and Eagle Creek Formations. Several flows of the Frenchman Springs Member (approximately 15 Ma) have been identified as intracanyon flows that delineate channels of the ancestral Columbia River through the Cascade Range (Tolan and Beeson, 1984). The youngest intracanyon flow, the Pomona Member (approximately 12 Ma), is exposed in the Gorge overlying the fluvial sand and gravel deposits of the ancestral Bridal Veil Channel of the Columbia River in the Troutdale Formation (Anderson, 1980) (Figure 5.1).

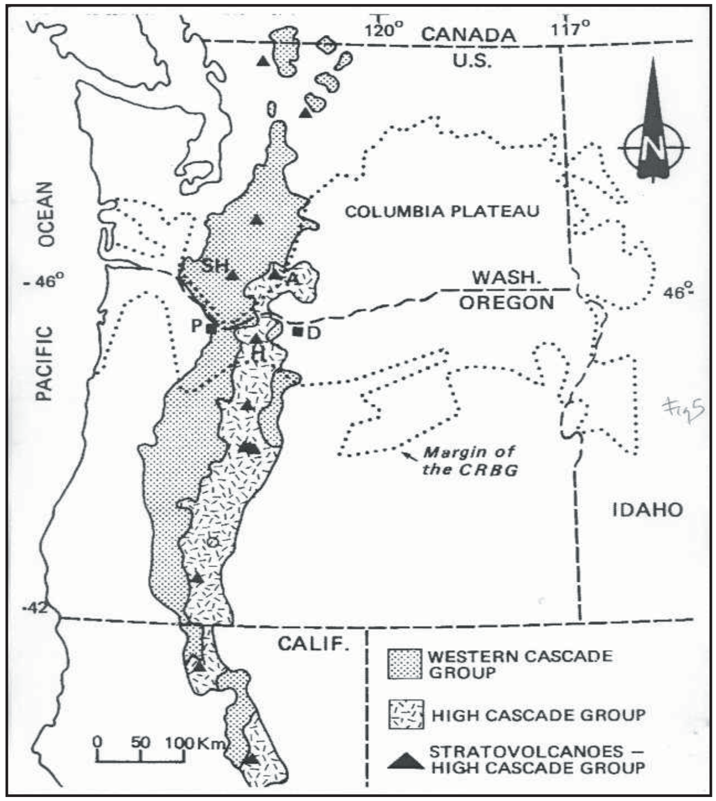


Figure 5.2. Generalized map showing distribution of Western Cascade, High Cascade, and Columbia River Basalt Groups. P=Portland, D-The Dalles, H=Mount Hood, SH=Mount St Helens, A=Mount Adams, CRBG=Columbia River Basalt Group (Tolan and Beeson, 1984).

Both the Ohanapecosh and Eagle Creek Formations, shown stratigraphically in Figure 5.1, are prone to slope instability. Consequently, the overlying strata, commonly basalt flows of the Columbia River Basalt Group are subject to sliding as well, especially along the tilted upper surface of the weathered Ohanapecosh Formation.

High Cascade volcanism began in the early Pliocene (Orr and Orr, 1999). An initial period of explosive volcanism that was centered in the ancestral Mount Hood area resulted in the deposition of andesitic to dacitic lahars, tuffs, and agglomerates of the Rhododendron Formation (Figure 5.1). Regional tectonic activity also began to form a series of northeast-trending folds warping the relatively flat-lying lava flows of the Columbia River Basalt Group. In the area of the Columbia River Gorge, the dip slope is now between 2 and 8^{o} south.

By 5 Ma, local volcanism of the high-alumina basalt flows of the High Cascades and the Boring volcanic field farther to the west were choking the ancestral Columbia River channel with hyaloclastic debris (Tolan and Beeson, 1984) (Figure 5.1). The continued filling of the channel by local basaltic lava and volcaniclastic debris forced the Columbia River to migrate northward. The river eventually established the modern-day channel where the more resistant Columbia River Basalt flows made contact with the southward-dipping, more easily eroded, underlying sedimentary and volcanic deposits (Tolan and Beeson, 1984; Orr and Orr, 1999).

Although volcanic activity during the Quaternary seems quite dramatic, with stratovolcanos such as Mount Hood and Mount St. Helens visible from the Gorge, it has actually decreased steadily since the middle Miocene (Orr and Orr, 1999). The present-day High Cascades consist of relatively small volcanic centers positioned upon the lava plateau of the earlier Western Cascade volcanism (Figure 5.2).

All this continental arc volcanism had been the result of the subduction of the Juan de Fuca Plate beneath the North American Plate. During the Pleistocene, the Columbia River Gorge was widened by jökulhlaups (glacial outburst floods) from glacial Lake Missoula in Montana. Although the flooding had no impact on the course of the Columbia River, it did leave lasting impressions on the landscape, from the channeled scablands to the northeast, to the kilometers-long, ripple-marked sand-and-gravel deposits on the Columbia Plateau, the gravel deposits underlying Portland, and the fertile silt deposits of the Willamette Valley. In addition, these Missoula floods oversteepened the Gorge walls, which exacerbates slope instability.

6.0 GEOLOGIC HAZARDS

The risk to commerce and economic activity from geologic hazards in the Columbia River Transportation Corridor may be relatively low but is still significant. Waterways, roads, bridges, tunnels, and overpasses are exposed to a variety of geologic risks from hazards, such as earthquakes and landslides. For example, waterway facilities (e.g., navigational locks, movable bridges), and roads can experience damage from fill failures, culverts clogging, rockfalls and to large global landslides that includes many road miles. Bridges and bridge abutments that are part of the mainline can fail. Tunnels, including the portals, can have unstable slopes (Figure 6.1). Overpasses can become a collapse hazard on a road that otherwise experiences no damage. Oftentimes, lifelines are carried across bridges, such as water and communication lines.

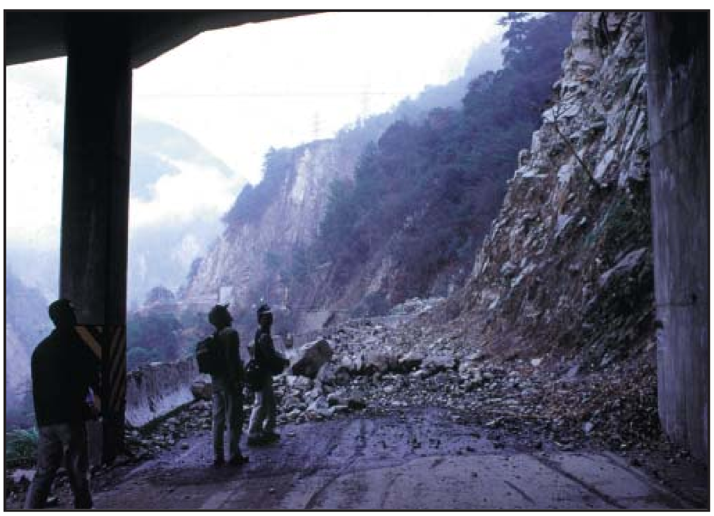


Figure 6.1. Rockfall triggered by earthquake shaking at a tunnel portal in the 1999 ChiChi, Taiwan earthquake (Photo credit: David K. Keefer).

6.1 Landslides and Landslide Hazards

The Gorge with its steep slopes and high rainfall commonly experiences slope failures. Active landslides of diverse types can be found, each producing its own specific hazard. For example, fast-moving landslides such as rockfalls, rock avalanches, and debris flows pose direct threats to life and property (Figure 6.2). Slow-moving landslides that bulge near the toe pose maintenance concerns for highways, railroads, and other lifelines. River bank failures and underwater landslides, including lateral spreading induced from high pore water pressures or ground shaking, can occur also.

The hydrogeologic conditions of the stratigraphic units increase the risk of sliding. Precipitation readily penetrates the columnar and hackly joints of the upper basalt flows and volcaniclastic deposits. This water tends to collect when it intercepts the less permeable Eagle Creek Formation. This condition is repeated where the Eagle Creek Formation, which has a much higher hydraulic conductivity and porosity, is in contact with the Ohanapecosh Formation, which has a very low hydraulic conductivity. Both geologic contacts provide weak, slide-prone surfaces for the thick, dense overlying basaltic lava flows (Waters, 1973).

Although the rocks typically dip only gently toward the south in the western part of the Gorge, the nature of the landslides is largely controlled by this dip. Washington landslides tend to be of a large scale and produce low slope angles after coming to rest. On the Oregon side of the Gorge, although the geology is the same, the rocks are less susceptible to large-scale landsliding because they dip into the Gorge valley walls, but landsliding problems tend to persist. For example, according to the Oregon Department of Transportation, the Fountain Landslide, 3 mi east of Cascade Locks, has remained active for more than 35 years and regularly causes distress to I-84 (Shuster and Chleborad, 1989).

In February 1996, heavy rains triggered several debris flows , including the large Dodson debris flow, which inundated a home (Figure 6.3), buried U.S. Interstate Highway 84 and the railroad and entered the Columbia River before entering the river.

Figure 6.2. Steep, landslide-prone slopes, including the Oregon Shore landslide and barge traffic near Cascade Locks, Oregon.

Rapidly moving landslide hazards have been mapped by DOGAMI for the western portion of the transportation corridor, from Hood River County on the east to Portland on the west (Hofmeister and others, 2002, 2003). This portion has historically experienced rapidly moving landslides in the steeply sloped areas; however, other portions of the transportation corridor can experience such landslides as well.

The website < http://www.coastalatlas.net/learn/topics/hazards/landslides> provides transportation data and coverage for topography, orthophotos and shaded elevation (Oregon Ocean-Coastal Management Program). In addition, it includes the above-mentioned DOGAMI landslide hazard maps for the transportation corridor. Figure 6.4 shows custom maps that include the Bonneville Dam and three close-up maps of the same region: landslide hazards on topography, landslide hazards on an orthophoto and landslide hazards on shaded relief.

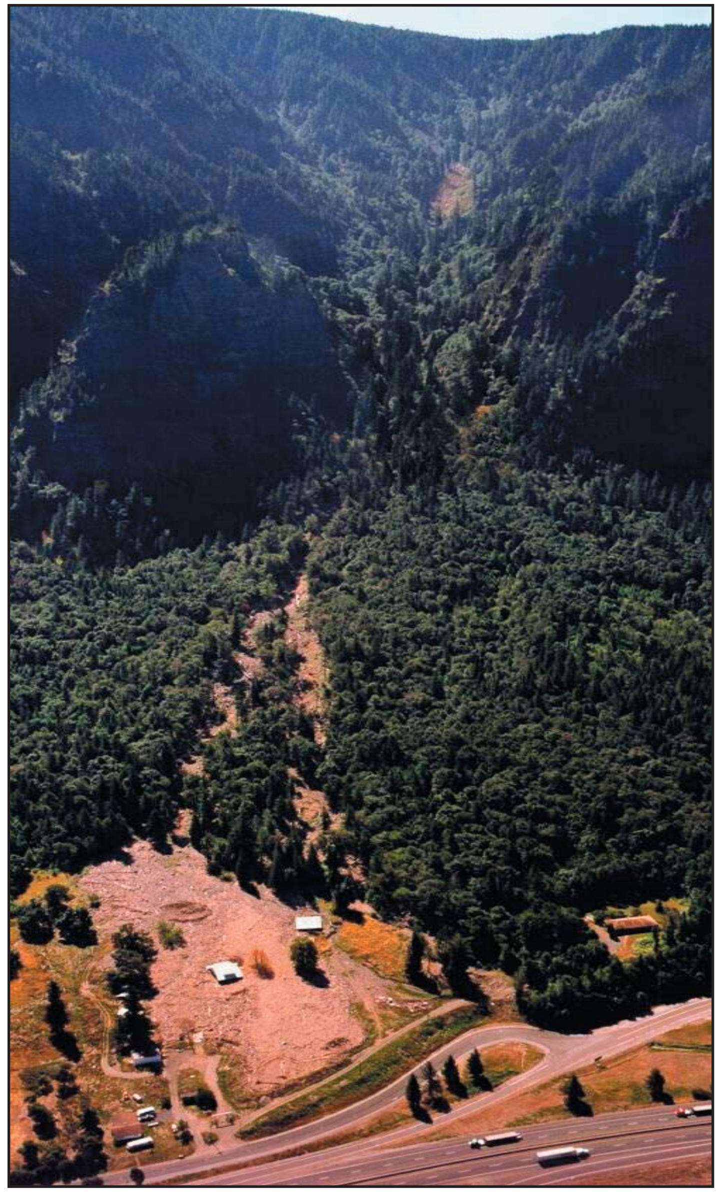


Figure 6.3. The 1996 Dodson debris flow inundated this residence before crossing I-84 and the railway and entering the Columbia River (photo: ODOT).

Additional digital coverage for this transportation corridor can be obtained at http://www.inforain.org/interactivemapping/gorge.htm. This website allows for interactive custom maps.

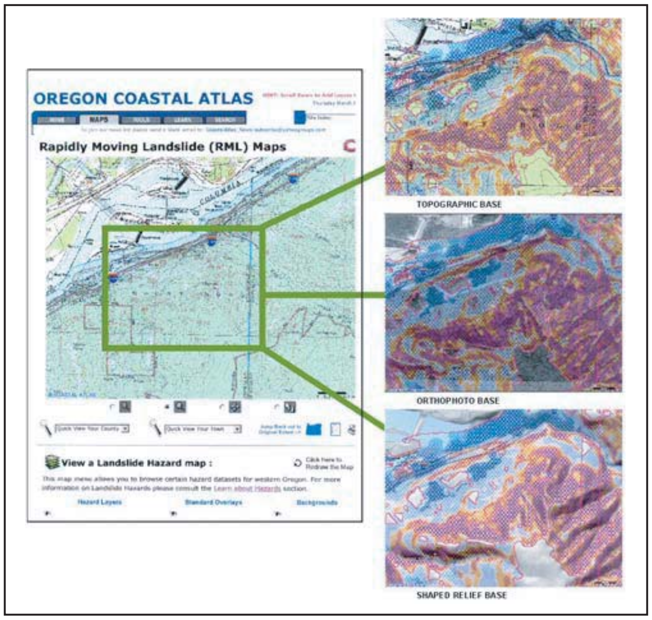


Figure 6.4. An example of DOGAMI rapidly moving landslide maps on three base maps near Bonneville Dam, located in the upper left part of the insets (modified from Oregon Ocean-Coastal Management Program and Hofmeister, and others, 2002).

Additional landslide maps are available. For example, the mapped landslides in the central Gorge region are shown on Figure 6.5.

The Oregon Department of Transportation has mapped the locations that are susceptible to rockfall risks (Figure 6.6). On December 9, 2003, a

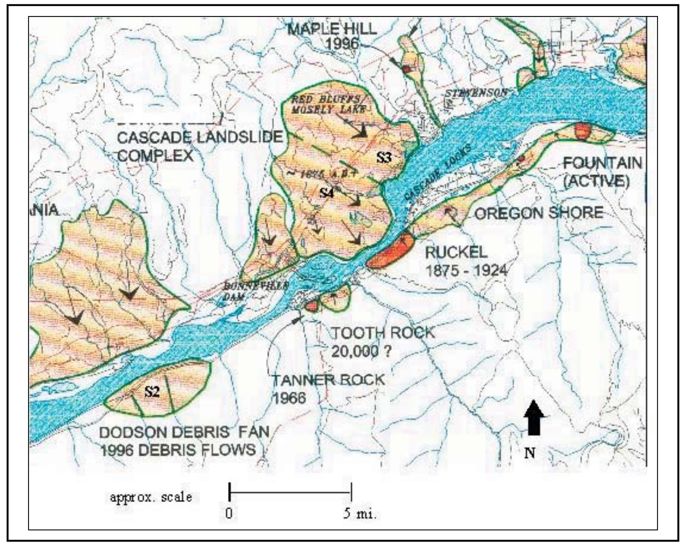


Figure 6.5. Landslide map of the central Gorge region (Squier Associates, 1999).

rockfall was triggered by freeze-thaw exposure at one of their mapped high-risk locations (Figure 6.7). Rocks estimated at 5 ft in diameter fell from a 150-ft-high vertical slope with overhanging areas and hit I-84 before entering the river. The rockfall damaged several cars and caused a closure of the I-84 for several hours in both directions. Rock falls in the Gorge have been known to have caused fatalities.

Regional impacts on the transportation systems are expected. Episodic debris-flow activity near Multnomah Falls, Warrendale, and Dodson has forced road and rail line closures. In 1996, the debris flows at Dodson and Tumalt Creek in Warrendale closed I-84 and the railroad for five and three days, respectively. Again in December 2001, a series of debris flows buried and closed the I-84 Exit 35 on-ramp in Dodson for over 12

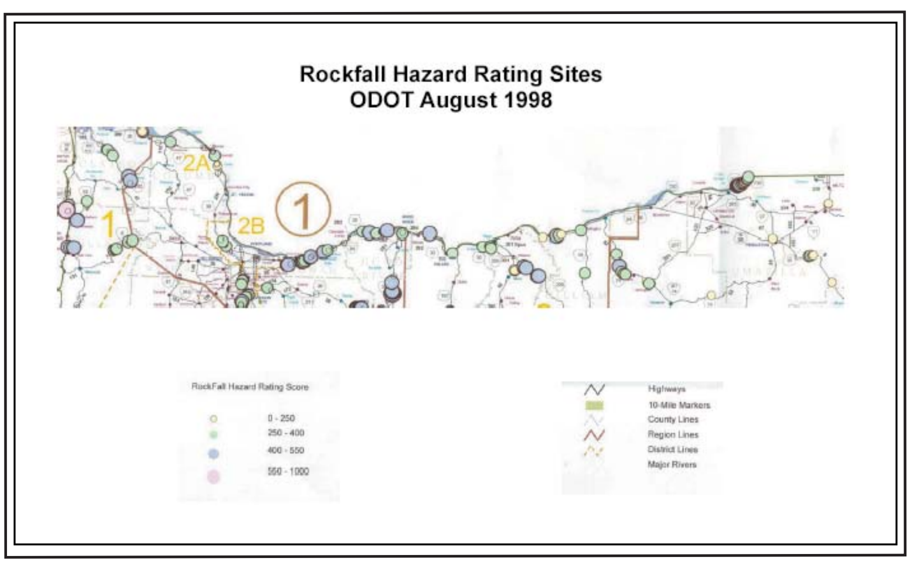


Figure 6.6. Oregon Department of Transportation rockfall risk map.

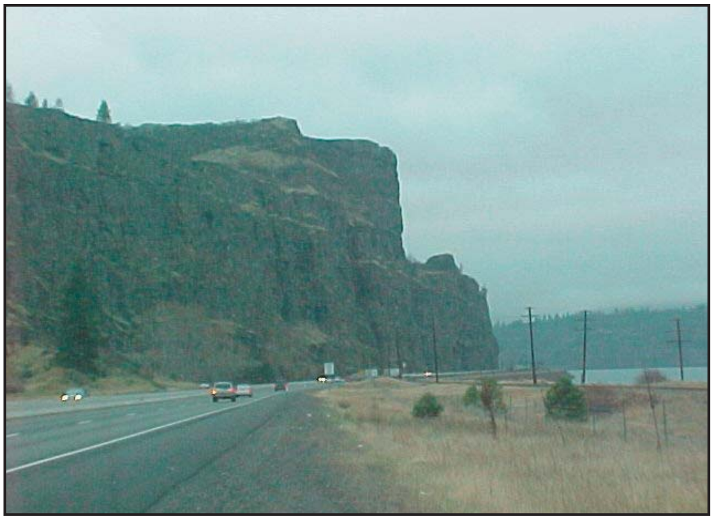


Figure 6.7. A rockfall, which occurred in a previously identified ODOT high-risk location, forced a temporary closure on I-84 (ODOT photograph by B. Dehart).

days. This debris flow was very fluid, and mud lines were observed as high as 23 m (75 ft) up tree trunks in the transport zone.

6.2 Earthquakes and Earthquake Hazards

Earthquake hazards are from shallow, crustal earthquakes and Cascadia Subduction Zone earthquakes, which occur at intervals ranging from decades to hundreds of years. In a typical year, several dozen small earthquakes are recorded near the northeastern portion of the study area for the U.S. Department of Energy Hanford site (Pacific Northwest National Laboratory, 2003). The USGS has mapped peak ground accelerations with a two-percent probability of exceedance in 50 years for the entire region (Figure 6.8). These ground shaking maps, which are available on the USGS website, indicate a significant risk to the dam facilities. The shaking is expected to trigger numerous rockfalls and landslides along the corridor, some of which would impact the waterways. Potentially costly coseismic geohazards include seiches, landslides, lateral spreading, liquefaction, and fault rupture. Volcanic earthquakes are considered to be less likely than earthquakes from a tectonic source. Earthquake records show that Mount Hood typically experiences one to three small earthquake swarms (tens to more than one hundred earthquakes lasting 2 to 5 days) every year.

Earthquake shaking in 2001 from the magnitude 6.8 intraplate earthquake at Nisqually, Washington, triggered rockfalls in the Gorge (David Keefer, U.S. Geological Survey, oral communication, 2001). Past earthquakes are suspected to have triggered large-scale landsliding. Naturally, future earthquakes also are expected to trigger landslides in this region.

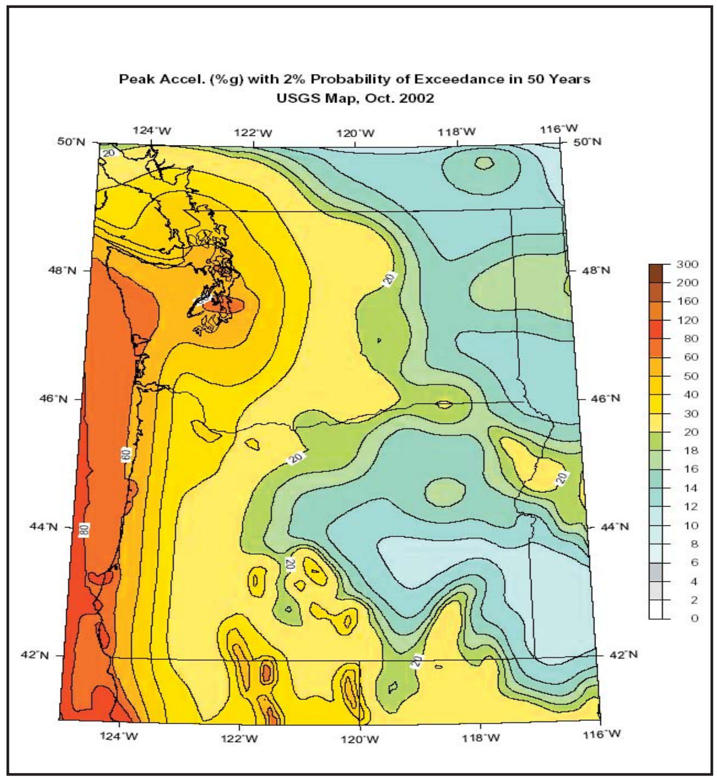


Figure 6.8. U.S. Geological Survey earthquake shaking map (Frankel and others, 2002).

6.3 Volcanoes and Volcanic Hazards

Volcanic hazards in the Cascade Range, including eruptions and lahars, occur in intervals of decades. Figure 6.9 shows the hydro-electric facilities at The Dalles with Mount Hood, an active volcano, in the background. The USGS has mapped the areas that are estimated to be in the lahar risk zones for Mount Hood, as shown on Figure 6.10.

Lahars are fast-moving landslides, or debris avalanches, that are triggered by volcanic activity. Mount Hood's last major eruption occurred in the 1790s, not long before the Lewis

Figure 6.9. View of The Dalles hydroelectric facilities and Mount Hood, an active volcano, in the background (USACE photo).

and Clark expedition to the Pacific Northwest. A tremendous amount of volcanic rock and sand entered the Sandy River drainage at that time and is easily seen on the riverbanks between the Columbia River and U.S. Interstate Highway 84. Other events include one lahar in 1980, causing one fatality, and another one 1,500 years ago with significant deposits. About 100,000 years ago, a large portion of the north flank and summit of Mount Hood collapsed. A debris avalanche was formed from this collapse and developed into a lahar that swept down the Hood River Valley. The lahar crossed the Columbia River and surged up the White Salmon River on the Washington side. The lahar deposit is 400 ft deep where the town of Hood River now stands.

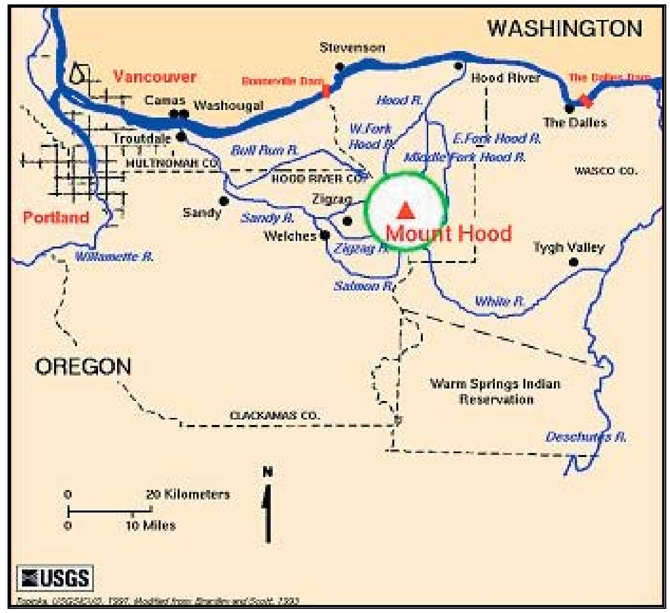


Figure 6.10. U.S. Geological Survey map showing volcanic lahar hazard zones (Gardner and others, 2000).

6.4. Flood Hazards

Before the dam system was constructed in the Columbia River and its tributaries, the flooding hazard was significant (Figure 6.11).

Figure 6.11. Flooding in downtown Portland in 1948 (US ACE photo).

In 1948, the town of Vanport on the Columbia

River was destroyed due to the failure of a railroad embankment and ensuing severe flooding. The current system of dams has largely controlled the flooding. However, due to the large watershed, flooding damage is still a hazard to communities and infrastructure. In the 1996 floods, liquefaction was triggered by the excess pore water pressures in the vicinity of the levee that protects the Portland International Airport. Sand boils were observed on the landward side of the levee. If flooding conditions are worse than in 1996, or if earthquake shaking occurs, it is possible that more extensive liquefaction and levee failure could occur. The levee, which was studied by the USACE, was found to be stable for river levels below an elevation of 42.2 ft (USACE, 2001) and potentially unstable for river level above. In addition, two worst-case scenarios (discussed below) reveal that flooding in low-lying areas, including parts of downtown Portland, Swan Island, and more, are possible.

7.0 Summary Assessment of Risks

The geologic hazards include rockfalls, debris flow landslides, volcanic landslides, earthquake ground shaking, floods, and dam stability hazards and can produce damage ranging from minor to significant. Large landslides and floods, including debris flows, are likely to occur frequently during heavy storms but are anticipated to have minimal effect on the waterway traffic. Landslides pose risk mostly to rail and highway traffic. However, a catastrophic landslide, such as a lahar or rock avalanche near a dam facility, could impact the waterway. Distant earthquakes that are centered over 50 miles away are likely to occur and cause minor rockfalls in the corridor, such as occurred in the 2001 Nisqually, Washington, earthquake. A great Cascadia earthquake, local earthquakes, and volcanic landslides are likely to occur and have damaging effects on the waterway traffic and dam facilities. The return period of these events is on the order of hundreds to thousands of years.

The hydroelectric facilities, including the locks and dams, require major capital improvements according to the Pacific Northwest Waterways Association. At the Bonneville Lock and Dam facilities, the north lock wall needs to be upgraded to prevent possible failure during an earthquake. Spillway power distribution equipment needs replacement and replacement parts are no longer available for the original equipment. The Dalles Lock has experienced continued aging/degradation that may lead to a future outage if not maintained. The John Day facilities require extensive structural repairs at an estimated cost of over $20 million. The lock and dam are founded on Miocene-aged basalts and flow breccia. Significant movement and distress in concrete structures of the navigation lock have been observed. A new downstream lock gate will be needed by 2008. A failure of the upstream lock gate occurred in 2002. Fortunately, a floating bulkhead can be used as a temporary upstream gate so that the navigation system can remain open while the permanent gate is being repaired.

We conducted a preliminary analysis of the bridges in seven counties using HAZUS99, FEMA software (FEMA, 1999) that estimates damage and losses from earthquake shaking. Our preliminary results show 31 bridges (located county wide and not just on I-84) with at least moderate damage from 1,000-yr probabilistic ground shaking levels and $24 million of direct losses to bridges (Appendix A: Summary of HAZUS results). However, in mid-2003, during the course of this study, the Oregon legislature passed an important transportation bill (House Bill 2041), which is referred to as Oregon Transportation Investment Act III (OTIA III). This Act augments the Statewide Transportation Improvement Program (STIP) with $2.5 billion. Over half of the $2.5 billion OTIA III funds will be spent on replacing and repairing state bridges, starting January 2004. Because all of I-84 is considered to be a critical freight route, all the bridges with weight capacity restrictions and non-seismic-related maintenance issues will be repaired or replaced.

The Oregon Department of Transportation (ODOT) owns 130 bridges on I-84 within the study region. ODOT's draft plan is to replace 25 of the bridges and repair seven of the bridges within the next five years in OTIA III phase 2. The bridges that are being replaced or repaired were constructed between 1942 and 1987. Five of the bridges in this corridor are considered to be highly vulnerable to earthquake hazards. After OTIA III is implemented, only three bridges from the "high priority" earthquake-vulnerability list will remain highly vulnerable to earthquake damage. These three I-84 bridges were each constructed in 1963 and are located within the first half-mile to the I-5 interchange (Don Crowne, ODOT, oral communication, December 2003). See

Appendix B for a list of the 130 bridges, which includes the replacement, repair, and earthquake retrofit status.

Vulnerable bridges and overpasses will pose a threat. For example, the I-84 interchange at Bridal Veil (exit 28) will still pose a collapse hazard onto I-84. The asymmetric construction of the off ramp and the absence of an on ramp contribute to vulnerabilities relating to torsion (Figure 7.1). Also, the movable bridges associated with river navigational locks at the hydroelectric facilities are vulnerable to small movements. If, for example, the movable bridge at Bonneville Dam cannot operate, then the locks will also not operate.

Figure 7.1. The Bridal Veil exit 28 off-ramp on I-84 is susceptible to earthquake damage.

ODOT relies on emergency routes during disasters, such as Highway 35 in Hood River County and Interstate Highway I-205 that connects to the Portland Airport (PDX). The slope adjacent and east of Highway 35, located just south of the I-84 interchange, is highly vulnerable to landslides (Figure 7.2). This steep slope exposes a fault that juxtaposes river channel deposits with basalts, and seeps that contribute to its instability. In contrast, the I-205 bridges that approach PDX from I-84 are considered to be less vulnerable to earthquake damage. These were generally constructed in the early 1980s and are not listed on the high-priority list of bridges vulnerable to earthquake damage. However, because numerous bridges cross over I-84 and I-205, especially on the access routes from downtown Portland, it is possible that collapses of overpasses will hamper initial emergency response efforts. Emergency plans that accommodate a reduced traffic capacity would be prudent.

Figure 7.2. Highway 35 just south of I-84 is susceptible to landslide failure.

8.0 WORST-CASE SCENARIOS

We have identified two low-probability, worst-case scenarios for this portion of the waterway as part of this study. They were presented to and published by the American Society of Civil Engineers (Wang and Scofield, 2003).

8.1 Worst-Case Scenario One: Landsliding

One scenario is a natural recurrence of a large-scale failure of the steep canyon walls similar to the Cascade Landslide Complex. We hypothesize that the Cascade Landslide Complex is affected by earthquake shaking (similar to the 1959 Montana earthquake that caused the Hebgen Lake landslide) or possibly nearby volcanic activity. Figure 8.1 shows a computer image of the Cascade Landslide Complex looking west. This landslide complex is monitored with instrumentation and is considered to be active. Two distinctly separate headscarps on the right side of the image form the top of the complex. The headscarps appear to be divided by the axis of a synform, which indicates past earthquake activity, and a volcanic feature. The Bonneville landslide includes the westernmost headscarp, which is the landslide mass that temporarily blocked the Columbia River (Figure 8.2). The slide geomorphology and an assessment of known earthquake-triggered landslides suggest that this slide was induced by an earthquake (Wang and Scofield, 2003). We conclude that it is possible for such a significant landslide to recur in this area.

The Bonneville facilities are constructed on the western most and youngest slide, which is on the toe of this landslide. The younger Bonneville landslide blocked and diverted the Columbia River south by over onemile, as shown in Figures 8.1 and 8.2. A similar event occurring today would result in complete disruption of transportation through the Gorge and heavy damage to, perhaps complete destruction of, major facilities upstream including dams, small cities, and industrial sites. The low-lying areas in Portland, including the port facilities and much of down-

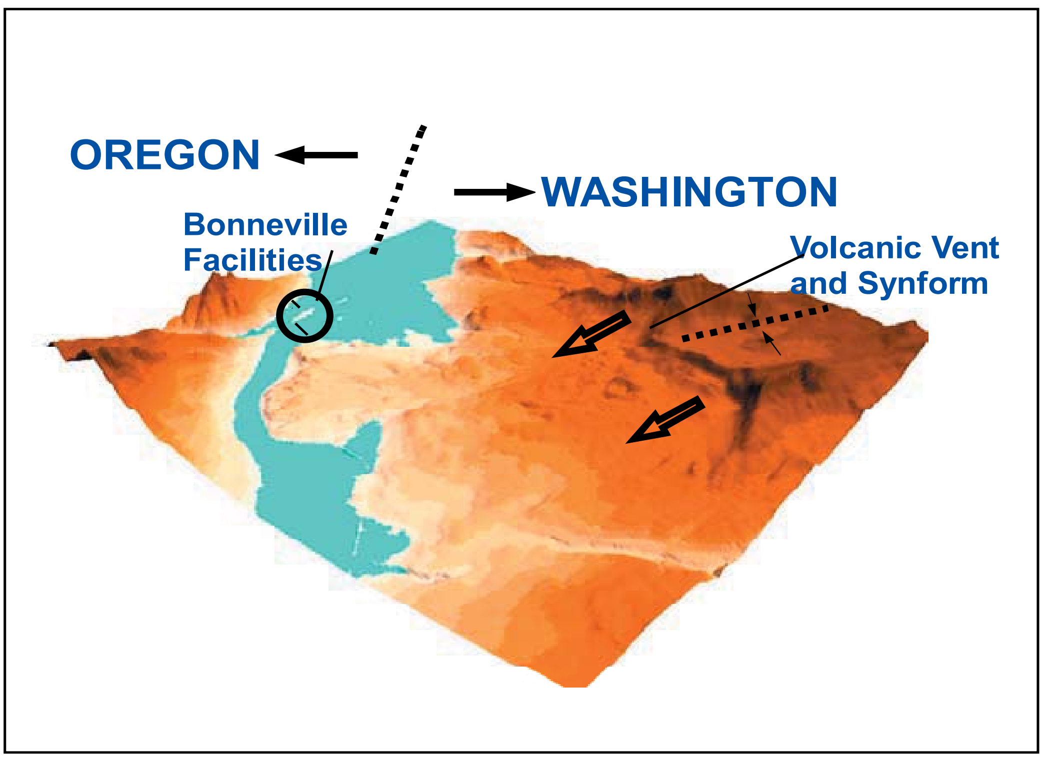


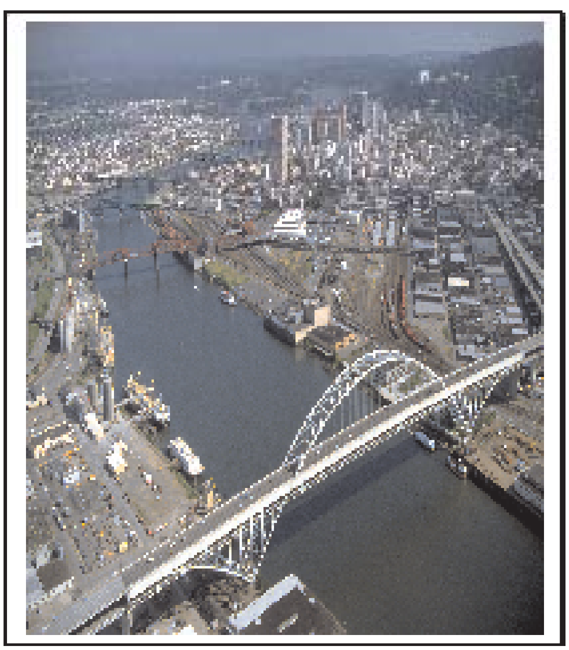
Figure 8.1. The Cascade landslide complex showing two separate landslides (Image source: R. Wardell and Y. Wang).

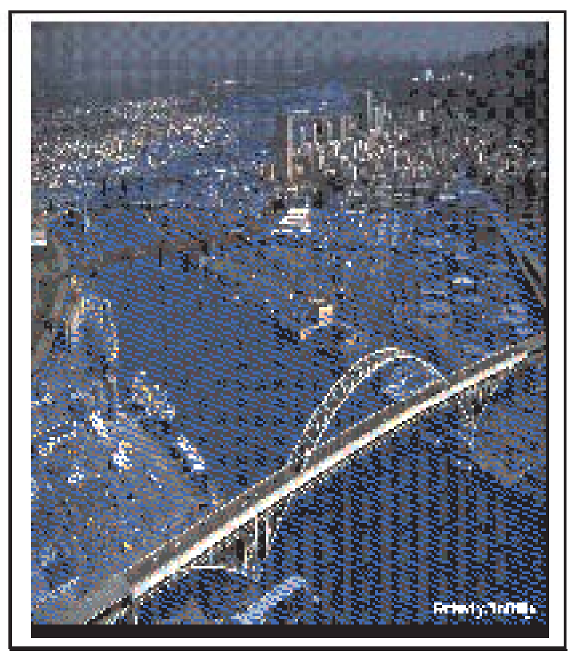
town Portland, would be heavily damaged (Figures 8.3 and 8.4).

Figure 8.2. Oblique aerial photograph of the Cascade landslide complex and Bonneville Dam facilities (source: D. Cornforth).

The Bonneville Lock and Dam includes two powerhouses, a spillway, a navigation lock, (Figures 8.5 and 8.6), fish facilities, and the Bonneville Power Administration (BPA) electrical switchyards. If destroyed, the facility would probably require over 10 years and $2 billion to replace today. It is also possible that only portions of the facility may become inoperable due to geologic hazards. For example, earthquake shaking could lock up the movable bridge that operates in conjunction with the navigational lock. That would render both the bridge and locks inoperable (Figure 8.6).

Figure 8.5. Bonneville facilities (source: U.S. ACE Digital Visual Library).





Figures 8.3 and 8.4. Hypothetical Portland flooding sequence from a Bonneville Dam breach.

Figure 8.6. Bonneville navigation lock and moveable bridge (source: US ACE Digital Visual Library).

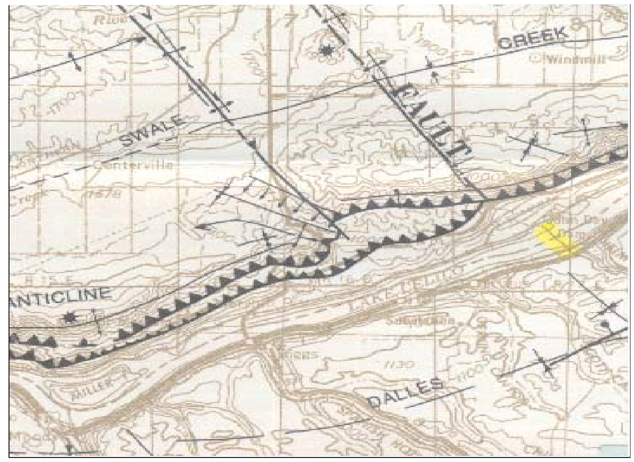


Figure 8.8. Neotectonics in the John Day Lock and Dam area showing nearby active fault structures. The dam is located to the right of the center (source: Bela, 1982).

8.2 Worst-Case Scenario Two: Flooding

The second scenario is a catastrophic failure and release from John Day Lock and Dam (Figure 8.7). Such a release has a very low probability and would require an extreme or infrequent event, such as a strong earthquake on a nearby fault. Figure 8.8 shows that a nearby active thrust fault exists just north of the dam facilities (Bela, 1982). Hartshorn and others (2003) discuss the seismicity of the area. This region is in an active compressive setting (although with very slow strain rates) and is therefore capable of generating damaging but infrequent earthquakes. Significant damages would extend downstream to the Pacific Ocean. Damages due to overtopping of dikes (US ACE, 2001) and levees would cause disruption to cities, including portions of downtown Portland, th Portland International Airport facilities, other smaller cities and power generation facilities, and transportation infrastructure. Figure 8.9 shows the Portland area flood inundation map, where major portions of downtown, the waterfront, and low-lying areas near the Columbia and Willamette Rivers would be flooded.

Figure 8.7. View of the John Day Dam (source USACE Digital Visual Library).

Inundation from flooding would have an impact on the transportation system and other lifelines, including the waterway traffic and hydroelectric facilities. The highways, including bridges and colocated lifelines, would sustain damage. The low-lying areas, including the port facilities, the rail terminals in Portland, Swan Island, and numerous petroleum tanks located near the Willamette River in northwest Portland, would be flooded. Figure 8.10 shows the following facilities in the flood inundation zone: the five Port of Portland terminals, the Union Pacific

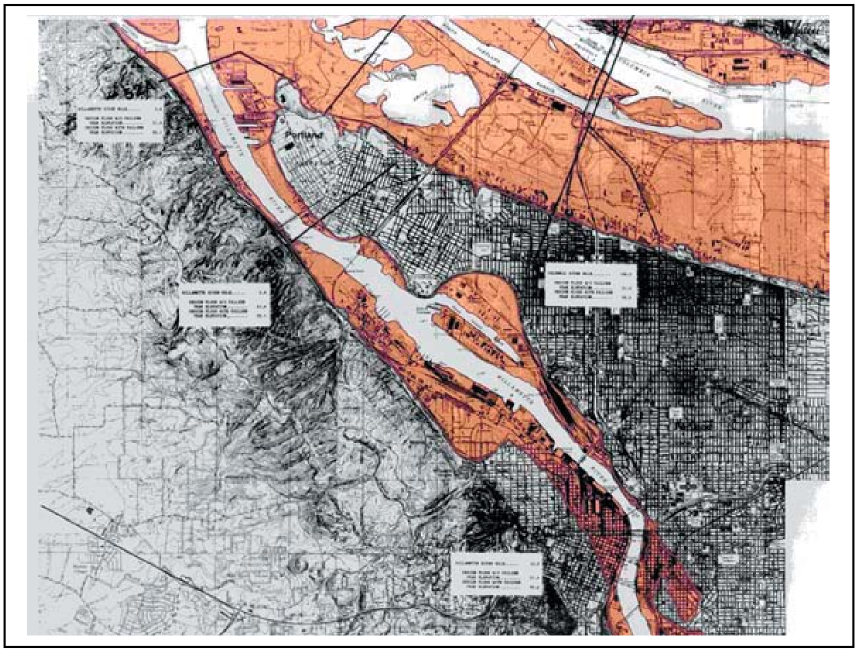


Figure 8.9. Portland area inundation map from a John Day Dam breach (USACE, 1989).

Albina yard and Brooklyn yard, the Burlington Northern Santa Fe Willbridge yard, and the Portland International Airport.

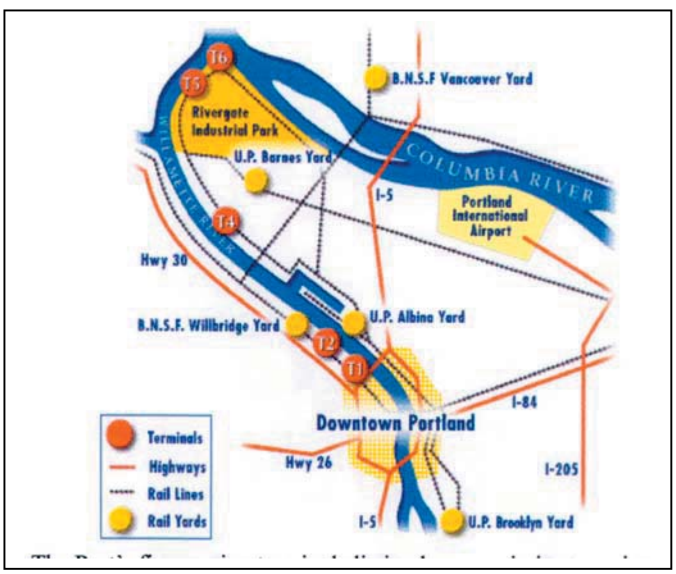


Figure 8.10. Sketch map showing port and rail terminal locations (Port of Portland website).

The Rivergate Industrial district, Mocks Landing Industrial Park, Swan Island Industrial Park, and Portland International Center are also in the flooding zone.

Inundation from flooding would have an impact on the transportation system and other lifelines, including the waterway traffic and hydroelectric facilities. The highways, including bridges and colocated lifelines, would sustain damage. The low-lying areas, including the port facilities, the rail terminals in Portland, Swan Island, and numerous petroleum tanks located near the Willamette River in northwest Portland, would be flooded. Figure 8.10 shows the following facilities in the flood inundation zone: the five Port of Portland terminals, the Union Pacific Albina yard and Brooklyn yard, the Burlington Northern Santa Fe Willbridge yard, and the Portland International Airport. The Rivergate Industrial district, Mocks Landing Industrial Park, Swan Island Industrial Park, and Portland International Center are also in the flooding zone.

9.0 CONCLUSION

Natural disasters can be particularly damaging to transportation infrastructure, because it extends over wide areas and is made up of a large number of components subject to failure. Large direct and indirect social and economic losses can be incurred: direct costs for repairing and restoring the functionality or partial functionality of the transportation infrastructure and indirect costs such as business interruptions, lossesof wage and income, and rental and relocation expenses. It is possible that repairing infrastructure damage will require years before it can return to normal service.

The Columbia River Transportation Corridor is significant to the economic health of the Pacific Northwest, especially the Portland region. Catastrophic damage is possible by large landslides, such as an earthquake-triggered landslides, by earthquake shaking, by flooding, and by volcanic activity. Two worst-case scenarios involving geologic hazards and dam failures have been identified. These have a very low probability of occurrence but would have major consequences and produce severe disruptions. Because of the serious consequences, a detailed study is needed to evaluate the likely economic impact and the possible cost to mitigate and to develop an emer-

10.0 FURTHER STUDIES

More detailed studies involving key stakeholders should be conducted on the worst-case scenarios that have been identified. Research and development that have the potential for improving the disaster resiliency of the Columbia River waterway and the parallel transportation system railways and I-84 should be conducted. Such studies have been identified as needed by the Governor's Oregon Seismic Safety Policy Advisory Commission (OSSPAC, 2000).

Further studies should address emergency preparedness, hazard evaluation, risk assessment, vulnerability reduction, mitigation plans and implementation mitigation. For example, table top exercises involving a design level earthquake (including analyses of infrastructure damage and loss) could be conducted with stakeholders and communities to develop a response plan can be conducted.

For transportation infrastructure, the importance of each component (i.e., link or node in the network) depends primarily on the consequences of an eventual failure. Thus, pertinent questions that may be researched are the following:

- How critical is the component to the function of the overall transportation system?
- Does the component provide access to an essential facility?
- Is the component part of an emergency transportation corridor?
- Is the transportation network topology such that a failure of the component will prevent access to certain areas of the community or of the region?
- Is the transportation network topology such that a failure of the component will have high societal impact for a long duration?
- How will the operations side (i.e., transportation operators, vehicles, traffic safety, power, command control and communications centers, and maintenance) of the transportation system function?

11.0 ACKNOWLEGEMENTS

The authors would like to thank Janet Benini, Dolph Diemont and Tom Sachs of the U.S. Department of Transportation for their leadership in funding this study. We gratefully acknowledge our reviewers, David Scofield and Vicki McConnell, and editor, Klaus K. Neuendorf. Also, we thank staff at the Oregon Department of Transportation, including Michael Long, Mark Hirota (now with Parsons Brinckerhoff Quade & Douglas), Rose Gentry, Rich Watanabe, Steven R. Kale, Ed Immel, Don Crowne, Brad Dehart, and the U.S. Army Corps of Engineers, including Rich Hannan, James Griffins and Carolyn Flaherty. Scott Drumm of the Port of Portland generously provided assistance with the economic transportation data. Robert Wardwell of the U.S. Geological Survey contributed his GIS and geologic expertise. The staff members at the Oregon Department of Geology and Mineral Industries were helpful, in particular Geneva Beck, who took the lead role on graphics.

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APPENDIX A

Quick Assessment Report

February 26, 2003

Regional Statistics

Area (Square Miles)		10,700
Number of Census Tracts		196
Number of Buildings		
Residential (x 1000)		216
Total (x 1000)		224
Number of People in the Region (x 1000)		693
Building Exposure ($ Millions)		
Residential		30,900
Total		43,100

Scenario Results

Maximum PGA (g)		0.34
Number of Buildings Damaged		
Damage Level	***Residential***	***Total***
Slight	72,200	73,200
Moderate	59,100	61,300
Extensive	12,300	14,100
Complete	6,100	7,600
Total	149,700	156,200
Casualties		
Severity 1 (Medical treatment without hospitalization)		6,289
Severity 2 (Hospitalization but not life threatening)		1,180
Severity 3 (Hospitalization and life threatening)		151
Severity 4 (Fatalities)		150
Shelter		
Displaced Households (# households)		17,970
Short Term Shelter (# people)		11,630
Economic Loss		
Property Damage (Capital Stock) Losses ($ Millions)		7,400
Business Interruption (Income) Losses ($ Millions)		3,670
Total ($ Millions)		11,070

Disclaimer:
The estimates of social and economic impacts contained in this report were produced using HAZUS loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, goetechnical, and observed ground motion data.

Study Region : USDOT_7counties-1

Scenario : 1000yr_counties

HAZUS 99: Earthquake Event Report

Region Name: USDOT_7counties-1

Earthquake Scenario: 1000yr_counties

Print Date: Wednesday, February 26, 2003

Disclaimer:
The estimates of social and economic impacts contained in this report were produced using HAZUS loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, goetechnical, and

Table of Contents

General Description of the Region

HAZUS is a regional earthquake loss estimation model that was developed by the Federal Emergency Management Agency and the National Institute of Building Sciences. The primary purpose of HAZUS is to provide a methodology and software application to develop earthquake losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from earthquakes and to prepare for emergency response and recovery.

The earthquake loss estimates provided in this report was based on a region that includes 7 county(ies) from the following state(s):

- Oregon

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 10,700 square miles and contains 196 census tracts. There are over 284 thousand households in the region and has a total population of 693,000 people (1990 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 224 thousand buildings in the region with a total building replacement value (excluding contents) of 43,125 million dollars (1994 dollars). Approximately 96% of the buildings (and 72% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 27,295 and 4,712 million dollars (1994 dollars), respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 224,000 buildings in the region which have an aggregate total replacement value of 43.13 million dollars (1994 dollars). Figure 1 presents the relative distribution of the value with respect to the general occupancies. Appendix B provides a general distribution of the building value by State and County.

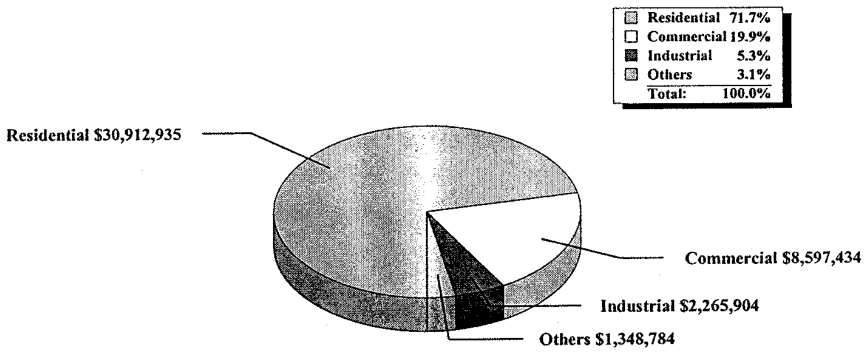

Figure 1: Building Exposure by Occupancy Type
(Thousands of dollars)

In terms of building construction types found in the region, wood frame construction makes up 89% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

HAZUS breaks critical facilites into two (2) groups: essential facilities and high potential loss (HPL) facilities. Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

For essential facilities, there are 22 hospitals in the region with a total bed capacity of 3,076beds. There are 278 schools, 35 fire stations, 33 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 71 dams identified within the region. Of these, 19 of the dams are classified as 'high hazard'. The inventory also includes 2,674 hazardous material sites, 0 military installations and 0 nuclear power plants.

Transportation and Utility Lifeline Inventory

Within HAZUS, the lifeline inventory is divided between transportation and utility lifeline systems. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The lifeline inventory data is provided in the Tables 2 and 3.

The total value of the lifeline inventory is over 32,007 million dollars. This inventory includes over 2,052 kilometers of highways, 1,171 bridges, 0 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Major Roads	224	20,522
	Bridges	1,171	3,205
	Tunnels	2	20
		Subtotal	23,747
Railways	Rail Tracks	948	2,005
	Bridges	0	0
	Tunnels	4	40
	Facilities	0	0
		Subtotal	2,045
Light Rail	Rail Tracks	0	0
	Bridges	0	0
	Tunnels	0	0
	Facilities	0	0
		Subtotal	0
Bus	Facilities	1	1
Ferry	Facilities	0	0
Port	Facilities	61	92
Airport	Facilities	58	319
	Runways	39	1,092
		Subtotal	1,411
		Total	27,295

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Pipelines	0	0
	Facilities	0	0
		Subtotal	0
Waste Water	Pipelines	0	0
	Facilities	1	60
		Subtotal	60
Natural Gas	Pipelines	19	0
	Facilities	0	94
		Subtotal	94
Oil Systems	Pipelines	6	18
	Facilities	15	30
		Subtotal	48
Electrical Power	Facilities	5	2,500
Communication	Facilities	133	266
		Total	4,712

Earthquake Scenario

HAZUS uses the following set of information to define the earthquake parameters used for the earthquake loss estimate provided in this report.

Scenario Name	1000yr_counties
Type of Earthquake	Probabiltistic event
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	4
Longitude of Epicenter	NA
Latitude of Epicenter	NA
Earthquake Magnitude	7.00
Depth (Km)	NA
Rupture Length (Km)	
Rupture Orientation (degrees)	NA
Attenuation Function	NA

Building Damage

HAZUS estimates that over 83 thousand buildings will be at least moderately damaged. This is over 37% of the total number of buildings in the region. There are an estimated 7,569 buildings that will be completely destroyed. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the HAZUS technical manual. Table 4 below summaries the expected damage by general occupancy for the buildings in the region. Table 5 summaries the expected damage by general building type.

Table 4: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Residential	66,847	98.28	72,162	98.59	59,130	96.46	12,294	87.12	6,134	81.04
Commercial	769	1.13	791	1.08	1,604	2.62	1,353	9.59	1,067	14.10
Industrial	202	0.30	137	0.19	372	0.61	352	2.49	290	3.83
Agriculture	77	0.30	27	0.00	34	0.06	11	0.08	5	0.07
Religion	72	0.11	52	0.00	108	0.18	66	0.47	49	0.65
Government	2	0.00	4	0.00	4	0.01	3	0.02	2	0.03
Education	47	0.07	22	0.03	47	0.08	32	0.23	22	0.29
Total	68,016		73,195		61,299		14,111		7,569	

Table 5: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	289	0.4	246	0.3	489	0.8	427	4.6	346	3.0
Mobile Homes	2,041	3.0	2,786	3.8	4,640	7.6	2,966	24.2	1,828	21.0
Precast Concrete	215	0.3	111	0.2	448	0.7	511	5.9	446	3.6
Reinforced Masonry	322	0.5	223	0.3	571	0.9	511	4.8	366	3.6
Steel	470	0.7	154	0.2	430	0.7	515	5.9	447	3.6
Unreinforced Masonry	225	0.3	337	0.5	750	1.2	731	8.7	661	5.2
Wood	64,454	94.8	69,338	94.7	53,971	88.0	8,450	45.9	3,475	59.9

Essential Facility Damage

Before the earthquake, the region had 3,076 hospital beds available for use. On the day of the earthquake, the model estimates that only 7,854 hospital beds (12%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 24% of the beds will be back in service. By 30 days, 50% will be opreational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		With at Least Moderate Damage	With Complete Damage	with Functionality > 50% at day 1
Hospitals	22	22	0	0
Schools	278	278	0	32
EOCs	2	2	0	1
Police Stations	33	33	0	27
Fire Stations	35	35	0	6

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 % After Day 1	With Functionality > 50 % After Day 7
Highway	Roads	224			224	224
	Bridges	1,171	31	1	1,171	1,171
	Tunnels	2	0	0	2	2
Railways	Tracks	0			948	948
	Bridges	0	0	0	0	0
	Tunnels	4	0	0	4	4
	Facilities	0	0	0	0	0
Light Rail	Tracks	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	1	0	0	1	1
Ferry	Facilities	0	0	0	0	0
Port	Facilities	61	0	0	61	61
Airport	Facilities	58	16	1	58	58
	Runways	39	0	0	39	39

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8-10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Table 8 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 % After Day 1	with Functionality > 50 % After Day 7
Potable Water	0	0	0	0	0
Waste Water	1	0	0	0	1
Natural Gas	0	0	0	0	0
Oil Systems	15	11	1	0	15
Electrical Power	5	2	0	4	5
Communication	133	57	2	133	133
Total	156	71	3	137	154

Table 9 : Expected Utility System Pipeline Damage

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	561	68	21
Oil	109	12	4
Total	670	80	25

Table 10: Expected Potable Water and Electric Power System Performance

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	283,631	0	0	0	0	0
Electric Power	283,631	205,590	136,360	60,200	3,496	0

Induced Earthquake Damage

Fire Following Earthquake

Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. HAZUS uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there will be 196 ignitions that will burn about 0.08% of the region's total area. The model also estimates that the fires will displace about 660 people and burn about 33.0 million dollars of building value.

Debris Generation

HAZUS estimates the amount of debris that will be generated by the earthquake. The model breaks the debris into two general categories: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 0 thousand tons of debris will be generated. Of the total amount, Brick/Wood comprises 0% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 0 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Social Impact

Shelter Requirement

HAZUS estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 17,970 households to be displaced due of the earthquake. Of these, 11,631 people (65%) will seek temporary shelter in publicly shelters.

Casualties

HAZUS estimates the number of people that will be injured and killed by the earthquake. The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

- Severity Level 1: Injuries will require medical attention but hospitalization is not needed.
- Severity Level 2: Injuries will require hospitalization but are not considered life-threatening
- Severity Level 3: Injuries will require hospitalization and can become life threatening is not promptly treated.
- Severity Level 4: Victims are killed by the earthquake.

The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum and 5:00 PM represents peak commute time.

Table 11: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	Residential	2,718	472	39	39
	Non-Residential	140	27	4	4
	Commute	0	0	0	0
	Total	2,858	499	43	43
2 PM	Residential	814	141	11	11
	Non-Residential	5,474	1,039	139	139
	Commute	0	0	0	0
	Total	6,289	1,180	151	150
5 PM	Residential	967	167	14	14
	Non-Residential	2,499	475	63	63
	Commute	0	1	1	0
	Total	3,466	643	78	77

Economic Loss

The total economic loss estimated for the earthquake is 11,067 million dollars, which represents 35 % of the total replacement value of the region's buildings. The following three sections provide more detailed information about these losses.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

The total building-related losses were 11,067 million dollars. 33% of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies made up over 48% of the total loss. Table 12 below provides a summary of the losses associated with the building damage.

Table 12: Building-Related Economic Loss Estimates
(Millions of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Building Loss	Structural	618.4	612.8	135.7	72.7	1,439.7
	Non-Structural	2,922.6	1,149.4	208.1	182.5	4,462.6
	Content	881.2	390.9	129.7	64.1	1,465.9
	Inventory	N/A	9.8	20.9	0.7	31.4
	Subtotal	4,422.2	2,162.9	494.5	320.0	7,399.6
Business Interruption Loss	Wage	43.9	806.5	27.4	20.0	897.8
	Income	18.6	1,186.9	17.4	6.5	1,229.4
	Rental	311.7	245.2	14.4	11.6	582.9
	Relocation	462.3	353.5	35.9	105.6	957.2
	Subtotal	836.6	2,592.1	95.0	143.7	3,667.4
	Total	5,258.8	4,755.0	589.5	463.7	11,067.0

Transportation and Utility Lifeline Losses

For the transportation and utility lifeline systems, HAZUS computes the direct repair cost for each component only. There are no losses computed by HAZUS for business interruption due to lifeline outages. Tables 13 & 14 provide a detailed breakdown in the expected lifeline losses.

HAZUS estimates the long-term economic impacts to the region for 15 years after the earthquake. The model quantifies this information in terms of income and employment changes within the region. Table 15 presents the results of the region for the given earthquake.

Table 13: Transportation System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio
Highway	Roads	20,522.0	0.0	0.0
	Bridges	3,205.0	27.5	0.0
	Tunnels	20.0	0.3	0.0
	Subtotal	23,747.0	27.8	0.0
Railways	Tracks	2,004.9	0.0	0.0
	Bridges	0.0	0.0	0.0
	Tunnels	40.0	0.5	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	2,044.9	0.0	0.0
Light Rail	Tracks	0.0	0.0	0.0
	Bridges	0.0	0.0	0.0
	Tunnels	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	0.0	0.0	0.0
Bus	Facilities	1.0	0.3	0.3
Ferry	Facilities	0.0	0.0	0.0
Port	Facilities	91.5	0.0	0.0
Airport	Facilities	318.5	45.9	6.9
	Runways	1,092.0	0.0	0.0
	Subtotal	1,410.5	45.9	0.0

Table 14: Utility System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	0.0	0.0	0.0
Waste Water	Pipelines	0.0	0.0	0.0
	Facilities	60.0	18.3	30.5
	Subtotal	60.0	18.3	30.5
Natural Gas	Pipelines	93.6	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	93.6	0.0	0.0
Oil Systems	Pipelines	18.1	0.0	0.0
	Facilities	30.0	15.0	49.9
	Subtotal	48.1	15.0	0.0
Electrical Power	Facilities	4,711.6	79.2	3.2
Communication	Facilities	266.0	60.6	22.8

Table 15: Indirect Economic Impact
(Millions of dollars & # of employees)

Category	Elapsed Time after an Earthquake						
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6 - 15	Average
Income Change	-72	-222	-288	-288	-288	-288	-270
% Income Change	-0.04	-0.17	-2.63	-2.63	-2.63	-2.63	-2.46
Employment Change	2,412	1,011	0	0	0	0	228
% Employment Change	0.03	0.02	0.00	0.00	0.00	0.00	0.05

Appendix A: County Listing for the Region

Oregon

- Gilliam
- Hood River
- Morrow
- Multnomah
- Sherman
- Umatilla
- Wasco

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon					
	Gilliam	1,700	90	20	110
	Hood River	16,900	740	290	1,030
	Morrow	7,600	290	80	360
	Multnomah	583,900	26,390	10,870	37,260
	Sherman	1,900	80	20	100
	Umatilla	59,200	2,350	650	3,000
	Wasco	21,700	970	290	1,260
State Total		*693,000*	*30,910*	*12,210*	*43,130*
Region Total		**693,000**	**30,910**	**12,210**	**43,130**

APPENDIX B

Bridge#	Yr Blt	Service_Unde	Hwy	MP	FEAT_INTER	BR_NAME	Service_W	Service_Co
08588C	1963	Highway-wate	002	0.23	HWY 1 I-5	Hwy 1 SB to Hwy 2 EB over Hwy 1 & Conns (Banfield Intchg	No Work	0
08588A	1963	Highway-railr	002	0.24	UPRR	Hwy 2 WB to Hwy 1 NB over UPRR (Banfield Intchg)	No Work	0
H8588A	1963	Highway, witl	002	0.33	CITY STREET	Hwy 2 WB Conn over City Streets	No Work	0
07981A	1958	Highway, witl	002	1.82	DOERNBECKER ACC RD	Hwy 2 over Doernbecher Access Rd (NE Sullivan St)	No Work	0
R7025B	1985	Railroad	002	1.95	LIGHT RAIL	NW 33rd Ave Conn to Hwy 2 WB over UPRR & MAX LRT	No Work	0
07026A	1984	Highway-railr	002	2.4	HWY 2 I-84 & LRT TRACKS	Hwy 59 (NE Sandy Blvd) over Hwy 2 & MAX LRT	No Work	0
16553	1985	Highway-railr	002	3.26	UPRR & LRT	Hwy 2 WB Conn to NE 42nd Ave over UPRR & MAX LRT	No Work	0
07032A	1955	Highway, witl	002	3.55	OXNG I-84 CONN WB	Hwy 2 over NE 58th Ave Conn to Hwy 2 WB	No Work	0
13516A	1978	Highway-railr	002	5.78	HWY 2 I-84	Hwy 64 over Hwy 2	No Work	0
13514H	1981	Highway, witl	002	6.6	CONN 1 (HWY 2)	Hwy 2 & UPRR over Hwy 2 EB Conn #1 to Hwy 64 NB	No Work	0
13514B	1979	Highway, witl	002	6.72	HWY 64 CONN 1	Hwy 2 EB Conn to Hwy 64 NB over Hwy 64 NB Conn to Hwy	No Work	0
13514L	1979	Highway, witl	002	6.83	I84, I205 CONNECTIONS	RR Service Rd over Hwy 2 & Hwy 64 Conns	No Work	0
13514F	1979	Highway, witl	002	6.94	HWY 64 CONNS	Hwy 2 WB over Hwy 2 WB Conns to Hwy 64	No Work	0
13514E	1977	Highway, witl	002	7.65	HY2 CON 2&3/HY64 CON 1&2	NE 102nd Ave over Hwy 2 Conns #2 &#3 & Hwy 64 Conns #	Repair	3281400
07043A	1990	Highway, witl	002	10.08	122ND AVE	Hwy 2 over NE 122nd Ave	No Work	0
07044A	1990	Highway, witl	002	11.43	148TH AVE	Hwy 2 over NE 148th Ave	No Work	0
07088A	1990	Highway, witl	002	12.13	162ND AVE	Hwy 2 over NE 162nd Ave	No Work	0
07089A	1992	Highway, witl	002	13.03	181ST AVE	Hwy 2 over NE 181st Ave	No Work	0
07498A	1992	Railroad	002	13.39	CERGHINO OXG UPRR	Hwy 2 over UPRR (Cereghino)	No Work	0
17212	1996	Highway, witl	002	14.05	201ST (BIRDSDALE RO)	Hwy 2 over NE 201st Ave (NE Birdsdale Rd)	No Work	0
17211	1996	Railroad	002	14.37	RAILROAD	Hwy 2 Conn (NE 207th Ave) over UPRR	No Work	0
17208	1996	Highway, witl	002	14.43	I-84 (HWY 002)	NE 207th Ave over Hwy 2	No Work	0
17213	1996	Highway, witl	002	15.22	NE 223RD (FAIRVIEW AVE)	Hwy 2 over NE 223rd Ave (NE Fairview Ave)	No Work	0
17356	1998	Railroad	002	15.97	UPRR	NE Arata Rd (NE 238th Ave) over UPRR	No Work	0
17365	1998	Highway, witl	002	16	HWY 2 I-84	NE Arata Rd (NE 238th Ave) over Hwy 2	No Work	0
08418B	1958	Highway, witl	002	16.9	OXG CONN	Hwy 2 EB over Marine Dr	No Work	0
08418A	1958	Highway, witl	002	16.9	OXG CONN	Hwy 2 WB over Marine Dr	No Work	0
07046A	1958	Highway, witl	002	17.37	TROUTDALE CONN	Hwy 2 WB over NW Graham Rd	No Work	0
07046	1948	Highway, witl	002	17.37	TROUTDALE CONN	Hwy 2 EB over NW Graham Rd	No Work	0
06875	1949	Waterway	002	17.68	SANDY RIVER	Sandy River, Hwy 2 EB	Replace	13382000
06875A	1959	Waterway	002	17.68	SANDY RIVER	Sandy River, Hwy 2 WB	Replace	10192000
06945	1946	Highway, witl	002	17.82	CONN 2 JORDAN RD	Hwy 2 EB over Conn #2 (Jordan Rd)	Replace	686000
06945A	1946	Highway, witl	002	17.82	CONN 2 JORDAN ROAD	Hwy 2 WB over Conn #2 (Jordan Rd)	Replace	686000
13516G	1985	Highway, witl	064	21.19	HWY 64 NB TO HWY 2 WB	NE Glisan St to Hwy 64 NB over Hwy 64 NB Conn to Hwy 2	No Work	0
13516F	1985	Highway, witl	064	21.72	EB HWY 2 TO SB HWY 64	Hwy 64 SB Conn #6 to NE Glisan St over Hwy 2 EB to Hwy 6	No Work	0
06671A	1960	Highway, witl	002	27.57	I-84 (HWY 002)	Bridal Veil Conn over Hwy 2	No Work	0

18097	1998	Highway, witl	455	27.73	IDAHO AVENUE INTERCHANGE	Hwy 455 Spur over Hwy 6 (Idaho Avenue Intchg)	No Work	0
02681A	1949	Pedestrian-bic	002	31.39	PEDESTRIAN TUNNEL	Hwy 2 EB over Pedestrian Tunnel at Multnomah Falls	No Work	0
02176	1949	Highway-railr	002	35.12	HWY 100 & UPRR	Hwy 2 WB over Hwy 100 & UPRR (Dodson)	No Work	0
02176A	1960	Highway-railr	002	35.12	HWY 100 & UPRR	Hwy 2 EB over Hwy 100 & UPRR (Dodson)	Replace	8600000
08692	1961	Highway, witl	002	37.12	CONN TO WARRENDALE	Hwy 2 over Conn to Warrendale	No Work	0
02193B	1962	Waterway	002	37.83	MCCORD CREEK	McCord Creek, Hwy 2 EB	No Work	0
18067	1998	Waterway	002	37.83	MCCORD CREEK	McCord Creek, Hwy 2 WB	No Work	0
02194A	1950	Waterway	002	38.98	MOFFETT CREEK	Moffett Creek, Hwy 2 WB	Replace	5114000
02194B	1962	Waterway	002	38.98	MOFFETT CREEK	Moffett Creek, Hwy 2 EB	Replace	6392000
02062A	1950	Waterway	002	40.14	TANNER CREEK	Tanner Creek, Hwy 2 WB	Replace	9438000
02062B	1962	Waterway	002	40.14	TANNER CREEK	Tanner Creek, Hwy 2 EB	Replace	6148000
06924	1951	Highway, witl	002	40.27	BONNEVILLE DAM CON	Hwy 2 over Bonneville Dam Conn	No Work	0
09382	1969	Highway-wate	002	41.31	EAGLE CREEK VIADUCT	Eagle Creek Viaduct, Hwy 2 WB	No Work	0
02063	1969	Waterway	002	41.55	EAGLE CREEK	Eagle Creek, Hwy 2 EB	No Work	0
09377	1969	Railroad	002	41.96	UPRR & RUCKEL CREEK	Ruckel Creek & UPRR, Hwy 2	No Work	0
08609	1962	Highway, witl	002	43.66	O'XING EB HWY 100	Hwy 2 over Hwy 100 EB	No Work	0
08610W	1962	Highway, witl	002	43.93	MOODY ST	Hwy 2 WB over Moody St (Cascade Locks)	Replace	3458000
08610	1962	Highway, witl	002	43.93	MOODY ST	Hwy 2 EB over Moody St (Cascade Locks)	Replace	3458000
08611	1962	Highway, witl	002	44.4	HAZEL ST	Hwy 2 EB over Hazel St (Cascade Locks)	No Work	0
08611W	1962	Highway, witl	002	44.4	HAZEL ST	Hwy 2 WB over Hazel St (Cascade Locks)	No Work	0
08605W	1962	Highway, witl	002	45.05	HWY 100	Hwy 2 WB over Hwy 2 WB Conn to Hwy 100	Replace	3236000
08605	1962	Highway, witl	002	45.05	HWY 100	Hwy 2 EB over Hwy 2 WB Conn to Hwy 100	Replace	3780000
07403A	1952	Waterway	002	46.1	HERMAN CREEK	Herman Creek, Hwy 2	Replace	3158000
08623	1965	Highway, witl	002	47.31	CONN HERMAN CREEK	Hwy 2 over Herman Creek Conn	Replace	3114000
08604	1965	Highway, witl	002	50.99	CONN WYETH INT	Hwy 2 over Conn (Wyeth Intchg)	Replace	2820000
08534	1965	Highway, witl	002	56.04	CONN VIENTO INT	Hwy 2 over Conn Viento Intchg	Replace	2820000
09017	1963	Highway, witl	002	61.81	HWY 2	Hwy 100 over Hwy 2	No Work	0
07496A	1964	Highway, witl	002	63.02	JAYMAR RD	Hwy 2 EB over Jaymar Rd (Westcliff Dr)	Replace	1850000
07496	1952	Highway, witl	002	63.02	JAYMAR RD	Hwy 2 WB overJaymar Rd (Westcliff Dr)	No Work	0
02443	1953	Railroad	002	63.41	UPRR	Hwy 2 WB over UPRR	No Work	0
08662	1964	Railroad	002	63.41	UPRR	Hwy 2 EB over UPRR	Repair	2637000
07459	1953	Highway, witl	002	63.92	HWY 2	Second Street (Hood River) over Hwy 2	No Work	0
07458	1952	Highway-railr	002	63.98	UPRR	Hwy 2 Frontage Rd (2nd St) over UPRR	Repair	1529000
02444A	1962	Waterway	002	64.15	HOOD RIVER	Hood River, Hwy 2 WB	No Work	0
02444	1953	Waterway	002	64.15	HOOD RIVER	Hood River, Hwy 2 EB	No Work	0
02471B	1974	Highway-railr	002	64.25	UPRR & FRONTAGE RD	Hwy 2 Conn over UPRR & Frontage Rd	No Work	0
07398	1953	Highway, witl	002	64.44	CONN 2	Hwy 2 over Conn 2	Replace	3118000

07392	1953	Waterway	002	69.62	ROCK CREEK	Rock Creek, Hwy 2	Replace	3668000
07393	1953	Waterway	002	70.1	MOSIER CREEK	Mosier Creek, Hwy 2	Replace	4400000
18408	2001	Railroad	002	71.16	UPRR	Hwy 2 over UPRR (Shogren)	No Work	0
07552A	1954	Highway, witl	002	76.64	ROWENA CONN	Hwy 2 over Rowena Conn	No Work	0
07550	1954	Highway, witl	002	80.79	TAYLOR-FRANTZ RD	Hwy 2 over Taylor-Frantz Rd Conn	No Work	0
07553	1954	Waterway	002	81.89	CHENOWETH CREEK	Chenoweth Creek, Hwy 2	No Work	0
18153	1997	Highway, witl	002	82.07	I-84 (HWY 002)	Hwy 2 River Rd Conn over Hwy 2 (Chenoweth Intchg)	No Work	0
18154	1998	Highway-railr	002	82.12	UPRR	Hwy 2 River Rd Conn over UPRR (Chenoweth Intchg)	No Work	0
08276	1957	Highway, witl	002	82.62	HOSTELLER WAY	Hwy 2 over Hostetler Way Conn	Repair	1073000
08766	1964	Highway, witl	002	83.67	US 30 (HWY 292)	Hwy 2 over Hwy 292 at MP 83.67	Replace	0
08775	1964	Highway, witl	002	84.15	HWY 292 O-XING	Hwy 2 over Hwy 292 at MP 84.15	No Work	0
08603W	1964	Railroad	002	84.28	UPRR	Hwy 2 WB over UPRR	No Work	0
08603	1964	Railroad	002	84.28	UPRR	Hwy 2 EB over UPRR	No Work	0
08805	1964	Highway, witl	002	85.51	I-84 (HWY 002)	Brewery Grade Conn over Hwy 2	No Work	0
08804	1964	Highway-railr	002	85.64	UPRR & HWY 292 FR	Hwy 2 Brewery Grade Conn over UPRR & Fire Rd	No Work	0
08526	1964	Highway, witl	002	87.01	HWY 002	Hwy 4 over Hwy 2	No Work	0
08776	1964	Railroad	002	87.45	UPRR	Hwy 2 over UPRR	No Work	0
00308A	1961	Waterway	002	88.04	FIFTEEN MILE CREEK	Fifteen Mile Creek, Hwy 2	Replace	8014000
07771	1954	Highway, witl	002	88.83	THE DALLES DAM ACC	Hwy 2 over The Dalles Dam Access Conn	Repair	1000000
08924	1965	Railroad	002	89.89	UPRR	Hwy 2 WB over UPRR (Big Eddy WB)	No Work	0
08923	1965	Railroad	002	95.76	UPRR	Hwy 2 over UPRR (WB Celilo)	No Work	0
08933	1965	Railroad	002	96.04	UPRR	Hwy 2 over UPRR (W Celilo Junction)	No Work	0
08934	1965	Highway, witl	002	97.14	OR 206 (HWY 301)	Hwy 2 over Hwy 301	No Work	0
08831	1965	Railroad	002	97.45	UPRR	Hwy 2 over UPRR	No Work	0
00332C	1964	Waterway	002	99.85	DESCHUTES RIVER	Deschutes River, Hwy 2	No Work	0
W1750B	1964	Waterway	002	101.68	FULTON CANYON	Fulton Canyon, Hwy 2 WB	No Work	0
01750B	1964	Waterway	002	101.68	FULTON CANYON	Fulton Canyon, Hwy 2 EB	No Work	0
08854	1962	Highway, witl	002	104.56	I-84 (HWY 002)	Hwy 42 over Hwy 2	No Work	0
02133A	1964	Waterway	002	104.76	SPANISH HOLLOW CREEK	Spanish Hollow Creek, Hwy 2	No Work	0
09213	1965	Railroad	002	109.02	UPRR	Hwy 2 WB over UPRR	No Work	0
09213A	1965	Railroad	002	109.02	UPRR	Hwy 2 EB over UPRR	No Work	0
09232	1965	Waterway	002	109.78	SCOTT CANYON WEST	Scott Canyon, Hwy 2 WB	No Work	0
09232A	1965	Waterway	002	109.78	SCOTT CANYON EAST	Scott Canyon, Hwy 2 EB	No Work	0
09225	1965	Highway, witl	002	109.95	RUFUS CONN	Hwy 2 EB over Rufus Conn	No Work	0
09225A	1965	Highway, witl	002	109.95	RUFUS CONN	Hwy 2 WB over Rufus Conn	No Work	0
08942	1963	Highway, witl	002	114.23	CONN RD	Hwy 2 over Conn (W John Day Intchg)	No Work	0
00108B	1963	Waterway	002	114.6	JOHN DAY RIVER	John Day River, Hwy 2	No Work	0

08944	1964	Highway, witl	002	123.31	I-84 (HWY 002)	Phillipi Canyon Rd over Hwy 2	No Work	0
08945	1964	Highway, witl	002	129.43	BLALOCK CANYON RD	Hwy 2 over Blalock Conn	No Work	0
08820	1964	Highway-wate	002	137.91	ARLINGTON VIADUCT	Arlington Viaduct, Hwy 2 over Hwy 5 NB	No Work	0
09198	1964	Highway, witl	002	147.12	I-84 (HWY 002)	Hwy 52 over Hwy 2	No Work	0
07520A	1954	Waterway	002	148.57	WILLOW CREEK WEST	Willow Creek WB, Hwy 2	No Work	0
09197	1965	Waterway	002	148.6	WILLOW CREEK EB	Willow Creek EB, Hwy 2	No Work	0
09307A	1964	Highway, witl	002	151.75	THREE MILE CANYON EAST	Three Mile Canyon, Hwy 2 EB	No Work	0
09307	1965	Highway, witl	002	151.79	THREE MILE CANYON WEST	Three Mile Canyon, Hwy 2 WB	No Work	0
09021	1964	Highway, witl	002	159.3	TOWER RD INT (AIRPORT RD	Hwy 2 Conn #2 over Tower Rd Intchg (Airport Rd)	No Work	0
16612	1984	Highway, witl	002	165.76	WB PORT OF MORROW INTER	Hwy 2 WB over Port of Morrow Intchg	No Work	0
16611	1984	Highway, witl	002	165.76	EB PORT OF MORROW INTER	Hwy 2 EB over Port of Morrow Intchg	No Work	0
08931E	1962	Highway, witl	006	167.95	IRRIGON JCT INTERCHANGE	Hwy 6 EB over Irrigon Junction Intchg Conn	Replace	4204000
08931W	1962	Highway, witl	006	167.95	IRRIGON JCT INTERCHANGE	Hwy 6 WB over Irrigon Junction Intchg Conn	No Work	0
09539	1967	Highway, witl	006	177.98	ORDNANCE INTERCHANGE	Hwy 6 Conn over Hwy 6 (Ordnance Intchg)	No Work	0
16452	1987	Highway, witl	006	179.42	EB I-82 & I-84	Hwy 6 EB Conn to Hwy 70 EB over Hwy 6	No Work	0
16453	1987	Highway, witl	006	179.43	I-82 - HWY (70)	Hwy 6 WB over Hwy 70 EB	Repair	1000000
16454	1987	Highway, witl	006	179.45	I-82-HWY (70)	Hwy 6 EB over Hwy 70 EB	Repair	1014000
09540	1967	Highway, witl	006	180.4	I-84 (HWY 006)	Hwy 6 Conn over Hwy 6 (Westland Intchg)	No Work	0
05204A	1967	Waterway	006	181.95	BUTTER CREEK	Butter Creek, Hwy 6 WB	No Work	0
05204B	1967	Waterway	006	181.95	BUTTER CREEK	Butter Creek, Hwy 6 EB	No Work	0
09541	1967	Highway, witl	006	182.86	HERMISTON INT-BUCKS CORN	Hwy 333 over Hwy 6 (Hermiston Intchg, Bucks Corner)	No Work	0
05209A	1968	Railroad-wate	006	188.42	UMATILLA R/UPRR/USRS CAN	Umatilla River & UPRR &USRS Canal, Hwy 6 WB	No Work	0
05209B	1942	Railroad-wate	006	188.43	UMATILLA R/UPRR/USRS CAN	Umatilla River & UPRR &USRS Canal, Hwy 6 EB	Replace	0
09314	1968	Highway, witl	006	188.84	STANFIELD JCT INTERCHANG	Hwy 54 over Hwy 6 (Stanfield Jct Intchg)	Replace	8086000

Bridge.	Yr Blt	Service_Unde	Hwy	Pfx	MP	FACILITY	FEAT_INTER
08588C	1963	Highway-watei	002		0.23	HY 1 SB TO HY 2 EB	HWY 1 I-5
08588A	1963	Highway-railro	002		0.24	HY 2 WB TO HY 1 NB	UPRR
H8588A	1963	Highway, with	002		0.33	I-84 (HWY 002) CON	CITY STREET
06875	1949	Waterway	002		17.68	I-84 (HWY 002) EB	SANDY RIVER
06875A	1959	Waterway	002		17.68	I-84 (HWY 002) WB	SANDY RIVER

will remain EQ vulnerable

on OTIA III

BR_NAME	Work_Lvl	Cost	STIP	OTIA_II	OTIA_I
Hwy 1 SB to Hwy 2 EB over Hwy 1 & Conns (Banfield Intchg)	No Work	0	NO	NO	NO
Hwy 2 WB to Hwy 1 NB over UPRR (Banfield Intchg)	No Work	0	NO	NO	NO
Hwy 2 WB Conn over City Streets	No Work	0	NO	NO	NO
Sandy River, Hwy 2 EB	Replace	13382000	NO	NO	NO
Sandy River, Hwy 2 WB	Replace	10192000	NO	NO	NO