OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
INTERPRETIVE MAP SERIES 24

GEOLOGIC HAZARDS, EARTHQUAKE AND LANDSLIDE HAZARD MAPS, AND FUTURE EARTHQUAKE DAMAGE ESTIMATES FOR SIX COUNTIES IN THE MID/SOUTHERN WILLAMETTE VALLEY INCLUDING YAMHILL, MARION, POLK, BENTON, LINN, AND LANE COUNTIES AND THE CITY OF ALBANY, OREGON

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HAZUS-MH GLOBAL REPORT FOR CRUSTAL SCENARIO
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CRUSTAL EARTHQUAKE SCENARIO DETAILS FOR BENTON COUNTY

Crustal Earthquake Scenario: A magnitude 6.5 earthquake on the Corvallis Fault.

For the magnitude 6.5 earthquake on the Corvallis Fault scenario, we defined the fault source using the "deterministic seismic source" option within HAZUS-MH (Figure A1) (FEMA, 2003b). The fault and earthquake event were chosen by examination of USGS (2004) data and data in the Geomatrix Consultants, Inc. (1995) *Seismic Design Mapping, State of Oregon* report prepared for the Oregon Department of Transportation. In general, a likely worst-case scenario was selected. In particular, this event was modeled after the scenario defined in DOGAMI Open-File Report O-01-05, titled *Preliminary Earthquake Hazard and Risk Assessment and Water-Induced Landslide Hazard in Benton County, Oregon*. Figure A1 has the location of the fault, shown as the dark line, within Benton County. Figure A2 displays the peak ground acceleration (PGA) for the crustal scenario.

Scenario Name	Corvallis Fault M6.5
Type of Earthquake	Deterministic Seismic Source - Arbitrary
Fault Name	Corvallis Fault
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	–123.358
Latitude of Epicenter	44.5437
Earthquake Magnitude	6.5
Depth (Km)	10
Rupture Length (Km)	22.38
Rupture Orientation (degrees)	30
Attenuation Function	Reverse-Slip

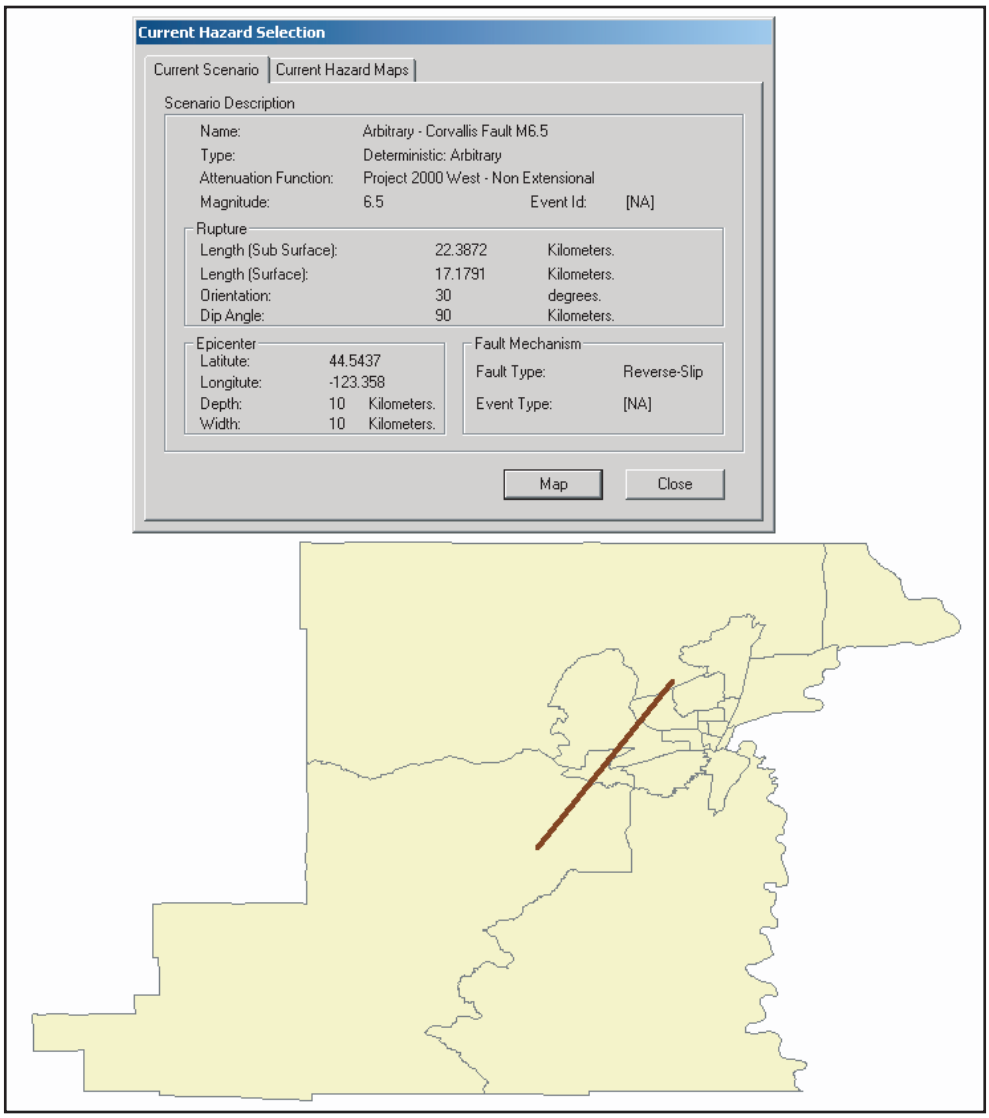

Figure A1. Corvallis Fault details from HAZUS-MH (FEMA, 2003b). The location of the fault is shown as the dark line.

Crustal Earthquake Scenario Ground Motion Map

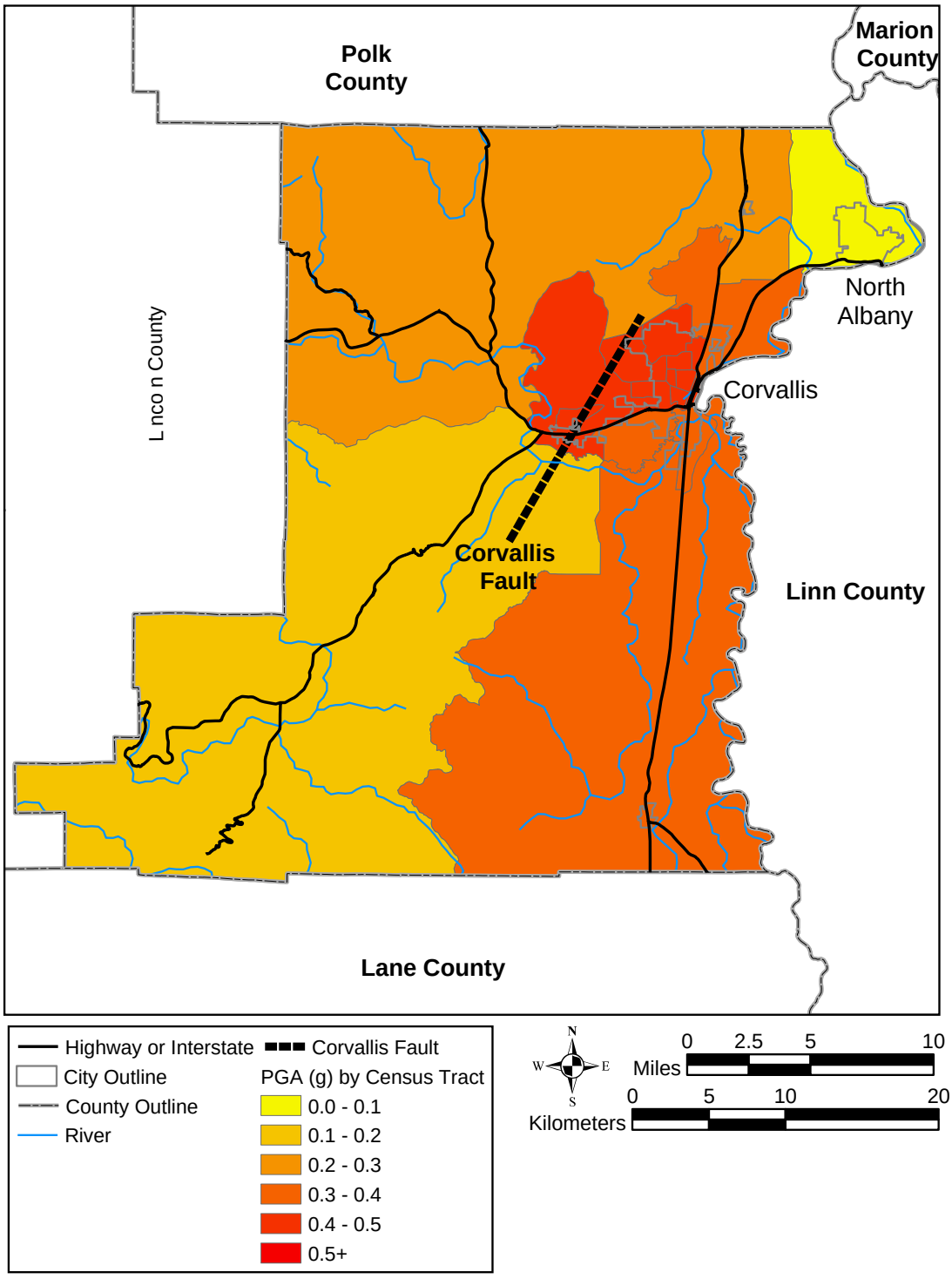

Figure A2. Peak ground acceleration (PGA) by census tracts map for the crustal earthquake scenario, Benton County, Oregon (FEMA, 2003b).

SUBDUCTION ZONE EARTHQUAKE SCENARIO DETAILS FOR BENTON COUNTY

Subduction Zone Scenario: A magnitude 9.0 earthquake on the Cascadia Subduction Zone was selected for the subduction zone earthquake scenario.

For the Cascadia Subduction Zone earthquake scenario, we used the "user-defined event" option within HAZUS-MH to incorporate ground motion maps developed by the Cascadia Region Earthquake Workgroup (CREW, 2003) to model damage and loss from a magnitude 9.0 earthquake (Figure A3). The CREW maps were developed from ground motion data provided by the U.S. Geological Survey. The CREW earthquake scenario required the input of four sets of GIS files that are included within the HAZUS-MH study region: regional peak ground acceleration (PGA), peak ground velocity (PGV), and the spectral velocity at 0.3 s and 1.0 s (CREW, 2003). Figure A4 displays the PGA for the subduction zone scenario.

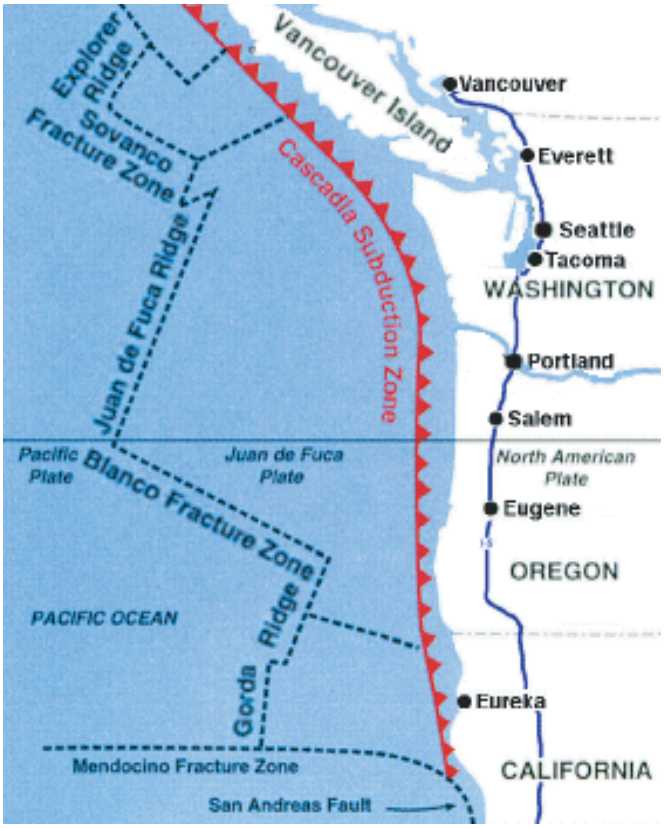

Figure A3. Location of the Cascadia Subduction Zone (CREW, 2003).

Subduction Zone Earthquake Scenario Ground Motion Map

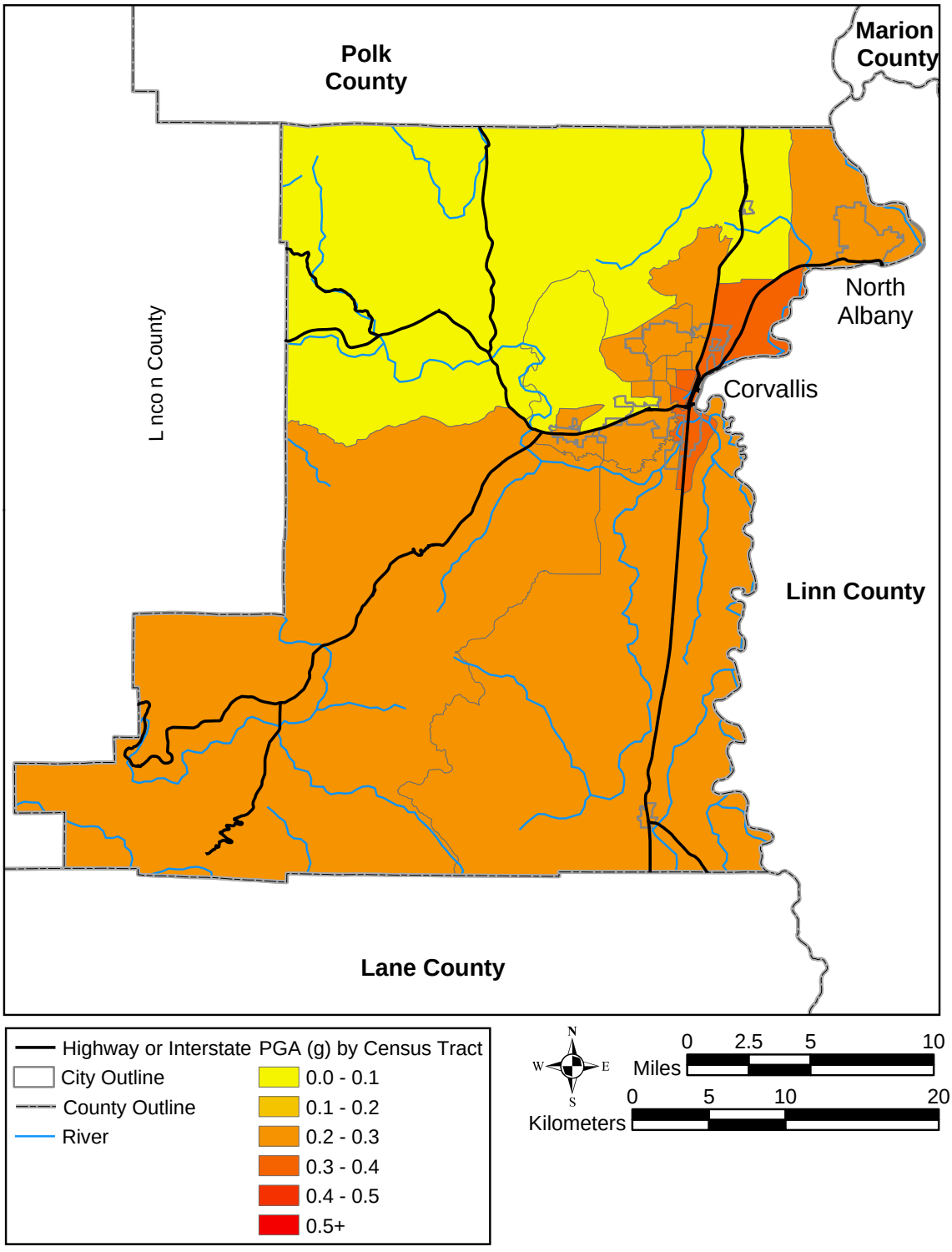

Figure A4. Peak ground acceleration (PGA) by census tracts map for the Cascadia Subduction Zone earthquake scenario, Benton County, Oregon (FEMA, 2003b).

GEOLOGIC HAZARD MAPS FOR BENTON COUNTY

Relative Ground-Shaking Amplification Susceptibility Map

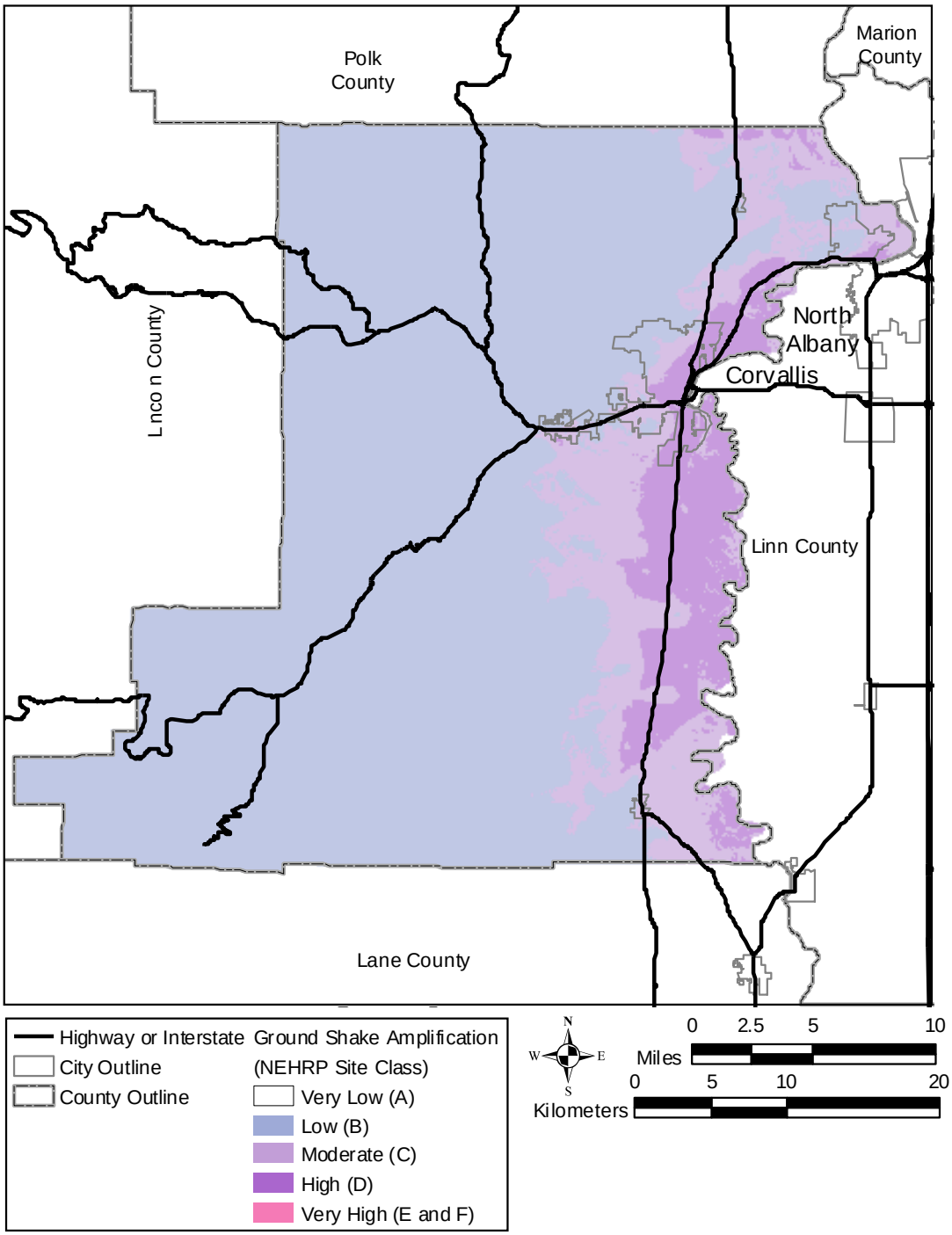

Figure A5. Relative ground-shaking amplification susceptibility map for Benton County, Oregon. Data were modified after Wang and others (2001).

Relative Liquefaction Hazard Susceptibility Map

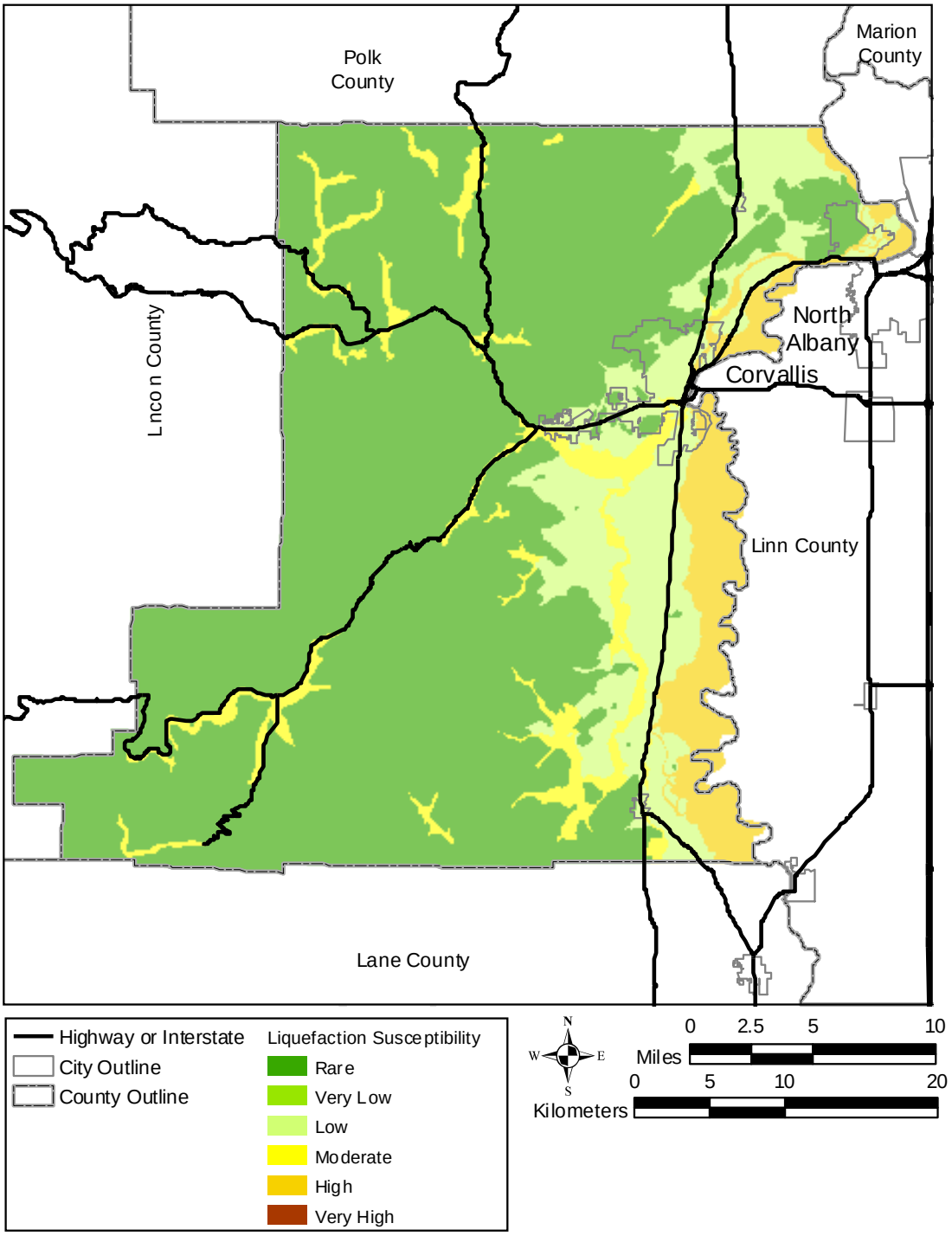

Figure A6. Relative liquefaction susceptibility map for Benton County, Oregon. Data were modified after Wang and others (2001).

Relative Earthquake-Induced Landslide Susceptibility Map

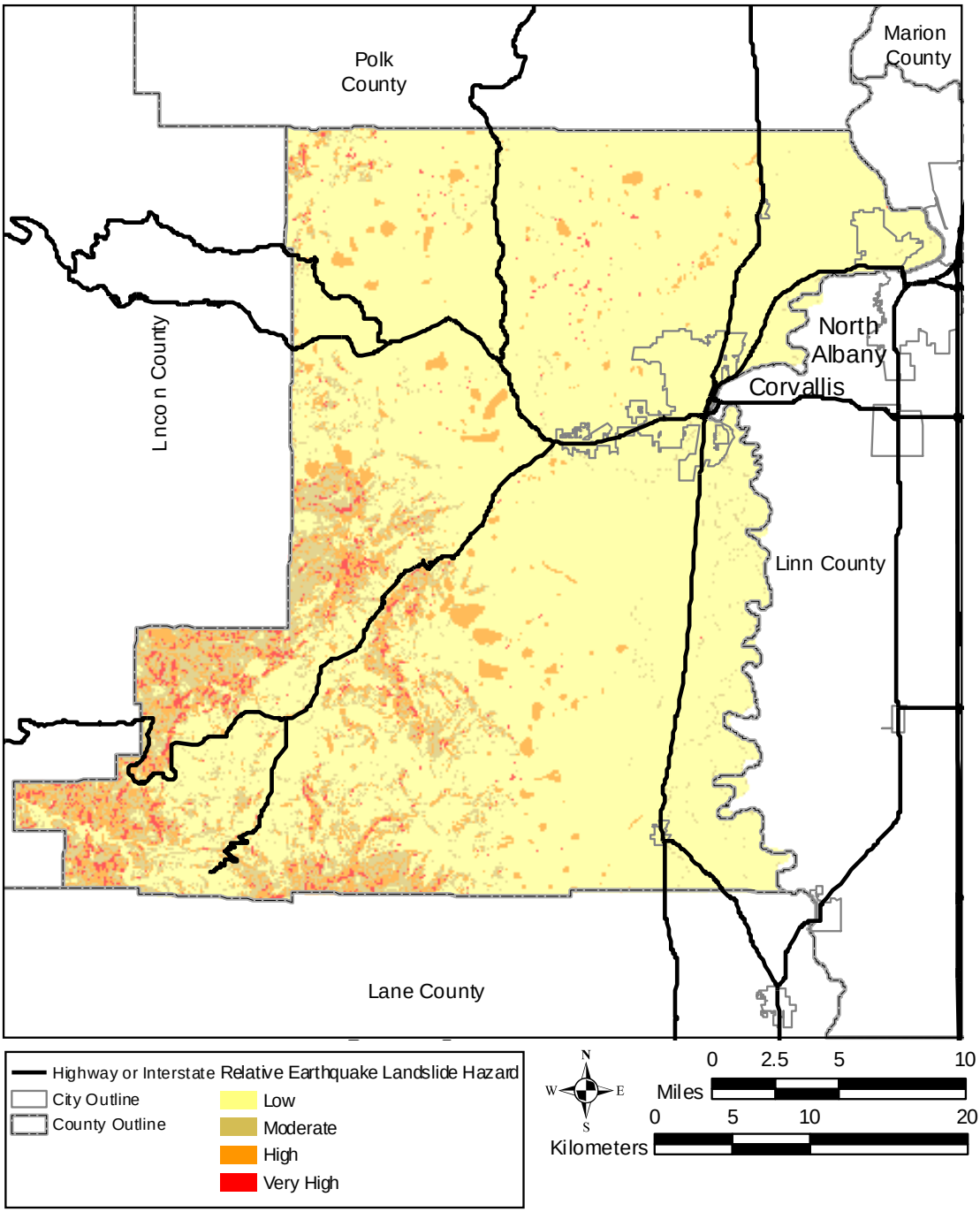

Figure A7. Relative earthquake-induced landslide susceptibility map for Benton County, Oregon. Data were modified after Wang and others (2001).

Identified Landslide Areas Map

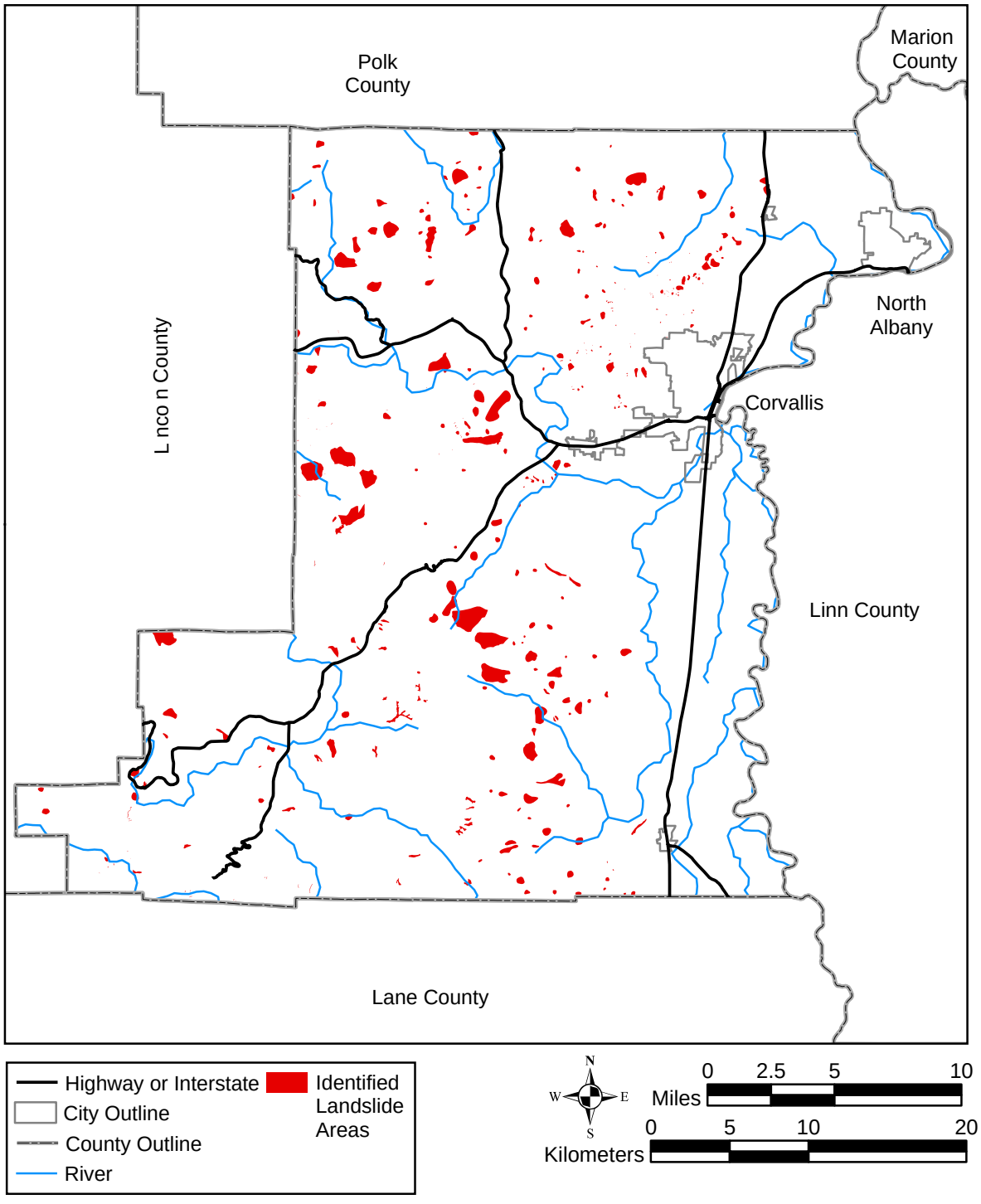

Figure A8. Identified landslide areas map for Benton County, Oregon.

HAZUS-MH: Earthquake Event Report

Region Name: ***Benton_Crustal_OFR_3***

Earthquake Scenario: ***Arbitrary - Corvallis Fault M6.5***

Print Date: ***August 24, 2005***

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, geotechnical, and observed ground motion data.

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Appendix A: County Listing for the Region

Appendix B: Regional Population and Building Value Data

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 1 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 677.35 square miles and contains 19 census tracts. There are over 30 thousand households in the region and has a total population of 78,153 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 24 thousand buildings in the region with a total building replacement value (excluding contents) of 4,850 (millions of dollars). Approximately 99.00 % of the buildings (and 89.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 1,526 and 689 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 24 thousand buildings in the region which have an aggregate total replacement value of 4,850 (millions of dollars) . Appendix B provides a general distribution of the building value by State and County.

In terms of building construction types found in the region, wood frame construction makes up 88% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

HAZUS breaks critical facilities 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 1 hospitals in the region with a total bed capacity of 134 beds. There are 44 schools, 4 fire stations, 4 police stations and 0 emergency operation facilities. With respect to HPL facilities, there are 9 dams identified within the region. Of these, 1 of the dams are classified as 'high hazard'. The inventory also includes 10 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 are provided in Tables 2 and 3.

The total value of the lifeline inventory is over 2,215.00 (millions of dollars). This inventory includes over 168 kilometers of highways, 22 bridges, 6,578 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	22	438.00
	Segments	35	569.00
	Tunnels	0	0.00
		Subtotal	**1,007.00**
Railways	Bridges	0	0.00
	Facilities	1	2.50
	Segments	40	106.30
	Tunnels	0	0.00
		Subtotal	**108.80**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	3	3.70
		Subtotal	**3.70**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	9	55.40
	Runways	10	351.20
		Subtotal	**406.60**
		Total	**1,526.10**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.80
	Facilities	3	112.90
	Pipelines	0	0.00
		Subtotal	**178.70**
Waste Water	Distribution Lines	NA	39.50
	Facilities	6	451.50
	Pipelines	0	0.00
		Subtotal	**491.00**
Natural Gas	Distribution Lines	NA	26.30
	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**26.30**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	1	124.30
		Subtotal	**124.30**
Communication	Facilities	10	1.10
		Subtotal	**1.10**
		Total	**821.40**

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	Arbitrary - Corvallis Fault M6.5
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-123.36
Latitude of Epicenter	44.54
Earthquake Magnitude	6.50
Depth (Km)	10.00
Rupture Length (Km)	17.18
Rupture Orientation (degrees)	30.00
Attenuation Function	Project 2000 West - Non Extensional

Building Damage

Building Damage

HAZUS estimates that about 7,759 thousand buildings will be at least moderately damaged. This is over 31.00 % of the total number of buildings in the region. There are an estimated 416 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	(%)
Agriculture	1	0.01	0	0.01	0	0.01	0	0.02	0	0.03
Commercial	23	0.24	26	0.35	53	0.95	46	2.64	29	7.05
Education	1	0.01	1	0.01	2	0.04	2	0.11	1	0.23
Government	2	0.02	2	0.02	3	0.06	2	0.14	1	0.29
Industrial	1	0.01	1	0.01	2	0.04	2	0.11	1	0.23
Other Residential	693	7.26	762	9.99	1,062	18.92	652	37.68	235	56.42
Religion	1	0.02	1	0.01	1	0.02	1	0.04	0	0.08
Single Family	8,834	92.44	6,833	89.59	4,488	79.96	1,025	59.26	149	35.67
Total	**9,557**		**7,627**		**5,613**		**1,730**		**417**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	21	0.01	1	0.01	3	0.05	3	0.17	2	0.43
MH*	422	4.41	401	5.26	707	12.60	493	28.49	168	40.22
Precast	4	0.03	2	0.02	5	0.09	6	0.34	3	0.77
RM*	3	0.03	2	0.02	5	0.09	6	0.33	2	0.56
Steel	13	0.02	1	0.02	6	0.11	10	0.56	8	1.91
UM*	65	0.68	70	0.91	111	1.97	89	5.13	70	16.79
Wood	9,029	94.42	7111	93.24	4,691	83.57	1,050	60.70	127	30.60
Total	**9,557**		**7,627**		**5,613**		**1,730**		**417**	

*Note:
RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 134 hospital beds available for use. On the day of the earthquake, the model estimates that only 63 hospital beds (47.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 81.00% of the beds will be back in service. By 30 days, 99.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		Least Moderate Damage > 50%	Complete Damage > 50%	# likely Functional on day 1
Hospitals	1	0	0	1
Schools	44	4	0	40
EOCs	0	0	0	0
PoliceStations	4	1	0	3
FireStations	4	1	0	3

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	After Day 7
Highway	Segments	35	0	0	35	35
	Bridges	22	1	0	22	22
	Tunnels	0	0	0	0	0
Railways	Segments	40	0	0	40	40
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	1	1	0	1	1
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	3	3	0	3	3
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	9	0	0	9	9
	Runways	10	0	0	10	10

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	After Day 7
Potable Water	3	2	0	1	3
Waste Water	6	4	0	1	6
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	1	1	0	0	1
Communication	10	9	0	10	10

Table 9 : Expected Utility System Pipeline Damage (Site Specific)

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,289	107	27
Waste Water	1,974	85	21
Natural Gas	1,316	91	23
Oil	0	0	0

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	30,145	0	0	0	0	0
Electric Power		10,550	5,835	2,019	333	16

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 3 ignitions that will burn about 0.09 sq. mi 0.01 % of the region's total area.) The model also estimates that the fires will displace about 169 people and burn about 10 (millions of 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 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 41.00% 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 (1,755 households to be displaced due to the earthquake. Of these, 501 people (out of a total population of 78,153 will seek temporary shelter in public 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 if 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 provides a summary of the casualties estimated for this earthquake

Table 11: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	Commercial	5	1	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	4	1	0	0
	Industrial	10	3	0	1
	Other-Residential	198	50	7	13
	Single Family	90	13	1	1
	Total	**307**	**68**	**8**	**16**
2 PM	Commercial	275	78	12	24
	Commuting	0	0	0	0
	Educational	86	24	4	7
	Hotels	1	0	0	0
	Industrial	73	20	3	6
	Other-Residential	7	1	0	0
	Single Family	10	2	0	0
	Total	**452**	**125**	**19**	**38**
5 PM	Commercial	230	65	10	20
	Commuting	2	2	3	1
	Educational	33	9	1	3
	Hotels	1	0	0	0
	Industrial	45	12	2	4
	Other-Residential	77	20	3	5
	Single Family	35	5	0	1
	Total	**423**	**114**	**20**	**33**

Economic Loss

The total economic loss estimated for the earthquake is 952.37 (millions of dollars), which includes building and lifeline related losses based on the region's available inventory. 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 762.25 (millions of dollars); 12 % of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 72 % 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	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Loses							
	Wage	0.00	1.66	21.90	0.43	1.35	25.34
	Capital-Related	0.00	0.71	20.89	0.25	0.46	22.32
	Rental	8.37	20.89	9.41	0.12	0.74	39.53
	Relocation	1.00	0.53	0.54	0.01	0.22	2.30
	Subtotal	**9.37**	**23.79**	**52.75**	**0.81**	**2.77**	**89.49**
Capital Stock Loses							
	Structural	42.67	33.86	22.78	1.97	4.21	105.50
	Non_Structural	193.66	154.65	62.57	6.27	14.34	431.50
	Content	58.74	34.20	29.11	4.04	7.51	133.59
	Inventory	0.00	0.00	1.03	1.03	0.11	2.16
	Subtotal	**295.08**	**222.71**	**115.49**	**13.31**	**26.17**	**672.76**
	Total	**304.45**	**246.50**	**168.24**	**14.12**	**28.94**	**762.25**

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	Segments	568.98	$4.07	0.72
	Bridges	438.01	$14.61	3.34
	Tunnels	0.00	$0.00	0.00
	Subtotal	**1007.00**	**18.70**	
Railways	Segments	106.31	$0.08	0.08
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	2.46	$0.87	35.38
	Subtotal	**108.80**	**1.00**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	3.70	$1.35	36.56
	Subtotal	**3.70**	**1.40**	
Ferry	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Port	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Airport	Facilities	55.43	$15.77	28.44
	Runways	351.20	$3.50	1.00
	Subtotal	**406.60**	**19.30**	
	Total	**1526.10**	**40.30**	

Table 14: Utility System Economic Losses

(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.00	$0.00	0.00
	Facilities	112.90	$26.16	23.17
	Distribution Line	65.80	$0.97	1.47
	Subtotal	**178.67**	**$27.12**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	451.50	$89.90	19.91
	Distribution Line	39.50	$0.76	1.94
	Subtotal	**491.02**	**$90.67**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Distribution Line	26.30	$0.82	3.10
	Subtotal	**26.31**	**$0.82**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	124.30	$31.02	24.95
	Subtotal	**124.30**	**$31.02**	
Communication	Facilities	1.10	$0.24	21.38
	Subtotal	**1.13**	**$0.24**	
	Total	**821.44**	**$149.86**	

Table 15. Indirect Economic Impact with outside aid
(Employment as # of people and Income in millions of $)

	LOSS	Total	%
First Year			
	Employment Impact	0	0.00
	Income Impact	(23)	-2.91
Second Year			
	Employment Impact	0	0.00
	Income Impact	(37)	-4.57
Third Year			
	Employment Impact	0	0.00
	Income Impact	(42)	-5.28
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(42)	-5.28
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(42)	-5.28
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(42)	-5.28

Appendix A: County Listing for the Region

Benton,OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon	Benton	78,153	4,305	544	4,850
Total State		**78,153**	**4,305**	**544**	**4,850**
Total Region		**78,153**	**4,305**	**544**	**4,850**

HAZUS-MH: Earthquake Event Report

Region Name: ***Benton_Cascadia_OFR_3***

Earthquake Scenario: ***Cascadia M9.0***

Print Date: ***August 24, 2005***

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, geotechnical, and observed ground motion data.

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Appendix A: County Listing for the Region

Appendix B: Regional Population and Building Value Data

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 1 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 677.35 square miles and contains 19 census tracts. There are over 30 thousand households in the region and has a total population of 78,153 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 24 thousand buildings in the region with a total building replacement value (excluding contents) of 4,850 (millions of dollars). Approximately 99.00 % of the buildings (and 89.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 1,526 and 689 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 24 thousand buildings in the region which have an aggregate total replacement value of 4,850 (millions of dollars) . Appendix B provides a general distribution of the building value by State and County.

In terms of building construction types found in the region, wood frame construction makes up 88% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

HAZUS breaks critical facilities 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 1 hospitals in the region with a total bed capacity of 134 beds. There are 44 schools, 4 fire stations, 4 police stations and 0 emergency operation facilities. With respect to HPL facilities, there are 9 dams identified within the region. Of these, 1 of the dams are classified as 'high hazard'. The inventory also includes 10 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 are provided in Tables 2 and 3.

The total value of the lifeline inventory is over 2,215.00 (millions of dollars). This inventory includes over 168 kilometers of highways, 22 bridges, 6,578 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	22	438.00
	Segments	35	569.00
	Tunnels	0	0.00
		Subtotal	**1,007.00**
Railways	Bridges	0	0.00
	Facilities	1	2.50
	Segments	40	106.30
	Tunnels	0	0.00
		Subtotal	**108.80**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	3	3.70
		Subtotal	**3.70**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	9	55.40
	Runways	10	351.20
		Subtotal	**406.60**
		Total	**1,526.10**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.80
	Facilities	3	112.90
	Pipelines	0	0.00
		Subtotal	**178.70**
Waste Water	Distribution Lines	NA	39.50
	Facilities	6	451.50
	Pipelines	0	0.00
		Subtotal	**491.00**
Natural Gas	Distribution Lines	NA	26.30
	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**26.30**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	1	124.30
		Subtotal	**124.30**
Communication	Facilities	10	1.10
		Subtotal	**1.10**
		Total	**821.40**

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	Cascadia M9.0
Type of Earthquake	User-defined
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	NA
Latitude of Epicenter	NA
Earthquake Magnitude	8.50
Depth (Km)	NA
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	NA

Building Damage

Building Damage

HAZUS estimates that about 7,897 thousand buildings will be at least moderately damaged. This is over 32.00 % of the total number of buildings in the region. There are an estimated 1,159 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	(%)
Agriculture	1	0.01	0	0.01	0	0.01	0	0.02	0	0.03
Commercial	17	0.17	10	0.14	31	0.64	46	2.52	74	6.39
Education	0	0.00	1	0.01	1	0.03	2	0.11	3	0.22
Government	1	0.01	1	0.01	2	0.04	3	0.15	4	0.37
Industrial	2	0.02	0	0.00	1	0.01	1	0.07	3	0.27
Other Residential	527	5.35	465	6.45	737	14.97	802	44.15	874	75.41
Religion	1	0.01	1	0.01	1	0.02	1	0.06	1	0.10
Single Family	9,292	94.42	6,728	93.38	4,149	84.29	961	52.91	200	17.22
Total	**9,841**		**7,205**		**4,922**		**1,816**		**1,159**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	12	0.00	0	0.00	1	0.02	3	0.15	5	0.44
MH*	180	1.83	166	2.30	467	9.48	662	36.46	716	61.77
Precast	4	0.02	1	0.01	2	0.05	5	0.25	9	0.74
RM*	2	0.02	1	0.01	3	0.05	5	0.27	8	0.67
Steel	10	0.02	0	0.00	2	0.03	4	0.23	19	1.62
UM*	42	0.43	37	0.52	81	1.65	94	5.18	149	12.87
Wood	9,591	97.44	6989	97.00	4,323	87.83	970	53.39	133	11.47
Total	**9,841**		**7,205**		**4,922**		**1,816**		**1,159**	

*Note:
RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 134 hospital beds available for use. On the day of the earthquake, the model estimates that only 134 hospital beds (100.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 100.00% of the beds will be back in service. By 30 days, 100.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		Least Moderate Damage > 50%	Complete Damage > 50%	# likely Functional on day 1
Hospitals	1	0	0	1
Schools	44	4	0	40
EOCs	0	0	0	0
PoliceStations	4	0	0	4
FireStations	4	0	0	4

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	After Day 7
Highway	Segments	35	0	0	35	35
	Bridges	22	3	0	20	21
	Tunnels	0	0	0	0	0
Railways	Segments	40	0	0	40	40
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	1	0	0	1	1
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	3	0	0	3	3
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	9	0	0	9	9
	Runways	10	0	0	10	10

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	After Day 7
Potable Water	3	0	0	3	3
Waste Water	6	0	0	6	6
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	1	0	0	1	1
Communication	10	0	0	10	10

Table 9 : Expected Utility System Pipeline Damage (Site Specific)

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,289	335	84
Waste Water	1,974	265	66
Natural Gas	1,316	283	71
Oil	0	0	0

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	30,145	644	0	0	0	0
Electric Power		0	0	0	0	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 2 ignitions that will burn about 0.05 sq. mi 0.01 % of the region's total area.) The model also estimates that the fires will displace about 41 people and burn about 2 (millions of 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 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 34.00% 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 (2,375 households to be displaced due to the earthquake. Of these, 669 people (out of a total population of 78,153 will seek temporary shelter in public 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 if 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 provides a summary of the casualties estimated for this earthquake

Table 11: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	Commercial	12	4	1	1
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	8	2	0	1
	Industrial	32	10	2	3
	Other-Residential	411	118	17	32
	Single Family	97	17	1	3
	Total	**560**	**151**	**21**	**40**
2 PM	Commercial	647	202	34	67
	Commuting	0	0	0	0
	Educational	232	73	12	24
	Hotels	2	0	0	0
	Industrial	235	74	12	24
	Other-Residential	18	4	0	1
	Single Family	12	2	0	0
	Total	**1,146**	**357**	**59**	**116**
5 PM	Commercial	570	178	30	58
	Commuting	3	4	7	1
	Educational	76	24	4	8
	Hotels	2	1	0	0
	Industrial	147	46	8	15
	Other-Residential	158	46	7	12
	Single Family	38	7	1	1
	Total	**995**	**305**	**56**	**96**

Economic Loss

The total economic loss estimated for the earthquake is 1,091.14 (millions of dollars), which includes building and lifeline related losses based on the region's available inventory. 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 1,049.51 (millions of dollars); 13 % of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 61 % 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	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Loses							
	Wage	0.00	2.27	38.51	0.78	2.51	44.08
	Capital-Related	0.00	0.97	35.69	0.46	0.87	37.99
	Rental	8.15	28.95	15.35	0.21	1.37	54.04
	Relocation	0.97	0.67	0.89	0.01	0.40	2.95
	Subtotal	**9.12**	**32.86**	**90.45**	**1.47**	**5.15**	**139.06**
Capital Stock Loses							
	Structural	42.30	53.77	42.77	4.06	8.64	151.54
	Non_Structural	174.64	234.55	128.13	15.53	30.68	583.53
	Content	43.25	47.20	56.35	9.55	14.32	170.65
	Inventory	0.00	0.00	2.12	2.39	0.22	4.73
	Subtotal	**260.18**	**335.52**	**229.36**	**31.53**	**53.86**	**910.45**
	Total	**269.31**	**368.38**	**319.82**	**32.99**	**59.01**	**1,049.51**

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	Segments	568.98	$9.01	1.58
	Bridges	438.01	$24.47	5.59
	Tunnels	0.00	$0.00	0.00
	Subtotal	**1007.00**	**33.50**	
Railways	Segments	106.31	$0.20	0.19
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	2.46	$0.00	0.00
	Subtotal	**108.80**	**0.20**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	3.70	$0.00	0.00
	Subtotal	**3.70**	**0.00**	
Ferry	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Port	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Airport	Facilities	55.43	$0.00	0.00
	Runways	351.20	$0.00	0.00
	Subtotal	**406.60**	**0.00**	
	Total	**1526.10**	**33.70**	

Table 14: Utility System Economic Losses

(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.00	$0.00	0.00
	Facilities	112.90	$0.00	0.00
	Distribution Line	65.80	$3.01	4.58
	Subtotal	**178.67**	**$3.01**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	451.50	$0.00	0.00
	Distribution Line	39.50	$2.38	6.04
	Subtotal	**491.02**	**$2.38**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Distribution Line	26.30	$2.55	9.68
	Subtotal	**26.31**	**$2.55**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	124.30	$0.00	0.00
	Subtotal	**124.30**	**$0.00**	
Communication	Facilities	1.10	$0.00	0.00
	Subtotal	**1.13**	**$0.00**	
	Total	**821.44**	**$7.94**	

Table 15. Indirect Economic Impact with outside aid
(Employment as # of people and Income in millions of $)

	LOSS	Total	%
First Year			
	Employment Impact	0	0.00
	Income Impact	(26)	-3.21
Second Year			
	Employment Impact	0	0.00
	Income Impact	(44)	-5.47
Third Year			
	Employment Impact	0	0.00
	Income Impact	(52)	-6.43
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(52)	-6.43
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(52)	-6.43
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(52)	-6.43

Appendix A: County Listing for the Region

Benton,OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon	Benton	78,153	4,305	544	4,850
Total State		**78,153**	**4,305**	**544**	**4,850**
Total Region		**78,153**	**4,305**	**544**	**4,850**