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

APPENDIX E: MARION COUNTY

CRUSTAL EARTHQUAKE SCENARIO DETAILS FOR MARION COUNTY

Crustal Earthquake Scenario: A magnitude 6.9 earthquake on the Mount Angel Fault.

For the magnitude 6.9 earthquake on the Mount Angel Fault scenario, we defined the fault source using the "deterministic seismic source" option within HAZUS-MH (Figure E1) (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. Figure E1 has the location of the fault, shown as the dark line, and the census tracts within Marion County. Figure E2 displays the peak ground acceleration (PGA) for the crustal scenario.

Scenario Name	Mount Angel M6.9
Type of Earthquake	Source
Fault Name	Mount Angel Fault
Historical Epicenter ID #	67
Probabilistic Return Period	NA
Longitude of Epicenter	–122.83
Latitude of Epicenter	45.05
Earthquake Magnitude	6.90
Depth (km)	0.00
Rupture Length (km)	30.69
Rupture Orientation (degrees)	0.00
Attenuation Function	Project 2000 West - Non Extensional

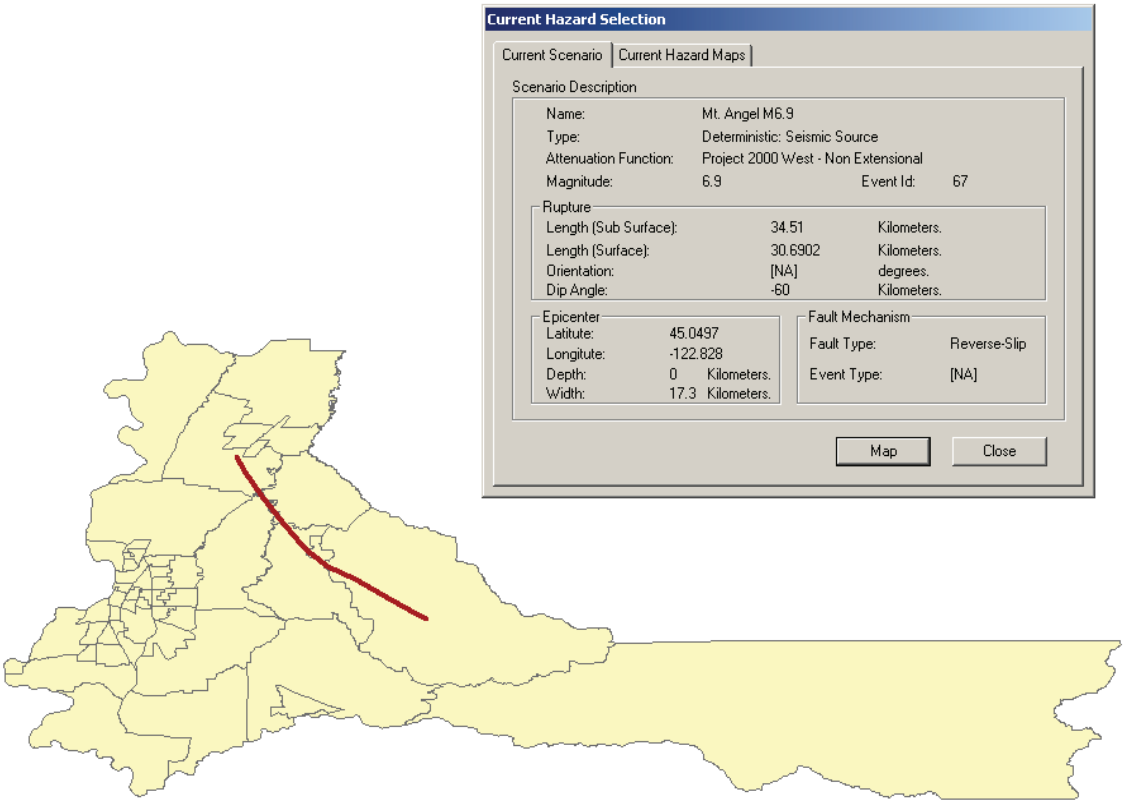

Figure E1. Mount Angel Fault details from HAZUS-MH (FEMA, 2003b). The location of the fault is shown as the dark line.

Crustal Earthquake Scenario Ground Motion Map

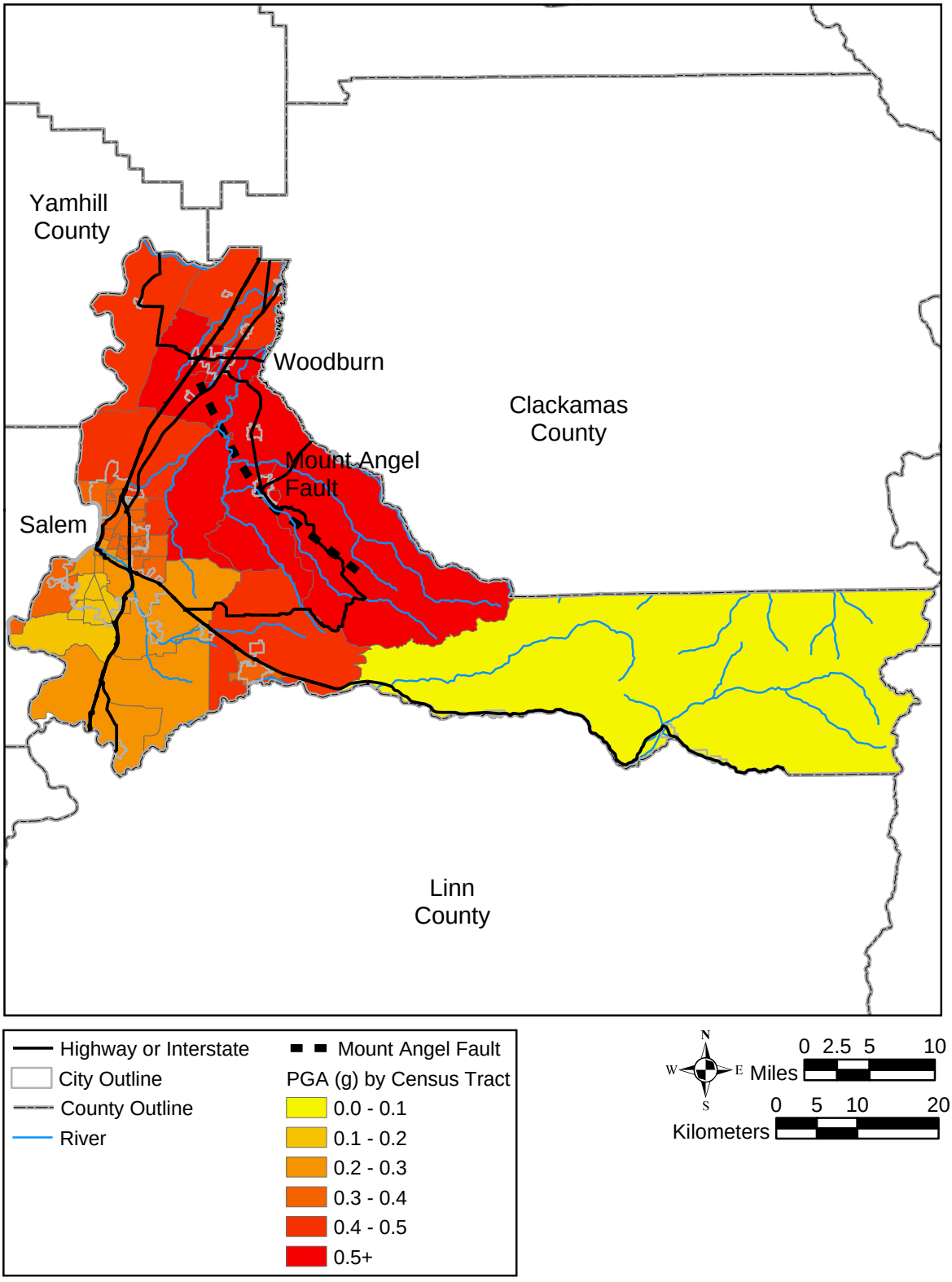

Figure E2. Peak ground acceleration (PGA) by census tracts map for the crustal earthquake scenario, Marion County, Oregon (FEMA, 2003b)

SUBDUCTION ZONE EARTHQUAKE SCENARIO DETAILS FOR MARION 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 E3). 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 E4 displays the PGA for the subduction zone scenario.

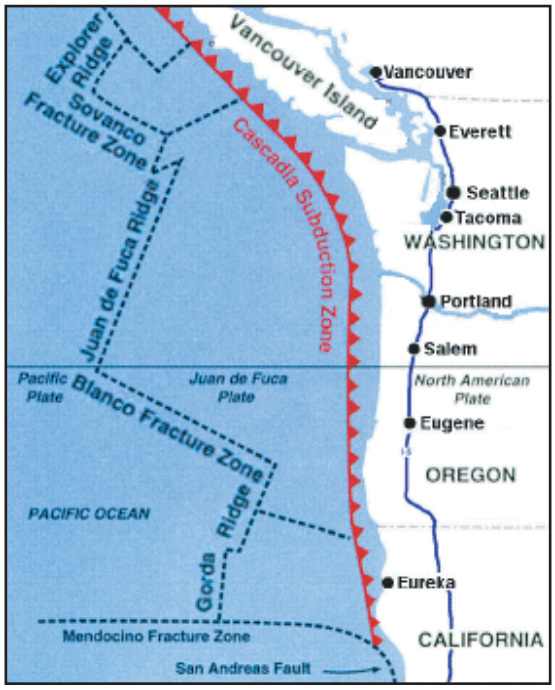

Figure E3. Location of the Cascadia Subduction Zone (CREW, 2003).

Subduction Zone Earthquake Scenario Ground Motion Map

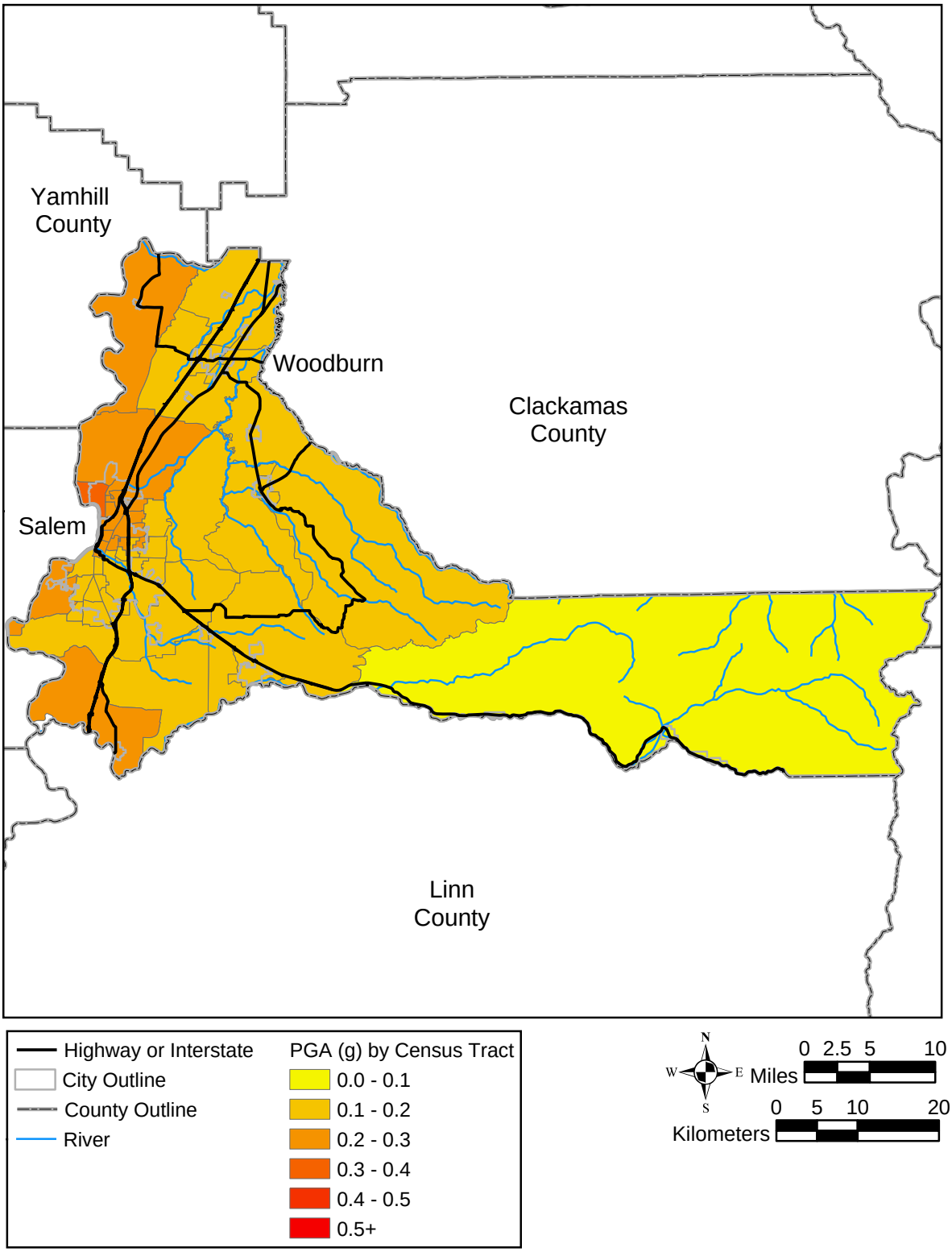

Figure E4. Peak ground acceleration (PGA) by census tracts map for the Cascadia Subduction Zone earthquake scenario, Marion County, Oregon (FEMA, 2003b).

GEOLOGIC HAZARD MAPS

Relative Ground-Shaking Amplification Susceptibility Map

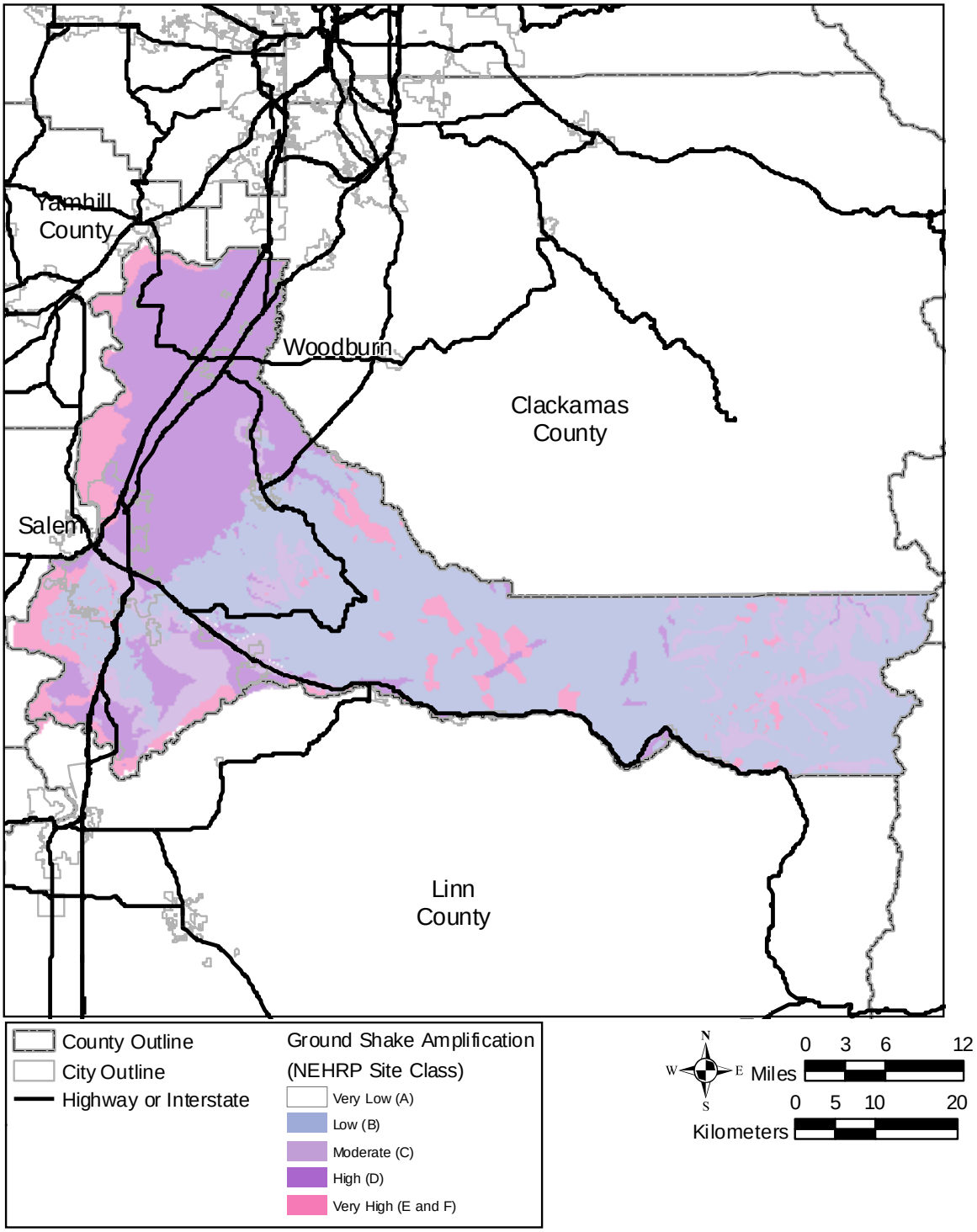

Figure E5. Relative ground-shaking amplification susceptibility map for Marion County, Oregon.

Relative Liquefaction Hazard Susceptibility Map

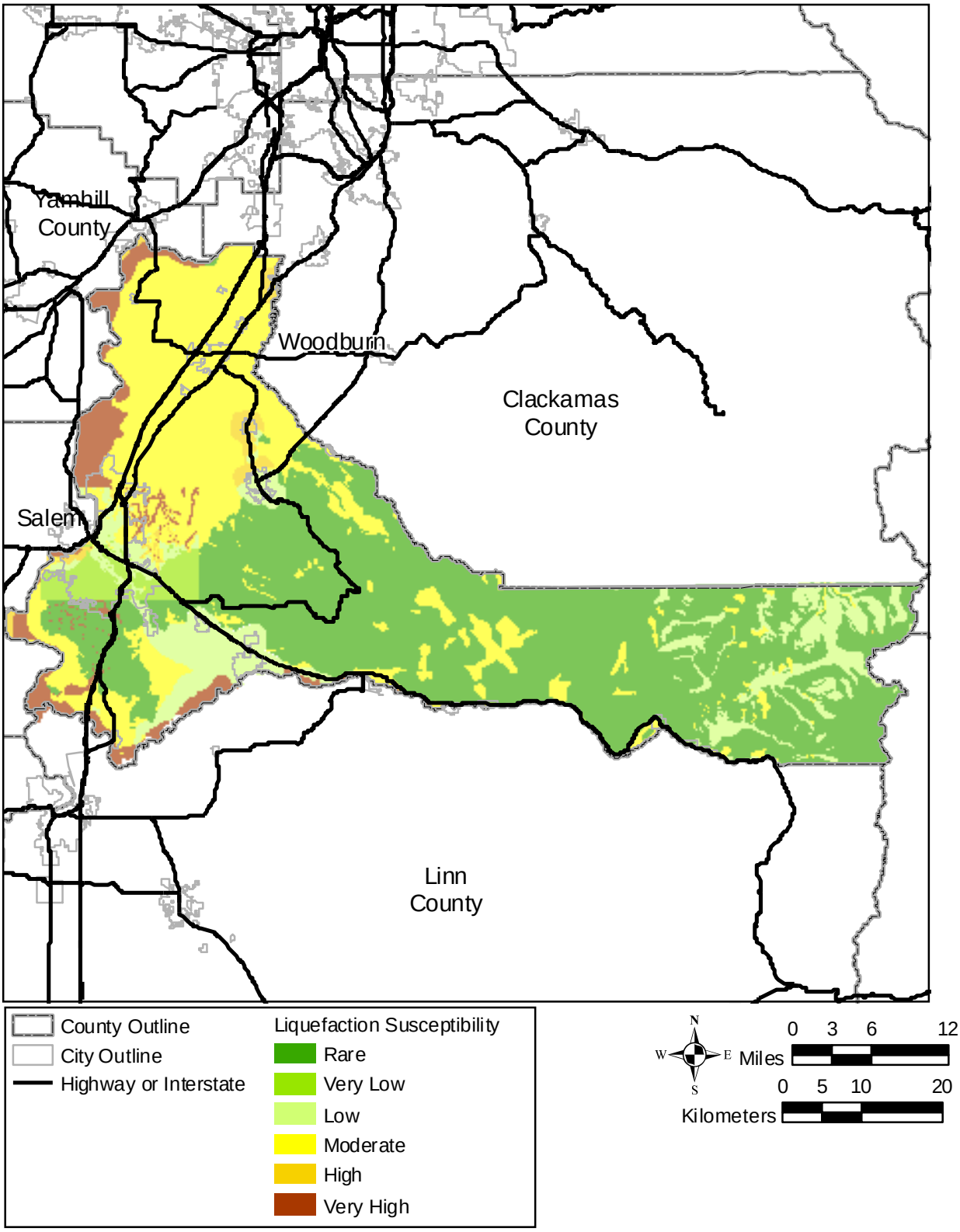

Figure E6. Relative liquefaction susceptibility map for Marion County, Oregon.

Relative Earthquake-Induced Landslide Susceptibility Map

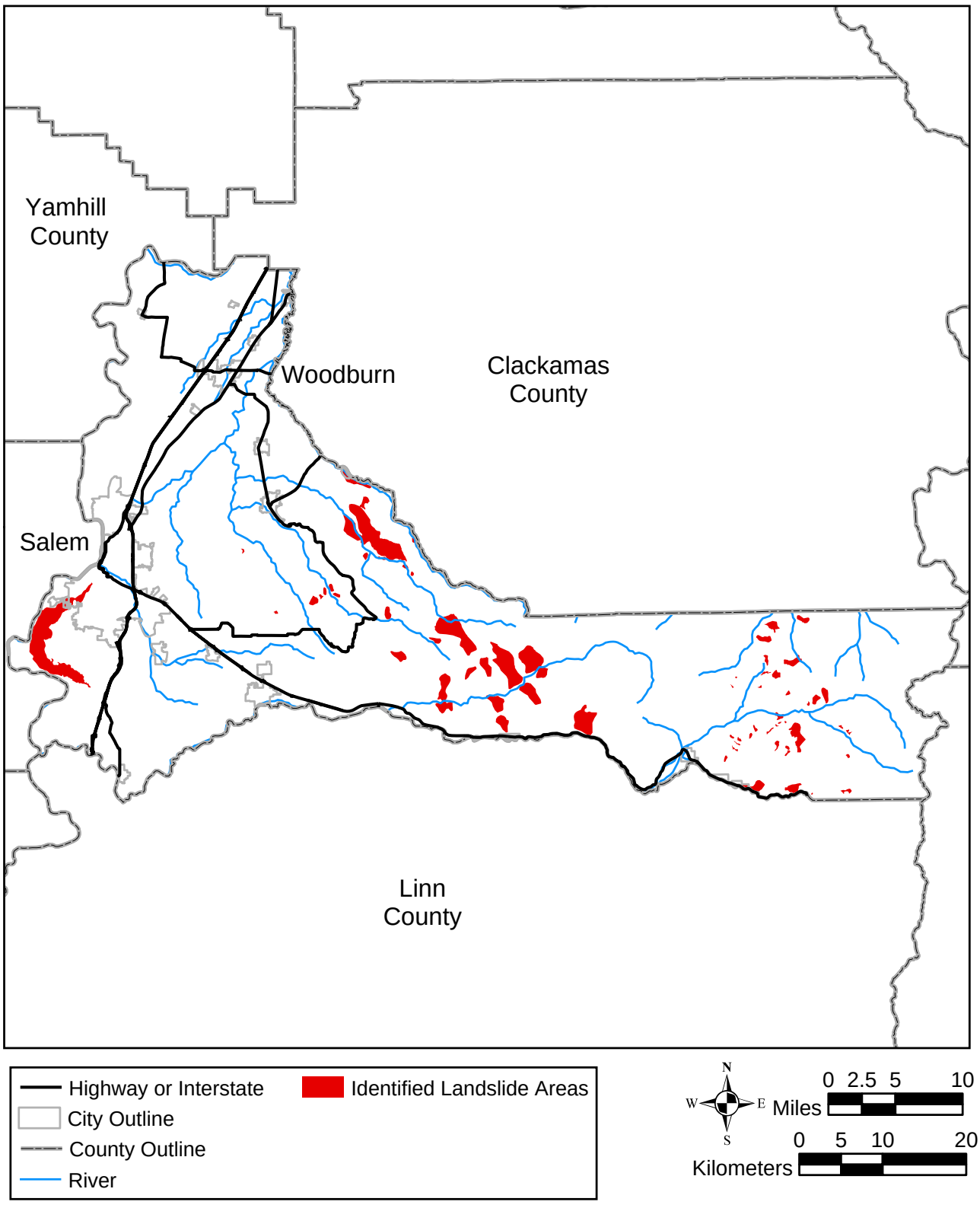

Figure E7. Relative earthquake-induced landslide susceptibility map for Marion County, Oregon.

Identified Landslide Areas Map

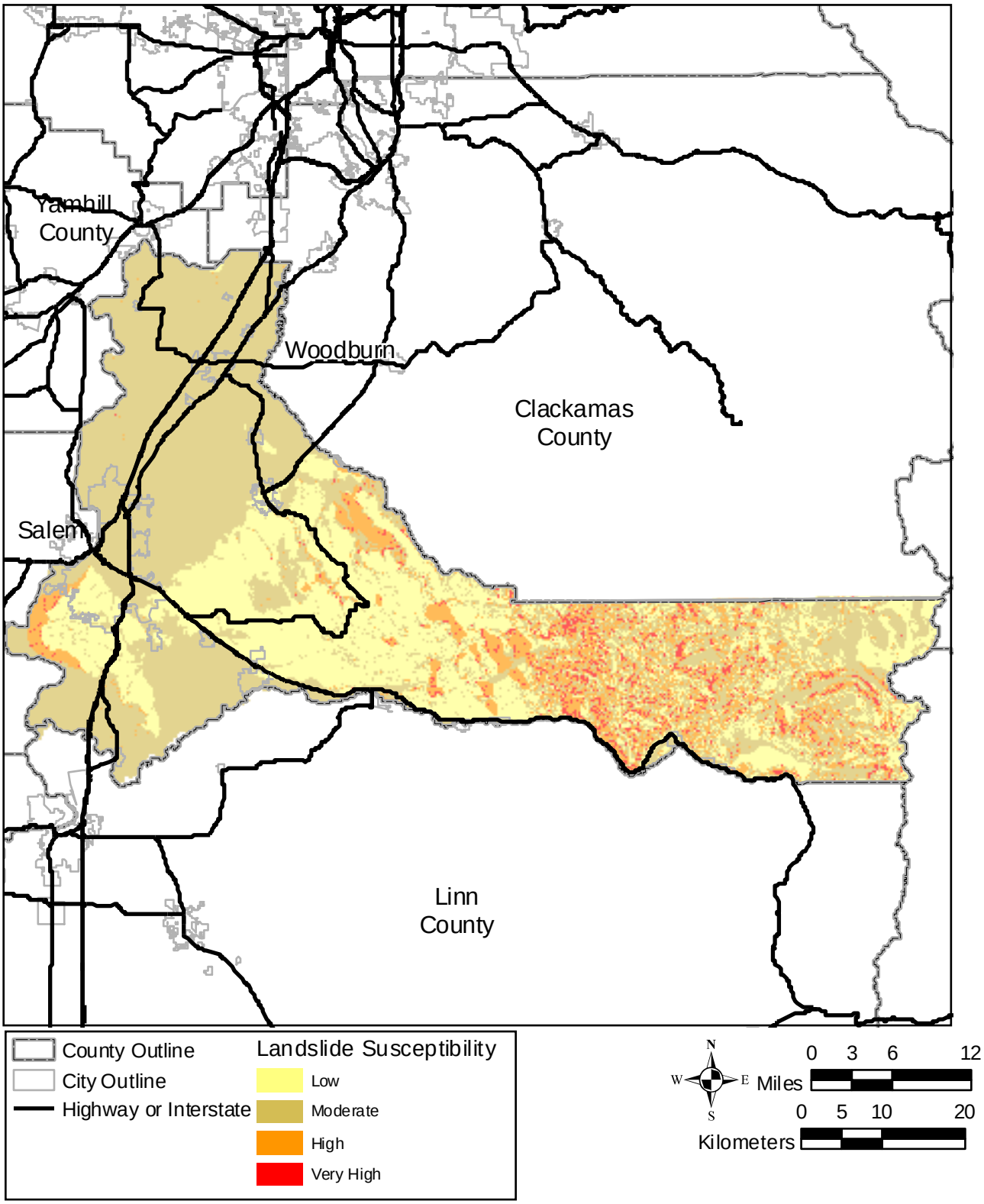

Figure E8. Identified landslide map for Marion County, Oregon.

HAZUS-MH: Earthquake Event Report

Region Name: ***Marion Crustal***

Earthquake Scenario: ***Mt. Angel M6.9***

Print Date: ***March 14, 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.

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 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 1,191.16 square miles and contains 51 census tracts. There are over 101 thousand households in the region and has a total population of 284,834 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 87 thousand buildings in the region with a total building replacement value (excluding contents) of 15,860 (millions of dollars). Approximately 99.00 % of the buildings (and 85.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 4,945 and 1,341 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 87 thousand buildings in the region which have an aggregate total replacement value of 15,860 (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 85% 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 5 hospitals in the region with a total bed capacity of 1,078 beds. There are 140 schools, 18 fire stations, 20 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 29 dams identified within the region. Of these, 3 of the dams are classified as 'high hazard'. The inventory also includes 37 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 6,286.00 (millions of dollars). This inventory includes over 347 kilometers of highways, 161 bridges, 11,650 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	161	2,826.40
	Segments	87	1,289.10
	Tunnels	0	0.00
		Subtotal	**4,115.50**
Railways	Bridges	0	0.00
	Facilities	1	2.50
	Segments	72	170.10
	Tunnels	0	0.00
		Subtotal	**172.50**
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	15	92.40
	Runways	16	561.90
		Subtotal	**654.30**
		Total	**4,946.00**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	116.50
	Facilities	3	112.90
	Pipelines	0	0.00
		Subtotal	**229.40**
Waste Water	Distribution Lines	NA	69.90
	Facilities	13	978.40
	Pipelines	0	0.00
		Subtotal	**1,048.30**
Natural Gas	Distribution Lines	NA	46.60
	Facilities	1	1.20
	Pipelines	0	0.00
		Subtotal	**47.80**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	2	248.60
		Subtotal	**248.60**
Communication	Facilities	5	0.60
		Subtotal	**0.60**
		Total	**1,574.70**

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	Mt. Angel M6.9
Type of Earthquake	Source
Fault Name	Mount Angel Fault
Historical Epicenter ID #	67
Probabilistic Return Period	NA
Longitude of Epicenter	-122.83
Latitude of Epicenter	45.05
Earthquake Magnitude	6.90
Depth (Km)	0.00
Rupture Length (Km)	30.69
Rupture Orientation (degrees)	0.00
Attenuation Function	Project 2000 West - Non Extensional

Building Damage

Building Damage

HAZUS estimates that about 37,487 thousand buildings will be at least moderately damaged. This is over 43.00 % of the total number of buildings in the region. There are an estimated 7,958 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	5	0.02	7	0.03	11	0.05	10	0.11	11	0.14
Commercial	119	0.42	104	0.48	196	0.96	173	1.91	173	2.17
Education	0	0.00	0	0.00	1	0.01	1	0.01	1	0.01
Government	14	0.05	11	0.05	17	0.09	11	0.12	6	0.08
Industrial	12	0.04	11	0.05	25	0.12	27	0.29	30	0.37
Other Residential	2,231	7.77	2,009	9.23	3,479	17.00	3,303	36.43	2,872	36.09
Religion	8	0.03	6	0.03	8	0.04	6	0.06	5	0.06
Single Family	26,306	91.67	19,622	90.13	16,724	81.73	5,537	61.07	4,861	61.08
Total	**28,696**		**21,772**		**20,462**		**9,067**		**7,958**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	73	0.02	3	0.01	8	0.04	8	0.08	8	0.10
MH*	1,326	4.62	1276	5.86	2,797	13.67	2,976	32.83	2,552	32.06
Precast	21	0.04	9	0.04	25	0.12	32	0.35	30	0.38
RM*	10	0.03	5	0.02	12	0.06	15	0.16	12	0.14
Steel	60	0.02	5	0.02	15	0.07	22	0.24	31	0.38
UM*	215	0.75	181	0.83	292	1.43	266	2.93	361	4.53
Wood	26,993	93.97	20172	92.65	17,074	83.44	5,537	61.07	4,777	60.03
Total	**28,696**		**21,772**		**20,462**		**9,067**		**7,958**	

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

Essential Facility Damage

Before the earthquake, the region had 1,078 hospital beds available for use. On the day of the earthquake, the model estimates that only 321 hospital beds (30.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 58.00% of the beds will be back in service. By 30 days, 87.00% 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	5	2	0	3
Schools	140	37	0	103
EOCs	2	0	0	2
PoliceStations	20	7	0	13
FireStations	18	7	0	11

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	87	0	0	87	87
	Bridges	161	23	12	138	145
	Tunnels	0	0	0	0	0
Railways	Segments	72	0	0	72	72
	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	15	8	0	12	15
	Runways	16	0	0	16	16

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	2
Waste Water	13	12	0	0	11
Natural Gas	1	1	0	0	1
Oil Systems	0	0	0	0	0
Electrical Power	2	2	0	0	2
Communication	5	5	0	3	5

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	5,825	1044	801
Waste Water	3,495	826	634
Natural Gas	2,330	883	677
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	101,641	64,244	61,206	54,250	222	0
Electric Power		21,496	14,356	7,030	1,842	28

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 18 ignitions that will burn about 0.17 sq. mi 0.01 % of the region's total area.) The model also estimates that the fires will displace about 336 people and burn about 14 (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 1 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 42.00% 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 40,000 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 (10,701 households to be displaced due to the earthquake. Of these, 2,730 people (out of a total population of 284,834 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	20	6	1	2
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	17	5	1	1
	Industrial	40	12	2	4
	Other-Residential	977	252	28	53
	Single Family	1,209	268	18	30
	Total	**2,263**	**544**	**50**	**90**
2 PM	Commercial	1,466	441	72	141
	Commuting	1	1	2	0
	Educational	516	157	26	50
	Hotels	3	1	0	0
	Industrial	292	89	15	29
	Other-Residential	226	59	7	13
	Single Family	279	62	5	7
	Total	**2,784**	**811**	**127**	**240**
5 PM	Commercial	1,290	390	65	123
	Commuting	23	32	52	10
	Educational	47	14	2	4
	Hotels	5	2	0	0
	Industrial	183	56	9	18
	Other-Residential	371	97	11	20
	Single Family	484	108	9	12
	Total	**2,403**	**698**	**148**	**189**

Economic Loss

The total economic loss estimated for the earthquake is 4,728.50 (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 3,979.57 (millions of dollars); 10 % 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 69 % 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	14.74	99.38	4.99	5.28	124.38
	Capital-Related	0.00	6.25	91.43	2.98	1.84	102.51
	Rental	60.72	65.72	45.97	1.84	2.53	176.78
	Relocation	6.67	1.74	2.44	0.13	0.73	11.70
	Subtotal	**67.39**	**88.46**	**239.22**	**9.94**	**10.37**	**415.37**
Capital Stock Loses							
	Structural	321.27	114.03	124.46	27.43	34.73	621.91
	Non_Structural	1,211.44	514.06	342.90	102.87	68.82	2,240.10
	Content	307.69	109.90	157.52	65.56	36.60	677.27
	Inventory	0.00	0.00	6.93	15.33	2.64	24.91
	Subtotal	**1,840.40**	**738.00**	**631.81**	**211.20**	**142.79**	**3,564.19**
	Total	**1,907.78**	**826.45**	**871.03**	**221.14**	**153.17**	**3,979.57**

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	1,289.06	$31.71	2.46
	Bridges	2,826.41	$239.77	8.48
	Tunnels	0.00	$0.00	0.00
	Subtotal	**4115.50**	**271.50**	
Railways	Segments	170.07	$3.74	2.20
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	2.46	$0.53	21.54
	Subtotal	**172.50**	**4.30**	
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	$0.76	20.55
	Subtotal	**3.70**	**0.80**	
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	92.38	$31.60	34.21
	Runways	561.93	$6.41	1.14
	Subtotal	**654.30**	**38.00**	
	Total	**4946.00**	**314.50**	

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	$32.30	28.62
	Distribution Line	116.50	$20.20	17.34
	Subtotal	**229.39**	**$52.50**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	978.40	$285.02	29.13
	Distribution Line	69.90	$15.97	22.85
	Subtotal	**1,048.26**	**$301.00**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	1.20	$0.36	29.47
	Distribution Line	46.60	$17.08	36.64
	Subtotal	**47.83**	**$17.44**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	248.60	$63.30	25.46
	Subtotal	**248.60**	**$63.30**	
Communication	Facilities	0.60	$0.18	31.06
	Subtotal	**0.57**	**$0.18**	
	Total	**1,574.65**	**$434.41**	

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

	LOSS	Total	%
First Year			
	Employment Impact	1,043	1.61
	Income Impact	(161)	-4.39
Second Year			
	Employment Impact	412	0.64
	Income Impact	(235)	-6.40
Third Year			
	Employment Impact	9	0.01
	Income Impact	(266)	-7.27
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(267)	-7.29
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(267)	-7.29
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(267)	-7.29

Appendix A: County Listing for the Region

Marion,OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon	Marion	284,834	13,461	2,399	15,860
Total State		**284,834**	**13,461**	**2,399**	**15,860**
Total Region		**284,834**	**13,461**	**2,399**	**15,860**

HAZUS-MH: Earthquake Event Report

Region Name: ***Marion Cascadia***

Earthquake Scenario: ***Cascadia M8.5***

Print Date: ***March 14, 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.

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 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 1,191.16 square miles and contains 51 census tracts. There are over 101 thousand households in the region and has a total population of 284,834 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 87 thousand buildings in the region with a total building replacement value (excluding contents) of 15,860 (millions of dollars). Approximately 99.00 % of the buildings (and 85.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 4,945 and 1,341 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 87 thousand buildings in the region which have an aggregate total replacement value of 15,860 (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 85% 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 5 hospitals in the region with a total bed capacity of 1,078 beds. There are 140 schools, 18 fire stations, 20 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 29 dams identified within the region. Of these, 3 of the dams are classified as 'high hazard'. The inventory also includes 37 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 6,286.00 (millions of dollars). This inventory includes over 347 kilometers of highways, 161 bridges, 11,650 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	161	2,826.40
	Segments	87	1,289.10
	Tunnels	0	0.00
		Subtotal	**4,115.50**
Railways	Bridges	0	0.00
	Facilities	1	2.50
	Segments	72	170.10
	Tunnels	0	0.00
		Subtotal	**172.50**
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	15	92.40
	Runways	16	561.90
		Subtotal	**654.30**
		Total	**4,946.00**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	116.50
	Facilities	3	112.90
	Pipelines	0	0.00
		Subtotal	**229.40**
Waste Water	Distribution Lines	NA	69.90
	Facilities	13	978.40
	Pipelines	0	0.00
		Subtotal	**1,048.30**
Natural Gas	Distribution Lines	NA	46.60
	Facilities	1	1.20
	Pipelines	0	0.00
		Subtotal	**47.80**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	2	248.60
		Subtotal	**248.60**
Communication	Facilities	5	0.60
		Subtotal	**0.60**
		Total	**1,574.70**

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 M8.5
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 21,700 thousand buildings will be at least moderately damaged. This is over 25.00 % of the total number of buildings in the region. There are an estimated 4,629 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	12	0.03	7	0.03	8	0.07	8	0.15	8	0.16
Commercial	94	0.21	101	0.48	199	1.68	192	3.66	179	3.87
Education	0	0.00	0	0.00	1	0.01	1	0.02	1	0.02
Government	8	0.02	8	0.04	16	0.14	16	0.31	12	0.26
Industrial	8	0.02	10	0.05	26	0.22	31	0.59	30	0.66
Other Residential	2,197	4.89	2,016	9.46	3,464	29.32	3,583	68.19	2,634	56.90
Religion	8	0.02	5	0.02	7	0.06	7	0.13	6	0.13
Single Family	42,606	94.82	19,173	89.92	8,095	68.51	1,415	26.94	1,759	38.00
Total	**44,933**		**21,322**		**11,817**		**5,254**		**4,629**	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	40	0.00	2	0.01	7	0.06	10	0.19	11	0.24
MH*	815	1.81	1318	6.18	3,030	25.64	3,353	63.81	2,411	52.08
Precast	11	0.02	7	0.03	24	0.20	35	0.67	35	0.76
RM*	6	0.01	4	0.02	13	0.11	17	0.33	13	0.28
Steel	24	0.00	2	0.01	12	0.10	23	0.44	39	0.85
UM*	281	0.62	254	1.19	341	2.88	235	4.47	203	4.39
Wood	43,757	97.34	19639	92.11	8,153	69.00	1,318	25.09	1,676	36.21
Total	**44,933**		**21,322**		**11,817**		**5,254**		**4,629**	

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

Essential Facility Damage

Before the earthquake, the region had 1,078 hospital beds available for use. On the day of the earthquake, the model estimates that only 424 hospital beds (39.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 65.00% of the beds will be back in service. By 30 days, 93.00% 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	5	2	0	3
Schools	140	2	0	138
EOCs	2	0	0	2
PoliceStations	20	0	0	20
FireStations	18	0	0	18

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	87	0	0	87	87
	Bridges	161	17	0	144	158
	Tunnels	0	0	0	0	0
Railways	Segments	72	0	0	72	72
	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	15	0	0	15	15
	Runways	16	0	0	16	16

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	13	1	0	9	13
Natural Gas	1	0	0	1	1
Oil Systems	0	0	0	0	0
Electrical Power	2	0	0	2	2
Communication	5	0	0	5	5

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	5,825	435	230
Waste Water	3,495	344	182
Natural Gas	2,330	368	195
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	101,641	11,171	6,093	293	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 12 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 155 people and burn about 8 (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 1 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 33.00% 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 40,000 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 (5,787 households to be displaced due to the earthquake. Of these, 1,470 people (out of a total population of 284,834 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	21	6	1	2
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	11	3	1	1
	Industrial	36	11	2	3
	Other-Residential	787	202	23	44
	Single Family	435	94	6	11
	Total	**1,290**	**317**	**33**	**61**
2 PM	Commercial	1,411	425	71	138
	Commuting	0	0	1	0
	Educational	411	125	21	40
	Hotels	2	1	0	0
	Industrial	264	80	13	25
	Other-Residential	181	47	6	11
	Single Family	97	21	2	3
	Total	**2,367**	**699**	**113**	**218**
5 PM	Commercial	1,164	349	58	112
	Commuting	9	10	19	4
	Educational	46	14	2	5
	Hotels	3	1	0	0
	Industrial	165	50	8	16
	Other-Residential	294	76	9	17
	Single Family	173	38	3	4
	Total	**1,854**	**538**	**100**	**157**

Economic Loss

The total economic loss estimated for the earthquake is 2,868.62 (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 2,604.95 (millions of dollars); 14 % 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 53 % 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	13.45	103.83	5.10	6.10	128.48
	Capital-Related	0.00	5.70	96.51	3.05	1.69	106.94
	Rental	22.73	49.72	48.93	1.93	3.12	126.43
	Relocation	2.67	1.40	2.56	0.15	0.78	7.56
	Subtotal	**25.39**	**70.28**	**251.82**	**10.22**	**11.69**	**369.41**
Capital Stock Loses							
	Structural	122.58	98.02	130.29	28.79	31.78	411.46
	Non_Structural	480.99	386.77	336.66	97.18	65.10	1,366.70
	Content	128.03	75.41	141.95	59.95	30.63	435.97
	Inventory	0.00	0.00	6.16	13.58	1.68	21.42
	Subtotal	**731.60**	**560.21**	**615.06**	**199.49**	**129.19**	**2,235.54**
	Total	**756.99**	**630.49**	**866.88**	**209.71**	**140.88**	**2,604.95**

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	1,289.06	$2.71	0.21
	Bridges	2,826.41	$125.02	4.42
	Tunnels	0.00	$0.00	0.00
	Subtotal	**4115.50**	**127.70**	
Railways	Segments	170.07	$0.38	0.23
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	2.46	$0.33	13.27
	Subtotal	**172.50**	**0.70**	
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	$0.52	14.09
	Subtotal	**3.70**	**0.50**	
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	92.38	$12.48	13.51
	Runways	561.93	$0.55	0.10
	Subtotal	**654.30**	**13.00**	
	Total	**4946.00**	**142.00**	

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	$6.40	5.67
	Distribution Line	116.50	$6.35	5.45
	Subtotal	**229.39**	**$12.74**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	978.40	$80.37	8.21
	Distribution Line	69.90	$5.02	7.18
	Subtotal	**1,048.26**	**$85.39**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	1.20	$0.07	5.97
	Distribution Line	46.60	$5.36	11.51
	Subtotal	**47.83**	**$5.44**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	248.60	$18.08	7.27
	Subtotal	**248.60**	**$18.08**	
Communication	Facilities	0.60	$0.03	5.95
	Subtotal	**0.57**	**$0.03**	
	Total	**1,574.65**	**$121.68**	

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

	LOSS	Total	%
First Year			
	Employment Impact	544	0.84
	Income Impact	(150)	-4.09
Second Year			
	Employment Impact	225	0.35
	Income Impact	(196)	-5.35
Third Year			
	Employment Impact	6	0.01
	Income Impact	(216)	-5.89
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(216)	-5.90
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(216)	-5.90
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(216)	-5.90

Appendix A: County Listing for the Region

Marion,OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon	Marion	284,834	13,461	2,399	15,860
Total State		**284,834**	**13,461**	**2,399**	**15,860**
Total Region		**284,834**	**13,461**	**2,399**	**15,860**