

HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *1882 M6.6 State RMNP epc CEUS Event*

Print Date: *January 25, 2006*

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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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):

Colorado

Note:

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

The geographical size of the region is 154.74 square miles and contains 136 census tracts. There are over 239 thousand households in the region and has a total population of 554,636 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 143 thousand buildings in the region with a total building replacement value (excluding contents) of 36,233 (millions of dollars). Approximately 97.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,247 and 428 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 143 thousand buildings in the region which have an aggregate total replacement value of 36,233 (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 74% 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 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 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 2,675.00 (millions of dollars). This inventory includes over 147 kilometers of highways, 426 bridges, 6,508 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	426	1,461.00
	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	1882 M6.6 State RMNP epc CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-105.74
Latitude of Epicenter	40.41
Earthquake Magnitude	6.60
Depth (Km)	10.00
Rupture Length (Km)	21.58
Rupture Orientation (degrees)	45.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 4,943 buildings will be at least moderately damaged. This is over 3.00 % of the total number of buildings in the region. There are an estimated 35 buildings that will be damaged beyond repair. 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	7	0.01	1	0.01	0	0.01	0	0.01	0	0.02
Commercial	2,446	1.92	399	3.36	266	6.35	58	8.04	4	11.29
Education	6	0.01	1	0.01	1	0.02	0	0.02	0	0.02
Government	147	0.12	23	0.20	15	0.37	3	0.42	0	0.54
Industrial	223	0.18	39	0.32	30	0.72	7	1.02	0	1.21
Other Residential	7,992	6.29	913	7.69	390	9.32	65	8.92	3	9.21
Religion	109	0.09	15	0.13	9	0.23	2	0.26	0	0.34
Single Family	116,184	91.40	10,477	88.28	3,471	82.98	590	81.31	27	77.37
Total	127,115		11,868		4,183		726		35	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	96,241	75.71	8454	71.23	1,517	36.26	100	13.84	3	8.92
Steel	1,011	0.80	164	1.38	139	3.32	30	4.15	2	6.82
Concrete	1,000	0.79	175	1.48	108	2.59	20	2.73	1	2.15
Precast	449	0.35	71	0.60	74	1.78	25	3.46	1	2.41
RM	24,579	19.34	2169	18.27	1,791	42.82	415	57.19	5	12.87
URM	3,128	2.46	678	5.72	436	10.43	121	16.72	23	64.98
MH	707	0.56	156	1.32	117	2.79	14	1.90	1	1.85
Total	127,115		11,868		4,183		726		35	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 2,464 hospital beds (74.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 94.00% 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		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	0	0	14
Schools	200	0	0	200
EOCs	2	0	0	2
PoliceStations	17	0	0	17
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	52	0	0	52	52
	Bridges	426	0	0	426	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	0	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	0	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	0	0	7	7
Electrical Power	4	0	0	4	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	16	4
Waste Water	1,953	13	3
Natural Gas	1,302	14	3
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	239,235	0	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 11 ignitions that will burn about 0.04 sq. mi 0.03 % of the region's total area.) The model also estimates that the fires will displace about 197 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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 756 households to be displaced due to the earthquake. Of these, 205 people (out of a total population of 554,636 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	3	0	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	2	0	0	0
	Industrial	3	0	0	0
	Other-Residential	43	5	0	1
	Single Family	61	7	1	1
	Total	111	13	1	2
2 PM	Commercial	151	22	2	4
	Commuting	0	0	0	0
	Educational	11	2	0	0
	Hotels	0	0	0	0
	Industrial	19	3	0	0
	Other-Residential	8	1	0	0
	Single Family	12	1	0	0
	Total	200	28	2	5
5 PM	Commercial	98	14	1	2
	Commuting	0	0	0	0
	Educational	3	0	0	0
	Hotels	0	0	0	0
	Industrial	12	2	0	0
	Other-Residential	16	2	0	0
	Single Family	24	3	0	0
	Total	153	21	2	3

Economic Loss

The total economic loss estimated for the earthquake is 527.25 (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 512.66 (millions of dollars); 19 % 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 55 % 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 Losses							
	Wage	0.00	1.06	29.21	0.68	0.89	31.85
	Capital-Related	0.00	0.45	27.16	0.44	0.18	28.24
	Rental	5.58	12.12	15.00	0.37	0.48	33.55
	Relocation	0.57	0.28	0.83	0.05	0.11	1.84
	Subtotal	6.15	13.92	72.20	1.55	1.66	95.48
Capital Stock Losses							
	Structural	29.52	14.71	27.98	4.08	2.33	78.60
	Non_Structural	95.03	74.76	59.79	10.10	5.74	245.42
	Content	31.13	19.01	30.95	6.82	2.93	90.84
	Inventory	0.00	0.00	0.95	1.34	0.03	2.33
	Subtotal	155.67	108.48	119.67	22.35	11.02	417.19
	Total	161.82	122.39	191.87	23.90	12.68	512.66

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$0.57	0.04
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	0.60	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$0.37	4.36
	Subtotal	105.40	0.40	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$0.41	6.39
	Subtotal	6.30	0.40	
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	5.29	\$0.08	1.59
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.10	
	Total	2247.50	1.40	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.07	0.11
	Subtotal	65.08	\$0.07	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.06	0.15
	Subtotal	39.05	\$0.06	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.00	0.21
	Distribution Line	26.00	\$0.06	0.24
	Subtotal	27.09	\$0.06	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.02	3.25
	Subtotal	0.68	\$0.02	
Electrical Power	Facilities	426.80	\$12.94	3.03
	Subtotal	426.80	\$12.94	
Communication	Facilities	0.20	\$0.00	0.26
	Subtotal	0.19	\$0.00	
	Total	558.90	\$13.16	

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

	LOSS	Total	%
First Year			
	Employment Impact	744	0.23
	Income Impact	(2)	-0.02
Second Year			
	Employment Impact	315	0.10
	Income Impact	(11)	-0.10
Third Year			
	Employment Impact	7	0.00
	Income Impact	(15)	-0.13
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(15)	-0.13
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(15)	-0.14
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(15)	-0.14

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233

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	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	Anton M7.6 Denver CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-102.93
Latitude of Epicenter	39.60
Earthquake Magnitude	7.60
Depth (Km)	10.00
Rupture Length (Km)	118.58
Rupture Orientation (degrees)	140.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 21,191 buildings will be at least moderately damaged. This is over 15.00 % of the total number of buildings in the region. There are an estimated 1,384 buildings that will be damaged beyond repair. 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	4	0.00	1	0.01	1	0.01	1	0.01	0	0.02
Commercial	1,131	1.13	531	2.30	816	6.09	527	8.23	168	12.14
Education	3	0.00	1	0.00	2	0.01	1	0.02	0	0.03
Government	66	0.07	33	0.14	50	0.37	31	0.49	9	0.68
Industrial	86	0.09	45	0.20	84	0.62	62	0.97	23	1.67
Other Residential	6,059	6.08	1,558	6.76	1,048	7.82	542	8.47	155	11.23
Religion	62	0.06	21	0.09	28	0.21	19	0.29	6	0.41
Single Family	92,259	92.56	20,875	90.50	11,378	84.86	5,215	81.51	1,022	73.83
Total	99,669		23,066		13,408		6,399		1,385	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	81,916	82.19	18326	79.45	5,458	40.71	581	9.08	34	2.49
Steel	371	0.37	167	0.73	372	2.78	302	4.72	134	9.69
Concrete	473	0.47	221	0.96	336	2.51	214	3.34	60	4.33
Precast	187	0.19	72	0.31	156	1.17	151	2.36	54	3.91
RM	14,392	14.44	3231	14.01	5,932	44.24	4,540	70.96	864	62.37
URM	1,979	1.99	868	3.76	886	6.60	455	7.12	199	14.35
MH	352	0.35	180	0.78	267	1.99	155	2.43	40	2.86
Total	99,669		23,066		13,408		6,399		1,385	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 1,085 hospital beds (33.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 60.00% of the beds will be back in service. By 30 days, 92.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	0	0	3
Schools	200	0	0	200
EOCs	2	0	0	2
PoliceStations	17	0	0	17
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	52	0	0	52	52
	Bridges	426	0	0	426	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	0	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	0	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	0	0	7	7
Electrical Power	4	0	0	4	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	94	24
Waste Water	1,953	75	19
Natural Gas	1,302	80	20
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	239,235	0	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 19 ignitions that will burn about 0.06 sq. mi 0.04 % of the region's total area.) The model also estimates that the fires will displace about 348 people and burn about 19 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 8,393 households to be displaced due to the earthquake. Of these, 2,242 people (out of a total population of 554,636 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	30	8	1	2
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	14	3	0	1
	Industrial	34	9	1	3
	Other-Residential	385	89	12	23
	Single Family	502	115	17	33
	Total	965	224	32	63
2 PM	Commercial	1,665	429	66	131
	Commuting	0	0	0	0
	Educational	135	35	6	11
	Hotels	3	1	0	0
	Industrial	249	66	10	20
	Other-Residential	73	17	2	4
	Single Family	94	21	3	6
	Total	2,219	569	88	172
5 PM	Commercial	1,105	284	44	86
	Commuting	5	6	10	2
	Educational	34	9	1	3
	Hotels	4	1	0	0
	Industrial	156	41	6	12
	Other-Residential	146	34	5	9
	Single Family	195	44	7	13
	Total	1,644	419	73	124

Economic Loss

The total economic loss estimated for the earthquake is 3,045.36 (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 3,010.61 (millions of dollars); 22 % 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 47 % 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 Losses							
	Wage	0.00	8.26	208.60	5.08	6.17	228.11
	Capital-Related	0.00	3.53	191.35	3.31	1.29	199.47
	Rental	32.64	76.83	91.81	2.67	4.16	208.11
	Relocation	3.40	1.59	5.48	0.28	0.86	11.61
	Subtotal	36.04	90.21	497.24	11.34	12.48	647.30
Capital Stock Losses							
	Structural	173.17	90.45	205.23	31.38	18.95	519.19
	Non_Structural	447.00	386.42	442.39	77.43	43.97	1,397.21
	Content	112.37	78.38	176.10	47.65	16.91	431.41
	Inventory	0.00	0.00	5.95	9.40	0.15	15.51
	Subtotal	732.54	555.24	829.67	165.87	79.98	2,363.31
	Total	768.58	645.45	1,326.92	177.20	92.46	3,010.61

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$9.17	0.63
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	9.20	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.00	0.16
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$0.68	7.98
	Subtotal	105.40	0.70	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.03
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$0.61	9.63
	Subtotal	6.30	0.60	
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	5.29	\$0.33	6.24
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.30	
	Total	2247.50	10.80	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.42	0.65
	Subtotal	65.08	\$0.42	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.34	0.86
	Subtotal	39.05	\$0.34	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.02	1.72
	Distribution Line	26.00	\$0.36	1.38
	Subtotal	27.09	\$0.38	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.04	5.89
	Subtotal	0.68	\$0.04	
Electrical Power	Facilities	426.80	\$22.78	5.34
	Subtotal	426.80	\$22.78	
Communication	Facilities	0.20	\$0.00	0.67
	Subtotal	0.19	\$0.00	
	Total	558.90	\$23.96	

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

	LOSS	Total	%
First Year			
	Employment Impact	8,444	2.64
	Income Impact	(27)	-0.24
Second Year			
	Employment Impact	3,841	1.20
	Income Impact	(122)	-1.08
Third Year			
	Employment Impact	95	0.03
	Income Impact	(168)	-1.49
Fourth Year			
	Employment Impact	5	0.00
	Income Impact	(171)	-1.52
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(171)	-1.52
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(171)	-1.52

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233

HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *Chase Gulch M6.75 CEUS Event*

Print Date: *January 25, 2006*

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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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):

Colorado

Note:

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

The geographical size of the region is 154.74 square miles and contains 136 census tracts. There are over 239 thousand households in the region and has a total population of 554,636 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 143 thousand buildings in the region with a total building replacement value (excluding contents) of 36,233 (millions of dollars). Approximately 97.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,247 and 428 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 143 thousand buildings in the region which have an aggregate total replacement value of 36,233 (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 74% 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 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 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 2,675.00 (millions of dollars). This inventory includes over 147 kilometers of highways, 426 bridges, 6,508 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	426	1,461.00
	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	Chase Gulch M6.75 CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-105.62
Latitude of Epicenter	39.00
Earthquake Magnitude	6.75
Depth (Km)	10.00
Rupture Length (Km)	27.86
Rupture Orientation (degrees)	157.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 9,295 buildings will be at least moderately damaged. This is over 6.00 % of the total number of buildings in the region. There are an estimated 104 buildings that will be damaged beyond repair. 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	6	0.01	1	0.01	1	0.01	0	0.01	0	0.02
Commercial	2,058	1.76	526	3.00	447	5.98	130	7.56	12	11.68
Education	5	0.00	1	0.01	1	0.02	0	0.02	0	0.03
Government	124	0.11	31	0.18	26	0.35	7	0.40	1	0.55
Industrial	189	0.16	49	0.28	47	0.63	14	0.84	1	1.19
Other Residential	7,275	6.21	1,287	7.33	647	8.66	144	8.37	10	9.78
Religion	95	0.08	20	0.12	16	0.22	5	0.26	0	0.37
Single Family	107,319	91.67	15,646	89.09	6,286	84.14	1,420	82.53	80	76.39
Total	117,070		17,562		7,471		1,721		104	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	90,191	77.04	12977	73.89	2,906	38.90	231	13.40	10	9.99
Steel	844	0.72	206	1.17	224	3.00	65	3.75	8	7.39
Concrete	834	0.71	229	1.30	188	2.52	50	2.89	3	3.10
Precast	371	0.32	86	0.49	110	1.48	50	2.88	3	3.10
RM	21,535	18.40	3051	17.37	3,254	43.55	1,090	63.33	29	27.95
URM	2,707	2.31	817	4.65	609	8.16	205	11.89	48	46.48
MH	587	0.50	195	1.11	178	2.39	32	1.86	2	1.99
Total	117,070		17,562		7,471		1,721		104	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 2,010 hospital beds (60.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 87.00% 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		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	0	0	14
Schools	200	0	0	200
EOCs	2	0	0	2
PoliceStations	17	0	0	17
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	52	0	0	52	52
	Bridges	426	0	0	426	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	0	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	0	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	0	0	7	7
Electrical Power	4	0	0	4	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	33	8
Waste Water	1,953	26	6
Natural Gas	1,302	28	7
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	239,235	0	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 17 ignitions that will burn about 0.03 sq. mi 0.02 % of the region's total area.) The model also estimates that the fires will displace about 125 people and burn about 6 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 1,769 households to be displaced due to the earthquake. Of these, 474 people (out of a total population of 554,636 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	6	1	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	3	0	0	0
	Industrial	5	1	0	0
	Other-Residential	85	12	1	2
	Single Family	121	16	1	3
	Total	219	30	2	5
2 PM	Commercial	307	52	5	11
	Commuting	0	0	0	0
	Educational	23	4	0	1
	Hotels	1	0	0	0
	Industrial	38	6	1	1
	Other-Residential	15	2	0	0
	Single Family	22	3	0	0
	Total	407	67	7	13
5 PM	Commercial	201	34	4	7
	Commuting	1	1	1	0
	Educational	6	1	0	0
	Hotels	1	0	0	0
	Industrial	24	4	0	1
	Other-Residential	32	5	0	1
	Single Family	47	6	1	1
	Total	311	50	6	10

Economic Loss

The total economic loss estimated for the earthquake is 1,008.01 (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 982.10 (millions of dollars); 19 % 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 56 % 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 Losses							
	Wage	0.00	2.07	57.61	1.24	1.70	62.62
	Capital-Related	0.00	0.88	52.89	0.80	0.36	54.93
	Rental	11.18	23.61	28.20	0.68	1.01	64.68
	Relocation	1.16	0.54	1.61	0.08	0.22	3.61
	Subtotal	12.34	27.10	140.31	2.81	3.29	185.84
Capital Stock Losses							
	Structural	58.10	27.94	53.62	7.31	4.67	151.64
	Non_Structural	182.58	143.20	112.68	17.33	11.05	466.85
	Content	62.39	37.83	56.37	11.60	5.52	173.71
	Inventory	0.00	0.00	1.72	2.28	0.05	4.06
	Subtotal	303.07	208.98	224.38	38.52	21.30	796.25
	Total	315.41	236.08	364.69	41.33	24.59	982.10

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$1.72	0.12
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	1.70	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.00	0.01
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$0.53	6.26
	Subtotal	105.40	0.50	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$0.55	8.70
	Subtotal	6.30	0.60	
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	5.29	\$0.10	1.87
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.10	
	Total	2247.50	2.90	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.15	0.22
	Subtotal	65.08	\$0.15	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.12	0.30
	Subtotal	39.05	\$0.12	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.00	0.23
	Distribution Line	26.00	\$0.12	0.48
	Subtotal	27.09	\$0.13	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.04	5.61
	Subtotal	0.68	\$0.04	
Electrical Power	Facilities	426.80	\$22.58	5.29
	Subtotal	426.80	\$22.58	
Communication	Facilities	0.20	\$0.00	0.77
	Subtotal	0.19	\$0.00	
	Total	558.90	\$23.01	

Table 15. Indirect Economic Impact with outside aid

(Employment as # of people and Income in millions of \$)

	LOSS	Total	%
First Year			
	Employment Impact	1,498	0.47
	Income Impact	(5)	-0.04
Second Year			
	Employment Impact	647	0.20
	Income Impact	(21)	-0.18
Third Year			
	Employment Impact	14	0.00
	Income Impact	(29)	-0.25
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(29)	-0.26
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(29)	-0.26
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(29)	-0.26

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233

HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *Cheraw M7.0 CEUS Event*

Print Date: *January 25, 2006*

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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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):

Colorado

Note:

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

The geographical size of the region is 154.74 square miles and contains 136 census tracts. There are over 239 thousand households in the region and has a total population of 554,636 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 143 thousand buildings in the region with a total building replacement value (excluding contents) of 36,233 (millions of dollars). Approximately 97.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,247 and 428 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 143 thousand buildings in the region which have an aggregate total replacement value of 36,233 (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 74% 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 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 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 2,675.00 (millions of dollars). This inventory includes over 147 kilometers of highways, 426 bridges, 6,508 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	426	1,461.00
	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	Cheraw M7.0 CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-103.42
Latitude of Epicenter	38.28
Earthquake Magnitude	7.00
Depth (Km)	10.00
Rupture Length (Km)	42.66
Rupture Orientation (degrees)	44.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 96 buildings will be at least moderately damaged. This is over 0.00 % of the total number of buildings in the region. There are an estimated 0 buildings that will be damaged beyond repair. 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	8	0.01	0	0.00	0	0.00	0	0.00	0	0.00
Commercial	3,158	2.20	10	3.20	4	5.12	1	5.63	0	7.68
Education	8	0.01	0	0.00	0	0.00	0	0.00	0	0.00
Government	189	0.13	0	0.00	0	0.00	0	0.00	0	0.00
Industrial	300	0.21	0	0.03	0	0.04	0	0.04	0	0.01
Other Residential	9,322	6.50	31	10.08	9	10.55	1	9.18	0	7.56
Religion	136	0.09	0	0.03	0	0.04	0	0.04	0	0.05
Single Family	130,405	90.86	264	86.66	72	84.24	9	85.11	0	84.70
Total	143,526		304		85		11		0	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	106,089	73.92	200	65.78	25	29.21	1	11.57	0	0.00
Steel	1,339	0.93	5	1.55	3	3.09	0	3.48	0	3.16
Concrete	1,298	0.90	4	1.45	1	1.75	0	1.27	0	0.32
Precast	617	0.43	2	0.60	1	1.45	0	2.14	0	0.67
RM	28,849	20.10	64	21.11	40	46.54	6	54.72	0	0.00
URM	4,344	3.03	25	8.38	13	15.83	3	25.90	0	95.39
MH	989	0.69	3	1.13	2	2.14	0	0.93	0	0.46
Total	143,526		304		85		11		0	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 3,328 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		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	0	0	14
Schools	200	0	0	200
EOCs	2	0	0	2
PoliceStations	17	0	0	17
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	52	0	0	52	52
	Bridges	426	0	0	426	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	0	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	0	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	0	0	7	7
Electrical Power	4	0	0	4	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	0	0
Waste Water	1,953	0	0
Natural Gas	1,302	0	0
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	239,235	0	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 0 ignitions that will burn about 0.00 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 0 people and burn about 0 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 17 households to be displaced due to the earthquake. Of these, 4 people (out of a total population of 554,636 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	0	0	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	0	0	0	0
	Other-Residential	1	0	0	0
	Single Family	1	0	0	0
	Total	2	0	0	0
2 PM	Commercial	2	0	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	0	0	0	0
	Other-Residential	0	0	0	0
	Single Family	0	0	0	0
	Total	3	0	0	0
5 PM	Commercial	2	0	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	0	0	0	0
	Other-Residential	0	0	0	0
	Single Family	0	0	0	0
	Total	3	0	0	0

Economic Loss

The total economic loss estimated for the earthquake is 8.02 (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 8.02 (millions of dollars); 18 % 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 71 % 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 Losses							
	Wage	0.00	0.01	0.39	0.00	0.00	0.40
	Capital-Related	0.00	0.00	0.40	0.00	0.00	0.40
	Rental	0.11	0.32	0.21	0.00	0.00	0.64
	Relocation	0.01	0.01	0.01	0.00	0.00	0.03
	Subtotal	0.12	0.34	1.01	0.00	0.00	1.48
Capital Stock Losses							
	Structural	0.60	0.42	0.34	0.01	0.01	1.40
	Non_Structural	1.57	1.92	0.62	0.02	0.02	4.15
	Content	0.35	0.37	0.24	0.01	0.01	0.98
	Inventory	0.00	0.00	0.00	0.00	0.00	0.01
	Subtotal	2.52	2.71	1.21	0.05	0.05	6.54
	Total	2.64	3.05	2.22	0.06	0.05	8.02

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	0.00	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$0.00	0.00
	Subtotal	105.40	0.00	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$0.00	0.00
	Subtotal	6.30	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	5.29	\$0.00	0.00
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.00	
	Total	2247.50	0.00	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.00	0.00
	Subtotal	65.08	\$0.00	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.00	0.00
	Subtotal	39.05	\$0.00	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.00	0.00
	Distribution Line	26.00	\$0.00	0.00
	Subtotal	27.09	\$0.00	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.00	0.00
	Subtotal	0.68	\$0.00	
Electrical Power	Facilities	426.80	\$0.00	0.00
	Subtotal	426.80	\$0.00	
Communication	Facilities	0.20	\$0.00	0.00
	Subtotal	0.19	\$0.00	
	Total	558.90	\$0.00	

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	0	0.00
Second Year			
	Employment Impact	0	0.00
	Income Impact	0	0.00
Third Year			
	Employment Impact	0	0.00
	Income Impact	0	0.00
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	0	0.00
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	0	0.00
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	0	0.00

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233

HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *Frontal M7.0 CEUS Event*

Print Date: *January 25, 2006*

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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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):

Colorado

Note:

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

The geographical size of the region is 154.74 square miles and contains 136 census tracts. There are over 239 thousand households in the region and has a total population of 554,636 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 143 thousand buildings in the region with a total building replacement value (excluding contents) of 36,233 (millions of dollars). Approximately 97.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,247 and 428 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 143 thousand buildings in the region which have an aggregate total replacement value of 36,233 (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 74% 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 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 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 2,675.00 (millions of dollars). This inventory includes over 147 kilometers of highways, 426 bridges, 6,508 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	426	1,461.00
	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	Frontal M7.0 CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-106.16
Latitude of Epicenter	39.68
Earthquake Magnitude	7.00
Depth (Km)	10.00
Rupture Length (Km)	42.66
Rupture Orientation (degrees)	156.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 13,469 buildings will be at least moderately damaged. This is over 9.00 % of the total number of buildings in the region. There are an estimated 227 buildings that will be damaged beyond repair. 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	0.00	1	0.01	1	0.01	0	0.01	0	0.02
Commercial	1,753	1.61	585	2.68	594	5.71	214	7.52	27	12.01
Education	5	0.00	1	0.01	1	0.01	1	0.02	0	0.03
Government	105	0.10	35	0.16	35	0.34	12	0.41	1	0.58
Industrial	156	0.14	54	0.25	63	0.60	24	0.85	3	1.34
Other Residential	6,668	6.14	1,568	7.17	870	8.37	234	8.23	22	9.83
Religion	83	0.08	23	0.11	21	0.21	7	0.26	1	0.38
Single Family	99,817	91.92	19,598	89.63	8,809	84.74	2,354	82.69	172	75.82
Total	108,592		21,866		10,395		2,847		227	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	84,730	78.03	16738	76.55	4,419	42.51	409	14.37	20	8.62
Steel	709	0.65	224	1.02	292	2.81	105	3.68	17	7.45
Concrete	720	0.66	249	1.14	246	2.36	82	2.87	8	3.39
Precast	307	0.28	92	0.42	137	1.32	76	2.68	8	3.50
RM	19,257	17.73	3460	15.83	4,328	41.64	1,828	64.20	86	37.83
URM	2,368	2.18	892	4.08	750	7.21	293	10.28	84	37.14
MH	501	0.46	211	0.96	223	2.15	55	1.92	5	2.07
Total	108,592		21,866		10,395		2,847		227	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 1,686 hospital beds (51.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 80.00% of the beds will be back in service. By 30 days, 98.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	0	0	3
Schools	200	0	0	200
EOCs	2	0	0	2
PoliceStations	17	0	0	17
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	52	0	0	52	52
	Bridges	426	0	0	426	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	0	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	0	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	0	0	7	7
Electrical Power	4	0	0	4	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	53	13
Waste Water	1,953	42	11
Natural Gas	1,302	45	11
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	239,235	0	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 21 ignitions that will burn about 0.04 sq. mi 0.03 % of the region's total area.) The model also estimates that the fires will displace about 245 people and burn about 13 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 2,930 households to be displaced due to the earthquake. Of these, 789 people (out of a total population of 554,636 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	10	2	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	5	1	0	0
	Industrial	9	2	0	0
	Other-Residential	133	21	2	4
	Single Family	192	29	3	6
	Total	348	55	5	10
2 PM	Commercial	516	99	12	23
	Commuting	0	0	0	0
	Educational	38	7	1	2
	Hotels	1	0	0	0
	Industrial	66	13	1	3
	Other-Residential	24	4	0	1
	Single Family	36	6	1	1
	Total	681	128	15	30
5 PM	Commercial	336	64	8	15
	Commuting	2	2	3	1
	Educational	10	2	0	0
	Hotels	1	0	0	0
	Industrial	41	8	1	2
	Other-Residential	51	8	1	1
	Single Family	74	11	1	2
	Total	514	96	14	22

Economic Loss

The total economic loss estimated for the earthquake is 1,479.89 (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 1,443.53 (millions of dollars); 20 % 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 55 % 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 Losses							
	Wage	0.00	3.40	87.65	1.93	2.56	95.55
	Capital-Related	0.00	1.45	80.70	1.26	0.54	83.95
	Rental	16.99	35.55	42.13	1.07	1.61	97.35
	Relocation	1.77	0.80	2.44	0.12	0.34	5.47
	Subtotal	18.75	41.20	212.93	4.39	5.05	282.31
Capital Stock Losses							
	Structural	87.85	41.53	82.91	11.52	7.24	231.04
	Non_Structural	264.14	204.51	170.31	26.42	16.53	681.91
	Content	85.00	51.71	80.38	17.40	7.78	242.27
	Inventory	0.00	0.00	2.51	3.41	0.07	5.99
	Subtotal	436.98	297.75	336.11	58.75	31.63	1,161.21
	Total	455.73	338.95	549.04	63.14	36.67	1,443.53

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$4.29	0.29
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	4.30	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.00	0.05
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$0.70	8.30
	Subtotal	105.40	0.70	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$0.68	10.70
	Subtotal	6.30	0.70	
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	5.29	\$0.14	2.62
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.10	
	Total	2247.50	5.80	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.24	0.37
	Subtotal	65.08	\$0.24	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.19	0.49
	Subtotal	39.05	\$0.19	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.00	0.44
	Distribution Line	26.00	\$0.20	0.78
	Subtotal	27.09	\$0.21	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.05	7.38
	Subtotal	0.68	\$0.05	
Electrical Power	Facilities	426.80	\$29.86	7.00
	Subtotal	426.80	\$29.86	
Communication	Facilities	0.20	\$0.00	1.03
	Subtotal	0.19	\$0.00	
	Total	558.90	\$30.55	

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

	LOSS	Total	%
First Year			
	Employment Impact	2,179	0.68
	Income Impact	(7)	-0.06
Second Year			
	Employment Impact	969	0.30
	Income Impact	(31)	-0.27
Third Year			
	Employment Impact	20	0.01
	Income Impact	(42)	-0.37
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(43)	-0.38
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(43)	-0.38
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(43)	-0.38

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233

HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *Golden M6.5 Denver CEUS Event Normal*

Print Date: *June 28, 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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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):

Colorado

Note:

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

The geographical size of the region is 154.74 square miles and contains 136 census tracts. There are over 239 thousand households in the region and has a total population of 554,636 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 143 thousand buildings in the region with a total building replacement value (excluding contents) of 36,233 (millions of dollars). Approximately 97.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,247 and 428 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 143 thousand buildings in the region which have an aggregate total replacement value of 36,233 (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 74% 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 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 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 2,675.00 (millions of dollars). This inventory includes over 147 kilometers of highways, 426 bridges, 6,508 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	426	1,461.00
	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	Golden M6.5 Denver CEUS Event Normal
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-105.22
Latitude of Epicenter	39.74
Earthquake Magnitude	6.50
Depth (Km)	10.00
Rupture Length (Km)	18.20
Rupture Orientation (degrees)	157.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 56,664 buildings will be at least moderately damaged. This is over 39.00 % of the total number of buildings in the region. There are an estimated 4,286 buildings that will be damaged beyond repair. 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	2	0.00	2	0.00	2	0.01	2	0.01	1	0.02
Commercial	603	1.29	464	1.15	943	2.57	785	5.00	379	8.85
Education	2	0.00	1	0.00	2	0.01	2	0.01	1	0.02
Government	31	0.07	28	0.07	60	0.16	49	0.31	21	0.49
Industrial	50	0.11	42	0.10	93	0.25	80	0.51	35	0.83
Other Residential	2,682	5.73	2,594	6.41	2,531	6.90	1,173	7.47	383	8.93
Religion	28	0.06	24	0.06	39	0.11	31	0.20	13	0.31
Single Family	43,393	92.74	37,318	92.21	32,998	89.99	13,587	86.50	3,453	80.56
Total	46,790		40,472		36,669		15,708		4,287	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	36,974	79.02	35,487	87.68	26,335	71.82	6,591	41.96	929	21.67
Steel	228	0.49	144	0.36	381	1.04	377	2.40	216	5.05
Concrete	264	0.56	208	0.51	394	1.07	312	1.99	126	2.94
Precast	96	0.20	64	0.16	170	0.46	195	1.24	97	2.25
RM	8,403	17.96	3,664	9.05	7,893	21.53	7,009	44.62	1,989	46.41
URM	670	1.43	728	1.80	1,168	3.19	979	6.23	842	19.63
MH	156	0.33	178	0.44	329	0.90	244	1.55	88	2.04
Total	46,790		40,472		36,669		15,708		4,287	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 509 hospital beds (15.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 39.00% of the beds will be back in service. By 30 days, 81.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	12	0	0
Schools	200	7	0	62
EOCs	2	0	0	0
PoliceStations	17	0	0	3
FireStations	4	0	0	0

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	52	0	0	52	52
	Bridges	426	23	0	403	414
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	3	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	3	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	7	0	0	7
Electrical Power	4	4	0	0	4
Communication	2	2	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	339	85
Waste Water	1,953	268	67
Natural Gas	1,302	286	72
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	239,235	5,511	0	0	0	0
Electric Power		60,801	36,011	13,861	2,515	88

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 35 ignitions that will burn about 0.14 sq. mi 0.09 % of the region's total area.) The model also estimates that the fires will displace about 992 people and burn about 44 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 20,014 households to be displaced due to the earthquake. Of these, 5,360 people (out of a total population of 554,636 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	67	19	3	6
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	36	9	1	3
	Industrial	57	16	3	5
	Other-Residential	932	221	29	56
	Single Family	1,473	342	47	92
	Total	2,565	608	83	161
2 PM	Commercial	3,632	1,027	166	328
	Commuting	0	1	1	0
	Educational	275	77	12	24
	Hotels	7	2	0	1
	Industrial	421	118	19	37
	Other-Residential	171	40	5	10
	Single Family	280	65	9	17
	Total	4,786	1,330	213	416
5 PM	Commercial	2,345	660	107	209
	Commuting	27	34	61	12
	Educational	68	19	3	6
	Hotels	11	3	0	1
	Industrial	263	74	12	23
	Other-Residential	360	85	11	21
	Single Family	577	134	19	35
	Total	3,651	1,010	213	306

Economic Loss

The total economic loss estimated for the earthquake is 7,510.48 (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 7,341.77 (millions of dollars); 16 % 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 59 % 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 Losses							
	Wage	0.00	19.14	332.38	7.13	10.16	368.81
	Capital-Related	0.00	8.16	315.99	4.75	2.17	331.07
	Rental	92.17	175.84	150.49	3.59	6.99	429.07
	Relocation	9.69	3.70	8.79	0.37	1.46	24.01
	Subtotal	101.86	206.84	807.65	15.83	20.77	1,152.95
Capital Stock Losses							
	Structural	474.56	201.21	346.44	44.63	32.82	1,099.67
	Non_Structural	1,586.86	1,089.92	917.56	137.31	92.62	3,824.26
	Content	433.28	244.69	421.86	90.96	42.59	1,233.36
	Inventory	0.00	0.00	13.32	17.79	0.41	31.52
	Subtotal	2,494.69	1,535.82	1,699.18	290.69	168.44	6,188.82
	Total	2,596.56	1,742.66	2,506.83	306.52	189.21	7,341.77

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$59.90	4.10
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	59.90	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.04	2.02
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$2.17	25.65
	Subtotal	105.40	2.20	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.95
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$2.14	33.81
	Subtotal	6.30	2.10	
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	5.29	\$0.43	8.20
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.40	
	Total	2247.50	64.70	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$1.52	2.34
	Subtotal	65.08	\$1.52	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$1.20	3.09
	Subtotal	39.05	\$1.20	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.04	3.52
	Distribution Line	26.00	\$1.29	4.95
	Subtotal	27.09	\$1.33	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.15	22.62
	Subtotal	0.68	\$0.15	
Electrical Power	Facilities	426.80	\$99.75	23.37
	Subtotal	426.80	\$99.75	
Communication	Facilities	0.20	\$0.06	28.56
	Subtotal	0.19	\$0.06	
	Total	558.90	\$104.02	

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

	LOSS	Total	%
First Year			
	Employment Impact	8,444	2.64
	Income Impact	(27)	-0.24
Second Year			
	Employment Impact	3,841	1.20
	Income Impact	(122)	-1.08
Third Year			
	Employment Impact	95	0.03
	Income Impact	(168)	-1.49
Fourth Year			
	Employment Impact	5	0.00
	Income Impact	(171)	-1.52
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(171)	-1.52
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(171)	-1.52

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233

HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *Mosquito M7.0 CEUS Event*

Print Date: *January 25, 2006*

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Building and Lifeline Inventory

Building Inventory

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For essential facilities, there are 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 hazardous material sites, 0 military installations and 0 nuclear power plants.

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	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	Mosquito M7.0 CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-106.16
Latitude of Epicenter	39.38
Earthquake Magnitude	7.00
Depth (Km)	10.00
Rupture Length (Km)	42.66
Rupture Orientation (degrees)	9.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 11,808 buildings will be at least moderately damaged. This is over 8.00 % of the total number of buildings in the region. There are an estimated 185 buildings that will be damaged beyond repair. 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	0.00	1	0.01	1	0.01	0	0.01	0	0.02
Commercial	1,821	1.62	575	2.91	562	6.13	192	7.80	23	12.31
Education	5	0.00	1	0.01	1	0.02	1	0.02	0	0.03
Government	110	0.10	34	0.17	33	0.36	10	0.42	1	0.60
Industrial	163	0.15	53	0.27	59	0.65	22	0.88	3	1.35
Other Residential	6,915	6.16	1,435	7.26	786	8.58	208	8.43	19	10.16
Religion	86	0.08	22	0.11	20	0.22	7	0.27	1	0.39
Single Family	103,245	91.90	17,645	89.26	7,696	84.03	2,024	82.15	139	75.13
Total	112,351		19,768		9,159		2,464		186	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	87,726	78.08	14,742	74.58	3,533	38.58	299	12.12	15	8.27
Steel	736	0.66	221	1.12	279	3.04	96	3.89	15	7.91
Concrete	745	0.66	244	1.24	233	2.55	75	3.03	7	3.56
Precast	323	0.29	91	0.46	131	1.43	69	2.81	6	3.46
RM	19,846	17.66	3,385	17.12	4,055	44.27	1,608	65.27	65	35.00
URM	2,454	2.18	876	4.43	715	7.80	269	10.90	74	39.65
MH	520	0.46	208	1.05	213	2.33	49	1.98	4	2.14
Total	112,351		19,768		9,159		2,464		186	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 1,750 hospital beds (53.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 82.00% 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		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	0	0	3
Schools	200	0	0	200
EOCs	2	0	0	2
PoliceStations	17	0	0	17
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	52	0	0	52	52
	Bridges	426	0	0	426	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	0	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	0	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	0	0	7	7
Electrical Power	4	0	0	4	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	49	12
Waste Water	1,953	39	10
Natural Gas	1,302	41	10
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	239,235	0	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 19 ignitions that will burn about 0.04 sq. mi 0.03 % of the region's total area.) The model also estimates that the fires will displace about 214 people and burn about 13 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 2,584 households to be displaced due to the earthquake. Of these, 695 people (out of a total population of 554,636) 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	8	2	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	4	1	0	0
	Industrial	8	1	0	0
	Other-Residential	118	18	2	3
	Single Family	166	25	2	5
	Total	304	47	4	9
2 PM	Commercial	458	85	10	20
	Commuting	0	0	0	0
	Educational	34	6	1	1
	Hotels	1	0	0	0
	Industrial	58	11	1	2
	Other-Residential	22	3	0	1
	Single Family	31	5	0	1
	Total	604	110	13	25
5 PM	Commercial	299	55	7	13
	Commuting	1	2	3	1
	Educational	9	2	0	0
	Hotels	1	0	0	0
	Industrial	36	7	1	1
	Other-Residential	45	7	1	1
	Single Family	64	10	1	2
	Total	455	82	12	18

Economic Loss

The total economic loss estimated for the earthquake is 1,318.61 (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 1,286.01 (millions of dollars); 20 % 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 54 % 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 Losses							
	Wage	0.00	3.03	80.18	1.76	2.34	87.31
	Capital-Related	0.00	1.29	73.71	1.15	0.49	76.64
	Rental	14.70	31.71	38.59	0.98	1.46	87.44
	Relocation	1.53	0.71	2.23	0.11	0.31	4.89
	Subtotal	16.23	36.73	194.72	4.00	4.60	256.28
Capital Stock Losses							
	Structural	76.15	37.16	75.27	10.44	6.58	205.60
	Non_Structural	227.62	181.37	153.76	23.74	14.95	601.45
	Content	75.55	46.38	72.70	15.62	7.05	217.30
	Inventory	0.00	0.00	2.26	3.06	0.07	5.39
	Subtotal	379.32	264.91	303.99	52.86	28.65	1,029.73
	Total	395.55	301.65	498.70	56.86	33.25	1,286.01

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$3.61	0.25
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	3.60	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.00	0.04
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$0.64	7.57
	Subtotal	105.40	0.60	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$0.63	9.96
	Subtotal	6.30	0.60	
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	5.29	\$0.13	2.41
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.10	
	Total	2247.50	5.00	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.22	0.34
	Subtotal	65.08	\$0.22	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.17	0.45
	Subtotal	39.05	\$0.17	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.00	0.38
	Distribution Line	26.00	\$0.19	0.71
	Subtotal	27.09	\$0.19	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.05	6.67
	Subtotal	0.68	\$0.05	
Electrical Power	Facilities	426.80	\$26.96	6.32
	Subtotal	426.80	\$26.96	
Communication	Facilities	0.20	\$0.00	0.93
	Subtotal	0.19	\$0.00	
	Total	558.90	\$27.59	

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

	LOSS	Total	%
First Year			
	Employment Impact	1,926	0.60
	Income Impact	(6)	-0.05
Second Year			
	Employment Impact	848	0.26
	Income Impact	(27)	-0.24
Third Year			
	Employment Impact	18	0.01
	Income Impact	(37)	-0.33
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(38)	-0.34
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(38)	-0.34
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(38)	-0.34

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233

HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *N Sangre M7.5 CEUS Event*

Print Date: *January 25, 2006*

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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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):

Colorado

Note:

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

The geographical size of the region is 154.74 square miles and contains 136 census tracts. There are over 239 thousand households in the region and has a total population of 554,636 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 143 thousand buildings in the region with a total building replacement value (excluding contents) of 36,233 (millions of dollars). Approximately 97.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,247 and 428 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 143 thousand buildings in the region which have an aggregate total replacement value of 36,233 (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 74% 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 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 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 2,675.00 (millions of dollars). This inventory includes over 147 kilometers of highways, 426 bridges, 6,508 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	426	1,461.00
	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	N Sangre M7.5 CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-105.63
Latitude of Epicenter	37.90
Earthquake Magnitude	7.50
Depth (Km)	10.00
Rupture Length (Km)	100.00
Rupture Orientation (degrees)	161.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 11,605 buildings will be at least moderately damaged. This is over 8.00 % of the total number of buildings in the region. There are an estimated 273 buildings that will be damaged beyond repair. 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	0.00	1	0.01	1	0.01	0	0.02	0	0.03
Commercial	1,612	1.40	552	3.18	662	7.74	292	10.51	55	20.19
Education	4	0.00	1	0.01	2	0.02	1	0.03	0	0.06
Government	95	0.08	33	0.19	40	0.47	17	0.62	3	1.18
Industrial	139	0.12	51	0.29	70	0.82	33	1.19	6	2.38
Other Residential	6,959	6.05	1,247	7.18	786	9.20	316	11.35	55	20.16
Religion	79	0.07	21	0.12	23	0.27	11	0.39	2	0.75
Single Family	106,063	92.26	15,459	89.02	6,967	81.47	2,110	75.88	151	55.27
Total	114,956		17,365		8,551		2,781		273	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	90,646	78.85	12608	72.61	2,825	33.03	226	8.14	11	3.86
Steel	532	0.46	201	1.16	359	4.20	200	7.18	55	20.22
Concrete	641	0.56	232	1.33	281	3.28	130	4.66	21	7.70
Precast	294	0.26	83	0.48	137	1.60	91	3.28	15	5.41
RM	19,674	17.11	3238	18.65	4,106	48.02	1,835	65.98	106	38.65
URM	2,700	2.35	814	4.69	613	7.17	209	7.51	51	18.55
MH	469	0.41	188	1.08	231	2.70	90	3.25	15	5.62
Total	114,956		17,365		8,551		2,781		273	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 1,450 hospital beds (44.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 73.00% of the beds will be back in service. By 30 days, 97.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	0	0	3
Schools	200	0	0	200
EOCs	2	0	0	2
PoliceStations	17	0	0	17
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	52	0	0	52	52
	Bridges	426	0	0	426	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	0	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	0	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	0	0	7	7
Electrical Power	4	0	0	4	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	53	13
Waste Water	1,953	42	10
Natural Gas	1,302	44	11
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	239,235	0	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 12 ignitions that will burn about 0.02 sq. mi 0.01 % of the region's total area.) The model also estimates that the fires will displace about 131 people and burn about 7 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 4,078 households to be displaced due to the earthquake. Of these, 1,091 people (out of a total population of 554,636 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	13	3	0	1
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	5	1	0	0
	Industrial	13	3	0	1
	Other-Residential	172	33	4	7
	Single Family	155	24	2	5
	Total	358	63	7	13
2 PM	Commercial	679	144	19	38
	Commuting	0	0	0	0
	Educational	58	13	2	3
	Hotels	1	0	0	0
	Industrial	97	21	3	5
	Other-Residential	31	6	1	1
	Single Family	28	4	0	1
	Total	895	188	25	48
5 PM	Commercial	444	94	13	24
	Commuting	1	2	3	1
	Educational	15	3	0	1
	Hotels	2	0	0	0
	Industrial	61	13	2	3
	Other-Residential	65	12	1	3
	Single Family	60	9	1	2
	Total	647	134	20	34

Economic Loss

The total economic loss estimated for the earthquake is 1,474.46 (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 1,456.74 (millions of dollars); 25 % 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 45 % 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 Losses							
	Wage	0.00	3.93	118.78	2.71	3.54	128.96
	Capital-Related	0.00	1.68	109.05	1.77	0.74	113.24
	Rental	14.23	42.74	53.10	1.44	2.31	113.81
	Relocation	1.48	0.92	3.14	0.15	0.48	6.18
	Subtotal	15.71	49.27	284.07	6.08	7.07	362.20
Capital Stock Losses							
	Structural	74.25	50.50	107.58	15.92	10.38	258.63
	Non_Structural	185.53	193.85	205.30	31.50	21.32	637.50
	Content	49.76	37.76	78.11	18.74	7.82	192.19
	Inventory	0.00	0.00	2.41	3.74	0.07	6.23
	Subtotal	309.54	282.11	393.40	69.91	39.58	1,094.54
	Total	325.24	331.38	677.47	75.99	46.65	1,456.74

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$3.89	0.27
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	3.90	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.00	0.05
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$0.32	3.84
	Subtotal	105.40	0.30	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$0.38	5.98
	Subtotal	6.30	0.40	
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	5.29	\$0.06	1.16
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.10	
	Total	2247.50	4.70	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.24	0.36
	Subtotal	65.08	\$0.24	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.19	0.48
	Subtotal	39.05	\$0.19	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.00	0.09
	Distribution Line	26.00	\$0.20	0.77
	Subtotal	27.09	\$0.20	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.02	3.14
	Subtotal	0.68	\$0.02	
Electrical Power	Facilities	426.80	\$12.42	2.91
	Subtotal	426.80	\$12.42	
Communication	Facilities	0.20	\$0.00	0.31
	Subtotal	0.19	\$0.00	
	Total	558.90	\$13.06	

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

	LOSS	Total	%
First Year			
	Employment Impact	1,974	0.62
	Income Impact	(7)	-0.06
Second Year			
	Employment Impact	900	0.28
	Income Impact	(30)	-0.27
Third Year			
	Employment Impact	19	0.01
	Income Impact	(41)	-0.37
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(42)	-0.37
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(42)	-0.37
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(42)	-0.37

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233

HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *N Sangre M7.5 WUS-Extensional*

Print Date: *January 25, 2006*

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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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):

Colorado

Note:

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

The geographical size of the region is 154.74 square miles and contains 136 census tracts. There are over 239 thousand households in the region and has a total population of 554,636 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 143 thousand buildings in the region with a total building replacement value (excluding contents) of 36,233 (millions of dollars). Approximately 97.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,247 and 428 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 143 thousand buildings in the region which have an aggregate total replacement value of 36,233 (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 74% 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 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 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 2,675.00 (millions of dollars). This inventory includes over 147 kilometers of highways, 426 bridges, 6,508 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	426	1,461.00
	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	N Sangre M7.5 WUS-Extensional
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-105.63
Latitude of Epicenter	37.90
Earthquake Magnitude	7.50
Depth (Km)	10.00
Rupture Length (Km)	100.00
Rupture Orientation (degrees)	161.00
Attenuation Function	WUS Shallow Crustal Event - Extensional

Building Damage

Building Damage

HAZUS estimates that about 809 buildings will be at least moderately damaged. This is over 1.00 % of the total number of buildings in the region. There are an estimated 3 buildings that will be damaged beyond repair. 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	8	0.01	0	0.01	0	0.01	0	0.01	0	0.01
Commercial	2,998	2.14	119	4.40	49	6.73	6	7.63	0	9.99
Education	8	0.01	0	0.01	0	0.02	0	0.02	0	0.02
Government	180	0.13	6	0.23	2	0.31	0	0.28	0	0.37
Industrial	283	0.20	11	0.42	5	0.72	1	0.88	0	0.62
Other Residential	9,068	6.46	225	8.32	64	8.87	5	6.29	0	5.19
Religion	130	0.09	4	0.16	2	0.21	0	0.20	0	0.29
Single Family	127,734	90.97	2,342	86.46	602	83.12	70	84.70	3	83.51
Total	140,408		2,709		724		83		3	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	104,623	74.51	1534	56.64	152	20.96	7	7.90	0	0.00
Steel	1,270	0.90	52	1.93	22	3.07	2	2.67	0	4.32
Concrete	1,246	0.89	44	1.64	12	1.72	1	1.08	0	0.20
Precast	577	0.41	25	0.93	16	2.19	3	3.47	0	0.74
RM	27,866	19.85	690	25.46	358	49.49	45	54.26	0	0.00
URM	3,916	2.79	304	11.24	139	19.15	25	29.60	3	94.14
MH	910	0.65	59	2.16	25	3.42	1	1.02	0	0.60
Total	140,408		2,709		724		83		3	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 3,184 hospital beds (96.00%) 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		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	0	0	14
Schools	200	0	0	200
EOCs	2	0	0	2
PoliceStations	17	0	0	17
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	52	0	0	52	52
	Bridges	426	0	0	426	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	0	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	0	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	0	0	7	7
Electrical Power	4	0	0	4	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	15	4
Waste Water	1,953	12	3
Natural Gas	1,302	12	3
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	239,235	0	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 0.01 sq. mi 0.01 % of the region's total area.) The model also estimates that the fires will displace about 11 people and burn about 0 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 63 households to be displaced due to the earthquake. Of these, 17 people (out of a total population of 554,636 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	0	0	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	0	0	0	0
	Other-Residential	6	1	0	0
	Single Family	10	1	0	0
	Total	17	2	0	0
2 PM	Commercial	22	3	0	0
	Commuting	0	0	0	0
	Educational	2	0	0	0
	Hotels	0	0	0	0
	Industrial	3	0	0	0
	Other-Residential	1	0	0	0
	Single Family	2	0	0	0
	Total	30	3	0	0
5 PM	Commercial	15	2	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	2	0	0	0
	Other-Residential	2	0	0	0
	Single Family	4	0	0	0
	Total	23	3	0	0

Economic Loss

The total economic loss estimated for the earthquake is 69.87 (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 67.97 (millions of dollars); 20 % 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 54 % 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 Losses							
	Wage	0.00	0.12	4.42	0.09	0.14	4.77
	Capital-Related	0.00	0.05	4.17	0.06	0.03	4.32
	Rental	0.86	1.40	2.19	0.04	0.04	4.53
	Relocation	0.09	0.04	0.12	0.01	0.01	0.26
	Subtotal	0.95	1.61	10.90	0.20	0.22	13.88
Capital Stock Losses							
	Structural	4.90	2.16	4.30	0.60	0.32	12.29
	Non_Structural	12.66	9.51	7.76	1.21	0.78	31.92
	Content	3.09	2.00	3.44	0.75	0.34	9.62
	Inventory	0.00	0.00	0.10	0.15	0.00	0.25
	Subtotal	20.66	13.66	15.60	2.71	1.46	54.09
	Total	21.61	15.27	26.49	2.92	1.68	67.97

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$0.38	0.03
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	0.40	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$0.05	0.60
	Subtotal	105.40	0.10	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$0.08	1.33
	Subtotal	6.30	0.10	
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	5.29	\$0.00	0.00
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.00	
	Total	2247.50	0.50	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.07	0.10
	Subtotal	65.08	\$0.07	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.05	0.13
	Subtotal	39.05	\$0.05	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.00	0.00
	Distribution Line	26.00	\$0.06	0.21
	Subtotal	27.09	\$0.06	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.00	0.31
	Subtotal	0.68	\$0.00	
Electrical Power	Facilities	426.80	\$1.21	0.28
	Subtotal	426.80	\$1.21	
Communication	Facilities	0.20	\$0.00	0.00
	Subtotal	0.19	\$0.00	
	Total	558.90	\$1.38	

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

	LOSS	Total	%
First Year			
	Employment Impact	77	0.02
	Income Impact	0	0.00
Second Year			
	Employment Impact	28	0.01
	Income Impact	(1)	-0.01
Third Year			
	Employment Impact	0	0.00
	Income Impact	(2)	-0.02
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(2)	-0.02
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(2)	-0.02
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(2)	-0.02

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233

HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *N Sawatch M7.0 CEUS Event*

Print Date: *January 25, 2006*

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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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):

Colorado

Note:

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

The geographical size of the region is 154.74 square miles and contains 136 census tracts. There are over 239 thousand households in the region and has a total population of 554,636 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 143 thousand buildings in the region with a total building replacement value (excluding contents) of 36,233 (millions of dollars). Approximately 97.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,247 and 428 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 143 thousand buildings in the region which have an aggregate total replacement value of 36,233 (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 74% 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 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 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 2,675.00 (millions of dollars). This inventory includes over 147 kilometers of highways, 426 bridges, 6,508 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	426	1,461.00
	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	N Sawatch M7.0 CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-106.39
Latitude of Epicenter	39.15
Earthquake Magnitude	7.00
Depth (Km)	10.00
Rupture Length (Km)	42.66
Rupture Orientation (degrees)	147.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 6,282 buildings will be at least moderately damaged. This is over 4.00 % of the total number of buildings in the region. There are an estimated 53 buildings that will be damaged beyond repair. 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	6	0.01	1	0.01	1	0.01	0	0.01	0	0.02
Commercial	2,280	1.84	460	3.33	343	6.56	83	8.28	7	12.80
Education	6	0.00	1	0.01	1	0.02	0	0.02	0	0.03
Government	138	0.11	27	0.19	20	0.37	4	0.43	0	0.62
Industrial	210	0.17	43	0.31	37	0.70	10	0.95	1	1.28
Other Residential	7,729	6.24	1,043	7.54	489	9.36	97	9.66	6	11.29
Religion	103	0.08	17	0.13	12	0.24	3	0.29	0	0.41
Single Family	113,340	91.54	12,241	88.49	4,324	82.74	806	80.36	40	73.54
Total	123,813		13,832		5,226		1,003		54	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	94,256	76.13	9981	72.16	1,936	37.04	136	13.55	6	11.45
Steel	903	0.73	193	1.39	194	3.71	51	5.12	6	10.29
Concrete	939	0.76	197	1.42	138	2.63	29	2.93	1	2.74
Precast	424	0.34	77	0.56	86	1.65	32	3.22	1	2.56
RM	23,643	19.10	2483	17.95	2,236	42.80	587	58.57	9	16.70
URM	2,997	2.42	728	5.26	489	9.36	144	14.36	29	53.65
MH	651	0.53	173	1.25	146	2.80	23	2.26	1	2.62
Total	123,813		13,832		5,226		1,003		54	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 2,220 hospital beds (67.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 91.00% 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		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	0	0	14
Schools	200	0	0	200
EOCs	2	0	0	2
PoliceStations	17	0	0	17
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	52	0	0	52	52
	Bridges	426	0	0	426	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	0	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	0	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	0	0	7	7
Electrical Power	4	0	0	4	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	27	7
Waste Water	1,953	21	5
Natural Gas	1,302	23	6
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	239,235	0	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 11 ignitions that will burn about 0.02 sq. mi 0.01 % of the region's total area.) The model also estimates that the fires will displace about 47 people and burn about 3 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 1,162 households to be displaced due to the earthquake. Of these, 311 people (out of a total population of 554,636 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	4	1	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	2	0	0	0
	Industrial	3	1	0	0
	Other-Residential	58	7	0	1
	Single Family	77	9	1	1
	Total	145	18	1	2
2 PM	Commercial	203	31	3	6
	Commuting	0	0	0	0
	Educational	15	2	0	0
	Hotels	0	0	0	0
	Industrial	26	4	0	1
	Other-Residential	10	1	0	0
	Single Family	14	2	0	0
	Total	269	41	4	7
5 PM	Commercial	132	20	2	4
	Commuting	0	0	1	0
	Educational	4	1	0	0
	Hotels	1	0	0	0
	Industrial	16	2	0	0
	Other-Residential	22	3	0	0
	Single Family	30	4	0	1
	Total	205	30	3	5

Economic Loss

The total economic loss estimated for the earthquake is 651.85 (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 637.53 (millions of dollars); 20 % 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 55 % 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 Losses							
	Wage	0.00	1.36	40.54	0.89	1.20	43.99
	Capital-Related	0.00	0.58	37.47	0.58	0.25	38.88
	Rental	7.16	16.55	19.93	0.48	0.67	44.79
	Relocation	0.74	0.38	1.12	0.06	0.15	2.45
	Subtotal	7.90	18.87	99.05	2.01	2.27	130.10
Capital Stock Losses							
	Structural	37.62	19.86	36.98	5.21	3.23	102.91
	Non_Structural	114.51	92.08	73.94	11.31	7.28	299.11
	Content	35.35	21.91	34.94	7.31	3.37	102.88
	Inventory	0.00	0.00	1.06	1.45	0.03	2.54
	Subtotal	187.48	133.85	146.91	25.28	13.91	507.43
	Total	195.38	152.72	245.97	27.29	16.18	637.53

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$1.27	0.09
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	1.30	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.00	0.01
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$0.31	3.67
	Subtotal	105.40	0.30	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$0.37	5.77
	Subtotal	6.30	0.40	
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	5.29	\$0.05	0.87
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.00	
	Total	2247.50	2.00	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.12	0.19
	Subtotal	65.08	\$0.12	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.10	0.25
	Subtotal	39.05	\$0.10	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.00	0.07
	Distribution Line	26.00	\$0.10	0.40
	Subtotal	27.09	\$0.10	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.02	2.99
	Subtotal	0.68	\$0.02	
Electrical Power	Facilities	426.80	\$11.98	2.81
	Subtotal	426.80	\$11.98	
Communication	Facilities	0.20	\$0.00	0.26
	Subtotal	0.19	\$0.00	
	Total	558.90	\$12.32	

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

	LOSS	Total	%
First Year			
	Employment Impact	918	0.29
	Income Impact	(3)	-0.03
Second Year			
	Employment Impact	396	0.12
	Income Impact	(13)	-0.12
Third Year			
	Employment Impact	9	0.00
	Income Impact	(19)	-0.16
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(19)	-0.17
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(19)	-0.17
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(19)	-0.17

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233

HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *Rampart M7 Denver CEUS Event*

Print Date: *June 28, 2005*

Disclaimer:

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General Description of the Region

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The earthquake loss estimates provided in this report was based on a region that includes 1 county(ies) from the following state(s):

Colorado

Note:

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

The geographical size of the region is 154.74 square miles and contains 136 census tracts. There are over 239 thousand households in the region and has a total population of 554,636 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 143 thousand buildings in the region with a total building replacement value (excluding contents) of 36,233 (millions of dollars). Approximately 97.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,247 and 428 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 143 thousand buildings in the region which have an aggregate total replacement value of 36,233 (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 74% 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 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 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 2,675.00 (millions of dollars). This inventory includes over 147 kilometers of highways, 426 bridges, 6,508 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	426	1,461.00
	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	Rampart M7 Denver CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-104.92
Latitude of Epicenter	39.06
Earthquake Magnitude	7.00
Depth (Km)	10.00
Rupture Length (Km)	42.66
Rupture Orientation (degrees)	171.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 38,815 buildings will be at least moderately damaged. This is over 27.00 % of the total number of buildings in the region. There are an estimated 2,118 buildings that will be damaged beyond repair. 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	3	0.00	2	0.00	2	0.01	1	0.01	0	0.01
Commercial	909	1.32	568	1.57	927	3.51	587	5.72	182	8.59
Education	3	0.00	1	0.00	2	0.01	2	0.02	1	0.03
Government	53	0.08	35	0.10	58	0.22	34	0.33	9	0.41
Industrial	81	0.12	52	0.14	92	0.35	59	0.57	17	0.78
Other Residential	4,164	6.04	2,381	6.58	1,877	7.10	762	7.43	179	8.44
Religion	46	0.07	26	0.07	35	0.13	22	0.21	6	0.29
Single Family	63,672	92.37	33,115	91.53	23,448	88.68	8,789	85.71	1,726	81.45
Total	68,931		36,180		26,442		10,255		2,119	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	55,008	79.80	30,867	85.31	16,922	64.00	3,197	31.18	321	15.15
Steel	376	0.55	191	0.53	398	1.51	278	2.71	104	4.92
Concrete	405	0.59	243	0.67	375	1.42	225	2.20	56	2.64
Precast	149	0.22	80	0.22	178	0.67	165	1.61	49	2.34
RM	11,575	16.79	3,792	10.48	7,164	27.09	5,428	52.93	999	47.14
URM	1,141	1.66	807	2.23	1,096	4.14	791	7.71	551	26.02
MH	275	0.40	201	0.55	310	1.17	171	1.66	38	1.80
Total	68,931		36,180		26,442		10,255		2,119	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 860 hospital beds (26.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 54.00% of the beds will be back in service. By 30 days, 90.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	9	0	2
Schools	200	0	0	84
EOCs	2	0	0	2
PoliceStations	17	0	0	8
FireStations	4	0	0	1

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	52	0	0	52	52
	Bridges	426	8	0	418	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	0	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	0	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	6	0	1	7
Electrical Power	4	3	0	0	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	196	49
Waste Water	1,953	155	39
Natural Gas	1,302	166	42
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	239,235	287	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 37 ignitions that will burn about 0.14 sq. mi 0.09 % of the region's total area.) The model also estimates that the fires will displace about 886 people and burn about 58 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 12,255 households to be displaced due to the earthquake. Of these, 3,229 people (out of a total population of 554,636 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	38	10	1	3
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	18	4	1	1
	Industrial	32	8	1	2
	Other-Residential	552	121	15	29
	Single Family	863	188	25	49
	Total	1,502	331	43	85
2 PM	Commercial	2,042	526	81	159
	Commuting	0	0	0	0
	Educational	165	43	7	13
	Hotels	4	1	0	0
	Industrial	233	60	9	18
	Other-Residential	101	22	3	5
	Single Family	159	35	5	9
	Total	2,704	686	104	203
5 PM	Commercial	1,348	348	54	104
	Commuting	12	15	27	5
	Educational	42	11	2	3
	Hotels	5	1	0	0
	Industrial	146	37	6	11
	Other-Residential	212	47	6	11
	Single Family	337	74	10	19
	Total	2,103	533	104	154

Economic Loss

The total economic loss estimated for the earthquake is 4,652.06 (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 4,555.40 (millions of dollars); 17 % 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 59 % 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 Losses							
	Wage	0.00	11.06	230.05	4.75	6.79	252.64
	Capital-Related	0.00	4.72	212.70	3.11	1.48	222.00
	Rental	59.06	114.07	105.17	2.49	4.56	285.35
	Relocation	6.20	2.46	6.20	0.26	0.97	16.09
	Subtotal	65.26	132.30	554.12	10.61	13.79	776.08
Capital Stock Losses							
	Structural	304.73	131.33	228.24	28.90	21.15	714.35
	Non_Structural	954.45	682.63	542.96	77.49	54.18	2,311.70
	Content	256.63	155.74	247.50	51.01	24.48	735.36
	Inventory	0.00	0.00	7.71	9.97	0.24	17.92
	Subtotal	1,515.80	969.70	1,026.41	167.36	100.06	3,779.32
	Total	1,581.06	1,101.99	1,580.52	177.97	113.85	4,555.40

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$23.00	1.57
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	23.00	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.01	0.63
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$1.41	16.66
	Subtotal	105.40	1.40	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.19
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$1.29	20.40
	Subtotal	6.30	1.30	
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	5.29	\$0.37	7.02
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.40	
	Total	2247.50	26.10	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.88	1.36
	Subtotal	65.08	\$0.88	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.70	1.79
	Subtotal	39.05	\$0.70	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.02	2.15
	Distribution Line	26.00	\$0.75	2.87
	Subtotal	27.09	\$0.77	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.11	16.66
	Subtotal	0.68	\$0.11	
Electrical Power	Facilities	426.80	\$68.09	15.95
	Subtotal	426.80	\$68.09	
Communication	Facilities	0.20	\$0.01	6.49
	Subtotal	0.19	\$0.01	
	Total	558.90	\$70.57	

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

	LOSS	Total	%
First Year			
	Employment Impact	8,444	2.64
	Income Impact	(27)	-0.24
Second Year			
	Employment Impact	3,841	1.20
	Income Impact	(122)	-1.08
Third Year			
	Employment Impact	95	0.03
	Income Impact	(168)	-1.49
Fourth Year			
	Employment Impact	5	0.00
	Income Impact	(171)	-1.52
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(171)	-1.52
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(171)	-1.52

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Denver, CO

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State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
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HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *RMA M5.0 CEUS Event*

Print Date: *January 25, 2006*

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Note:

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

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Building and Lifeline Inventory

Building Inventory

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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 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 hazardous material sites, 0 military installations and 0 nuclear power plants.

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	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	RMA M5.0 CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-104.90
Latitude of Epicenter	39.90
Earthquake Magnitude	5.00
Depth (Km)	10.00
Rupture Length (Km)	1.41
Rupture Orientation (degrees)	130.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 1,470 buildings will be at least moderately damaged. This is over 1.00 % of the total number of buildings in the region. There are an estimated 6 buildings that will be damaged beyond repair. 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	7	0.01	0	0.01	0	0.01	0	0.01	0	0.01
Commercial	2,930	2.12	155	3.52	74	5.79	13	7.27	0	8.14
Education	8	0.01	0	0.01	0	0.01	0	0.01	0	0.00
Government	175	0.13	9	0.21	4	0.32	1	0.31	0	0.34
Industrial	267	0.19	19	0.44	11	0.89	2	1.29	0	1.16
Other Residential	8,905	6.45	343	7.82	104	8.06	10	5.88	0	4.94
Religion	128	0.09	6	0.13	2	0.17	0	0.17	0	0.18
Single Family	125,643	91.00	3,860	87.87	1,090	84.74	152	85.07	5	85.23
Total	138,063		4,393		1,286		179		6	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	103,095	74.67	2836	64.55	364	28.33	21	11.71	0	0.00
Steel	1,266	0.92	52	1.19	25	1.96	3	1.85	0	1.51
Concrete	1,207	0.87	69	1.57	25	1.94	2	1.39	0	0.39
Precast	546	0.40	38	0.87	30	2.30	7	3.99	0	1.99
RM	27,246	19.73	979	22.29	629	48.90	105	58.67	0	7.41
URM	3,812	2.76	351	7.98	181	14.04	38	21.49	5	88.30
MH	892	0.65	68	1.55	32	2.52	2	0.90	0	0.41
Total	138,063		4,393		1,286		179		6	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 3,121 hospital beds (94.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 99.00% 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		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	0	0	14
Schools	200	0	0	200
EOCs	2	0	0	2
PoliceStations	17	0	0	17
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	52	0	0	52	52
	Bridges	426	0	0	426	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	0	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	0	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	0	0	4	7
Electrical Power	4	0	0	1	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	3	1
Waste Water	1,953	2	1
Natural Gas	1,302	2	1
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	239,235	0	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 25 ignitions that will burn about 0.10 sq. mi 0.06 % of the region's total area.) The model also estimates that the fires will displace about 580 people and burn about 31 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 114 households to be displaced due to the earthquake. Of these, 32 people (out of a total population of 554,636) 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	1	0	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	1	0	0	0
	Industrial	1	0	0	0
	Other-Residential	11	1	0	0
	Single Family	19	2	0	0
	Total	32	3	0	0
2 PM	Commercial	39	5	0	1
	Commuting	0	0	0	0
	Educational	2	0	0	0
	Hotels	0	0	0	0
	Industrial	6	1	0	0
	Other-Residential	2	0	0	0
	Single Family	4	0	0	0
	Total	54	6	0	1
5 PM	Commercial	26	3	0	0
	Commuting	0	0	0	0
	Educational	1	0	0	0
	Hotels	0	0	0	0
	Industrial	4	0	0	0
	Other-Residential	4	0	0	0
	Single Family	7	1	0	0
	Total	41	5	0	1

Economic Loss

The total economic loss estimated for the earthquake is 543.70 (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 496.91 (millions of dollars); 5 % 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 62 % 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 Losses							
	Wage	0.00	0.30	6.74	0.21	0.22	7.48
	Capital-Related	0.00	0.13	6.25	0.13	0.04	6.55
	Rental	1.64	2.62	3.80	0.12	0.09	8.27
	Relocation	0.17	0.06	0.21	0.02	0.02	0.48
	Subtotal	1.81	3.11	17.00	0.48	0.38	22.78
Capital Stock Losses							
	Structural	8.96	3.52	7.79	1.34	0.52	22.14
	Non_Structural	100.61	85.09	61.89	16.64	5.72	269.94
	Content	67.85	38.07	52.64	13.92	5.02	177.49
	Inventory	0.00	0.00	1.75	2.76	0.05	4.55
	Subtotal	177.42	126.67	124.07	34.66	11.30	474.13
	Total	179.23	129.79	141.07	35.14	11.68	496.91

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$0.14	0.01
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	0.10	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$1.31	15.43
	Subtotal	105.40	1.30	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$1.12	17.59
	Subtotal	6.30	1.10	
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	5.29	\$0.34	6.37
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.30	
	Total	2247.50	2.90	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.01	0.02
	Subtotal	65.08	\$0.01	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.01	0.02
	Subtotal	39.05	\$0.01	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.04	3.48
	Distribution Line	26.00	\$0.01	0.04
	Subtotal	27.09	\$0.05	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.08	11.15
	Subtotal	0.68	\$0.08	
Electrical Power	Facilities	426.80	\$43.75	10.25
	Subtotal	426.80	\$43.75	
Communication	Facilities	0.20	\$0.00	0.93
	Subtotal	0.19	\$0.00	
	Total	558.90	\$43.90	

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

	LOSS	Total	%
First Year			
	Employment Impact	979	0.31
	Income Impact	(2)	-0.01
Second Year			
	Employment Impact	402	0.13
	Income Impact	(10)	-0.08
Third Year			
	Employment Impact	7	0.00
	Income Impact	(13)	-0.12
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(14)	-0.12
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(14)	-0.12
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(14)	-0.12

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233

HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *RMA M5.5 CEUS Event*

Print Date: *January 25, 2006*

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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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):

Colorado

Note:

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

The geographical size of the region is 154.74 square miles and contains 136 census tracts. There are over 239 thousand households in the region and has a total population of 554,636 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 143 thousand buildings in the region with a total building replacement value (excluding contents) of 36,233 (millions of dollars). Approximately 97.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,247 and 428 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 143 thousand buildings in the region which have an aggregate total replacement value of 36,233 (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 74% 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 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 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 2,675.00 (millions of dollars). This inventory includes over 147 kilometers of highways, 426 bridges, 6,508 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	426	1,461.00
	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	RMA M5.5 CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-104.90
Latitude of Epicenter	39.90
Earthquake Magnitude	5.50
Depth (Km)	10.00
Rupture Length (Km)	3.31
Rupture Orientation (degrees)	130.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 9,511 buildings will be at least moderately damaged. This is over 7.00 % of the total number of buildings in the region. There are an estimated 101 buildings that will be damaged beyond repair. 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	6	0.01	1	0.01	1	0.01	0	0.01	0	0.01
Commercial	2,367	2.05	416	2.17	301	3.81	82	5.46	7	6.86
Education	6	0.01	1	0.00	1	0.01	0	0.01	0	0.01
Government	141	0.12	25	0.13	18	0.23	4	0.27	0	0.30
Industrial	203	0.18	43	0.23	40	0.50	13	0.84	1	1.02
Other Residential	7,302	6.34	1,374	7.17	587	7.42	95	6.34	6	5.76
Religion	105	0.09	18	0.09	11	0.14	2	0.16	0	0.17
Single Family	105,110	91.21	17,297	90.21	6,954	87.90	1,302	86.90	87	85.87
Total	115,240		19,175		7,911		1,498		102	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	86,085	74.70	15,331	79.96	4,419	55.86	457	30.48	23	22.56
Steel	1,046	0.91	151	0.79	122	1.55	26	1.74	2	1.93
Concrete	990	0.86	179	0.93	112	1.42	21	1.43	1	0.82
Precast	413	0.36	79	0.41	91	1.15	37	2.44	2	1.91
RM	23,245	20.17	2,521	13.15	2,453	31.01	725	48.38	15	14.59
URM	2,755	2.39	757	3.95	597	7.55	219	14.59	59	57.61
MH	707	0.61	157	0.82	116	1.46	14	0.95	1	0.58
Total	115,240		19,175		7,911		1,498		102	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 2,514 hospital beds (76.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 94.00% 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		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	0	0	14
Schools	200	0	0	200
EOCs	2	0	0	2
PoliceStations	17	0	0	17
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	52	0	0	52	52
	Bridges	426	0	0	426	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	1	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	0	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	6	0	1	7
Electrical Power	4	3	0	0	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	20	5
Waste Water	1,953	16	4
Natural Gas	1,302	17	4
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	239,235	0	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 35 ignitions that will burn about 0.12 sq. mi 0.08 % of the region's total area.) The model also estimates that the fires will displace about 687 people and burn about 41 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 1,134 households to be displaced due to the earthquake. Of these, 314 people (out of a total population of 554,636 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	4	1	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	3	1	0	0
	Industrial	4	1	0	0
	Other-Residential	71	9	1	1
	Single Family	135	18	1	3
	Total	218	29	2	4
2 PM	Commercial	224	38	4	8
	Commuting	0	0	0	0
	Educational	15	2	0	0
	Hotels	1	0	0	0
	Industrial	30	5	1	1
	Other-Residential	14	2	0	0
	Single Family	26	4	0	1
	Total	311	51	5	10
5 PM	Commercial	146	25	3	5
	Commuting	1	1	1	0
	Educational	3	1	0	0
	Hotels	1	0	0	0
	Industrial	19	3	0	1
	Other-Residential	27	4	0	1
	Single Family	52	7	1	1
	Total	250	40	5	8

Economic Loss

The total economic loss estimated for the earthquake is 1,412.63 (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 1,338.09 (millions of dollars); 9 % 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 65 % 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 Losses							
	Wage	0.00	2.09	34.64	0.97	1.09	38.79
	Capital-Related	0.00	0.89	32.15	0.62	0.22	33.88
	Rental	11.59	19.09	18.69	0.58	0.61	50.56
	Relocation	1.20	0.43	1.04	0.07	0.13	2.87
	Subtotal	12.79	22.49	86.52	2.24	2.04	126.10
Capital Stock Losses							
	Structural	59.35	22.19	37.24	5.93	2.89	127.60
	Non_Structural	298.94	223.09	140.89	30.46	13.66	707.04
	Content	145.27	83.05	105.54	24.67	10.54	369.06
	Inventory	0.00	0.00	3.33	4.85	0.11	8.29
	Subtotal	503.56	328.32	286.99	65.92	27.19	1,211.99
	Total	516.35	350.82	373.51	68.16	29.24	1,338.09

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$1.54	0.11
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	1.50	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.00	0.02
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$1.88	22.18
	Subtotal	105.40	1.90	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$1.58	24.96
	Subtotal	6.30	1.60	
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	5.29	\$0.65	12.26
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.60	
	Total	2247.50	5.60	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.09	0.14
	Subtotal	65.08	\$0.09	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.07	0.19
	Subtotal	39.05	\$0.07	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.10	9.21
	Distribution Line	26.00	\$0.08	0.30
	Subtotal	27.09	\$0.18	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.11	16.85
	Subtotal	0.68	\$0.11	
Electrical Power	Facilities	426.80	\$68.44	16.04
	Subtotal	426.80	\$68.44	
Communication	Facilities	0.20	\$0.01	3.14
	Subtotal	0.19	\$0.01	
	Total	558.90	\$68.90	

Table 15. Indirect Economic Impact with outside aid

(Employment as # of people and Income in millions of \$)

	LOSS	Total	%
First Year			
	Employment Impact	2,354	0.73
	Income Impact	(6)	-0.05
Second Year			
	Employment Impact	1,020	0.32
	Income Impact	(28)	-0.25
Third Year			
	Employment Impact	19	0.01
	Income Impact	(38)	-0.34
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(39)	-0.35
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(39)	-0.35
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(39)	-0.35

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233

HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *RMA M6.0 CEUS Event*

Print Date: *July 19, 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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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):

Colorado

Note:

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

The geographical size of the region is 154.74 square miles and contains 136 census tracts. There are over 239 thousand households in the region and has a total population of 554,636 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 143 thousand buildings in the region with a total building replacement value (excluding contents) of 36,233 (millions of dollars). Approximately 97.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,247 and 428 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 143 thousand buildings in the region which have an aggregate total replacement value of 36,233 (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 74% 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 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 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 2,675.00 (millions of dollars). This inventory includes over 147 kilometers of highways, 426 bridges, 6,508 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	426	1,461.00
	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	RMA M6.0 CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-104.90
Latitude of Epicenter	39.90
Earthquake Magnitude	6.00
Depth (Km)	10.00
Rupture Length (Km)	7.76
Rupture Orientation (degrees)	130.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 33,823 buildings will be at least moderately damaged. This is over 24.00 % of the total number of buildings in the region. There are an estimated 1,331 buildings that will be damaged beyond repair. 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	3	0.00	2	0.01	2	0.01	1	0.01	0	0.01
Commercial	1,278	1.67	593	1.77	793	3.27	410	4.99	99	7.45
Education	4	0.01	1	0.00	2	0.01	1	0.01	0	0.01
Government	73	0.09	36	0.11	50	0.20	25	0.30	6	0.42
Industrial	90	0.12	48	0.14	85	0.35	58	0.70	19	1.41
Other Residential	4,624	6.04	2,309	6.88	1,743	7.18	586	7.13	100	7.51
Religion	60	0.08	28	0.08	31	0.13	14	0.17	3	0.20
Single Family	70,428	91.99	30,525	91.00	21,570	88.85	7,122	86.68	1,105	82.99
Total	76,561		33,543		24,276		8,216		1,332	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	58,285	76.13	28,210	84.10	16,171	66.61	3,285	39.98	366	27.45
Steel	539	0.70	210	0.63	356	1.46	189	2.30	54	4.02
Concrete	552	0.72	254	0.76	320	1.32	151	1.84	27	2.00
Precast	201	0.26	85	0.25	166	0.68	135	1.64	34	2.57
RM	15,051	19.66	3,726	11.11	5,986	24.66	3,718	45.25	477	35.82
URM	1,537	2.01	854	2.55	1,014	4.18	627	7.63	354	26.62
MH	396	0.52	203	0.61	264	1.09	112	1.36	20	1.51
Total	76,561		33,543		24,276		8,216		1,332	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 1,332 hospital beds (40.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 70.00% of the beds will be back in service. By 30 days, 96.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	0	0	3
Schools	200	0	0	91
EOCs	2	0	0	2
PoliceStations	17	0	0	7
FireStations	4	0	0	1

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	52	0	0	52	52
	Bridges	426	9	0	417	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	2	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	1	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	1	0	0	1
Oil Systems	7	7	0	0	7
Electrical Power	4	4	0	0	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	123	31
Waste Water	1,953	97	24
Natural Gas	1,302	104	26
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	239,235	0	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 16 ignitions that will burn about 0.17 sq. mi 0.11 % of the region's total area.) The model also estimates that the fires will displace about 1,017 people and burn about 81 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 8,203 households to be displaced due to the earthquake. Of these, 2,252 people (out of a total population of 554,636 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	24	6	1	2
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	18	4	1	1
	Industrial	29	7	1	2
	Other-Residential	375	72	8	15
	Single Family	676	133	16	30
	Total	1,122	223	26	51
2 PM	Commercial	1,341	326	48	95
	Commuting	0	0	0	0
	Educational	95	22	3	6
	Hotels	4	1	0	0
	Industrial	210	54	8	16
	Other-Residential	76	15	2	3
	Single Family	132	27	3	6
	Total	1,858	445	65	126
5 PM	Commercial	881	214	32	62
	Commuting	13	15	28	5
	Educational	22	5	1	1
	Hotels	5	1	0	0
	Industrial	131	34	5	10
	Other-Residential	144	28	3	6
	Single Family	265	53	6	12
	Total	1,461	350	75	96

Economic Loss

The total economic loss estimated for the earthquake is 3,887.85 (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 3,776.62 (millions of dollars); 15 % 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 62 % 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 Losses							
	Wage	0.00	10.21	155.31	4.39	4.80	174.71
	Capital-Related	0.00	4.36	143.94	2.84	0.96	152.09
	Rental	48.77	86.43	75.16	2.41	3.19	215.96
	Relocation	5.13	1.88	4.39	0.25	0.64	12.30
	Subtotal	53.91	102.87	378.80	9.89	9.59	555.05
Capital Stock Losses							
	Structural	246.53	96.50	165.06	27.27	14.24	549.60
	Non_Structural	857.15	570.54	402.70	81.55	39.15	1,951.09
	Content	262.49	150.11	212.62	56.28	20.88	702.38
	Inventory	0.00	0.00	7.24	11.05	0.21	18.50
	Subtotal	1,366.17	817.15	787.62	176.15	74.48	3,221.56
	Total	1,420.07	920.02	1,166.42	186.04	84.07	3,776.62

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$18.64	1.28
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	18.60	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.01	0.40
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$2.45	28.95
	Subtotal	105.40	2.50	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.03
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$1.98	31.15
	Subtotal	6.30	2.00	
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	5.29	\$1.16	21.96
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	1.20	
	Total	2247.50	24.20	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.55	0.85
	Subtotal	65.08	\$0.55	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.44	1.12
	Subtotal	39.05	\$0.44	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.22	20.66
	Distribution Line	26.00	\$0.47	1.79
	Subtotal	27.09	\$0.69	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.14	20.22
	Subtotal	0.68	\$0.14	
Electrical Power	Facilities	426.80	\$85.17	19.96
	Subtotal	426.80	\$85.17	
Communication	Facilities	0.20	\$0.01	7.53
	Subtotal	0.19	\$0.01	
	Total	558.90	\$87.00	

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

	LOSS	Total	%
First Year			
	Employment Impact	8,444	2.64
	Income Impact	(27)	-0.24
Second Year			
	Employment Impact	3,841	1.20
	Income Impact	(122)	-1.08
Third Year			
	Employment Impact	95	0.03
	Income Impact	(168)	-1.49
Fourth Year			
	Employment Impact	5	0.00
	Income Impact	(171)	-1.52
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(171)	-1.52
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(171)	-1.52

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233

HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *RMA M6.25 CEUS Event*

Print Date: *February 15, 2006*

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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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):

Colorado

Note:

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

The geographical size of the region is 154.74 square miles and contains 136 census tracts. There are over 239 thousand households in the region and has a total population of 554,636 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 143 thousand buildings in the region with a total building replacement value (excluding contents) of 36,233 (millions of dollars). Approximately 97.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,247 and 428 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 143 thousand buildings in the region which have an aggregate total replacement value of 36,233 (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 74% 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 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 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 2,675.00 (millions of dollars). This inventory includes over 147 kilometers of highways, 426 bridges, 6,508 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	426	1,461.00
	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	RMA M6.25 CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-104.90
Latitude of Epicenter	39.90
Earthquake Magnitude	6.25
Depth (Km)	10.00
Rupture Length (Km)	11.89
Rupture Orientation (degrees)	130.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 45,403 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 2,786 buildings that will be damaged beyond repair. 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	2	0.00	2	0.01	2	0.01	1	0.01	0	0.01
Commercial	929	1.49	543	1.51	897	2.94	592	4.89	211	7.59
Education	3	0.00	1	0.00	2	0.01	1	0.01	0	0.01
Government	50	0.08	33	0.09	56	0.18	37	0.31	13	0.45
Industrial	61	0.10	40	0.11	86	0.28	75	0.62	38	1.36
Other Residential	3,673	5.88	2,433	6.75	2,156	7.07	880	7.27	221	7.93
Religion	45	0.07	27	0.07	36	0.12	22	0.18	6	0.22
Single Family	57,713	92.37	32,966	91.46	27,265	89.39	10,509	86.73	2,297	82.42
Total	62,478		36,046		30,500		12,117		2,786	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	48,020	76.86	30942	85.84	21,442	70.30	5,200	42.92	712	25.54
Steel	381	0.61	181	0.50	381	1.25	282	2.33	122	4.38
Concrete	411	0.66	235	0.65	363	1.19	229	1.89	66	2.36
Precast	142	0.23	72	0.20	167	0.55	169	1.40	70	2.51
RM	12,071	19.32	3633	10.08	6,788	22.26	5,281	43.59	1,185	42.54
URM	1,151	1.84	791	2.19	1,073	3.52	788	6.50	584	20.97
MH	303	0.48	191	0.53	286	0.94	168	1.38	47	1.69
Total	62,478		36,046		30,500		12,117		2,786	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 959 hospital beds (29.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 56.00% of the beds will be back in service. By 30 days, 90.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	8	0	3
Schools	200	1	0	77
EOCs	2	0	0	0
PoliceStations	17	0	0	5
FireStations	4	0	0	1

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	52	0	0	52	52
	Bridges	426	13	0	414	419
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	4	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	1	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	1	0	0	1
Oil Systems	7	7	0	0	7
Electrical Power	4	4	0	0	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	234	58
Waste Water	1,953	185	46
Natural Gas	1,302	197	49
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	239,235	909	0	0	0	0
Electric Power		6,803	3,665	1,224	194	11

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 45 ignitions that will burn about 0.19 sq. mi 0.12 % of the region's total area.) The model also estimates that the fires will displace about 1,104 people and burn about 77 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 13,992 households to be displaced due to the earthquake. Of these, 3,809 people (out of a total population of 554,636 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	43	12	2	4
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	30	8	1	2
	Industrial	50	14	2	4
	Other-Residential	637	140	17	33
	Single Family	1,100	245	32	63
	Total	1,860	419	54	106
2 PM	Commercial	2,360	634	100	196
	Commuting	0	0	1	0
	Educational	170	45	7	14
	Hotels	6	1	0	0
	Industrial	370	104	17	33
	Other-Residential	129	29	4	7
	Single Family	214	48	7	12
	Total	3,249	861	134	262
5 PM	Commercial	1,552	417	66	128
	Commuting	27	32	59	11
	Educational	39	10	2	3
	Hotels	9	2	0	1
	Industrial	231	65	10	20
	Other-Residential	246	54	7	13
	Single Family	431	96	13	24
	Total	2,536	677	157	200

Economic Loss

The total economic loss estimated for the earthquake is 5,557.58 (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 5,421.03 (millions of dollars); 15 % 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 60 % 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 Losses							
	Wage	0.00	15.21	232.84	6.42	7.22	261.69
	Capital-Related	0.00	6.49	216.74	4.17	1.45	228.84
	Rental	70.96	130.59	109.01	3.38	4.90	318.84
	Relocation	7.47	2.78	6.41	0.35	0.99	18.00
	Subtotal	78.42	155.07	565.00	14.32	14.55	827.36
Capital Stock Losses							
	Structural	362.78	146.64	251.03	40.70	22.29	823.43
	Non_Structural	1,207.16	805.34	620.30	126.67	60.50	2,819.96
	Content	323.10	186.89	299.11	84.68	29.01	922.79
	Inventory	0.00	0.00	10.52	16.68	0.28	27.48
	Subtotal	1,893.04	1,138.87	1,180.96	268.73	112.07	4,593.67
	Total	1,971.46	1,293.94	1,745.96	283.04	126.63	5,421.03

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$38.06	2.60
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	38.10	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.02	1.11
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$2.72	32.15
	Subtotal	105.40	2.70	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.16
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$2.16	34.03
	Subtotal	6.30	2.20	
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	5.29	\$1.57	29.69
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	1.60	
	Total	2247.50	44.50	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$1.05	1.62
	Subtotal	65.08	\$1.05	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.83	2.13
	Subtotal	39.05	\$0.83	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.30	28.21
	Distribution Line	26.00	\$0.89	3.41
	Subtotal	27.09	\$1.19	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.14	20.99
	Subtotal	0.68	\$0.14	
Electrical Power	Facilities	426.80	\$88.79	20.80
	Subtotal	426.80	\$88.79	
Communication	Facilities	0.20	\$0.02	10.21
	Subtotal	0.19	\$0.02	
	Total	558.90	\$92.02	

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

	LOSS	Total	%
First Year			
	Employment Impact	8,444	2.64
	Income Impact	(27)	-0.24
Second Year			
	Employment Impact	3,841	1.20
	Income Impact	(122)	-1.08
Third Year			
	Employment Impact	95	0.03
	Income Impact	(168)	-1.49
Fourth Year			
	Employment Impact	5	0.00
	Income Impact	(171)	-1.52
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(171)	-1.52
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(171)	-1.52

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233

HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *S Sawatch M7.25 CEUS Event*

Print Date: *January 25, 2006*

Disclaimer:

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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):

Colorado

Note:

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

The geographical size of the region is 154.74 square miles and contains 136 census tracts. There are over 239 thousand households in the region and has a total population of 554,636 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 143 thousand buildings in the region with a total building replacement value (excluding contents) of 36,233 (millions of dollars). Approximately 97.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,247 and 428 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 143 thousand buildings in the region which have an aggregate total replacement value of 36,233 (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 74% 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 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 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 2,675.00 (millions of dollars). This inventory includes over 147 kilometers of highways, 426 bridges, 6,508 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	426	1,461.00
	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	S Sawatch M7.25 CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-106.18
Latitude of Epicenter	38.75
Earthquake Magnitude	7.25
Depth (Km)	10.00
Rupture Length (Km)	65.31
Rupture Orientation (degrees)	148.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 8,218 buildings will be at least moderately damaged. This is over 6.00 % of the total number of buildings in the region. There are an estimated 83 buildings that will be damaged beyond repair. 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	6	0.00	1	0.01	1	0.01	0	0.01	0	0.02
Commercial	2,077	1.74	519	3.19	441	6.60	124	8.50	12	14.72
Education	5	0.00	1	0.01	1	0.02	0	0.02	0	0.04
Government	126	0.11	30	0.19	26	0.38	7	0.46	1	0.75
Industrial	190	0.16	48	0.30	47	0.70	14	0.97	1	1.55
Other Residential	7,395	6.19	1,206	7.41	610	9.14	141	9.69	11	12.72
Religion	96	0.08	20	0.12	16	0.24	4	0.30	0	0.49
Single Family	109,531	91.72	14,458	88.79	5,538	82.91	1,164	80.04	58	69.71
Total	119,425		16,284		6,680		1,455		84	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	91,620	76.72	11,941	73.33	2,552	38.20	196	13.44	7	8.43
Steel	808	0.68	211	1.29	243	3.64	75	5.18	10	12.26
Concrete	852	0.71	221	1.36	180	2.70	47	3.25	3	3.77
Precast	383	0.32	84	0.51	105	1.57	46	3.16	3	3.35
RM	22,340	18.71	2,855	17.53	2,866	42.90	880	60.48	19	22.57
URM	2,828	2.37	783	4.81	559	8.36	177	12.18	39	46.59
MH	594	0.50	189	1.16	176	2.63	33	2.30	3	3.02
Total	119,425		16,284		6,680		1,455		84	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 1,956 hospital beds (59.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 86.00% 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		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	0	0	10
Schools	200	0	0	200
EOCs	2	0	0	2
PoliceStations	17	0	0	17
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	52	0	0	52	52
	Bridges	426	0	0	426	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	0	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	0	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	0	0	7	7
Electrical Power	4	0	0	4	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	39	10
Waste Water	1,953	31	8
Natural Gas	1,302	33	8
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	239,235	0	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 13 ignitions that will burn about 0.01 sq. mi 0.01 % of the region's total area.) The model also estimates that the fires will displace about 51 people and burn about 3 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 1,704 households to be displaced due to the earthquake. Of these, 458 people (out of a total population of 554,636) 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	3	0	0	0
	Industrial	5	1	0	0
	Other-Residential	80	11	1	2
	Single Family	102	13	1	2
	Total	195	26	2	4
2 PM	Commercial	291	48	5	10
	Commuting	0	0	0	0
	Educational	22	4	0	1
	Hotels	1	0	0	0
	Industrial	37	6	1	1
	Other-Residential	14	2	0	0
	Single Family	19	2	0	0
	Total	384	63	6	12
5 PM	Commercial	189	32	3	6
	Commuting	1	1	2	0
	Educational	6	1	0	0
	Hotels	1	0	0	0
	Industrial	23	4	0	1
	Other-Residential	30	4	0	1
	Single Family	40	5	0	1
	Total	290	47	6	9

Economic Loss

The total economic loss estimated for the earthquake is 866.07 (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 847.94 (millions of dollars); 21 % 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 Losses							
	Wage	0.00	1.92	56.76	1.24	1.67	61.59
	Capital-Related	0.00	0.82	52.23	0.81	0.35	54.21
	Rental	9.56	22.49	27.32	0.67	0.99	61.03
	Relocation	0.99	0.51	1.56	0.08	0.22	3.35
	Subtotal	10.54	25.75	137.87	2.80	3.22	180.19
Capital Stock Losses							
	Structural	49.80	26.68	51.42	7.25	4.59	139.74
	Non_Structural	147.37	120.33	100.22	15.00	9.93	392.85
	Content	44.85	28.11	45.02	9.52	4.39	131.88
	Inventory	0.00	0.00	1.36	1.88	0.04	3.29
	Subtotal	242.02	175.11	198.02	33.66	18.94	667.75
	Total	252.57	200.86	335.89	36.46	22.16	847.94

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$2.46	0.17
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	2.50	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.00	0.02
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$0.36	4.23
	Subtotal	105.40	0.40	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$0.41	6.44
	Subtotal	6.30	0.40	
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	5.29	\$0.06	1.14
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.10	
	Total	2247.50	3.30	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.18	0.27
	Subtotal	65.08	\$0.18	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.14	0.36
	Subtotal	39.05	\$0.14	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.00	0.10
	Distribution Line	26.00	\$0.15	0.58
	Subtotal	27.09	\$0.15	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.02	3.56
	Subtotal	0.68	\$0.02	
Electrical Power	Facilities	426.80	\$14.34	3.36
	Subtotal	426.80	\$14.34	
Communication	Facilities	0.20	\$0.00	0.36
	Subtotal	0.19	\$0.00	
	Total	558.90	\$14.84	

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

	LOSS	Total	%
First Year			
	Employment Impact	1,228	0.38
	Income Impact	(4)	-0.04
Second Year			
	Employment Impact	538	0.17
	Income Impact	(18)	-0.16
Third Year			
	Employment Impact	12	0.00
	Income Impact	(25)	-0.22
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(25)	-0.22
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(25)	-0.22
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(25)	-0.22

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State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
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HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *Ute Pass M7.0 Denver CEUS Event*

Print Date: *June 30, 2005*

Disclaimer:

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	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	Ute Pass M7.0 Denver CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-105.00
Latitude of Epicenter	38.92
Earthquake Magnitude	7.00
Depth (Km)	10.00
Rupture Length (Km)	42.66
Rupture Orientation (degrees)	152.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 24,245 buildings will be at least moderately damaged. This is over 17.00 % of the total number of buildings in the region. There are an estimated 787 buildings that will be damaged beyond repair. 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	4	0.00	2	0.01	1	0.01	1	0.01	0	0.01
Commercial	1,312	1.46	616	2.05	793	4.52	377	6.40	74	9.46
Education	3	0.00	1	0.00	2	0.01	1	0.02	0	0.03
Government	78	0.09	38	0.13	48	0.28	21	0.36	3	0.44
Industrial	116	0.13	56	0.19	80	0.46	40	0.68	8	0.97
Other Residential	5,484	6.12	2,045	6.79	1,326	7.55	443	7.50	65	8.30
Religion	64	0.07	26	0.09	29	0.17	14	0.23	2	0.30
Single Family	82,516	92.12	27,320	90.75	15,280	87.01	5,001	84.80	634	80.48
Total	89,577		30,105		17,561		5,897		787	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	71,032	79.30	24,573	81.63	9,380	53.41	1,249	21.17	82	10.44
Steel	542	0.61	221	0.73	364	2.08	177	3.00	42	5.33
Concrete	551	0.62	263	0.87	325	1.85	144	2.44	21	2.67
Precast	222	0.25	91	0.30	166	0.95	120	2.04	21	2.72
RM	15,147	16.91	3,828	12.72	6,056	34.49	3,567	60.48	360	45.77
URM	1,695	1.89	914	3.03	992	5.65	539	9.14	247	31.35
MH	387	0.43	215	0.71	277	1.58	102	1.73	14	1.72
Total	89,577		30,105		17,561		5,897		787	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 1,245 hospital beds (37.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 68.00% of the beds will be back in service. By 30 days, 96.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	0	0	2
Schools	200	0	0	173
EOCs	2	0	0	2
PoliceStations	17	0	0	16
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	52	0	0	52	52
	Bridges	426	0	0	426	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	0	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	0	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	0	0	1	7
Electrical Power	4	0	0	1	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	101	25
Waste Water	1,953	80	20
Natural Gas	1,302	85	21
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	239,235	0	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 30 ignitions that will burn about 0.08 sq. mi 0.05 % of the region's total area.) The model also estimates that the fires will displace about 444 people and burn about 30 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 6,234 households to be displaced due to the earthquake. Of these, 1,654 people (out of a total population of 554,636) 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	19	4	1	1
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	9	2	0	0
	Industrial	17	4	1	1
	Other-Residential	276	52	6	11
	Single Family	433	82	10	19
	Total	756	144	17	33
2 PM	Commercial	1,052	238	33	66
	Commuting	0	0	0	0
	Educational	81	18	3	5
	Hotels	2	0	0	0
	Industrial	128	29	4	8
	Other-Residential	51	10	1	2
	Single Family	80	15	2	4
	Total	1,394	310	43	84
5 PM	Commercial	692	157	22	43
	Commuting	5	6	10	2
	Educational	21	5	1	1
	Hotels	3	1	0	0
	Industrial	80	18	3	5
	Other-Residential	106	20	2	4
	Single Family	169	32	4	7
	Total	1,074	238	42	63

Economic Loss

The total economic loss estimated for the earthquake is 2,749.25 (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 2,686.91 (millions of dollars); 18 % 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 58 % 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 Losses							
	Wage	0.00	6.28	146.41	3.13	4.28	160.10
	Capital-Related	0.00	2.68	134.51	2.04	0.91	140.15
	Rental	33.79	65.50	68.68	1.70	2.80	172.47
	Relocation	3.53	1.44	4.03	0.19	0.59	9.79
	Subtotal	37.32	75.90	353.63	7.07	8.58	482.51
Capital Stock Losses							
	Structural	174.27	75.79	141.58	18.86	12.68	423.17
	Non_Structural	536.56	391.63	311.77	46.82	30.56	1,317.33
	Content	163.31	97.72	146.60	31.07	14.38	453.07
	Inventory	0.00	0.00	4.60	6.07	0.14	10.81
	Subtotal	874.13	565.13	604.54	102.82	57.77	2,204.39
	Total	911.45	641.03	958.18	109.89	66.35	2,686.91

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$10.24	0.70
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	10.20	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.00	0.20
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$1.05	12.41
	Subtotal	105.40	1.10	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.03
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$0.96	15.16
	Subtotal	6.30	1.00	
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	5.29	\$0.25	4.74
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.30	
	Total	2247.50	12.50	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.45	0.70
	Subtotal	65.08	\$0.45	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.36	0.92
	Subtotal	39.05	\$0.36	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.01	1.12
	Distribution Line	26.00	\$0.38	1.48
	Subtotal	27.09	\$0.40	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.08	12.11
	Subtotal	0.68	\$0.08	
Electrical Power	Facilities	426.80	\$48.54	11.37
	Subtotal	426.80	\$48.54	
Communication	Facilities	0.20	\$0.01	2.84
	Subtotal	0.19	\$0.01	
	Total	558.90	\$49.84	

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

	LOSS	Total	%
First Year			
	Employment Impact	8,444	2.64
	Income Impact	(27)	-0.24
Second Year			
	Employment Impact	3,841	1.20
	Income Impact	(122)	-1.08
Third Year			
	Employment Impact	95	0.03
	Income Impact	(168)	-1.49
Fourth Year			
	Employment Impact	5	0.00
	Income Impact	(171)	-1.52
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(171)	-1.52
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(171)	-1.52

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233

HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *Valmont M5.0 CEUS Event*

Print Date: *January 25, 2006*

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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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):

Colorado

Note:

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

The geographical size of the region is 154.74 square miles and contains 136 census tracts. There are over 239 thousand households in the region and has a total population of 554,636 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 143 thousand buildings in the region with a total building replacement value (excluding contents) of 36,233 (millions of dollars). Approximately 97.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,247 and 428 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 143 thousand buildings in the region which have an aggregate total replacement value of 36,233 (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 74% 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 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 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 2,675.00 (millions of dollars). This inventory includes over 147 kilometers of highways, 426 bridges, 6,508 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	426	1,461.00
	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	Valmont M5.0 CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-105.20
Latitude of Epicenter	40.03
Earthquake Magnitude	5.00
Depth (Km)	10.00
Rupture Length (Km)	1.41
Rupture Orientation (degrees)	75.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 335 buildings will be at least moderately damaged. This is over 0.00 % of the total number of buildings in the region. There are an estimated 0 buildings that will be damaged beyond repair. 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	8	0.01	0	0.01	0	0.01	0	0.01	0	0.01
Commercial	3,101	2.18	51	4.01	19	6.06	2	8.15	0	6.98
Education	8	0.01	0	0.01	0	0.01	0	0.02	0	0.01
Government	185	0.13	3	0.22	1	0.27	0	0.29	0	0.25
Industrial	292	0.21	5	0.41	2	0.69	0	1.00	0	0.28
Other Residential	9,229	6.49	107	8.39	25	8.22	1	5.34	0	4.74
Religion	133	0.09	2	0.15	1	0.18	0	0.20	0	0.19
Single Family	129,357	90.90	1,110	86.81	259	84.55	24	85.00	1	87.54
Total	142,313		1,278		307		28		1	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	105,581	74.19	677	52.93	58	19.03	0	0.61	0	0.00
Steel	1,326	0.93	15	1.20	5	1.54	0	1.45	0	0.00
Concrete	1,278	0.90	21	1.67	5	1.49	0	1.02	0	0.00
Precast	599	0.42	14	1.07	7	2.39	1	3.94	0	0.00
RM	28,440	19.98	350	27.39	154	50.13	16	56.20	0	0.00
URM	4,134	2.90	173	13.54	69	22.36	10	36.07	1	100.00
MH	956	0.67	28	2.21	9	3.07	0	0.71	0	0.00
Total	142,313		1,278		307		28		1	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 3,286 hospital beds (99.00%) 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		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	0	0	14
Schools	200	0	0	200
EOCs	2	0	0	2
PoliceStations	17	0	0	17
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	52	0	0	52	52
	Bridges	426	0	0	426	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	0	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	0	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	0	0	7	7
Electrical Power	4	0	0	4	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	1	0
Waste Water	1,953	0	0
Natural Gas	1,302	1	0
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	239,235	0	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 9 ignitions that will burn about 0.02 sq. mi 0.01 % of the region's total area.) The model also estimates that the fires will displace about 86 people and burn about 3 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 17 households to be displaced due to the earthquake. Of these, 4 people (out of a total population of 554,636 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	0	0	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	0	0	0	0
	Other-Residential	3	0	0	0
	Single Family	4	0	0	0
	Total	7	1	0	0
2 PM	Commercial	9	1	0	0
	Commuting	0	0	0	0
	Educational	1	0	0	0
	Hotels	0	0	0	0
	Industrial	1	0	0	0
	Other-Residential	0	0	0	0
	Single Family	1	0	0	0
	Total	12	1	0	0
5 PM	Commercial	6	1	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	1	0	0	0
	Other-Residential	1	0	0	0
	Single Family	2	0	0	0
	Total	9	1	0	0

Economic Loss

The total economic loss estimated for the earthquake is 98.40 (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 86.60 (millions of dollars); 6 % 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 58 % 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 Losses							
	Wage	0.00	0.05	1.55	0.04	0.05	1.69
	Capital-Related	0.00	0.02	1.48	0.02	0.01	1.54
	Rental	0.34	0.44	0.80	0.01	0.01	1.61
	Relocation	0.04	0.01	0.05	0.00	0.00	0.10
	Subtotal	0.38	0.52	3.88	0.07	0.08	4.94
Capital Stock Losses							
	Structural	2.06	0.85	1.73	0.24	0.12	5.01
	Non_Structural	16.07	14.75	12.52	3.05	1.12	47.51
	Content	9.30	5.92	9.89	2.36	0.90	28.37
	Inventory	0.00	0.00	0.30	0.47	0.01	0.78
	Subtotal	27.43	21.52	24.45	6.11	2.15	81.66
	Total	27.81	22.04	28.33	6.18	2.23	86.60

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	0.00	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$0.36	4.21
	Subtotal	105.40	0.40	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$0.38	6.06
	Subtotal	6.30	0.40	
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	5.29	\$0.04	0.77
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.00	
	Total	2247.50	0.80	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.00	0.00
	Subtotal	65.08	\$0.00	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.00	0.01
	Subtotal	39.05	\$0.00	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.00	0.09
	Distribution Line	26.00	\$0.00	0.01
	Subtotal	27.09	\$0.00	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.02	2.81
	Subtotal	0.68	\$0.02	
Electrical Power	Facilities	426.80	\$10.99	2.57
	Subtotal	426.80	\$10.99	
Communication	Facilities	0.20	\$0.00	0.10
	Subtotal	0.19	\$0.00	
	Total	558.90	\$11.02	

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

	LOSS	Total	%
First Year			
	Employment Impact	136	0.04
	Income Impact	0	0.00
Second Year			
	Employment Impact	46	0.01
	Income Impact	(2)	-0.02
Third Year			
	Employment Impact	0	0.00
	Income Impact	(2)	-0.02
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(2)	-0.02
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(2)	-0.02
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(2)	-0.02

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233

HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *Walnut Creek M6.0 Denver CEUS Event*

Print Date: *June 30, 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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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):

Colorado

Note:

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

The geographical size of the region is 154.74 square miles and contains 136 census tracts. There are over 239 thousand households in the region and has a total population of 554,636 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 143 thousand buildings in the region with a total building replacement value (excluding contents) of 36,233 (millions of dollars). Approximately 97.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,247 and 428 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 143 thousand buildings in the region which have an aggregate total replacement value of 36,233 (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 74% 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 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 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 2,675.00 (millions of dollars). This inventory includes over 147 kilometers of highways, 426 bridges, 6,508 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	426	1,461.00
	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	Walnut Creek M6.0 Denver CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-105.15
Latitude of Epicenter	39.88
Earthquake Magnitude	6.00
Depth (Km)	10.00
Rupture Length (Km)	7.76
Rupture Orientation (degrees)	31.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 26,336 buildings will be at least moderately damaged. This is over 18.00 % of the total number of buildings in the region. There are an estimated 653 buildings that will be damaged beyond repair. 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	3	0.00	2	0.01	2	0.01	1	0.01	0	0.02
Commercial	1,418	1.69	610	1.82	742	3.71	338	5.95	64	9.81
Education	4	0.00	1	0.00	2	0.01	1	0.01	0	0.01
Government	81	0.10	38	0.11	47	0.23	20	0.35	3	0.49
Industrial	120	0.14	56	0.17	78	0.39	38	0.67	7	1.06
Other Residential	4,979	5.92	2,331	6.97	1,552	7.76	445	7.83	57	8.67
Religion	64	0.08	28	0.08	29	0.15	12	0.21	2	0.30
Single Family	77,466	92.07	30,388	90.83	17,546	87.74	4,830	84.96	521	79.63
Total	84,136		33,454		19,998		5,685		654	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	64,176	76.28	27741	82.92	12,325	61.63	1,920	33.77	153	23.42
Steel	601	0.71	226	0.68	341	1.71	147	2.59	31	4.75
Concrete	604	0.72	266	0.80	300	1.50	119	2.09	15	2.30
Precast	237	0.28	93	0.28	163	0.81	110	1.94	17	2.65
RM	16,459	19.56	3957	11.83	5,584	27.92	2,765	48.64	194	29.72
URM	1,652	1.96	945	2.82	1,018	5.09	538	9.47	233	35.64
MH	407	0.48	225	0.67	268	1.34	85	1.49	10	1.52
Total	84,136		33,454		19,998		5,685		654	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 1,454 hospital beds (44.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 75.00% of the beds will be back in service. By 30 days, 97.00% will be operational.

Table 6: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	0	0	3
Schools	200	0	0	102
EOCs	2	0	0	2
PoliceStations	17	0	0	8
FireStations	4	0	0	1

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	52	0	0	52	52
	Bridges	426	0	0	426	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	2	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	0	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	7	0	0	7
Electrical Power	4	4	0	0	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	72	18
Waste Water	1,953	57	14
Natural Gas	1,302	61	15
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	239,235	0	0	0	0	0
Electric Power		290	157	52	8	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 42 ignitions that will burn about 0.14 sq. mi 0.09 % of the region's total area.) The model also estimates that the fires will displace about 855 people and burn about 56 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 5,779 households to be displaced due to the earthquake. Of these, 1,599 people (out of a total population of 554,636 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	18	4	1	1
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	12	2	0	1
	Industrial	16	3	0	1
	Other-Residential	267	46	5	9
	Single Family	428	73	8	15
	Total	742	130	13	26
2 PM	Commercial	977	219	30	60
	Commuting	0	0	0	0
	Educational	64	13	2	3
	Hotels	2	0	0	0
	Industrial	115	26	3	7
	Other-Residential	50	9	1	2
	Single Family	83	14	2	3
	Total	1,291	282	38	75
5 PM	Commercial	620	138	19	37
	Commuting	3	4	8	1
	Educational	15	3	0	1
	Hotels	4	1	0	0
	Industrial	72	16	2	4
	Other-Residential	103	18	2	3
	Single Family	167	29	3	6
	Total	985	210	35	53

Economic Loss

The total economic loss estimated for the earthquake is 3,152.92 (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 3,049.51 (millions of dollars); 15 % 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 62 % 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 Losses							
	Wage	0.00	7.50	129.13	2.93	3.90	143.46
	Capital-Related	0.00	3.20	123.26	1.94	0.80	129.21
	Rental	34.94	67.54	63.66	1.65	2.57	170.36
	Relocation	3.66	1.49	3.65	0.18	0.53	9.52
	Subtotal	38.61	79.73	319.70	6.70	7.80	452.54
Capital Stock Losses							
	Structural	176.23	75.99	129.80	18.03	11.48	411.53
	Non_Structural	658.05	477.47	329.86	55.60	32.45	1,553.43
	Content	239.51	136.39	183.33	40.41	18.62	618.25
	Inventory	0.00	0.00	5.71	7.86	0.19	13.75
	Subtotal	1,073.78	689.85	648.69	121.90	62.74	2,596.97
	Total	1,112.39	769.59	968.39	128.60	70.54	3,049.51

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$11.67	0.80
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	11.70	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.00	0.21
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$2.02	23.85
	Subtotal	105.40	2.00	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.03
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$1.84	29.07
	Subtotal	6.30	1.80	
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	5.29	\$0.36	6.77
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.40	
	Total	2247.50	15.90	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.32	0.50
	Subtotal	65.08	\$0.32	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.26	0.65
	Subtotal	39.05	\$0.26	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.03	3.01
	Distribution Line	26.00	\$0.27	1.05
	Subtotal	27.09	\$0.30	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.14	20.13
	Subtotal	0.68	\$0.14	
Electrical Power	Facilities	426.80	\$86.47	20.26
	Subtotal	426.80	\$86.47	
Communication	Facilities	0.20	\$0.02	8.92
	Subtotal	0.19	\$0.02	
	Total	558.90	\$87.51	

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

	LOSS	Total	%
First Year			
	Employment Impact	8,444	2.64
	Income Impact	(27)	-0.24
Second Year			
	Employment Impact	3,841	1.20
	Income Impact	(122)	-1.08
Third Year			
	Employment Impact	95	0.03
	Income Impact	(168)	-1.49
Fourth Year			
	Employment Impact	5	0.00
	Income Impact	(171)	-1.52
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(171)	-1.52
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(171)	-1.52

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233

HAZUS-MH: Earthquake Event Report



Region Name: *Denver County New*

Earthquake Scenario: *Williams Fork M6.75 CEUS Event*

Print Date: *January 25, 2006*

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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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):

Colorado

Note:

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

The geographical size of the region is 154.74 square miles and contains 136 census tracts. There are over 239 thousand households in the region and has a total population of 554,636 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 143 thousand buildings in the region with a total building replacement value (excluding contents) of 36,233 (millions of dollars). Approximately 97.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 2,247 and 428 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 143 thousand buildings in the region which have an aggregate total replacement value of 36,233 (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 74% 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 14 hospitals in the region with a total bed capacity of 3,328 beds. There are 200 schools, 4 fire stations, 17 police stations and 2 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 5 of the dams are classified as 'high hazard'. The inventory also includes 74 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 2,675.00 (millions of dollars). This inventory includes over 147 kilometers of highways, 426 bridges, 6,508 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	426	1,461.00
	Segments	52	511.50
	Tunnels	0	0.00
	Subtotal		1,972.50
Railways	Bridges	25	2.00
	Facilities	4	8.50
	Segments	214	95.00
	Tunnels	0	0.00
	Subtotal		105.40
Light Rail	Bridges	1	0.30
	Facilities	0	0.00
	Segments	3	6.90
	Tunnels	0	0.00
	Subtotal		7.20
Bus	Facilities	6	6.30
	Subtotal		6.30
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	0	0.00
	Subtotal		0.00
Airport	Facilities	1	5.30
	Runways	5	150.70
	Subtotal		156.00
		Total	2,247.50

Table 3: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	65.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		65.10
Waste Water	Distribution Lines	NA	39.10
	Facilities	0	0.00
	Pipelines	0	0.00
	Subtotal		39.10
Natural Gas	Distribution Lines	NA	26.00
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		27.10
Oil Systems	Facilities	7	0.70
	Pipelines	0	0.00
	Subtotal		0.70
Electrical Power	Facilities	4	426.80
	Subtotal		426.80
Communication	Facilities	2	0.20
	Subtotal		0.20
	Total		558.90

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	Williams Fork M6.75 CEUS Event
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-106.15
Latitude of Epicenter	39.87
Earthquake Magnitude	6.75
Depth (Km)	10.00
Rupture Length (Km)	27.86
Rupture Orientation (degrees)	140.00
Attenuation Function	CEUS Event

Building Damage

Building Damage

HAZUS estimates that about 7,853 buildings will be at least moderately damaged. This is over 5.00 % of the total number of buildings in the region. There are an estimated 73 buildings that will be damaged beyond repair. 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	6	0.01	1	0.01	1	0.01	0	0.01	0	0.02
Commercial	2,165	1.80	497	3.12	395	6.16	107	7.86	9	12.28
Education	6	0.00	1	0.01	1	0.02	0	0.02	0	0.03
Government	130	0.11	29	0.18	23	0.36	6	0.42	0	0.60
Industrial	197	0.16	47	0.29	43	0.66	13	0.92	1	1.32
Other Residential	7,482	6.23	1,184	7.45	572	8.91	118	8.67	7	10.04
Religion	99	0.08	19	0.12	14	0.22	4	0.27	0	0.38
Single Family	110,092	91.61	14,118	88.82	5,372	83.66	1,113	81.83	55	75.34
Total	120,177		15,896		6,420		1,360		73	

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

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	92,059	76.60	11615	73.07	2,449	38.14	186	13.66	7	9.37
Steel	893	0.74	196	1.23	199	3.10	53	3.89	6	7.67
Concrete	877	0.73	217	1.37	167	2.60	41	2.98	2	3.13
Precast	391	0.33	84	0.53	101	1.58	42	3.11	2	3.19
RM	22,493	18.72	2819	17.73	2,791	43.47	839	61.70	17	23.22
URM	2,845	2.37	779	4.90	552	8.59	173	12.73	38	51.32
MH	619	0.52	186	1.17	161	2.51	26	1.92	2	2.11
Total	120,177		15,896		6,420		1,360		73	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,328 hospital beds available for use. On the day of the earthquake, the model estimates that only 2,137 hospital beds (64.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 89.00% 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		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	14	0	0	14
Schools	200	0	0	200
EOCs	2	0	0	2
PoliceStations	17	0	0	17
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	52	0	0	52	52
	Bridges	426	0	0	426	426
	Tunnels	0	0	0	0	0
Railways	Segments	214	0	0	214	214
	Bridges	25	0	0	25	25
	Tunnels	0	0	0	0	0
	Facilities	4	0	0	4	4
Light Rail	Segments	3	0	0	3	3
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	6	0	0	6	6
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	1	0	0	1	1
	Runways	5	0	0	5	5

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	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	1	0	0	1	1
Oil Systems	7	0	0	7	7
Electrical Power	4	0	0	4	4
Communication	2	0	0	2	2

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

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	3,254	27	7
Waste Water	1,953	21	5
Natural Gas	1,302	23	6
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	239,235	0	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 15 ignitions that will burn about 0.03 sq. mi 0.02 % of the region's total area.) The model also estimates that the fires will displace about 153 people and burn about 7 (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 2.00 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 28.00% 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 80,000 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 1,406 households to be displaced due to the earthquake. Of these, 380 people (out of a total population of 554,636 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	2	0	0	0
	Industrial	4	1	0	0
	Other-Residential	70	9	1	1
	Single Family	99	13	1	2
	Total	181	24	2	4
2 PM	Commercial	256	41	4	8
	Commuting	0	0	0	0
	Educational	19	3	0	1
	Hotels	0	0	0	0
	Industrial	32	5	0	1
	Other-Residential	13	2	0	0
	Single Family	19	2	0	0
	Total	339	53	5	10
5 PM	Commercial	166	27	3	5
	Commuting	0	0	1	0
	Educational	5	1	0	0
	Hotels	1	0	0	0
	Industrial	20	3	0	1
	Other-Residential	27	4	0	1
	Single Family	38	5	0	1
	Total	257	40	5	7

Economic Loss

The total economic loss estimated for the earthquake is 849.99 (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 826.59 (millions of dollars); 19 % 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 55 % 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 Losses							
	Wage	0.00	1.79	48.57	1.08	1.45	52.89
	Capital-Related	0.00	0.76	44.84	0.70	0.30	46.61
	Rental	9.22	19.85	24.18	0.60	0.84	54.69
	Relocation	0.95	0.45	1.37	0.07	0.18	3.03
	Subtotal	10.17	22.86	118.96	2.46	2.78	157.22
Capital Stock Losses							
	Structural	48.00	23.57	45.72	6.41	3.92	127.62
	Non_Structural	151.66	119.81	96.14	15.37	9.33	392.30
	Content	51.09	31.22	48.56	10.34	4.68	145.89
	Inventory	0.00	0.00	1.49	2.03	0.04	3.57
	Subtotal	250.74	174.60	191.91	34.15	17.98	669.38
	Total	260.91	197.46	310.86	36.61	20.75	826.59

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	511.51	\$0.00	0.00
	Bridges	1,460.99	\$1.32	0.09
	Tunnels	0.00	\$0.00	0.00
	Subtotal	1972.50	1.30	
Railways	Segments	94.96	\$0.00	0.00
	Bridges	2.03	\$0.00	0.01
	Tunnels	0.00	\$0.00	0.00
	Facilities	8.46	\$0.51	6.07
	Subtotal	105.40	0.50	
Light Rail	Segments	6.87	\$0.00	0.00
	Bridges	0.32	\$0.00	0.00
	Tunnels	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Subtotal	7.20	0.00	
Bus	Facilities	6.34	\$0.53	8.36
	Subtotal	6.30	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	5.29	\$0.09	1.79
	Runways	150.74	\$0.00	0.00
	Subtotal	156.00	0.10	
	Total	2247.50	2.50	

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	0.00	\$0.00	0.00
	Distribution Line	65.10	\$0.12	0.19
	Subtotal	65.08	\$0.12	
Waste Water	Pipelines	0.00	\$0.00	0.00
	Facilities	0.00	\$0.00	0.00
	Distribution Line	39.10	\$0.10	0.24
	Subtotal	39.05	\$0.10	
Natural Gas	Pipelines	0.00	\$0.00	0.00
	Facilities	1.10	\$0.00	0.24
	Distribution Line	26.00	\$0.10	0.39
	Subtotal	27.09	\$0.10	
Oil Systems	Pipelines	0.00	\$0.00	0.00
	Facilities	0.70	\$0.03	5.10
	Subtotal	0.68	\$0.03	
Electrical Power	Facilities	426.80	\$20.59	4.82
	Subtotal	426.80	\$20.59	
Communication	Facilities	0.20	\$0.00	0.57
	Subtotal	0.19	\$0.00	
	Total	558.90	\$20.95	

Table 15. Indirect Economic Impact with outside aid

(Employment as # of people and Income in millions of \$)

	LOSS	Total	%
First Year			
	Employment Impact	1,272	0.40
	Income Impact	(4)	-0.03
Second Year			
	Employment Impact	542	0.17
	Income Impact	(17)	-0.15
Third Year			
	Employment Impact	12	0.00
	Income Impact	(24)	-0.21
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(24)	-0.22
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(24)	-0.22
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(24)	-0.22

Appendix A: County Listing for the Region

Denver, CO

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Colorado	Denver	554,636	28,051	8,182	36,233
Total State		554,636	28,051	8,182	36,233
Total Region		554,636	28,051	8,182	36,233