CHAPTER 5. EARTHQUAKES

An earthquake is generally defined as a sudden motion or trembling in the Earth caused by the abrupt release of slowly accumulated strain. The most common types of earthquakes are caused by movements along faults and by volcanic forces, although they can also result from explosions, cavern collapse, and other minor causes not related to slowly accumulated strains.

Historically, earthquakes have occurred in every County in Wyoming (Figure 5.1). The first was reported in Yellowstone National Park in 1871. Yellowstone National Park is a one of the more seismically active areas of the United States.

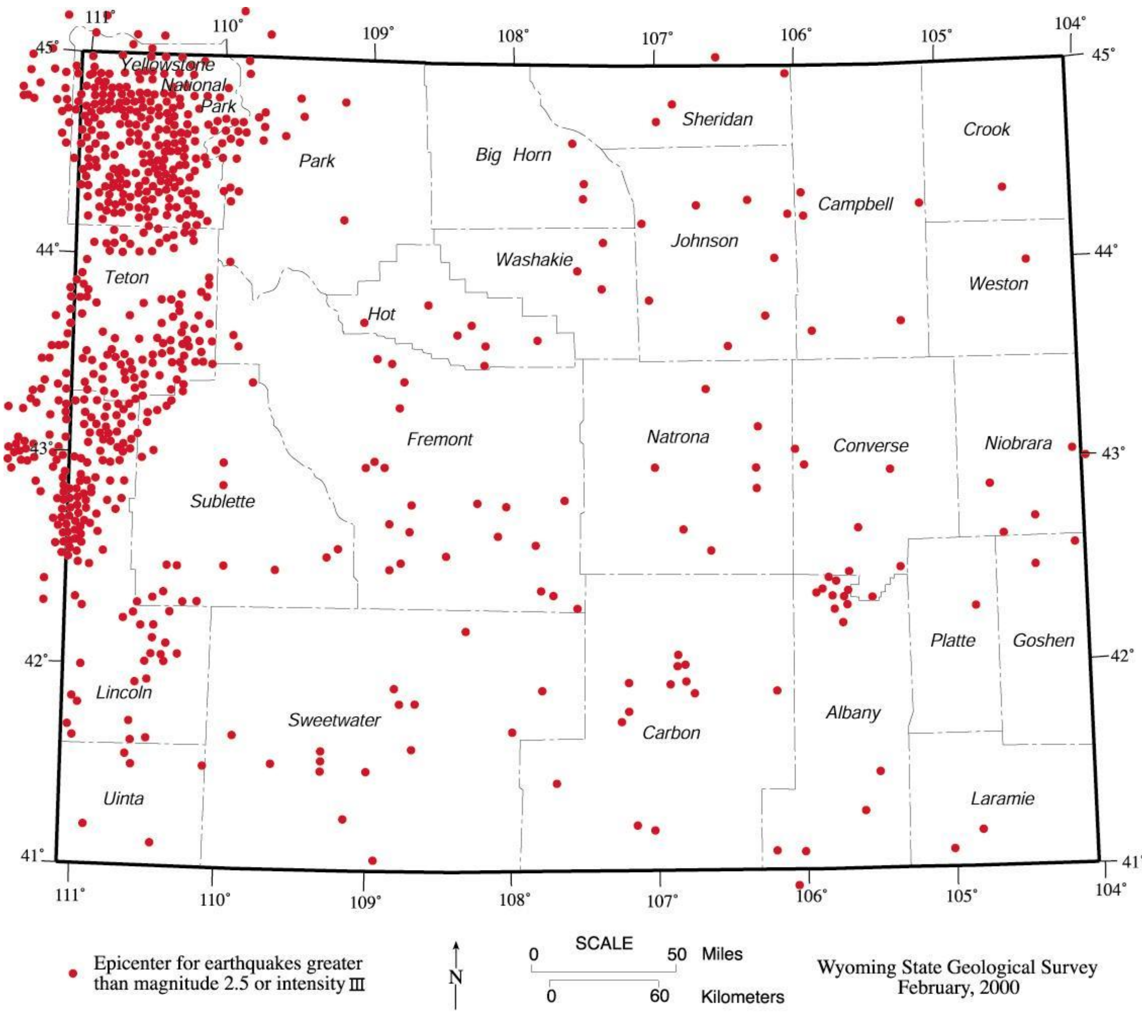

Figure 5.1 Historic Earthquakes in Wyoming

One item to note from Figure 5.1 is even if the epicenter of an earthquake is not located within Converse County, the effects of the earthquake may still be felt in the

County. For example, the area in north Albany County with a high-density cluster of past earthquakes could impact the south area of Converse County.

History

According to the Wyoming State Geological Survey, there are no known active or suspected active faults in Converse County. However, there have been multiple earthquakes with magnitudes greater than 3.0 recorded in or near Converse County. The most recent event was a 3.8 earthquake on August 29, 2004 with the epicenter approximately 11 miles northwest of Douglas. There was no reported damage, but the earthquake was felt throughout the city and even on nearby highways.

The Wyoming State Geological Survey compiled a document titled "Basic Seismological Characterization for Converse County, Wyoming" in September of 2002. This report includes a history of magnitude 3.0 or greater earthquakes recorded in Converse County. Results from that report are summarized in Table 5.1, below:

Table 5.1 Converse County Earthquake History

Date	**Location**	**Magnitude/ Intensity**	**Comments**
April 14, 1947	Near LaPrele Creek southwest of Douglas	Intensity V	The earthquake was felt by everyone in a ranch house and by a few outdoors. Windows were rattled, chairs were moved, and buildings shook
August 21, 1952	Approximately 7 miles north-northeast of Esterbrook	Intensity IV	Felt by several people in the area, and was reportedly felt 40 miles to the southwest of Esterbrook
September 2, 1952	Same location, approximately 7 miles north-northeast of Esterbrook	No associated magnitude or intensity	Small magnitude event, no damage reported
January 5, 1957	Same location, approximately 7 miles north-northeast of Esterbrook	Intensity III	No damage reported
March 31, 1964	Same location, approximately 7 miles north-northeast of Esterbrook	Intensity IV	No damage reported

Date	Location	Magnitude/ Intensity	Comments
November 15, 1983	Approximately 15 miles northeast of Casper in western Converse County	Magnitude 3.0, Intensity III	No damage reported
December 5, 1984	In the Laramie Range in southern Converse County	Magnitude 2.9	No damage reported
June 30, 1993	Approximately 15 miles north of Douglas	Magnitude 3.0	No damage reported
July 23, 1993	Southern Converse County, approximately 13 miles north-northwest of Toltec in northern Albany County	Magnitude 3.7, Intensity IV	The event was felt as far away as Laramie
December 13, 1993	Approximately 8 miles east of Toltec	Magnitude 3.5	No damage reported
October 19, 1996	Approximately 15 miles northeast of Casper in western Converse County	Magnitude 4.2	No damage reported, although the event was felt by many Casper residents

Other earthquake history obtained from Converse County reports an earthquake event of magnitude 5.5, intensity VI event that occurred on October 18, 1984, roughly four miles west of Toltec in northern Albany County. The epicenter was approximately 21 miles south of Esterbrook. The earthquake was felt in Wyoming, South Dakota, Nebraska, Colorado, Utah, Montana, and Kansas. It cracked buildings and shook items from shelves in grocery stores in Douglas. An exterior wall of the Douglas Town Hall was found to have shifted a half inch. This earthquake was one of the largest felt in eastern Wyoming.

Many of the earthquakes noted above have originated in the Laramie mountain range in southern Converse County and northern Albany County.

The discussion in the following sections is largely from a September 2002 WSGS publication by Case et al.

Deterministic Analysis of Regional Active Faults with a Surficial Expression

There are no known exposed active faults with a surficial expression in Converse County. As a result, no fault-specific analysis can be generated for Converse County (Case et al, 2002).

Figure 5.2 below shows known active or suspected active faults in Wyoming (WSGS, 1995)

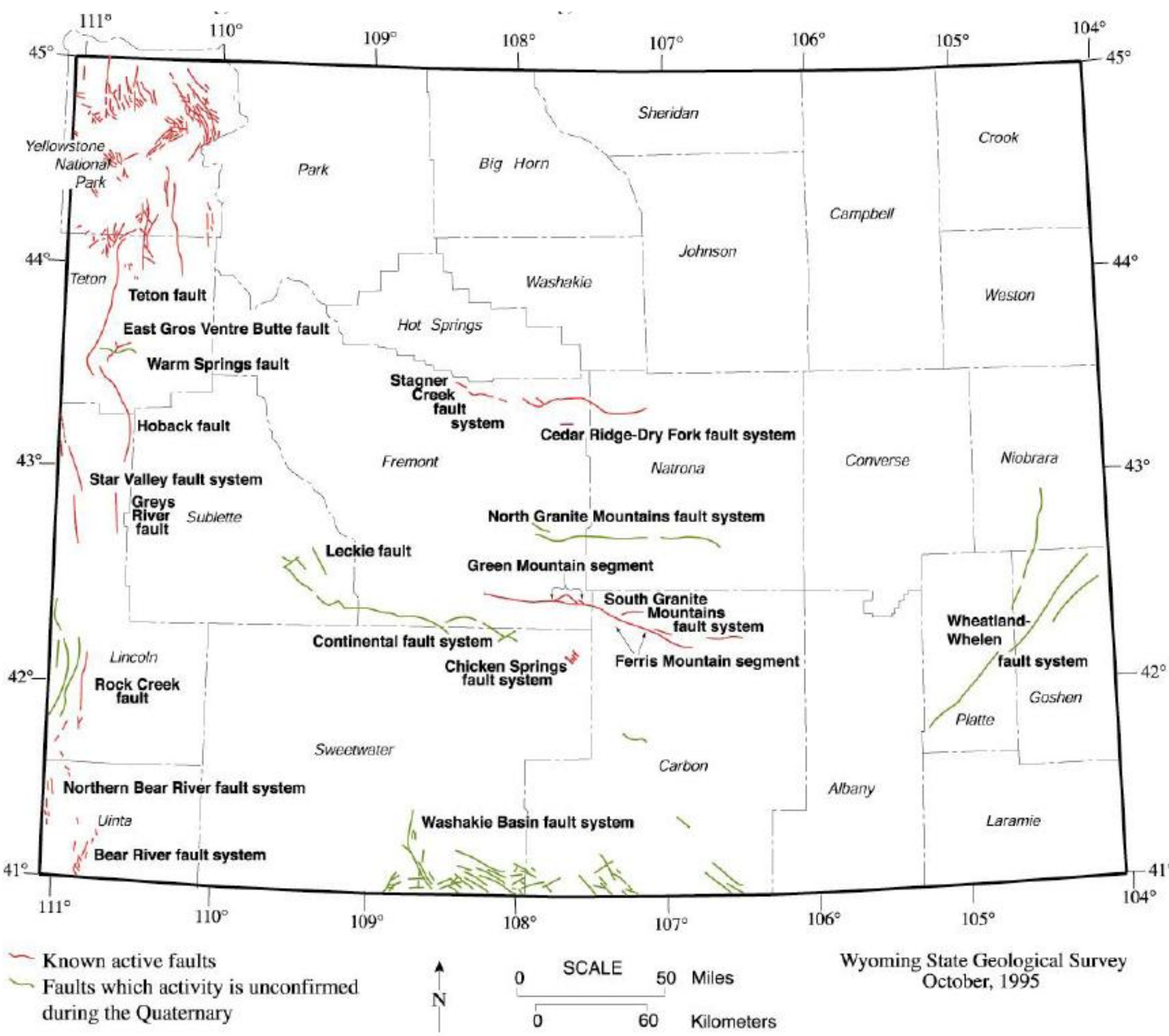

Figure 5.2 Known or Suspected Active Faults in Wyoming

Floating or Random Earthquake Sources

Many federal regulations require an analysis of the earthquake potential in areas where active faults are not exposed, and where earthquakes are tied to buried faults with no surface expression. Regions with a uniform potential for the occurrence of such earthquakes are called tectonic provinces. Within a tectonic province, earthquakes associated with buried faults are assumed to occur randomly, and as a result can theoretically occur anywhere within that area of uniform earthquake potential. In reality, that random distribution may not be the case, as all earthquakes are associated with specific faults. If all buried faults have not been identified, however, the distribution has to be considered random. “Floating earthquakes” are earthquakes that are considered to occur randomly in a tectonic province (Case et al, 2002).

It is difficult to accurately define tectonic provinces when there is a limited historic earthquake record. When there are no nearby seismic stations that can detect small-magnitude earthquakes, which occur more frequently than larger events, the problem is compounded. Under these conditions, it is common to delineate larger, rather than smaller, tectonic provinces.

The U.S. Geological Survey (USGS) identified tectonic provinces in a report titled “Probabilistic Estimates of Maximum Acceleration and Velocity in Rock in the Contiguous United States” (Algermissen et al, 1982). In that report, Converse County was classified as being in a tectonic province with a “floating earthquake” maximum magnitude of 6.1. Geomatrix (1988) suggested using a more extensive regional tectonic province, called the “Wyoming Foreland Structural Province”, which is approximately defined by the Idaho-Wyoming Thrust Belt on the west, 104° West longitude on the east, 40° North latitude on the south, and 45° North latitude on the north. Geomatrix (1988) estimated that the largest “floating” earthquake in the “Wyoming Foreland Structural Province” would have a magnitude in the 6.0 – 6.5 range, with an average value of magnitude 6.25 (Case et al, 2002).

Federal or State regulations usually specify if a “floating earthquake” or tectonic province analysis is required for a facility. Usually, those regulations also specify at what distance a floating earthquake is to be placed from a facility. For example, for uranium mill tailings sites, the Nuclear Regulatory Commission requires that a floating earthquake be placed 15 kilometers from the site. That earthquake is then used to determine what horizontal accelerations may occur at the site.

A magnitude 6.25 “floating” earthquake, placed 15 kilometers from any structure in Converse County, would generate horizontal accelerations of approximately 15%g at the site. That acceleration would be adequate for designing a uranium mill tailings site, but may be too large for less critical sites, such as a landfill. Critical facilities, such as dams, usually require a more detailed probabilistic analysis of random earthquakes. Based upon probabilistic analyses of random earthquakes in an area distant from exposed active faults (Geomatrix, 1988), however, placing a magnitude 6.25 earthquake at 15 kilometers from a site will provide a fairly conservative estimate of design ground accelerations (WSGS Case et al, 2002).

Probabilistic Seismic Hazard Analyses

The USGS publishes probabilistic acceleration maps for 500-, 1000-, and 2,500-year time frames. The maps show what accelerations may be met or exceeded in those time frames by expressing the probability that the accelerations will be met or exceeded in a shorter time frame. For example, a 10% probability that acceleration may be met or exceeded in 50 years is roughly equivalent to a 100% probability of exceedance in 500 years.

The USGS has a 2009 Probabilistic Seismic Hazard Assessment (PSHA) model that can generate earthquake probability maps for locations within the U.S. Figure 5.3 on the next page shows the probability of an earthquake with magnitude (M) greater than 5.0 within 50 years and 50 kilometers. The map is centered on Douglas, which is shown as having between a 3% and 4% probability of such an event. Further east within Converse County the probability drops to around 2%. The highest probability (4%) is found near the southern part of the County, around Esterbrook and Boxelder.

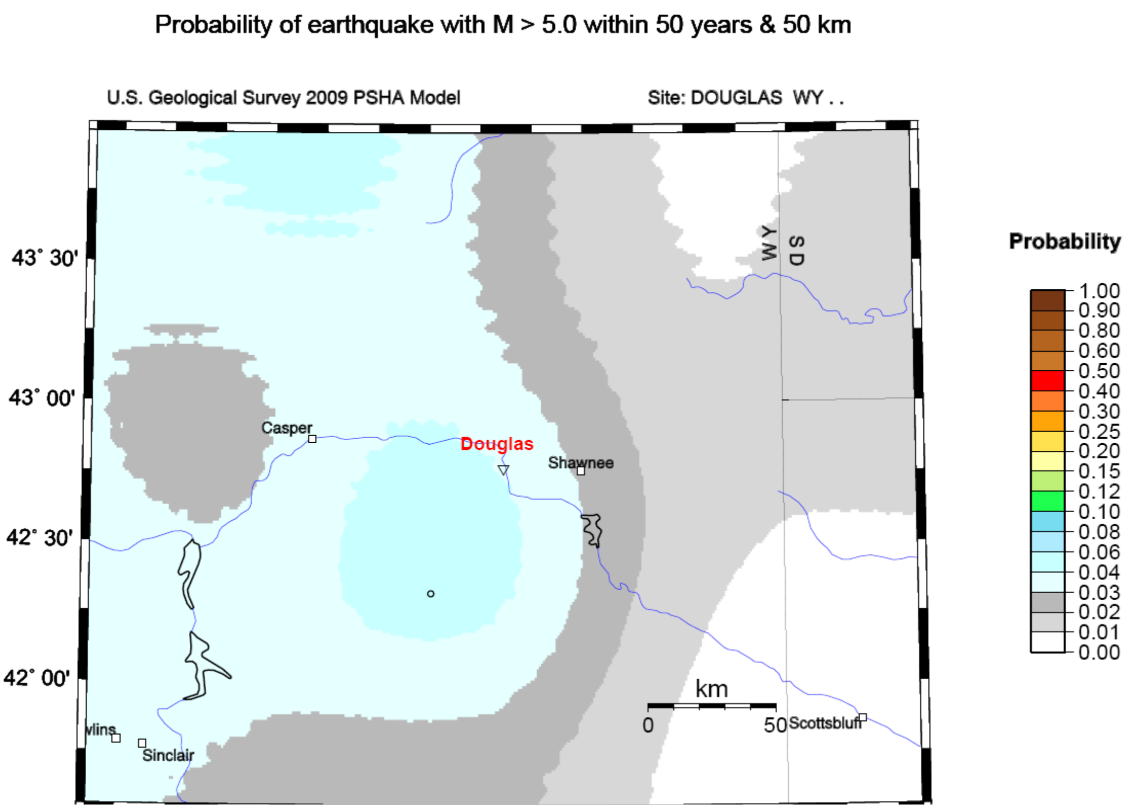

Figure 5.3 Probability of Earthquakes > M 5.0 in Converse County

The USGS has recently generated new probabilistic acceleration maps for 500-, 1,000-, and 2,500-year time frames for Wyoming. The 500-year (10% probability of exceedance in 50 years) map is shown as Figure 5.4, the 1,000-year (5% probability of exceedance in 50 years) is shown as Figure 5.5, and the 2,500-year (2% probability of exceedance in 50 years) map is shown as Figure 5.6.

Until recently, the 500-year map was often used for planning purposes for average structures, and was the basis of the most current Uniform Building Code. The new International Building Code, however, uses a 2,500-year map as the basis for building design. The maps reflect current perceptions on seismicity in Wyoming. In many areas of Wyoming, ground accelerations shown on the USGS maps can be increased due to local soil conditions. For example, if fairly soft, saturated sediments are present at the surface, and seismic waves are passed through them, surface ground accelerations will usually be greater than would be experienced if only bedrock was present. In this case, the ground accelerations shown on the USGS maps would underestimate the local hazard, as they are based upon accelerations that would be expected if firm soil or rock were present at the surface. Explanations of intensity values can be found in Table 5.2.

Based upon the 500-year map (10% probability of exceedance in 50 years) (Figure 5.4), the estimated peak horizontal acceleration in Converse County ranges from 4%g in the northeastern portion of the County to greater than 7%g in the southwestern portion of the County. These accelerations are roughly comparable to intensity V earthquakes (3.9%g – 9.2%g). These accelerations are comparable to the low end of accelerations to be expected in Seismic Zone 1 of the Uniform Building Code. Intensity V earthquakes can result in cracked plaster and broken dishes. Douglas would be subjected to an acceleration of approximately 6%g or intensity V.

Based upon the 1,000-year map (5% probability of exceedance in 50 years) (Figure 5.5), the estimated peak horizontal acceleration in Converse County ranges from 7%g in the northeastern part of the County to greater than 10%g in the southwestern portion of the County. These accelerations are roughly comparable to intensity V earthquakes to intensity VI earthquakes (9.2%g – 18.0%g). Intensity VI earthquakes can result in fallen plaster and damaged chimneys. Douglas would be subjected to an acceleration of approximately 10 – 11%g or intensity VI.

Based upon the 2,500-year map (2% probability of exceedance in 50 years) (Figure 5.6), the estimated peak horizontal acceleration in Converse County ranges from 11%g in the northeastern half of the County to over 20%g in the southwestern quarter of the County. Those accelerations are roughly comparable to intensity VI earthquakes to intensity VII earthquakes (18.0% - 34.0%g). Intensity VII earthquakes can result in slight to moderate damage in well-built ordinary structures and considerable damage in poorly built or badly designed structures. Douglas would be subjected to an acceleration of approximately 20%g or intensity VII.

As the historic record is limited, it is nearly impossible to determine when a 2,500-year event last occurred in the County. Because of the uncertainty involved, and based upon the fact that the new International Building Code utilizes 2,500-year events for building design, it is suggested that the 2,500-year probabilistic maps be used for Converse County analyses. This conservative approach is in the interest of public safety.

Table 5.2 Modified Mercalli Intensity and Peak Ground Acceleration

Modified Mercalli Intensity	Acceleration (%g) (PGA)	Perceived Shaking	Potential Damage
I	<0.17	Not felt	None
II	0.17 – 1.4	Weak	None
III	0.17 – 1.4	Weak	None
IV	1.4 – 3.9	Light	None
V	3.9 – 9.2	Moderate	Very Light
VI	9.2 – 18	Strong	Light
VII	18 – 34	Very Strong	Moderate
VIII	34 – 65	Severe	Moderate to Heavy
IX	65 – 124	Violent	Heavy
X	>124	Extreme	Very Heavy
XI	>124	Extreme	Very Heavy
XII	>124	Extreme	Very Heavy

Source: Wald et al, 1999

Abridged Modified Mercalli Intensity Scale

Intensity value and description:

I Not felt except by a very few under especially favorable circumstances.

II Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing automobiles may rock slightly. Vibrations like a truck passing close by. Duration estimated.

IV During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensations like a heavy truck striking the building. Standing automobiles rocked noticeably.

V Felt by nearly everyone, many awakened. Some dishes, windows, and so on broken; cracked plaster in a few places; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

VI Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster and damaged chimneys. Damage slight.

VII Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures. Some chimneys may be broken. Noticed by persons driving cars.

VIII Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving cars disturbed.

IX Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed, slopped over banks.

XI Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown into the air.

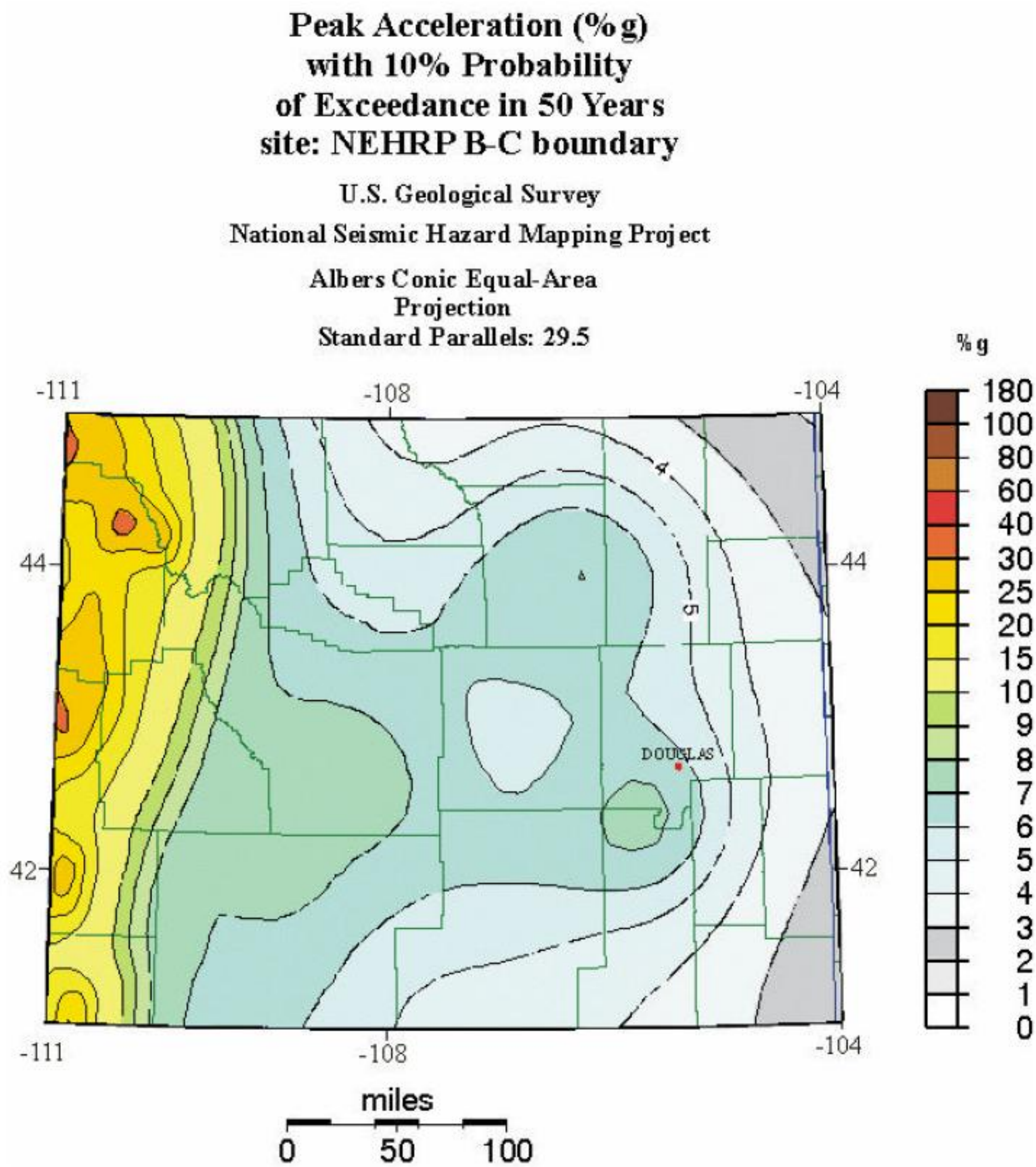

Figure 5.4 500-year probabilistic ground motion map (10% probability of exceedance in 50 years).

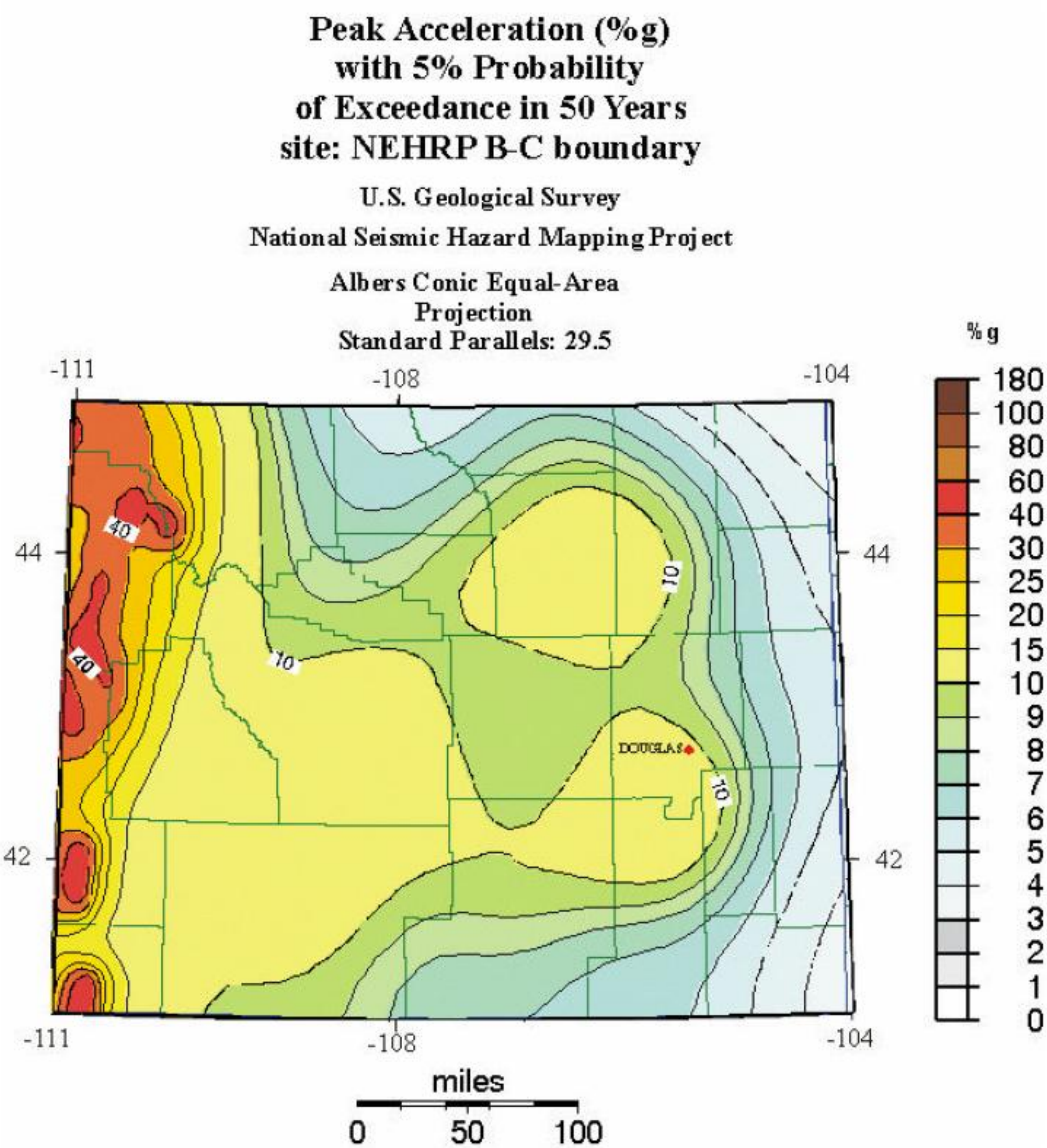

Figure 5.5 1,000-year probabilistic ground motion map (5% probability of exceedance in 50 years).

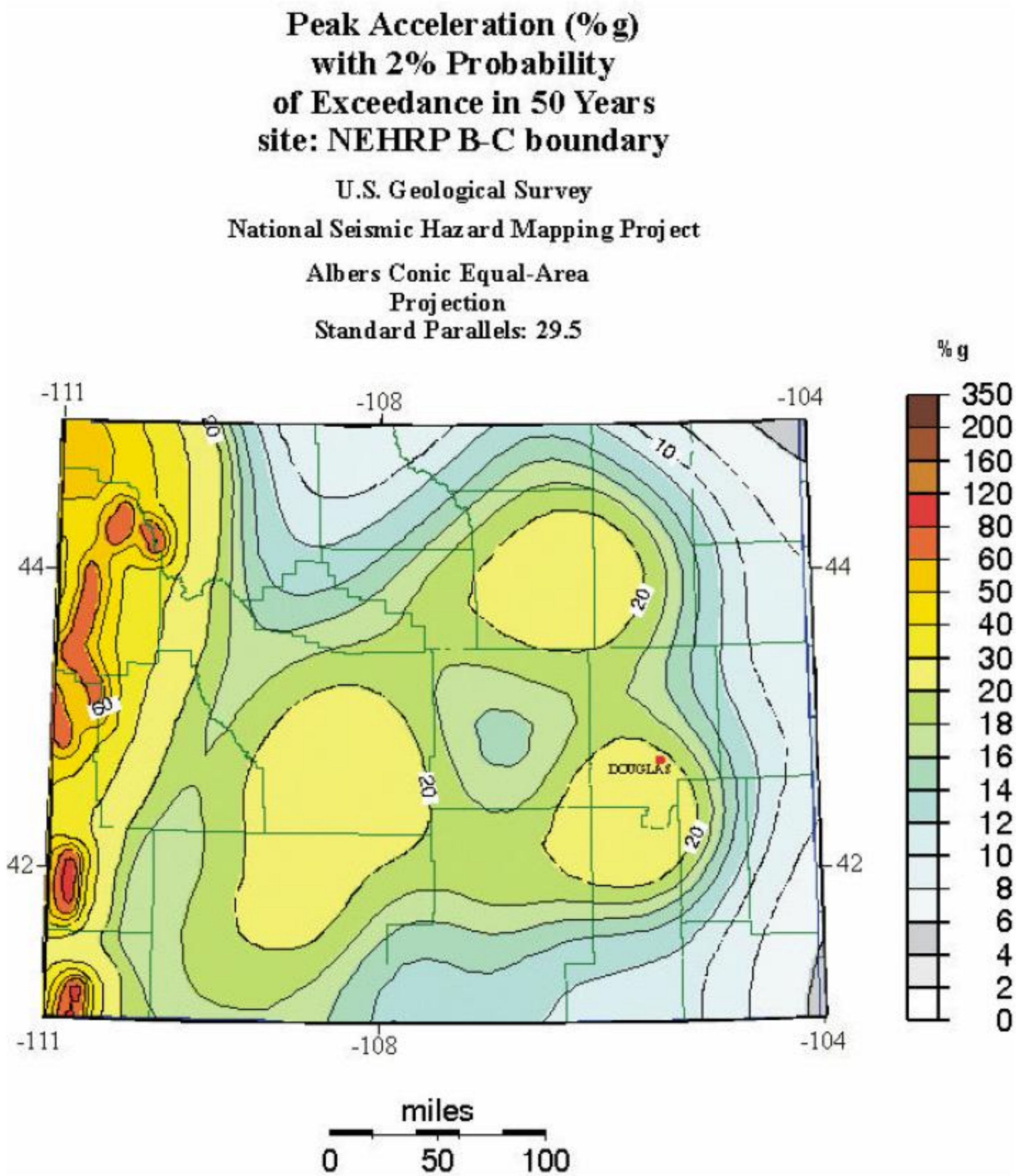

Figure 5.6 2,500-year ground motion map (2% probability of exceedance in 50 years).

Impacts

There have been 29 historic earthquakes with magnitudes greater than 3.0 recorded in or near Converse County. Because of the limited historic record, it is possible to underestimate the seismic hazard in Converse County if historic earthquakes are used as the sole basis for analysis. Earthquake and ground motion probability maps give a more reasonable estimate of damage potential in areas without exposed active faults at the surface, such as Converse County.

Current earthquake probability maps that are used in the newest building codes suggest a scenario that would result in moderate damage to buildings and their contents, with damage increasing from the northeast to the southwest. More specifically, the probability-based worst-case scenario could result in the following damage at points throughout the County:

Intensity VII Earthquake Areas

Boxelder

Douglas

Glenrock

Orin

Orpha

Rolling Hills

In intensity VII earthquakes, damage is negligible in buildings of good design and construction, slight-to-moderate in well-built ordinary structures, considerable in poorly built or badly designed structures such as unreinforced masonry buildings. Some chimneys will be broken.

Intensity VI Earthquake Areas

Bill

Lost Springs

Shawnee

In intensity VI earthquakes, some heavy furniture can be moved. There may be some instances of fallen plaster and damaged chimneys.

Potential Future Impacts

HAZUS (Hazards U.S.) is a nationally standardized, GIS-based, risk assessment and loss estimation computer program that was originally designed in 1997 to provide the user with an estimate of the type, extent, and cost of damages and losses that may occur during and following an earthquake. It was developed for FEMA by the National Institute of Building Sciences (NIBS). There have been a number of versions of HAZUS generated by FEMA, with HAZUS-MH (HAZUS – Multi-Hazard) being the most recent release. HAZUS-MH incorporates a flood and wind module with the previously existing earthquake module. Hazus-99 (1999 version) was previously used by the Wyoming State Geological Survey (WSGS).

HAZUS was originally designed to generate damage assessments and associated ground motions based largely upon analysis at the census-tract level. Census tracts average 4,000 inhabitants, with the tract boundaries usually representing visible features. HAZUS-99 calculated a ground motion value for the centroid of a census tract, and applied that value to the entire tract. The calculations are based on United States Geological Survey National Seismic Hazard Maps. In many of the western states, census tracts are very large, and parts of the tracts may be subjected to ground shaking that is considerably different than the value at the centroid.

In the early 2000's FEMA Region VIII and their subcontractor on HAZUS worked with the WSGS to develop a census-block-based analysis for HAZUS-MH in Wyoming. Wyoming was the national pilot project for the census-block-based analysis. The block-level analysis is a significant improvement. Census blocks are a subdivision of census tracts. Many blocks correspond to individual city blocks bounded by streets, but blocks – especially in rural areas – may include many square miles and may have some boundaries that are not streets. Ground motion values for Wyoming are now calculated at the centroid of census blocks.

During the development of this plan in 2011 A HAZUS-MH MR 4 probabilistic scenario was run for Converse County. The scenario used a 2,500 year return period, and uses the 2,500-year ground shaking data represented in Figure 5.6. The probability of such an event is 2% in 50 years. A driving magnitude of 6.5 was used with the scenario. The results are presented in Table 5.3, below.

Table 5.3 Earthquake Impacts to Converse County – HAZUS 2,500-year

Type of Impact	Impacts to County
Total Buildings Damaged	Slight: 1,490 Moderate: 855 Extensive: 204 Complete: 17
Building and Income Related Losses	$58.27 million 78.6% of damage related to capital stock losses

Type of Impact	Impacts to County
	21.4% of loss due to income losses
Total Economic Losses (including building, income, and lifeline losses)	$69.08 million
Injuries (based on 2 a.m. time of occurrence)	Without requiring hospitalization: 8 Requiring hospitalization: 1 Life threatening: 0 Fatalities: 0
Injuries (based on 2 p.m. time of occurrence)	Without requiring hospitalization: 10 Requiring hospitalization: 2 Life threatening: 0 Fatalities: 0
Injuries (based on 5 p.m. time of occurrence)	Without requiring hospitalization: 8 Requiring hospitalization: 1 Life threatening: 0 Fatalities: 0
Damage to Transportation and Utility Systems and Essential Facilities	Minor damage (with functionality >50% on day 1) only to transportation systems Some damage to utility pipeline systems (isolated leaks and breaks) Minor damage to 1 hospital, 14 schools, 4 police stations, and 3 fire stations
Displaced Households	16
Shelter Requirements	11

Source: HAZUS-MH MR4 2,500-year Global Summary Report, 2011

There are two methods to rank the counties to determine where earthquake impacts may be the greatest. Either total damage (Table 5.3) or loss ratios can be used for damage estimates. The loss ratio is determined by dividing the sum of the structural and non-structural damage by the total building value for the County. The loss ratio is another measure of impact for a County as it gives an indication of the percent of damage to buildings. The total damage figure by itself does not reflect the percentage of building damage. If a County has a number of valuable buildings, such as Laramie County, small damage to a number of valuable buildings may result in a higher total damage figure that may be found in a County with fewer, less expensive buildings and higher percentage of damage.

HAZUS estimates that about 1,075 buildings (a loss ratio of over 15% of the total number of buildings in the region) will be at least moderately damaged. Of these, 17 buildings are expected to be damaged beyond repair. Total building-related losses were $45.79 million, and 27% of the estimated losses were related to regional business interruption. By far the largest loss was sustained by residential occupancies, which make up over 52% of the total loss. Table 5.4 indicates the anticipated to transportation and utility system losses. Electrical power facilities will have the greatest economic losses. HAZUS estimates the replacement value of the transportation and utility lifeline systems to be $3.7 billion and $115 million, respectively.

Table 5.4 Transportation and Utility System Economic Losses –HAZUS 2,500-yr.

System	Component	Inventory Value	Economic Loss ($M)	Loss Ratio (%)
Highway	Segments	3,270.91	0	0
	Bridges	98.08	0.28	0.29
	Tunnels	0	0	0
	Subtotal	3,369.00	0.30	
Railways	Segments	281.43	0	0
	Bridges	1.03	0	0.02
	Tunnels	0	0	0
	Facilities	0	0	0
	Subtotal	282.50	0	
Bus	Facilities (subtotal)	1.0	0.2	19.68
Airport	Facilities	10.65	2.12	19.93
	Runways	75.93	0	0
	Subtotal	86.60	2.10	
Transportation	**TOTAL**	**3,739.00**	**2.60**	
Potable Water	Pipelines	0	0	0
	Facilities	0	0	0
	Distribution lines	269.70	2.51	0.93
	Subtotal	269.75	2.51	
Wastewater	Pipelines	0	0	0
	Facilities	0	0	0
	Distribution lines	161.80	1.98	1.23
	Subtotal	161.85	1.98	
Natural Gas	Pipelines	0	0	0
	Facilities	15.70	1.40	8.94
	Distribution lines	107.90	2.12	1.97

System	Component	Inventory Value	Economic Loss ($M)	Loss Ratio (%)
	Subtotal	123.59	3.52	
Electrical Power	Facilities (subtotal)	99.00	12.62	12.75
Communication	Facilities (subtotal)	0.40	0.04	11.13
Utilities	**TOTAL**	**654.55**	**20.68**	

Source: HAZUS-MH: Earthquake Event Report, 2011

There are a number of events associated with earthquakes that increase the potential for damage, such as landslides, dam failure, mine subsidence, wildfires, and debris generation. Converse County has a number of facilities that may be at risk from seismic activity. These include a power plant, transportation routes (interstate, highways, and railroads), dams, schools, a hospital, oil and gas related facilities, and other mineral-related operations.

Summary

PROPERTY AFFECTED: Medium
POPULATION AFFECTED: Medium
PROBABILITY: Low to Medium
JURISDICTION AFFECTED: Douglas, County

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