

Chapter 11: Earthquakes

POTENTIAL, AND IMPACTS

Information for this section has been provided by Wyoming State Geological Survey (WSGS).

Fremont County has experienced damaging earthquakes in the past and will have damaging earthquakes in the future. Presented below is an analysis of historic earthquakes, future earthquake potential, and estimated earthquake damage for the county.

Seismological characterizations of an area can range from an analysis of historic seismicity to a long-term probabilistic seismic hazard assessment. A complete characterization usually includes a summary of historic seismicity, an analysis of the Seismic Zone Map of the Uniform Building Code, deterministic analyses on active faults, “floating earthquake” analyses, and short- or long-term probabilistic seismic hazard analyses.

Presented below, for Fremont County, Wyoming, is an analysis of historic seismicity, an analysis of the Uniform Building Code, deterministic analyses of nearby active faults, an analysis of the maximum credible “floating earthquake”, and current short- and long-term probabilistic seismic hazard analyses.

Historic Seismicity in Fremont County

Over thirty magnitude 2.0 or intensity III and greater earthquakes have been recorded in Fremont County. These earthquakes are discussed below.

The first earthquake that was reported in Fremont County occurred on December 10, 1873. This earthquake, which was located in the southern part of the county near Atlantic City, was felt as an intensity III event at nearby Camp Stambaugh. On January 22, 1889, an intensity III-IV earthquake was reported near Lander. An intensity IV earthquake also occurred in the Lander area on November 21, 1895. People reported that houses were jarred and dishes rattled.

On August 11, 1916, an earthquake occurred in the Sand Draw/Gas Hills area. No damage was reported from this intensity III event, which was centered approximately 6 miles south of Jeffrey City.

Two earthquakes were reported in Fremont County in the 1920s. The first occurred on December 12, 1923, when an intensity V earthquake was detected approximately three miles west-northwest of Atlantic City. No significant damage was reported. This area experienced another non-damaging, intensity III earthquake on October 30, 1925.

Only one earthquake was reported in the county in the 1930s. On November 23, 1934, an intensity V earthquake was reported approximately 20 miles northwest of Lander. Residents in a 10-mile radius around Lander reported that dishes were thrown from cupboards and pictures fell from walls. Buildings in two business blocks were cracked, and the brick chimney of the Fremont County Courthouse was moved two inches away from the building. The earthquake was felt as far away as Rock Springs and Green River.

No earthquakes were reported in Fremont County in the 1940s, but several were reported in the county in the 1950s. On August 17, 1950, an intensity IV earthquake occurred approximately 2.5 miles south-southeast of Lander. It caused loose objects to rattle and buildings to creak. Intensity II and intensity IV earthquakes occurred in the same area on January 11, 1954 and December 13, 1955, respectively. No damage was reported from either event. On August 22, 1959, an intensity IV earthquake was detected approximately 3.5 miles west-northwest of Atlantic City. No damage was associated with this earthquake. A few days later, an earthquake was recorded on August 25, 1959. This event, which was located just southeast of Fort Washakie, was later determined to be non-tectonic in origin.

On October 12, 1961, a small-magnitude earthquake was detected approximately seven miles northwest of Pavillion. Two earthquakes were recorded in northern Fremont County on April 26, 1967. A magnitude 4.7 event and a magnitude 4.2 event occurred approximately 32 miles southwest and approximately 38 miles west-southwest of Thermopolis, respectively. No damage was associated with any of the earthquakes that occurred in the county in the 1960s.

Several earthquakes were reported in Fremont County in the 1970s. The first occurred on April 22, 1973, approximately 12 miles north of Jeffrey City. This magnitude 4.8, intensity V earthquake rattled dishes and disturbed pictures on walls in Jeffrey City. A small earthquake occurred on June 14, 1973, approximately eight miles east-northeast of Lander. This event was later determined to be the result of an explosion in the area. On March 25, 1975, a magnitude 4.8, intensity II earthquake was detected approximately 18 miles northwest of Jeffrey City. A mobile home located 35 miles southeast of Riverton was moved an inch off its foundation by this earthquake. A magnitude 3.5 earthquake occurred on December 19, 1975, approximately 25 miles northeast of Jeffrey City. This earthquake did not cause any damage. Later that same month, on December 30, 1975, an earthquake of no specific magnitude or intensity was recorded in eastern Fremont County, approximately 27 miles east-southeast of Riverton. No one reported feeling this event.

Four earthquakes were reported in the county in the 1980s. On January 28, 1980, a magnitude 2.8 earthquake was recorded in the northwestern part of the county, approximately 28 miles northwest of Dubois. This earthquake was not felt. A magnitude 3.1 earthquake occurred on September 4, 1980, approximately 15 miles west-southwest of Atlantic City. No damage was reported. A magnitude 3.2, intensity IV earthquake occurred in Fremont County on August 31, 1982. No significant damage was reported from this earthquake, which was centered approximately 10 miles southwest of Lander. On November 3, 1984, a magnitude 5.1, intensity VI earthquake was detected approximately 10 miles northwest of Atlantic City. The earthquake was felt in Lander, Dubois, Atlantic City, and Casper. Residents in Lander and Atlantic City reported cracked walls, foundations, and windows. This event was one of the largest

earthquakes to occur in the southwestern quarter of the state. The last earthquake to occur in Fremont County in the 1980s took place on August 16, 1985. This magnitude 4.3, intensity IV event occurred approximately 25 miles southeast of Jeffrey City. No damage was associated with this earthquake.

On August 7, 1991, a magnitude 3.5 earthquake was recorded in northern Fremont County, approximately 35 miles southwest of Thermopolis. Residents of Thermopolis reported feeling this non-damaging earthquake. Another non-damaging earthquake occurred on January 31, 1992, approximately 20 miles northwest of Lander. Area residents reported feeling this magnitude 2.8 event. On October 10, 1992, a magnitude 4.0, intensity III earthquake was detected approximately 22 miles east of Lander. Again, people in the area felt this earthquake, but no damage was reported from it. A magnitude 3.8, intensity III earthquake occurred near Bairoil on June 1, 1993, approximately 17 miles southeast of Jeffrey City. No damage was reported. On August 22, 1993, a magnitude 3.1 earthquake was recorded in northwestern Fremont County, approximately 14 miles west-northwest of Dubois. No one reported feeling this earthquake. A magnitude 3.4 earthquake occurred approximately 11 miles southeast of Jeffrey City on December 11, 1996. Again, no damage was associated with this earthquake. This earthquake was followed by another non-damaging, magnitude 3.1 event on April 25, 1997. No one felt this earthquake that was centered approximately 10 miles south of Lander. Lander city officials reported, however, that the earthquake may have caused a crack in the city's water tank, releasing 600,000 gallons of water. On July 21, 1999, another magnitude 3.1 earthquake occurred approximately 23 miles southeast of Lander. No one reported feeling this event.

On August 19, 2000, an earthquake was reported approximately 25 miles west-northwest of Jeffrey City. Area residents reported feeling this magnitude 3.2 earthquake. Most recently, a magnitude 3.0 earthquake occurred on November 8, 2000, in northeastern Fremont County. This event was centered approximately 29.5 miles southeast of Thermopolis. No one reported feeling this earthquake.

Regional Historic Seismicity

Several earthquakes have also been reported near Fremont County. On February 13, 1928, an earthquake occurred in Hot Springs County, approximately 18 miles north-northwest of Shoshoni. The intensity IV earthquake was felt as three shocks in Thermopolis, and was "felt sharply" in Worland, Owl Creek, Gebo, Crosby, and Kirby. It was also strongly felt at a mine in the Copper Mountain mining district near Bonneville. Reports indicate that two men entered their mine when aftershocks were occurring and found that many of the mine props were so loose that they could be moved by hand. On June 19, 1928, another intensity IV earthquake was reported in the area, with the epicenter located approximately 34 miles north-northwest of Shoshoni. A single shock from this event was felt in Thermopolis, with sounds slightly preceding the earthquake.

No earthquakes were reported in the region until the 1940s. On October 11, 1944, an intensity IV earthquake was reported in Hot Springs County, approximately 3 miles south of Thermopolis. Several landslides occurred as a result of the earthquake, and rocks fell onto the highway in Wind River Canyon. At Hot Springs State Park, there was a "...caving of earth on the south rim

of the large hot spring in the park". Another intensity IV earthquake occurred in the same area on January 26, 1946. This event, which was felt for approximately ten seconds, rattled windows and dishes and clouded the water in Hot Springs State Park for a few days.

On January 23, 1950, an intensity V earthquake was felt near Hamilton Dome, approximately 39 miles north-northeast of Pavillion. Houses shook and dishes rattled in the Hamilton Dome area, and the earthquake was felt in Thermopolis. Another intensity V earthquake occurred approximately three miles south of Thermopolis on January 31, 1954. No damage was reported from this event.

Several earthquakes were reported near Fremont County in the 1960s. A magnitude 4.3, intensity V earthquake occurred in southeastern Sublette County on February 25, 1963, approximately 25 miles west-northwest of Atlantic City. The earthquake was felt for over a minute in Atlantic City, and for approximately six seconds in the Lander and Hudson areas. Windows, doors, and dishes were rattled in Fort Washakie as a result of the earthquake. On June 25, 1963, a magnitude 4.2 earthquake occurred in southwestern Park County, approximately 37 miles northwest of Dubois. No one reported feeling this earthquake. On October 14, 1963, a magnitude 4.5 earthquake was recorded in northeastern Sweetwater County, approximately 30 miles southeast of Atlantic City. No damage was reported. An earthquake of no specific magnitude or intensity was recorded in northern Sublette County on December 18, 1967. No one reported feeling this earthquake, which was centered approximately 11.5 miles southwest of Dubois. On November 15, 1968, a magnitude 3.9 earthquake was recorded in eastern Teton County, approximately 30 miles northwest of Dubois. No one reported feeling the earthquake.

On December 8, 1972, a magnitude 4.1, intensity V earthquake was detected in Hot Springs County, approximately 28 miles northwest of Shoshoni. It caused two cracks in the ceiling of a new addition to a Thermopolis rest home, and the floor in a local lumberyard sank a few inches. The earthquake was felt in Kinnear, Pavillion and the Riverton area, and was reportedly felt as far away as Craig, Colorado. A magnitude 4.0 earthquake was recorded in Hot Springs County on June 6, 1978, approximately 30 miles northeast of Shoshoni. No damage was associated with this earthquake. Another non-damaging earthquake occurred on November 9, 1983, in eastern Teton County. This magnitude 3.6, intensity III earthquake was centered approximately 30 miles northwest of Dubois. The U.S.G.S. National Earthquake Information Center reported that this event was felt. Several other earthquakes occurred in eastern Teton County during the 1990s, but most were not felt. On December 28, 1993, however, a magnitude 4.7 earthquake, intensity V earthquake occurred in Teton County, approximately 24.5 miles west-southwest of Dubois. The earthquake was felt in Jackson, Dubois, Hudson, Lander, and Rock Springs. Most reports indicated that the earthquake felt like a heavy truck passing by. A ranch near the epicenter reported swinging lights, but no damage.

In 2000, two earthquakes were reported in northeastern Sweetwater County near the town of Bairoil. A magnitude 4.00 event was recorded on May 26, 2000, and a magnitude 3.2 event was recorded four days later on May 30, 2000. People reported feeling both earthquakes. The most recent earthquake to occur near Fremont County took place on September 27, 2001, near the Fremont County-Teton County-Sublette County borders. Area residents reported feeling this magnitude 4.3 earthquake.

Uniform Building Code

The Uniform Building Code (UBC) is a document prepared by the International Conference of Building Officials. Its stated intent is to “provide minimum standards to safeguard life or limb, health, property, and public welfare by regulating and controlling the design, construction, quality of materials, use and occupancy, location and maintenance of all buildings and structures within this jurisdiction and certain equipment specifically regulated herein.”

The UBC contains information and guidance on designing buildings and structures to withstand seismic events. With safety in mind, the UBC provides Seismic Zone Maps to help identify which design factors are critical to specific areas of the country. In addition, depending upon the type of building, there is also an “importance factor”. The “importance factor” can, in effect, raise the standards that are applied to a building.

The current UBC Seismic Zone Map (**Figure 1**) (1997) has five seismic zones, ranging from Zone 0 to Zone 4, as can be seen on the enclosed map. The seismic zones are in part defined by the probability of having a certain level of ground shaking (horizontal acceleration) in 50 years. The criteria used for defining boundaries on the Seismic Zone Map were established by the Seismology Committee of the Structural Engineers Association of California (Building Standards, September-October, 1986). The criteria they developed are as follows:



Figure 1. UBC Seismic Zone Map.

Zone Effective Peak Acceleration, % gravity (g)

4	30% and greater
3	20% to less than 30%
2	10% to less than 20%
1	5% to less than 10%
0	less than 5%

The committee assumed that there was a 90% probability that the above values would not be exceeded in 50 years, or a 100% probability that the values would be exceeded in 475 to 500 years.

Fremont County is in Seismic Zones 1 and 2 of the UBC. The southeastern two-thirds of the county is in Seismic Zone 1, and the northwestern third of the county is in Seismic Zone 2. Since effective peak accelerations (90% chance of non-exceedance in 50 years) can range from 5%g-20%g in these zones, and there has been some significant historic seismicity in the county, it may be reasonable to assume that an average peak acceleration of 10%g could be applied to the design of a non-critical facility located in the county if only the UBC were used. Such an acceleration, however, is less than would be suggested through newer building codes.

Recently, the UBC has been replaced by the International Building Code (IBC). The IBC is based upon probabilistic analyses, which are described in a following section. Fremont County has not adopted the UBC or the IBC, although Lander and Riverton have adopted the codes.

Deterministic Analysis Of Regional Active Faults With A Surficial Expression

Fremont County has two known active fault systems and one suspected active fault system with a surficial expression within the county boundary. The known systems are the South Granite Mountain fault system and the Stagner Creek fault system. The suspected active fault is the Cedar Ridge/Dry Fork fault system.

The South Granite Mountain fault system is located in southeastern Fremont County and northwestern Carbon County. The fault system is composed of several west-northwest-trending faults that border the northern flanks of the Seminoe Mountains, Ferris Mountain, Green Mountain, and Crooks Mountain. Geomatrix Corporation divided the South Granite Mountain fault system into five segments. The segments, from east to west, are the Seminoe Mountains segment, the Ferris Mountains segment, the Muddy Gap segment, the Green Mountain segment, and the Crooks Mountain segment. Geomatrix Corporation discovered evidence of late-Quaternary faulting on the Ferris Mountains and Green Mountain segments of the fault system. They concluded that the Ferris Mountains segment was capable of generating a maximum credible earthquake of magnitude 6.5 – 6.75 with a recurrence interval of 5,000 to 13,000 years. They also concluded that the Green Mountain segment was capable of generating a maximum credible earthquake of magnitude 6.75 with a recurrence interval of 2,000 to 6,000 years. Geomatrix Corporation did not find evidence of late-Quaternary movement on the Seminoe Mountains, Muddy Gap, and Crooks Mountain fault segments. These segments, however, may

be extensions of the known active faults in the South Granite Mountain fault system. These segments should therefore be considered to be potentially active. Geomatrix Corporation estimated the length of the Seminole Mountains segment to be 22.5 miles (36 km). Such a fault length would result in a magnitude 6.85 earthquake if the entire length ruptured. The length of the Crooks Gap fault segment was estimated to be 21.25 miles (34 km). This fault length could generate a magnitude 6.86 earthquake if the entire length ruptured. The Muddy Gap fault system is approximately 14.4 miles (23 km) in length. If the entire fault ruptured, a magnitude 6.66 earthquake could be generated.

There are two approaches to doing a deterministic analysis on a segmented fault system such as the South Granite Mountain fault system. The first approach involves finding the shortest distance from the area of interest to a specific fault segment. A deterministic analysis is then applied to each individual fault segment. The second approach involves measuring the distance from the area of interest to the closest point on the fault system as a whole. An average magnitude is then used for activation anywhere along the entire fault. For the purposes of this report, the second, more conservative approach will be used. Because the active segments of the South Granite Mountain fault system have been assigned a maximum magnitude of 6.75, it may be reasonable to assume that a magnitude 6.75 earthquake could be generated anywhere along the length of the fault system. A magnitude 6.75 earthquake could generate peak horizontal accelerations of approximately 6.7%g at Atlantic City, approximately 3%g at Ethete, approximately 34%g at Jeffrey City, approximately 4.5%g at Lander, approximately 2.1%g at Lysite and Pavillion, approximately 3.75%g at Riverton, and approximately 2.4%g at Shoshoni (Campbell, 1987). These accelerations would be roughly equivalent to an intensity VIII earthquake at Jeffrey City, intensity V earthquakes at Lander and Atlantic City, and intensity IV earthquakes at Ethete, Lysite, Pavillion, Riverton, and Shoshoni. Jeffrey City could sustain moderate to heavy damage, whereas very light damage could occur at Lander and Atlantic City. No damage should occur at Ethete, Lysite, Pavillion, Riverton, and Shoshoni. Dubois would be subjected to ground accelerations of less than 1.5%g, which should not cause any damage. Pipelines crossing the South Granite Mountain Fault System could be damaged or ruptured if the segment activates.

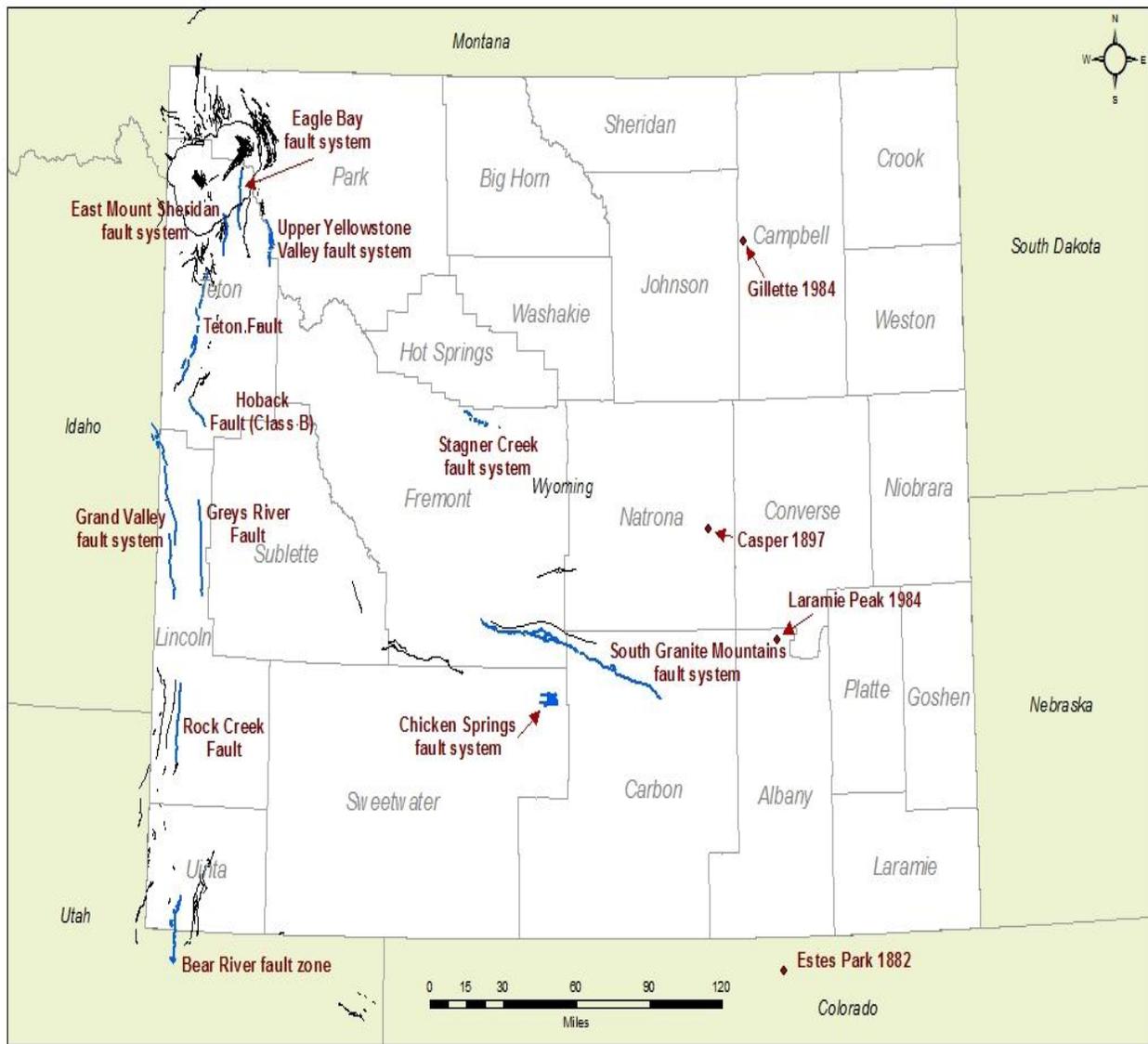
The Stagner Creek fault system is an east-west trending system located near Boysen Reservoir on the south flank of the Owl Creek uplift. Geomatrix Corporation determined that the maximum length of the fault is 24 miles (38 km), with Quaternary-age displacement found along a 17-mile (27 km) segment of the fault between Mexican Pass and Tough Creek. The maximum credible earthquake for this fault system was determined to be a magnitude 6.75 event. A magnitude 6.75 earthquake originating on the Stagner Creek fault system could generate peak horizontal accelerations of approximately 64% at Boysen Dam, 1.6%g at Atlantic City, approximately 1.9%g at Dubois, approximately 4.4%g at Ethete, approximately 1.8%g at Jeffrey City, approximately 3%g at Lander, approximately 7.6%g at Lysite, approximately 9.4%g at Pavillion, approximately 6%g at Riverton, and nearly 18%g at Shoshoni. These accelerations would be roughly equivalent to intensity VIII at Boysen Dam, intensity VI earthquakes at Pavillion and Shoshoni, intensity V earthquakes at Ethete, Lysite, and Riverton, and intensity IV earthquakes at Atlantic City, Dubois, Jeffrey City, and Lander. An intensity VIII earthquake could cause moderate to heavy damage at Boysen Dam. An intensity VI earthquake could cause light damage at Pavillion and Shoshoni, and intensity V earthquakes could cause very light

damage at Ethete, Lysite, and Riverton. Atlantic City, Dubois, Jeffrey City, and Lander should not sustain any damage.

The Cedar Ridge/Dry Fork fault system is present in northeastern Fremont County and northwestern Natrona County. The 35-mile long Cedar Ridge fault comprises the western portion of the fault system, and the 15-mile long Dry Fork fault makes up the eastern portion. The only Pleistocene-age movement on the fault system was found in northeastern Fremont County (T39N R92W NE ¼ Section 10). A short scarp on the Cedar Ridge fault, approximately 0.8 miles long, was identified at that location. Since the entire fault system is approximately 50 miles long, and only one small active segment was discovered, Geomatrix Corporation stated that the “age of this scarp and the absence of evidence for late Quaternary faulting elsewhere along the Cedar Ridge/Dry Creek fault suggest that this fault is inactive.” As a result of this assessment, it is not possible to conduct a reliable deterministic analysis on the fault system; however, general estimates can be made.

Although there is no compelling reason to believe that the Dry Fork fault system is active, if it did activate as an isolated system, it could potentially generate a magnitude 6.7 earthquake. This is based upon a postulated fault rupture length of 15 miles. A magnitude 6.7 earthquake on the fault system could generate peak horizontal accelerations of approximately 2%g at Jeffrey City, approximately 10.3%g at Lysite, approximately 1.7%g at Pavillion, approximately 2.3%g at Riverton, and approximately 4.2%g at Shoshoni. These accelerations would be roughly equivalent to an intensity VI earthquake at Lysite, an intensity V earthquake at Shoshoni, and intensity IV earthquakes at Jeffrey City, Pavillion, and Riverton. An intensity VI earthquake could cause light damage at Lysite, while an intensity V earthquake could cause very light damage at Shoshoni. No damage should occur at Jeffrey City, Pavillion, or Riverton. Atlantic City, Dubois, Ethete, and Lander would be subjected to ground accelerations of less than 1.5%g, which should not cause any damage. Again, there is no compelling reason to believe that the Dry Fork fault system is active.

There is also no compelling reason to believe that the Cedar Ridge fault system is active. Based upon its fault rupture length of 35 miles, however, if the fault did activate it could potentially generate a maximum magnitude 7.1 earthquake. A magnitude 7.1 event could generate peak horizontal accelerations of approximately 2.5%g at Ethete and Jeffrey City, approximately 2.1%g at Lander, approximately 26.5%g at Lysite, approximately 3.1%g at Pavillion, approximately 4%g at Riverton, and approximately 8.8%g at Shoshoni, 30%g at the Burlington Resources Oil and Gas Company/Lost Cabin Gas Plant and approximately. These accelerations would be roughly equivalent to an intensity VII earthquake at Lysite and the Lost Cabin Gas Plant, intensity V earthquakes at Riverton and Shoshoni, and intensity IV earthquakes at Ethete, Jeffrey City and Pavillion. Lysite could sustain moderate damage and very light damage could occur at Riverton and Shoshoni. No damage should occur at Ethete, Jeffrey City and Pavillion. Atlantic City and Dubois would be subjected to ground accelerations of less than 1.5%g, which should not cause any damage.



Quaternary faults

- ◆ Random event scenarios
- County boundaries
- Probable Quaternary faults
- Faults used in loss estimations

Figure 2. Fault Systems in the State of 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.

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 identified tectonic provinces in a report titled “Probabilistic Estimates of Maximum Acceleration and Velocity in Rock in the Contiguous United States”. In that report, Fremont County was classified as being in a tectonic province with a “floating earthquake” maximum magnitude of 6.1. Geomatrix Corporation 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 Corporation 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.

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 Fremont 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, however, placing a magnitude 6.25 earthquake at 15 kilometers from a site will provide a fairly conservative estimate of design ground accelerations.

Probabilistic Seismic Hazard Analyses

The U.S. Geological Survey (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 accelerations may be met or exceeded in 50 years is roughly equivalent to a 100% probability of exceedance in 500 years.

The USGS has recently generated new probabilistic acceleration maps for Wyoming. Copies of the 500-year (10% probability of exceedance in 50 years), 1000-year (5% probability of exceedance in 50 years), and 2,500-year (2% probability of exceedance in 50 years) maps are attached. 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. Intensity values can be found in **Table 11.1**.

Based upon the 500-year map (10% probability of exceedance in 50 years) (**Figure 2**), the estimated peak horizontal acceleration in Fremont County ranges from approximately 6%g in the eastern and north-central portions of the county to nearly 20%g in the northwestern portion of the county. These accelerations are roughly comparable to intensity V earthquakes (3.9%g – 9.2%g), intensity VI earthquakes (9.2%g – 18%g), and intensity VII earthquakes (18%g – 34%g). Intensity V earthquakes can result in cracked plaster and broken dishes. Intensity VI earthquakes can result in fallen plaster and damaged chimneys. 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, such as unreinforced masonry. Chimneys may be broken. Lander and Riverton would be subjected to accelerations of approximately 7-8%g or intensity V.

Based upon the 1000-year map (5% probability of exceedance in 50 years) (Figure 3), the estimated peak horizontal acceleration in Fremont County ranges from 9%g in the north-central and northeastern portions of the county to 25%g in the far northwestern corner of the county. These accelerations are roughly comparable to intensity V earthquakes (3.9%g – 9.2%g), intensity VI earthquakes (9.2%g – 18%g), and intensity VII earthquakes (18%g – 34%g). Intensity V earthquakes can result in cracked plaster and broken dishes. Intensity VI earthquakes can result in fallen plaster and damaged chimneys. 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, such as unreinforced masonry. Chimneys may be broken. Lander and Riverton would be subjected to accelerations of approximately 10-15%g or intensity VI.

Based upon the 2500-year map (2% probability of exceedance in 50 years) (**Figure 5**), the estimated peak horizontal acceleration in Fremont County ranges from approximately 16%g in the north-central portion of the county to over 20%g in the central and southern portions of the county to nearly 40%g in the far northwestern corner of the county. These accelerations are roughly comparable to intensity VI earthquakes (9.2%g – 18%g), intensity VII earthquakes (18%g – 34%g), and intensity VIII earthquakes (34%g-65%g). Intensity VI earthquakes can result in fallen plaster and damaged chimneys. 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, such as unreinforced masonry. Chimneys may be broken. Intensity VIII earthquakes can result in considerable damage in ordinary buildings and great damage in poorly built structures. Panel walls may be thrown out of frames. Chimneys, walls, columns, factory stacks may fall. Heavy furniture may be overturned. Lander and Riverton would be subjected to accelerations of greater than 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 Fremont County analyses, unless the ground acceleration derived from the deterministic analyses on faults exceed the probabilistic analyses. This conservative approach is in the interest of public safety.

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

Table 1: Modified Mercalli Intensity and peak ground acceleration (PGA)

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. Vibration like passing of truck. 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. Sensation like heavy truck striking 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 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.

**Peak Acceleration (%g)
with 10% Probability
of Exceedance in 50 Years
site: NEHRP B-C boundary**

U.S. Geological Survey
National Seismic Hazard Mapping Project
Albers Conic Equal-Area
Projection
Standard Parallels: 29.5

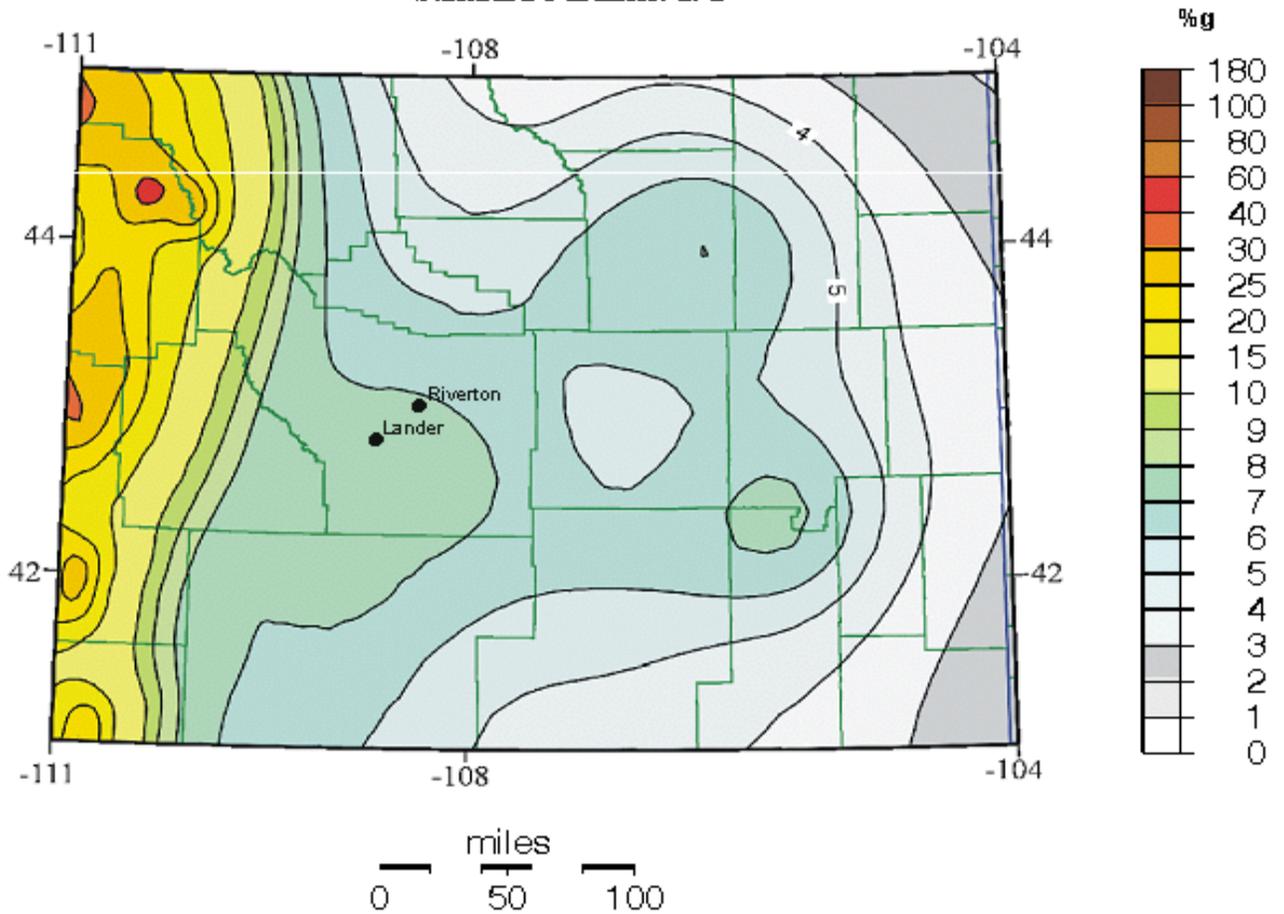


Figure 3. 500-year probabilistic acceleration map (10% probability of exceedance in 50 years).

**Peak Acceleration (% g)
with 5% Probability
of Exceedance in 50 Years
site: NEHRP B-C boundary**

U.S. Geological Survey
National Seismic Hazard Mapping Project
Albers Conic Equal-Area
Projection
Standard Parallels: 29.5

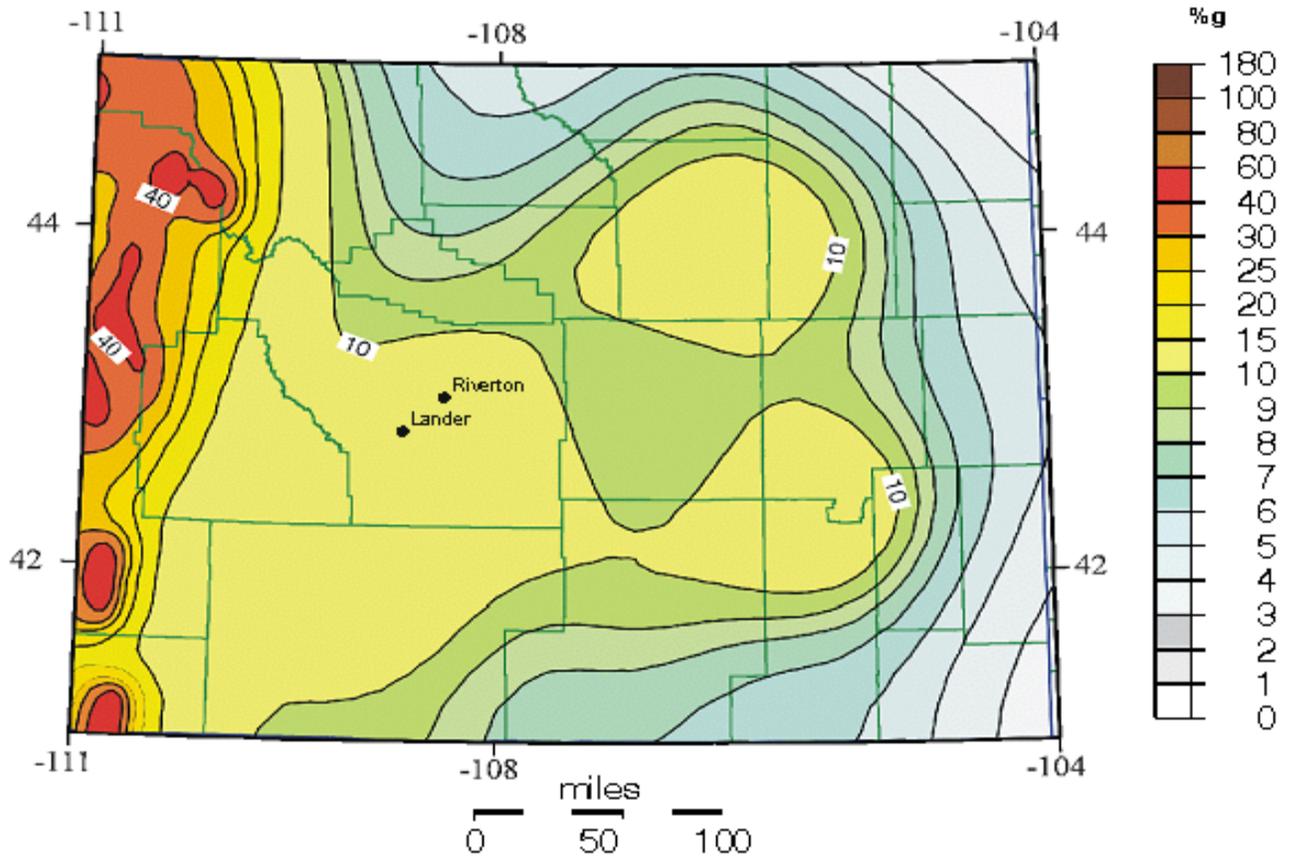


Figure 4. 1000-year probabilistic acceleration map (5% probability of exceedance in 50 years).

**Peak Acceleration (%g)
with 2% Probability
of Exceedance in 50 Years
site: NEHRP B-C boundary**

U.S. Geological Survey
National Seismic Hazard Mapping Project
Albers Conic Equal-Area
Projection
Standard Parallels: 29.5

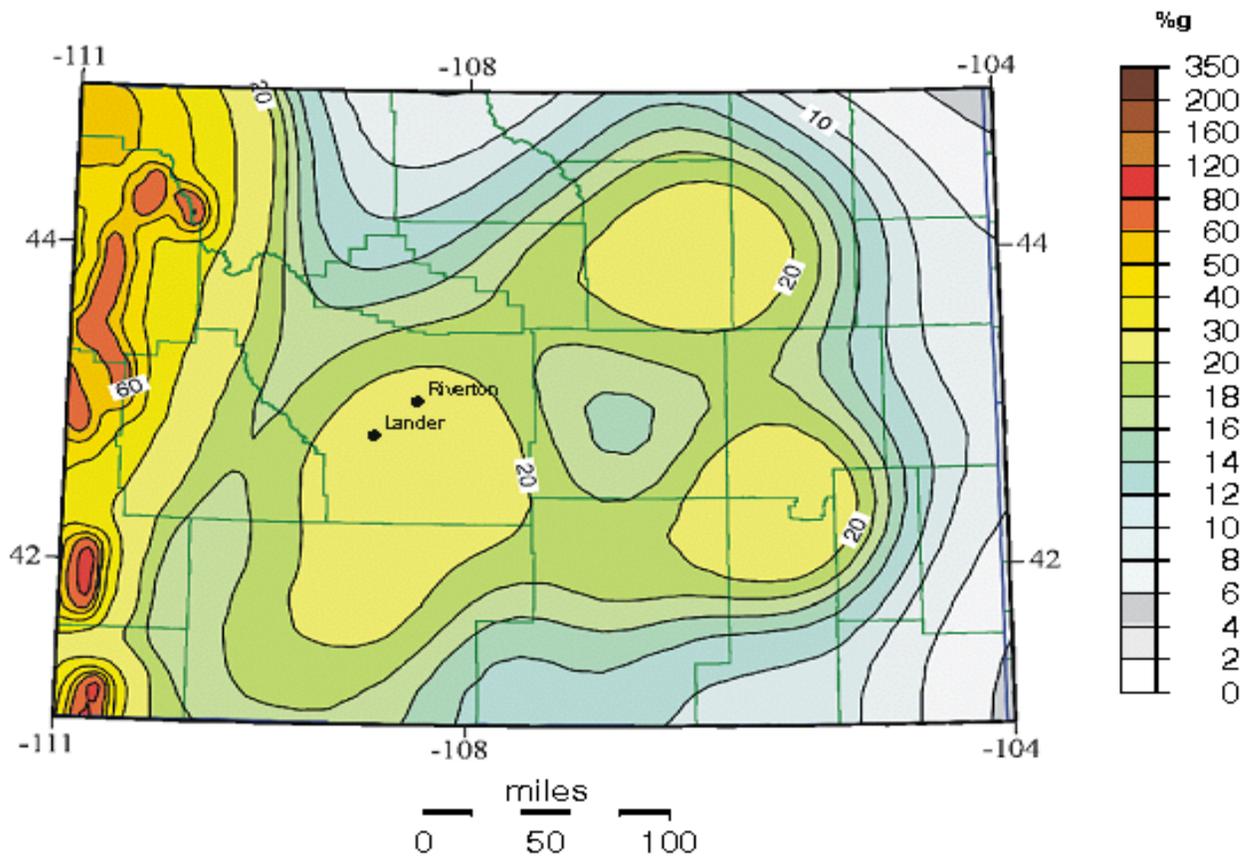


Figure 5. 2500-year probabilistic acceleration map (2% probability of exceedance in 50 years).

There have been numerous historic earthquakes with magnitudes greater than 2.0 or intensity III and greater recorded in or near Fremont County. Because of the limited historic record, it is possible to underestimate the seismic hazard in Fremont County if historic earthquakes are used as the sole basis for analysis. Earthquake and ground motion probability maps and specific fault analyses give a more reasonable estimate of damage potential in Fremont County.

Current earthquake probability maps that are used in the newest building codes suggest a scenario that would result in light to heavy damage to buildings and their contents, with damage increasing from the north-central to the northwest and south. More specifically, the probability-based or fault activation-based worst-case scenario could result in the following damage at points throughout the county:

Intensity VIII Earthquake Areas

Jeffrey City

Intensity VIII earthquakes can result in considerable damage in ordinary buildings and great damage in poorly built structures. Panel walls may be thrown out of frames. Chimneys, walls, columns, factory stacks may fall. Heavy furniture may be overturned.

Intensity VII Earthquake Areas

Atlantic City
Arapahoe
Boysen Dam
Dubois
Ethete
Fort Washakie
Gas Hills
Hudson
Kinnear
Lander
Lost Cabin

Lost Cabin Gas Plant
Lysite
Moneta
Morton
Pavillion
Riverton
Shoshoni
South Pass City
St. Stephan's

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 un-reinforced masonry buildings. Some chimneys will be broken.

Intensity VI Earthquake Areas

Burris
Crowheart

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

Potential Earthquake Damage Estimates

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 the 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. FEMA Region VIII and their subcontractor on HAZUS, PBS&J from Atlanta, have worked closely with the Wyoming State Geological Survey (WSGS) to develop a census-block-based analysis for HAZUS-MH in Wyoming. In fact, Wyoming is 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.

The results of the HAZUS-MH analysis for each county are presented in **Tables 2, 3, and 4**. There are two methods to rank the counties to determine where earthquake impacts may be the greatest. Either the loss ratios (**Table 3**) or total damage (**Table 4**) figures can be used. The loss

ration 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 a better 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, with a higher percentage of damage.

Table 2

County	Capital Stock Losses (Thousands of Dollars)				Loss Ratio (%)	Income Losses (Thousands of Dollars)				Total Loss (Thousands of Dollars)
	Structural	Non- structural	Contents	Inventory		Relocation	Capital- Related	Wages	Rental	
Albany	9,714	36,865	13,946	151	2.32	276	2,717	3,198	4,210	71,078
Big Horn	3,470	12,203	4,647	65	2.43	84	533	694	963	22,660
Campbell	5,116	20,093	9,419	282	1.37	144	1,484	2,013	1,592	40,144
Carbon	7,140	26,320	10,480	170	3.08	190	2,120	2,700	1,810	50,920
Converse	6,054	24,172	9,787	185	4.15	152	984	1,303	1,845	44,482
Crook	836	2,640	896	17	1.04	21	107	139	211	4,867
Fremont	14,890	61,030	24,640	460	3.75	380	2,920	3,940	3,190	111,450
Goshen	2,168	6,982	2,543	69	1.13	57	392	528	623	13,364
Hot Springs	3,038	10,871	4,176	52	4.20	82	799	1,149	969	21,136
Johnson	3,293	13,062	5,514	94	3.40	86	557	648	1,066	24,320
Laramie	13,605	47,839	17,577	233	1.25	406	3,926	4,402	4,976	92,963
Lincoln	65,670	225,594	64,429	2,538	31.08	1,211	8,579	10,359	15,347	391,727
Natrona	36,764	137,379	57,269	1,149	3.99	981	9,890	13,033	12,245	268,911
Niobrara	423	1,585	617	12	1.20	12	72	83	132	2,935
Park	11,430	42,694	15,289	429	2.98	285	5,173	6,217	4,487	86,004
Platte	1,875	6,894	2,697	36	1.60	51	326	418	554	12,850
Sheridan	7,830	29,154	12,057	233	2.09	213	1,898	2,402	2,636	56,423
Sublette	9,654	30,667	9,436	222	8.24	206	2,438	3,052	2,665	58,340
Sweetwater	12,782	50,213	20,753	542	2.84	313	2,180	2,514	3,719	93,017
Teton	92,477	359,169	110,323	2,402	24.72	1,821	37,784	43,975	34,030	681,981
Uinta	39,912	135,111	38,841	1,007	15.84	782	5,888	8,741	11,004	241,284
Washakie	4,115	13,761	5,656	134	3.54	99	904	1,019	1,236	26,925
Weston	897	3,016	1,085	21	0.96	26	147	266	302	5,760

Table 3 - County Impacts Rated by Loss Ratio		
County	Loss Ratio	Total Loss (Thousands of Dollars)
Lincoln	31.08	391,727
Teton	24.72	681,981
Uinta	15.84	241,284
Sublette	8.24	58,340
Hot Springs	4.20	21,136
Converse	4.15	44,482
Natrona	3.99	268,911
Fremont	3.75	111,450
Washakie	3.54	26,925
Johnson	3.40	24,320
Carbon	3.08	37,762
Park	2.98	86,004
Sweetwater	2.84	93,017
Big Horn	2.43	22,660
Albany	2.32	71,078
Sheridan	2.09	56,423
Platte	1.60	12,850
Campbell	1.37	40,144
Laramie	1.25	92,963
Niobrara	1.20	2,935
Goshen	1.13	13,364
Crook	1.04	4,867
Weston	0.96	5,760

Table 4 - County Impacts Rated by Dollar Loss		
County	Total Loss (Thousands of Dollars)	Loss Ratio
Teton	681,981	24.72
Lincoln	391,727	31.08
Natrona	268,911	3.99
Uinta	241,284	15.84
Fremont	111,450	3.75
Sweetwater	93,017	2.84
Laramie	92,963	1.25
Park	86,004	2.98
Albany	71,078	2.32
Sublette	58,340	8.24
Sheridan	56,423	2.09
Converse	44,482	4.15
Campbell	40,144	1.37
Carbon	37,762	3.08
Washakie	26,925	3.54
Johnson	24,320	3.4
Big Horn	22,660	2.43
Hot Springs	21,136	4.2
Goshen	13,364	1.13
Platte	12,850	1.6
Weston	5,760	0.96
Crook	4,867	1.04
Niobrara	2,935	1.2

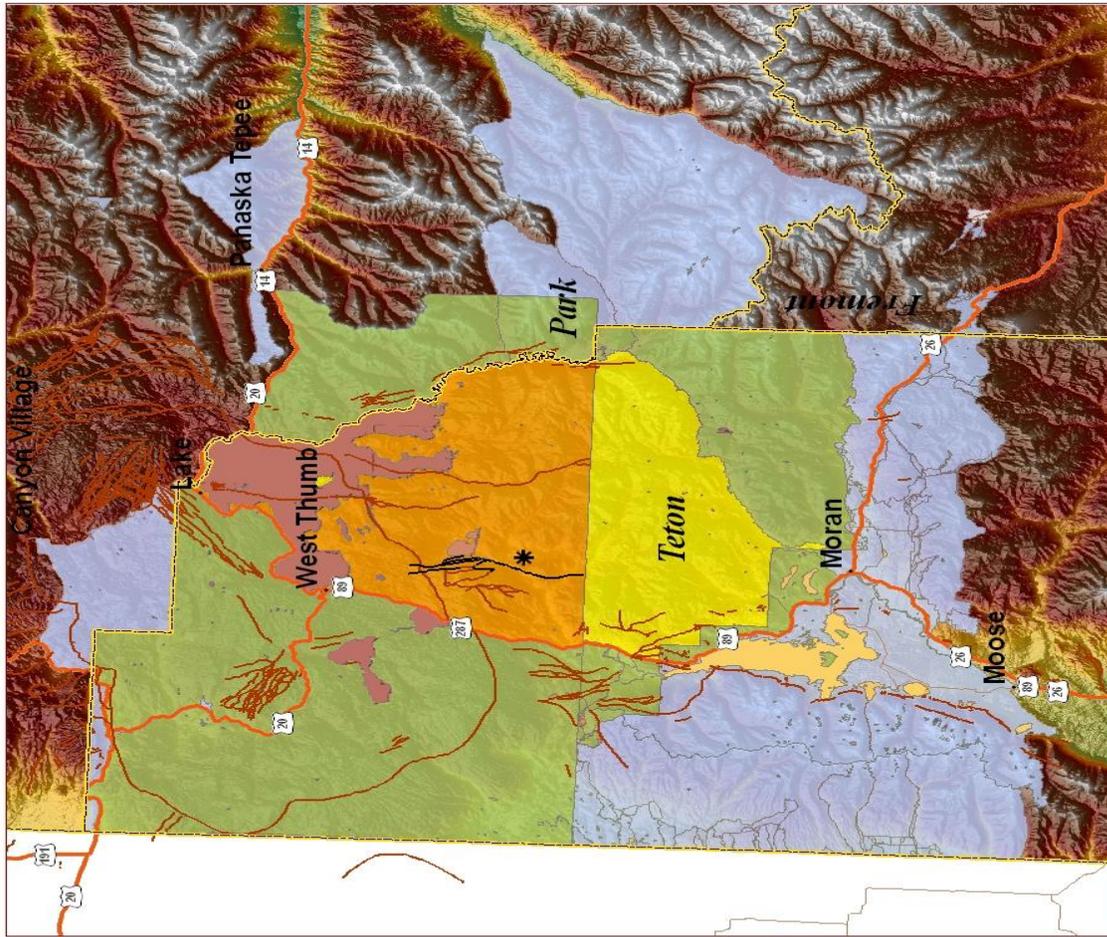
Fault System affecting Fremont County

Faults systems that may cause earthquakes in areas of Fremont County are:

East Mount Sheridan, Chicken Springs, South Granite Mountain, Stagner Creek, Upper Yellowstone Valley and Teton fault.

Wyoming State Geological Survey (Source: 2011 Draft) has established earthquake scenario quick reference pages for each fault to show multiple facts on each fault. Items included in the quick reference information include scenario magnitude; regional population (2000 census); infrastructure damage expected with scenario magnitude; possible debris generated and number of people who may be displaced. Direct economic loss is also estimated at the scenario magnitude projected. Scenario quick reference pages can be obtained for each fault system noted at http://www.wsgs.uwyo.edu/temp/Wy_Eq_Scenarios.zip

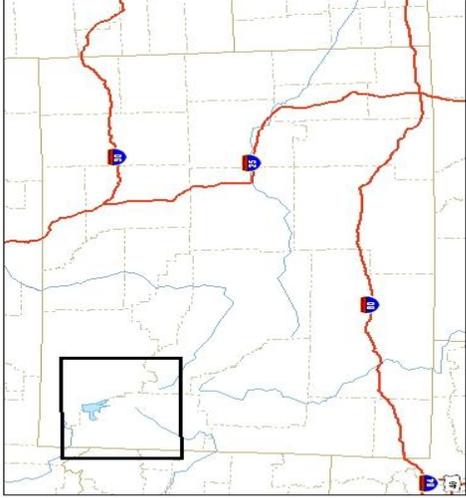
Maps follow on pages 11.25 to 11.30 showing the area affected by each fault system that may cause damage to Fremont County citizens.



0 2.5 5 10 15 20
Miles
Lambert Conformal Conic

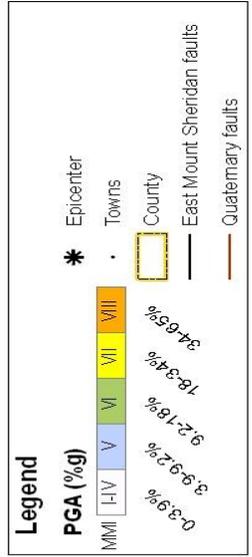


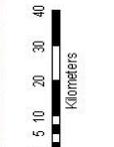
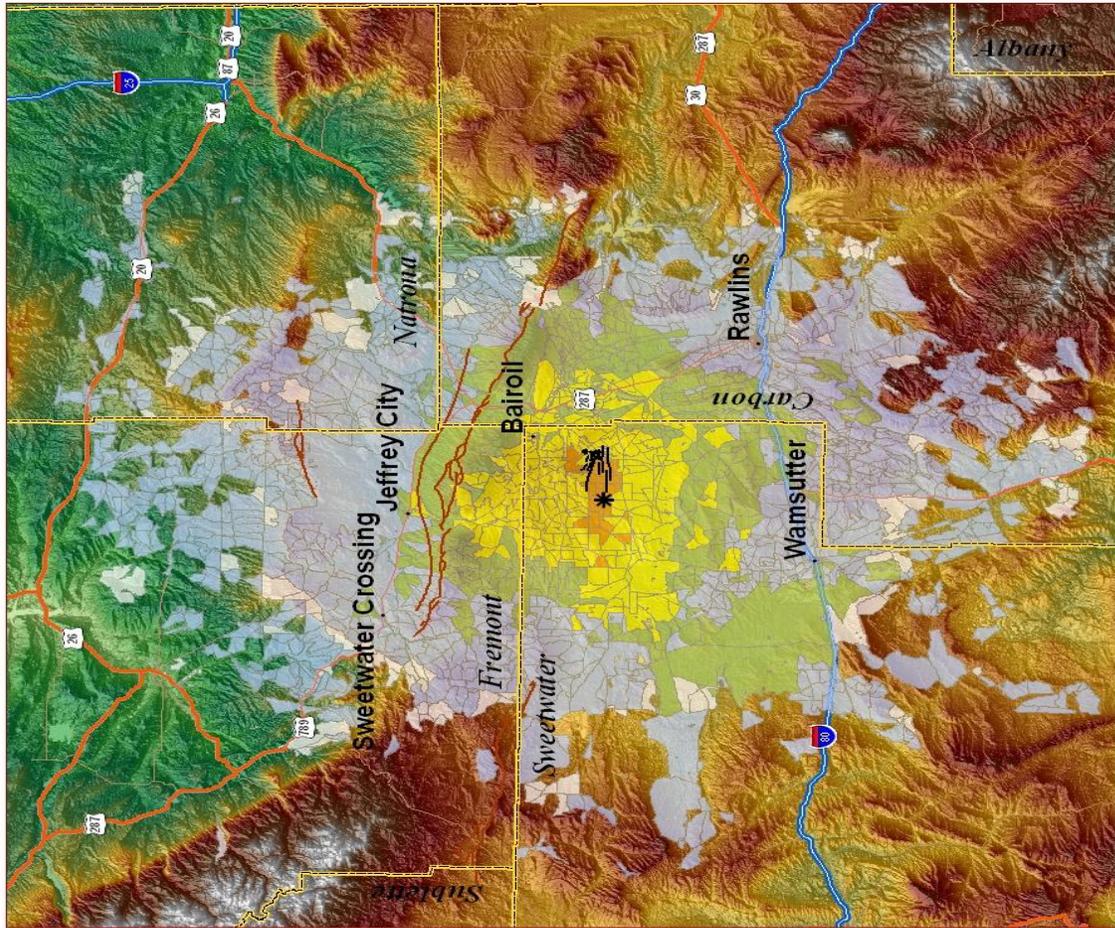
0 2.5 5 10 15 20
kilometers



East Mount Sheridan Fault System

County: Teton
 Scenario magnitude: 6.4
 Strike: 3°
 Dip: unknown
 Slip rate: 1.0 - 5.0 mm/yr
 Recurrence interval: unknown



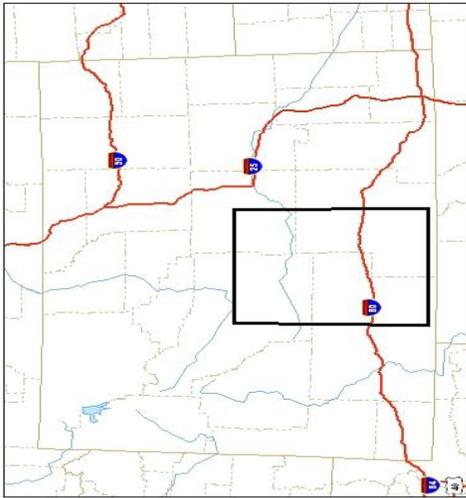


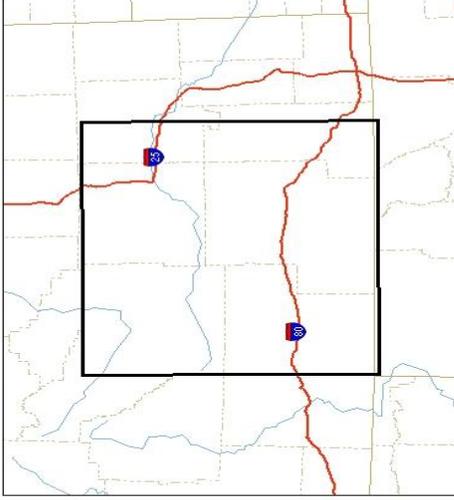
Lambert Conformal Conic



Chicken Springs Fault System

County: Sweetwater
 Scenario magnitude: 6.5
 Strike: 281°
 Dip: Unknown
 Slip rate: < 0.2 mm/year
 Recurrence interval: Unknown





South Granite Mountain Fault System

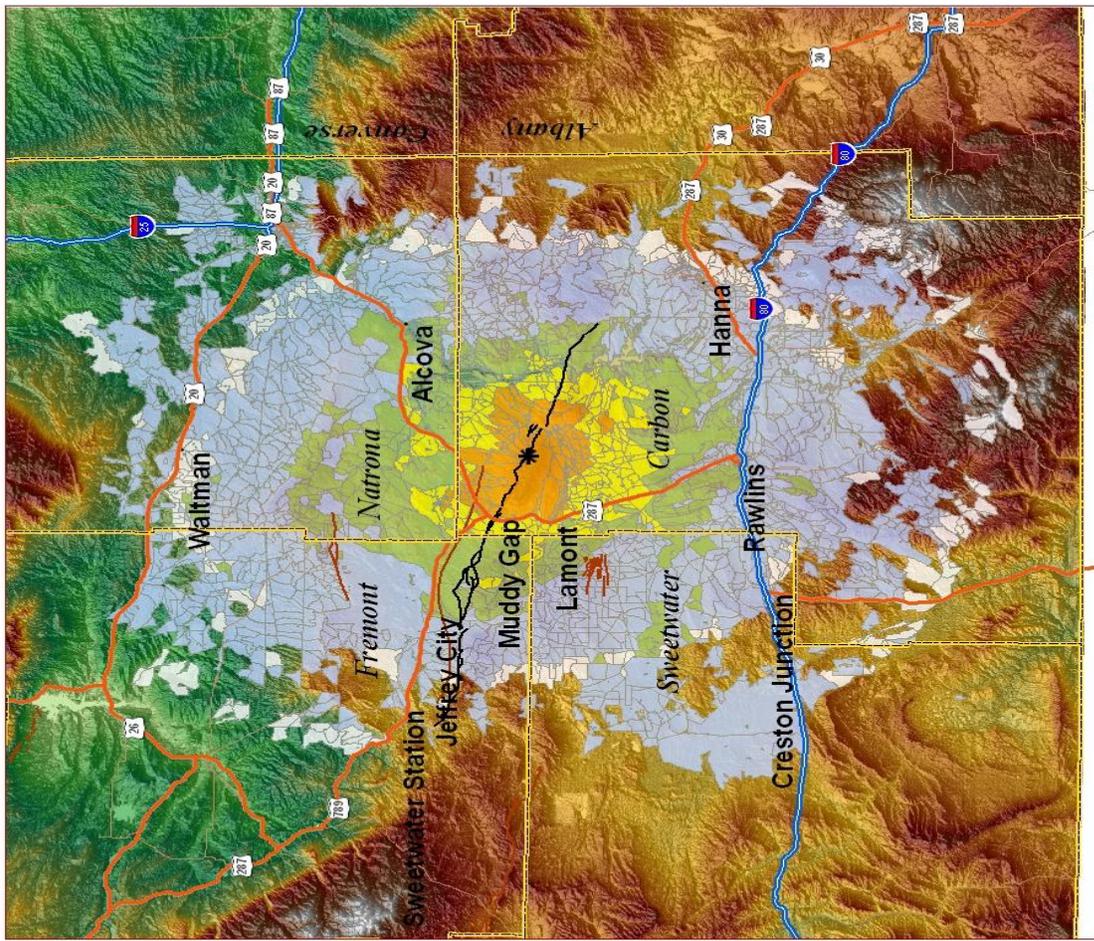
Countries: Carbon
 Scenario magnitude: 6.75
 Strike: 288°
 Dip: Unknown
 Slip rate: < 0.2 mm/year
 Recurrence interval: Unknown

Legend

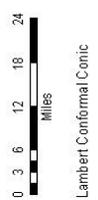
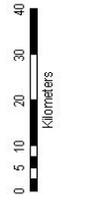
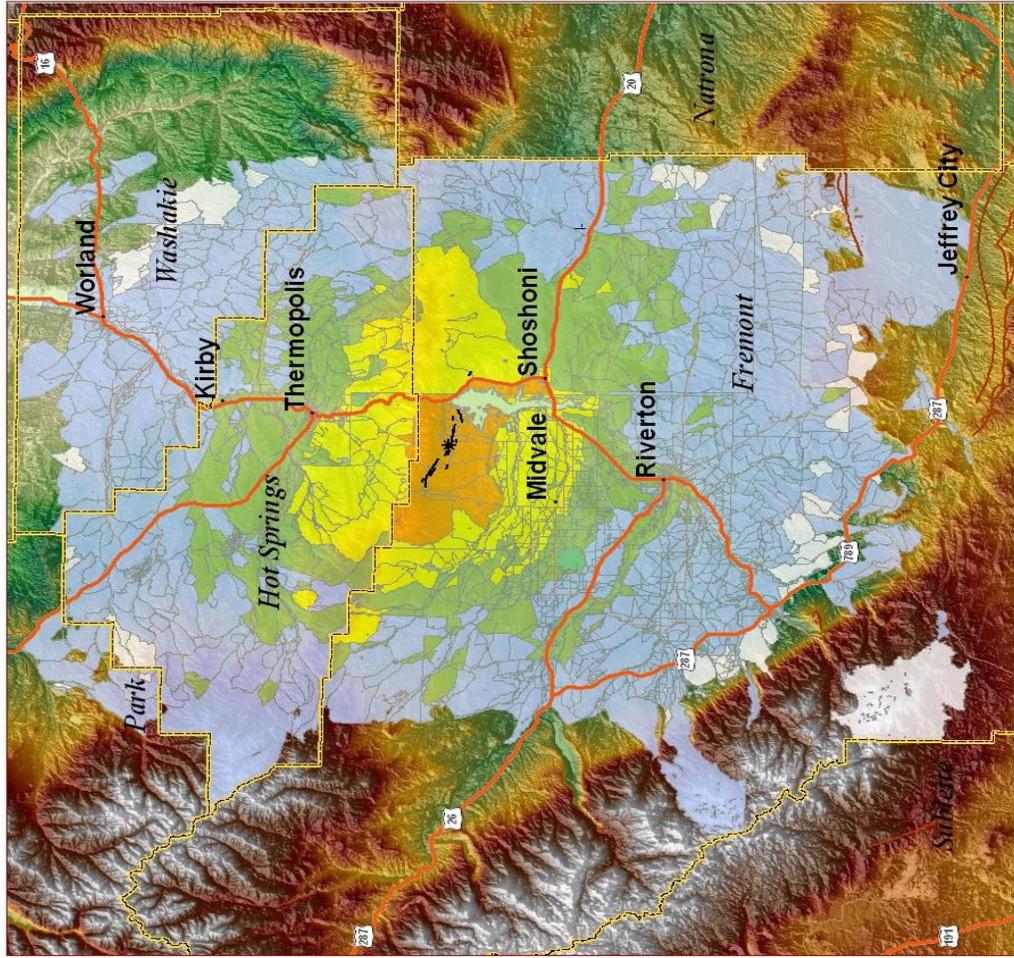
PGA (%g)

MMI I-IV	0-3.9%
V	3.9-9.2%
VI	9.2-18%
VII	18-34%
VIII	34-65%

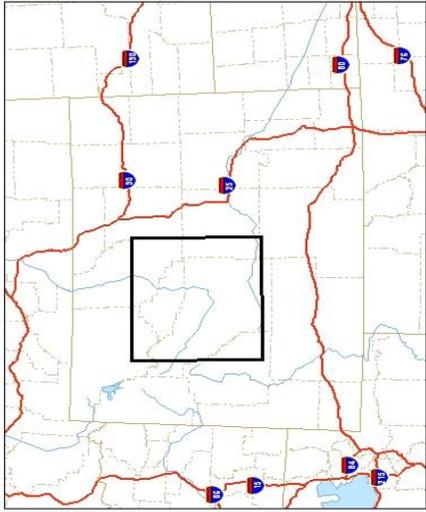
* Epicenter
 • Towns
 □ County
 — South Granite Mountain faults
 — Quaternary faults



Lambert Conformal Conic



Lambert Conformal Conic



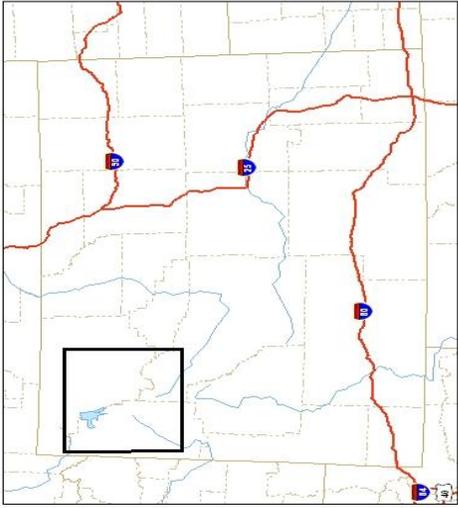
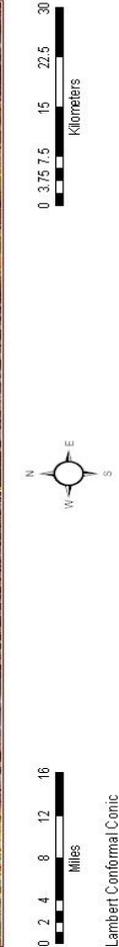
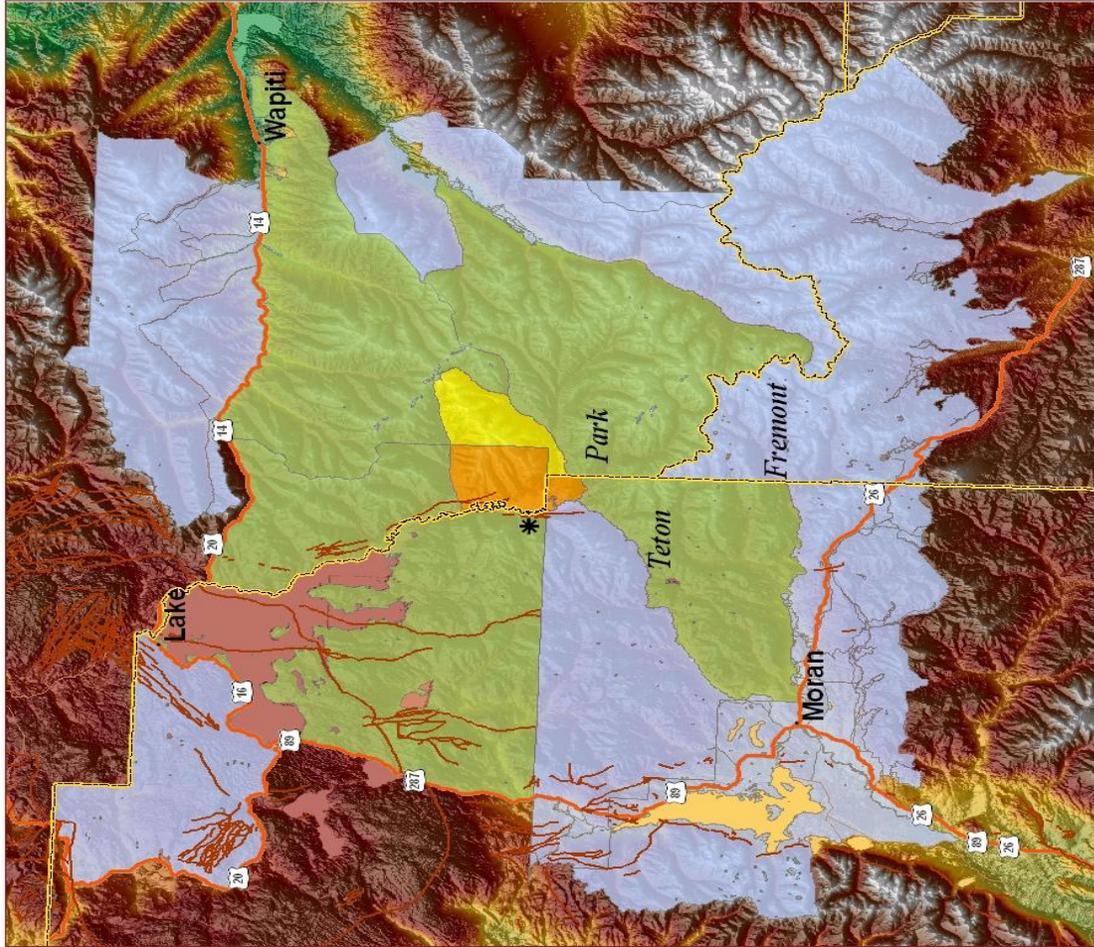
Stagner Creek Fault System

Counties: Fremont
 Scenario magnitude: 6.75
 Strike: 283°
 Dip: Unknown
 Slip rate: < 0.2 mm/year
 Recurrence interval: Unknown

Legend

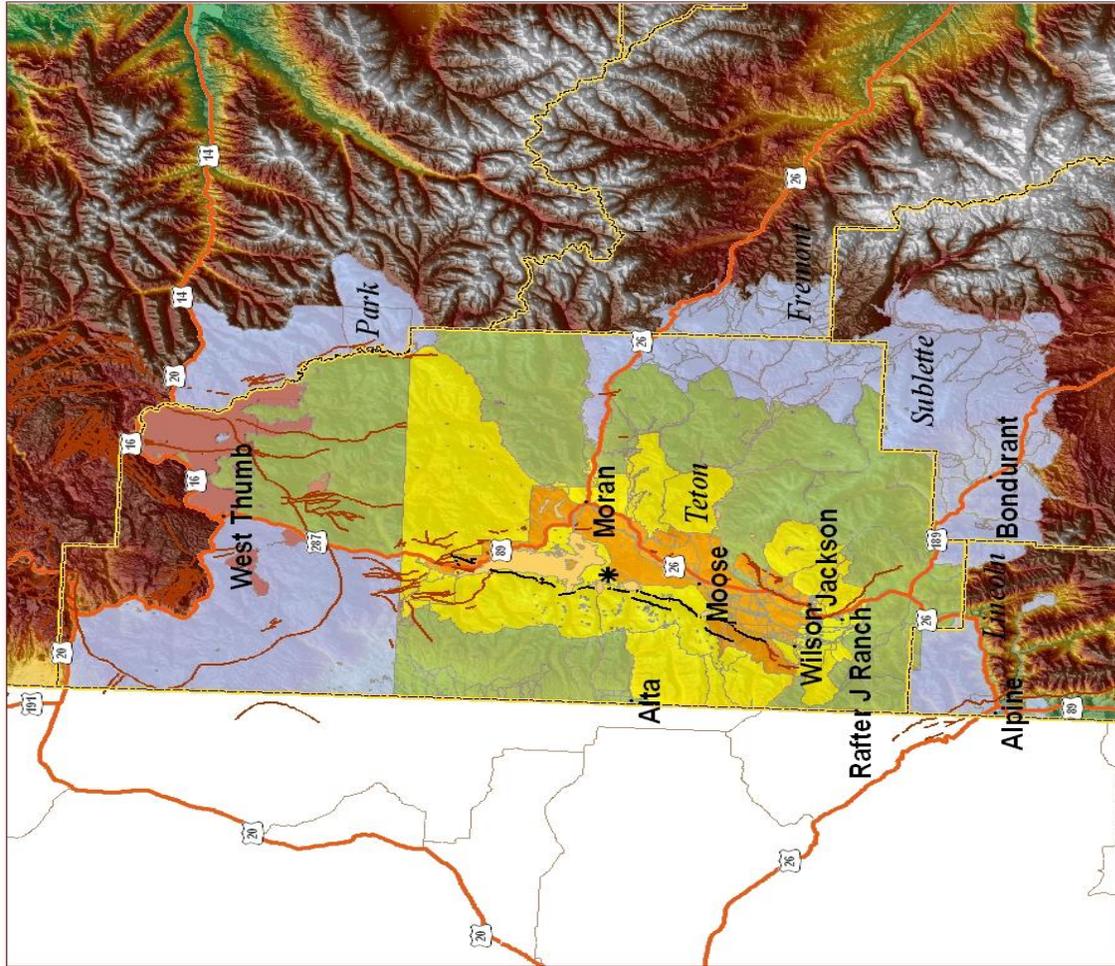
MMI I-IV	V	VI	VII	VIII	*	Epicenter
0-3.9%	3.9-9.2%	9.2-18%	18-34%	34-65%	•	Towns
County					□	County
Stagner Creek fault					—	Stagner Creek fault
Quaternary faults					—	Quaternary faults





Upper Yellowstone Valley Fault System

County: Teton
 Scenario magnitude: 6.5
 Strike: 351°
 Dip: Unknown
 Slip rate: <0.2mm/yr
 Recurrence interval: Unknown



0 3 6 12 18 24
Miles
Lambert Conformal Conic



0 5 10 20 30 40
Kilometers

Teton Fault

County: Teton
 Scenario magnitude: 7.2
 Dip: 60°-80° E
 Slip rate: 0.2-1.0 mm/year
 Recurrence interval: 5-7.5 ky



Legend

PGA (%g)

III	IV	V	VI	VII	VIII
-----	----	---	----	-----	------

0-3.9%
 3.9-9.2%
 9.2-18%
 18-34%
 34-65%

* Epicenter
 • Towns
 □ County
 — Teton fault
 — Quaternary faults



Potential Impact of Earthquakes in Fremont County

Based upon the HAZUS analysis data presented above it can be seen that Fremont County has the potential for significant damage from a large earthquake. \$111,450,000 in building damage alone is estimated for the county. The loss ratio calculated for the county is 3.75%. The HAZUS analysis, which is on file at the Fremont County Emergency Management office, also indicates that there will be loss of life associated with a maximum earthquake event.

In summary, damage in excess of \$111,450,000 and loss of life can be expected in Fremont County if a large earthquake occurs. Damaging earthquakes occur approximately every 14 years in Fremont County.

EARTHQUAKE MITIGATION ACTION ITEMS

Education

Basic education of the population must be considered as an important project in Fremont County due to the fact that most people think we don't have earthquakes. In the western section of the state, people have felt the earthquakes and experienced them. In Fremont County, however, most of the earthquakes have been in remote areas or felt by few people. Due to modern technology, we can tell more about earthquakes than we can from oral history.

EARTHQUAKE RESOURCE DIRECTORY

At the time of preparation of this document, various emergency resources are available through the Fremont County Emergency Management Agency and the current resource listings. The resource classification is being revised on the national level which will be continuing to our level. If the item needed is not available in the county, assistance will be requested through the adjoining counties and the Wyoming Office of Homeland Security.

Fremont County Emergency Management Agency feels that public education is one of the best avenues of support for our county. Fremont County Emergency Management Agency will assist with logistical support and response to all emergencies. Public education to the population of the county will be continued. Notification of the population is expanding also through the NOAA Weather Alert Radio notifications of all emergencies or hazards.

Summary

PROPERTY AFFECTED:	medium
POPULATION AFFECTED:	medium
PROBABILITY:	medium
JURISDICTION AFFECTED:	county wide