

X. Landslides

Landslides are one of the most common geologic hazards in Wyoming, with some of the highest landslide densities in the country found in the State. The figure below shows mapped landslides in Wyoming.

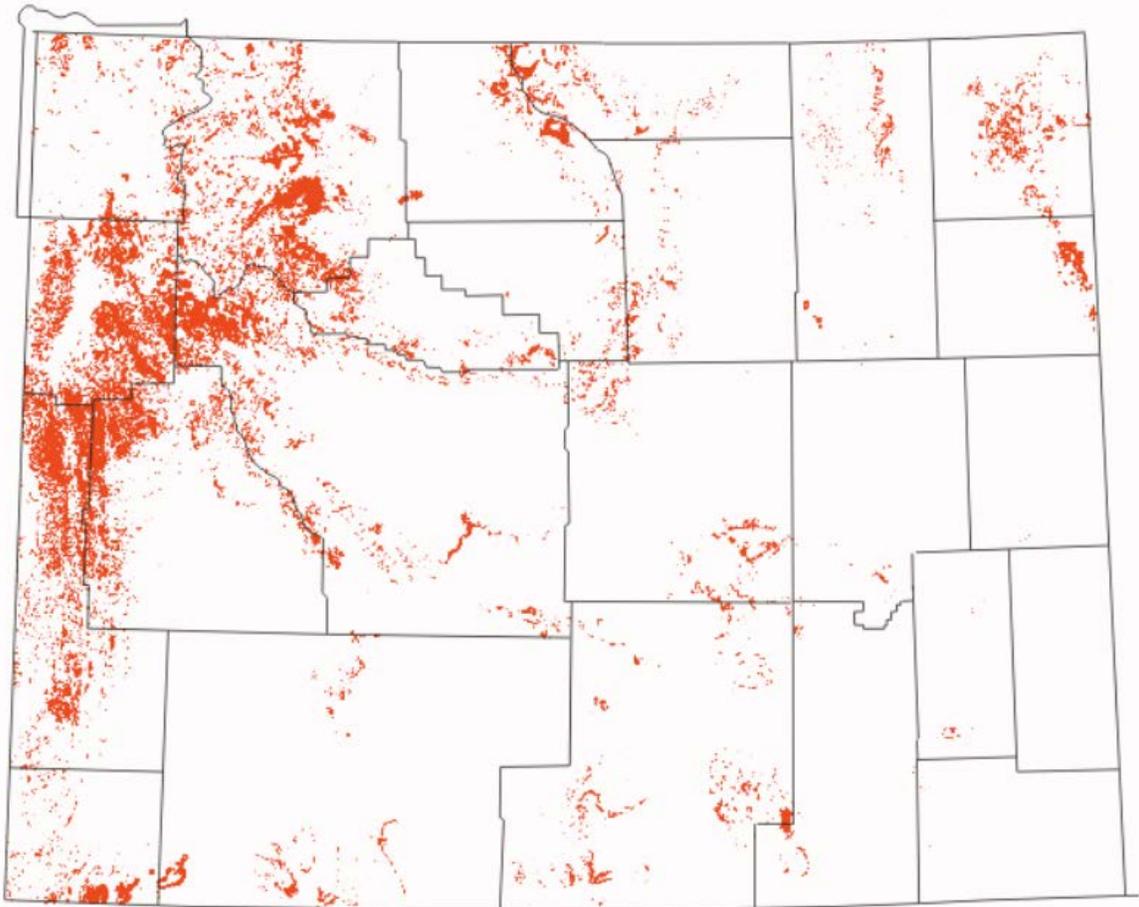


Figure 10.1. Mapped Landslides in Wyoming

There are many types of landslides present in Wyoming. In order to properly describe landslide type, the Geologic Hazards Section developed a landslide classification modified from Varnes (1978) and Campbell (1985). As can be seen in Figure 10.2 there are five basic types of landslides that occur in three types of material. Falls, topples, slides, lateral spreads, and flows can occur in bedrock, debris, or earth. While individual landslide types can occur in nature, most landslides are complex, or composed of combinations of basic types of landslides.

Falls and topples are easy to visualize. In a fall, material detached from a steep slope or cliff descends through the air, and may bounce and roll. In a topple, a mass rotates forward on a pivot point. If a toppling mass pivots far enough, a fall may result.

Slides are characterized by shear displacement along one or several surfaces. Two general types of slides are recognized: rotational and translational. In a rotational slide, the surface of rupture is concave upward, and the mass rotates along the concave shear surface. Rotational slides are usually called slumps, and they can occur in bedrock, debris, or earth. In a translational slide, the surface of rupture is a planar or gently undulatory surface. In bedrock and earth, translational slides are usually called block slides if an intact mass slides down the slope. If rock fragments or debris slide down a slope on a distinct shear plane, the movements are called rock slides or debris slides. It is easy to see that confusion can result by applying the term “slide” to all types of landslides.

Lateral spreads are characterized by lateral extension movements in a fractured mass. Lateral spread movements may occur in bedrock and soil as a result of liquefaction or plastic flow of subjacent materials, or in bedrock without a well-defined basal shear surface or zone of plastic flow. Lateral spreads in bedrock without a well-defined zone of shearing or flow, usually occur on ridge crests.

In general, a flow is a moving mass that has differential internal movements that are distributed throughout the mass. While most flows occur in debris and earth, one type of flow, gravitational sagging, does occur in bedrock. Flows in debris and earth can be cohesive or non-cohesive. Both cohesive and non-cohesive flows are further subdivided by water content and material properties.

Cohesive flows in debris include soil creep, solifluction, block streams, talus flows, and rock glaciers. Soil creep is an imperceptibly slow deformation that continues under constant stress. Solifluction is a slow flow in soil that is often observed in areas with perennially or permanently frozen ground. Block streams are slow moving tongues or rocky debris on steep slopes, and are often fed by talus cones. Talus flows are slow flows that occur in the basal portions of talus slopes. Rock glaciers are not true landslides, but have been included in the classification scheme because they are mass movements composed of coarse debris. Interstitial ice between debris fragments plays a role in the movement of rock glaciers, which are similar in form to a true glacier.

Cohesive flows in earth include soil creep, solifluction, earth flows, and debris laden earth flows. Soil creep and solifluction in earth are similar to those in debris. Earth flows are very slow to rapid flows that have a distinct source area, a main flow track, and a lobate depositional area. Debris laden earth flows are flows that appear to be earth flows but are composed of debris. Standard classifications do not recognize debris laden earth flows, but many have been observed in Wyoming. Many of the landslides present in Wyoming have an earth flow component.

Non-cohesive flows in debris include rock fragment flows and debris flows. Rock fragment flows are extremely rapid flows composed of dry to moist rock debris. This type of flow can be initiated by a rock fall, by seismic activity, or by other processes. In some cases, it appears that rock debris has moved on a cushion of air, although other

mechanisms may have dominated the process. Rock fragment flows can cause significant destruction in a short period of time. Debris flows are a slurry flow composed of debris and a significant amount of water. They are usually associated with unusually heavy precipitation or with rapid snowmelt. Debris flows commonly follow preexisting drainage ways, and commonly form debris levees along their main flow track. Debris flows are a significant component of alluvial fans in mountainous areas with the main debris flow deposit having a broad, fairly flat, fan shape. Debris flows are very common in the mountainous areas of Wyoming.

Non-cohesive flows in earth include loess flows, dry sand flows, wet sand flows, rapid earth flows, and mud flows. Loess flows and dry sand flows are rapid to very rapid flows of dry material. Loess flows are usually initiated by seismic activity, and are a fluid suspension of silt in air. Fortunately, none have yet been identified in Wyoming. Dry sand flows usually occur along shorelines or in Aeolian deposits. In Wyoming, most dry sand flows are very small. Wet sand flows occur along river banks or shorelines composed of saturated clean sand. The destabilized sand usually flows into an adjacent body of water. Wet sand flows are not common in Wyoming. Rapid earth flows, also called quick clay flows, are very rapid flows that involve the liquefaction of subjacent material and the entire slide mass. They usually initiate in sensitive materials, such as quick clay, and are not common in Wyoming. Mud flows are slurry flows composed of earth and a significant amount of water. They differ from debris flows only in the size of their component materials.

Most landslides mapped in Wyoming are classified as being complex. For example, many landslides in the state are slump/earth flow complexes. That type of landslide is composed of a slump at its head, with the main body and deposit being an earth flow. Block slides often grade into rock slides, which can further grade into earth flows or debris laden earth flows. Such a movement would be classified as a block slide/rock slide/flow complex.

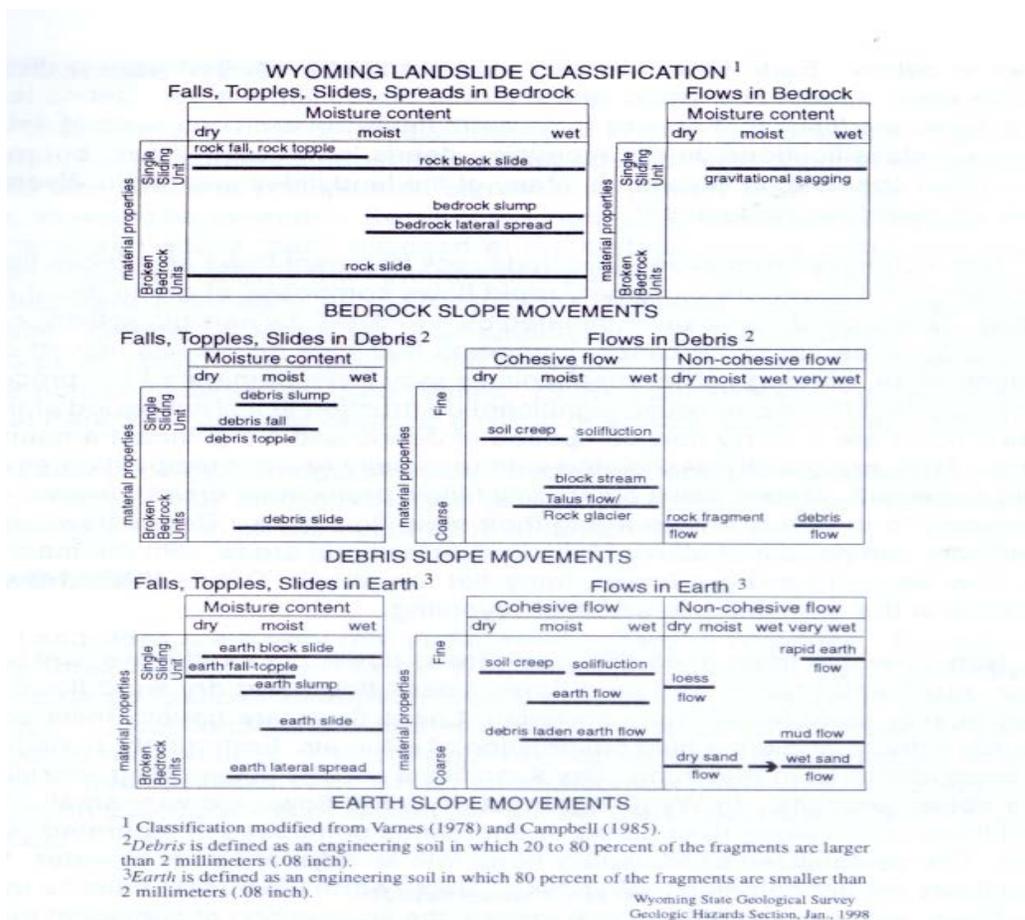


Figure 10.2 Wyoming Landslide Classifications

History and Distribution

Numerous landslides are present in Crook County. Specifically, landslides are present on the following USGS 1:24,000 scale topographic map Quadrangles:

Aladdin

Alva

Arrowhead Reservoir

Antelope Gulch

Beulah

Black Hills

Carlile

Cedar Ridge

Devils Run

Devils Tower

Duling Hill

Edith Creek

Gaff Creek

Garland Hill

Grasshopper Butte

Hulett

Inyan Kara Mountain

Kruger Lake

Linden

Middle Creek Butte

Missouri Buttes

Moore Hill
Mona
New Haven
Pfeiffer Hill
Red Canyon Creek
Rozet NE
Schoolmarm Butte
Seely
Sheldon Creek
Sherrard Hill

Strawberry Hill
Stoney Point
Slaughter Reservoir
Sugarloaf Mountain
Sundance East
Sundance West
The Notch
The Rocks
Wonder View
Wood Canyon

All Quadrangles were examined by the Wyoming State Geological Survey and Crook County Emergency Management, and the following areas were determined to pose a potential hazard to homes, roads, or other facilities.

Alva Quadrangle: Several blockslide/flow complexes are located near the town of Alva and near the main roads leading into Alva (T54N R63W Sections 5, 8, 9, 10, 15, 16, 17, 20). If these landslides destabilize, damage could occur to nearby structures, State Route 24, or the road south of Alva that follows Lame Jones Creek. Heavy periods of precipitation or significant development could have an effect on slope stability.

Black Hills Quadrangle: Several blockslide/slump complexes are located near Cook Lake (T53N R63W Section 10), and a blockslide/slump/flow complex is present in the southeastern part of the quadrangle (T52N R63W Section 3). A road actually crosses through the southeastern landslide. If these landslides destabilize, damage could occur to the nearby roads. Landslides could also damage or destroy Cook Lake and/or the Cook Lake Dam. Heavy periods of precipitation or significant development could have an effect on slope stability.

Carlile Quadrangle: A blockslide/slump complex is located approximately one mile northeast of Carlile (T52N R66W Section 16). If this landslide destabilized, damage could occur to the nearby road. A blockslide/slump complex is also present on the northern edge of Keyhole Reservoir. If this landslide destabilized, it could be hazardous for boaters, campers, and fishermen in the area. Heavy periods of precipitation or significant development could have an effect on slope stability.

Devils Tower Quadrangle: A rock fall/rock slide/talus flow complex is located at Devils Tower National Monument in T53N R65W Section 7. If part of this complex were to destabilize, damage could occur to nearby structures and may pose a risk to tourists. In addition, several blockslide/slump complexes are present along State Highway 24 and the county road paralleling Lytle Creek (T53N R65W Sections 9, 16, 20, 22, 23, 26, 28, 29, 32). If these landslides destabilize, damage could occur to the nearby roads. Slope stability may be affected by heavy periods of precipitation or significant development.

Duling Hill Quadrangle: A debris flow/alluvial cone/slope wash complex is located in the south-central part of the quadrangle (T50N RR62W Section 33). If this landslide

destabilized, damage could occur to State Route 585. Slope stability may be affected by heavy periods of precipitation or significant development.

Hulett Quadrangle: Numerous blockslide/slump and slump/flow complexes are present along Blacktail Creek (T54N R64W Sections 19, 28, 29, 30, 33 and T54N R65W Section 13, 24) and Whitetail Creek (T54N R65W 25, 26, 35, 36). If these landslides destabilize, damage could occur to nearby roads and structures. In addition, a series of blockslide/slump complexes are present along an unnamed creek in T54N R64W Sections 2, 3, 4, 9, 10, and 11. If any of these landslides destabilize, damage could occur to nearby State Highway 24 and/or nearby structures. Slope stability may be affected by heavy periods of precipitation or significant development.

Kruger Lake Quadrangle: There is a blockslide/slump/flow complex and a blockslide on the east side of Pine Creek Reservoir. If they destabilize, damage could occur to the reservoir and dam. Slope stability may be affected by heavy periods of precipitation or significant development.

Linden Quadrangle: A blockslide/flow complex is located along Inyan Kara Creek (T49N R64W Section 2 and T50N R65W Section 35). Farther north, a blockslide/slump/flow complex and a blockslide/flow complex are present near Beaver Creek (T50N R64W Sections 23 and 26). The nearby road cuts through all three of these landslides. If these landslides destabilized, damage could occur to this road and/or nearby structures. Slope stability may be affected by heavy periods of precipitation or significant development.

Missouri Buttes Quadrangle: Two large blockslides occur on the north and south sides of Left Creek in T53N R66W Sections 21, 27, and 28. If these blockslides destabilize, they could potentially dam Left Creek. A blockslide/rockslide/slump/flow complex is present on the east side of Missouri Buttes Lake. If the landslide destabilizes, the lake could be severely damaged or destroyed. Slope stability may be affected by heavy periods of precipitation or significant development.

Moore Hill Quadrangle: Multiple blockslide/slump and slump/flow complexes occur in the northeastern (T55N R65W Section 26 and 27), western (T54N R66W Section 11, 12, 24), and southeastern (T54N R65W Section 26 and 27) portions of the quadrangle. If these landslides destabilize, damage could occur to nearby structures and roads, including State Highways 24 and 112. Slope stability may be affected by heavy periods of precipitation or significant development.

Mona Quadrangle: Several blockslide/rockslide/slump complexes are present in the southwestern corner of the quadrangle (T55N R64W Sections 1, 11, 12, 13). If these landslides destabilize, damage could occur to the nearby county road that parallels Beaver Creek. Slope stability may be affected by heavy periods of precipitation or significant development.

New Haven Quadrangle: Two blockslide/rockslide complexes and one flow are located near a road in the southeastern corner of the quadrangle (T54N R66W Sections 15, 22, 23). If these landslides destabilize, damage could occur to nearby structures and the road through Barlow Canyon. Slope stability may be affected by heavy periods of precipitation or significant development.

Pfeiffer Hill Quadrangle: A blockslide/rockslide/flow complex is located near State Highway 116 in the southeastern portion of the quadrangle (T50N R63W Sections 34 and 35). If this landslide destabilizes, damage could occur to the highway. Slope stability may be affected by heavy periods of precipitation or significant development.

Seely Quadrangle: Several blockslide/slump complexes are located approximately 2-3 miles south of Seely (T55N R65W Sections 1, 2, 11, 12). If these landslides destabilize, damage could occur to State Highway 112. Slope stability may be affected by heavy periods of precipitation or significant development.

Sherrard Hill Quadrangle: Numerous blockslide/slump, blockslide/rockslide/slump, and blockslide/flow complexes are present near roads (T52N R64W Sections 2, 3, and 4, T53N R64W Sections 3, 10, 14, 15, 22, 23, 28, 30, 31, 32, 33, and 34, and T54N R64W Section 34). The road bordering Lytle Creek cuts through the landslides in several places. If the landslides on this quadrangle destabilize, damage could occur to nearby structures and roads. In addition, landslides along Lytle Creek could dam the creek if they destabilize. This would pose a hazard to downstream residents if the dam breaks. Slope stability may be affected by heavy periods of precipitation or significant development.

Sugarloaf Mountain Quadrangle: Numerous blockslide/rockslide, blockslide/flow, blockslide/rockslide/flow, and slump/flow complexes are located near roads in this quadrangle (T53N R62W Sections 16, 17, 18, 29, 30, 31 and T53N R63W Sections 13, 24, 25). If these landslides destabilize, nearby roads could be damaged. It is also remotely possible that the landslides may dam North Redwater Creek or Redwater Creek. Downstream structures could be damaged if landslide dams form and then rupture. Slope stability may be affected by heavy periods of precipitation or significant development.

Sundance West Quadrangle: Several blockslide/slump complexes are present approximately 3-4 miles west of Sundance (T51N R63W Section 17). U.S. Highway 14 cuts through one of the landslides. If the landslides destabilized, damage could occur to the highway. In addition, a blockslide/slump complex on the eastern side of Coal Mine Hill (T51N R63W Section 19 and T51N R64W Section 24) poses a threat to nearby structures if it were to destabilize. The slump and the blockslide/slump complex northwest of Sundance in T51N R63W Section 4 may damage nearby roads and campgrounds if they were to destabilize. A slump complex in T52N R63W Section 18 and a blockslide/flow complex in T52N R64W Section 13 are present along a county road. If the landslides destabilize, the county roads could be damaged. Slope stability may be affected by heavy periods of precipitation or significant development.

The Notch Quadrangle: There are a series of blockslide/rockslide/flow, blockslide/slump/flow, rockslide/slump, and blockslide/flow complexes along Miller Creek, South Fork Miller Creek, Middle Fork Miller Creek, and the North Fork Miller Creek. If any of the landslides destabilize, they could dam the nearby creeks. Slope stability may be affected by heavy periods of precipitation or significant development.

The Rocks Quadrangle: Several blockslide/slump and blockslide/slump/flow complexes are located along U.S. Highway 14 in the western and northwestern areas of the quadrangle (T51N R65W Section 2 and T52N R65W Sections 13, 14, 23, 24, 25, 35). If these landslides destabilized, damage may occur to the highway Slope stability may be affected by heavy periods of precipitation or significant development.

Wonder View Quadrangle: Several blockslide/slump/flow complexes are present in the northern and western portion of the quadrangle (T52N R65W Sections 16,17,18,31 and T52N R66W Sections 25 and 36). A slump is also present approximately one mile northwest of Wonder View in T52N R65W Section 35. If any of these landslides destabilized, damage may occur to nearby roads. Slope stability may be affected by heavy periods of precipitation or significant development.



Figure 10.3 Old slide area on State Highway 14 between Sundance and Devils Tower

Mapped landslides for Crook County are shown on the figure below.

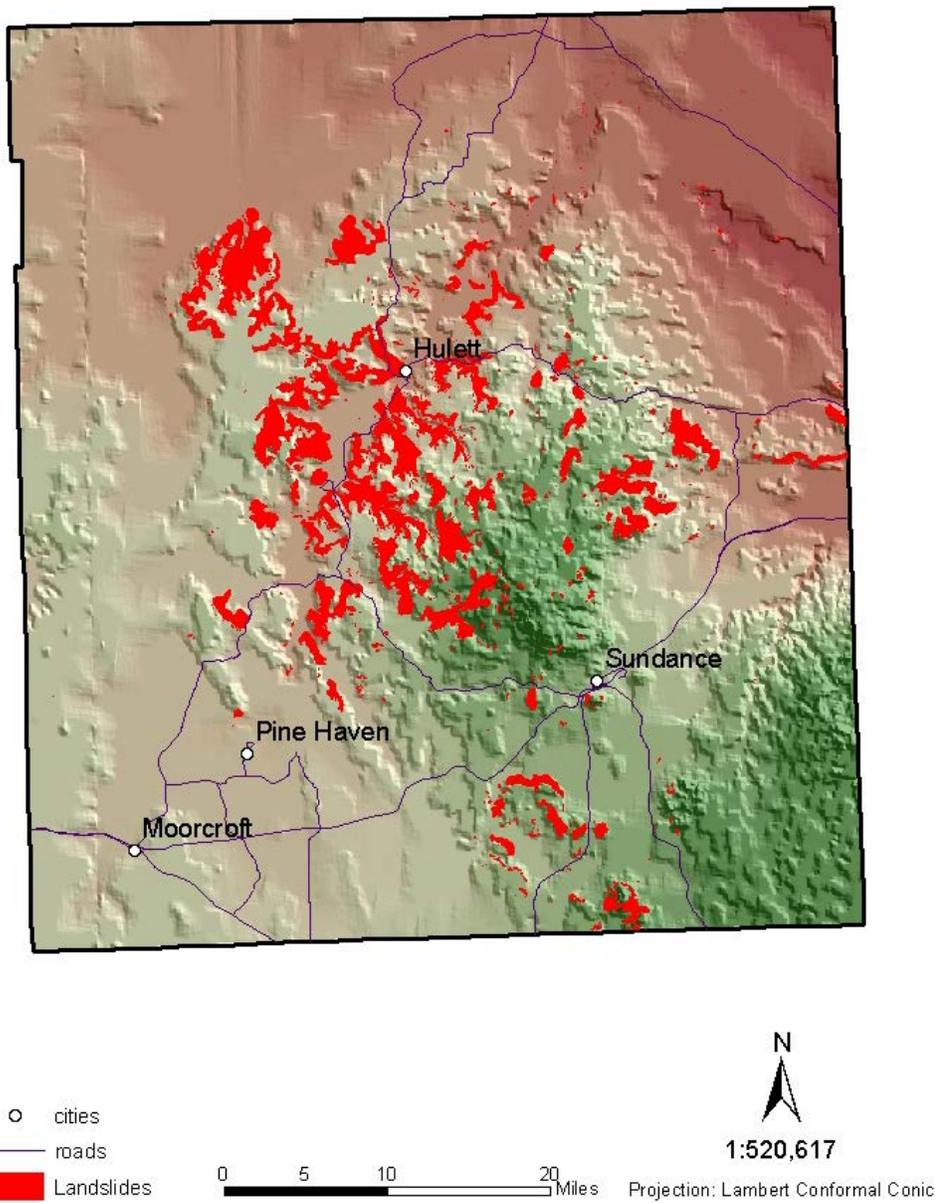


Figure 10.4 Mapped Landslides in Crook County

Impacts

Between 2004 and 2012, WYDOT spent an estimated \$7.8 million in Crook County to fix three slide areas that have damaged state highways. There is still ongoing work on a major slide near Devils Tower. Landslides can also damage utility lines and disrupt services.

Future Impacts

There are three measures of future landslide impacts – historic dollar damages, estimated yearly damages, and building exposure values. There are not enough current data to reasonably estimate historic or yearly dollar damages.

For the 2008 Wyoming Multi-Hazard Mitigation Plan, the WSGS calculated the building exposure value for buildings that may occur in or within 100 feet of a mapped landslide. All landslides mapped in Wyoming have been digitized. The landslides then had a 100-foot buffer digitally added to the outside of the landslides. The modified landslides were then digitally crossed with census block building values. In some cases, a landslide boundary will dissect a census block. In that case the proportional value of buildings in the census block will be assigned to the landslide. If a census block is within a landslide, then the values of all the buildings in the census block is assigned. The values derived by county are shown in Figure 10.5 below. Table 10.1 shows the ranking of counties based upon landslide building exposure values.

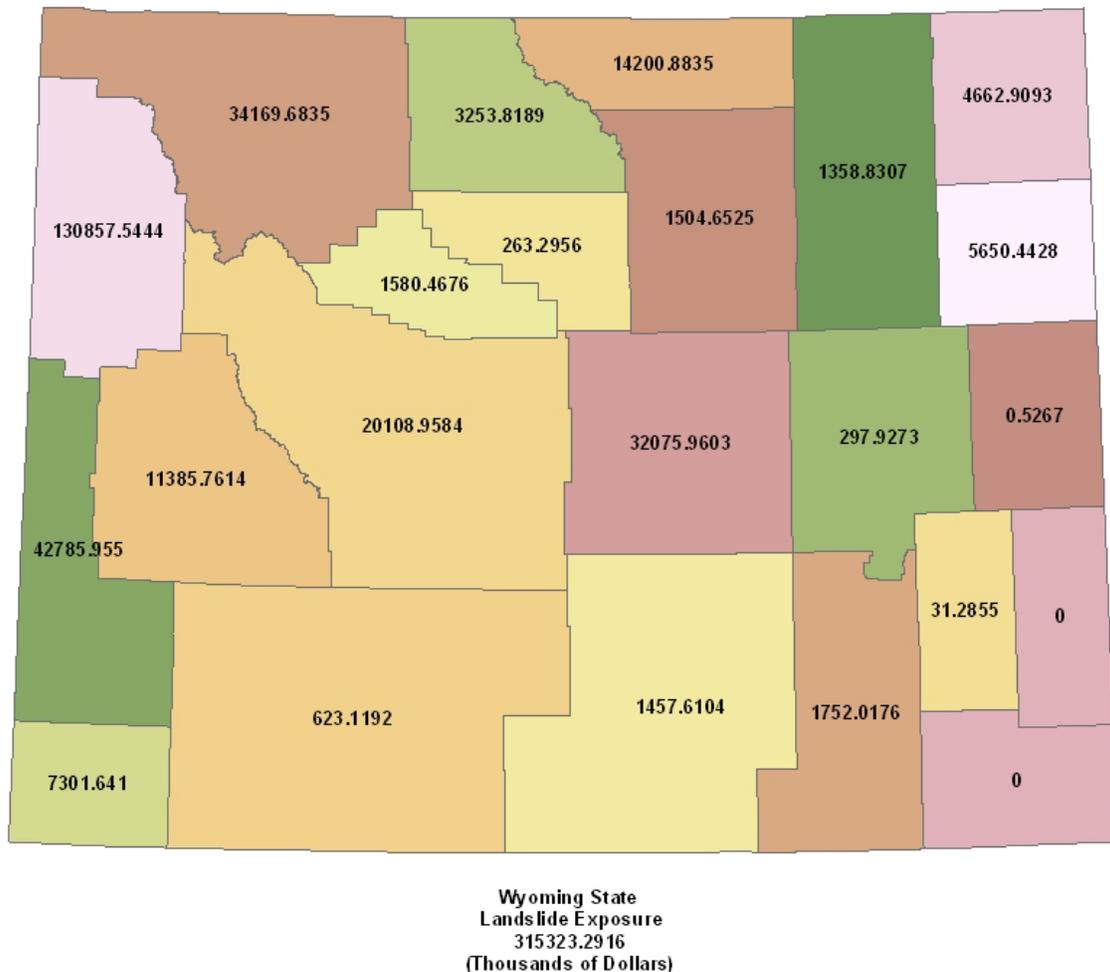


Figure 10.5 Wyoming Landslide Exposure by County

As can be seen above, there is approximately \$4.6 Million in building value that is built on or near landslides in Crook County. More detail for the County is provided in Figure 10.6.

Crook County Landslides Building Exposure Values

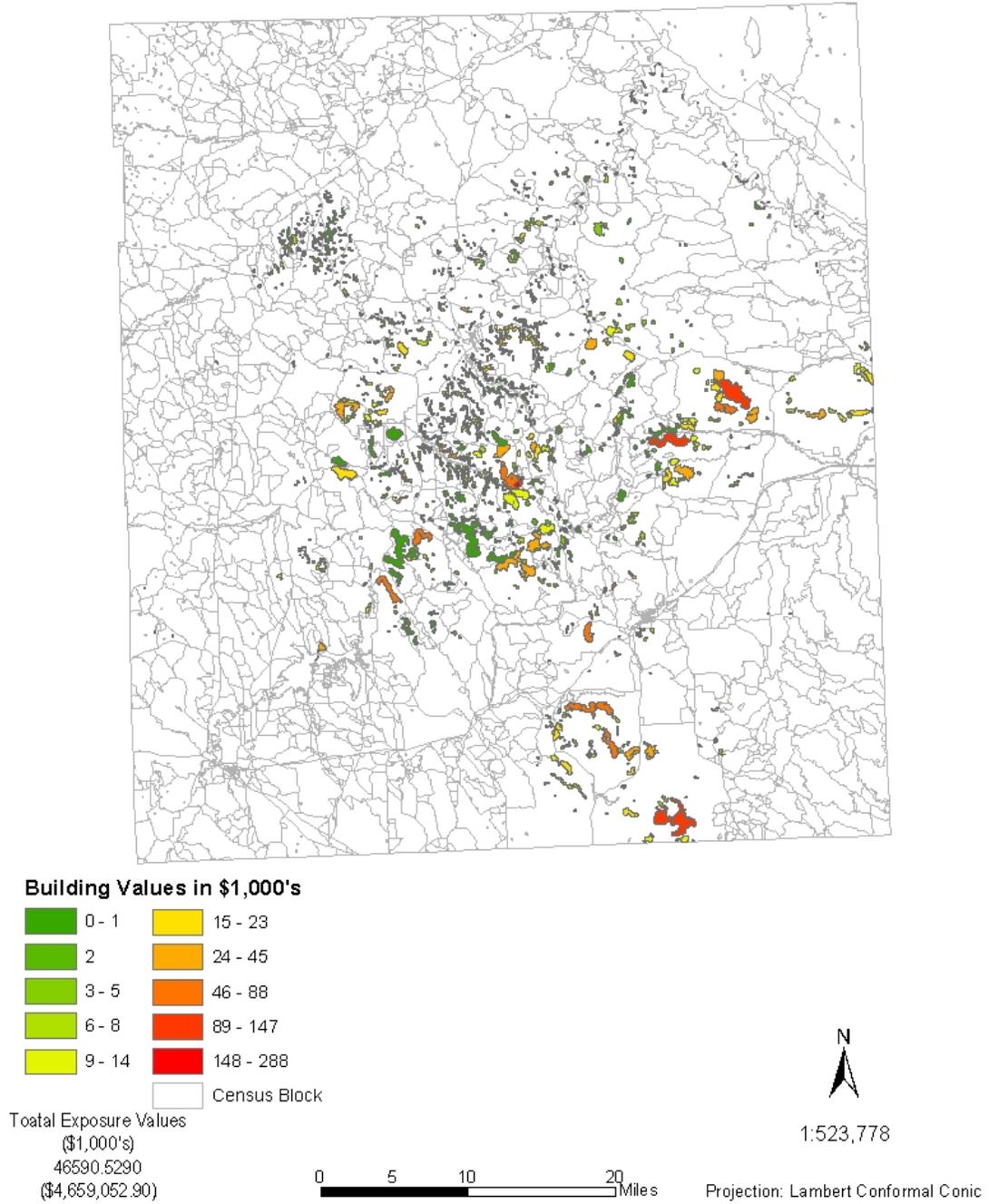


Figure 10.6 Wyoming Landslide Exposure in Crook County

Table 10.1 Building Exposure Values for Landslides	
County	Landslide Building Exposure Value (USD)
Teton	130,857,545
Lincoln	42,785,955
Park	34,169,685
Natrona	32,075,960
Fremont	20,108,960
Sheridan	14,200,885
Sublette	11,385,760
Uinta	7,301,640
Weston	5,650,450
Crook	4,662,910
Big Horn	3,253,820
Albany	1,752,020
Hot Springs	1,580,470
Johnson	1,504,650
Carbon	1,457,610
Campbell	1,358,830
Sweetwater	623,120
Converse	297,930
Washakie	263,295
Platte	31,285
Niobrara	525
Goshen	0
Laramie	0
Total	315,323,305

This information was re-analyzed and refined during the 2012 development of the Crook County HMP using assessors data as the source for structure valuations. The results of an overlay analysis of improved parcels with the landslide hazard data revealed a smaller value of \$1.5 M exposed. These results are shown in more detail in the following table.

Table 10.2 Building Exposure Values for Landslides				
City	Landslide	Property Type	Property Count	Improved Value
Unincorporated	Yes	Agricultural	14	\$373,667
Unincorporated	Yes	Commercial	1	\$231,804
Unincorporated	Yes	Residential	10	\$932,666
		Total	25	\$1,538,137

The probability of a landslide causing damage in Crook County is difficult to determine because of the poor historic data.

Based on the geologic studies, future impacts are likely to affect transportation corridors, reservoirs, and the occasional structure in the county. There is also a remote possibility that many smaller creeks within the county could be dammed by landslide activity. This could create a flash flood hazard downstream if the landslide dam fails or is overtopped. Heavy periods of precipitation or significant development could have an effect on slope stability in the mapped hazard areas.

Summary

PROPERTY AFFECTED: Low

POPULATION AFFECTED: Low

PROBABILITY: High

JURISDICTION AFFECTED: Portions of unincorporated County, Hulett and Sundance area