LANDSLIDE, MUD/DEBRIS FLOW, AND ROCKFALL

DESCRIPTION

Landslides, mud flows, debris flows, and rockfalls are among many geologic and soil hazards that impact Colorado.

Landslides are the downward and outward movement of slopes composed of natural rock, soils, artificial fills, or combinations thereof. Common names for landslide types include slump, rockslide, debris slide, lateral spreading, debris avalanche, earth flow, and soil creep (*Colorado Natural Hazards Mitigation Plan*, 2013*)*. Landslides move by falling, sliding, and flowing along surfaces marked by differences in soil or rock characteristics. A landslide is the result of a decrease in resisting forces that hold the earth mass in place and/or an increase in the driving forces that facilitate its movement. The rates of movement for landslides can be very quick (tens of feet per second) or very slow (fractions of inches per year). Landslides can occur as reactivated old slides or as new slides in areas that have not previously experienced them. Areas of past or active landslides can be recognized by their topographic and physical appearance. Areas susceptible to landslides but not previously active can frequently be identified by the similarity of geologic materials and conditions to areas of known landslide activity (p. 3-267 to 3-270).

A **mud flow** is a mass of water and fine-grained earth materials that flows down a stream, ravine, canyon, arroyo, or gulch. If more than half of the solids in the mass are larger than sand grains—-rocks, stones, boulders—the event is called a **debris flow**. Debris and mud flows are combinations of fast-moving water and great volumes of sediment and debris that surge down a slope with tremendous force. They are similar to flash floods and can occur suddenly without time for adequate warning. When the drainage channel eventually becomes less steep, the liquid mass spreads out and slows down to form a part of a debris fan or a mud flow deposit. In the steep channel itself, erosion is the dominant process as the flow picks up more solid material. Any given drainage area may have several mud flows a year, or none for several years or decades. They are common events in the steep terrain of Colorado and vary widely in size and destructiveness. Extreme amounts of precipitation in a very short period of time (e.g., cloudbursts) and flash floods are the usual sources for creating a mud flow in Colorado (p. 3-268 to 3-270).

Rockfalls are a newly detached mass of rock falling from a cliff or down a very steep slope. Rockfalls are the fastest type of landslide and occur most frequently in mountains or other steep areas during early spring when there is abundant moisture and repeated freezing and thawing. Ice wedging, root growth, or ground shaking, as well as a loss of support through erosion or chemical weathering may start the fall (p. 3-269 to 3-270).

2011 landslide along West Mosquito Creek in Park County, Colorado.

Source: Colorado Geological Survey, photo by Division of Reclamation and Mining.
coloradogeologicalsurvey.org/geologic-hazards/landslides-2/colorado-landslide-inventor/

LANDSLIDE, MUD/DEBRIS FLOW AND ROCKFALL IN COLORADO

Land movement related to landslides, mud and debris flows, and rockfalls occurs naturally across Colorado on a continuous basis, and can also be triggered through human activity (primarily related to mining, land development, and other disturbances). These events can occur at any time of the year from almost any location along a slope; however, because they are correlated with elevation change, these hazards largely occur in the mountainous region from the Front Range to the West Slope.

According to *READY Colorado*, it is estimated that there are thousands of landslides in Colorado each year, with varying degrees of frequency and severity. Most of these events do not result in casualties or property damage, though the annual damage in Colorado is estimated to exceed $3 million to buildings alone (*Colorado Natural Hazards Mitigation Plan,* 2013, p. 3-185). A massive landslide in a relatively unpopulated area of Mesa County near Grand Junction killed three people in 2014, leaving a swath of debris three miles long and ¾ of a mile wide. A deadly rockfall in September 2013 claimed five lives of a vacationing family following heavy rains near a popular hiking location near Buena Vista, Colorado (Shoichet, et al., 2013). Rockfalls are less frequent but remain a constant threat, particularly to Colorado's mountain roadways. All of these geologic hazards may endanger Colorado's built environment and can damage or destroy buildings, roads, and other infrastructure when proper land use or mitigation practices are not considered.

RELATED HAZARDS

Flash flooding or ongoing heavy rain can be precursors to landslides, mud/debris flows, and even rockfalls. Additionally, drought conditions may lead to soil compaction, and severe wildfire events may leave slopes denuded and hydrophobic. In these cases, a single heavy rain event can lead to higher volumes of runoff and correspondingly a higher risk for flash flooding, erosion, and especially mud/debris flows. Rockfalls are often caused by erosion of earth around larger rocks that then become loose and fall. Earthquakes can also lead to landslides and rockfalls.

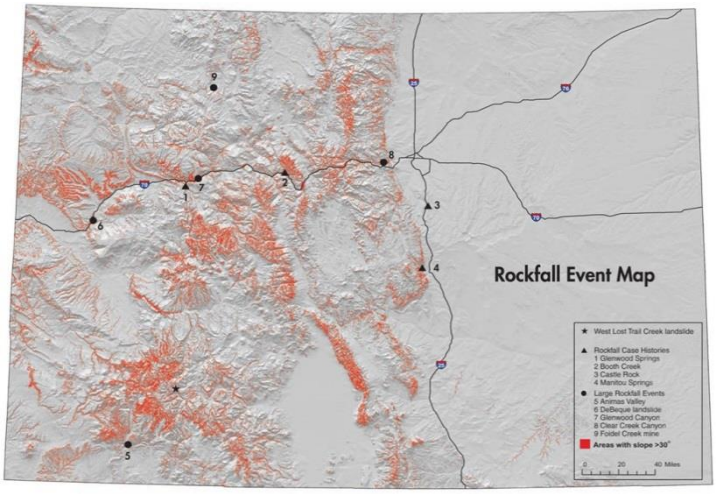
ASSESSING THE RISK OF GEOLOGIC AND SOIL HAZARDS

Nearly all geologic and soil hazards are highly localized events. The nature and extent of risk associated with each hazard is specific to local terrain conditions such as slope stability, vegetative cover, and geologic and soil composition beneath the earth's surface. In fact, much of what helps determine the level of hazard risk at a precise location are the features and process that lie underground. Other factors include seasonal, climate, and weather-related phenomena (including other hazards) that can alter the local conditions that affect an area's current risk. These variables make the identification, assessment, and mapping of geologic and soil hazards more difficult, especially for the purpose of designing and implementing planning tools or strategies. However, given the extreme danger these hazards pose, the knowledge and understanding of a site's geology is essential in order to adequately plan, design, and construct a safe development.

In recognition of this fact, the Colorado Geological Survey (CGS) provides a range of services and resources to assist and advise local planners on geologic hazards, including the review of preliminary plans or reports for new development as well as conducting studies, collecting geologic information, and publishing maps, reports, and bulletins with regard to land use activities.

Still, while a variety of relevant national and statewide data exists to determine hazard risk in a very general sense (including geologic, topographic, and soil maps), most Colorado communities do not have readily accessible information or detailed maps necessary for implementing local regulations. Doing so often requires field surveys and even geotechnical tests by trained earth scientists to identify specific problems associated with land development and public safety.

Consultation with geologists and other experts familiar with local conditions is an important first step for local planners seeking to assess the risk of their community and specific areas that are susceptible to geologic and soil hazards. The CGS and other official sources can provide map information on levels of risk, past hazard events, and the probability of future events. More site-specific data and mapping, however, will need to be obtained through technical studies for specific areas of concern. Communities may opt to hire a consulting geologist or geotechnical engineer to perform this work, or require such expert studies as part of the local development permitting process.



The Colorado Geological Survey's "Rockfall Event Map" identifies locations of historic rockfall events along with steeply sloped areas that are more susceptible to future occurrences.

As summarized in Chapter 2, there are several state statutes and regulations that specify requirements for the submission of geologic suitability reports in conjunction with land use applications to be reviewed by CGS.[1] Other statutes address the manner in which geologic and soil hazards are to be addressed by developers and local governments, including but not limited to hazard analyses and site recommendations.

At a minimum, planners should have a general understanding of where geologic and soil hazards exist and what their implications are for safe development so that the viability of available planning tools and strategies to reduce their risk can be further evaluated. Ideally, using this information, most communities should be able to prepare a map of the entire community that distinguishes particular areas of concern. This type of map can help planners and decision makers identify areas that are generally less desirable for future development and may require further technical study, along with smaller-scale maps for implementing regulations or requiring closer examination during the review of development proposals.

[1] Senate Bill 35 (1972)-3 requires subdividers to submit reports concerning geologic characteristics and any soil or topographic conditions that present hazards or require special precautions. House Bill 1041 requires that all developments in areas designated by counties as geological hazard areas be engineered and administered in a manner that will minimize significant hazards to public health and safety or to property. House Bill 1045 (1984)-4 requires school districts to submit reports regarding geologic suitability for raw land purchases, new school plans, and improvements to existing schools to the CGS for review.

AVAILABLE DATA SOURCES

Geologic hazards such as landslides, mud and debris flows, and rockfalls are sporadic and somewhat unpredictable; however, geologic studies can determine historic runs and existing movement in the earth suggesting movement is occurring or imminent.

Colorado Geological Survey

The Colorado Geological Survey is the primary State agency for providing information and maps on geologic hazards such as landslides, mud/debris flows, and rockfall. Additionally, the Colorado Landslide Hazard Mitigation Plan and the Colorado Landslide Viewer are useful tools addressing these hazards locally. coloradogeologicalsurvey.org

- Landslides - coloradogeologicalsurvey.org/geologic-hazards/landslides-2
- Mud/debris flow - coloradogeologicalsurvey.org/geologic-hazards/debris-flows-fans-mudslides
- Rockfall - coloradogeologicalsurvey.org/geologic-hazards/rockfall
- Landslide Hazard Mitigation Plan - store.coloradogeologicalsurvey.org/product/colorado-landslide-hazard-mitigation-plan
- Colorado Landslide Viewer - coloradogeologicalsurvey.org/geologic-hazards/landslides-2/colorado-landslide-inventory
- Through the CGS's ongoing STATEMAP program, new geologic map information is becoming more readily available and more frequently incorporated into local and countywide decision-making. CGS also manages a GIS library of digital geologic data that can be combined with local datasets to better understand the relationship between community assets and areas of potential hazard concern. coloradogeologicalsurvey.org/geologic-mapping/statemap-program

United States Geological Survey (USGS)

USGS is the primary federal reference for national data regarding these hazards. The USGS Landslides Hazards Program provides several useful resources related to these hazards including the USGS Landslide Overview Map of the Conterminous United States.

- Landslide program - landslides.usgs.gov
- Landslide overview map - landslides.usgs.gov/hazards/nationalmap

Colorado Department of Transportation

The Colorado Department of Transportation, Materials and Geotechnical Branch, manages the state's soils and rockfall program. This agency is responsible for the Rockfall Mitigation Project Plan (RMPP), which includes a list of the 756 rockfall sites identified in Colorado as having chronic rockfall problems. codot.gov/business/designsupport/materials-and-geotechnical

APPLICABLE PLANNING TOOLS AND STRATEGIES

In addition to the tools and strategies cited below that are profiled in this guide, **hillside development standards** are also important tools for reducing potential risks from landslides and similar hazards. Hillside standards often include limitations on grading and earth removal and standards for site improvements such as retaining walls.

APPLICABLE PLANNING TOOLS AND STRATEGIES – LANDSLIDE, MUD/DEBRIS FLOW, AND ROCKFALL	
Addressing Hazards in Plans and Policies	• Comprehensive plan • Climate plan • Hazard mitigation plan • Parks and open space plan • Pre-disaster planning
Strengthening Incentives	• Development agreement • Density bonus • Transfer of development rights
Protecting Sensitive Areas	• 1041 regulations • Cluster subdivision • Conservation easement • Land acquisition • Overlay zoning • Stream buffers and setbacks
Improving Site Development Standards	• Stormwater ordinance • Site-specific assessment • Subdivision and site design standards • Use-specific standards
Improving Buildings and Infrastructure	• Building code • Critical infrastructure protection
Enhancing Administration and Enforcement	• Application submittal requirements • Post-disaster building moratorium