Bureau of Reclamation
Missouri Basin Region
Geology and Exploration Services Group

June 18, 2025

TRAVEL REPORT

To: Area Manager, Eastern Colorado Area Office
EC-1000 (JRieker)
Missouri Basin Region

From: [redacted]

Subject: Inspection of New Landslide at Green Mountain Dam, Colorado

1. [redacted]

2. **Travel Period:** May 5th to May 9th, 2025

3. **Places Visited:** Green Mountain Dam, Colorado

4. **Purpose of Trip:** The purpose of the trip was to inspect and photograph the recent 2025 landslide above the left abutment powerplant access road.

5. **Synopsis of Trip:** On May 5th, we flew from Billings, MT to Denver, CO, and then drove to Green Mountain Dam where we met with the powerplant supervisor and a VP study team from TSC to inspect the new landslide. We spent the night in Silverthorne, CO. The next day, C. Clark and I returned to Green Mountain Dam to inspect the right abutment access road and a rockfall area above the inlet gates, then stayed the night in Lakewood, CO. On May 7th and 8th, we participated in the VP study at TSC while staying in Lakewood, CO. We drove home to Billings, MT on May 9th.

6. **Report of Findings:**

Location and General Description of Green Mountain Reservoir:

Green Mountain Dam and Reservoir are located on the Blue River in Summit County, Colorado. The Blue River flows north-northwest out of Dillon Reservoir to its junction with the Colorado River near Kremmling, Colorado. Green Mountain Dam and Reservoir are located on the Blue River approximately 13 miles southeast of Kremmling, Colorado. The dam and reservoir are major features of the Colorado-Big Thompson Project and provide storage for irrigation water for the Colorado River, power generation, and recreation.

The purpose of this trip was to inspect the recent landslide above Summit County Road 1812 (CR 1812), located downstream of the left abutment above the spillway of Green Mountain Dam. This road serves as access to the Green Mountain Powerplant and the Blue River boat drop-in (Figure 1).

Site Geology:

There are Jurassic, Cretaceous, Tertiary, and Quaternary formations in the left valley wall downstream of the dam near County Road 1812. Mesozoic sandstone, limestone, and shale, and Tertiary trachyte is mantled with Quaternary surficial deposits including glacial drift (outwash and till), and colluvium that is derived from glacial sediments.

- The Quaternary Glacial Drift (outwash and till) varies greatly in composition ranging from gravel and sand with silt and clay as matrix materials. Oversized cobbles and boulders are present and previously estimated in surface exposures to be about 30 percent by volume. Quaternary Units overlie bedrock units across the left abutment and slide area. Quaternary colluvium consists of reworked glacial sediments and is not differentiated.
- The Cretaceous Dakota Formation consists of thick, hard quartzose sandstone beds interbedded with carbonaceous shale and minor coal seams. The Dakota Formation crops out upstream of the right abutment, but the thickness of this unit varies considerably. Thin beds of Dakota sandstone overlie the Morrison upstream of the left abutment.
- Cretaceous shale formations including the Cretaceous Benton, Niobrara, and Pierre Formations outcrop upstream of the right abutment, but based upon preconstruction geology drawings do not appear to be involved in the slide area downstream of the dam.
- The Jurassic Morrison Formation is composed of calcareous shale, limey sandstone and limestone. The Morrison Formation is not exposed at the surface in the right abutment area and underlies a mantle of unconsolidated sediments.
- A Tertiary trachyte porphyry has intruded the Morrison Formation. This volcanic rock locally intruded into sedimentary rocks. This formation forms a prominent cliff downstream of the dam, below the powerplant access road.
- Quaternary Landslide Deposits: There is a history of landslide activity in the Blue River Valley and along the rim of Green Mountain Reservoir. At the dam, landslide activity has been noted as far back as construction of the dam. The presence of numerous landslides illustrates the potential for slope failures in the area. Much of the landslide deposits are reworked glacial material.

A prominent cliff of igneous trachyte rock is exposed in a horizontal cliff that outcrops along both sides of the river from the bottom of the spillway chute to the powerplant road bridge. The Jurassic Morrison Formation overlies the trachyte on the left valley wall. Reclamation drawings show that the Jurassic Morrison Formation is the primary bedrock unit along the powerplant access road downstream of the dam. In several locations a thin discontinuous bed of Cretaceous Dakota sandstone overlies the Jurassic Morrison Formation. The Mesozoic Formations are covered in a mantle of unconsolidated glacial and landslide sediments.

Description of the Slide Area and Slide History:

The powerplant access road, or Summit County Road 1812, is cut into the southwest valley wall and extends about 1/3 of a mile, approximately 1,700 feet, from the upper left abutment of the dam to the bottom of the hill. At the bottom of the hill the powerplant access turns east onto a bridge that crosses the Blue River tailrace to the powerplant. The short stretch of road from the bottom of 1812 to the powerplant is designated Summit County Road 1813 (Figure 1).

In March 2025, powerplant staff observed an increase in seepage attributed to spring runoff and periodic raveling of saturated soil and boulders onto the access road. The first movement of the slope was noted on March 3 following a warm spell that triggered rapid snowmelt. Several large boulders slid into the drainage ditch and onto the road. Debris from the road and drainage ditch was being removed until March 11, when an additional large movement made this unfeasible. In total, Reclamation staff and Northern Water Conservancy District (NWCD) removed approximately 150 cubic yards of slide debris from the area. The following day, March 12, powerplant staff installed jersey barriers along the toe of the slide. On March 25, the slope failed again and overtopped the jersey barriers, rendering the roadway impassible.

The access road was closed to the public on March 27 and remains closed as of June 2025. The slide scarp is approximately 60-70 feet wide at the base and has a 10- to 20-foot-tall active scarp. The difference in elevation from the road to the top of the scarp is 60 feet (Figure [redacted] 3).

This slide event littered the roadway with 4- to 10-inch diameter cobbles, and boulders 12-inch and larger. Additionally, other parts of the site contain very large boulders exposed in the access road cut slopes that pose a risk of falling from the hillside and impacting the access road below.

The road was constructed across a steep valley wall, resulting in a cut slope that was too steep for these soil and rock types to be stable when saturated. The slope along the access road is being further steepened by progressive undercutting and erosion. Bureau staff have repeatedly noted during field investigations that the slope can transport groundwater and materials downhill towards the access road.

The first reported slope failure above the road was in 2008, although during that investigation powerplant staff anecdotally noted that it was a reactivation of a slide from approximately 10 years prior. This 2008 slide is about 100 feet downstream from the 2025 slide scarp [redacted]. The 2025 slide is the second reported slope failure above the access road. There are other scarps seen above the access road, but many of these are remnants from the road construction and have been subject to steady erosion as opposed to rapid slope failure.

There are numerous landslides in the Green Mountain reservoir area. Although many slope failures can be attributed to natural geologic conditions and processes, they are also influenced by human activities and modifications to slopes. A list of possible factors that can contribute to landslides are discussed in Table 1.

Natural factors:	Anthropogenic factors:
• Geometry of the slope and surface topography	[redacted]
• Amount of vegetation	• Slope modifications
• Erosion rates	• Over-steepened or undercut slopes
• Volume of precipitation and snowmelt	• Poor or blocked surface drainage
• Groundwater levels and piezometric pressures	• Vibrations and weight loading from heavy equipment
• Permeability of geologic units	
• Physical properties of soil and rock	
• Bedding planes and geologic contacts	
• Faulting and weak zones in bedrock	
• Existing landslide scarps	
• Buttressing support at the toe of the slide	

Table 1: Potential factors that influence the stability of a slope.

Observations and Slide Characteristics:

Based upon what is exposed and observed at the surface, the recent slide was a translational debris slide of unconsolidated Quaternary sediments possibly involving the upper beds of bedrock. A rotational component is possible and could be evaluated with additional data.

The slide area's geology consists of unconsolidated glacial till with zones of clay or shale beds that have been incorporated into the slide and act as an impermeable layer. Perched water tables may develop on less pervious beds, allowing water to flow at shallow depths within the hillside (Figure 4). During the team's onsite visit, active water flow was noted approximately two-thirds up the landslide slope face. The flow was only seeping, but there was enough water exiting the scarp to saturate some of the slide debris covering the bottom half of the slope (Figure 5). The quantity was a fraction of the water exiting the scarp just after the large slope failure on March 11th (Figure 6) and in early April (Figure 4).

The unconsolidated materials in the scarp are a heterogeneous mix of clay, silt, sand, gravel, cobbles, and occasional boulders up to 24 inches in diameter (Figure 7). The material exposed in the scarp ranges from matrix supported to clast supported. Most of the material exposed in the scarp is a coarse-grained soil containing a high percentage of gravels, cobbles and boulders, however it varies widely throughout the slide area. Pockets of finer grained materials exist with only a trace of cobbles and boulders. Cobbles and boulders range from angular to subrounded and from hard sedimentary sandstone and crystalline rocks to soft decomposed shales. Some of the material is oxidized. Geologic investigations in the Heeney slide area in 2003 found a wide range of permeabilities in the glacial deposits. Therefore, some glacial sediments may create perched water tables or not adequately drain.

Several decomposed beds of displaced shale were observed in the scarp of the recent slide, indicating weathered shale bedrock units were also involved in the slide (Figure 7). Translational sliding can explain how shale blocks were incorporated into glacial deposits.

The recent slide appears to be within a larger, deeper-seated slide that predates this sliding event. Larger arcuate scarps at the crown with about 1-2 feet of displacement were noted between about 30-60 feet uphill of the head scarp of the 2025 slide [redacted]. The scarps were unvegetated indicating relatively recent offset, probably within the last 5 years (Figure 9). The displaced and highly weathered shale beds exposed in the landslide scarp also indicate that the recent slide could be part of a deeper-seated slide. This is concerning since the 2025 slide will have decreased the stability of the older slide, because it has removed some of the material supporting the toe, potentially reducing the slope materials' shear strengths.

A grove of aspen trees at the top of the head scarp indicates a perennial presence of groundwater directly upslope from the slide area (Figure 2). The aspen trees vary in age with trees ranging from about 10 to 30 feet tall. Some of the younger aspens, 10-20 feet tall, had distinctly bent trunks about 1-2 feet above the base of the trunk (Figure 10). This indicates a period of slumping that could have occurred within the last 5 years, estimating tree growth of several feet per year. Power poles cross the top of the slide were standing vertically with no indication of movement [redacted]. However, movement could be near vertical near the top of the slide area.

No springs were noted during this inspection. No standing water was found at the top of the slide during this inspection, but there was moisture within the reach of the roots. Thick grass above the scarp points to higher soil moisture content compared to the sparser vegetated areas along the slope. Some high plasticity clay soils and bentonitic shales may expand or contract in response to changes in moisture content. This can cause a plane of weakness and trigger movement in bedrock. Several of the bedrock shale units and surficial glacial deposits in the local bedrock units contain significant amounts of bentonite. The water that saturated the soils and caused the 2025 landslide likely derives from multiple sources which include, but aren't limited to, those described in Table 2.

Surface Water	Groundwater
• Surface runoff concentrated in a small swale by the local topography • Rapid snowmelt • Heavy or prolonged precipitation • Runoff from ditches along access road	• Perched and unconfined water tables • Natural springs or ponds • Ruptured buried water lines [redacted]

Table 2: Potential sources of water that caused oversaturation of the soils within the 2025 slide area

[redacted]

<u>Damage and Risk:</u>

The access road receives a high volume of traffic from Reclamation staff and the public. In the summer months vehicular and foot traffic is particularly high for recreational fishing and boating. [redacted]

There is evidence that this a progressive slide based upon additional 1- to 2-foot-tall scarps (unvegetated) above the recent scarp and shale beds incorporated into the slide debris. A progressive slide would result in increasingly larger slope failures as each subsequent [redacted] and decreases the strength of remaining slide materials. If the deeper-seated slide were to reactivate, larger slide volumes are possible. This larger slump could have a volume of 1,000-10,000 cubic yards of unconsolidated materials. If the slump involves the upper beds of the shale, the volume is larger and difficult to estimate.

A subsequent, larger slide at the 2025 slide area has the potential to engulf the road in slide debris, [redacted] deposit slide [redacted] or push a vehicle off the cliff into the tailwater. [redacted]

Conclusions:

The access road, constructed on a slide area both uphill and potentially downhill, presents significant access and safety issues, ultimately leading to its closure to public vehicles and limiting personnel access [redacted]

[redacted] Another slide event would likely be triggered by the same factors as the recent one; an influx of groundwater or infiltrating surface water causing the oversaturation of poorly consolidated glacial soils. Further erosion of the slide scarp and slide debris could further undercut and destabilize the surrounding slope. The vertical scarp that resulted from the recent slide is not stable in its current condition even when dry.

[redacted]

Geologic information on the subsurface on the slide characteristics, water table, and geologic units is limited to preconstruction drawings for the dam construction and historical landslide reports. Assumptions on sliding mechanisms are made based upon this initial reconnaissance and documentation on previous slide events along the road and in the Heeney landslide area, and more information on the lithology of the slide area is necessary to fully understand the geology of the slide, the triggering mechanisms, and to develop successful long-term mitigation strategies.

Recommendations:

This slide should be added to the Missouri Basin Landslide Surveillance Program and monitored annually.

[redacted]

Geologic investigations should be performed to collect design data to determine the most effective way to stabilize the slide area. A list of geotechnical design data that would be useful to fully characterize the subsurface conditions is included in Table 3.

• Map the limits of the slide • Create topographic drawings • Create geologic cross sections • Identify and sample lithologic units in the subsurface of the slide area • Define the depth to bedrock • Map locations of slide planes	• Test physical properties of geologic units • Install observation wells or piezometers to establish water table or perched water tables. • Measure seasonal groundwater fluctuations • [redacted]

Table 3: Possible geotechnical data collection methods that could assist in mitigating the slope above CR 1812

Drill holes would be necessary to confirm material types, depth to bedrock, and the water table. Test pits may not be deep enough to provide adequate data and may encounter a water table that prevents excavation to required depths. Piezometers could be used to evaluate the influence of natural and manmade seasonal fluctuations and the canal operations on the groundwater table.

Construction or earthwork should be supervised by qualified geotechnical personnel to assure the stability of cuts and adequate compaction of fill material.

Steps should be taken to limit groundwater or surface water in the slide area. These could include adding horizontal drains to the slide area, controlling water from the cistern drainpipe, and fully lining the Elliot Creek Canal. Other man-made factors that could potentially introduce water to the slope should be identified.

A VP study was performed to assess possible alternatives to mitigate the slope above the powerplant access road and will be documented in a separate report. The mitigation alternatives proposed in the VP study were made with the goals of opening the road and reducing the risks or damage caused by future landslides in the area.

Figures

Figure 1 – An overview of the 2025 landslide area in relation to the Green Mountain Dam and Powerplant, the county roads, and the public Blue River boat drop in point. CR 1812, which is currently closed, is the only developed roadway that leads to the boat drop in.
Satellite imagery from Google Earth (2019)

[redacted]

[redacted]

Figure 3 – A northwest facing view of the recent landslide taken shortly after the initial slide prior to this site visit. There is a person in a blue jacket at the top of the slide, marked by an arrow, for scale. The head scarp is approximately 10-20 feet tall. Some cobbles and boulders are seen sliding down the slope. Photo by T. Kummer (USBR) – 3/17/2025

Figure 4 – A west facing view of the landslide taken prior to this site visit. Groundwater is seen exiting the slide in multiple areas along a similar plane. This plane is evidence of perched water tables bound by an impermeable layer of rock or soil.
Photo by T. Kummer (USBR) – 4/10/2025

Figure 5 – A photo of groundwater exiting from the slide face seen during our site visit. The water exiting the slide is creating an erosional channel and saturating slide deposits towards the toe. The amount of water seen during our visit was minor compared to the amount of water seen exiting the slope following the larger slide events in March and April.
Photo by P. Kohart (USBR) – 5/5/2025

Figure 6 – A west facing view of the landslide taken from the toe. There is a person in a blue jacket at the top of the slide, marked by an arrow. The head scarp is approximately 10-20 feet tall. Some cobbles and boulders are seen coming down the slope. The slide debris in the foreground has a soft and saturated consistency due to the amount of water exiting the slide face.
Photo by T. Kummer (USBR) – 3/17/2025

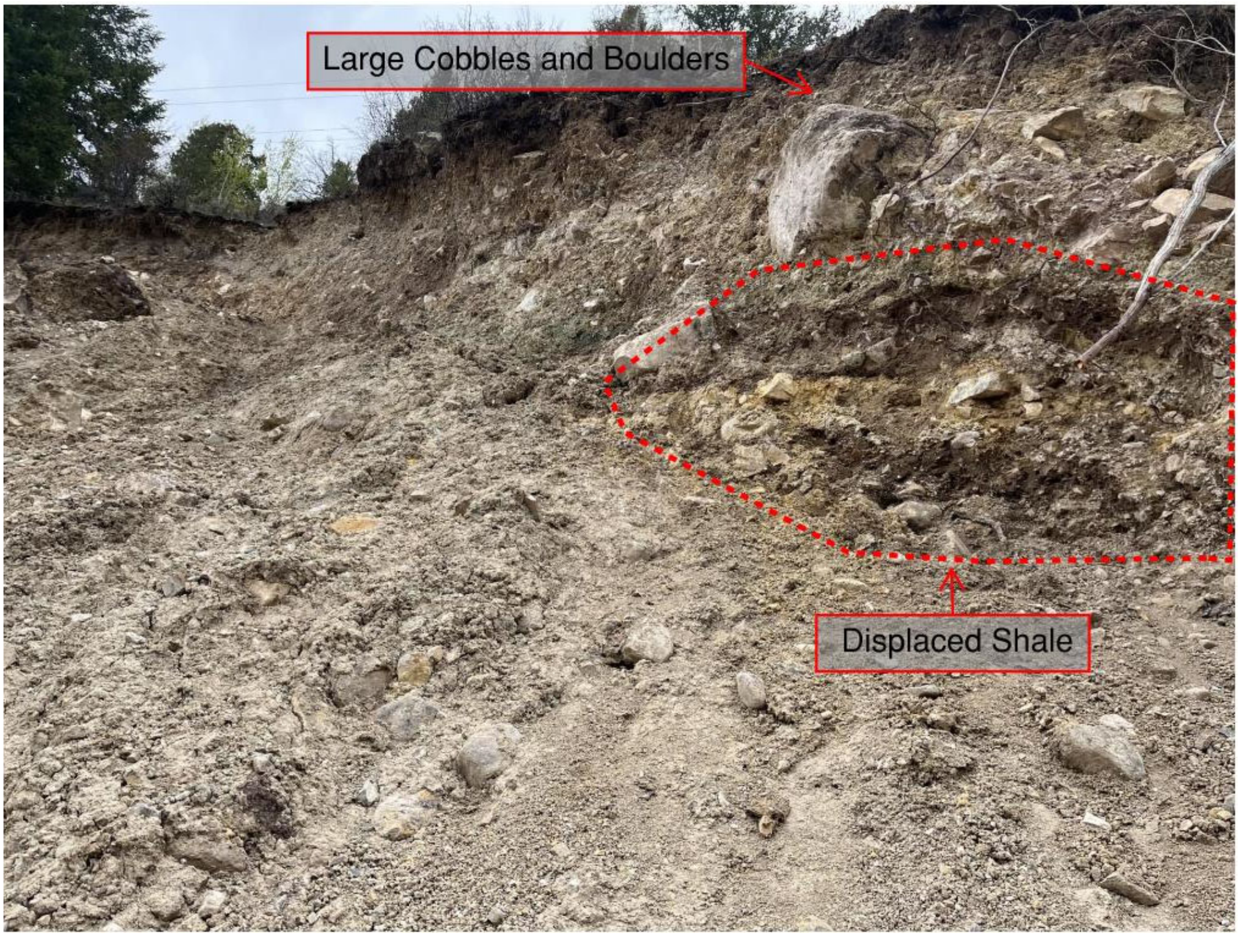

Figure 7 – A close up view of the slide materials in the right (northwest) flank of the recent 2025 slide scarp. Blocks of maroon and ochre displaced shale are circled on the right. This shale could have been incorporated into glacial materials by translational sliding. Also shown is the amount of variation within the size of material within the scarp, ranging from very fine clays and silts up to large boulders and cobbles.
Photo by C. Clark (USBR) – 5/5/2025

[redacted]

Figure 9 – A southwest facing view of one (less than 2 foot tall) scarp located above the major landslide area. Many small scarps forming a larger arc were seen above the recent slide area during our investigation. These indicate surficial material upslope from the powerplant access road is susceptible to soil creep. They could also possibly be along the failure plane of a future, larger rotational slide.
Photo by C. Clark (USBR) – 5/5/2025

Figure 10 – A southeast facing view of one warped tree located above the recent landslide area. This warping of the tree trunk shows that during growth the soil underneath has slumped downslope, and the tree had to bend to continue growing vertically. There were many warped tree trunks seen upslope of the slide area during this investigation. The age of the trees and the height of the bend in the trunk are evidence that the slope has been slumping within the last 5 years.
Photo by C. Clark (USBR) – 5/5/2025

[redacted]

[redacted]

[redacted]

[redacted]