DOE–EM/GJTAC1816

Office of Environmental Management – Grand Junction

UMTRA Project

Moab UMTRA Project
Hillside Geology Assessment

May 2009

U.S. Department of Energy

Office of Environmental Management

Prepared by the Technical Assistance Contractor under contract number DE-AC30-07CC60012 for the U.S. Department of Energy Office of Environmental Management, Grand Junction, Colorado.

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Revision 0

Review and Approval

5/21/09

Elizabeth Glowiak
TAC Hydrogeologist

Date

5/27/10

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Date

Revision History

Revision No.	Date	Reason/Basis for Revision
0	May 2009	Initial issue.

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1.0 Introduction

The Moab, Utah, Uranium Mill Tailings Remedial Action (UMTRA) Project (Moab site) is the site of a former uranium processing facility that was in operation from 1955 to 1984. Currently, 16 million tons of mill tailings remain on the site, which is approximately 500 feet (ft) west of the Colorado River. Transport of the tailings by rail to Crescent Junction, Utah, began on April 20, 2009.

In August 2008, the decision to move the tailings and mill debris to Crescent Junction by rail was finalized, and the hillside rail construction began in early October 2008. To load railcars on the northwest side of the Bootlegger Portal Tunnel (the portal) adjacent to the site, the rail line grade had to be decreased, and the rail line had to be moved laterally in toward the hillside.

1.1. Purpose and Scope

As observed during a flash flood in early July 2006, intense rain and freeze-thaw cycles have the potential to transport sand, gravel, and boulders downslope onto the rail line. The purpose of this hillside investigation is to identify locations that could create potential drainage, rockfall, and slumping hazards to the rail line. To monitor the hillside and identify potential hazard areas, a geologic map of the hillside was created; eight different locations were monitored for possible movement above the location of a slope failure in early February 2009.

The scope of this investigation is limited to the area above the rail line. Some limitations were associated with the accessibility of steep slopes.

1.2 Methods

A geologic map of the Moab Quadrangle, composed by the U.S. Geologic survey (USGS) in 2002, includes the hillside area adjacent to the portal. However, the 1:24,000 scale of the map was too large to include any specific detail associated with drainage or rockfall hazards. On March 11 and 12, 2009, Technical Assistance Contractor personnel mapped the geology of the hillside from the portal to the area immediately north of the cul-de-sac drainage area, approximately 2,206 ft to the northwest. The intent of the investigation was to document drainage channels that could pose a threat to property and to identify areas of bedrock versus areas of loose boulders.

For this investigation, the hillside slope above the rail line was divided into five different areas separated by drainage channels. For description purposes, a letter was assigned to each slope (A through E, from south to north, respectively), and a number was assigned to each drainage channel (1 through 4, from south to north, respectively) as shown in Photo 1. A description of each slope and drainage can be found in Section 2.1 of this report. Most southern slopes above the Honaker Trail cap rock area were deemed unsafe to map due to steepness and an unstable surface, so this area was mapped using the USGS Moab Quadrangle map and aerial photographs.

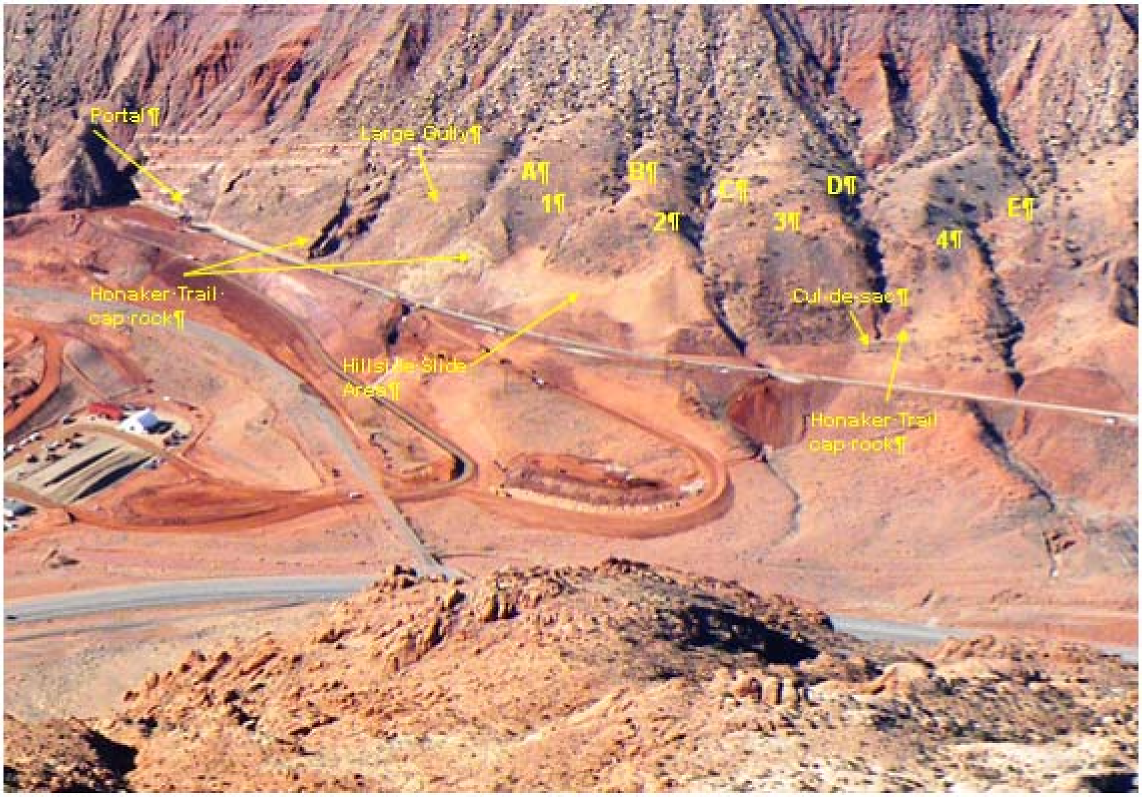


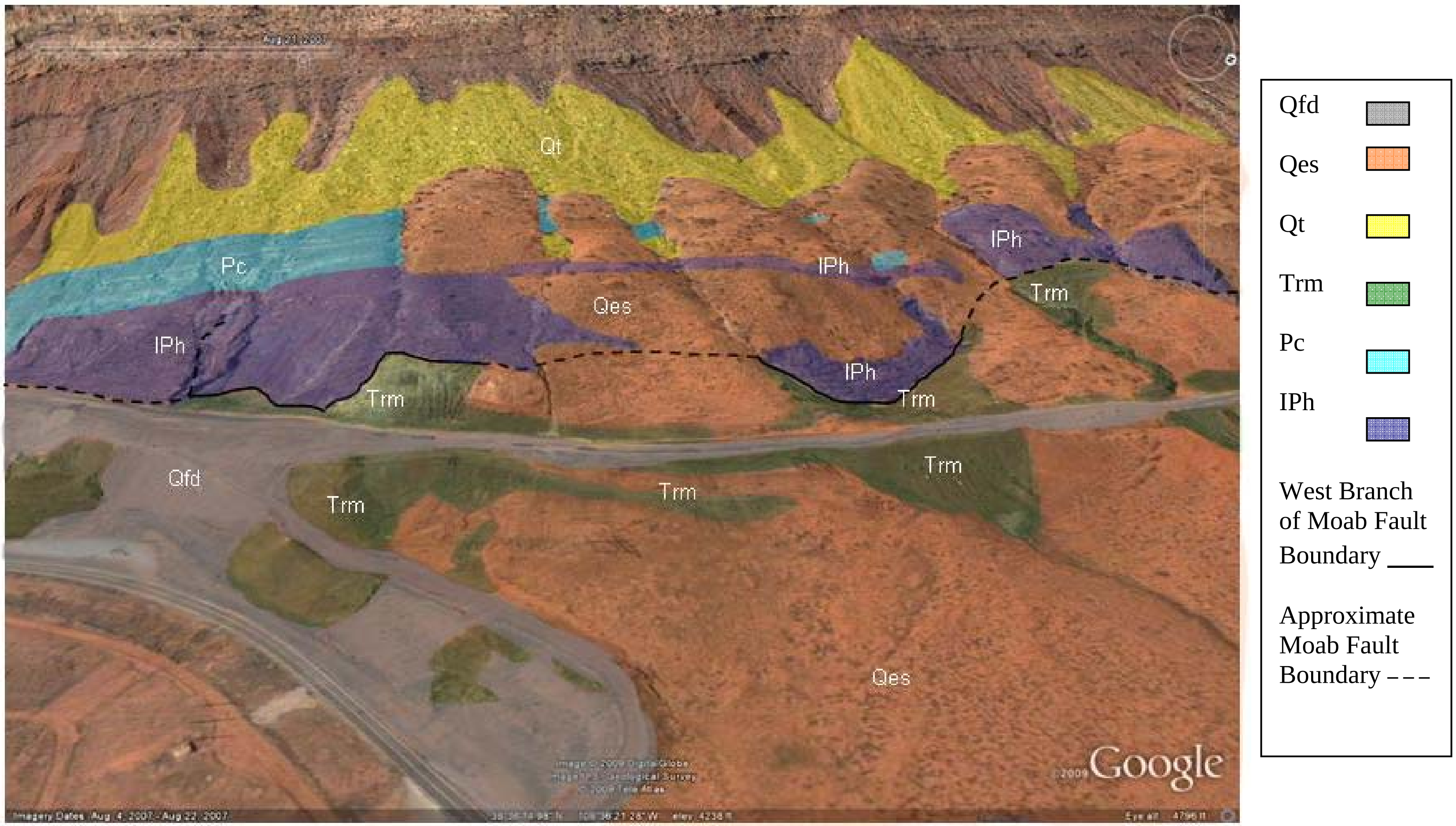
Photo 1. Railroad Adjacent to Moab Site and Hillside Locations

The hillside monitoring began in February 2009 (approximately 1,900 ft northwest of the portal) after a landslide occurred on a newly excavated slope along the Moab Fault trace. Many stepped sand features present above the excavation were monitored for movement by measuring stakes located both upslope and downslope of these features. Several of these locations mentioned in this report are referred to with specific names (e.g., cap rock, cul-de-sac). Photo 1 includes descriptive names for each of these locations.

2.0 Geologic Mapping

In mid-March, field observations were made to prepare a detailed geologic map of the hillside. Inaccessible portions of the slope were mapped by using the current USGS geologic map of the Moab Quadrangle and aerial photographs. Historical and current aerial photographs were used to determine areas of competent bedrock on the inaccessible slope faces. The primary stratigraphic units that comprise the lower portion of the slope include the Pennsylvanian Honaker Trail Formation, the Permian Cutler Formation, the Triassic Moenkopi Formation, and Quaternary eolian sand (Figure 1 and Table 1).

A photograph taken in 1955 before rail construction was used to determine the original morphology of the hillside (Photo 2). The photograph shows that a large gully was once present before the construction of the portal. The east flank of the large gully was believed to have been blasted back during the portal construction. The amount of downslope eolian sand was also greatly diminished during construction activities.



Note: Qfd = Quarternary Fill Deposits; Qes = Quaternary Eolian Sand; Qt = Quaternary Talus; Trm = Triassic Moenkopi; Pc = Permian Cutler Formation; IPh = Pennsylvanian Honaker Trail Formation

Figure 1. Geologic Map of Hillside Before Construction Activities

Table 1. Stratigraphy Present Near the Moab Site

Age	Formation and Members	Thickness (ft)	Description
Quaternary	Fill Deposits (Qfd)	Varies	Backfill from construction activities
	Eolian Sand (Qes)	0-30	Well-sorted, non-stratified to cross-bedded sand deposits
	Talus (Qt)	0-20	Slopewash and rockfall blocks, poorly sorted, angular fragments
Jurassic	Entrada Sandstone (Jes)	At least 250	Thick, cross-bedded eolian sandstone
	Carmel Formation, Dewey Bridge Member (Jcd)	90-110	Muddy to silty, fine- to medium-grained sandstone with contorted bedding
	Navajo Sandstone (Jn)	300-700	Fine grained, well-sorted, cross-bedded sandstone
	Kayenta Formation (Jk)	250-400	Fluvial sandstone, siltstone, conglomerate, and calcareous mudstone
	Wingate Sandstone (Jw)	250-400	Very fine- to fine-grained sandstone
Triassic	Chinle Formation (Trc)	100-700	Interbedded fluvial sandstone, mudstone, siltstone, and pebble conglomerate
	Moenkopi Formation (Trm)	0-750	Interbedded siltstone, fine-grained sandstone, and mudstone
Permian	Cutler Formation (Pc)	0-5,000	Fine-grained, inter-bedded arkosic sandstone and conglomeritic sandstone
Pennsylvanian	Honaker Trail Formation (IPh)	0-2,700	Interbedded sandstone, limestone, and siltstone, abundant marine fossils
	Paradox Formation	300-9,000	Cyclic bedded evaporates, dolomites, and carbonaceous shale

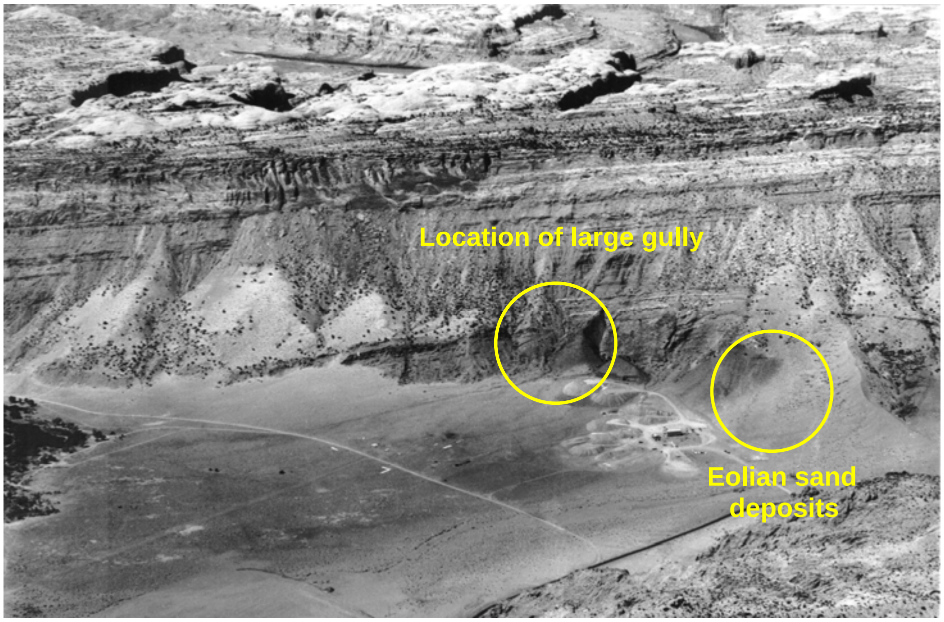


Photo 2. Portal Hillside in 1955 Before Rail Construction

The cliff face closest to the portal (south) was altered during the 1962 construction activities. An allochthonous slab of the Honaker Trail Formation crops out north of the portal. This sandstone cap rock dips approximately 25 to 35 degrees northeast and marks the location of the west branch of the Moab Fault. Most of the hillside is composed of segments of the Honaker Trail cap rock and the Moenkopi Formation along the fault trace (Figure 1). To the northwest, Quaternary eolian sand covers the fault trace, but small outcrops of the Honaker Trail sandstone and limestone are located upslope of the rail. Honaker Trail and Cutler outcrops are also present in and along the drainage channels that separate the slopes. A thin outcrop of the Honaker Trail Formation (fossiliferous limestone member) can be traced along the entire hillslope at an elevation of approximately 4,600 ft (Figure 1 and Photo 3). The upper portions of the slopes are covered with talus from previous rockfall events from the Wingate and Kayenta Formations that form cliffs at the top of the slopes. These blocks range in size from a few inches to 18 ft.

The 1962 construction activities also altered the surficial geology of the hillside. During the hillside excavation, the Moenkopi Formation was exposed where there was once Quaternary eolian sand (Figure 2). Also, a gully bounded by an embankment for the railroad, forming a depression at a location of 2,206 ft from the portal, was filled in with soil from the construction activities (the cul-de-sac).

2.1 Description of Slope Faces

Differences exist between each of the five slopes, mainly due to lithology and slope aspect. Slope A (Photo 3) is the slope farthest to the southeast that was mapped during this project. It was deemed unsafe to continue further, past the gully and to the Honaker Trail cap rock. This slope consists of many stepped outcrops of Honaker Trail fossiliferous limestone, sandstone, and siltstone (Photo 4). The contact of the Honaker Trail and Cutler Formations is located on this slope face at an elevation of approximately 4,700 ft (Photo 5). Abundant vegetation, including yucca, Mormon tea, sage, rice grass, and juniper, cover the gravelly surface of Slope A. The lower portion of this slope is covered with a section of the Honaker Trail cap rock (Figure 1).

Photo 3. Looking South from Slope A Towards Honaker Trail Cap Rock

The surface of Slope B (Figure 2 and Photos 6, 7, and 8) also consists of an angular gravel surface with many stepped outcrops of the Honaker Trail and Cutler Formations (Photo 8). This slope also contains two small drainage channels that originate at the base of one of the Honaker Trail outcrops. These channels are approximately 1 to 4 ft deep and 1 to 6 ft wide (Photo 6); they join together immediately above the Honaker Trail cap rock (Figure 1), above the recent excavation in the Moenkopi Formation.

Slope C is the least vegetated slope (Figure 2), likely due to the migration of eolian sand. One notable characteristic of this slope is the presence of stepped sand features and surficial cracks within the sand. These features have been monitored and are discussed in Section 3.0 of this report. An outcrop of the Honaker Trail Formation is present at the top of the February 2009 excavation (Figure 1 and Photos 9 and 10). The slope becomes more gradual at higher elevation and contains an active dune field with little vegetation. Outcrops of the Honaker Trail and Cutler Formations are visible on the sides of the slope, near the adjacent drainage channels.

The lower half of Slope D (Figure 1) consists of a slab of the Honaker Trail sandstone cap rock above the new cul-de-sac. Above the cap rock, the slope contains abundant shrubs and grasses and highly developed cryptobiotic soil. Sand has filled in some of the low-lying areas. The sides of the slope are flanked by the Moenkopi Formation (Photo 11). During the construction, the cul-de-sac was filled in with backfill material up to the rail grade (Figure 2).

The surface of Slope E (Figure 2) is covered with eolian sand, similar to Slope C. However, shrubs, grasses, and cryptobiotic soil are found further up the slope. The base of this slope is composed of the Moenkopi Formation.

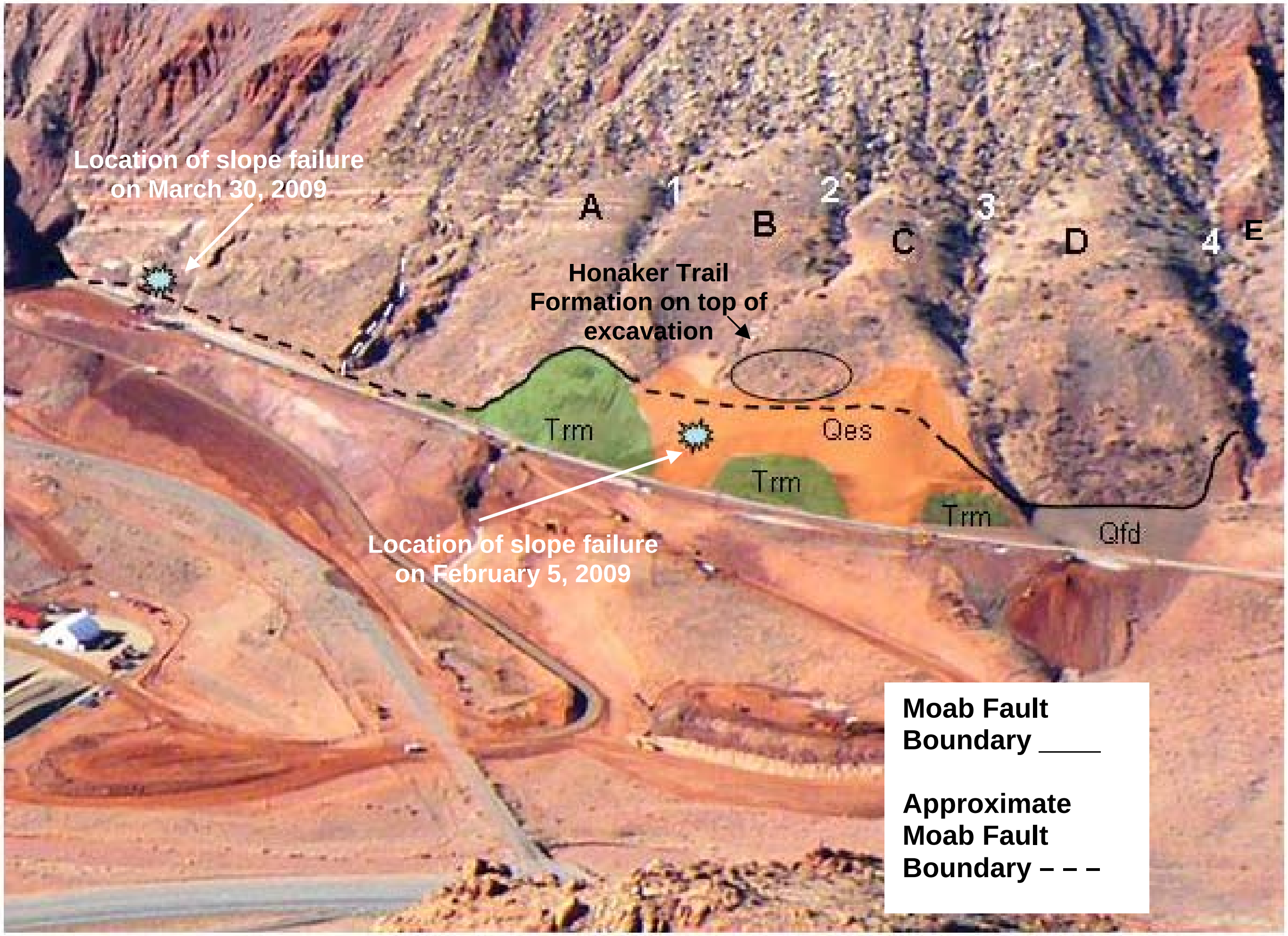


Figure 2. Changes to Geologic Map After Rail Construction

Photo 4. Crinoid and Rugose Coral Fossils in Honaker Trail Formation in Drainage 3

Photo 5. Close-up of Contact of Honaker Trail and Cutler Formations

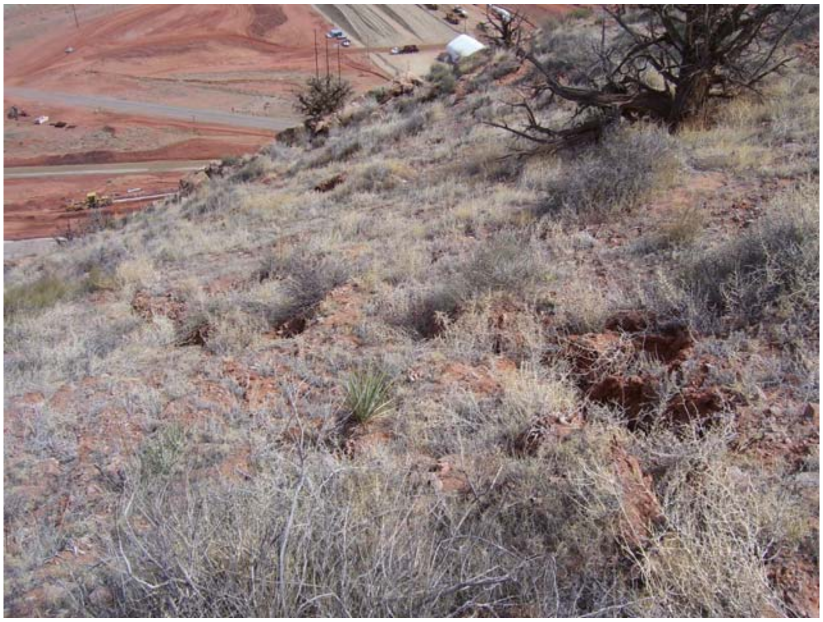


Photo 6. Slope B Mini-drainage Channel

Photo 7. Slope B Looking Southeast Towards Tailings Pile

Photo 8. Small Outcrop of Honaker Trail Formation

Photo 9. Location of Honaker Trail Outcrop in Relation to February 2009 Excavation

Photo 10. Looking Up Towards Honaker Trail Outcrop from February 2009 Excavation

Photo 11. Base of Slope D

2.2 Description of Drainage Channels

Four main drainage channels were identified from the Honaker Trail gully to immediately northwest of the cul-de-sac. The drainage area above the Honaker Trail gully was not mapped due to its inaccessibility.

Drainage Channel 1 (Figure 2 and Photo 12) extends from the top of the talus field, downslope to the area where the rilled Moenkopi Formation meets the rail line. The area immediately above the Moenkopi Formation is composed of Honaker Trail sandstone dipping at 25 to 35 degrees. The drainage is characterized by numerous sandstone boulders and cobbles, and a natural dam of the Honaker Trail Formation is present approximately 400 ft upslope (Figure 1 and Photo 13).

Drainage Channel 2 is the channel that could possibly have the most profound impact on the new rail construction because it meets the rail at the location of the February 2009 slope failure. It is possible that the presence of the drainage may have been a factor in the slide that occurred on this slope. There are areas of stepped bedrock outcrops near the talus slope within this drainage channel. Downslope, however, the drainage cuts into the eolian sand and eventually cuts down to the Honaker Trail bedrock immediately above the excavation area (Figure 1 and Photos 14 and 15). During a significant storm event, sand would likely be transported downslope of this drainage channel.

Drainage Channels 3 and 4 (Photos 16, 17, and 18) are characterized by large stepped natural dams of the Honaker Trail Formation and large boulders (up to 30 ft in height). These drainage channels empty downslope into the cul-de-sac area (Figures 1 and 2). It appears that most of the large boulders are upslope, near the talus; the lower section of the drainage contains mostly sand and cobbles.

Photo 12. Looking Downslope from Drainage 1

Photo 13. Natural Dam of Honaker Trail in Drainage 1

Photo 14. Drainage 2 Looking Downslope at Bedrock Above Excavation

Photo 15. Drainage 2 Looking Upslope Where Sand Has Been Eroded

Photo 16. Looking Upslope at Honaker Trail Formation in Drainage 3

Photo 17. Looking Downslope at Drainage 3

Photo 18. Boulders Located Upslope from Drainage 4

2.3 Moab Fault

There are two primary branches of the Moab Fault: the main branch, which runs along U.S. Highway 191, and the west branch, which runs along the west side of U.S. Highway 191 and across the Moab site. At the portal, the fault zone contains an unusual zone of attenuated brittle rocks where the Cutler and Honaker Trail Formations are dragged downward and smeared along the west branch of the fault in a reverse dip direction (Figure 3 and Photos 19 and 20). This portion of the fault is present along the new construction of the rail as shown in Figures 1 and 2.

The two areas of slope failure in February and March 2009 occurred along the slip plane on the west branch of the Moab Fault (Figure 2). The first slide occurred along a portion of the fault that was covered by eolian sand, and the excavation of the slide material revealed a smooth face of the Moenkopi Formation. It is likely that this fault plane was also weakened by the drainage channel that cuts through this surface (Photos 21 and 22). This slip plane can be traced northwest towards the bowl and south towards the Honaker Trail cap rock and the location of a minor slope failure event near the portal.

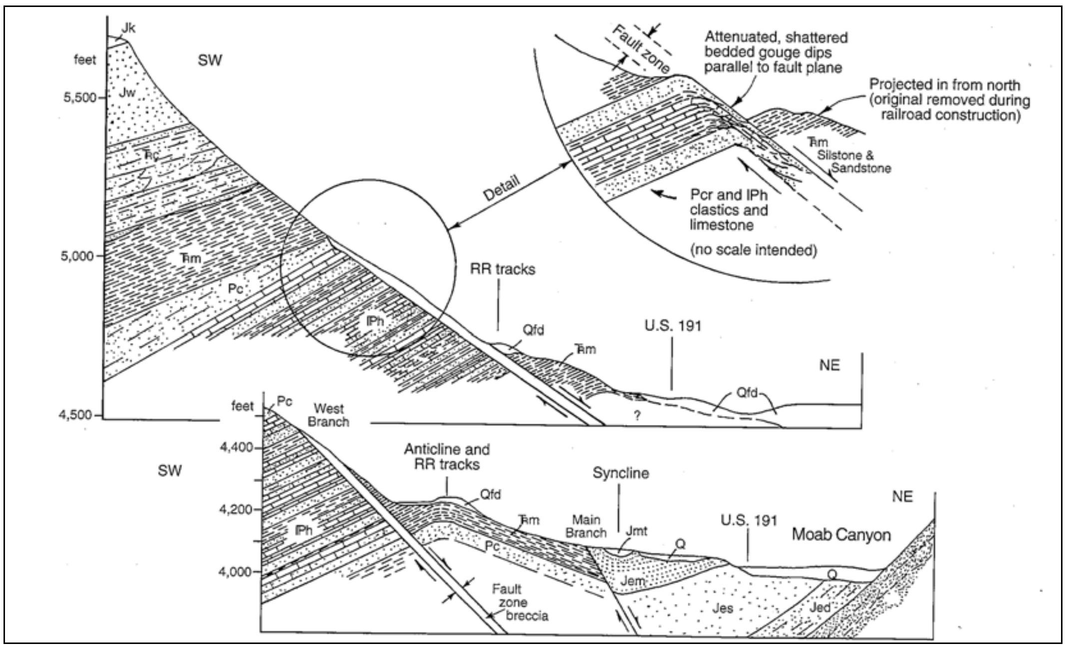


Figure 3. Schematic of Geometry of Moab Fault Along Rail Tracks

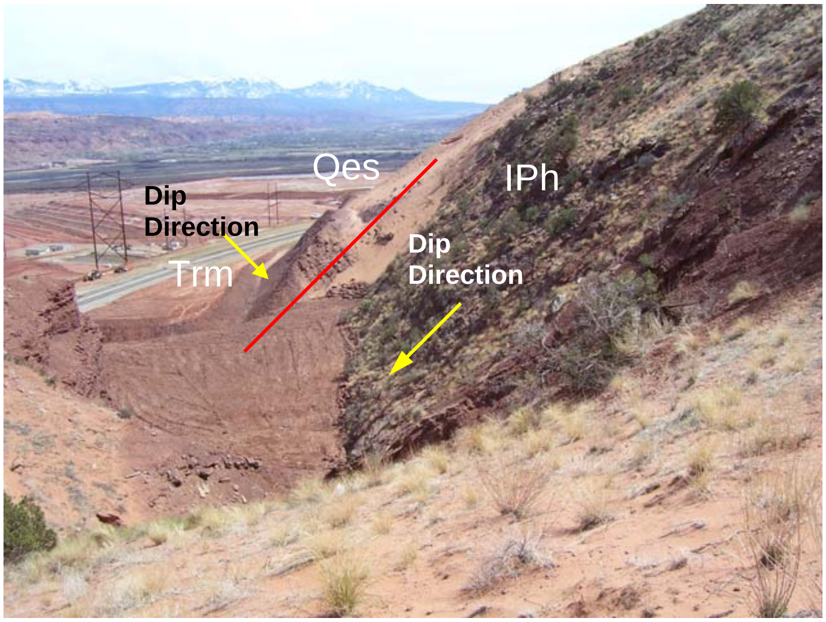


Photo 19. Fault Depicted in Figure 3

Photo 20. Faulted Surfaces Within Main Gully and Fault Offset Between Honaker Trail and Moenkopi Formations

3.0 Hillslope Movement Monitoring

Eolian sand above the hillslope excavation (upslope of the location pictured in Photos 21 and 22) exhibited many stepped sand features and surficial cracking within the sand. Following the slide on February 5, 2009, slope monitoring began to determine if any continuing movement is occurring.

On February 9, 2009, five locations of stepped sand and surficial cracking were staked and photographed (Photo 23), and global positioning system (GPS) coordinates were collected. The staked locations represent areas both above the slide area and along the excavated area immediately to its north that exhibit movement such as slumping or surface cracks. During this time, the hillside monitoring was completed once a week. On February 25, three additional locations were identified and photographed, and the locations were recorded with a GPS unit. Wooden stakes were placed upslope and downslope of each feature, and the distance between the two stakes was measured to the nearest tenth of an inch (Table 2). At this time, the frequency of the monitoring was increased to once a day. While some surface sloughing was noted, major movement was not recorded on the slope. Photographs of the eight staked locations are included in Attachment A.

On March 3, 2009, the frequency of the monitoring was reduced to once a week, and no major changes were reported. Several windstorms in late March reworked much of the sand on this slope, depositing up to 10 inches of sand in some locations.

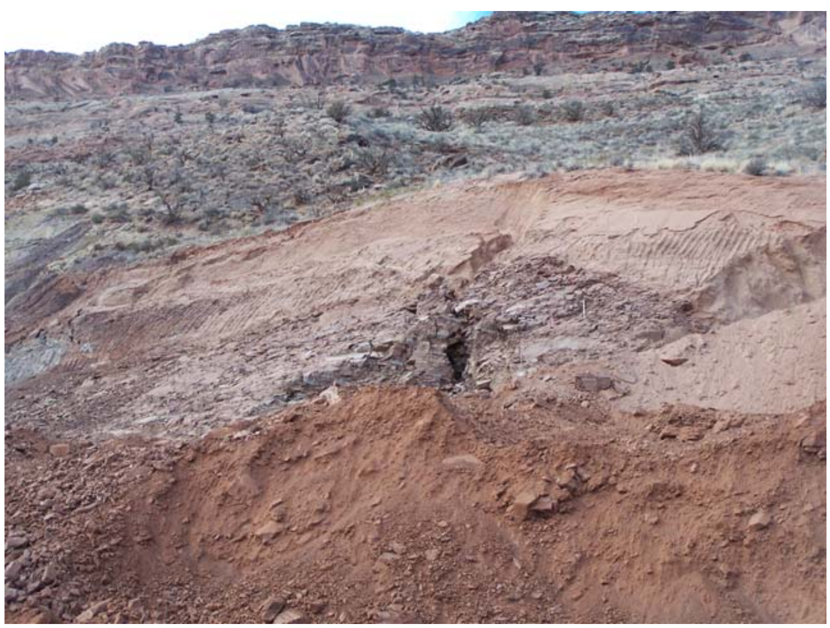


Photo 21. Hillslope One Day After February 2009 Slide

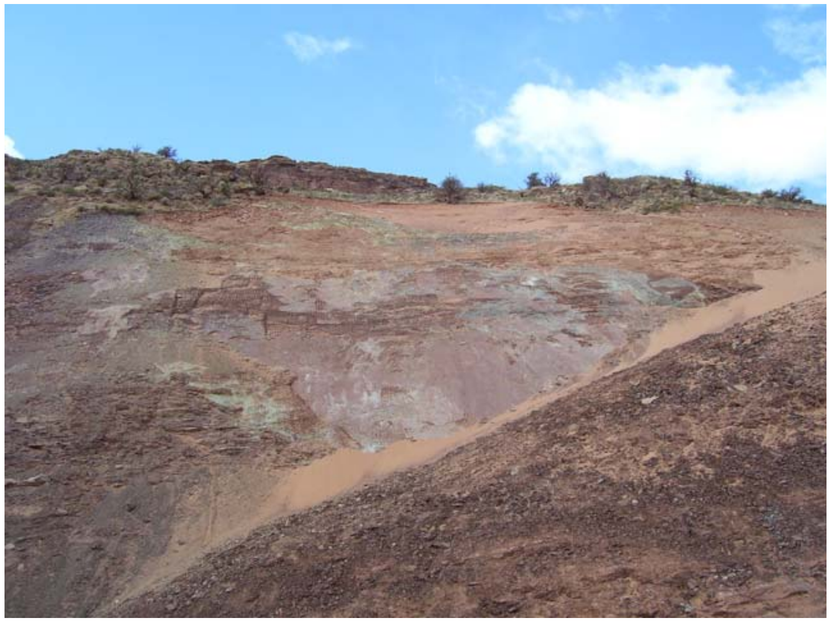


Photo 22. Hillslope Slide Area After Cleaning of Slumped Material

Photo 23. Staked Locations Monitored on Hillside

Table 2. Measurements Between Stakes

Stake Location Number	Northing	Easting	2/25/09	2/27/09	2/28/09	3/1/09	3/2/09	3/3/09	3/11/09	3/18/09	3/25/09	3/31/09	4/07/09	Difference in Initial and Final Readings
1	6666005.028	2181481.331	56	56	56	56	55.5	55.5	55.5	55.75	55.75	55.75	55.75	0.25
2	6665995.886	2181470.897	71.25	71.25	71.25	71.25	71.25	71.25	71.25	71.25	71.25	71.25	71.25	0
3	6665991.625	2181426.745	93	93	93	93	93	93	93	93	93	93	93	0
4	6666002.714	2181417.880	94.50	95	95	95	95	95	95	95	95	95	95	0.50
5	6665993.271	2181361.556	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	0
6	6666044.261	2181501.371	30	30	30	30	30	30	30	30	*	*	*	0
7	6665966.994	2181359.434	70	70	70	70	70	70.20	70.20	69.75	69.75	69.75	69.75	0.60
8	6665923.653	2181485.926	54.25	54.25	54.25	54.25	54.25	54.25	54.25	54.25	54.25	54.25	54.25	0

Note: Measurements in inches between two wood stakes placed both uphill and downhill of a stepped or cracked feature in the soil.
*Stakes at Location 6 were covered by sand during a windstorm.

4.0 Potential Areas of Concern

On July 10, 2006, the site experienced 2 to 4 inches of rainfall within approximately 1 hour. As a result, abundant silt, sand, gravel, and cobbles washed down the drainage channels onto the existing rail line. Following the storm, photographs were only taken near the portal; however, aerial photographs taken soon after the storm portray the damage further down the rail.

The photographs of the storm damage reveal areas of future potential concern. The 1955 photograph (Photo 2) shows a large gully located just northwest of the portal. During rail construction in 1962, the southeast flank of the gully was removed; however, photos from July 2006 show that this is a location of high-energy erosion during significant storm events. Along the Honaker Trail cap rock (Photos 24, 25, and 26), mostly silt, sand, and gravel covered the rail line.

An aerial photograph taken in September 2006, two months after the flash flood event, shows other areas of potential concern. For example, it appears that the location of the February 2009 slope failure consisted of a deep drainage channel and was covered with debris (Photo 27). The area near the cul-de-sac also appears to have contained minor debris flows.

Another area of potential concern is along the face of the west branch of the Moab Fault (Figures 1 and 3). The two slope failure events that have taken place since February 2009 occurred on the slip plane of the fault (Figure 1). The fault slip zone between the Moenkopi and Honaker Trail Formations consists of a smooth face bordered by a brecciated zone of shale and sandstone. Slope failure is possible along this slip face.

To mitigate the impact of storm events, the need for a control structure on drainage channels should be further evaluated. It is recommended that some sort of break be installed where Drainage Channel 2 meets the excavated slope to slow the velocity of storm water that could potentially damage the rail line (Photo 28). In addition, the base of the Moenkopi along the rail elevation has accumulated windblown sand and is blocking the drainage ditch that leads to culverts to the north and south (Photo 29). Also, site drainage should be closely monitored for sloughing or windblown deposits that may impede flow. The sand in the ditch may prohibit proper water drainage and may cause storm water to spill out towards the rail.

Damage to the hillside and rail line may occur during intense storm events, and inspection and monitoring should take place after any storm event that leads to storm water drainage or material transport on the hillside. During extended dry periods, monitoring should be performed at least quarterly to determine if any significant changes in the hillside morphology have taken place.

Photo 24. Rockfall Near Portal

Photo 25. Rock and Sand Debris Flow Southeast of Honaker Trail Cap Rock

Photo 26. Facing North Towards Old Gantry Crane and Honaker Trail Cap Rock

Photo 27. Rail Damage from July 2006 Flash Flood

Photo 28. Hillside Excavation Showing Junction of Drainage Channel and Excavated Face

Photo 29. Windblown Sand in Drainage Ditch Along New Moenkopi Exposure on Excavated Hillside

Attachment A.
Photographs of Hillside Monitoring Staked Locations Above Excavation

Photo A-1. Location 1

Photo A-2. Location 2

Photo A-3. Location 3

Photo A-4. Location 4

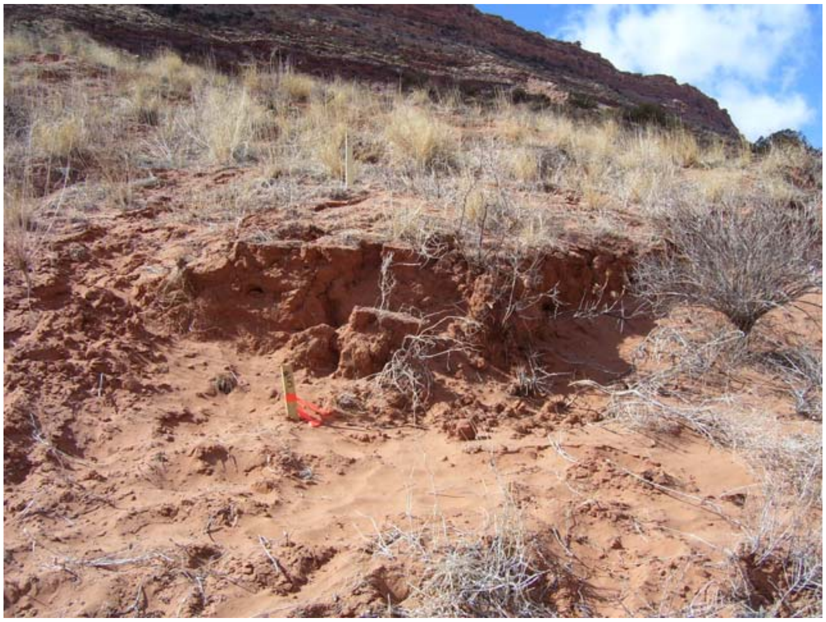


Photo A-5. Location 5

Photo A-6. Location 6

Photo A-7. Location 7

Photo A-8. Location 8

Photo A-9. Locations of Assessment Photographs 3 through 22, 28, and 29