Geologic Report
for
Monte Creek - 86 Landslide Stabilization Project

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This report documents and describes the ongoing investigation and monitoring of a landslide on Forest Road 11N09 approximately one-quarter mile from its junction with Forest Highway 93. This report updates an earlier report dated 16 March 1990 and incorporates a draft report dated 30 November 1995. This landslide lies in T11N, R7E, Section 7, Humboldt Base and Meridian. The landslide is underlain by gabbroic and dioritic rocks of the Hayfork Terrance of the Klamath Mountains Geologic Province. This landslide has been termed the Monte Creek - 86 Landslide, to prevent confusion with other stability problems in the Monte Creek sub-watershed.

History

The Monte Creek - 86 Landslide covers an area of about 10.5 acres. This slide body is a localized reactivation of the northern portion of a larger (approximately 50 acre) slide mass. This larger slide mass is most likely a post-Pleistocene (<10,000 years before present) slump/earth flow complex. The Monte Creek - 86 Landslide was identified in March of 1986, after approximately 24 inches of rain fell in February of that year, reactivating the lower portion of the larger slide mass.

At the time of this initial activation, the slide mass measured approximately 300 feet lengthwise and about 200 feet in width. In June of 1986, a vertical hole was drilled to a depth of 52 feet. Twenty feet of slotted pipe below 32 feet of regular pipe was used to monitor the standing water level in the hole. At the time this monitoring hole was drilled, the slide measured about 250 feet lengthwise. The failure plane was assumed to be a well developed clay layer at a depth of 39 feet.

Designed stabilization measures were implemented in 1987 and 1988. These measures included reshaping the road prism and installation of horizontal drains. Water years (October 1 to September 30) were extremely dry with 43.52 inches and 44.15 inches for those years respectively. Mean annual precipitation at Somes Bar, Ca. is 64.37 inches.

On 20 January 1989 new cracks were observed on the southeastern portion of the slide, across Road 11N09. Although at that time cumulative precipitation was lower than normal for water year 1989, heavier than normal rain had fall in November of that year (21.17 compared to 10.93 inches, normal for that month). Some expansion of those cracks occurred between 20 January and 21 February 1989. Rainfall at Somes Bar was 3.24 inches as opposed to 9.34 inches normal for that time period. In March of 1989 precipitation was almost double normal (16.47 vs. 8.33 inches). Between 10 March and 18 April 1989 the southeast lateral scarp had grown almost 4 feet in height on Road 11N09, and new crown scarps up to 10 feet in height had appeared in the previously inactive portion of the slide. Only minor movement occurred after 18 April 1989. By this time the slide had grown to approximately 700 feet in length and 350 feet in width.

Present Monitoring Network

Between 20 January and 21 June 1989 monitoring consisted of visual observations and measurements of stake arrays placed across the scarps. These stake arrays were initially installed on 31 March 1989, other arrays were added throughout the course of the summer. Also on 31 March, topographic profiles were run to intersect the cracks and scarps, as well as the basal plane that is exposed in the cut slope between Road 11N09 and Forest Highway 93. These profiles indicated that the slide could have a depth of up to 150 feet, although it was felt that a depth of 100 feet was a more accurate estimate.

In late June of 1989, seismic refraction surveys were performed across the slide mass. Two different interpretations of the resulting data yielded similar results; that a failure plan appeared to occur between a depth of 100 and 120 feet. The deeper of these figures was uncorrected for topography. Speculative interpretation indicates the possibility of a shallower, secondary basal failure plane, at a depth of about 37 feet. These interpretations, limited as they are, were used to design a drill hole network for subsurface monitoring.

Between 24 July and 4 August 1989, a series of seven holes were drilled in the slide body. These holes served a dual purpose: To yield subsurface information concerning lithology and structure; and for the installation of piezometers to monitor the slide mass response to groundwater fluctuation. The piezometers and electronic monitoring gear were installed in late October of 1989. A summary of the drill hole data is given below.

Drill Hole #1:

Surface to 8 feet: Hard, bouldery deposits, gray porphyritic material and black metamorphic cobbles. Probably stream terrace deposits.

8 feet to 30 feet: Highly oxidized sand and silts with lenses of decomposed granitic sand.

30 feet to 50 feet: Weathered granitic material with increasing chlorite alteration at depth. Fracture surfaces show oxidation.

50 feet to 52 feet: Facture surfaces slickensided. Jointing planes 60-80 degrees to normal.

52 feet to 55 feet: Shear zone
55 feet to 58 feet: Hard metamorphic rocks below shear zone.

58 feet to 80 feet: Granitic rocks freshening with depth. Jointing planes 30-60 degrees to normal. Abundant calcite as fracture fill at 60 feet.

DH #1 - Total Depth: 80.5 feet; Solid Pipe 0-65 feet; Slotted Pipe 65-80 feet.
DH#1A - Total Depth: 51.5 feet; Solid Pipe 0-21 feet; Slotted Pipe 21-51 feet.

Drill Hole #2

Surface to 63 feet: Colluvial material, 0-30 feet is fractured, angular to sub angular metamorphic gravels and cobbles. 32-63 feet is angular cobbles in silty clay matrix. 57- 63 feet shows increasing Fe++ stain.

63 to 70 feet: Transition from oxidizing (above) to reducing (below) environment._ May represent basal failure plane.

70 feet to 73 feet: Core contains what appears to be sheared serpentenite, with abundant calcite fracture filling 60 degrees to normal.

73 feet to 80 feet: Greenschist with chert stringers and occasional "serpentenized" rocks.

80 feet to 82.5 feet: Hornsfels zone near granitic contact.

DH#2 - Total Depth: 82.5 feet; Solid Pipe 0-52 feet; Slotted Pipe 52-80 feet.
DH#2A - Total Depth: 45 feet; Solid Pipe 0-15 feet; Slotted pipe 15-45 feet.

Drill Hole #3

Surface to 35 feet: Colluvial material, landslide terrace, fining with depth.

35 feet to 72 feet: Second colluvial terrace, fining downward to possible failure plane.

72 feet to 75 feet: Top of weathered granitics at 72 feet.

DH#3 - Total Depth: 75 feet; Solid Pipe 0-65; Slotted Pipe 65-75 feet.
DH#3A - Total Depth: 55 feet; Solid Pipe 0-35; Slotted Pipe 35-55 feet.

Drill Hole #4

Surface to 25 feet: Colluvial material, silty clay at top of the section. Clay probably derived from altered granitics, granularity increasing with depth.

25 feet to 65 feet: Altered granitics. Abundant chlorite alteration at the top of the section, weathering decreasing slightly with depth.

DH#4 - Total Depth: 62 feet; Solid Pipe 0-32 feet; Slotted Pipe 32-62 feet.

Geology of the Area

Three separate classes of surficial deposits are found within the slide mass. Stratigraphically, from the top to the bottom, these deposits are: Active landslide deposits; colluvial and stream terrace deposits; and old (post-Pleistocene) landslide deposits. These surficial deposits overlie granitic bedrock material.

The active landslide deposits are comprised predominantly of reworked older colluvial material, and decomposed or highly weathered and disintegrated granitic material. Generally, these materials are not recoverable during core-drilling operations, because of the high silt- clay content.
The colluvium and stream terraces generally lie above granitic soils in the area of investigation. Terrace soils appear to have a higher degree of oxidation, whereas colluvial deposits are somewhat darker in color than the terrace deposits and granitic soils. Colluvial and stream terrace material could be differentiated by the degree of angularity in the cobbles and gravels.

Old landslide deposits are comprised of rock, shallow soils that tend to have a higher clay content at depth. In core recoveries, this section was represented by cobbles and boulders of mixed lithology.

The granitic bedrock component of the stratigraphic column is a medium grained rock that appears to be granodiorite in hand sample. In outcrop it is generally highly weathered, freshening with depth in core recovery. The cut slope adjacent to Forest Highway 93 is highly jointed and fractured, with calcite and aplitic material as fracture filling. Numerous faults occur along this cut face.
The structure throughout this area of investigation is largely joint and fracture controlled. The basal slope surface that is exposed along the southern portion of the Forest Highway 93 cut face is a north-westerly trending feature with a north trending strike. Dip along this feature ranges from 12 to 24 degrees to the east. Rocks above and below this feature are of similar composition, but much more highly weathered above the surface than below. Movement along this slip surface appears to be along strike, rather than down dip.

Interpretation

Cross sections MP 1 and MP3 represent graphic interpretation of the subsurface geology of the area of investigation. The simplest interpretation is that there is on large rotational slide mass that has broken into at least three and possible four internal blocks. These blocks are all moving above the basal slip plane. Unfortunately the actual slide geometry is not that simplistic.

A more complex interpretation is as follows. The largest rotational slump block is moving along the basal failure plane. Rather than being a discrete internal plane, this feature appears to closely follow the granitic contact. Correlation of the core logs, and seismic data, indicate that this granitic surface maybe undulatory in nature, with alternating steeper and shallower pitches. The changing surface pitches may serve to cause further internal sliding. Surficial expression of these sliding blocks is given by the appearance of new cracks and scarps. The larger, older rotational block, and to a lesser extent the internal block, may be rotating counterclockwise around a vertical axis forming a pressure ridge in the south central portion of the slide. These components of motion are made even more complex by the evidence that the tow area of the slide is being affected by wedge failures in the underlying granitic rocks. This evidence is given by the linear nature of the cracks in the east portion of the slide mass, suggesting strong structural control. The western portion of the slide mass involves mostly colluvium, with more arcuate cracks.

The core sample in Drill Hole #2 that was described as "serpentenitic material" was after petrographic analysis, found to be a breccia with clasts of actinolite and chlorite in a matrix of stilpnomolene (green biotite) and calcite. There was little or no serpentine. The highly brecciated clasts and matrix had little resistance to shear. This indicates that an altered fracture zone exists within the granitic rocks are involved in the sliding.

A third type of failure occurs in the northern portion of the area of investigation adjacent to Road 11N09. A debris flow has occurred along a slip surface in metamorphic rock near the granitic contact. The head of this debris flow coincides with a lateral scarp of a larger internal block. This slip surface has a northeasterly strike and dips from 37 to 48 degrees to the southeast. This slip surface appears to be the result of a previous block failure.

Of the approximately 112,000 cubic yards of material involved in the Monte Creek - 86 Landslide approximately one quarter of that volume poses a risk to Forest Highway 93 and to the Salmon River. In the immediate are there are precedents for blockages of the Salmon River. The nearest of these, the Murderers Bar Landslide approximately a mile down river, formed a temporary dam of the river, probably as result of the 1995 storm and flood events. This area may have failed again causing another blockage in 1958. The Bloomer Slide, approximately 6 miles upriver formed another temporary dam on the Salmon river as result of the 1964 flood event. In march of 1990 a rock fall caused a partial blockage of the river near mile post 11.5 on Forest Highway 93, between the Monte Creek - Landslide and the Bloomer Slide. These historical events characterize the higher range of consequences possible if serious stabilization measures are not undertaken.

Stabilization Discussion Points

1. The landslide is translational in character, and the basal slip surface is a planar feature where it daylights at the tow of the slide. This conclusion is based on:

a. The trace of the surface forms a relatively straight line in the area between the Forest Highway 93 and Road 11N09.

b. Direct measurements of attitude were taken in 1989 when the surface was exposed.

2. The direction of movement (from stake array data) at the toe is not directly down the dip of the basal slip surface, but rather oblique to it by about 30 degrees. In the southwest portion of the slide (pressure ridge area, stakes CC1-CC5, and DD1-DD3), movement appears to be directly down sip if the slip surface is assumed to maintain the same attitude as that displayed at the tow.

3. The basal slip surface separates deeply weathered granitic rock from less weathered and much stronger granitic rock below. The failure plane appears to follow a preexisting plane of weakness or fault in the bedrock.

4. The south lateral scarp is a long linear feature which parallels a steeply dipping joint set, and with the exception of the pressure ridge area, appears to be controlled by this joint set. The north lateral scarp is influenced by a fault which dips about 40 degrees ESE at the county road where it separates different types of metamorphic rock and contains about an inch of clay gorge. At the Forest Service Road this fault separates landslide debris and terrace deposits from the underlying metamorphic rock, and dips about 35 degrees ESE. This portion of the landslide appears to be a wedge failure which is controlled by:

a. The gently dipping (12-15 degrees) basal slip surface,

b. Vertical ENE striking joints along the south lateral scarp, and

c. A fault dipping 35-45 degrees ESE along the north lateral scarp.

5. Loss of restraining force as a result of excavation in the toe sone played an important role in the activation of the slide.

6. Since 1986, movement of the slide has occurred during wet winters, as demonstrated in the precipitation table and graph below.

Rain Year	Total Rain (Inches)	Max./Month	Slide Movement
1983-84	68	19/NOV; 18/DEC	NO
1984-85	55	25/NOV	NO
1985-86	75	24/FEB	YES
1986-87	44	11/JAN	NO
1987-88	44	15/DEC	NO
1988-89	63	21NOV; 15/MAR	YES
1989-90	43	11/JAN	NO
1990-91	30	9/MAR	NO
1991-92	32	6/FEB	NO
1992-93	60	12/DEC	YES
1993-94	32	10/DEC	NO
1994-95	67	20/JAN; 13/MAR	YES

Stabilization Measures

Stabilization measures will be most effective if they focus on improving mass balance, drainage, and increasing shear strength along the slip surface.

A. Mass Balance

The current slope configuration is unstable when water levels reach critical levels as occurred in 1992-93 and 1994-95. During those winters, slide movement on the order of feet occurred throughout the landslide. Widening of the county road in about 1984 and excavation of material from the Forest Service road in 1988 reduced the restraining force in the toe of the landslide. The factor of safety decrease in association with this removal. Replacement of last material alone would serve to increase the frictional resistance to sliding.

B. Drainage

By preventing high pore water pressures which occurred in response to heavy precipitation, the factor of safety could be raised considerably. Piezometers revealed spikes in ground water levels after certain antecedent conditions were met. Effective drainage will be difficult to attain due to slope configuration. In order to drain the head of the slide, excavation in excess of 30 feet in depth would be needed. Alternatively, long horizontal drains could reach this area. Experience with horizontal drains installed in 1988; however, revealed that zones of saturation are scattered throughout the slide, and not interconnected. For example, DH#1 had standing water more than 10 feet deep, and horizontal drains drilled very near this hole flowed no water. It is possible that the drains may have paralleled the joints carrying water, and did not intersect them. Piezometer data from DH#2 and 21 showed that the two separate aquifers tapped by these holes rose sharply at the same time. Thus, even though they are separate, they appear to be fed by upslope water in a similar fashion. Drainage in the head could be attained by deep excavation, vertical wells, of vertical wick drains (3-4 feet in diameter).

C. Increase Shear Strength

The well defined basal slip surface consists of a clay seam several inches thick. The factor of safety would be increased by interrupting this failure plane and replacing it with a stronger material. This could be accomplished with a keyed-in, reinforced buttress at the toe placed below the plane, by installation of shear-resisting piles, or with tie back methods.

D. Rock Wedge Failures Below the Landslide

Ongoing rock wedge failures below the NE corner of the slide shed debris to the county road, in 1994-95 a wedge about 3 feet deep failed. These failures are bounded at their base by a fault plane with a clay seam and steeply dipping joints. These failures appear to be below the basal slip surface of the main slide.

MONTE CREEK-86 Landslide Stake Arrays												
			Measurement Date									
Array	06/21/89	10/26/89	11/09/89	01/18/90	02/04/90	03/18/93	05/27/93	06/01/94	09/21/95	02/20/97	06/09/98	Comments
A1-A2	6.95	7.01	******	6.91	6.92	6.94	7.03	6.94	******	******	******	Lost A1
A1-A3	6.98	9.05	******	8.91	6.91	9.21	10.88	******	******	******	******	
A2-A3	10.25	10.41	******	10.26	10.26	******	******	******	******	******	******	Relocated A3 to A4
A2-A4						17.02	18.83	18.75	******	17.47	******	
B1-B2	16.13	27.21	14.84	14.71	******	******	******	******	******	******	******	Stake relocated
B1-B3	18.91	27.92	22.11	22.39	******	******	******	******	******	******	******	Stake relocated
B2-B3	25.31	25.41	25.24	25.17	******	******	******	******	******	******	******	
D1-D2	8.31	8.32	******	******	******	******	7.71	13.74	11.9	******	******	
D1-D3	7.27	7.28	******	******	******	******	9.81	10.96	8.8	******	******	
D2-D3	6.52	6.59	******	******	******	******	6.59	6.47	6.6	******	******	
F1-F2	24.05	24.19	24.13	24.13	******	******	******	******	******	******	******	
F1-F3	20.46	20.51	20.39	Buried	******	20.31	******	******	******	******	******	
F2-F3	14.01	14.11	14.01		******	******	******	******	******	12.39	******	
G1-G2	21.65	21.71	******	21.58	21.58	******	23.55	******	******	******	******	
G1-G3	16.35	16.41	******	16.25	16.25	******	16.75	16.56	16.9	17.09	******	
G2-G3	27.14	27.21	******	27.15	27.05	******	26.01	******	******	******	******	
J0-J1	36.85	37.01	36.75	******	******	******	38.61	******	41.45	34.81	35.01	
C1-J2	39.89	40.01	******	******	******	******	42.51	******	47.15	48.27	51.49	
L1-L2	68.3	68.4	******	******	******	******	******	******	72.2	******	77.5	
K1-K2	21.4	21.18	21.33	******	******	******	24.3	******	26.6	******	29.4	Stake array gone by T1 (inclined tree)
K1-K3	******	******	15.47	******	******	******	14.1	******	13.5	******	12.8	T2 inclined 77 degrees
K2-K3	******	******	27.39	******	******	******	27.7	******	30.3	******	******	
M1-M2	18.54	18.66	18.53	******	18.12	******	18.88	******	******	21.2	21.2	
H1-H2	16.89	16.9	16.83	******	16.73	******	56.8	******	18	52.78	******	Reset stake
AA1-AA2		37.7			37.58	37.58		37.75	37.9			
AA1-AA3		39.8		39.76	39.69	39.69		39.91	40.2			
AA2-AA3		21.3		21.17	21.12	21.12		21.15	21.4			
CC1-CC2	******	******	******	23.65	******	******	23.74	******	23.72	23.77	23.8	
CC1-CC3	******	******	******	32.05	******	******	31.78	******	31.35	30.68	31	
CC1-CC4	******	******	******	26.63	******	******	21.66	******	20.2	19.18	19	
CC1-CC5	******	******	******		******	******	******	******	******	******	28.9	
CC2-CC3	******	******	******	28.15	******	******	31.13	******	28.65	27.57	27.4	
CC2-CC4	******	******	******	35.29	******	******	33.95	******	32.05	30.68	30.3	
CC3-CC4	******	******	******	31.11	******	******	18.15	******	18.15	******	******	
CC3-CC5	******	******	******	******	******	******	******	******	******	******	14.5	
CC4-CC5	******	******	******	29.26	******	******	28.22	******	******	25.55	25.3	
DD1-DD2	******	******	26.01	******	******	******	25.66	******	25.02	24.51	24.4	
DD1-DD3	******	******	31.23	******	******	******	30.08	******	28.2	26.82	26.5	
DD2-DD3	******	******	34.18	******	******	******	34.25	******	34.2	34.07	35	
GG1-GG2	******	******	57.7	******	******	******	55.92	55.74	53.55	51.49	52	
HH1-HH2	******	******	58.4	******	******	******	56.8	56.73	54.75	52.78	52.8	
II1-II2	******	******	******	******	******	******	******	******	******	14.46	14.6	
II1-II3	******	******	******	******	******	******	******	******	******	11.84	11.6	
II2-II3	******	******	******	******	******	******	******	******	******	17.02	16.8	

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