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MEMORANDUM

From: Edwin L. Harp, Mark E. Reid, and Jonathan W. Godt, U.S. Geological Survey

To: Alan Gallegos and Jerry DeGraff, U.S. Forest Service

Date: June 23, 2006

Subject: Ferguson Rock Slide, Mariposa County, California

At the request of the U.S. Forest Service, Edwin L. Harp, Geologist, Jonathan W. Godt, Geomorphologist, and Mark E. Reid, Hydrologist, visited the Ferguson Rock Slide on June 12th - 14th, 2006. The slide blocks California State Highway 140 approximately 6 miles west of Yosemite National Park. The current rock slide is a reactivation of an existing rock slide and was first noticed on April 29, 2006, as a few scattered rocks rolled onto the highway. The Ferguson slide has since grown into a complex rock slide with a volume of approximately 1.5 to 2.0 million cubic meters. The slide emanates from a steep slope (38°– 45°) in metamorphic slate and phyllite. The main body of the slide mass is a rock-block slide with numerous internal slumps below the headscarp. The distal portion of the landslide is a steep (~42°) talus slope of about 100 m length that continues to produce abundant rock fall from its upper portions (Figure 1). The rock fall process has resulted in a talus slope that has buried the highway and extends approximately 10 meters into the Merced River.

After viewing the rock slide from the opposite canyon slope, from the air via helicopter, and visiting the slide on foot in the head-scarp region, we can make the following general statements regarding the landslide:

- The main slide mass appears to be a reactivation of an older rock slide. Recent motion on the older main headscarp (Figure 2) is about 30-40 feet. The basal shear surface of the rock slide does not toe out below the steep, disrupted rocks at the head of the talus slope but extends farther downslope to near the bottom of the slope (see Figure 2). The right side (looking downslope) of the slide toe has shed enough rock debris recently to exhume the shear surface in this area. Sheared slide material resting over intact bedrock is clearly visible on the lower right

margin of the slide (Figure 3). The left side of the slide toe is the area where rock fall was first noticed in April. This portion of the slide mass may be a separate rock slide as evidenced by the scarp above it shown in Figure 3. The exact location of the basal shear surface under the talus slope is unknown.

- The main body of the rock slide above the talus slope and the disrupted rocks at the head of the talus slope appeared to be stationary at the time of our visit (June 14th). However, it is possible that this part of the slide is creeping slowly, but not rapidly enough that movement could be discerned by visual inspection. Currently, it is unknown whether the main slide mass is slowly creeping, accelerating, decelerating, or completely at rest.
- The area of disrupted rocks at the head of the talus slope continues to shed rock. However, the rate of rock fall activity appears to be decelerating based on anecdotal evidence supplied by those who have been observing the slide since its reactivation. The talus slope is at the angle of repose of the rock material and will be in a quasi-stable condition even after all rock fall ceases. Any disturbance to the bottom of the talus slope will result in shifting of the talus and renewed rock-fall activity from this slope.
- Although unlikely, catastrophic failure of the main slide mass is possible. Such a failure would travel at high velocity into the Merced River Canyon and would probably block the river and bury Incline road on the opposite bank of the river. Portions of the main slide mass could also fail rapidly. In this case, some of the material might reach the opposite bank of the Merced River.
- It is likely that any current movement of the main slide body will cease during the summer dry season. However, movement may be renewed by elevated groundwater levels during the winter wet season or by any significant seismic activity in the area. Seismic activity may also trigger additional rock fall.
- Should there be a blockage of the Merced River from a catastrophic failure of the slide mass, we expect that the river would be dammed temporarily. The rate at which an impounded reservoir would rise behind the dam will depend on the flow of the river at that time. We suspect that most of such a landslide dam would remain in place although the dam material would be eroded as the river over tops and cuts down through the landslide dam. A significant rapids or pool might remain behind the landslide dam for some time. In addition to flow over the dam, a significant flow through the dam material might also occur.

In view of the proposed temporary solution by Caltrans to move the highway to the opposite side of the Merced River to reestablish traffic access to Yosemite National Park via Highway 140, we offer the following advice and recommendations for consideration.

- The main body of the rock-slide mass needs to be continuously monitored in near-real time to detect any movement preliminary to a catastrophic failure and to provide a warning in the event that the main slide mass should accelerate and pose the threat of catastrophic failure. Such warning would allow for rerouted traffic to be stopped and for people to be evacuated from the area directly across the Merced River from the slide mass. Devices considered for this are Global Positioning Satellite (GPS) sensors to give continuous position information and a geophone/tiltmeter assembly to monitor rock noise and changes in orientation of

the slide surface. We also recommend placing water-level gaging stations above and below the slide area to monitor any sudden changes in river level resulting from a catastrophic failure. Also, it would be prudent to minimize human activity directly across the river from the slide.

- The activity of the talus slope burying the highway and the highly fractured rocks just above it should be constantly monitored either visually or by some other means of detection so that any significant changes and readjustments in the talus or broken rock masses above can be noted for signs of increased motion of the main slide mass. Obviously, no human activity should be undertaken on, or immediately in front of the talus slope now, and probably not in the future.
- Ambient seismicity in the area should be monitored using a seismometer deployed near the slide mass or by establishing an earthquake notification service so that traffic could be halted upon the occurrence of predetermined levels of earthquake activity.
- With good estimates of the volume of the main slide mass and LiDAR DEMs of the slide and adjacent river-canyon topography models of a worst-case failure of the slide mass could be generated. Such a model could predict the three-dimensional shape of the landslide dam that would block the river should such a failure occur and provide more realistic dam heights from which reservoir levels and time-to-overtopping estimates could be made.

The steepness of the slopes above the Merced River and morphology of this rock-block slide are such that future reliable estimates of the stability of this slide will be difficult. Its stability will always be in question as long as it remains on the slope. It is for this reason that we feel that the documentation and monitoring efforts that have been mentioned are needed for public safety in the Merced River Canyon.

Figure 1. Oblique aerial photograph of Ferguson Rock Slide. Merced River in foreground is flowing left to right. Photo taken by Ed Harp, USGS on June 13th, 2006.

Figure 2. Oblique aerial photograph of Ferguson Rock Slide. Dashed yellow lines indicate extent of the rock slide based on visual inspection. Rock-fall source area, talus, and new scarps are indicated. Photo taken by Ed Harp on June 13th, 2006.

Figure 3. Photograph of Ferguson Rock Slide taken from the opposite bank of the Merced River on June 13th, 2006. Recently exhumed shear surface on the lower right margin of the slide is indicated.