East Fork Landslide Report May 18, 2008

On May 14, 2008, the Colorado Geological Survey (CGS) was contacted about a significant landslide event on US Forest Service property in Archuleta County. The slide is named the East Fork Slide, in reference to its location 2 miles up the East Fork of the San Juan River from the point where it joins the West Fork along US Hwy 160. This location is 12 miles northeast from Pagosa Springs. CGS geologist Chris Carroll, who was working in Pagosa Springs area, was sent to respond to the initial call from the Archuleta County Office of Emergency Management (OEM). At their request, Mr. Carroll and one of the OEM coordinators boarded a Civil Air Patrol plane to fly the landslide-affected area. Due to the constricted nature of the box canyon of the East Fork Valley the plane could only fly within 1,000 ft of the ground. Over 100 photographs of the East Fork landslide (Figure 1), the downstream floodplain toward Pagosa, and the nearby Jackson Mountain Landslide were collected.

Figure 1. Eastward looking view of the East Fork Landslide showing the Forest Service Road, Excel Energy pipeline right-of-way, and the constriction of the river.

At 3:00 PM OEM held a conference of pertinent emergency personnel for Archuleta Co. Over 40 people were in attendance including several from the State of Colorado in Denver on the phone. During this meeting Mr. Carroll discussed the geologic aspects of the landslide based on the overflight. An initial report indicating that about 35 acres were involved in the active landslide was confirmed. But the active landslide is just one within a larger complex of older earthflow-type landslides on the hill covering approximately 350 acres. The older landslide goes uphill toward a 300 ft high head scarp of volcanic bedrock (Figure 2).

Figure 2. Upper head scarp of an ancient landslide above the 350-acre landslide complex. This cliff is not immediately connected to the highest scarps of the active landslide, but is separated by about ¼ mile of rockfall debris, mostly still covered by snow in this photo.

It is evident that the landslide toe is pinching the East Fork of the San Juan River. A large boulder constricts the channel forming a small dam and creating a wider river width for about 100 ft long upstream (Figure 3). This channel constriction is certainly caused by the landslide as it is an area of the toe with newly downed trees. This constriction may have been present before the current episode of movement due to previous landslide activity. The widened portion of the river could be an incipient “lake” and bears watching.

Early reports estimate that the landslide moved 50 ft horizontally toward the river within the first 10 days of May 2008. If the slide moves at that rate into the East Fork, it could potentially block the river, but it depends on the ability of the river to remove the dirt and rocks being pushed into it by the landslide. This location is 12 miles upstream from the town of Pagosa Springs, hence the emergency situation. Excel Energy has been monitoring the slide with surface stakes and lath, and at last measurement the landslide moved toward the creek 3.3 ft in 20 hours time as measured by the US Geological Survey May 15-16.

Figure 3. Aerial view of the landslide toe affecting the East Fork of the San Juan River. Note the cliff-face across the river exposing Tertiary Volcanic bedrock.

On May 15, 2008, Mr. Carroll conducted a field investigation on the ground at the landslide complex. To gauge movement of the slide in the widened channel portion, five stakes were installed into the toe of the landslide complex 1 ft above the “lake” level. Access to the stable north side of the slope was not possible. Large boulders of volcaniclastic conglomerates partially block the river channel forming a cataract (Figure 4).

The entire length of the recent landslide surface was reconnoitered. A long lateral shear continues along the eastern flank of the slide from the toe upslope to the eastern headwall in the South San Juan Wilderness Area. Associated with this shear are a series of rolling hummocks and pressure ridges that parallel it.

Figure 4. View looking downstream from the small-impounded "lake" through the constricted zone. Landslide toe is on the left. Conglomerate boulders on the right are typical of the bedrock in nearby cliffs about 200 ft higher than the strata observed in the north side of the river channel.

Excel Energy maintains a major natural gas pipeline in the East Fork Valley. This pipeline was compromised on May 2 during the initial landslide movement. An Excel Energy geotechnical geologist is monitoring the landslide for additional movement with a series of 50 lath markers (Figure 5) situated along the USFS road across the toe of the landslide. They noted that the slide has moved 50 ft horizontally in two weeks time. Excel has responded by excavating the 8-inch pipeline and replacing it with an above ground flexible 4-inch line that can be moved uphill daily.

Figure 5. Lath marker in a meadow area along the east shear ridge that marks the eastern extent of the current landslide. A pressure ridge to the right is part of an older landslide that previously buckled the land surface. View is downhill toward the river.

The middle section of the landslide consists of extensional land features that have pulled the surface apart in dramatic fashion. The aspen and conifer trees in the area are severely stressed and ripped out in many places. Trees lean at various angles due to the 4 ft to 24 ft high land surface displacements. This part of the landslide is difficult to traverse (Figure 6). The orientation of the scarps trend north-south parallel to the eastern lateral shear, changing to east-west higher on the slope nearer the headwall scarps.

Figure 6. Small scarps within the upper to middle sections of the landslide show extension features pulling apart the surface terrain. Some scarps are up to 24 ft in height. Both live and dead trees have been twisted in this area. Small sag ponds impound water in this area also, especially along the main creek channel.

The upper part of the landslide consists of at least two circular headwall scarps on the east and central parts of the landslide. This area is also located within the South San Juan Wilderness Area. Five stakes were placed above the head scarps to monitor headward or retrograde movement of the headwalls. Stakes were also placed to monitor motion on a major pressure ridge on the east side, and the moving part of the eastern headwall. The highest part of the landslide daylights within the volcaniclastic rockfall debris at the top of the hill (fig. 7).

Figure 7. Rockfall debris along the main landslide creek channel just above the highest head scarp of the recent landslide. This area of volcanic rocks and large house-sized boulders may be periglacial in origin. This basin forms the collection point for all surface water moving through the landslide.

A helicopter overflight (arranged by Archuleta OEM) on May 16, 2008 allowed closer viewing of landslide features. Over 300 aerial photographs were taken of the landslide. From this closer viewpoint one can see all of the features of the landslide including the affected East Fork River (Figure 8). An additional smaller landslide also exists on the north side of the river just downstream from the East Fork slide reviewed in this report.

Figure 8. East Fork landslide toe downriver from the boulder constricted area. The swift moving water flow and steep gradient is assisting in removing landslide debris that moves into the channel. Left edge of the photo is on the active landslide and the cars are located on the USFS road just west of the active landslide on older landslide material.

The landslide toe juts out into the river. It is not clear whether the basal glide plane daylights at the surface or not, but it is clear that the entire tree covered toe that extends out into the river is moving. If the steep gradient of the river with high water velocity can erode the soil, rock, and trees that are being pushed into it, then the dynamic system will remain in balance. If the weather becomes wetter, or the oncoming snow runoff induces increased landslide movement, then the river may become more constricted. It will take a considerable amount of force to block the channel and for now the river seems to be able to erode the landslide toe. But the next four weeks during the peak runoff will be critical for monitoring the situation.

Figure 9. Aerial view of the rockfall channel just above the recent landslide. The main surface drainage for the landslide goes through this area and is still somewhat snow covered. Large vertical cliffs are uphill from this point by ¼ mile. This area is a large collection point for water and is very well shaded by the cliffs.

The head scarp area is interesting in that a large 300 ft vertical cliff forms the southernmost boundary of the older landslide. The bedrock is Tertiary volcaniclastic rock and a valley ¼ mile in length is formed downhill from the feature. This valley is mostly snow covered now but large house-sized boulders can be seen in this rockfall area. The valley seems to have a moderate to shallow slope, and then steepen downhill after a knick point (Figure 9), where the head scarp of the current landslide starts. The current landslide head scarp may be located at the transition between the “zone of deflation” (upslope) and the “zone of accumulation” (downslope) of the larger older landslide. Within this head scarp area volcaniclastic boulders are jumbled. Some shale was found within the head scarp face also. Care was taken by the helicopter to stay on the National Forest part of the landslide and not fly over the South San Juan Wilderness Area containing the southern end and head scarp area of the landslide.

Conclusions

After reviewing all of the data it seems clear that this partial reactivation of an older, large landslide complex (Figure 10) is a threat to the East Fork of the San Juan River. Movements recorded so far indicate that the landslide has the potential to block the river channel for up to 600 ft in length. Immediate monitoring should be conducted. The USGS geologists suggested this to the Archuleta County OEM, but OEM only has so many resources. Since the area is somewhat remote it is suggested that satellite monitoring of electronic distance measuring devices be installed to relay data back to the office to warn about catastrophic failure.

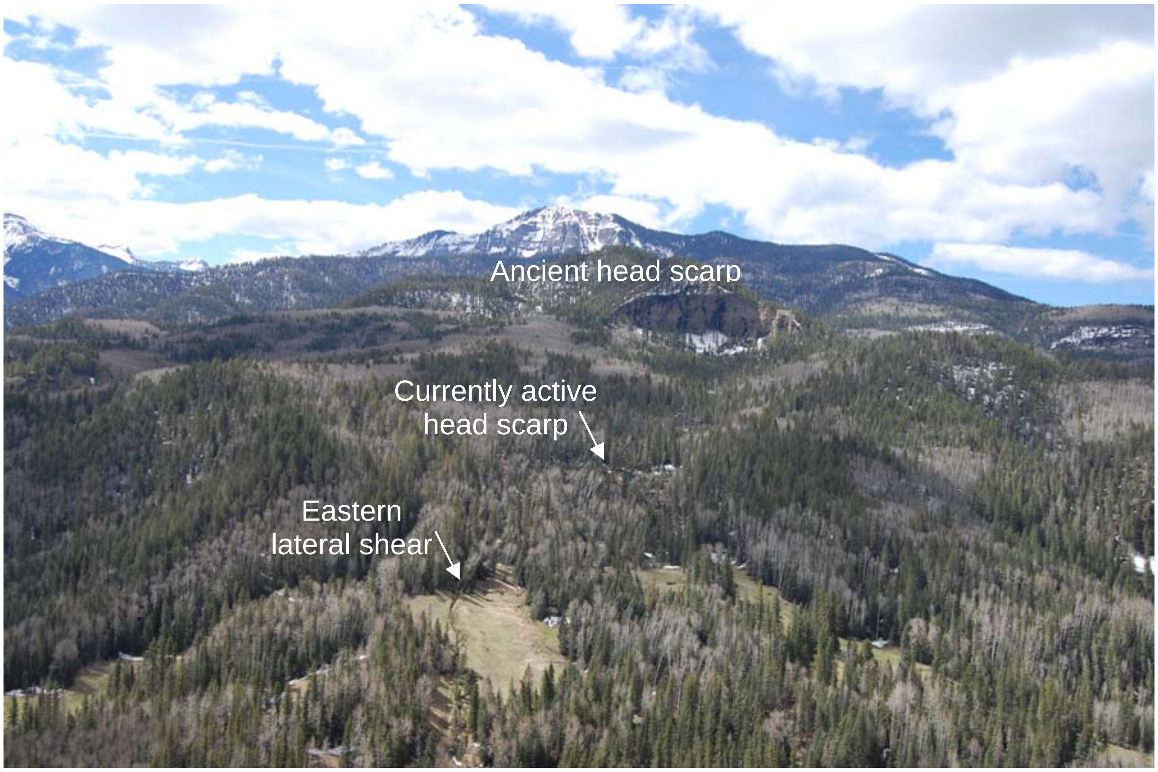

Figure 10. Aerial view of the middle and upper part of the ancient (older) and active landslides. The eastern shear fault is visible in the meadow. Downed aspens uphill from there show the distressed extensional rotation areas, and the cliff face in the background shows the ancient head scarp and rockfall debris area.

The USFS will be installing river flow stream gauges from the Colorado Division of Water Resources on the East Fork. The USFS hydrologist indicated that this landslide has moved in the past, but never this dramatically. Shale rock found in some of the head scarps may indicate that the deeper glide plane may be sliding on Cretaceous Lewis Shale. All of these parameters must be considered in the characterization of the landslide. Further characterization may include drilling to determine the slip plane, electronic distance measuring to track movement over time, and inclinometers for measuring tilt and at what depth the landslide is moving. For now, Excel Energy is very concerned and is taking the lead on monitoring the landslide.

The Pagosa Springs newspaper picked up the East Fork Landslide story and reported on it in the following article:
http://www.pagosadailypost.com/news/8419/Landslide_on_East_Fork_Sparks_Emergency_Planning/

Geologic Context of East Fork Landslide

The East Fork Landslide is located in an area where volcanic rocks cover most of the land surface. These volcanic lavas and breccias are 31 to 35 million years old (Oligocene). The volcanic rocks overlay older Tertiary to Upper Cretaceous sedimentary rocks of the Blanco Basin and Animas Formations in the vicinity of the landslide.

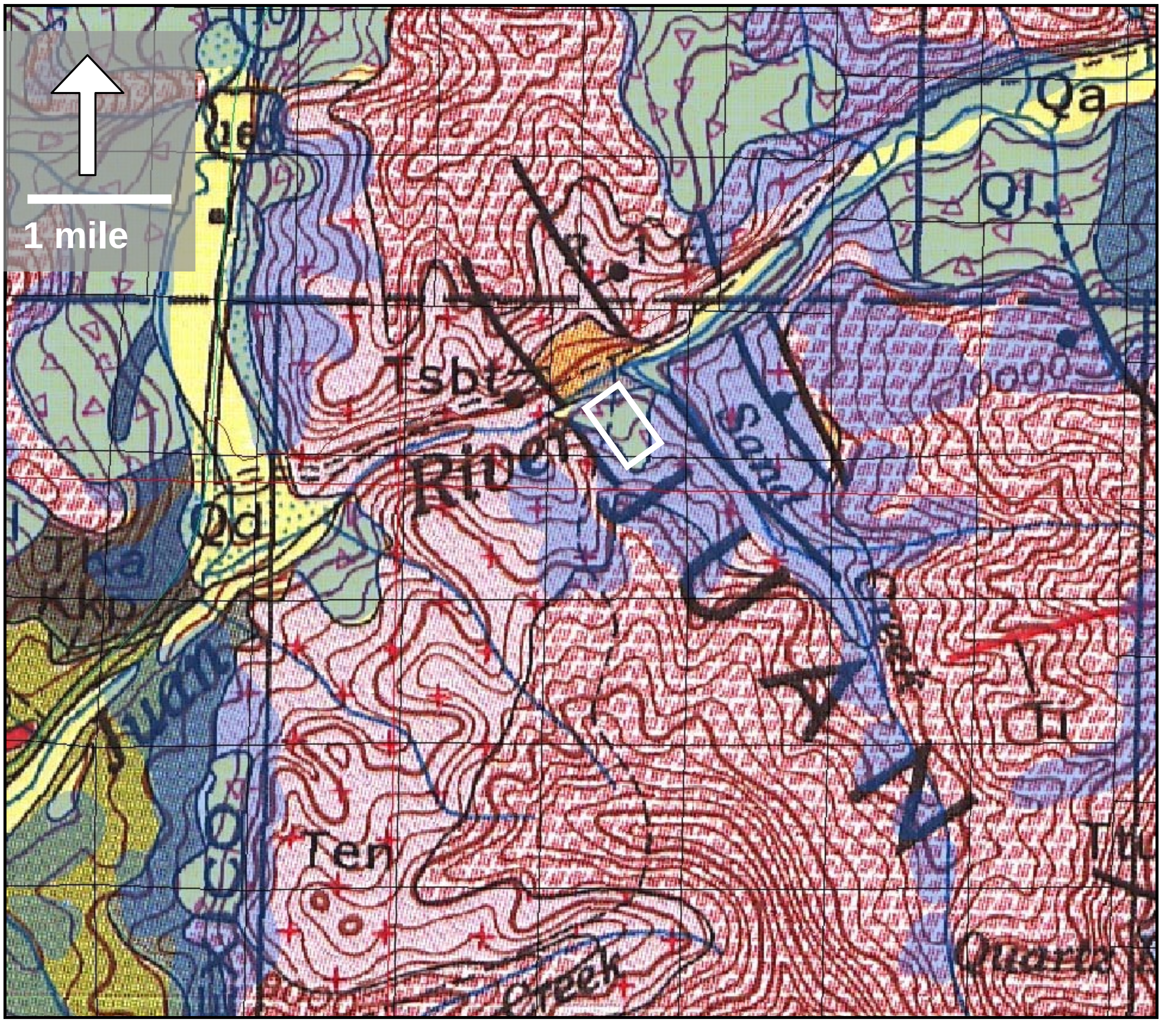

Figure 11. Geologic map of the East Fork landslide area. Green and blue shaded areas are mapped landslide terrain. Pink areas are volcanic rocks. Bold black lines indicate faults with bar and ball on downthrown side. (Steven and others, 1974, USGS Map I-764; Colton and others, 1976, USGS Map I-964)

The East Fork San Juan River drainage basin contains abundant landslide terrain (Figure 11) and the current reactivation constitutes only a small part of a larger landslide complex. The landslide is bounded on the east and west by faults trending north-northwest. Sand Creek follows the trace of the fault on the east side of the current landslide.