Utah Geological Survey Technical Report

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<tr><td colspan="3">Project:
Landslides of 2005 at a horse ranch near the East Lawn Memorial Hills Cemetery, Provo, Utah County, Utah</td><td rowspan="3"></td></tr>
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F.X. Ashland, P.G.</td><td>Date:
January 11, 2006</td><td>County:
Utah</td></tr>
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Orem (1047)</td><td colspan="2">Section/Township/Range:
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INTRODUCTION

On March 17, 2005, Utah Geological Survey (UGS) geotechnician Michael Kirschbaum observed a recent large landslide on a southwest-trending ridge east of the East Lawn Memorial Hills Cemetery in northern Provo, Utah (figures 1 and 2A). The landslide impacted the western part of a cooperative horse ranch property, affecting the ground surface in a corral area, and subsequently damaging a tack shed and fencing. Three other small landslides (figure 2) also occurred upslope of the main slide in cut and/or fill slopes.

UGS geologists made a reconnaissance of the main landslide on March 29, and subsequent reconnaissance visits on April 18 and May 12 to photograph changes to the main slide. On June 23, Michael Kirschbaum and I mapped the perimeters of each landslide and deformation features in the main slide in detail. The purpose of these investigations was to document the landslide, including the types of movement, amount and extent of ground deformation, and duration of landslide activity, particularly because of the geologic similarities between this site and the northern part of the Sherwood Hills subdivision to the south (figure 1).

CONCLUSIONS

The main landslide on the horse ranch property will likely reactivate in future wet years. Given the currently high measured ground-water levels in the Sherwood Hills subdivision directly to the south, reactivation of the main landslide in early 2006 is possible even with normal precipitation in the intervening time period. Reactivation may be accompanied by additional enlargement of the main landslide, threatening upslope infrastructure and the barn. Additional offset of existing internal (minor) scarps will cause more damage to the western part of the horse ranch, further damaging paved areas and the tack shed. Reactivation of the southern part of the landslide poses some risk of blocking the drainage at the base of the slope. Subsequent flooding from the eventual breach of such a blockage would likely impact the access corridor to the cemetery and possibly residential properties downstream and to the southwest.

This landslide also suggests the marginal stability of local steep slopes in prehistoric landslide deposits in northern Provo, particularly where hillslope modifications have occurred. The similarities in local slope, geology, and hillslope modifications of this area and the northern part of the Sherwood Hills subdivision, suggest some potential for similar landsliding in the subdivision.

GEOLOGY

The horse ranch is underlain by prehistoric landslide deposits that comprise the northern part of the Sherwood Hills landslide complex (Machette, 1992; Ashland, 2003). Figure 3 shows the local geology and younger pre-existing landslides within the prehistoric older landslide deposits. The younger pre-existing landslides with well-defined boundaries indicate local partial reactivation of the prehistoric landslide deposits prior to the area's use as a horse ranch. Landslide deposits consist of clay-rich debris with angular cobble and boulder clasts supported in a clay-rich soil matrix. The debris is likely derived, in part, from residual and colluvial deposits formed on the Mississippian Manning Canyon Shale, a formation that underlies the eastern part of the Sherwood Hills landslide complex.

Some hillslope modification accompanied building and road construction on the horse ranch property, including site regrading that locally flattened the ridgetop. Locally derived fill was likely placed on the upper parts of the slopes during this regrading. Field observations suggest a considerable amount of fill likely existed near the west corner of the corral prior to the landslide. A second large fill area exists upslope and northeast of the main landslide in the upper part of the drainage that bounds the ridge and the slide on the north.

LANDSLIDE DESCRIPTIONS

Four separate landslides were active in 2005 on the horse ranch (figure 4). The main landslide is a reactivation of younger pre-existing landslides in the underlying prehistoric landslide deposits. The other three landslides occurred in either cut or fill slopes. Fill materials were likely locally derived, making distinguishing fill from native landslide deposits difficult.

Main Landslide

The main landslide is on the southwest-trending ridge occupied in part by the corral (figure 4). The landslide consists of two slides that overlap at the ridge crest, one on the northern slope of the ridge and one on the southern slope, that have divergent movement directions. Our mapping indicates that the northern part of the landslide moved first and that the southern part expanded upslope, capturing part of the northern part of the slide. Evidence for this includes a severed toe thrust on the western edge of the landslide that initially was in the northern part of the slide before it was cut off by the main scarp of the southern part of the slide. Figure 5 is a detailed map of the main landslide showing the major internal deformation features, movement directions, scarp heights, and deposit thicknesses. By June 23, the main landslide was about 2.4 acres in size.

The northern part of the main landslide (figure 2A) consisted of an earth flow in the lower western part, and an earth slide in the upper eastern part that together form a complex earth slide-earth flow. Figure 5 shows that movement in the earth flow was to the southwest. Scarp orientation indicates movement in the upper earth slide was generally westward and locally west-northwest. The entire northern part of the main landslide was about 490 feet long. Local relief between the toe of the earth flow and main scarp of the earth slide was about 165 feet, indicating an average slope of the complex earth slide-earth flow of about 34 percent. The average slope of the lower earth flow was slightly steeper, about 41 percent. Several internal (minor) scarps cut the upper earth slide, including two with large offsets. The lower of these two scarps was about 70 feet upslope of the top of the earth flow, arcuate in plan view, and between 3.5 and 7 feet high on June 23. The second large-offset scarp (figure 6D) crossed the middle of the corral and reached a maximum height of about 6 feet near the southeastern edge of the corral. Observations between March and June suggest that the northern part of the landslide remained active during this period and enlarged upslope of the tack shed. On June 23, the main scarp east of the large-offset internal scarps reached a maximum height of only about a foot and crossed a cut slope above a tack shed northeast of the corral.

The southern part of the main landslide consisted of an earth slide about 340 feet wide and between 160 and 200 feet long. Figure 5 shows the movement direction of the southern part of the slide was generally to the south-southwest. In the east, the southern part of the slide abutted the northern earth slide, but in the west the southern part of the slide overlapped the northern part. The northern boundary of the southern part of the landslide extended into the southern corner of the corral and about 80 feet of the northern part of the slide was captured by the southern part. Local relief in the southern part of the landslide ranged between about 50 and 95 feet, with an average slope between about 32 and 46 percent. The main scarp of the southern part of the slide consisted of two separate arcuate scarp areas divided by a narrow south-trending ridge (figure 5). The scarps locally reached a maximum height of about 6 feet on June 23. Figure 6F shows damage to a wooden fence caused by ground deformation in the upper part of the southern part of the main landslide. A well-defined landslide toe exists along the bank of a drainage in the east and near the base of the slope in the west (figures 4 and 5).

Small Landslides

Three other small landslides were also active in 2005 on the property (figures 2B through 2D and 4), all of which formed in cut and/or fill slopes. Because of the use of local landslide debris as fill, differentiating cut and fill slopes was not possible. The topography suggests that the slopes may be cuts in their lower parts and fills in their upper parts. Table 1 summarizes the dimensions of these landslides.

Table 1. *Summary of dimensions and slope of small landslides.*

Location of slide	Length (ft)	Width (ft)	Area (sq yds)	Slope (percent)
Near tack shed	45	59	308	47
East of barn	59	64	377	79
Northeast of arena	26	50	108	93

The closest small slide to the main landslide was in a steep southwest-facing slope below a paved access road to a large barn on the property, a short distance southeast of the tack shed. Offset on the main scarp caused minor damage to a wooden fence and to the edge of the pavement atop the slope (figure 2B). Based on its proximity to ground deformation features in the crown of the main landslide, the small slide may actually be within the limits of the main landslide, although it is mapped as a separate slide on figures 4 and 5.

The two other small slides were upslope of a large barn and riding arena (figure 4). One was on a southeast-facing slope east of the large barn (figure 2D). Offset on the main scarp severed a buried drain or water pipe. The other small slide (figure 2C) was in a cut slope directly northeast of a riding arena. The landslide was localized in a weathered block of Manning Canyon Shale or homogenous debris derived from the shale.

CAUSES AND IMPLICATIONS

Movement of the 2005 landslides initiated during a wetter than normal period and after most, if any, snowpack at this elevation (approximately 5,200 to 5,450 feet) had melted. Thus, rising ground-water levels in the underlying prehistoric landslide deposits likely triggered the movement. However, ground-water levels declined between February and March in most of the nearby monitoring wells in the Sherwood Hills subdivision to the south. Only two of the Sherwood Hills wells, both at about elevation 5,200 feet, had rising ground-water levels in March, suggesting the possibility that ground-water levels were rising at least in the lower part of the main landslide when movement triggered. Rising ground-water levels in the lower parts of the underlying younger pre-existing landslides may have reduced the resisting forces sufficiently, possibly in combination with a wetting-induced rise in soil weight that increased driving forces in the upper parts of these slides, to trigger movement.

The property owner of the affected part of the horse ranch indicated that minor ground deformation was noticed in 2004 in the corral area, suggesting movement in the previous year. Thus, another possibility is that movement in 2004 never suspended, but only fell to an extremely slow rate in the summer of 2004. The onset of rising ground-water levels and soil wetting in March 2005 may have caused a rapid acceleration in the rate of movement and the resulting ground deformation.

Grading and fill placement at the top of the younger pre-existing landslides ($Qmsy_1$ in figure 3) were also likely contributing causes of the landsliding. The additional load of the fill in the upper part of these landslides increased driving forces and likely left the pre-existing slides marginally stable prior to the rising ground-water levels in 2005 or the onset of movement in previous years.

The large amount of displacement and ground deformation of the main landslide in 2005 is notably different from that which occurred during the same time period in the remainder of the Sherwood Hills landslide complex directly to the south. Scarp heights on the horse property reached a maximum height of about 7 feet in the northern earth slide whereas the highest scarp in the Sherwood Hills subdivision part of the complex, caused by movement in 2005, measured only several inches in height. The amount and extent of displacement and ground deformation at the horse ranch landslide is likely due to both the local steep slopes (average slopes in the main landslide ranged typically between 30 and 45 percent with locally steeper slopes), and the type of movement (flow) in the northern part of the slide. Earth-flow displacement likely exceeded 50 feet in the northern part of the landslide and accommodated considerable stretching in the upslope earth slide, as indicated by the numerous scarps. Rapid failure of the fill slope and disruption of fill soils at the west corner of the corral during a time when the soil was wet or even locally saturated may have accelerated the transition to earth flow. However, scarp height and upslope enlargement of the landslide also suggests deeper seated movement of the underlying landslide deposits. Initial landslide boundary mapping in late March showed close conformity between the 2005 boundaries of the northern part of the landslide and the northern younger pre-existing landslide ($Qmsy_1$ in figure 3).

FIELD METHODS

Landslide boundaries were mapped using a handheld global positioning system device with an approximate accuracy range of between 10 and 30 feet at the time of the fieldwork. Maps of the 2005 landslides and dimensions listed in this report were derived using this method. Short-term variation in location was tested using duplicate measurements from the same device and was less than 2 feet. Duplicate measurements using two devices were also used to improve accuracy. Some measurements of landslide dimensions were checked in the field using a fiberglass tape.

ACKNOWLEDGMENTS

Michael Kirschbaum (formerly UGS) conducted the initial reconnaissance of the landslide and subsequent photographic documentation of the progression of landsliding. He also assisted with fieldwork for this study. Lucas Shaw (UGS) provided assistance in creating several of the figures in this report.

LIMITATIONS

Although this product represents the work of professional scientists, the Utah Department of Natural Resources, UGS, makes no warranty, expressed or implied, regarding its suitability for a particular use. The Utah Department of Natural Resources, UGS, shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to claims by users of this product.

REFERENCES

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Machette, M.N., 1992, Surficial geologic map of the Wasatch fault zone, eastern part of Utah Valley, Utah County and parts of Salt Lake and Juab Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-2095, 26 p. pamphlet, scale 1:50,000.

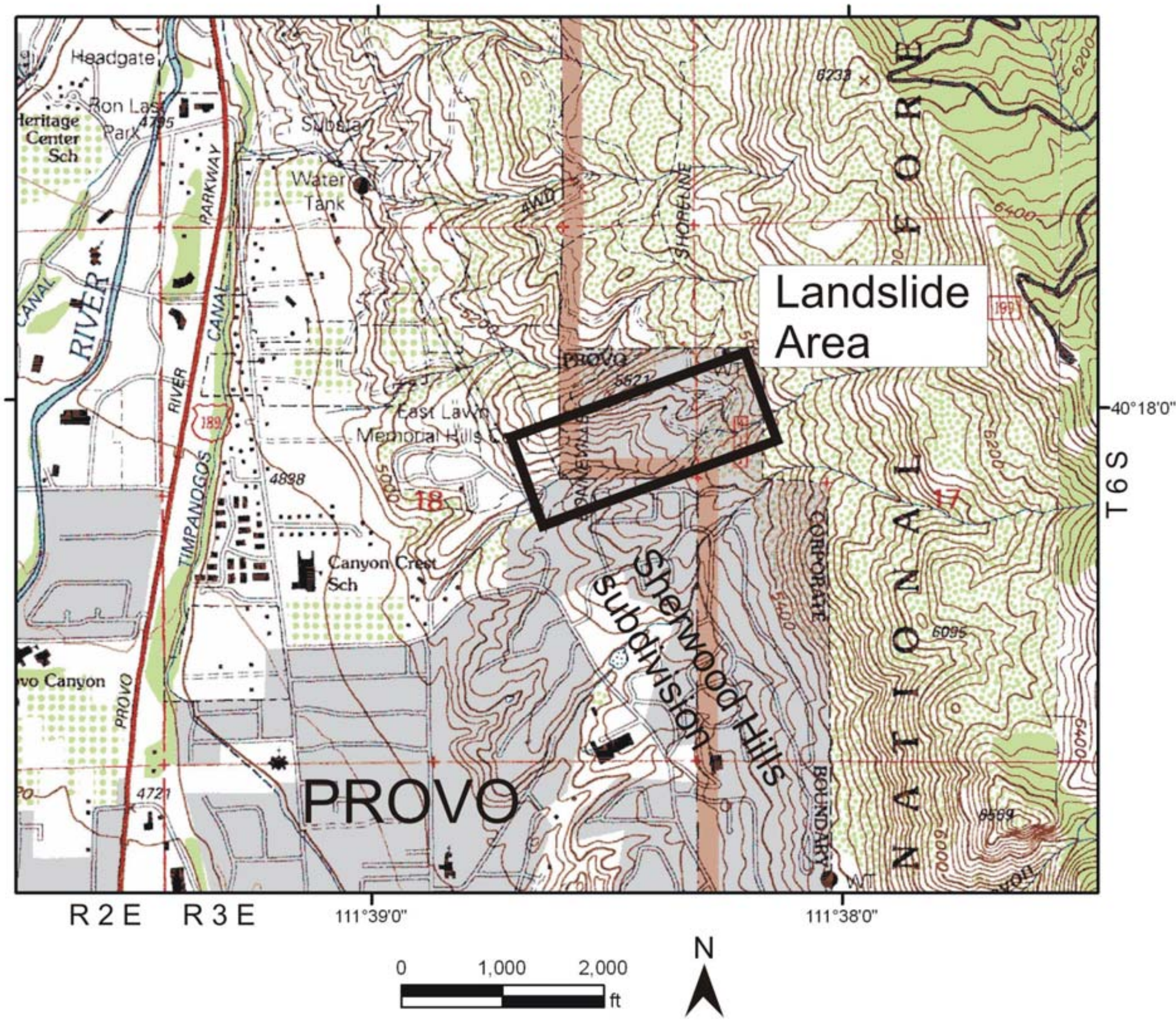

Figure 1. *Location map of landslide area on horse ranch east of East Lawn Memorial Hills Cemetery in northern Provo. Topographic base from the Orem 7.5-minute quadrangle.*

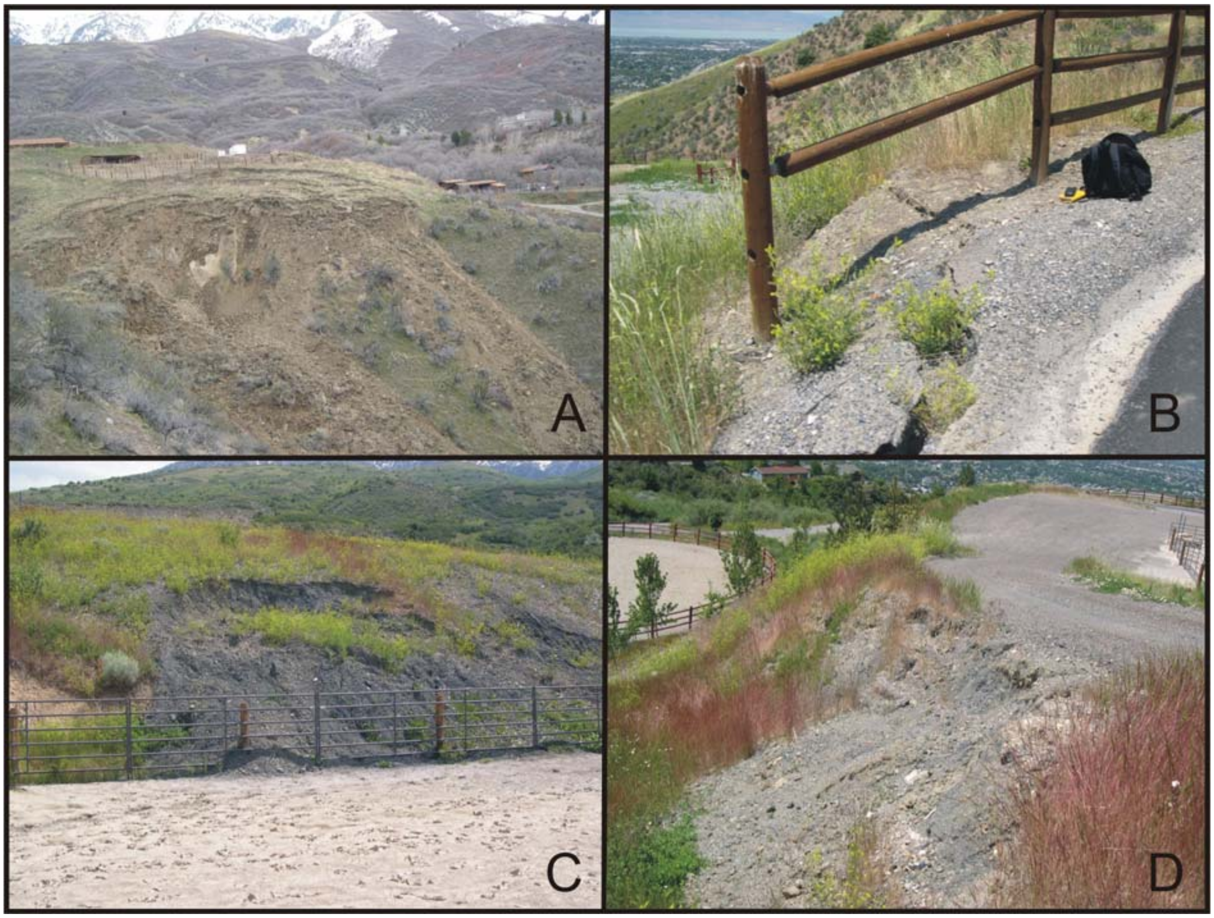

Figure 2. *Landslides in 2005 on horse ranch east of East Lawn Memorial Hills Cemetery, Provo. (A) View to the east of north part of main landslide on March 17. (B) Minor offset on main scarp of small companion slide to main landslide southeast of tack shed that caused minor damage to fence. View is to the west. (C) View to the east of small landslide northeast of riding arena in highly weathered Manning Canyon Shale or debris derived from the shale. Movement direction is to the west-southwest. (D) View to the west-southwest of main scarp of small landslide east of barn. Movement direction is to the southeast. Photographs of small landslides (B, C, and D) taken on June 23.*

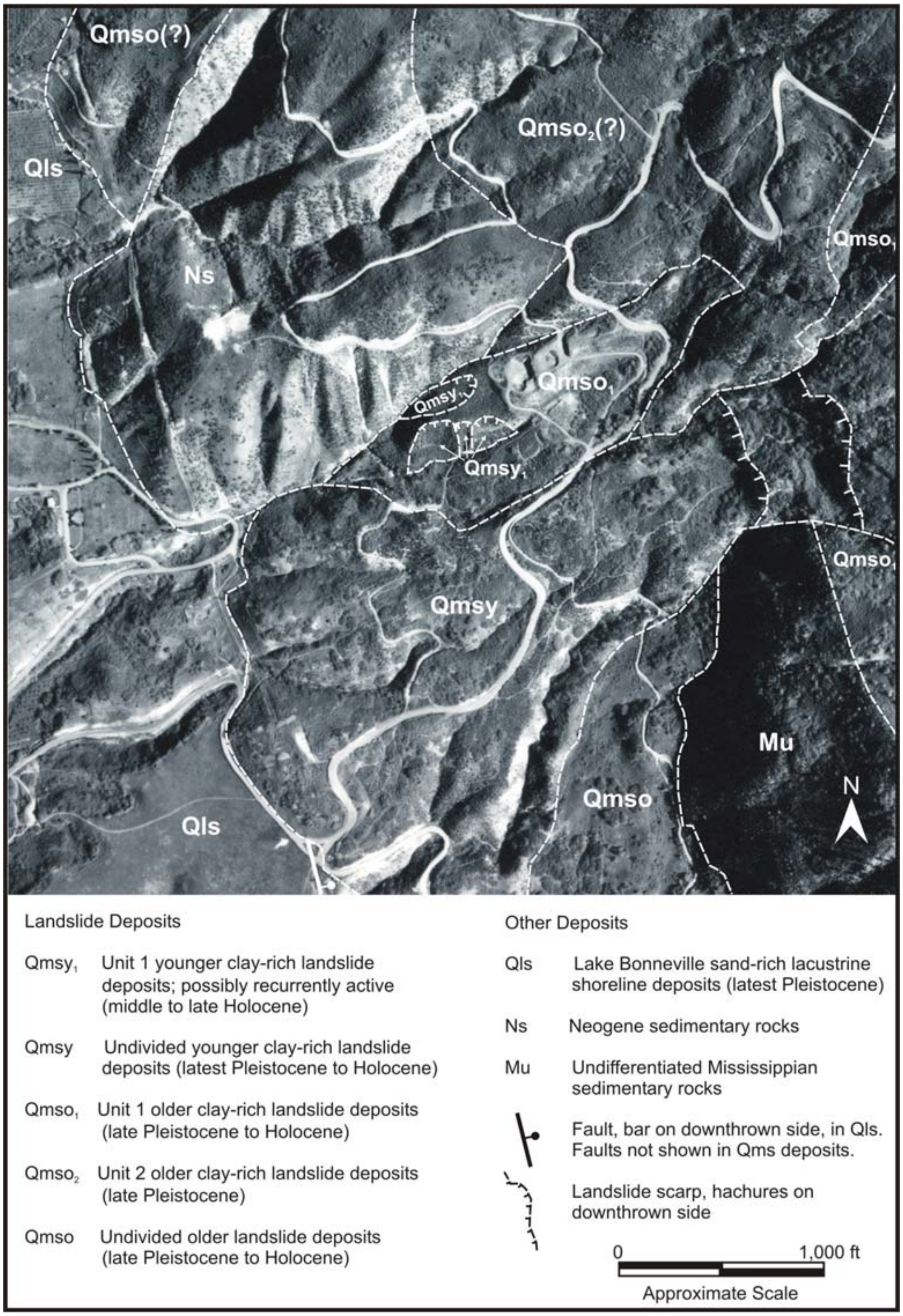

Figure 3. *Aerial photograph geologic map of the northern part of the Sherwood Hills landslide complex showing prehistoric landslides and landslide deposits prior to development. Unit 1 younger landslides ($Qmsy_1$) and unit 1 older landslide deposits ($Qmso_1$) underlie site of 2005 landslides on horse ranch property.*

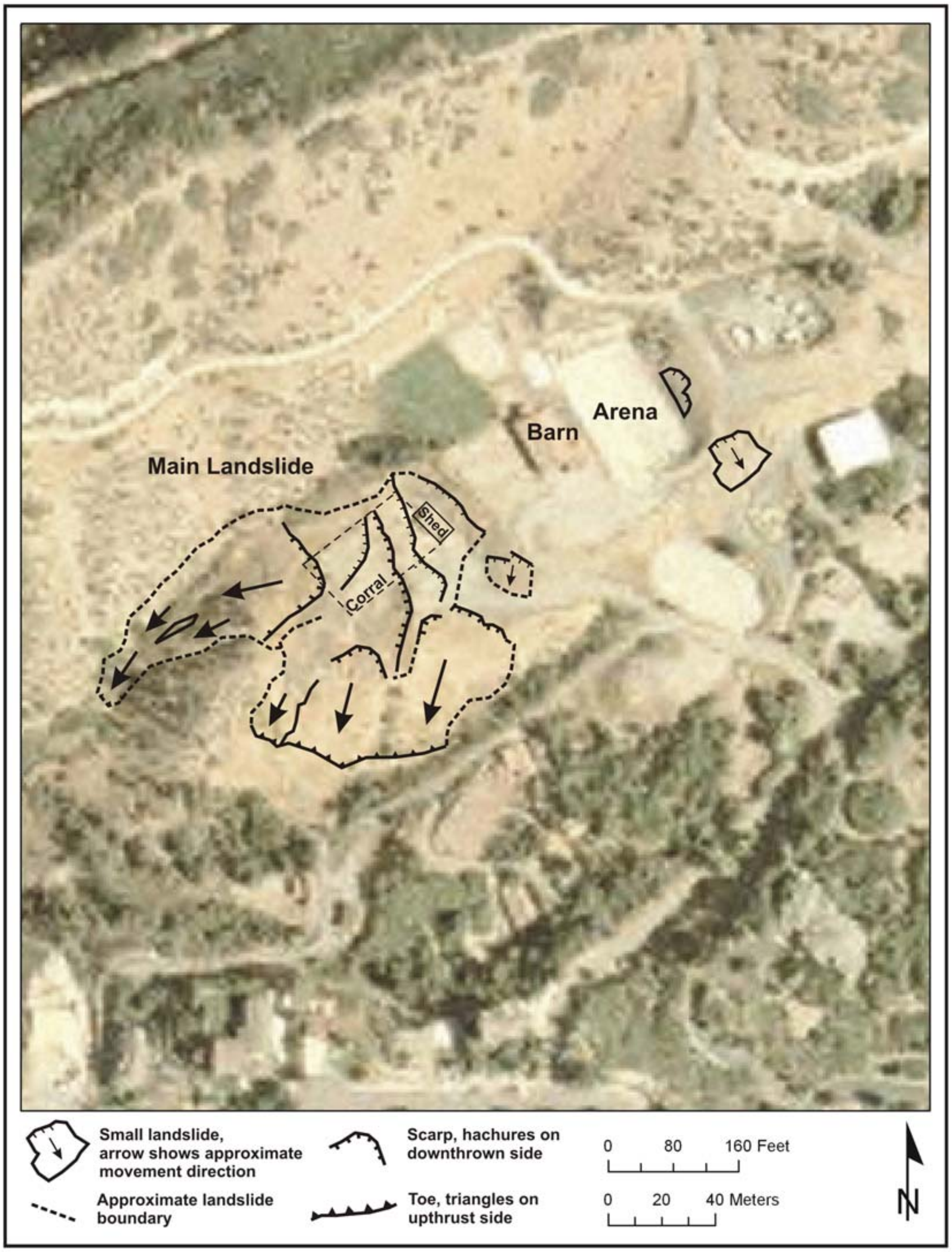

Figure 4. *Map showing 2005 landslides on horse ranch property. The main landslide consists of two parts that overlap near a southwest-trending ridge crest, a northern complex earth slide-earth flow that moved west-southwest and a southern earth slide that moved south-southwest. The other three small landslides occurred in either cut or fill slopes.*

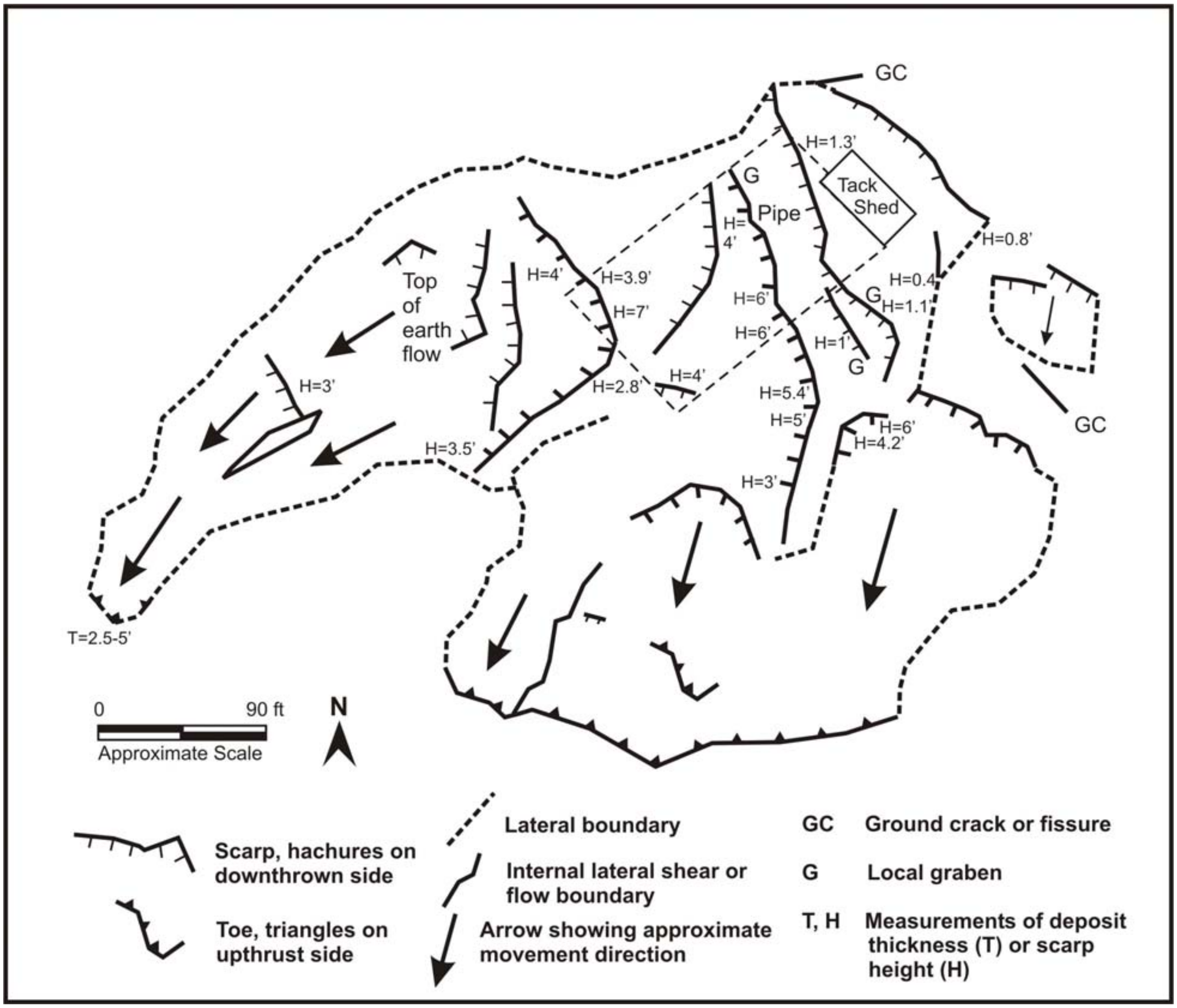

Figure 5. *Detailed map of main landslide. Height of scarps or deposit thicknesses in feet on June 23 also shown. Dashed rectangular area is approximate boundary of corral. Pipe indicates drainpipe exposed in scarp.*

Figure 6. *Ground deformation in the main landslide, March 17 to May 12, 2005. (A) View to the northeast of earth-flow toe (arrow) on March 17. (B) Slickensided clay in north part of landslide on March 17. (C) View to the north of south part of landslide on March 29. (D) View to the northwest of large internal scarp that crossed horse corral on April 18. (E) View to the northeast of north edge of landslide on April 18. (F) View to the east of damage to fence due to offset of main scarp of south part of landslide on May 12.*