Utah Geological Survey

Project: Reconnaissance of the April 9, 2006, 1650 East landslide, South Weber, Utah			
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USGS Quadrangles: Ogden (1345)	Section/Township/Range: SW¼NE¼ section 34, T. 5 N., R. 1 W., SLBLM		
Requested by: Ron Chandler, South Weber City Manager			Job number: 06-10

INTRODUCTION

At the request of Ron Chandler, the Utah Geological Survey (UGS) conducted a reconnaissance of the 1650 East landslide in the Highland View Estates subdivision, South Weber, Davis County, Utah (figures 1 and 2) on April 10, 2006. Rick Chesnut (Terracon) and Lee Cammack (JUB Engineers) were also conducting a field study of the landslide and damage to the Davis-Weber Canal for the Davis-Weber Canal Company at the time of our visit. On April 11, 2006, Richard Giraud discussed the landslide hazard with city officials and homeowners in a public meeting and on April 14, 2006, provided a letter (Giraud, 2006) to South Weber City outlining recommendations for managing the landslide hazard.

The landslide occurred around 9:30 p.m. on the evening of April 9, 2006. It flowed over and damaged the Davis-Weber Canal at the base of the slope, and impacted the back of the house at 1650 East 7687 South below the canal (figures 3 and 4). The landslide caused significant damage to the house, injured a child inside the house, and prompted evacuation of nearby houses. The purpose of our investigation was to determine the cause of the landslide, document physical characteristics of the landslide, and evaluate the remaining landslide hazard to aid South Weber City in determining when to allow evacuated residents to return and in assessing the long-term risk to development at the base of the bluff.

For this study, we reviewed relevant geologic maps and reports of geology, geologic-hazard, and landslide investigations in the area. We also reviewed 1:20,000-scale (1937), 1:10,000-scale (1958), and 1:24,000-scale (1985) stereo aerial photographs; U.S. Geological Survey 1997 and 2003 orthophotos at various scales (TerraServer USA, 2006); and National Agriculture Imagery Program orthophotos at various scales (Utah Automated Geographic Reference Center, 2006).

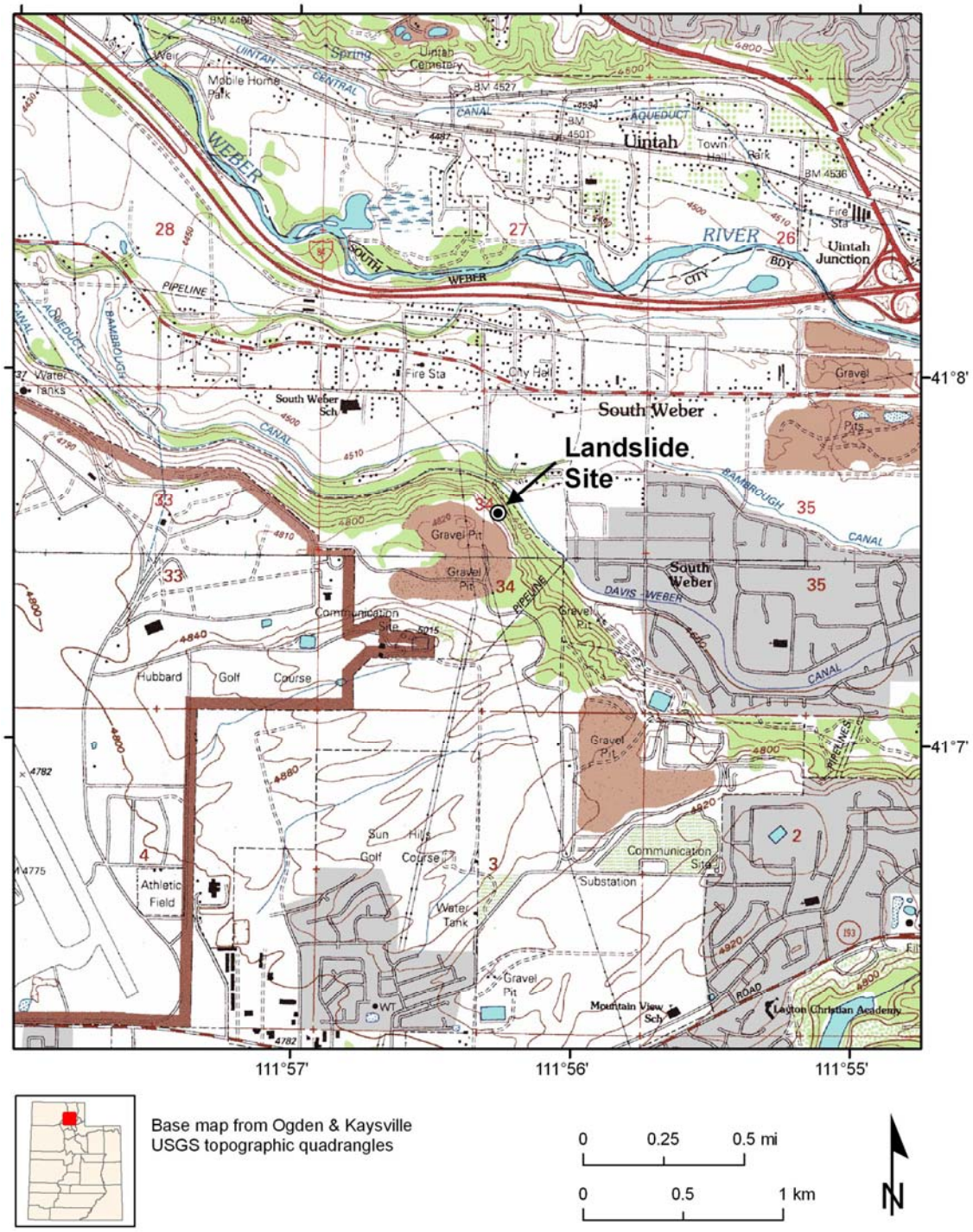

Figure 1. Location of the 1650 East landslide in South Weber, Utah.

Figure 2. Image showing landslide flow direction, Highland View Estates subdivision, gravel pit pond, and the Davis-Weber Canal. The pond boundary is approximate and is based on oblique aerial photographs taken by Davis County Sheriff's Office personnel on the morning of April 10, 2006.

Figure 3. Landslide damage to the house at 1650 East 7687 South.

Figure 4. Damage to the house and garage at 1650 East 7687 South.

CONCLUSIONS AND RECOMMENDATIONS

Based on this geologic investigation and hazard assessment of the 1650 East landslide, the UGS concludes the following:

- The 1650 East landslide was a rapid earth flow that damaged the Davis-Weber Canal and the house at 1650 East 7687 South, and injured a child inside the house.

- Piping holes near the head of the landslide below the slope crest indicate a pond and shallow ground water in the gravel pit atop the bluff saturated a zone in material along the slope crest and triggered the landslide. The steep slope, runoff of snowmelt into the pond, shallow ground water in the gravel pit, weight of embankment fill at the slope crest, and weak underlying geologic materials probably all contributed to the landslide.

- The houses along the base of the slope are in a runout zone for shallow rapidly moving landslides and may also be at risk from deep-seated rotational landslides.

- For potential deeper seated rotational landslides in the slope above the subdivision, Terracon's (2005) slope-stability investigation estimated a static factor of safety of 1.2, which is well below the normally accepted 1.5 factor of safety. Terracon's analysis indicates the slope will likely fail during an earthquake.

- Deep-seated landslides can impact the canal, and if the canal is conveying water and a landslide caused a canal breach, widespread flooding and sedimentation could occur at the base of the slope.

To reduce the potential impacts of landslide movement and manage the landslide hazard in this area, the UGS recommends the following:

- Implement surface- and ground-water control measures to ensure conditions at the slope crest that caused the 1650 East landslide do not reoccur.

- Because houses already exist along the base of the slope and are potentially impacted by both shallow and deep-seated landslides, a study should evaluate the landslide hazard, potential impacts to houses, and possible risk-reduction measures.

- Monitoring should continue of slope movement and ground-water levels in inclinometers and piezometers, respectively, installed by Terracon for the Davis-Weber, to assess potential movement of deep-seated landslides.

- South Weber City should consider both shallow and deep landslide hazards and hazards related to a possible canal breach when evaluating existing or future development and setbacks at the base of the slope along the city's entire south side.

- Disclose the existence of hazards reports and information to existing and future homeowners.

GEOLOGIC SETTING

The 1650 East landslide is in a steep northeast-facing slope forming the south side of the Weber River Valley (figure 1). The slope formed as the Weber River cut down into its former delta as Lake Bonneville receded from the Provo shoreline after 14,500 years ago to the present level of Great Salt Lake. The slope is approximately 220 feet high and has an average gradient of 45% (24°). The Davis-Weber Canal is in the lower slope just above houses built along the slope base.

Geologic evidence and historical records indicate relatively frequent landsliding in slopes in the area. Yonkee and Lowe (2004) mapped the northeast-facing slope as "older Holocene landslide deposits" that include widespread landslides developed within generally fine-grained lacustrine and deltaic sediments. The older Holocene landslide deposits are mainly slumps and earth flows. Lowe (1988) shows historically active landslides (LSa 331-334) near the 1650 East landslide and along the entire northeast-facing bluff, which he mapped as an older landslide complex (LS 335). Yonkee and Lowe (2004) mapped these historically active landslides as younger Holocene landslide deposits. Earthtec (2002) completed a geotechnical study for Highland View Estates subdivision and identified a landslide near the subdivision but did not show the landslide relative to the subdivision on a map. Other authors have documented numerous historical landslides in the slope east and west of the 1650 East landslide (Pashley and Wiggins, 1972; Lund, 1984; Black, 1999; Solomon, 1999). These landslide deposits are also derived from Lake Bonneville fine-grained lacustrine and deltaic deposits.

The 1650 East landslide is similar to the February 20, 2005, 425 East South Weber Drive landslide (Giraud, 2005). The 425 East South Weber Drive landslide threatened the Davis-Weber Canal, demolished a barn, blocked State Route 60 (South Weber Drive), and had a 150 foot runout beyond the slope toe onto flat ground. The Davis-Weber Canal Company installed drains and buttressed the slope to reduce the risk of future landslides.

LANDSLIDE DESCRIPTION

The 1650 East landslide was a rapid earth flow that started as a slide at the slope crest adjacent to a pond in a gravel pit (figures 2 and 5). The landslide main scarp extends a short distance back from the slope crest onto flat ground toward the pond in the gravel pit. The landslide is mostly a failure of fill pushed out of the gravel pit onto the upper slope to form a berm along the slope crest (figure 6). The landslide also involved native materials underlying and downslope of the fill. The slide at the crest mobilized into a flow that accelerated rapidly downslope, removing trees and crossing dirt roads, the canal, and a rock wall at the back of the lot before impacting the house at 7687 South 1650 East (figures 2 and 7). The landslide impact

Figure 5. View looking northwest at the pond in the gravel pit and the landslide head (arrow). A berm was placed between the pond and the landslide to prevent water from flowing onto the landslide. Photo taken on the morning of April 10, 2005, by Davis County Sheriff's Office personnel.

Figure 6. View to the southeast showing landslide main scarp and fill placed on the upper slope. Near the left edge of the photo, black top soil at the base of the scarp (arrow) underlying the brown fill is evident and indicates the original slope surface.

Figure 7. View looking down the landslide flow path at the damaged house at 1650 East 7687 South. The culvert in the lower slide path above the house was originally in the gravel pit. Subsequent water flow eroded the right side of the landslide.

broke through the house and garage walls and a small volume of sediment and tree debris was deposited in the house. A child inside the house was injured and the landslide impacted with sufficient force to break part of the house foundation wall (figure 8). The impact to the back of the garage pushed a car and pickup out through the garage doors. The landslide broke windows at the adjacent house to the southwest at 1650 East 7701 South. The landslide also damaged the Davis-Weber Canal which had recently been enclosed in a concrete box culvert but was not yet covered with backfill (Ray, 2006) (figure 9). Water had not yet been turned into the canal for the irrigation season so obstruction to flow in the canal by the landslide was not an issue.

The landslide likely moved initially as a shallow translational landslide but quickly transformed downslope into a rapidly moving earth flow. The landslide was about 80 feet wide and 600 feet long (figure 2). It initiated in the upper slope on gradients of as much as 60% (31°). The average gradient from the landslide main scarp to the impacted house is 45% (24°). The steep slopes accelerated the landslide downslope toward the subdivision. Some landslide material was deposited on the canal and canal access road (figure 9) and on dirt roads above the canal (figure 10), which reduced the landslide volume before impacting the house and likely reduced damage to the house. Following the landslide, water draining from the landslide crown and head eroded the right side of the landslide and flowed into the canal (figures 7 and 9).

The pond in the gravel pit collects surface-water runoff and also reflects the local shallow water table. Test pits excavated by the Davis County Public Works Department on April 10, 2006, near the landslide crown in the gravel pit showed shallow ground water perched at depths of 4 to 6 feet on clay beds. Cottonwood trees in the gravel pit and wetland vegetation in and near

Figure 8. Basement at 1650 East 7687 South showing upper foundation wall (right side of photo) broken by landslide impact.

Figure 9. View looking northwest of Davis-Weber Canal showing landslide material deposited on the box culvert and canal access road. Following the landslide water and sediment flowed into the canal left of the box culvert.

Figure 10. Landslide material deposited on a dirt road midslope above the Davis-Weber Canal.

the pond (figure 5) also indicate the presence of perennial shallow ground water since surface-water runoff alone would not sustain this vegetation. Cottonwood trees growing along the slope crest also indicate shallow ground water (figure 6). Following the landslide, a soil berm was placed between the pond and the landslide to prevent pond water from flowing onto the landslide head (figure 5).

CANAL SLOPE-STABILITY INVESTIGATION

Prior to construction of the Highland View Estates subdivision, Terracon (2000) completed an initial geotechnical-engineering investigation along the bluff to identify areas along the Davis-Weber Canal that are prone to landsliding. This investigation indicated that the slope above the Highland View Estates subdivision and the canal is marginally stable. To address the landslide hazard, Terracon (2005) completed a follow-up slope-stability investigation, which included installation of piezometers and inclinometers and a subsequent slope-stability analysis. The boreholes encountered interbedded clay, sand, silty sand, sandy silt, and gravel. For the slope above the canal and subdivision, Terracon (2005) estimated a factor of safety of 1.2 under static conditions for deep rotational landsliding. For earthquake ground-shaking conditions, Terracon (2005) estimated the factor of safety to be well below 1.0, meaning the slope would fail during an earthquake. Terracon (2005) states that lot grading for the subdivision cut the slope toe and canal embankment which may decrease the stability of the slope. Terracon (2005) provides recommendations to reduce the landslide hazard and potential impacts to the canal but did not address the potential for shallow landsliding and rapid earth-flow landslides.

PROBABLE CAUSES OF MOVEMENT

Several factors likely contributed to landslide movement. The fill placed along the slope crest added weight, loading the underlying weak native slope materials and promoting slope failure. The elevated pond level and related shallow ground water saturated part of the fill and native material in the upper part of the slope and triggered the April 9, 2006, landslide. Piping holes along the landslide flanks (figure 11) near the landslide head indicate active subsurface flow through the fill on the slope crest prior to the landslide. A major spring storm on April 4 through 6, 2006, resulted in 10 inches of snow (2.12 inches water) in South Ogden and 8 inches of snow (1.95 inches water) in Layton (National Weather Service, 2006). The subsequent snowmelt and runoff likely increased the pond-water level and ground-water level and saturated part of the fill along the slope crest. The steep slope, runoff of snowmelt water into the pond, shallow ground water, weight of embankment fill, and weak underlying materials probably all contributed to the landslide.

(a) (b)

Figure 11. Piping holes in the upper slope near the landslide flanks. (a) Small piping hole near the landslide right flank. (b) Large piping hole adjacent to the landslide left flank.

FUTURE LANDSLIDE HAZARD POTENTIAL

The April 9, 2006, and February 20, 2005, landslides clearly demonstrate the potential for shallow, rapidly moving, earth-flow-type landslides with significant runout distances on similar slopes in South Weber. Flow-type landslides are destructive and a threat to life safety due to their velocity and impact. When such landslides occur above subdivisions built within the landslide runout zone, the potential exists for loss of life in addition to property damage. Both the April 9, 2006, and February 20, 2005, landslides demonstrate the distance small earth flows can travel beyond the base of a slope.

Both shallow- and deep-seated landslides have potential to damage the Highland View Estates subdivision. Controlling the pond- and ground-water levels in the gravel pit, as discussed in the April 11, 2006, meeting and April 14, 2006, letter (Giraud, 2006), manages one landslide triggering mechanism but does not eliminate all risk from shallow landslides. Shallow landslides can be triggered by rapid snowmelt, prolonged rainfall, or periods of above-normal precipitation. The February 20, 2005, 425 East South Weber landslide (Giraud, 2005) was triggered in a year that had above-normal precipitation. For deep-seated landslides, Terracon (2005) estimated a static factor of safety of 1.2 for the slope and emphasized that 1.2 is below the normally accepted 1.5 factor of safety. Deep-seated landslides have the potential to damage both the subdivision and the canal. Earthquakes could trigger both shallow and deep landslides.

Because houses have been constructed along the base of the slope and can potentially be impacted by both shallow and deep-seated landslides, a study should evaluate the landslide hazard, potential impacts to houses and lots, and possible risk-reduction measures. The study should include an assessment of drainage and ground-water conditions in the gravel pit at the top of the slope, the extent of fill placed at the slope crest, and thickness and nature of shallow colluvial deposits on the face of the slope as they relate to shallow landslides and the potential to transform into rapid earth flows. The study should evaluate rapid snowmelt, prolonged rainfall, and periods of above-normal precipitation as potential landslide triggers. The landslide study should also evaluate global stability of the slope with respect to deep-seated rotational landslides and the stability effects of undercutting the base of the slope to enlarge back-yard areas in lots below the canal.

Because the canal is now buried in a concrete box culvert, rapid earth flows may travel over the canal but deep-seated landslides may still damage the canal. If deep-seated landslides impact the Davis-Weber Canal when the canal is conveying water, the potential exists for the canal to breach and cause widespread flooding and sediment deposition. The Davis-Weber Canal Company has studied the deep-seated landslide hazard relative to their canal and Terracon (2005) provided recommendations to reduce the potential impacts to the canal.

SUMMARY

The 1650 East landslide was a rapid earth flow that damaged the Davis-Weber Canal and a house at 1650 East 7687 South. The landslide also injured a child inside the house. Piping holes in the upper slope adjacent to the landslide head indicate saturation of part of the fill along the slope crest from a pond and shallow ground water and triggered the landslide. The steep slope, runoff of snowmelt into the pond, shallow ground water, weight of embankment fill, and weak underlying geologic materials probably all contributed to the landslide.

The Terracon study of deep-seated landsliding indicated the slope has a static factor of safety of 1.2, which is below the normally accepted factor of safety of 1.5. Both shallow and deep-seated landslides have the potential to damage houses constructed along the base of the slope. Deep-seated landslides may also damage the canal and cause widespread flooding and sediment deposition. We recommend a landslide study to evaluate shallow and deep-seated landslide hazards, potential impacts to houses, and possible risk-reduction measures. For

existing and future development in South Weber near the base of the slope along the city's south side, South Weber should consider the potential impacts of shallow and deep-seated landslides and the possibility of a breach of the Davis-Weber Canal.

LIMITATIONS

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