Progress Report for Geotechnical Study of the Jeffersonville Landslide, Northwestern Vermont, 2009

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Cover photo: cleanup of the 1954 landslide at Jeffersonville. Photo by Harold Thomas. From the Collection of Stub Wells, Jeffersonville.

Introduction

The Village of Jeffersonville is located near the confluence of the Lamoille River and the Brewster River in the Town of Cambridge in Lamoille County, Vermont (Figure 1).

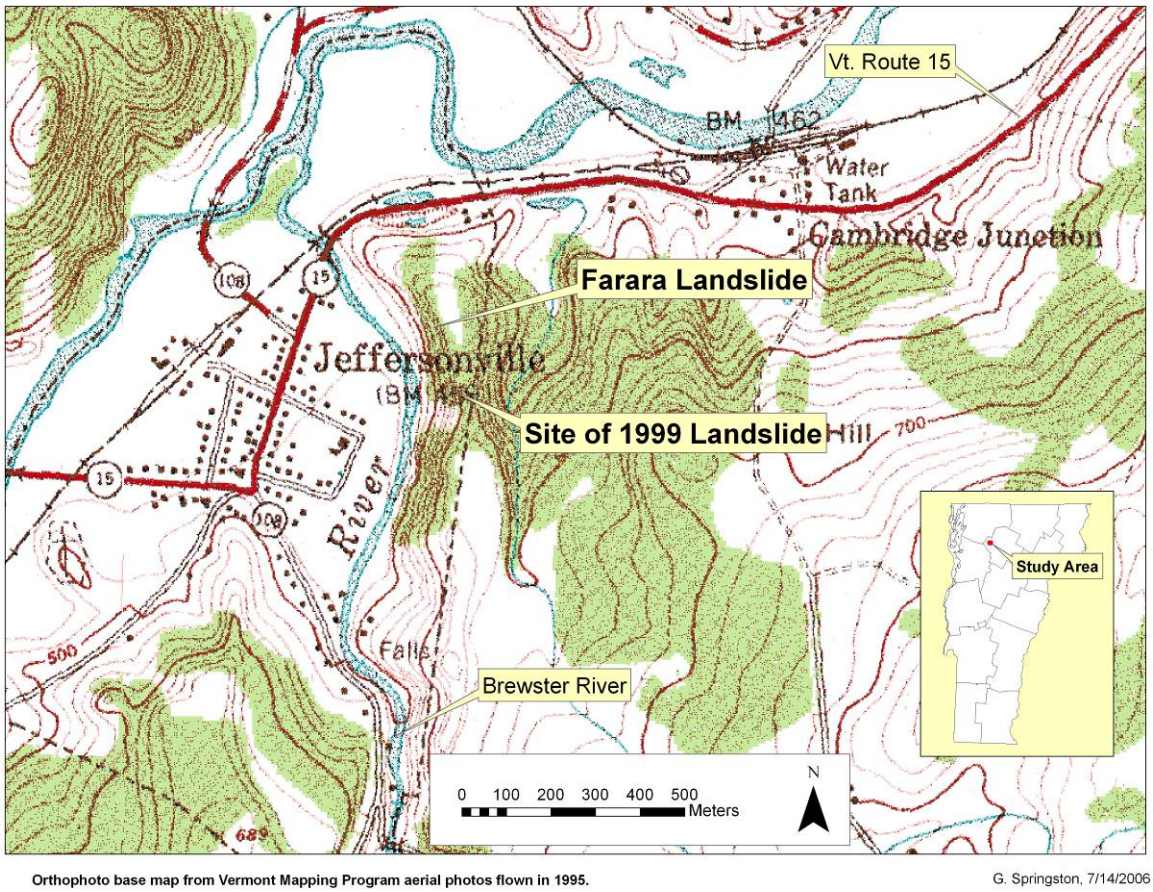

Figure 1. Location Map. The location of the 1999 landslides and a 2006 landslide on the Farara property to the north are indicated. Base map from U.S. Geological Survey Jeffersonville Quadrangle.

A series of three landslides occurred in 1999 on a steep bluff located east of the Brewster River, resulting in displacement of over 27,000 cubic meters of material toward the Village (Bierman and others, 1999). At the top of the slide a house was undermined and had to be removed. The slide material moved out over the Brewster River and onto the low terrace on the far side, the mud splashing up against two of the houses. Research into the history of the site clearly shows that these are not the first landslides to occur at this location (Bierman and others, 1999 and the chronology in Appendix A).

In 2006 the owners of a house located immediately north of the one removed by the 1999 slide returned home to find a lot more sunlight reaching their home – a noteworthy slide had occurred earlier in the day. In 2008, and further south along the ridge, a smaller, yet significant slide occurred above the Cambridge Elementary School. Slides continue to occur along the steep slopes of Deer Run Heights above the Brewster River. The Cambridge Elementary School and the numerous residences and businesses in the Village of Jeffersonville are situated in a potentially hazardous location. A careful slope stability analysis is needed to assess the situation.

The Vermont Geological Survey, in cooperation with the Norwich University Department of Geology and Environmental Science and the Johnson State College Department of Environmental Sciences, has initiated a detailed geologic assessment of the site. Due to the size of the site, the nature of the landslide, and limitations in funding, this work is still ongoing. This document lays out the work that has been accomplished, which includes the purchase of monitoring equipment, an accurate survey of control points around the site, geotechnical borings, and installation of monitoring wells and instruments to monitor rainfall, and stream water level.

The outcome of this first year and a half of the study is as follows:

1. A set of three borings with split spoon sampling has been completed. These were undertaken along an east-west transect of the field above and to the east of the school. Four monitoring wells were installed along this transect and two TDR cables were installed in additional boreholes on the west side of the field. We have developed a clearer idea of the variations in stratigraphy in the deposits underlying the slope.

2. We now have a detailed control survey to help measure future deformation and to aid in future surveys.

3. Time Domain Reflectometry (TDR) devices have been placed in two boreholes to enable us to check for subsurface deformation.

4. Rainfall amounts, stream water level, and groundwater level data are being collected and will be used to will be tied to slope stability observations.

5. A team of three Norwich University Civil Engineering Seniors, working under the direction of Professor Adam Sevi are beginning work on additional geotechnical testing and slope stability assessment. Their project is discussed under "Further Work."

Subsequent studies will include additional field mapping of selected gullies and landslide areas, continued monitoring of precipitation, water levels in the wells and water levels in the river. The resulting data will be used to undertake quantitative slope stability assessments.

Previous Work

The earliest geologic studies of the Jeffersonville site appear to be the stratigraphic sections of “slides” measured by Ernst Antevs in 1922 (Antevs, 1928). No geologic studies of the 1954 slide have been found and the only mention in the press appears to be a brief article in the Burlington Free Press (see the chronology in Appendix A). The 1999 landslides received wide coverage in the press and were studied by Jon Kim and Larry Becker of the Vermont Geological Survey. Researchers from the University of Vermont Department of Geology presented initial findings at the fall, 1999 meeting of the New England Intercollegiate Geologic Conference (Bierman and others, 1999) and Kyle Nichols of the Skidmore College Department of has a section of his website devoted to the landslide (http://www.skidmore.edu/~knichols/Jeffersonville.htm). The Vermont Geological Survey and Norwich University have made occasional visits to the site since 1999. With the occurrence of renewed landslide activity in the summer of 2006, the site has been visited at least 3 times per year. Since, 2006, students from Johnson State College have worked with Professor Leslie Kanat on monitoring slope stability at the landslide. Their work is described at a website maintained by Professor Kanat (http://kanat.jsc.vsc.edu/drh/).

Tasks

1. Conduct Control Survey.

The control survey consists of will include the installation and accurate surveying of about 30 survey monuments above, on, and below the historic and potential slide areas. This will permit detection of gradual soil deformation. A Total Station surveying instrument was used to establish accurate X-Y-Z site coordinates for each of the monuments. The monuments will be used subsequently as the basis for late slope profiling and general topographic surveying at the site. Resurveys of the monuments at later times can be used to detect any general deformation in the slide areas.

2. Purchase Time Domain Reflectometer.

A Megger Time Domain Reflectometer has been purchased by the Vermont Geological Survey. This device is being used with the Time Domain Reflectometry (TDR) cables described below to check for subsurface deformation.

3. Geotechnical borings and installation of Time Domain Reflectometry (TDR) cabling and monitoring wells.

Three borings with split spoon sampling were undertaken along an east-west transect of the field above the school. Four monitoring wells were installed on the transect and two TDR cables were installed in additional boreholes on the west side of the field. The data obtained from the geotechnical borings will be used in the slope stability modeling described below under "Further Work."

4. Installation of dataloggers to measure water levels in the Brewster River and a recording rain gage.

A pair of dataloggers was installed in the Brewster River to track water levels. Also, a recording rain gage has been installed at Deer Run Heights. The water level sensor in the Brewster River will allow us to track high stream-flow events, which have historically been the cause of toe erosion at the slide site. Such erosion has most probably played an important role in the earlier slope failures at this site. The rain gage is intended to help us understand local precipitation patterns, which may be critical to understanding the underlying groundwater conditions. Johnsons State College students working under the supervision of Professor Leslie Kanat are maintaining these instruments.

5. Conduct monthly monitoring visits.

Site visits are being made at monthly or closer intervals in order to measure depth to the water table, download dataloggers, inspect and service instruments, and continue observations of erosion and slope instability, especially in the gullies that cut into the main slope. The condition of riprap on the banks of the river will be monitored visually to look for signs of vertical or lateral shifting of the channel.

Further Work

Subsequent studies, starting in 2009, will include the following:

1. Continued monitoring of water levels, TDR readouts, erosion, and land deformation (if any). Winter visits will include notation of snow conditions.

2. A seismic refraction survey to determine depth to bedrock along one or more profiles at the site. George Springston will work with the Johnson State College students to collect and analyze the data. This task will be completed in the fall of 2009.

3. Geotechnical modeling of slope stability. A team of three Norwich University Civil Engineering Seniors, working under the direction of Professor Adam Sevi are beginning work on additional geotechnical tests on samples collected during the soil borings. They will use this information to

undertake slope stability modeling. Their work will include discussions of the potential for remediation of the slope and the feasibility of designing an early-warning system for the site. They will then present their findings to the Vermont Geological Survey and the other interested parties. This work will be completed by the end of the spring semester in 2010.

4. Additional topographic profiling as indicated by the results of the slope stability modeling. This profiling could include several complete river cross sections. It may be helpful to be able to document any vertical or horizontal channel shifts, as these may dramatically affect slope stability.

5. Resurveys of the control points to check for general deformation

6. Consideration of installation of warning systems. This last could perhaps be real-time TDR-triggered warnings. There are precedents for doing this but I think it would be best to gain experience with the system and have a full geotechnical analysis in hand first before committing substantial sums of money into such an undertaking. If our TDR cable installations in the wells work properly, they can be used as part of a later real-time system. The Norwich University students will address this issue in their findings.

Acknowledgements

Many thanks are due to the landowners who have allowed us to access their lands as part of the preceding studies. These include Joseph and Nancy Farara, Terry McCuin, and Mr. Alden Bryan. Thanks also to Mr. Dave Severance, Emergency Management Coordinator for the Village. The Brewster Uplands Conservation Trust generously allowed us to undertake the boring operations on their land.

Jonathan Kim of the Vermont Geological Survey worked with Laurence Becker in 1999 in the initial examinations of the slides and conducted several monitoring visits with George Springston. Michaela Forsberg and Jay Cairelli, both students at Johnson State College, worked with Les Kanat in monitoring studies in 2006-7 and 2007-8, respectively. Their reports will contribute substantially to our understanding of the slopes.

Thanks to Mr. Scott Hollabaugh, President of Expedition Drilling of Manchester, New Hampshire (in association with Wilcox and Barton, Inc.), for his generous donation of Geoprobe borings on the Farara property to the north of the main slide. Four holes were bored in the spring of 2007 and piezometers were installed to monitor pore pressure in the upper portions of the materials.

Thanks to Chris Aldrich and his assistant Matthew Martin of Specialty Drilling & Investigation of Burlington, Vermont, for their expert execution of the borings, the monitoring wells, and the TDR cables.

Primary funding for this project is provided by the Vermont Emergency Management office, Department of Public Safety. Additional funding needed to complete the TDR cables was generously supplied by the Norwich University Department of Geology and Environmental Science.

References

Antevs, E., 1928, The last glaciation with special reference to the last ice sheet in North America: American Geographical Research Series, no. 17, 292 p.

Bierman, P., Wright, S., and Nichols, K., 1999, Slope stability and late Pleistocene/ Holocene history, northwestern Vermont: in Wright, S.F., ed., New England Intercollegiate Geologic Conference Guidebook no 91, p. 17-50.

Appendix A. Chronology of Events

Circa 1911?

A photo taken by Harold Thomas in the fall of 1911(from the collection of Stub Wells) shows an extensive, partly healed slide scar on the upper part of the slope downstream of the school building, on or near the site of the 2006 Farara slide. This is downstream of the scar visible in the 1942 photo cited below. The 1911 photo shows an area of bare soil below and to the right of the partly healed slide scar that may be near the position of the scar shown on the 1942 photos. This may represent fresh toe erosion by the Brewster River. Thus, slope failure at the site appears to be ongoing from at least 1911. See comments on dates of photos below. Available from Vermont Landscape Change Project, UVM: File LS00195_000.jpg

Circa 1919?

A landslide is visible on the east bank of the Brewster River on a photograph taken by Harold Thomas (from the collection of Stub Wells). From comparison with the 1911 photo and the other images, I suspect this was actually taken prior to the 1911 one. It's unclear which image is dated correctly (if either). Available from Vermont Landscape Change Project, UVM: File LS00309_000.jpg

1922

Stratigraphic sections were measured by Ernst Antevs in 1922 at two slides on the east side of the Brewster River (Antevs, 1928). This reference is mistakenly given as Antevs (1922) in Bierman and others (1999). Site 169 of Antevs is described as being "...slide on brook at eastern edge of village, 125 yards S of the highway to Cambridge Junction" and his Site 170 is "...300 yards S of profile 169, slide on the brook" (Antevs, 1928, p. 199). Site 169 is near a minor slide scar visible on the 1942 aerial photos described below. Site 170 plots within the 1954 and 1999 landslide sites. This may be the one visible on the circa 1919(?) photo discussed above.

1942

Aerial photos taken on August 1, 1942 show a well-delineated slide scar just downstream of the school building. As there appears to be low vegetation on the lower parts of the slide scar, the movement must have taken place at least a few years previously. The location of the scar at an outside bend of the Brewster River suggests that toe erosion was an important factor in the slope failure. This site appears to be at the south end of the 1999 slide. Black and white vertical aerial photos DCC-6-153 and 154, housed at Vermont Department of Forests, Parks, and Recreation, Waterbury. Nominal scale 1:20,000.

1954

Landslides occurred on May 10 and 11, 1954. See article from Burlington Free Press dated May 12, 1954. See photos taken by Harold Thomas (in collection of Stub Wells). Slide debris (including whole trees) was carried across the Brewster River. The landslide site is clearly shown in the 1962 photos cited below.

1958

An article in the April 15, 1999 Morrisville News and Citizen refers to a slide in 1958 in the same area as the 1999 slides, but I saw no mention of such a slide anywhere in the 1958 issues of the News and Citizen. I think the reference is actually to the 1954 slides.

1962

Aerial photos taken on May 10, 1962 show that the 1954 slide occurred a few meters downstream (north) of the old slide seen in the 1942 photos. A small remnant of the toe of the landslide is visible on the west shore of the Brewster River (most was immediately trucked away; Stub Wells, personal communication, 2004). Black and white vertical aerial photos VT-62-H 21-274, and 275 and VT-62-L 11-187, 188, and 189 housed at the Vermont Geological Survey. Nominal scale 1:18,000.

1999
Landslides on April 11, April 18, and July 4, 1999. See Bierman, and others (1999, Stop 7) for details.

2006
Landslide at Farara property sometime between June 24 and July 2, 2006.

2008
April: Renewed slumping in one of the gully-landslide complexes on the slope above the Cambridge Elementary School. Although not a large slope-failure event, sediment from the slump did flow down and into the Brewster River. An indication of continued slope instability.