Vermont Geological Survey Open File Report VG2017-7

Landslide Inventory of Washington County, Central Vermont

George Springston
Norwich University Department of Earth and Environmental Sciences
108 Harmon Drive
Northfield, VT 05663
802-485-2734
gsprings@norwich.edu

2017

Prepared for
Vermont Geological Survey

On the cover: Recent rock slide-debris slide on southeast flank of Mount Ellen, Slide Brook watershed, Warren. George Springston, September 22, 2017.

Introduction

This report presents the results of a detailed study of the existing landslide, gullies, and other slope instability indicators in Washington County in central Vermont. This study is intended to provide an accurate basis for local, state, and Federal hazard planning in the area.

The current State Hazard Mitigation Plan identifies mapping of landslides gullies, and other slope instability hazards as an important component of hazard mitigation efforts in Vermont (http://vem.vermont.gov/plans/SHMP). This inventory of Washington County is based on the Phase 1 inventory method outlined in Clift and Springston (2012).

The inventory was undertaken using a variety of sources. Sources of locations of existing landslides and other features included:

1. Previous studies of slope instability hazards in the Mad River valley and the Great Brook watershed produced for the Vermont Geological Survey (VGS) and the Central Vermont Regional Planning Commission, respectively.

2. Surficial geologic mapping projects produced for the VGS.

3. Data from individual site visits conducted by the author for the VGS.

4. Data from the stream geomorphic assessment data provided by the Vermont Rivers Program. Of critical importance is the Phase 2 field data on mass failures and eroding banks derived from the Feature Indexing Tool (FIT).

Lidar (light distance and ranging) topographic data from the Vermont Center for Geographic Information was an essential component of the study. Lidar is very detailed airborne laser topographic mapping. Trees, buildings, and other structures have been removed in the processing in order to show the shape of the land surface. The data was used both as an accurate source for determining elevations and heights of features, and as the basis for calculating the steepness of slopes. In the slope maps shown in this report steep slopes are shown as black, intermediate slopes are gray, and flat areas are shown as white. The slope data was also classified to produce a GIS layer showing ranges of slope: 0 to 33%, 33-50%, 50-73%, 73-100%, and greater than 100%.

Interpretation of slope instability features was undertaken by viewing existing site data in combination with the coded lidar slope map, streams (1:5,000 surface waters) and orthophotos of several dates.

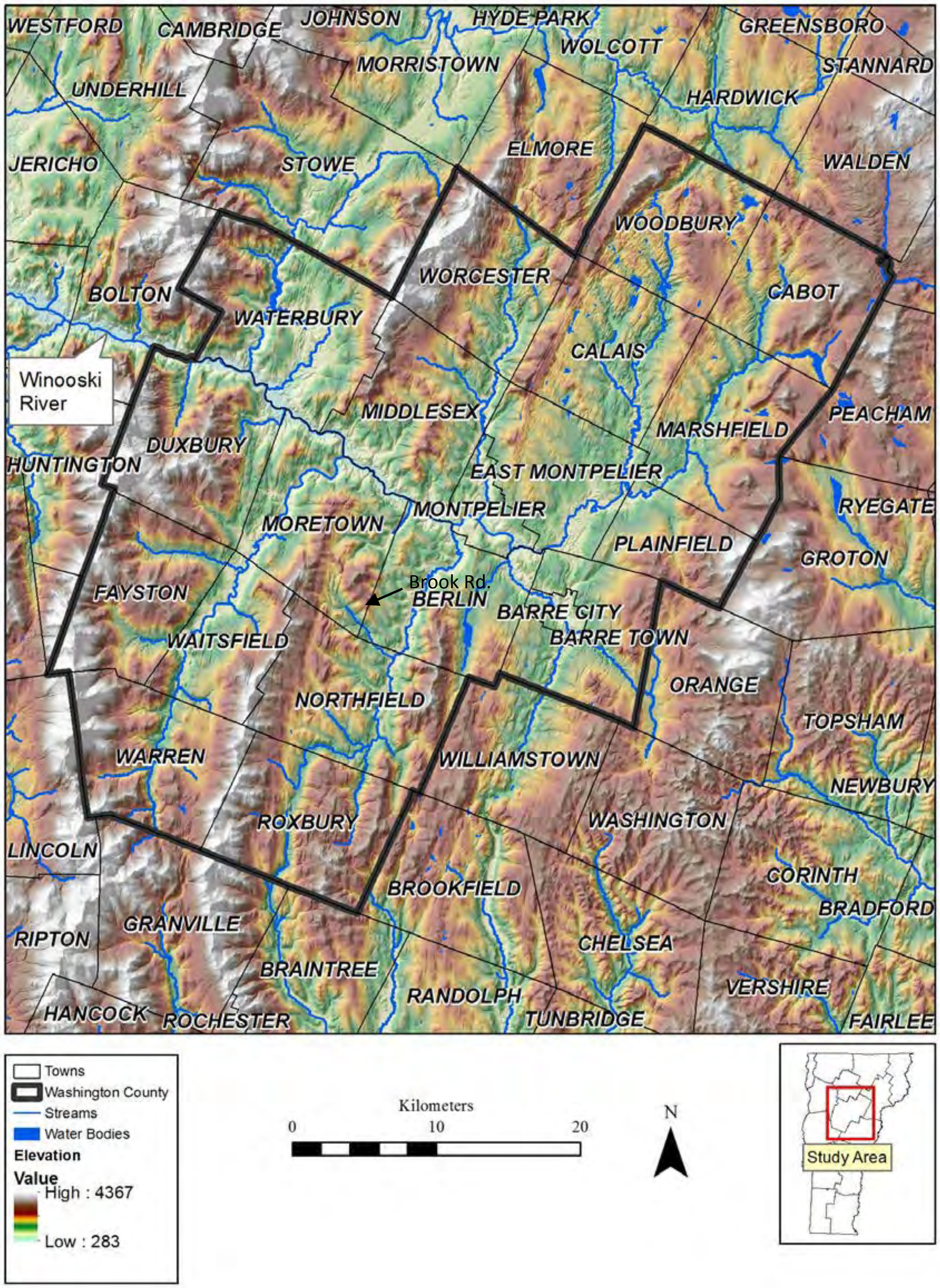

Figure 1. Location map.

Previous Work

Although there have been many studies of landslides and associated slope instability hazards in Vermont, most focus only on small areas or specific sites and a detailed inventory that is useful for hazard planning has been lacking. A detailed chronology of the earlier studies is given in Clift and Springston (2012). The only previous statewide inventory is that of Baskerville and Ohlmacher (2001), but that is a somewhat rough reconnaissance study on small-scale base maps.

Landslides in the Mad River watershed were mapped by the author as part of surficial geologic mapping project (Donahue and others (2007), Springston and Becker (2005).

Slope instability hazards have been addressed in several studies of the Great Brook watershed since the 1990s. Baskerville (1991) reports on recent damage due to "catastrophic flooding" in the watershed. The Plainfield Conservation Commission conducted a detailed study of stream flow, water quality, and stream habitats from 1997 to 2001 (Plainfield Conservation Commission, 2002). This work was conducted in cooperation with the Vermont Department of Environmental Conservation and the Vermont-New Hampshire office of the U.S. Geological Survey, Water Resources Division. Part of the work was funded by a Watershed Grant from the Vermont Department of Environmental Conservation in 2000. In 2000, the Vermont Geological Survey funded an assessment of fluvial geomorphology and surficial geology in the watershed. The results of the fluvial geomorphology study are in Barg and Springston (2001a and b) and the surficial geology is in Springston and Barg (2002).

Landslide Inventory

The inventory is shown in detail on Plate 1. A much-reduced version is shown in Figure 2. Examples of landslides in the county follow. Several sites in the Great Brook watershed in Plainfield are discussed below. Their locations are shown in Figure 3. For more detail on these sites, see Springston and Thomas (2013).

Eroding banks are common along many of the streams in the county. Examples are shown in Figure 4. Eroding banks are formed by the same mechanisms as landslides, but a cutoff has been set at about 4 meters in height, with eroding banks being below that height and landslides above it. Although the distinction may seem arbitrary, it is sometimes the case that eroding banks are forming on the sides of low terraces that are themselves subject to inundation flooding. In contrast, landslides are generally high enough that they are not going to have their tops flooded (at least during normal floods of short recurrence intervals). Thus, the landslide hazard may be more of a fluvial erosion hazard than an inundation hazard. Eroding banks are included here as those that are at the bases of high banks may be indicators that the banks are being destabilized by toe erosion and that landslides may subsequently develop in those locations.

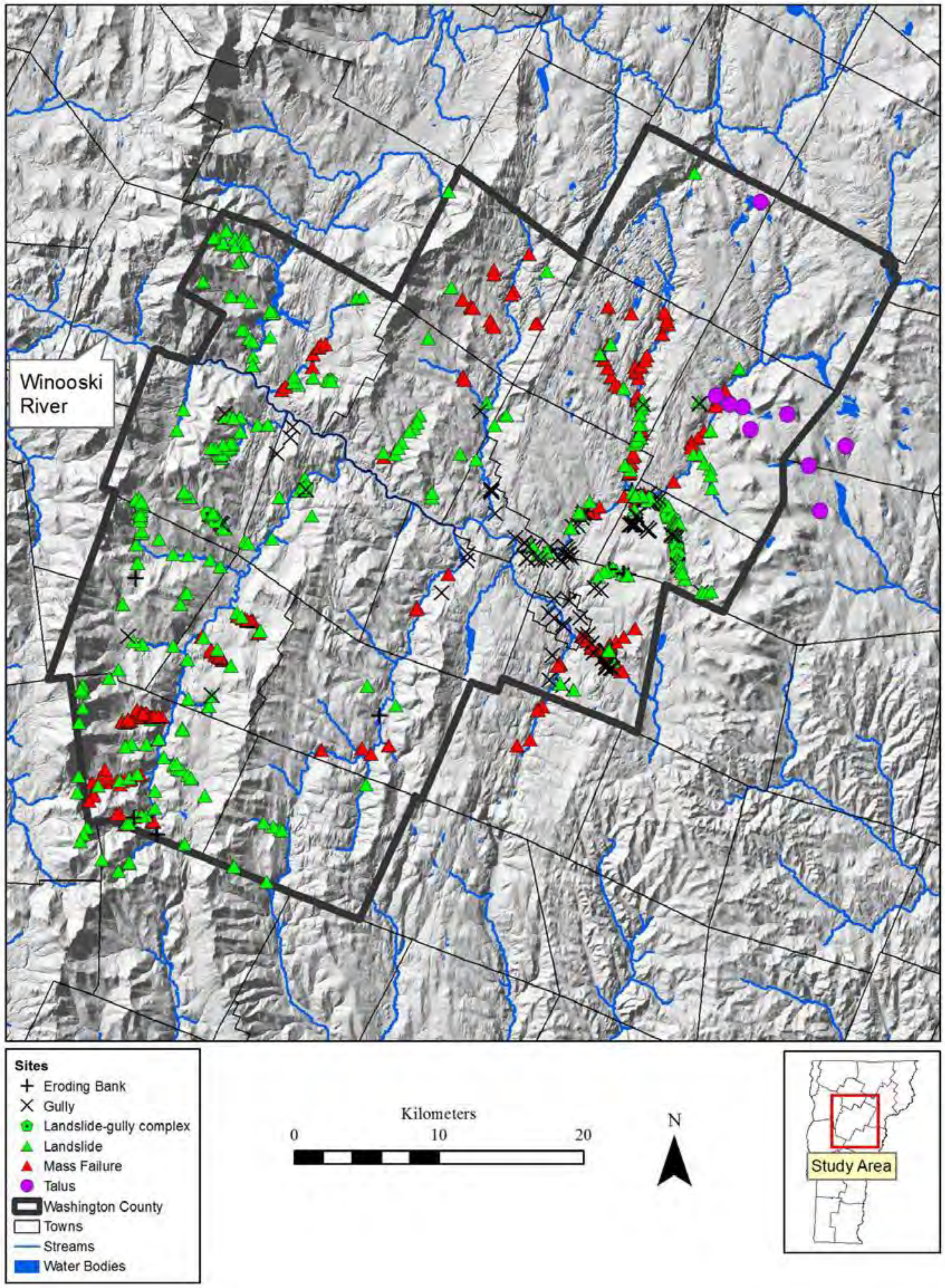

Figure 2. Generalized map of all slope instability hazard sites. This includes eroding stream banks, gullies, landslide-gully complexes, landslides and mass failures, and talus deposits. These features are shown at a larger scale on Plate 1.

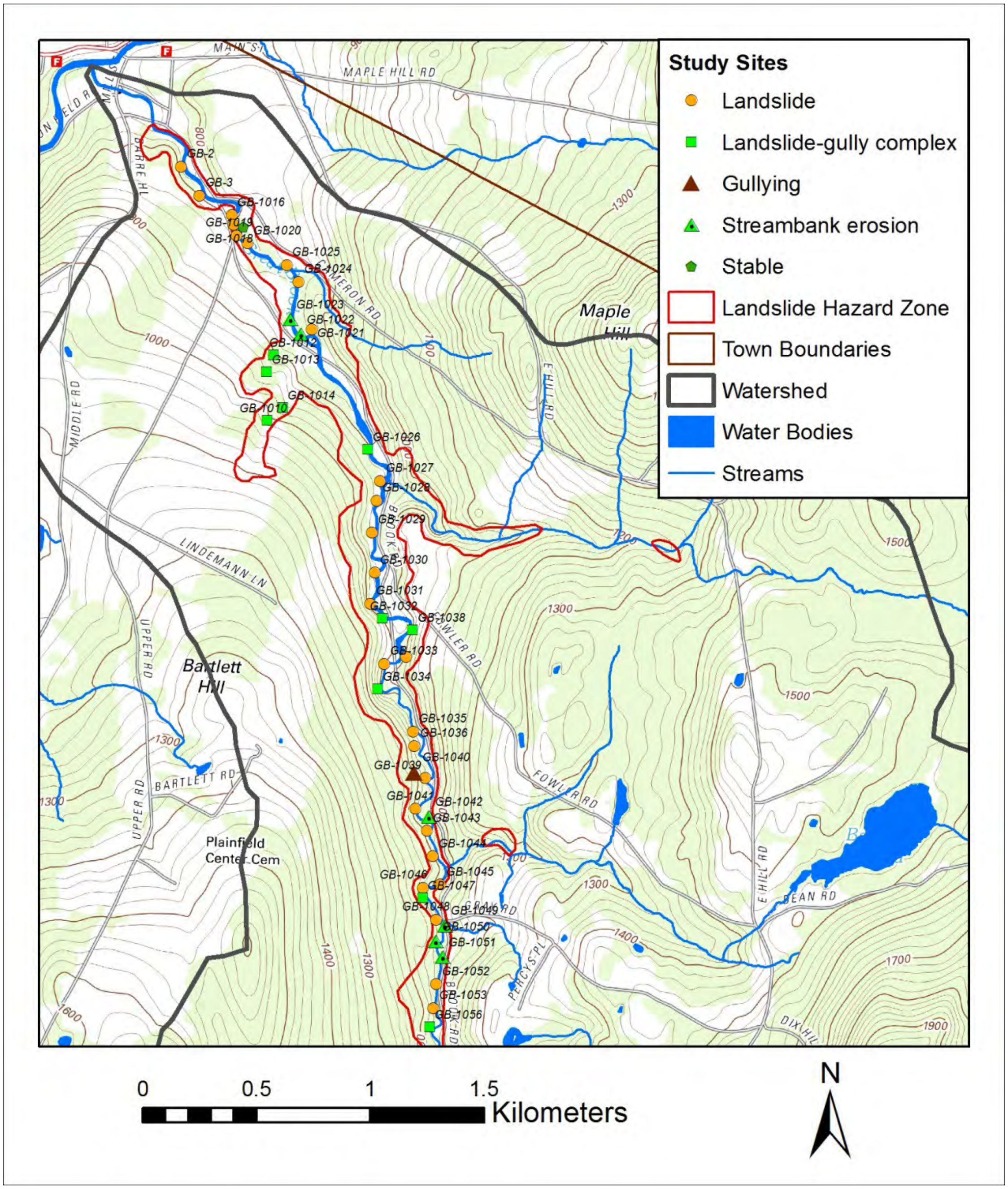

Figure 3a. Study sites in the northern part of the Great Brook watershed. Base map from U.S. Geological Survey. Contour interval 20 feet.

Figure 4a. Site GB-1023 looking downstream. Typical exposure of coarse-grained stream terrace deposits on outside of bend. Material failed during high stream flows of 2011, primarily by singe-grain detachment. Photo taken July 29, 2013.

Figure 4b. Close-up of stream terrace deposits at Site GB-1027. Boulder-cobble-pebble gravel in lower part is overlain by sandy pebble-cobble gravel. Similar to material at GB-1023 but coarser-grained. Photo taken July 29, 2013.

Gullies are locally common within the study area, with the majority being found in Montpelier, East Montpelier, Barre City, and Barre Town (Plate 1 and Figure 2). A particularly large example is shown in Figure 5 below.

Figure 5a. Site GB-1010, a large, active gully in the Great Brook watershed, Plainfield. Looking down gully on July 16, 2013. This is part of the large MacLaren-Fowler gully system, which has developed in ice-contact sands.

Figure 5b. Site GB-1010, looking upstream. Headcuts are actively incising the valley bottom, the bases of the slopes are being undercut, and the side walls are continuously collapsing into the gully bottom. Some of the boulders in the channel have fallen in from gravel lenses within the ice-contact deposits exposed in the side walls while others have probably washed down from till exposures near the head of the gully.

Landslides are the most common type of slope instability feature in the county. Examples are shown in Figures 6 through 17. Figure 6 shows one of the many large landslides in the Great Brook in Plainfield. A series of photos showing how the site has changed over almost 20 years is shown in Springston and Thomas (2016). Figure 7 shows a site where landslide activity along Great Brook jeopardized a house and garage. The property has recently been purchased by the Town of Plainfield through a FEMA buyout and the buildings have been removed.

Figure 6. Site GB-3 on July 11, 2013. The waters have receded and the fresh toe deposits have partially collapsed.

Figure 7a. Site GB-1025 on Great Brook in Plainfield. Active landslide on right bank. Lacustrine sand, silt, and silty clay over dense gray till. Note roof of garage visible just beyond top of landslide. Photo taken July 29, 2013.

Figure 7b. Site GB-1025 looking downstream and across. Note trees toppling over at top. Photo taken July 29, 2013. A garage is visible at the top of the slope. The property has recently been purchased by the Town of Plainfield through a FEMA buyout and the buildings have been removed.

Figures 8 and 9 show a site of active stream erosion undermining a slope in lacustrine silt-clay and overlying stream terrace deposits on the Winooski River in Plainfield. Historical analysis indicates that the river channel has been shifting around in this river segment since the 19th century.

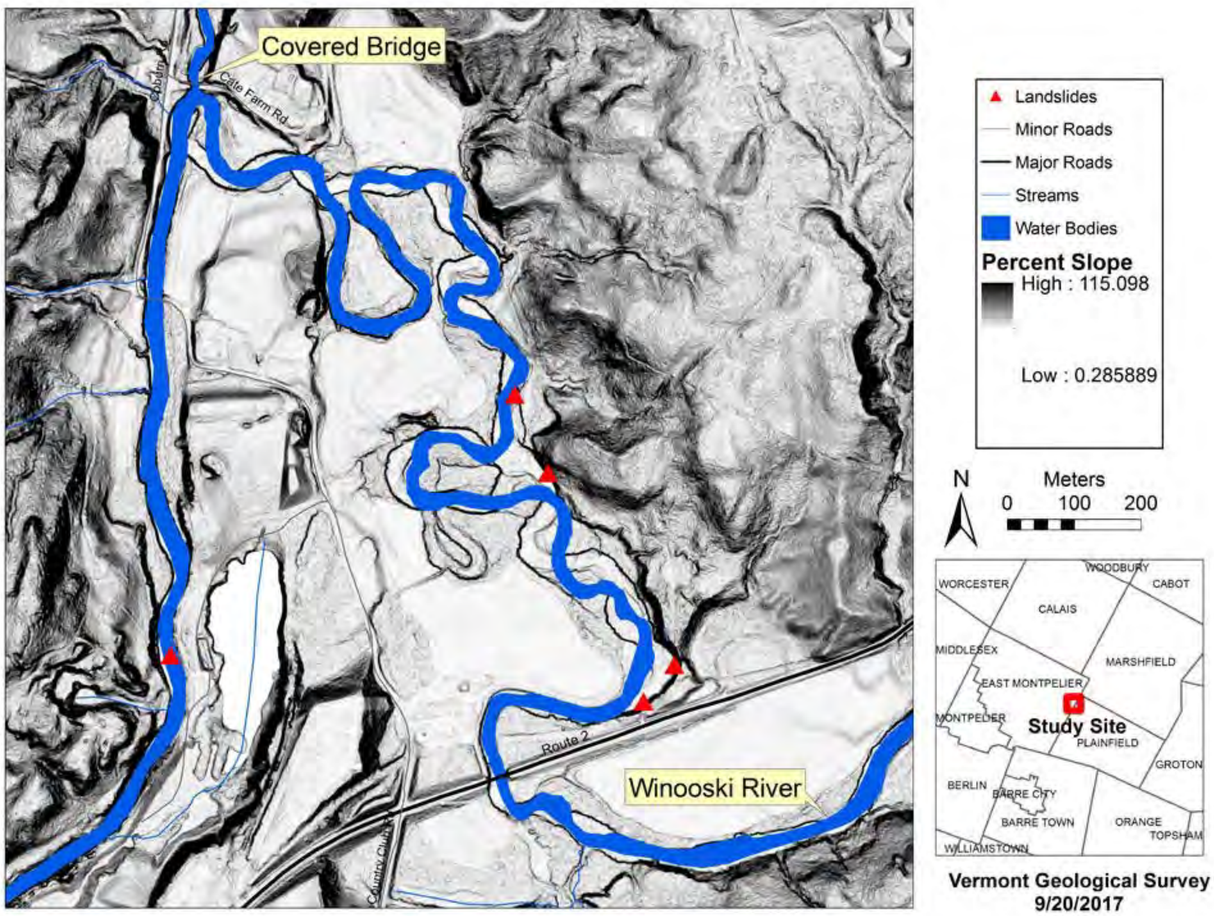

Figure 8. Lidar slope map showing location of landslide on southeast side of Winooski River, Plainfield.

Figure 9. Landslide on outside of meander bend on the Winooski River at Cate Farm, Plainfield. Photo taken april 2009. Since this photo was taken the river has continued to erode the toe of the slope and slope failures have continued.

Figures 10 and 11 show a site on the Mad River where a slope failure in 2003 caused a significant blockage of the Mad River and contributed an estimated 900 cubic years of fine sediment to the river system. Turbid water from this landlside extended at least as far as Waterubyr, 16 miles downstream. This too is a site of repeated landslide activity.

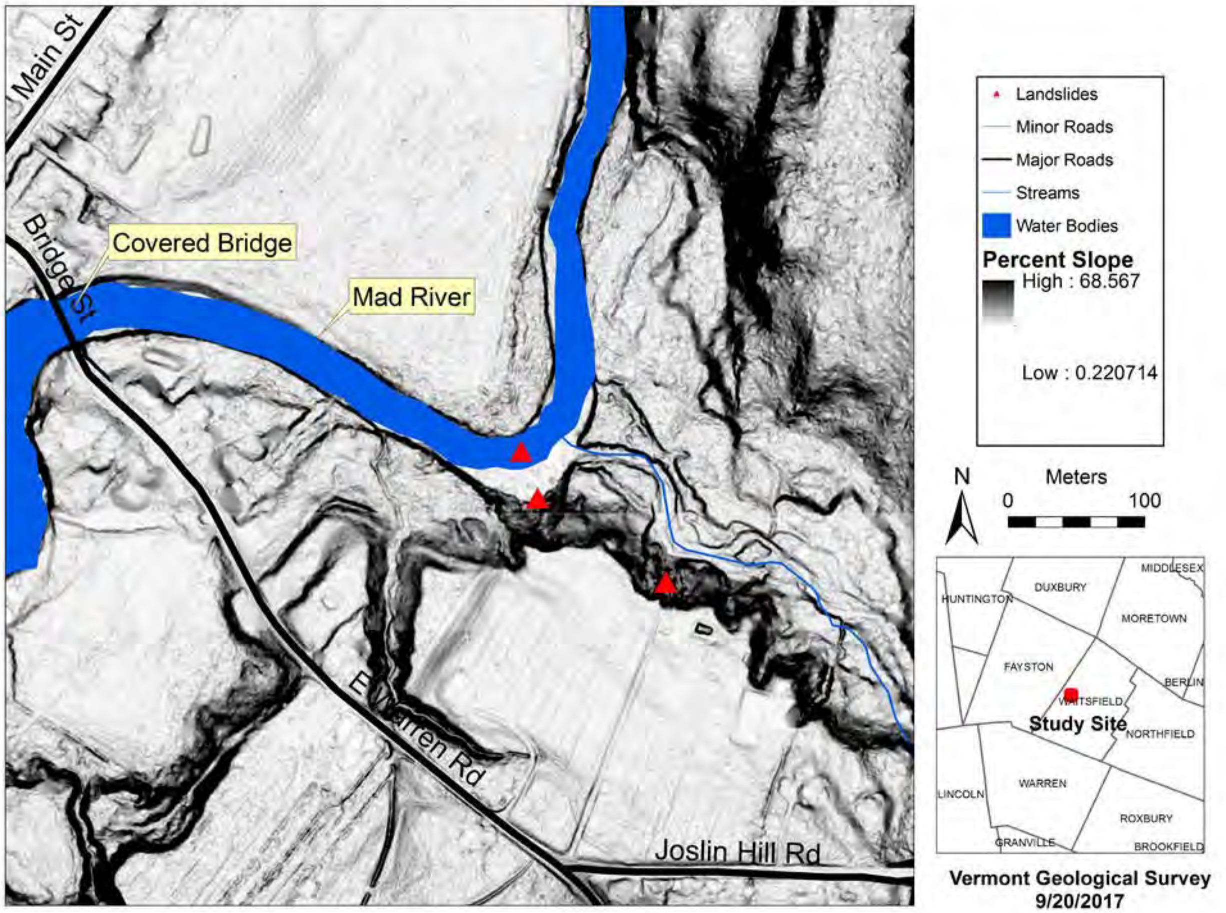

Figure 10. Lidar slope map showing location of landslide on southeast side of Mad River in Waitsfield.

A.

B.

Figure 11. Landslide on the southeast side of the Mad River in Waitsfield. The site has a long history of slope failure. The scenes above were taken in May and June of 2003. A: Looking down at river. B: Looking up from river. The landslide deposit in the foreground is being actively eroded by the river.

Figures 12 though 14 show two sites in the Mad River watershed where modern, active landslides are set into larger, apparently relict landslides. These larger landslides were only revealed by the lidar data.

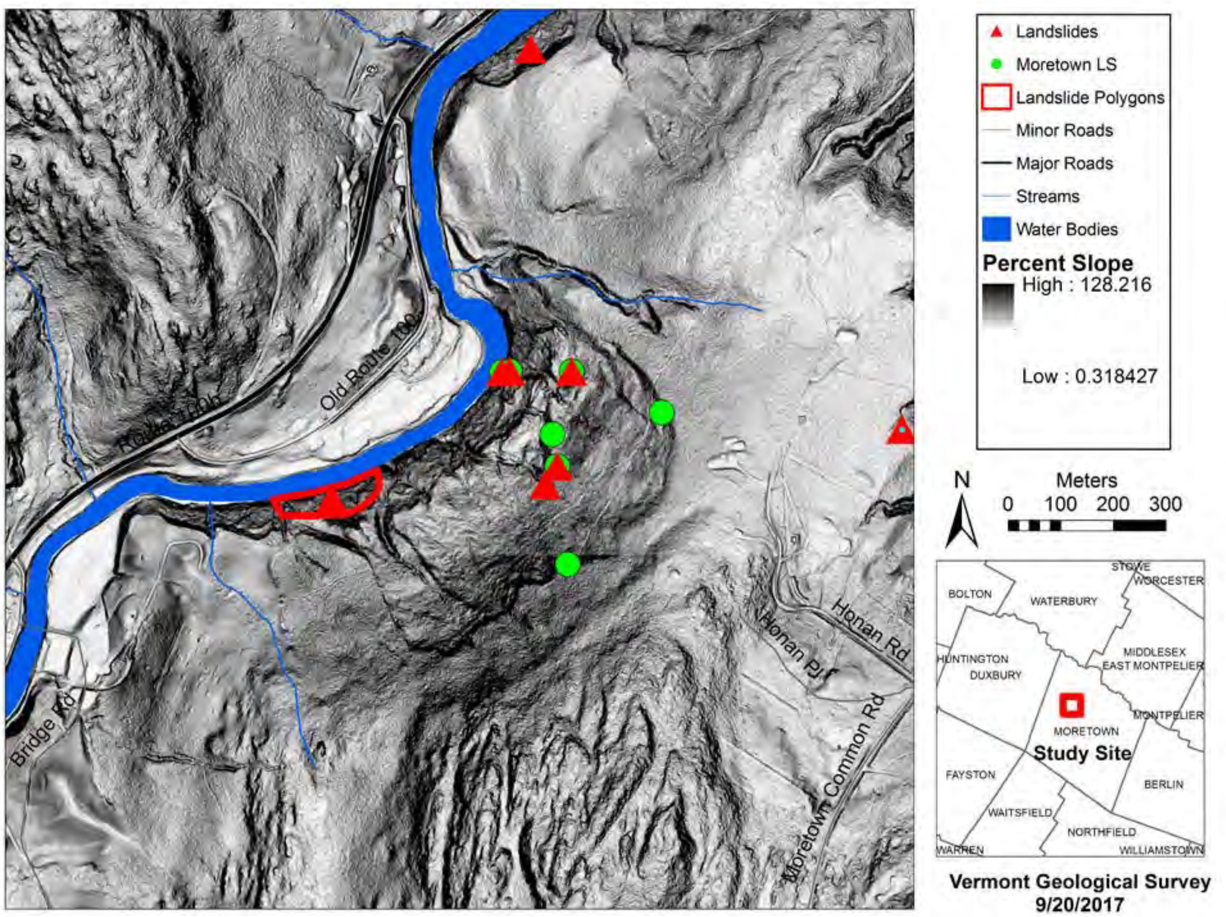

Figure 12. Lidar slope map showing location of modern landslides set into a large, relict landslide on the southeast side of the Mad River in Moretown.

A.

B.

Figure 13. Large landslide located southeast of the Mad River in Moretown. A: Moderate-sized active landslide (translational slide-flow) in lacustrine silt-clay near the Mad River. B: Old scarp at southeast margin of the larger relict landslide. Photos taken 9/8/2017.

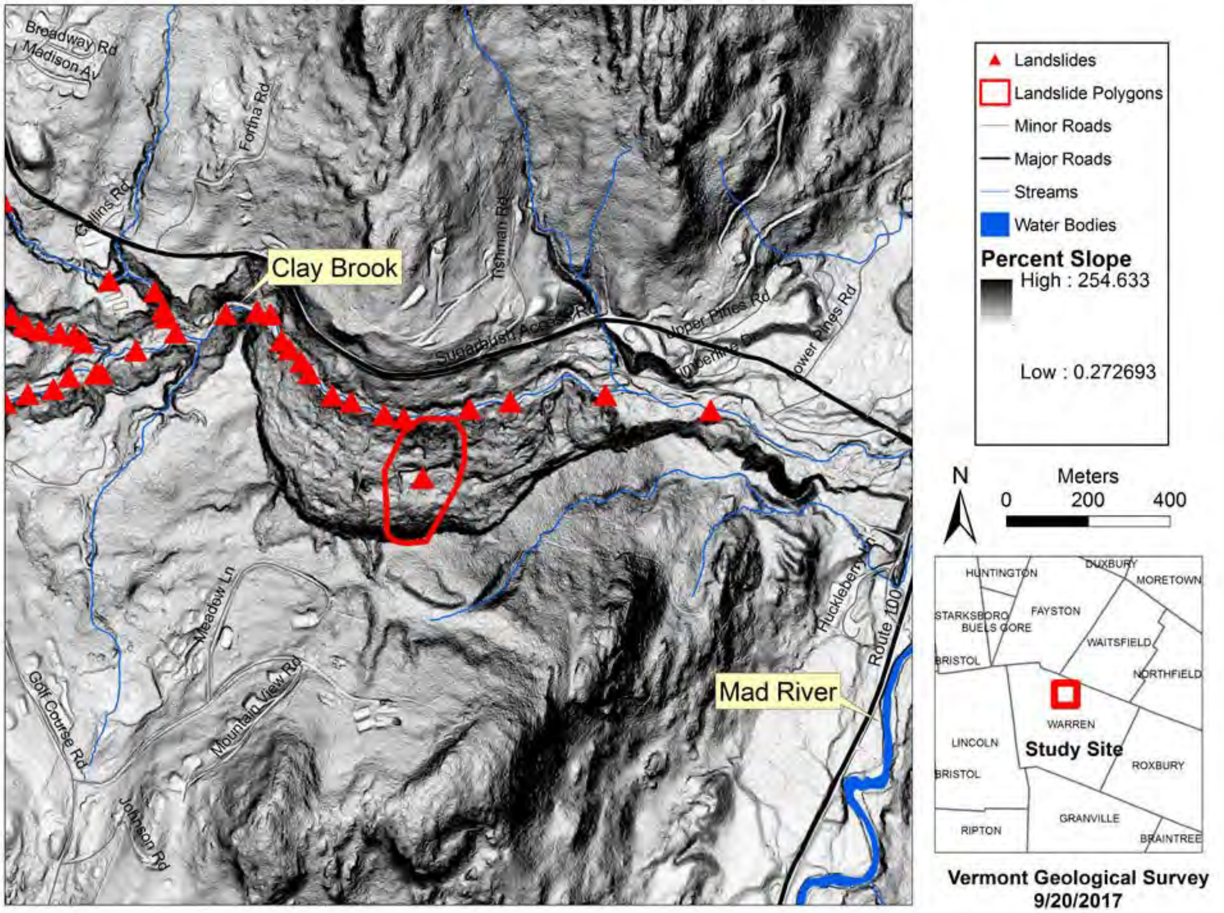

Figure 14. Lidar slope map showing location of modern landslide set into a large, relict landslide on the south side of Clay Brook in Warren.

Figures 15 and 16 show a recent rock slide-debris slide high up on the southeast side of Mount Ellen in Warren. The slide occurred on or about August 24. 2017. The Slide Brook watershed has been the site of at least 4 previous large landslides, including a very large event in 1897, which was clearly some sort of debris flow. Figure 17 shows tourists visiting what looks like the debris flow transport zone in Warren or Fayston.

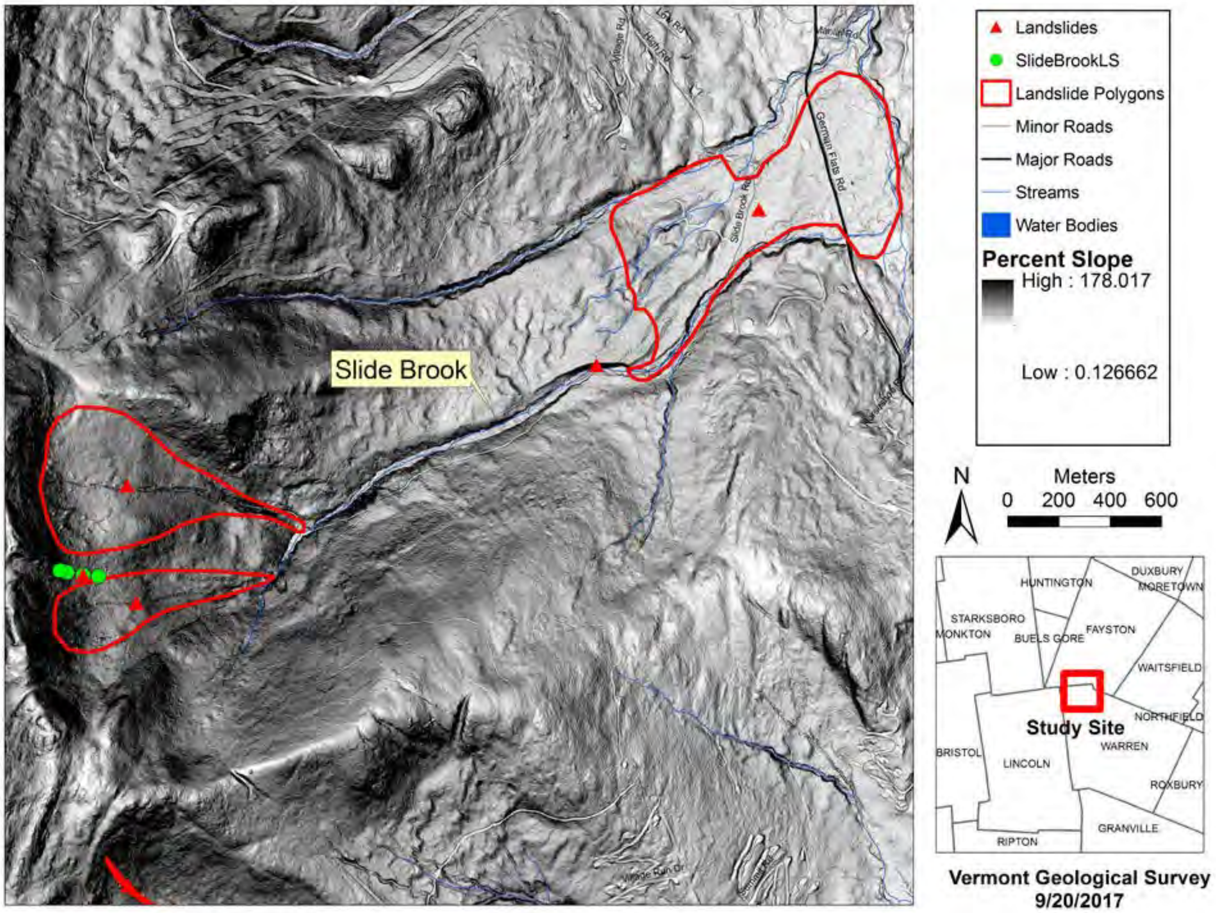

Figure 15. Lidar slope map showing location of a recent rock slide-debris slide located on the southeast flank of Mount Ellen in Warren.

A.

B.

C.

Figure 16. Recent rock slide-debris slide on southeast flank of Mount Ellen, Slide Brook watershed, Warren. A: Looking up from near base of slide. B: Woody debris near base of slide. C: Looking up at source area for rock fall.

Figure 17. Tourists viewing the aftermath of the 1897 debris flow at Slide Brook. The debris flow originated on the upper slopes of the watershed in Warren and appears to have extended down into the German Flats area of Fayston.

Patterns of Slope Failure

Observations of the landslides here and elsewhere in Vermont suggest the following as a common sequence of events in response to catastrophic flood events such as the relatively localized flash flood of May 26-27, 2011 in the Great Brook watershed or the much more widespread Tropical Storm Irene on August 28 and 29, 2011. Note that the events described below will not always take place in a sequence of discrete steps. For example, a translational slide on the upper part of a landslide may be occurring at the same time that the base is being undercut by flood waters.

1. Fluvial shear results in erosion of the bank and/or bed, over-steepening the slope and, if bed erosion occurs, increasing the effective height of the slope. Dense till and lacustrine diamict typically are detached as irregular blocks. Loose materials typically are detached as single grains. At sites where the material is very strong, the stream may undercut the bank, leaving an overhang.
2. Infiltration of rainfall results in an increase in pore-pressure in the surficial material, reducing the effective shear strength of the material.
3. Translational slides occur off the upper slope, commonly carrying blocks of soil and trees, with depths of 1.5 to 5 feet (0.5 to 1.5 meters). Parts of the sliding blocks may break up into flows. Although not observed in the Great Brook watershed, a rotational slump may occur in place of or following a shallow translational slide. This type of slope failure is more common in lacustrine or ice-contact or stream terrace deposits than in till, but a few examples of rotational slumps have been observed in dense till deposits that were severely undercut by catastrophic flooding.
4. Material reaching the base of the slope may either be swept away by the stream or accumulate to form a toe deposit.
5. The water level of the stream recedes, perhaps leading to additional slope failure as the support of the water on the lower face is removed.
6. Overhangs begin to fail and translational slides and flows remove material from the upper parts of the landslide.
7. With the passage of time, mass-wasting and weathering processes begin to alter the deposits. Material continues to fall, topple, slide, or flow off of the upper slopes. Weathering of the fresh deposits becomes evident after the first winter, with the outer 0.5 to 1 inch (1 to 2.5 cm) of even the densest till beginning to soften. Rills begin to dissect parts of the upper faces and the toe deposits. Even after only a single year, pioneer vegetation such as coltsfoot and horsetails begin to colonize the slopes.

Conclusions

This study shows that it is now feasible to make accurate maps of existing landslides over extensive areas. The maps are sufficiently accurate to help landowners and planners consider slope instability hazards.

Previous studies by Clift and Springston (2012) and Springston and Thomas (2013) suggested that lidar topographic data is a critical prerequisite for accurate and cost-effective landslide inventories in Vermont. The current study confirms that the lidar data makes the mapping much more efficient and considerably more accurate. Lack of signal return from areas of heavy conifer coverage remains a problem with some of the lidar data, but it is hoped that future projects will supply increasingly detailed penetration in these areas.

As Springston and Thomas (2013) showed in the Great Brook study, most of the landslides are located close to streams at sites of active streambank toe erosion. When long-term data is available, the landslides are generally in locations that have been failing for a long time. Gullies are an exception to this generalization. Although some gullies have clearly been in existence for many years, the fact that many of the actively eroding gullies in the county are receiving stormwater runoff from developed areas suggests that the development has destabilized or at least exacerbated the instability.

The principal causes of the slope failures appear to be the over-steepening of slopes due to fluvial erosion of banks and stream beds during the flash floods and decreases in shear strength of soils due to increases in soil water pore pressures due to the heavy rainfall.

The detailed (Phase 2) stream geomorphic data from the Vermont Rivers Program is critical to understanding the patterns of stream channel adjustment that are underway in the river corridors. In the Great Brook watershed Springston and Thomas (2012) had the advantage of having the 2001 data from Barg and Springston as well as the up-to-date 2012 and 2013 data from Bear Creek Environmental, thus allowing consideration of how the slopes had changed over time. The mass failure locations the river studies compared very well with site location from geologic field work and from lidar. It would be highly desirable to have similar Phase 2 data available for the streams in any areas where landslide mapping is to be undertaken.

Acknowledgements

Funding for this work was provided by the Vermont Geological Survey through a series of contracts and grants running from 1999 to the present. In the early years this work was direct contracting with George Springston and Lori Barg. Subsequently, the funding was through grants to Norwich University.

I extend my deep appreciation to current State Geologist Marjorie Gale and former State Geologist Laurence Becker for their consistent and enthusiastic funding for this work.

This work would also not be possible without the far-sighted work of the staff of the Vermont Rivers Program, headed by Mike Kline. Special thanks go to Mike, Barry Cahoon, Shayne Jaquith, Sacha Pealer, Staci Pomeroy, and Gretchen Alexander.

The study of landslides in Great Brook watershed was through a grant from the Central Vermont Regional Planning Commission via an Ecosystem Restoration Program Grant from the Vermont Department of Environmental Conservation, Agency of Natural Resources. Thanks to Mary Nealon and Pam DeAndrea of Bear Creek Environmental in Middlesex for sharing geomorphic data and photographs from their ongoing studies of the brook. Thanks to Lori Barg for sharing photographs and for her leadership in undertaking the original fluvial geomorphic assessment work along the brook, which is now an important basis for comparison with the post-2011 studies. Many area residents assisted with aspects of the post-flood studies, including Allen Clark, Charlie Cogbill, Dan Gadd, Brett Engstrom, Rose Paul, Sacha Pealer, and Matt Peters. Thanks to Bram Towbin for sharing numerous photos.

References

Barg, Lori, and Springston, G.E., 2001a, Assessment of Fluvial Geomorphology in Relation to Hazards from Riverine Erosion and Landslides in the Great Brook Watershed in Plainfield, Vermont: manuscript report submitted to the Vermont Geological Survey, Waterbury.

________, 2001b, Floods and the Great Brook in Plainfield, Vermont: Upper Winooski Field Naturalists Contributions Series, No. 2, p. 11-23.

Baskerville, Charles, 1991, 1991 Summer field trip: Styles of mass wasting in Vermont: Green Mountain Geologist, field trip itinerary, v. 18, no. 2, pp. 4-5.

Clift, A.E., and Springston, G.E., 2012, Protocol for identification of areas sensitive to landslide hazards in Vermont: Manuscript report submitted to the Vermont Geological Survey, Montpelier, 78 p. plus 2 appendices.

Dunn, R., Springston, G., and Donahue, N., 2007, Surficial Geologic Map of the Mad River Watershed, Vermont: Vermont Geological Survey Open File Map VG07-1, Waterbury, 2 color plates, scale 1:24,000.
http://www.anr.state.vt.us/DEC/GEO/images/digitalofrs/WebMad_River_Surficial_n.pdf
http://www.anr.state.vt.us/DEC/GEO/images/digitalofrs/webMad_River_Surficial_s.pdf

Milone and MacBroom, Inc., 2013, Gully stabilization alternatives analysis, Plainfield, Vermont: Unpublished report submitted to the Winooski Natural Resource Conservation District, 25 p.

Plainfield Conservation Commission, 2002, Great Brook watershed study: Water quality, stream flow, and aquatic habitats: Manuscript report, Plainfield, Vermont, 40 p. plus appendices.

Springston, G.E., and Barg, Lori, 2001, Surficial geology of the Great Brook watershed: Manuscript report submitted to the Vermont Geological Survey, Waterbury, 32 p. plus 2 plates.

Springston, G.E., and Becker, L.R., 2005, Landslide and riverine erosion hazard mapping in the Mad River watershed, central Vermont (abs.): Green Mountain Geologist, v.32, no. 1, p. 3.

Springston, G.E. and Thomas, E.J., 2014, Landslide hazard analysis of the Great Brook watershed, Plainfield, Vermont: Report prepared for the Central Vermont Regional Planning Commission, Montpelier, Vermont, 34 p., plus 1 plate (1:10,0000). Available at http://centralvtplanning.org/wp-content/uploads/2012/03/GreatBrookLandslideReportFinal03172014.pdf

Springston, G.E., 2016, Final report on a landslide inventory of the Town of Highgate, Vermont: Vermont Geological Survey Open File Report VG2016-4, text plus 6 plates, scale 24,000.

WashingtonCountyLandslideStudyDraft09252017.doc