Hazard Evaluation at the Jeffersonville Landslide Site

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Landslide Definition

- "The downslope movement of soil, rock and organic materials under the influence of gravity and also the landform that results from such a movement" (The Landslide Handbook, USGS Circular 1325, p. 4).

Landslide on Winooski River, Plainfield, VT, 2009

Outline

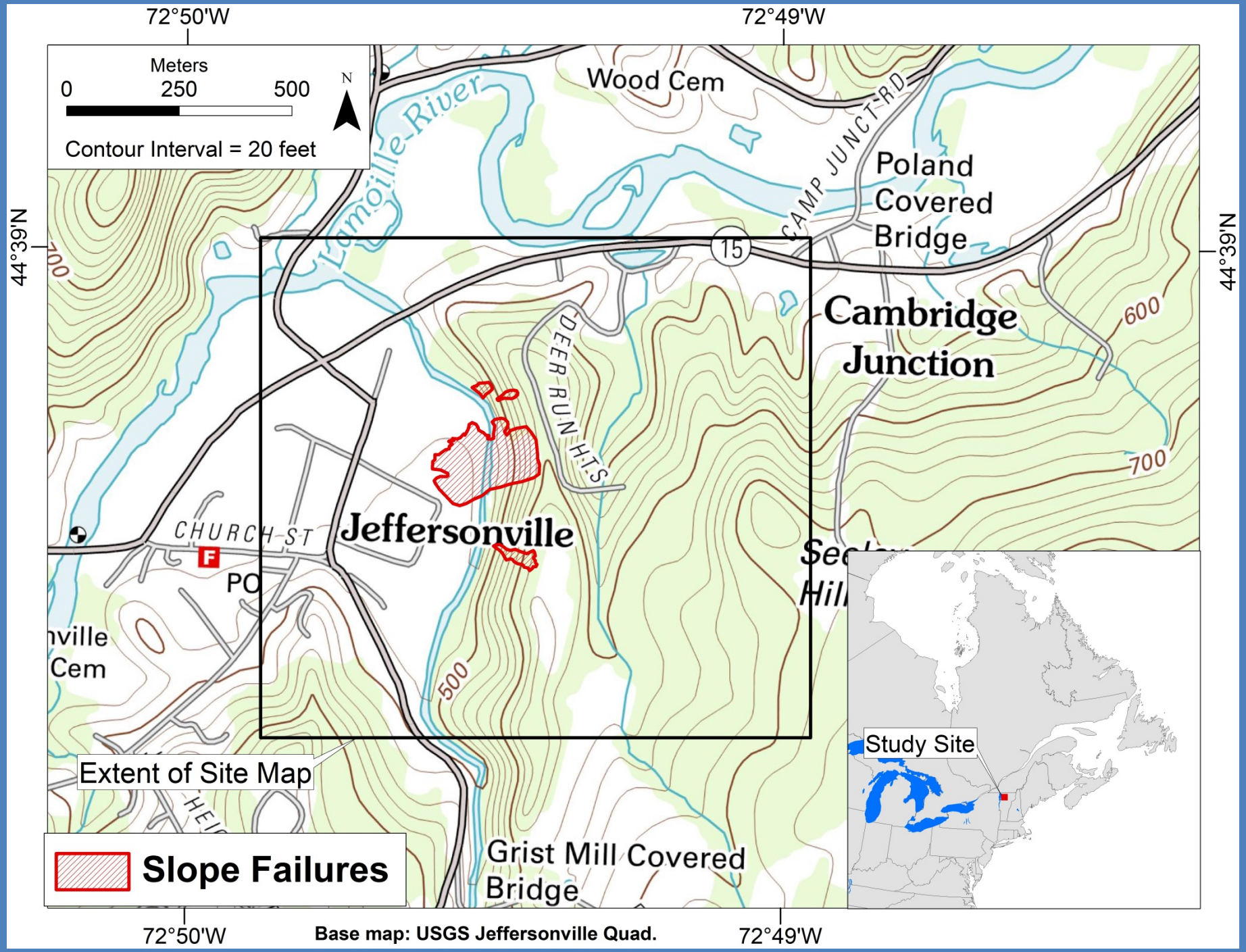
1. Introduction
2. Geologic background
3. History of landslides at site
4. Ongoing studies at site
5. Conclusions

Types of Slope Movements

Type of Movement	Type of Material		
	Bedrock	Engineering Soils	
		Predominantly coarse	Predominantly fine
Falls	Rock fall	Debris fall	Earth fall
Topples	Rock topple	Debris topple	Earth topple
Slides	Rock slide	Debris slide	**Earth slide**
Spreads	Rock spread	Debris spread	Earth spread
Flows		Debris flow	**Earth flow**
Complex	Combinations of two or more types of movement		
Creep	Several types		

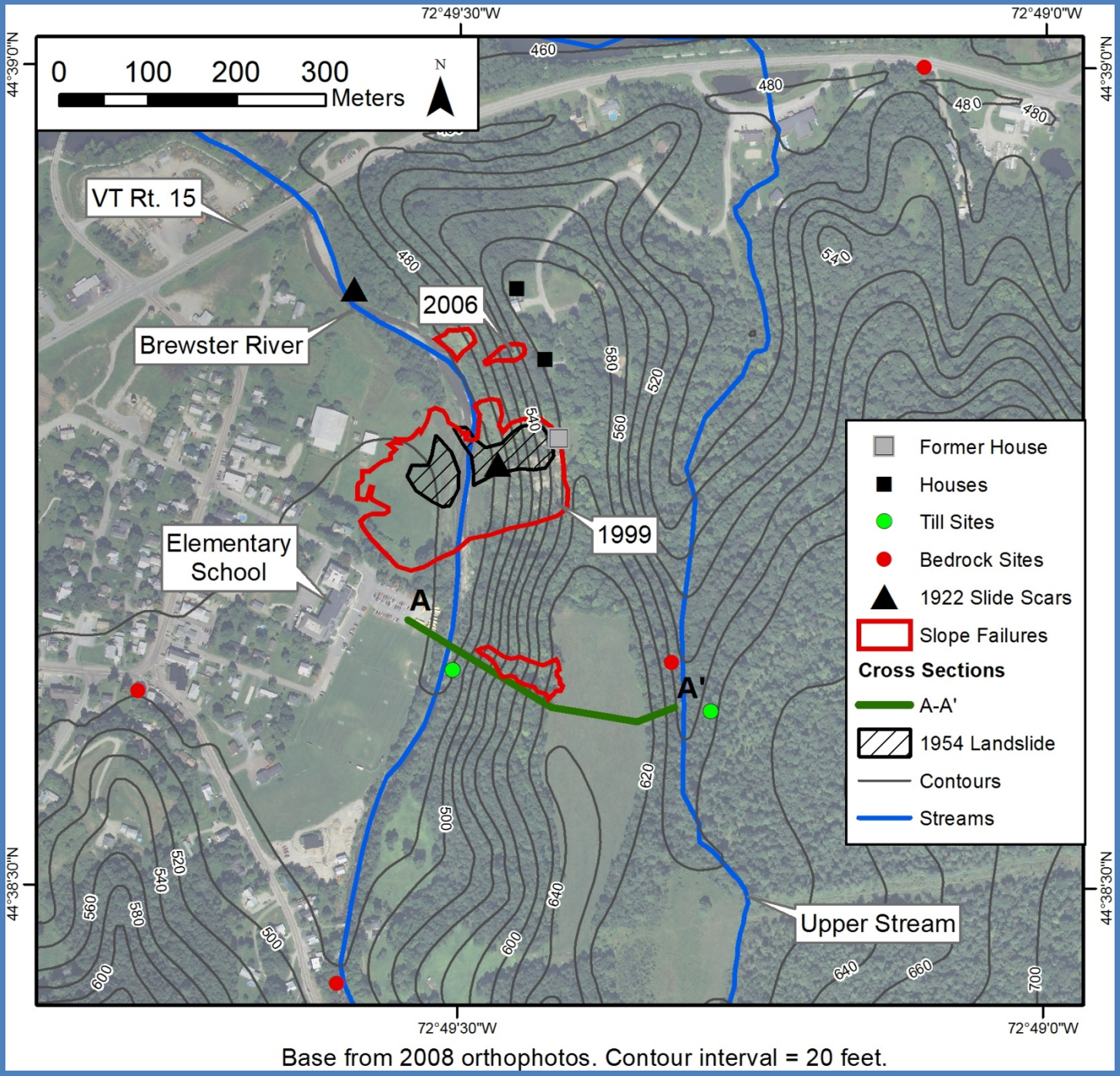
*** Landslide types at Jeffersonville shown in bold.**

Modified from Varnes (1978).

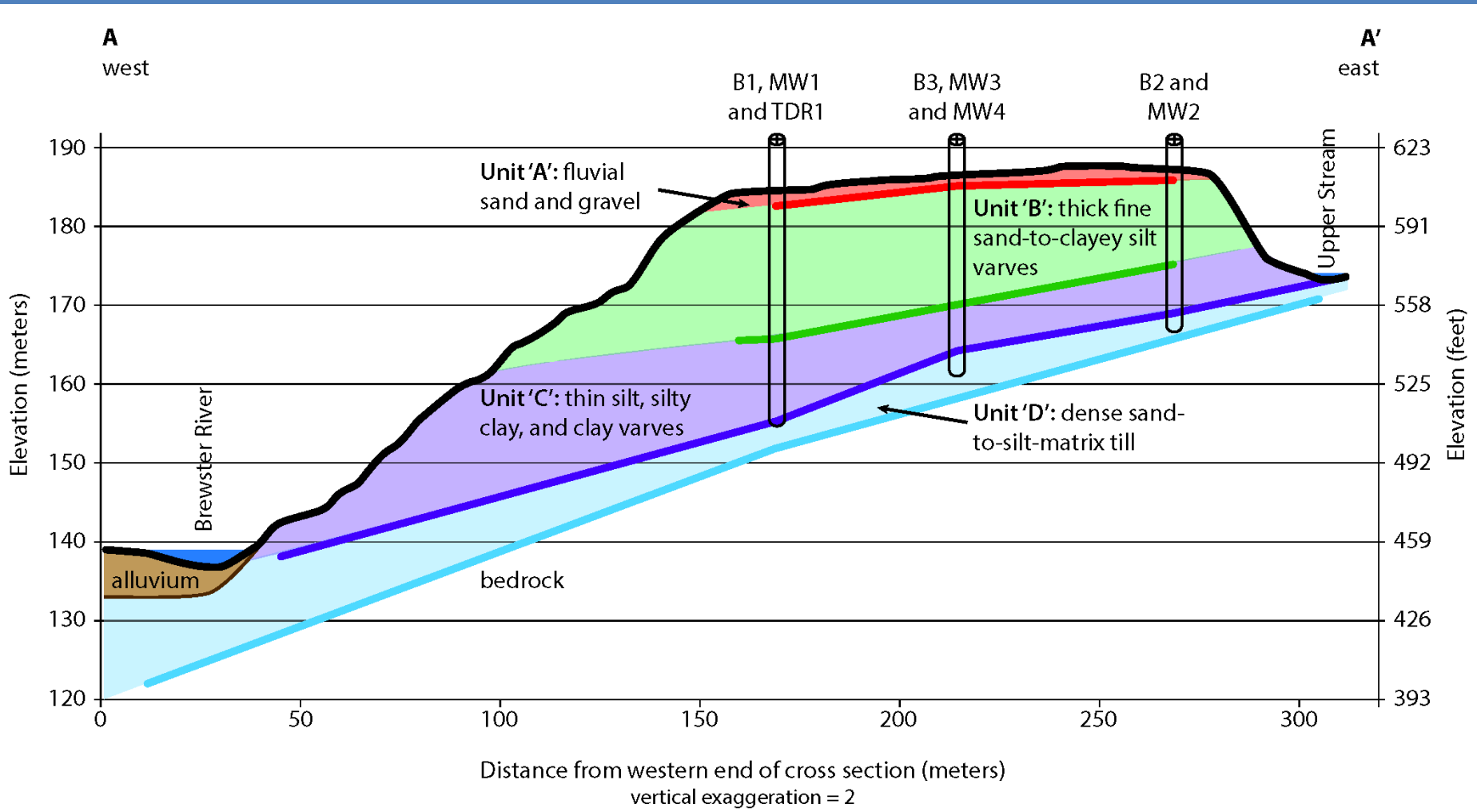

72°50'W
72°49'W
44°39'N
Meters
0
250
500
N
Contour Interval = 20 feet
Wood Cem
Lamoille River
CAMP JUNCT-RD
Poland
Covered
Bridge
15
Cambridge
Junction
DEER RUN H.T.S
600
700
500
CHURCH ST
Jeffersonville
PO
Cem
Extent of Site Map
Study Site
Slope Failures
Grist Mill Covered
Bridge
Base map: USGS Jeffersonville Quad.

Site map showing landslides and cross-section location

At the 1999 landslide the slope is about 46 meters (151 feet) high with an overall angle of 34°.



Cross Section A-A', Jeffersonville, VT.



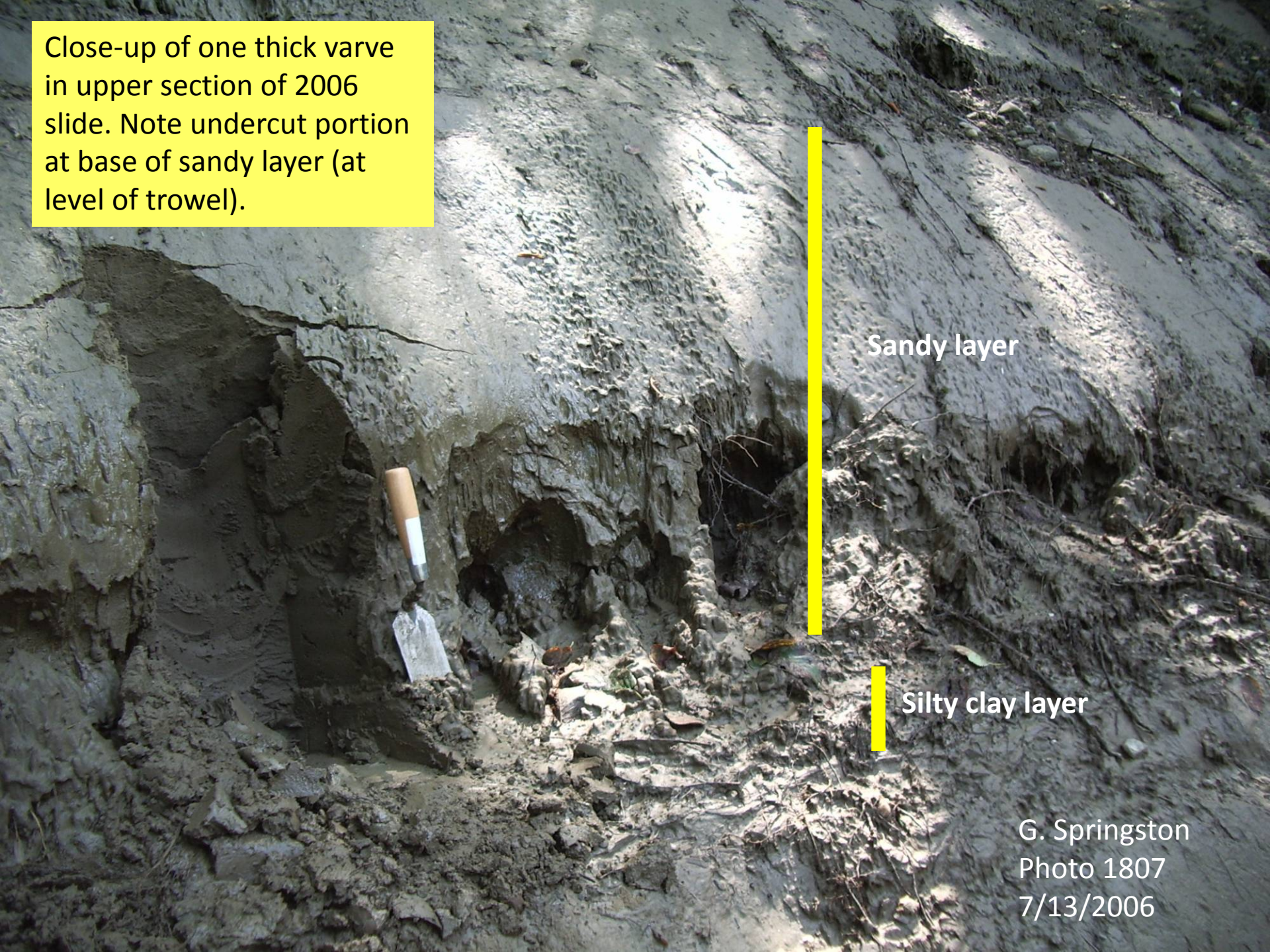
Environments of Deposition and Stratigraphic Units, Jeffersonville Landslide

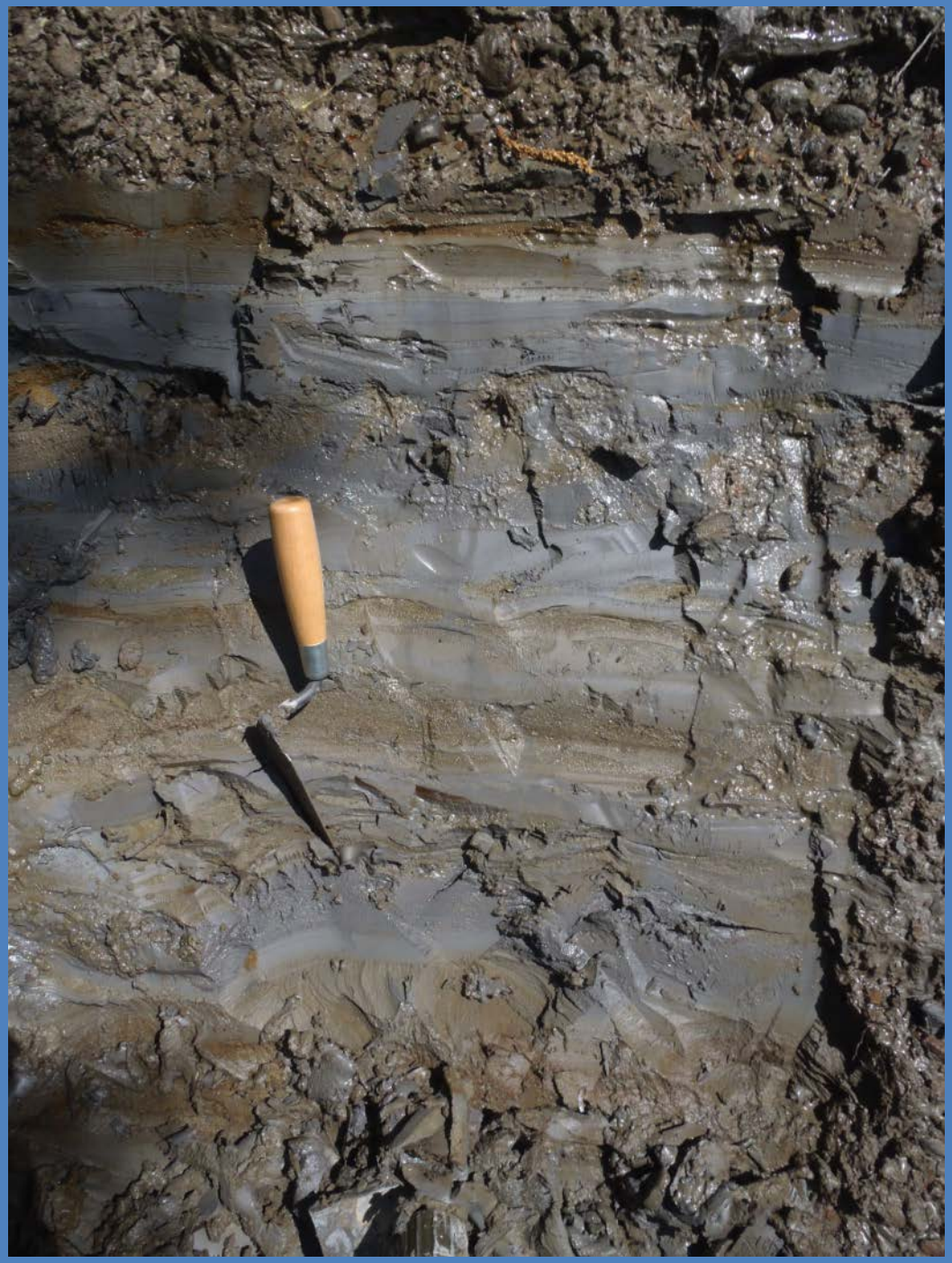
Environment of Deposition		Materials	Units
Stream Terrace (<10,000 years BP)		Sand and gravel	A
Lake Vermont	Fort Ann Stage	Sand-silt varves	B
	Coveville Stage	Silt-clay varves	C (upper)
Lake Mansfield		Silt-clay varves	C (lower)
Subglacial (>13,600 years BP)		Till	D

Upper fluvial sand and gravel (Unit A) at Cross Section A-A'). Photo by G. Springston, 5/19/2011.

At the 2006 landslide looking up at top of slide. This is Unit B, which consists of 1.5 -2.5 ft thick layers of fine sand separated by thin silty clay layers (i.e. thick varves).

Jon Kim
P7210183
7/21/2006


Close-up of one thick varve in upper section of 2006 slide. Note undercut portion at base of sandy layer (at level of trowel).
Sandy layer
Silty clay layer
G. Springston
Photo 1807
7/13/2006



Stiff, varved lacustrine deposit (Unit C) at site of 2011 landslide. Very fine sand and clayey silt are brown and silty clay is grey. Trowel for scale. Photo by G. Springston, 5/19/2011.

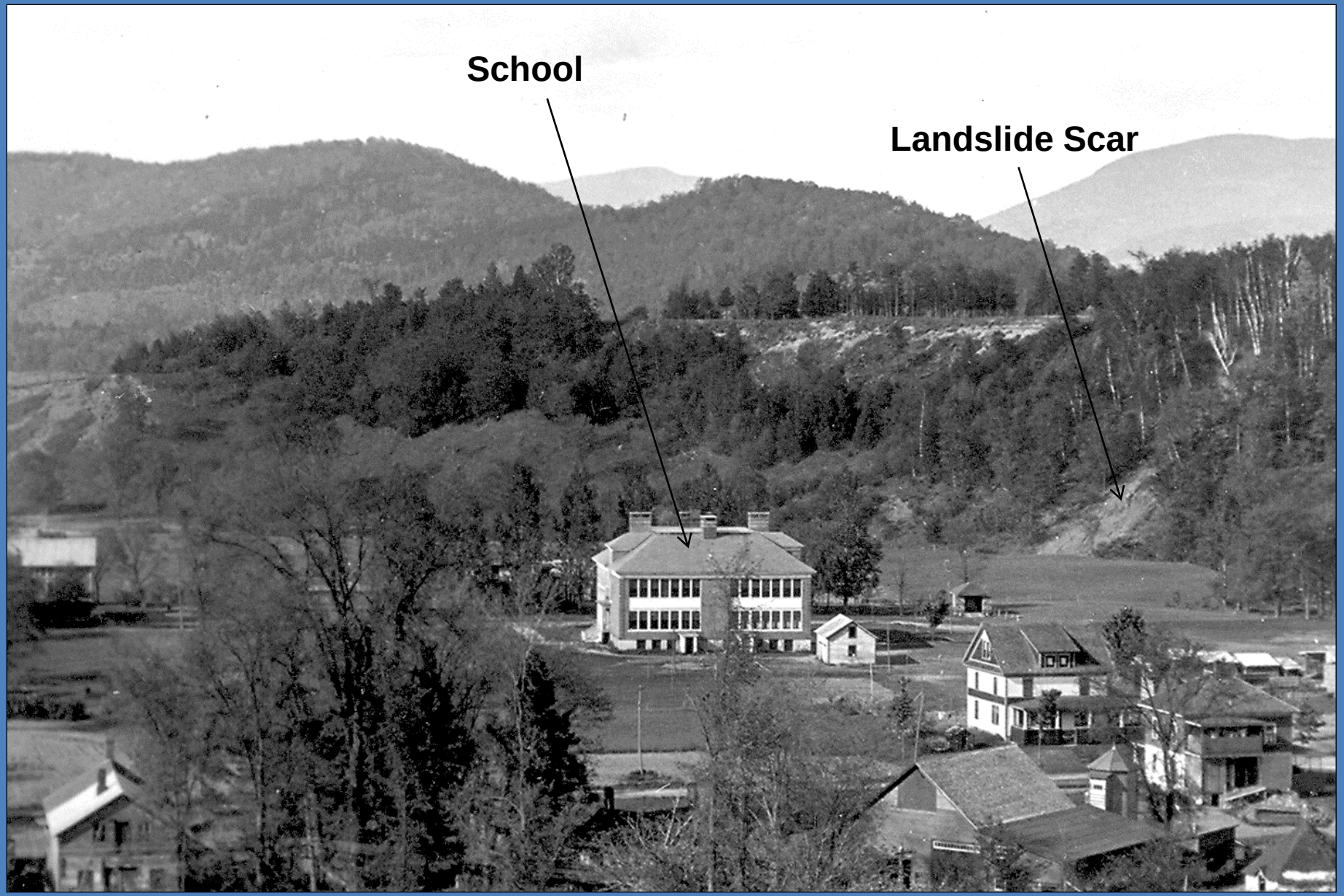
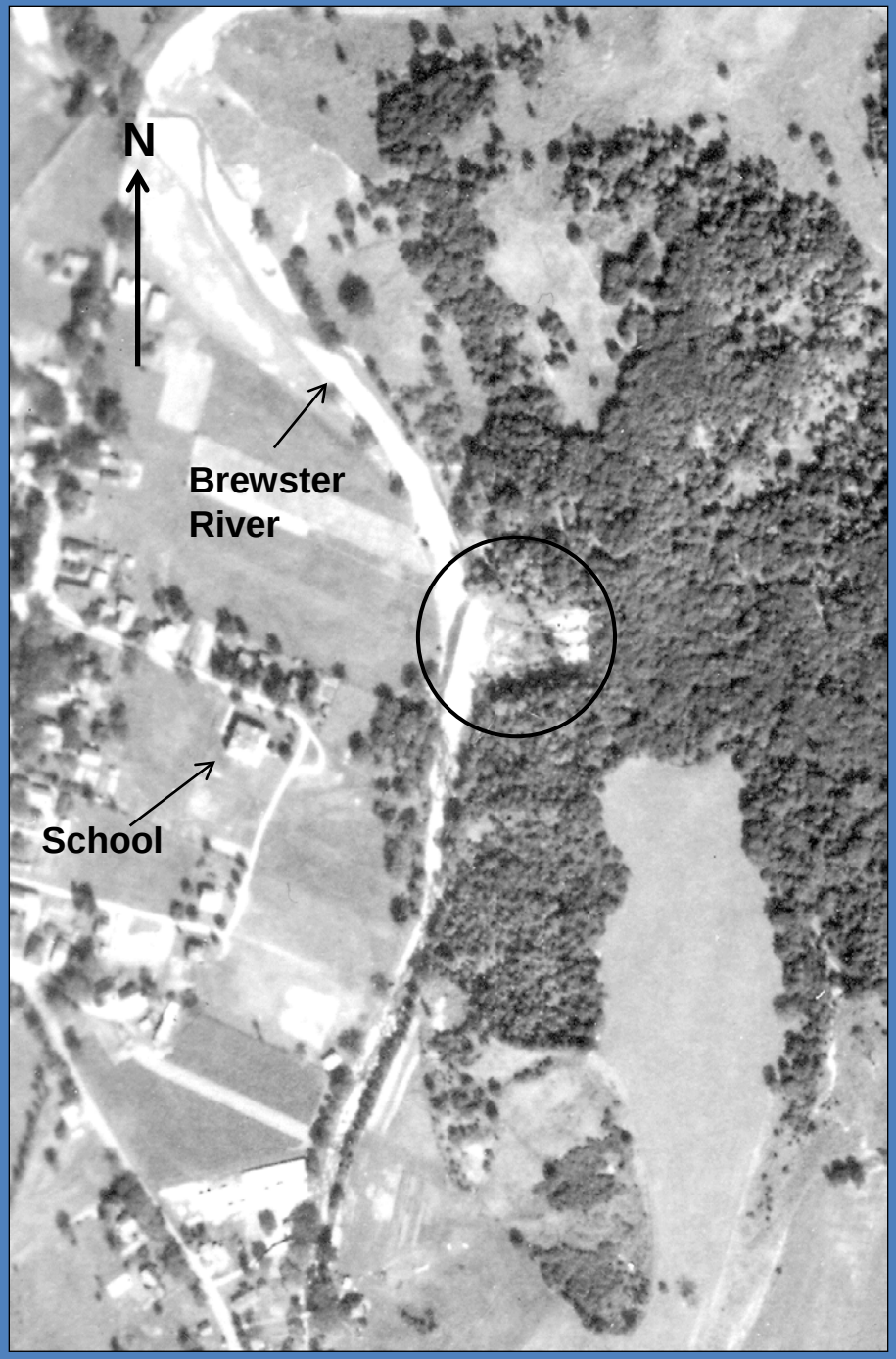


Photo taken in about 1911.

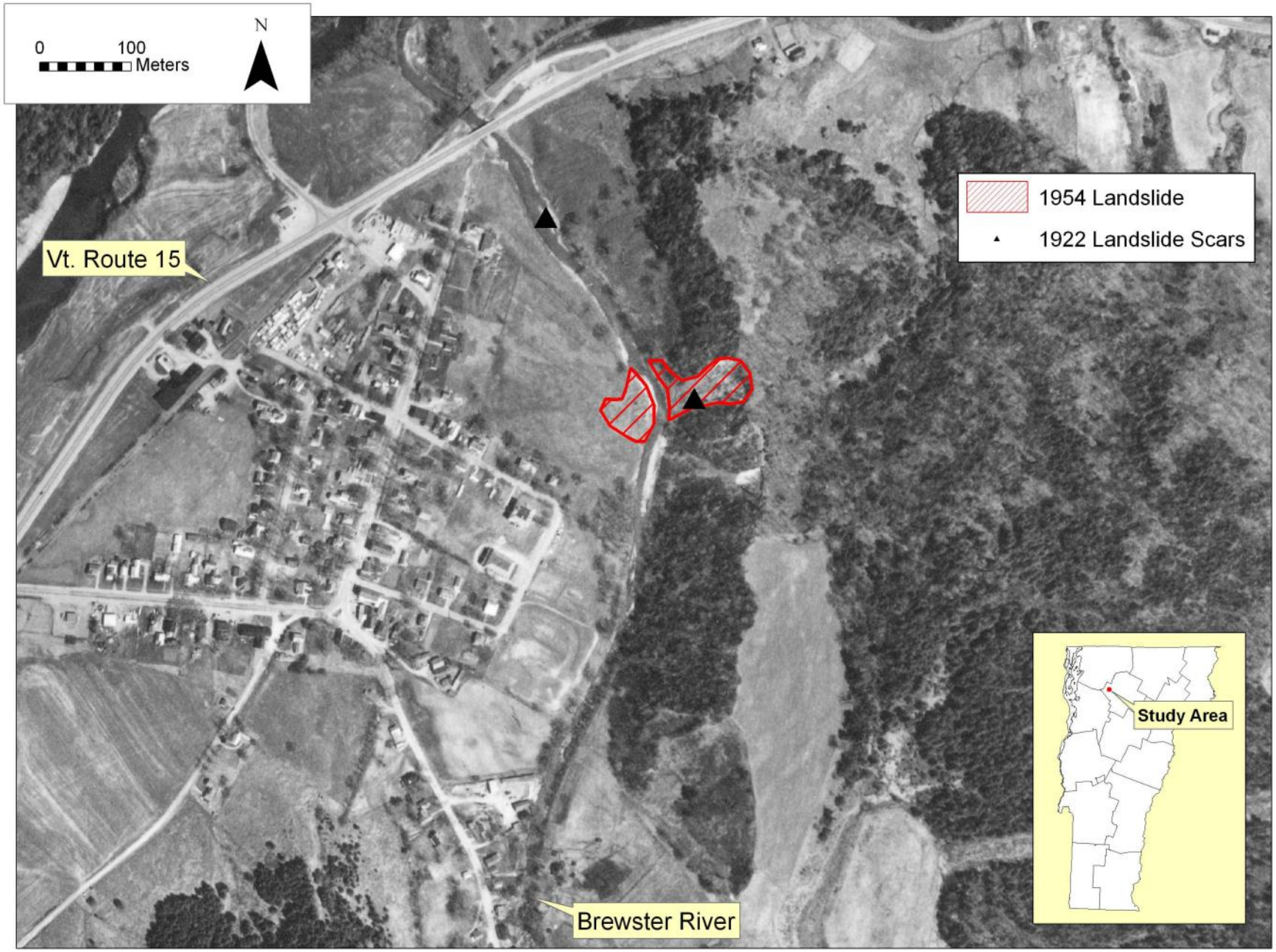
Photo by Harold Thomas from collection of Stub Wells, Jeffersonville.



Aerial photo taken
August 1, 1942.
Landslide scar is circled.

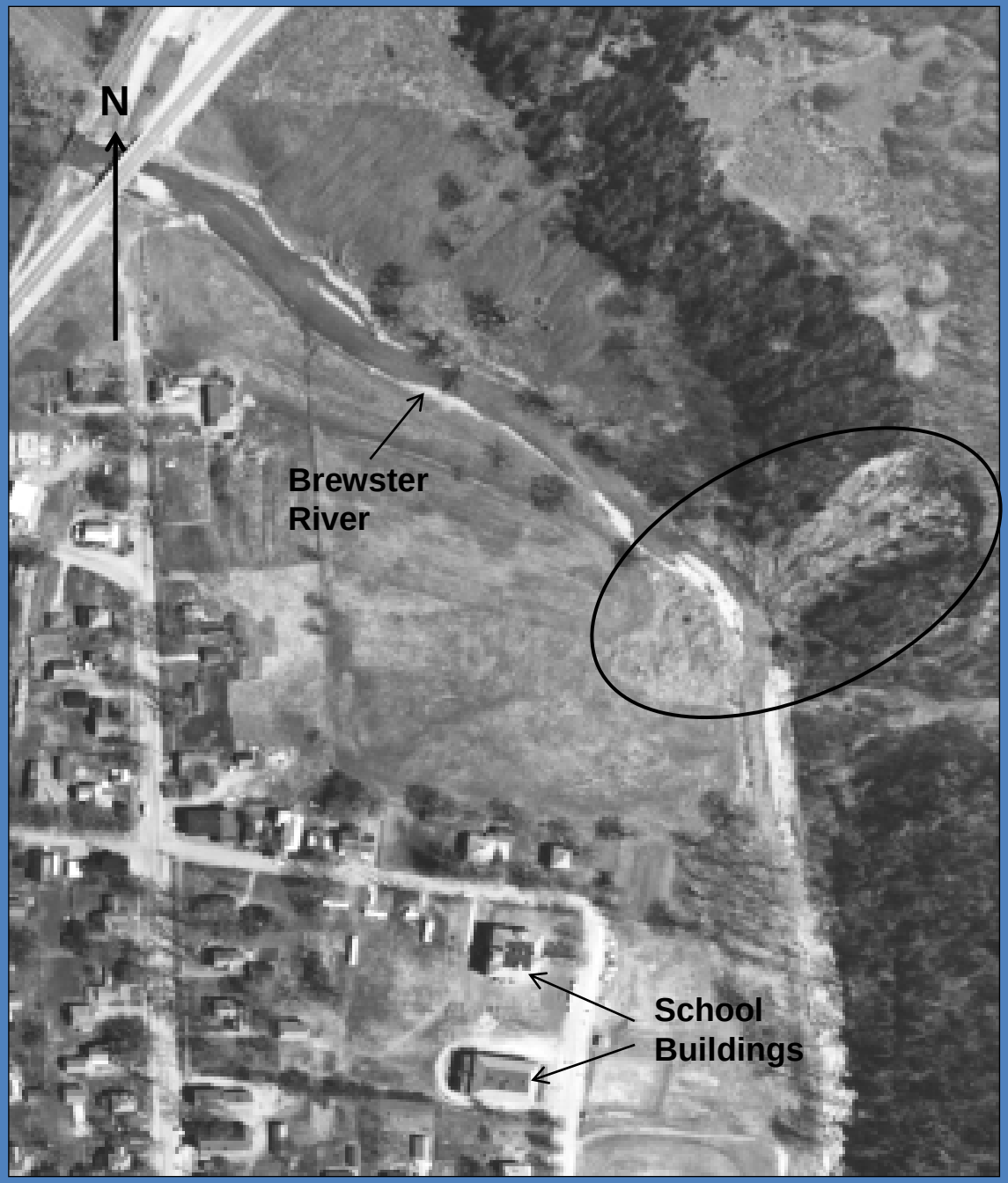
Jeffersonville Landslide, May, 1954

Photos by Harold Thomas from collection of Stub Wells, Jeffersonville.



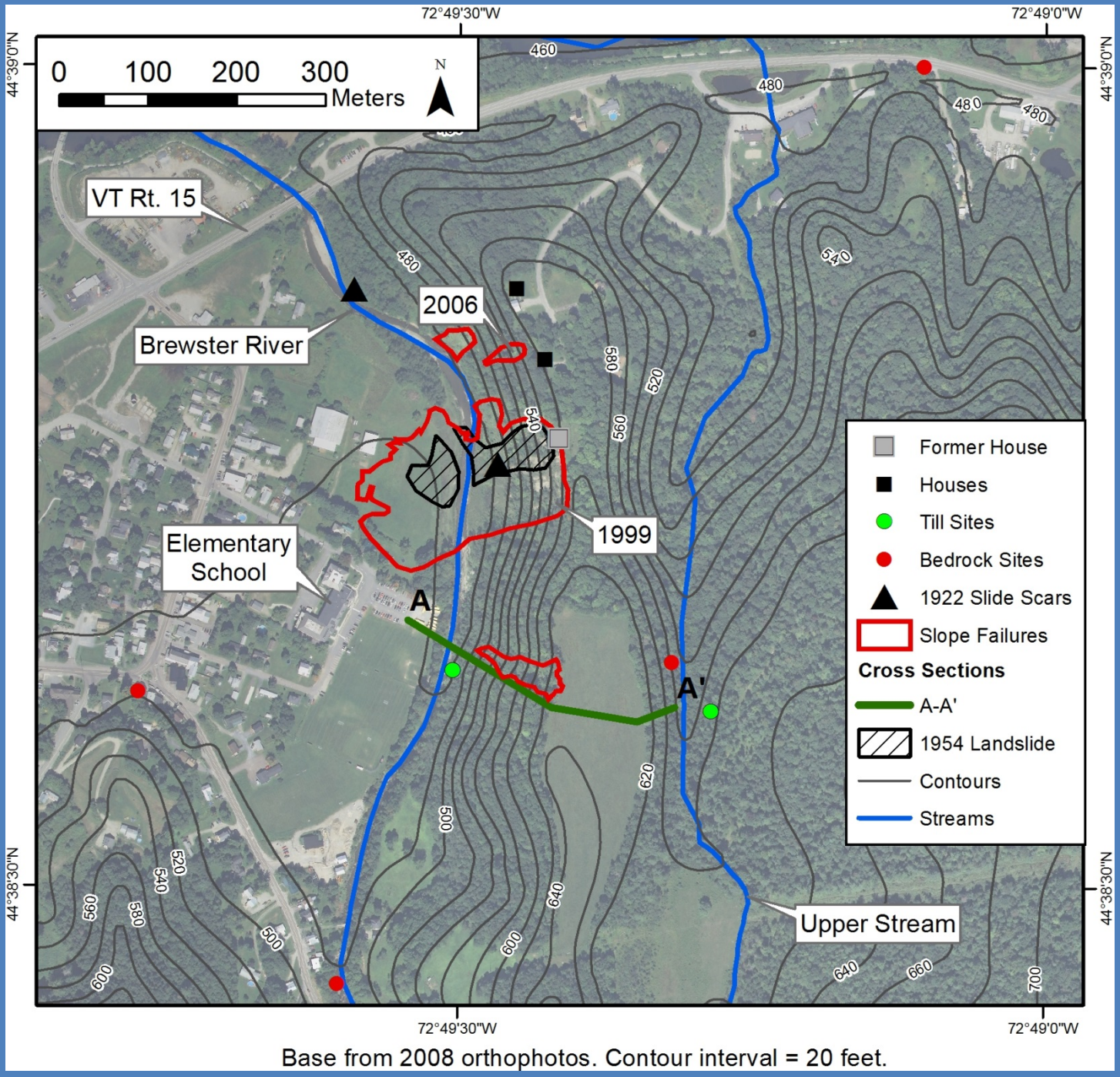
1962 Aerial Photo

George Springston, Norwich University, 5/4/2010



Aerial photo taken in the spring of 1962. The 1954 landslide is circled.

Site map showing landslides and cross-section location



Jeffersonville landslide after the April 18, 1999 slide

Note house on top at edge of landslide.
Mosaic of photos taken on April 20, 1999 by Jon Kim, Vermont Geological Survey.

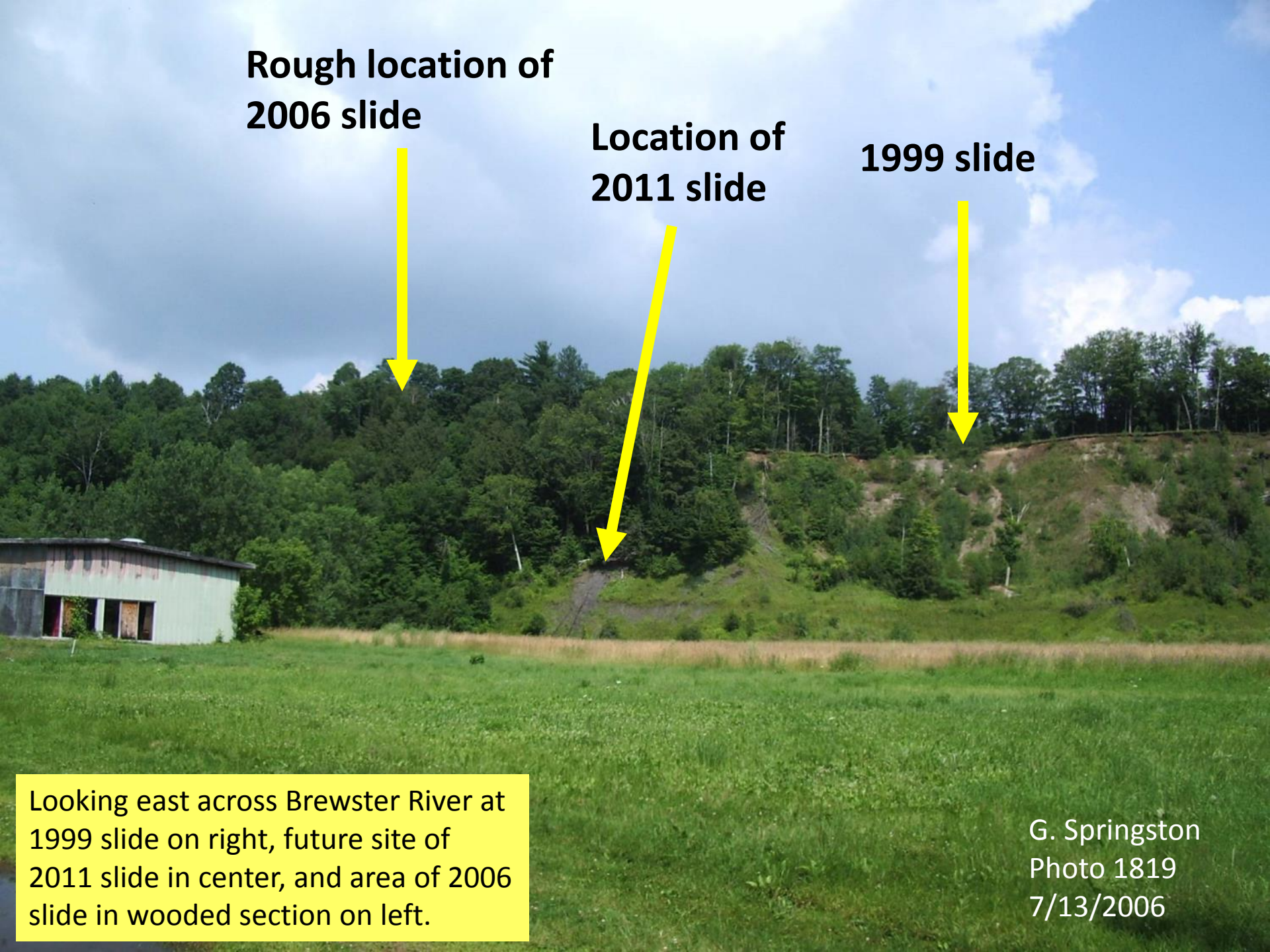
House perched at top of Jeffersonville landslide, 1999.

View of the 1999 landslide deposit looking southeast. Vermont Landscape Change Program photo LS21623_000 used courtesy of Paul Bierman, University of Vermont.

Landslide deposit pushed up against house at southwest corner of 1999 landslide. Vermont Landscape Change Program photo LS21615_000 used courtesy of Paul Bierman, University of Vermont.

Cut in silt and clay of the 1999 landslide deposit. Vermont Landscape Change Program photo LS21616_000 used courtesy of Paul Bierman, University of Vermont.

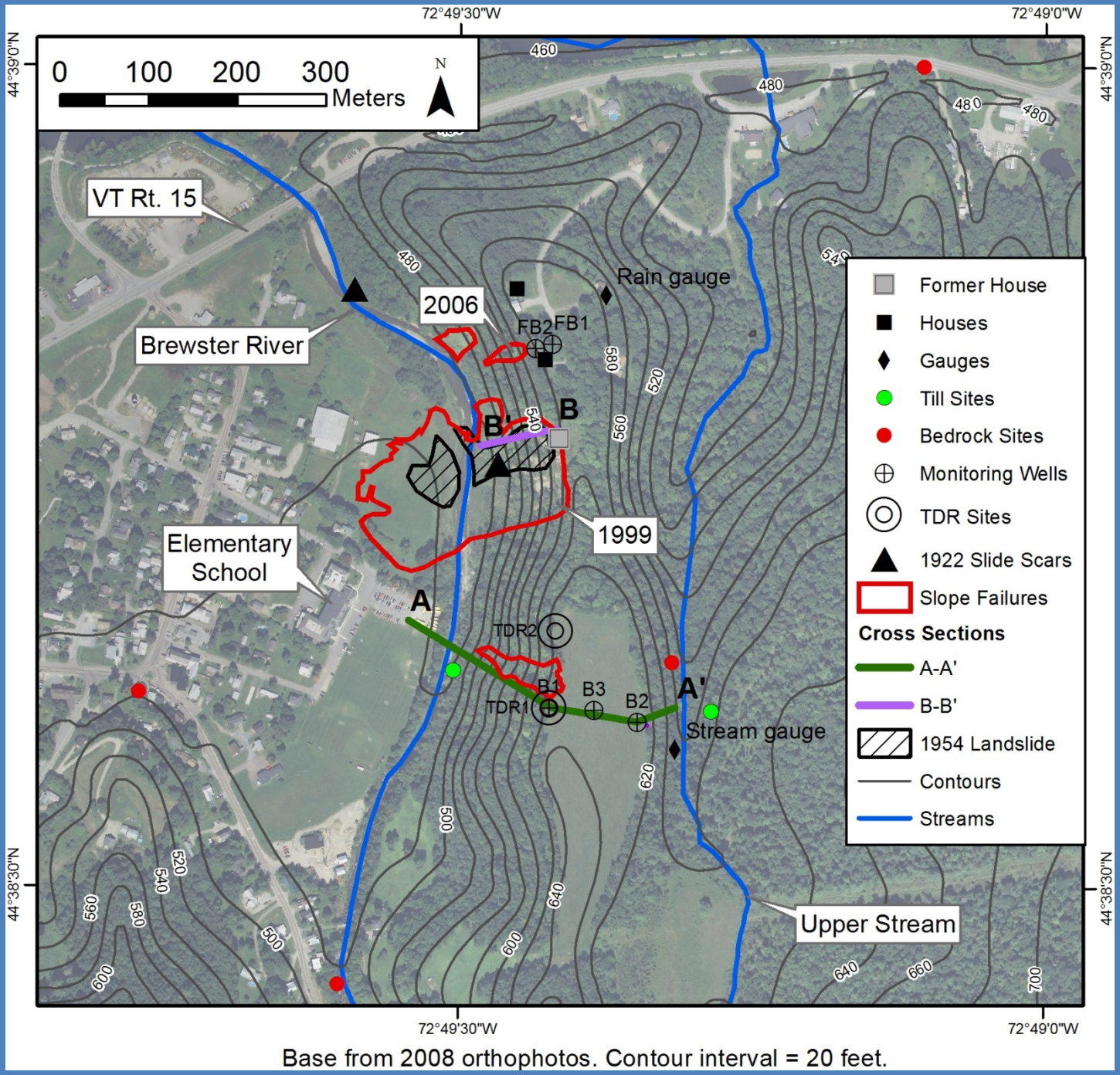
Looking east across river at 1999 landslide with house at top. Note prominent dark-grey bench on lower part of slope. Rip-rap has been placed at the toe of the slope on the far bank of the river. Vermont Landscape Change Program photo LS21620_000 used courtesy of Paul Bierman, University of Vermont.



Looking east across Brewster River at 1999 slide on right, future site of 2011 slide in center, and area of 2006 slide in wooded section on left.

G. Springston
Photo 1819
7/13/2006

Borings, gauges, and cross-section locations.



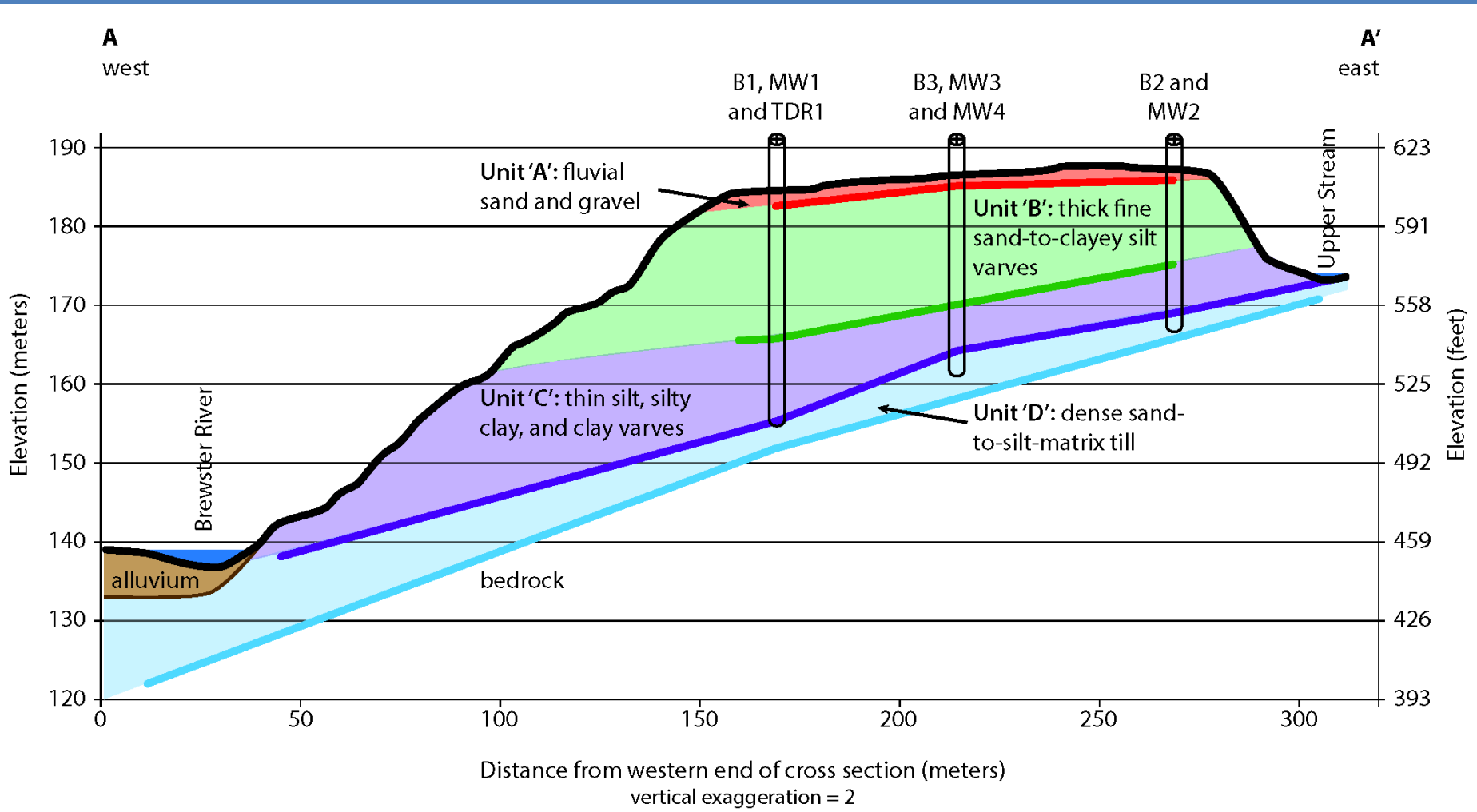
Base from 2008 orthophotos. Contour interval = 20 feet.


Installation of Boring B1, Jeffersonville.
G. Springston
Photo 1743, 7/20/2009

Examining a section of laminated fine sand and silt in the split spoon sampler, Jeffersonville.

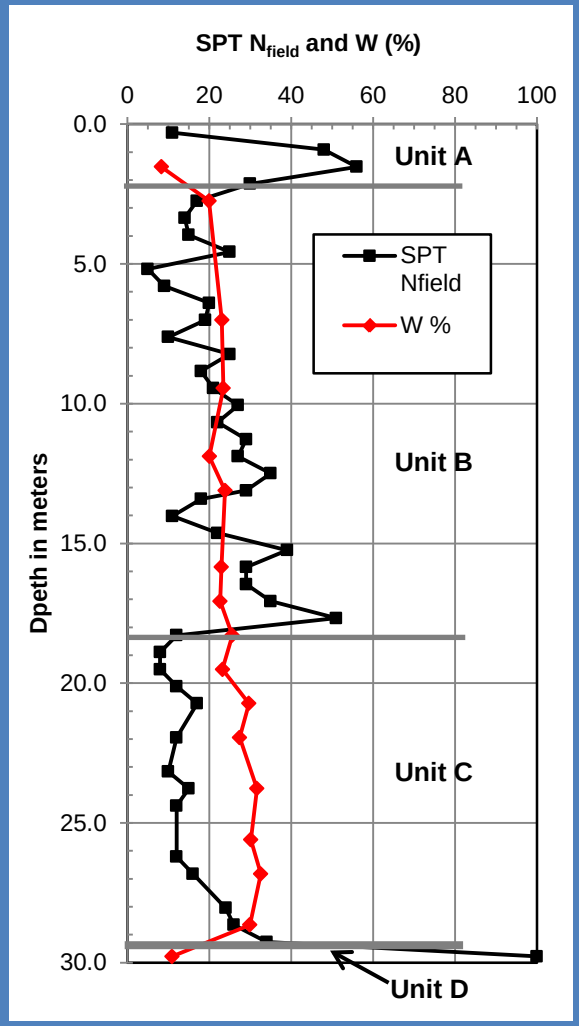
G. Springston
Photo 1796, 7/20/2009

Cross Section A-A', Jeffersonville, VT.

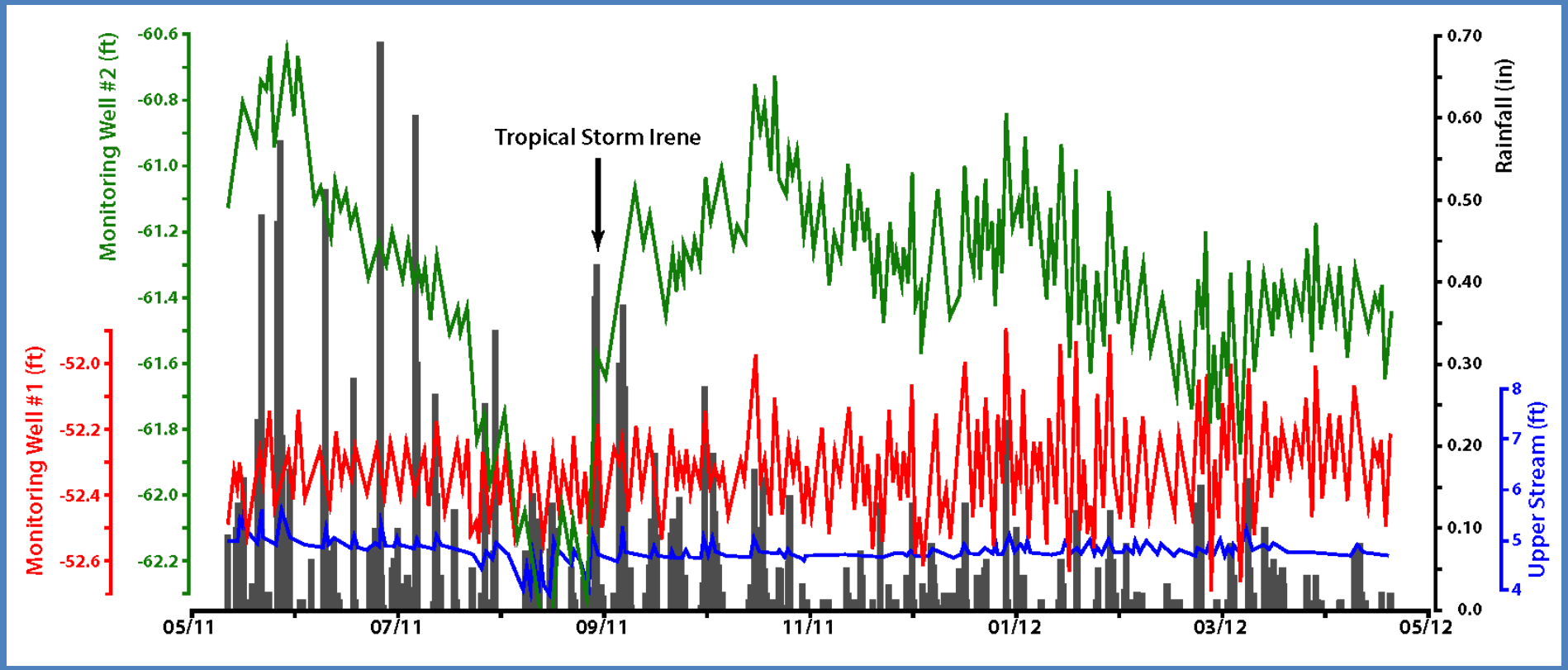


Engineering characteristics of materials in Boring B1 at Jeffersonville, VT.

Characteristics				
Units	A	B	C	D
Average SPT N_{field}	36	23	16	>100
USCS Group Symbol	SP-SM	SM	CL	SC-SM
Soil Classification	Poorly graded SAND with silt and gravel	Silty SAND w/ sandy lean clay lenses	Lean CLAY with silty lenses	Silty clayey SAND with gravel
Unit Weight (kN/m^3)	20	18	17.5	21
Cohesion (kPa)	0	0	62	200
Effective Angle of Internal Friction (deg.)	40°	31°	30°	40°
Hydraulic Conductivity (m/s)	$1.5x10^{-4}$	$3x10^{-5}$	$2x10^{-7}$	$7x10^{-8}$



Precipitation and water levels at Jeffersonville from May of 2011 to May of 2012.



Monitoring well MW1: red
Monitoring well MW2: green
Gauge on upper stream: dark blue
Rain gauge (hourly): grey

After Weiss, N. 2012. Analysis of Hydrologic Factors at the Deer Run Heights landslide in Jeffersonville, VT. Available from http://kanat.jsc.vsc.edu/drh/weiss2012.pdf

Some Causes of Landslides in Vermont

- **Stream erosion resulting in oversteepening of the base of a slope.**
- **Heavy rainfall or snowmelt causing saturation of soil and increase in pore pressure.**
- **Adding excess load onto slopes, such as by dumping of fill onto a slope.**
- **Excavation of base of slope, resulting in oversteepening.**
- **Reduction in strength of materials due to physical and chemical weathering of soil.**

Possible Causes of 1999 Jeffersonville Landslides

- **Both stream erosion and increased pore pressure may have played roles in the 1999 landslides.**
- **Rainfall appears to have been below average in spring of 1999, but heavy rains occurred in the summer of 1998. It's possible that water from the 1998 rains moved slowly through the fine-grained silts and clays, leading to slope failure in April of 1999 (Bierman and others, 1999).**
- **Another possibility is that the water infiltrated slowly from the upper stream.**
- **Toe erosion may have occurred during the heavy rains of the previous summer and may have contributed to the first slope failure in 1999 (April 11).**
- **The landslides of April 18 and July 4, 1999 broke out on top of the dark grey bench in the slope rather than at the toe of the slope, indicating that increased pore pressure was the cause rather than toe erosion (Bierman and others, 1999).**

Preliminary Conclusions

- **Landslides at the site go back more than a century.**
- **The 1954 and the 1999 landslides crossed the river, with the 1999 landslides involving over 27,000 cubic meters (35,300 cubic yards) of material and extending ~125 meters (400 feet) beyond the west bank of the river.**
- **Area of greatest concern appears to be north of 1999 slide.**
- **Area of secondary concern is south of 1999 slide and above the school.**
- **Heavy or extended rains or heavy snowmelt would make slope failures more likely.**
- **Any future toe erosion by the river would make slope failures more likely.**
- **Slope failures can occur long after the driving event and can be expected to extend across the river, placing the Village at risk.**
- **Although no earlier events are known to have dammed the river to a dangerous extent, this is a concern and would place the Village at risk of flooding.**

Further Information

General:

Highland, L.M., and Bobrowsky, Peter, 2008, The landslide handbook--A guide to understanding landslides: U.S. Geological Survey Circular 1325, 129 p.

Jeffersonville Landslide:

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.

Nicols, Kyle, Landslide initiation after drought at Jeffersonville, Vermont. Retrieved on 28 March 2014 from http://www.skidmore.edu/~knichols/Jeffersonville.htm .

Weiss, Nate, 2012. Analysis of Hydrologic Factors at the Deer Run Heights landslide in Jeffersonville, VT. Retrieved on 20 February 2014 from http://kanat.jsc.vsc.edu/drh/weiss2012.pdf.

Wright, S.F., Surficial geology of the Jeffersonville 7.5-minute quadrangle, northern Vermont: Open File Report, Vermont Geological Survey, Montpelier, retrieved on 20 February 2014 from http://www.anr.state.vt.us/DEC/GEO/images/digitalofrs/JeffQuadFinalRp.pdf.

Acknowledgements

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