Unstable Lake Sediments of Deer Run Heights
Represent a Potential Landslide Hazard
to the Cambridge Elementary School in Jeffersonville, Vermont

Figure 1. Landslide initiation after drought at Jeffersonville, Vermont (Nichols N.D.)

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Abstract:

The area of concern for this study is Deer Run Ridge which is a ridge line located near Deer Run Heights off Route 15 in Jeffersonville, Vermont. Due to landslide activity on the ridge, the ridge has been monitored for change in activity. Rebar stakes have been used to monitor the level of cutback along the top of the ridge. In nearly a three-month time period it was determined that the average rate of cutback was 0.12 meters. Also, tree transects and ground water levels have been monitored which showed little change in the three-month period of study. A Total Mapping Station was used to set up a topographic profile of the ridge for the monitoring of change in the future. It has been determined that there are two main areas of higher concern along the ridge. One area of concern is at the southern portion of the 1999 slide (right portion of Figure 1) and the other is a forming gully above the Cambridge Elementary School (Figure 8).

Geologic History:

Deer Run Heights has been an area of ongoing concern since the last major landslide occurred in 1999. This slope failure produced a large volume of debris which flowed over the Brewster River and across the flood plain where it reached residential properties. Along with the mud came large trees, rocks and any other debris existing on the slope. According to Forsberg (2007), the soil consists of alternating layers of clays, silts, and fine sands and these sediments become progressively coarser further up the slope. This is the cause for some of the instability in the slope especially when heavily saturated with water. In the following years there have been other smaller but significant slides in the same region. More recently, in 2006 a slide occurred on a residential property in a neighboring gully below the Farara property.

The origin of this landslide hazard begins at the time of the receding Laurentide ice sheet tens of thousands of years ago. "As the Laurentide ice sheet retreated to the west down the Lamoille River valley, it damned the valley forming a series of lakes at different elevations as different outlets were uncovered by the retreating ice sheets" (Wright N.D.). This creation and retreat of these lakes created poorly sorted unstable sediments along their banks as they receded. One of these ancient lake slopes lies along the western slope of the area known as Deer Run Heights.

The significance of these landslides is the future concern in which they impose. The most recent activity at Deer Run Heights (DRH) has been an emerging gully located southwest of the previously active Farara slide first identified by Jay Cairelli (2008). This gully is located directly above the Cambridge Elementary School, posing a potentially serious threat. If another slide occurred in this location with the same magnitude as the slide that occurred in 1999 the school could be in serious danger. The work done at the site by myself, Sam Hellman and George Springston will allow the monitoring of the entire ridge line that poses a threat to the eastern portion of the town of Jeffersonville below DRH. Through various measurements and use of technologies, prediction for future activity in the region will be explored.

Hypothesis:

Currently, the field to the east of the Cambridge Elementary school is losing soil regularly and liquefaction is taking place on the slope of this gully. In future years, a significant slide could take place in this region due to the various unstable sediment bands causing instability in the slope. The implications of this slide are unknown at this time but with further monitoring the timing and volume of future significant slope failures may be forecasted.

Research plan:

The plan of this study is to predict a future mass wasting event along Deer Run ridge. In order to do this, several methods need to be used to determine possible movement in the unstable sediments. The first important measurement that needs to be monitored is the pore water pressure deep beneath the surface. A high level of pore water pressure was likely the cause of the large 1999 slide according to Forsberg (2007) and by monitoring this it will be known if the pressure is increasing and posing any immediate hazards. Another important aspect to monitor is the rate of erosion along the slip face. This will show the degree of surface activity occurring on the slope. The next important aspect to be monitored is changing angles and distance between trees on an active part of the slide. This will determine if one section of the slope is failing and the rate of movement. The last and possibly most significant aspect to monitor is the shifting and slumping of the land along the ridge. This could aid in determining if there is any large-scale subsurface movement that would indicate a potential landslide.

Methods:

Groundwater Measurements

The water level in the four monitoring wells on the Farara property has been monitored for water depth near the edge of the slip face (Figure 2).
A water depth instrument, model 101 by Solinst, is used to monitor the water level in each well. A sensor attached to a tape measure is run down the PVC pipe until a beeping sound can be heard from the unit. The depth of the water is recorded at the top of the PVC piping.

Figure 2. Four Monitoring Wells (the fourth well is behind the brush in the upper left corner)

Erosion along the Slip Face

The rate of slip face erosion is an important measurement because it shows how fast the surface of the ground is eroding at DRH and gives a good indication of recent activity. Sections of rebar were previously placed in 2007 by Michaela Forsberg at nineteen locations along the ridge with stakes to mark each location. From these locations, three bearings at 30 degrees apart are used to monitor the rate of erosion along the slip face (some locations have two or four bearings). To measure these bearings a measuring tape is lined up with the bearing being measured and taken to the edge of the slip face. A stake is then held at 90 degrees to the edge of the face and the measurement is taken at the closest point on the stake. Since the nineteen stakes were placed, the first three points are no longer in use for an unknown reason. Stake number six has not been recorded because it is located in the center of a briar patch and accurate results could not be obtained. The bearing at 285 degrees at stake eight was no longer taken due to a fallen tree obstructing the measurement.

Tree Transects

While taking measurements of the tree transects, it was discovered that a nearly vertical fracture on the fall line may have occurred between trees T4 and T5 which could have effectively shifted a section of the slope. To monitor the movement of this shelf a rebar was hammered in horizontally on the vertical aspect of the fracture. During data collection, the end of the rebar is measured vertically to the slope below.

Topographic Mapping

Topographic mapping is an important aspect to the project at DRH. If the area is mapped precisely showing elevation then it can be determined at a later date what is moving near the slip face or along the ridgeline. The first step in the mapping project is setting up permanent points of a closed traverse. To do this, short stakes were hammered in flush with the ground. Nails were then hammered into the top of these stakes for precise measuring. A long wooden stake was then hammered in adjacent to these points in order the make the point more readily visible. In the open field (property of the Vermont Land Trust) above the Cambridge Elementary School, these Points could be located as far as a quarter mile from each other. In the woods they were closer to one other so they could be plotted. The reason for this is when plotting the points using a Total Mapping Station the two points must be visible from one another and therefore the sight range in the woods is much shorter.

The closed traverse extends from the top of the 1999 slide, down across the river to the field below. From there it extends past the Jeffersonville Elementary School, back across the river and up an old ski path to the top of the field on the far side. From the field it crosses back and forth to include the majority of the field then extends through the woods and back to the location of the 1999 slide where the traverse is closed (Figure 3).

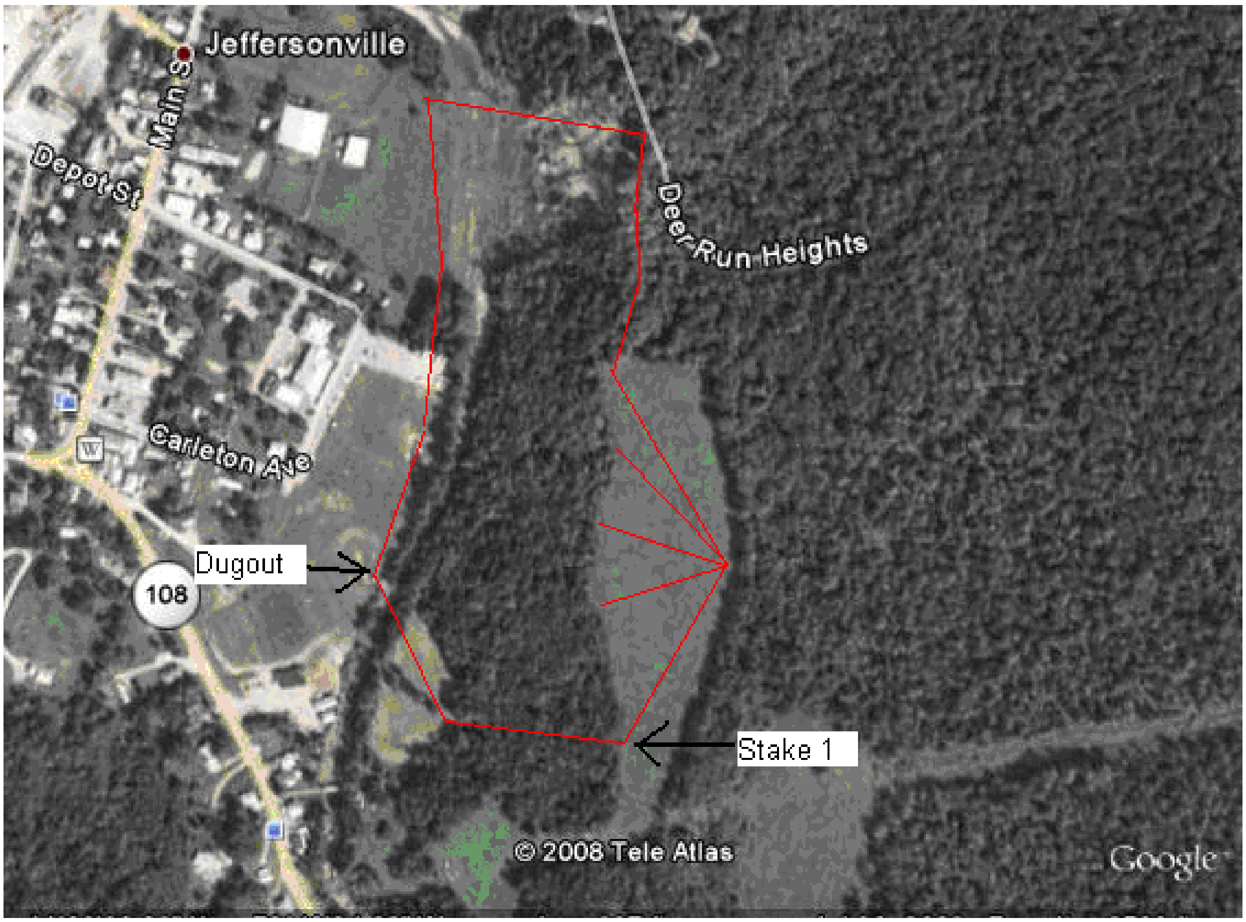

Figure 3. Route of Closed Traverse (Google Earth 2008)

Before the actual surveying of the closed traverse is started a known elevation must be obtained from an outside source. It was determined that a benchmark existed in downtown Jeffersonville across from Hanley General Store at the WWI monument. The benchmark has a known elevation of 479.99 feet above sea level. This known elevation must be carried over to the closed traverse so we can plot the area with its true elevation. To do this a surveyor's level, made by Sekkia, and a surveyor's rod were used to cross the street, move down the sidewalk, down the street to the school, crossing the field and ending at the dugout near the closed traverse. All this way the known elevation was taken to give an elevation of 463.44 at the dugout. The dugout is located west of the Brewster River (Figure 3).

Since the elevation had been determined and the waypoints had been made using the stakes, the surveying using the highly accurate Total Mapping Station was performed on the traverse. The Total Mapping Station used was model Leica TC407. Stake One of nineteen was used as the first point on the western side of the field above the Elementary School. To use the Total Mapping Station many steps must be taken to achieve precise measurements. First, the unit was mounted directly above the nail head on Point Two and made level using the rough leveling bubble. The unit was then turned on and emitted a laser dot to precisely mount the unit directly above the nail. After this was accomplished, the leveling was fine-tuned before moving on to set up the Station properly. Temperature and relative humidity were entered into the unit to increase accuracy of the laser. The coordinates were initially set to originate at 1000 North, 1000 East, and 1000 Height (elevation). This was done in hopes that no negative numbers were recorded during the surveying. The height of instrument was entered into the unit as well as the height of the rod. From Point Two, a back sight was taken to Point One where a rod was held directly onto the point. The coordinates were shot with the laser and recorded. The coordinates for North, East and Height were recorded in the unit as well as written down (Figure 4).

Figure 4. Sam (left) receives coordinates from Adam (right) on Point 16 back sighting Point 15.

The rod was then brought to Point Three and a foresight was taken in a similar fashion (the station did not need to be reset or re-leveled for the foresight). This process was repeated throughout the traverse. At every point the Total Mapping Station was set up and packed away in its case for protection while moving it. A back sight and foresight were taken at each point to ensure accuracy and to evaluate if any mistakes were made.

<u>Results:</u>

Groundwater Measurements

The monitoring wells did not prove to be that helpful in the evaluation of saturated sediments near the slip face. This is most likely because the wells were not dug deep enough and water was only detected in well B-2 (Figure 5). Also these wells can potentially produce much different readings during the spring time thaw.

Monitoring Well Measurements (feet)

	Well B-1	Well B-2	Well B-3	Well B-4
9/2/2008	Dry	Dry	Dry	Dry
9/10/2008	Dry	67.85	Dry	Dry
10/20/2008	Dry	67.5	Dry	Dry
12/6/2008	Dry	67.15	Dry	Dry

Figure 5. Data Collected from Monitoring Wells

Reflecting on the long term data taken by Cairelli (2008) it is clear that the fluctuation in water depth was much greater (Figure 6). This may be due to more frequent measurements. Also, another factor may be that nearly all the measurements taken in the fall of 2008 were taken on days lacking precipitation.

Monitoring Well Measurements 2007 (feet)

	B1	B2	B3	B4		B1	B2	B3	B4
26-Oct	62.9	67	Dry	Dry	6-Dec	57.25	66.85	Dry	Dry
27-Oct	62.5	66.9	Dry	Dry	7-Dec	57.7	66.9	Dry	Dry
28-Oct			Dry	Dry	8-Dec	58	66.9	Dry	Dry
29-Oct	61.5	66.6	Dry	Dry	9-Dec	58.4	66.9	Dry	Dry
30-Oct	60.6	66.8	Dry	Dry	10-Dec	58.9	66.9	Dry	Dry
31-Oct			Dry	Dry	11-Dec	Frozen	Frozen	Dry	Dry
1-Nov	58.6	66.8	Dry	Dry	12-Dec	Frozen	Frozen	Dry	Dry
2-Nov	59.7	67	Dry	Dry	13-Dec	Frozen	Frozen	Dry	Dry
3-Nov	62.2	67.1	Dry	Dry	14-Dec	Frozen	Frozen	Dry	Dry
4-Nov	58.75	67.1	Dry	Dry	15-Dec	Frozen	Frozen	Dry	Dry
5-Nov	59.7	67	Dry	Dry	16-Dec	Frozen	Frozen	Dry	Dry
6-Nov	59.1	67.2	Dry	Dry	17-Dec	Frozen	Frozen	Dry	Dry
7-Nov	60.7	67.1	Dry	Dry	18-Dec	Frozen	Frozen	Dry	Dry
8-Nov	62.1	67	Dry	Dry	19-Dec	Frozen	Frozen	Dry	Dry
9-Nov	61.9	67.1	Dry	Dry	20-Dec	Frozen	Frozen	Dry	Dry
10-	60	67	Dry	Dry	21-Dec	Frozen	Frozen	Dry	Dry

Nov									
11-Nov	60	66.9	Dry	Dry	22-Dec	63.25	67.15	Dry	Dry
12-Nov	59.9	67	Dry	Dry	23-Dec	59	67.15	Dry	Dry
13-Nov	59.4	66.8	Dry	Dry	24-Dec	55.4	66.9	Dry	Dry
14-Nov	59.5	66.8	Dry	Dry	25-Dec	58.25	66.9	Dry	Dry
15-Nov	59.1	67	Dry	Dry	26-Dec	58.3	6.9	Dry	Dry
16-Nov	58.7	66.9	Dry	Dry	27-Dec	58.3	6.8	Dry	Dry
17-Nov	58.8	67	Dry	Dry	28-Dec	58.3	6.8	Dry	Dry
18-Nov	59.3	67.1	Dry	Dry	29-Dec	58.3	66.75	Dry	Dry
19-Nov	59	67.1	Dry	Dry	30-Dec	58.3	66.75	Dry	Dry
20-Nov	59.1	67	Dry	Dry	31-Dec	56.9	66.9	Dry	Dry
21-Nov	58.6	67	Dry	Dry	1-Jan	57.9	66.8	Dry	Dry
22-Nov	58.1	66.9	Dry	Dry	2-Jan			Dry	Dry
23-Nov	59.4	67.1	Dry	Dry	3-Jan			Dry	Dry
24-Nov	N/A	N/A	N/A	N/A	4-Jan			Dry	Dry
25-Nov	58.9	67.1	Dry	Dry	5-Jan			Dry	Dry
26-Nov	58	66.9	Dry	Dry	6-Jan	58.6	67	Dry	Dry
27-Nov	56.9	66.8	Dry	Dry	7-Jan	58.1	66.95	Dry	Dry
28-Nov	56.8	66.9	Dry	Dry	8-Jan	56.6	66.8	Dry	Dry
29-Nov	56.1	66.9	Dry	Dry	9-Jan	54.7	66.65	Dry	Dry
30-Nov	56.3	66.9	Dry	Dry	10-Jan	55	66.7	Dry	Dry
1-Dec	56.4	66.9	Dry	Dry	11-Jan			Dry	Dry
2-Dec	56.8	66.85	Dry	Dry	12-Jan			Dry	Dry
3-Dec	56.4	66.9	Dry	Dry	13-Jan	56.8	66.9	Dry	Dry
4-Dec	56.9	66.9	Dry	Dry	14-Jan	56.7	67.05	Dry	Dry
5-Dec	57.3	66.9	Dry	Dry	15-Jan	57.75	67.3		
					16-Jan	60.8	66.9		

Figure 6. Data Collected from Monitoring Wells taken by Cairelli (2008)

Slip Face Measurements

The measurement of the eroding slip face proved to be the most dynamic of all the various measurements taken. These were in fact the only measurements that had noticeable changed throughout the study (Figure 7). The stakes producing the most cutbacks were stake numbers 9, 16 and 4 (in order from most to least). Stake Four is located towards the northern end of the slide that occurred in 1999. This bank appears to be eroding due to poorly sorted sand being weathered at the slip face and transported down slope. This is possible due to the steep inclination of the slope but more importantly the lack of vegetation. A similar scenario is occurring at Stake Nine at the southern limit of the 1999 slide.

Rate of Cutback Along Ridge (Average of all three bearings)

Stake Number	9/10/2008	10/20/2008	12/6/2008	Average Cutback (meters)
4	12.25	11.7	11.99	0.26
5	7.06	7.02	7	0.07
7	6.26	6.32	6.22	0.04
8	5.62	5.6	5.54	0.08
9	5.27	4.67	4.62	0.65
11	3.72	3.72	3.69	0.03
12	7.07	7.02	7.06	0
13	5.7	5.64	5.61	0.09
14	4.44	4.46	4.44	-0.01
15	3.72	3.74	3.72	-0.01
16	2.47	2.4	2.14	0.33
17	3.87	3.86	3.83	0.04
18	3.91	3.7	3.75	0.15
Average Cutback along entire Ridge				**0.12= 0.52meters/year**

Figure 7. Cutback Measurements

The historical data was difficult to match with the recent data due to largely differing numbers taken by different individuals with their own methods. According to Forsberg's data the average cutback along the ridge between 8/23/2006 and 4/20/2007 gave an estimated cutback of 0.62 meters per year.

The more recent data collected between 9/10/2008 and 12/6/2008 gave an estimated cutback of 0.52 meters per year.

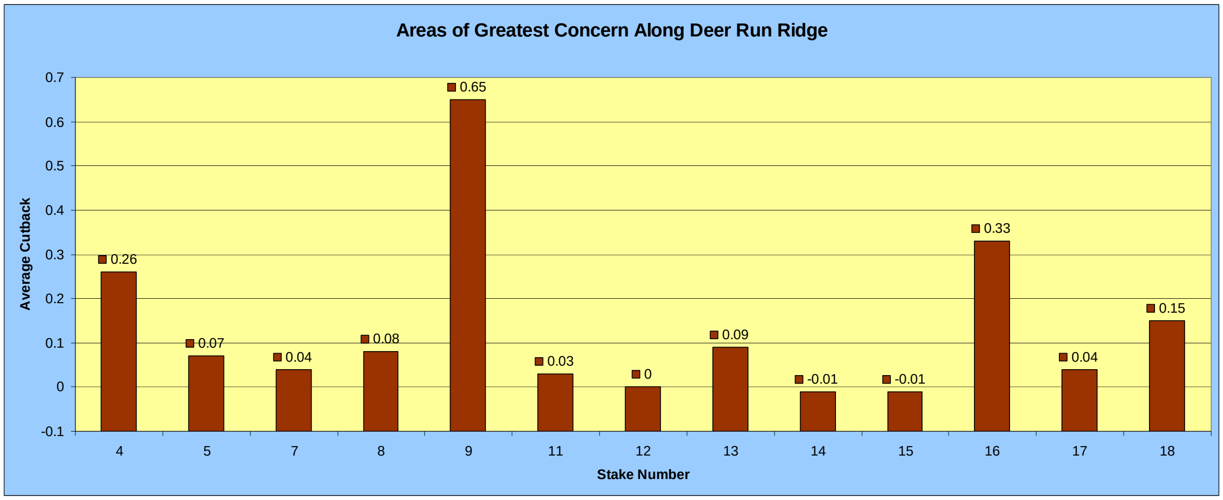

Figure 8. Areas of Greatest Concern

Stake 16 produced the most significant results of the study being located directly above the Jeffersonville Elementary School. This site has produced the most visually active and largest potential threat throughout the study. Although the cutback of this site measures less than at stake Nine the gully is much more active and is displacing much more material at the site of erosion. This gully consists of altering bands of differing sediment which contributes greatly to the relative instability (Figure 9).

Figure 9. Active Erosion at Gully above Elementary School with Stake Sixteen near Edge (11/14/2008)

Tree Transects

The trees transect measurements also provided feedback that little activity was occurring during the period of data collection. The distances between trees remained relatively constant for the duration of the study (Figure 10). The slight variation in numbers was most likely due to human error. Tree T-7 (a large white pine) had broken about 10 feet up and fallen at some point between the dates of 10/20/08 and 12/6/08 (the marker and nail was still in the base of the tree). The slope at the base of the tree appeared stable and the tree was not uprooted in the least. The most likely cause for this break was a wind storm.

Tree Transect Measurements (meters)

Transect 1	T1-T2	T2-T3	T3-T4	T4-T5	T5-T6	T6-T7	T7-T8	T8-T9
	5.22	4.95	1.03	10.3	16.04	7.81	12.26	6.14
	5.22	4.95	1.02	10.3	16.05	7.8	12.26	6.13
	5.23	4.95	1.03	10.3	16.05	7.8	12.27	6.13
Transect 3	T16-T17	T17-T18	T18-T19	T19-T20	T20-T21	T21-T22	T22-T23	
	12.26	10.53	5.69	5.14	8.86	7.72	12.57	
	12.26	10.55	5.7	5.14	8.86	7.71	12.57	
	12.26	10.54	5.71	5.12	8.85	7.72	12.57	
Transect 4	T24-T25	T25-T26	T26-T27	T27-T28	T28-T29	T29-T30		
	9.3	4.99	10.35	11.98	1.86	11.97		
	9.4	4.99	10.36	11.98	1.87	11.97		

Figure 10. Tree to Tree Measurements on the Slope below the Farara House

Looking at the historical data taken by Cairelli (2008) and comparing it to the new data it is clear that some movement has taken place on the slope (Figure 11). Some of this change may be due to measurements taken by different individuals but how much is difficult to determine.

Transect 1	T1-T2	T2-T3	T3-T4	T4-T5	T5-T6	T6-T7	T7-T8	T8-T9
28-Oct-07	5.21	4.95	1.02	10.30	16.00	7.80	12.25	6.58
13-Jan-07	5.22	4.95	1.20	10.29	16.10	7.80	12.15	6.56
24-Apr-08	5.21	4.95	1.10	10.29	16.03	7.80	12.25	6.15
2-Sep-08	5.22	4.95	1.03	10.30	16.04	7.81	12.26	6.14
20-Oct-08	5.22	4.95	1.02	10.30	16.05	7.80	12.26	6.13
6-Dec-08	5.23	4.95	1.03	10.30	16.05	7.80	12.27	6.13
Difference (m)	0.02	0.00	0.02	0.00	0.05	0.00	0.02	0.45

Transect 2	T10-T11	T11-T12	T12-T13	T13-T14	T14-T15
28-Oct-07	3.90	1.45	3.57	13.75	11.53
13-Jan-07	3.80	1.45	3.57	13.75	11.53
24-Apr-08					
Difference (m)	0.10	0.00	0.00	0.00	0.00

Transect 3	T16-T17	T17-T18	T18-T19	T19-T20	T20-T21	T21-T22	T22-T23
28-Oct-07	12.24	10.50	5.69	5.15	8.85	7.70	12.56
13-Jan-07	12.23	10.50	5.69	5.15	8.86	7.70	12.55
24-Apr-08	12.24	10.50	5.70	5.15	8.83	7.70	12.57
2-Sep-08	12.26	10.53	5.69	5.14	8.86	7.72	12.57
20-Oct-08	12.26	10.55	5.70	5.14	8.86	7.71	12.57
6-Dec-08	12.26	10.54	5.71	5.12	8.85	7.72	12.57
Difference (m)	0.02	0.04	0.02	0.03	0.00	0.02	0.01

Transect 4	T24-T25	T25-T26	T26-T27	T27-T28	T28-T29	T29-T30
28-Oct-07	9.28	5.98	10.33	11.80	1.45	11.95
13-Jan-07	9.29	5.98	10.34	11.98	1.85	11.96
24-Apr-08	9.29	5.99	10.35	11.98	1.85	11.96
2-Sep-08	9.30	4.99	10.35	11.98	1.86	11.97
20-Oct-08	9.40	4.99	10.36	11.98	1.87	11.97
6-Dec-08	9.40	5.00	10.35	11.97	1.87	11.97
Difference (m)	0.12	0.98	0.02	0.17	0.42	0.02

Figure 11. Tree to Tree Measurements Historical Data (meters)

Topographic Mapping

The leveling of the WWI monument benchmark to the dugout provided an accurate elevation of the dugout to incorporate into our closed traverse. The error margin for this survey was + 0.055 feet with a corrected elevation of 463.44 feet at the dugout (Figure 12).

Differential leveling at Jeffersonville landslide

Station	Backsight	Height of Instrument	Foresight	Elevation	Comments
H 5 1924	1.5	481.49		479.99	USGS Benchmark, PID PG0401, at WWI memorial
TP1	1.45	473.91	9.03	472.46	
TP2	0.69	466.56	8.04	465.87	
TBM1	6.03	466.75	5.84	460.72	Spike set in north side of Verizon utility pole 2/5/4
TBM2	3.485	466.925	3.31	463.44	top of westernmost bolt of southern dugout
TBM1	6.74	467.455	6.21	460.715	
TP2	8.58	474.475	1.56	465.895	
TP1	9.27	481.775	1.97	472.505	
H5 1924			1.73	480.045	

Figure 12. Differential Leveling Below DRH

The Total Mapping Station proved to be a highly valuable tool for mapping of the DRH region. The mapping provided accurate data that will be useful in furthering the entire project. Ideally, when the loop was closed on the traverse, it should have ended with the exact numbers that were set when the loop began. When fore sighting Point Twenty Six (the last point), back to Point One, an error was able to be obtained for the entire profile. The final errors were: Northing error = +0.01 feet, Easting error = -0.21 feet, and vertical error (z value) = -0.10 feet. Although there were slight errors from the original numbers it was impressively accurate for the approximately one mile traverse that had been completed. The height, or z value, was then corrected using the true elevation point that was taken to the dugout near the Jeffersonville Elementary School (Figure 13).

Corrected control survey, Jeffersonville landslide

Station	Corrected northing	Corrected easting	Elevation	Side shot from station #	Comments
1	1000.00	1000.00	620.57		stake set in field
2	1534.55	1265.49	616.30		point set
3	1554.34	1078.36	616.71	2	temporary wooden stake set in field
4	1345.58	940.85	619.03	2	point set
5	1615.05	881.29	610.46	2	point set or found?
6	1755.38	897.28	607.37	2	1/2 inch rebar found with aluminum tag 19
7	1942.63	930.76	606.13	2	1/2 inch rebar found with aluminum tag 13
8	2166.54	920.69	601.57		point set
9	2355.96	933.98	584.19		point set
10	2489.45	903.17	594.50		point set
11	2355.95	933.98	584.21	10	spike set in 10 inch hemlock
12	2642.42	894.82	596.22		point set
13	2651.89	921.06	595.74	12	chiseled square set on NW corner of concrete foundation
14	2847.02	884.66	585.29	12	chiseled "x" set near center of concrete foundation slab
15	2859.62	413.53	446.61		1/2 inch rebar set
16	2326.96	354.95	452.47		hub set
17	2888.13	381.50	446.79	15	spike set east side of tree
18	2261.23	463.27	450.41	16	1/2 inch rebar found "Peatman/LS 302"
19	2134.49	380.05	455.97		magnail set in northeast corner of pavement
20	1496.09	293.93	462.63		1/2 inch rebar set
21	2056.78	358.62	455.55	19	magnail set in southeast corner of pavement
22	1137.06	611.59	497.26		temporary wooden stake set in north side of woods road
TBM2	1509.86	211.44	463.41	20	westernmost bolt of center post of southern dugout
24	907.01	779.42	567.81		1/2 inch rebar set in north side of woods road
25	893.39	943.02	620.64		1/2 inch rebar set
26	861.53	938.66	620.26	25	spike set in north side of utility pole #183
1	1000.00	1000.00	620.57		Closing position of traverse back to Station 1

Figure 13. Data from DRH Survey

Analysis:

During the second collection of measurements of the slip face it was understood that the accuracy of this method was limited for certain bearings.

This is because certain bearings run nearly parallel to the slip face and the compass is not accurate enough to properly obtain these measurements (Figure14).

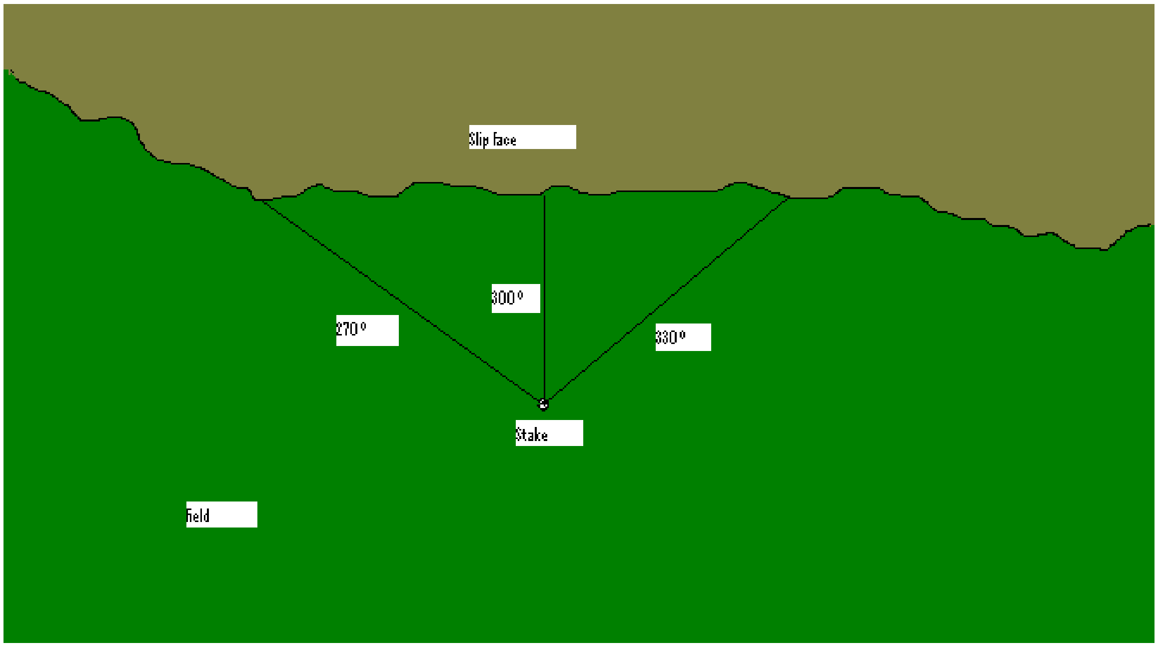

Figure 14. Possibility for Inaccuracies (note the 270° bearing if measured at 267° could produce a much larger measurement)

<u>Continued Work:</u>

Monitoring the tree transects below the Farara house depicted little alteration although this does not mean this site has been deemed inactive. What would be helpful to further the study is if tree transect markers were placed on the slope above the Jeffersonville Elementary School.

The monitoring of cutback along the slip face must be continued paying especially close attention to the stakes that have shown activity. Stake number 16 is currently very close to the edge of the slip face and should be relocated before it falls into the gully.

The planning of the four wells to be drilled in the field above the Jeffersonville Elementary School has already been accomplished. These wells must be drilled so that the Total Domain Reflectometer (TDR) can be used to measure movement deep beneath the ground. This is important because shifting in the land deep below the surface can be indicative of a large landslide.

To make the mapping of the area with the Total Mapping Station a success, it must be remapped after a given timeframe. This will provide insight to any slight shift in the land around the DRH area. This mapping should take place at least annually after the spring thaw if not more frequent.

Conclusions:

Superficial wasting of sediment near the slip face can be monitored by measuring the distance from the stakes to the slip face. However, it is not certain that the measurements will provide insight to any significant mass wasting event especially if taken irregularly. With wells dug and monitoring of land movement with a TDR a large-scale event could be more readily forecasted.

During the study a significant mass wasting event thankfully did not occur, although much was learned about the area through the use of modern technologies. From this it can be stated that many areas along the DRH slope have a landslide hazard. This has been established through past landslide history and active surface gullies that are changing regularly. Residents of the town of Jeffersonville should be on alert for any increased activity on the slope. When constructing buildings, especially schools, it is important to understand the potential hazards in the area. However, the landslide hazard was not accessed during the planning stage of the construction when landslides had already occurred on the ridge to the north.

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