Preliminary Field Report on the November 13th-14th 2011 landslide near Steam Mill Road, Deerfield, Massachusetts

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Prepared for: Carolyn Shores Ness, Town of Deerfield Board of Selectmen, Board of Public Health

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Landslide-derived sediments deposited in wetlands to the west of Route 5/10 in Wapping, town of Deerfield, Mass. (Photo by J. Kopera, November 21, 2011)

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Note: All maps presented in this report are for informational purposes only and should not be used as plans for construction or remediation. Such maps are inaccurate if enlarged beyond the presented scale in this report- all locations should be professionally surveyed before any work is undertaken.

Map and orthophoto datum is Universal Transverse Mercator 1983 (NSRS 2007), Mass State Plane Coordinate System (FIPS 2001).

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Introduction

On November 13th and 14th, 2011, residents and business owners in the area of Wapping Road in Deerfield, Massachusetts, began to notice light-gray, clay-rich mud appearing in the streams and wetlands east of State Route 5/10. The mud quickly clogged culverts under Wapping Road, Route 5/10, and the Pan Am Southern Railway tracks, partially filled in wetlands on both sides of Route 5/10, and partially filled in drainage ditches upgradient of these wetlands. This resulted in localized flooding of property along the east side of Route 5/10.

The source of the mud is an active landslide along a steeply-sided drainage located between Steam Mill Road and the Pan Am Southern Railroad tracks (Figure 1). The slope experienced a discreet failure event, presumably occurring immediately prior to or on November 13, that released mud into the adjacent stream. .

Moderate to heavy rain showers on Nov. 22-23rd continued to mobilize mud deposited in the stream channel and wetlands leading to repeated clogging of the culverts mentioned above. A second, brief, rain shower on November 29th also mobilized the deposited mud, however, with decreasing clogging and intensity of flooding. As of this writing, no new material has been released from the site of the landslide since approximately November 19th. Water flowing in the stream channel past the landslide remains clear to barely turbid. The site of the landslide is inherently unstable due to its geology and will likely continue to be active over the long term. However, it appears to be relatively stable for the immediate future pending any major precipitation or groundwater discharge events. While it is unknown when the slide will move again, it is almost certain that it will, possibly causing similar siltation of the stream channel, culverts, and wetlands.

General Geologic and Hydrogeologic Setting

General Geology

The landslide occurred in clay-rich, lake-bottom deposits of glacial Lake Hitchcock (Figures 2, 3; Jahns, 1966; Stone et al., 2010). The deposits form a 0.25 mile-wide flat-topped erosional terrace at the base of the Pocumtuck Range. This terrace extends south from Old Deerfield to Wapping on the eastern side of Route 5/10 (Figure 1). Its top surface is at approximately 250 feet elevation and steeply drops ~80 feet toward the west into the Deerfield River floodplain. Old lake-bottom terraces such as these are present throughout the Pocumtuck Valley and are deeply incised and gullied by small streams channels. From a geotechnical standpoint, these deposits have low shear strength and are subject to failure if slopes are oversteepened by erosion and soil moisture levels are high from extended periods of precipitation. The high soil moisture increases pore fluid pressure in the material

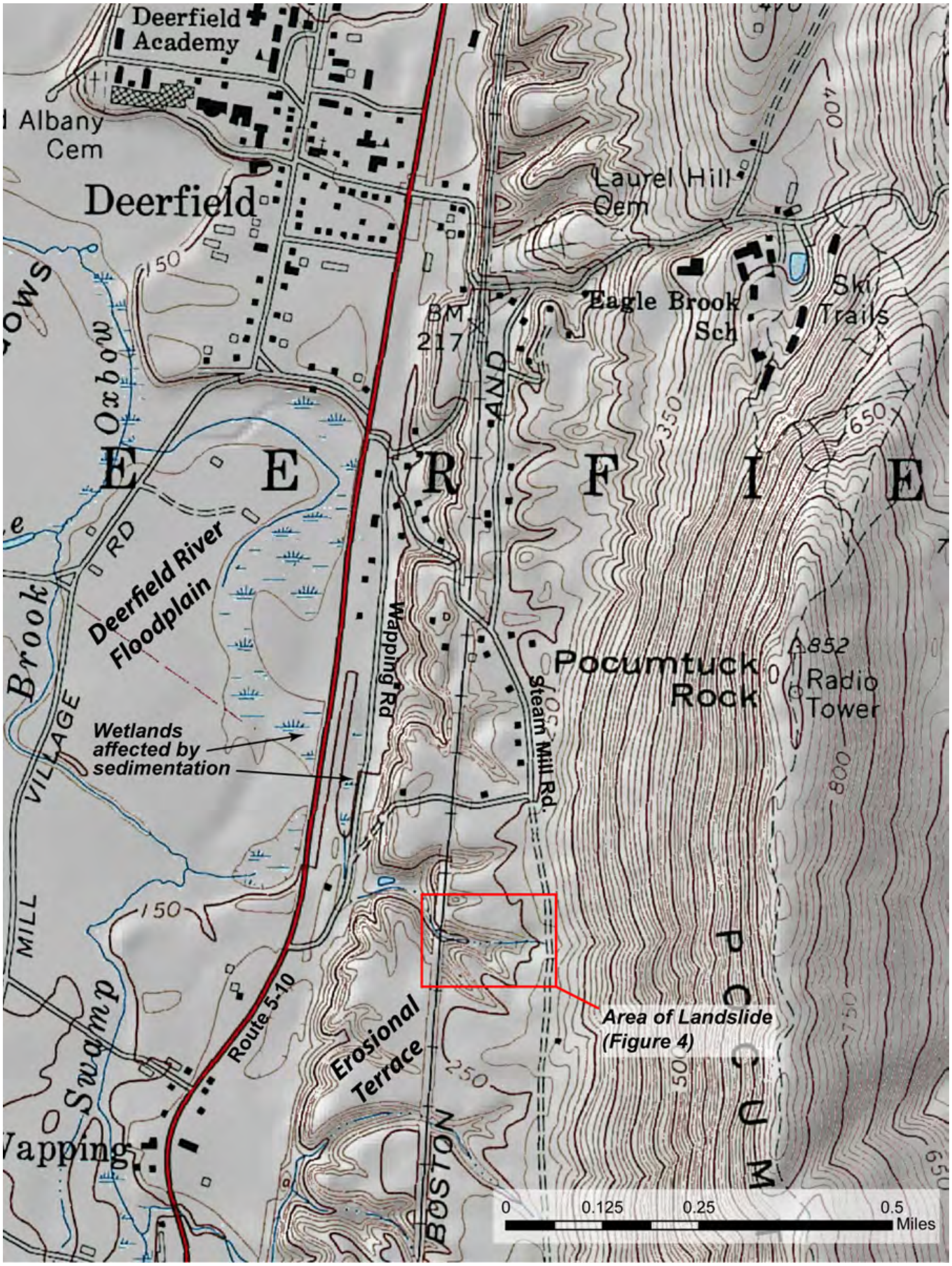

Figure 1 – Enlarged portion of Greenfield 7.5' topographic quadrangle (USGS, 1968) showing location of the landslide and features discussed in this report. Hillshading obtained from MassGIS (www.mass.gov/mgis).

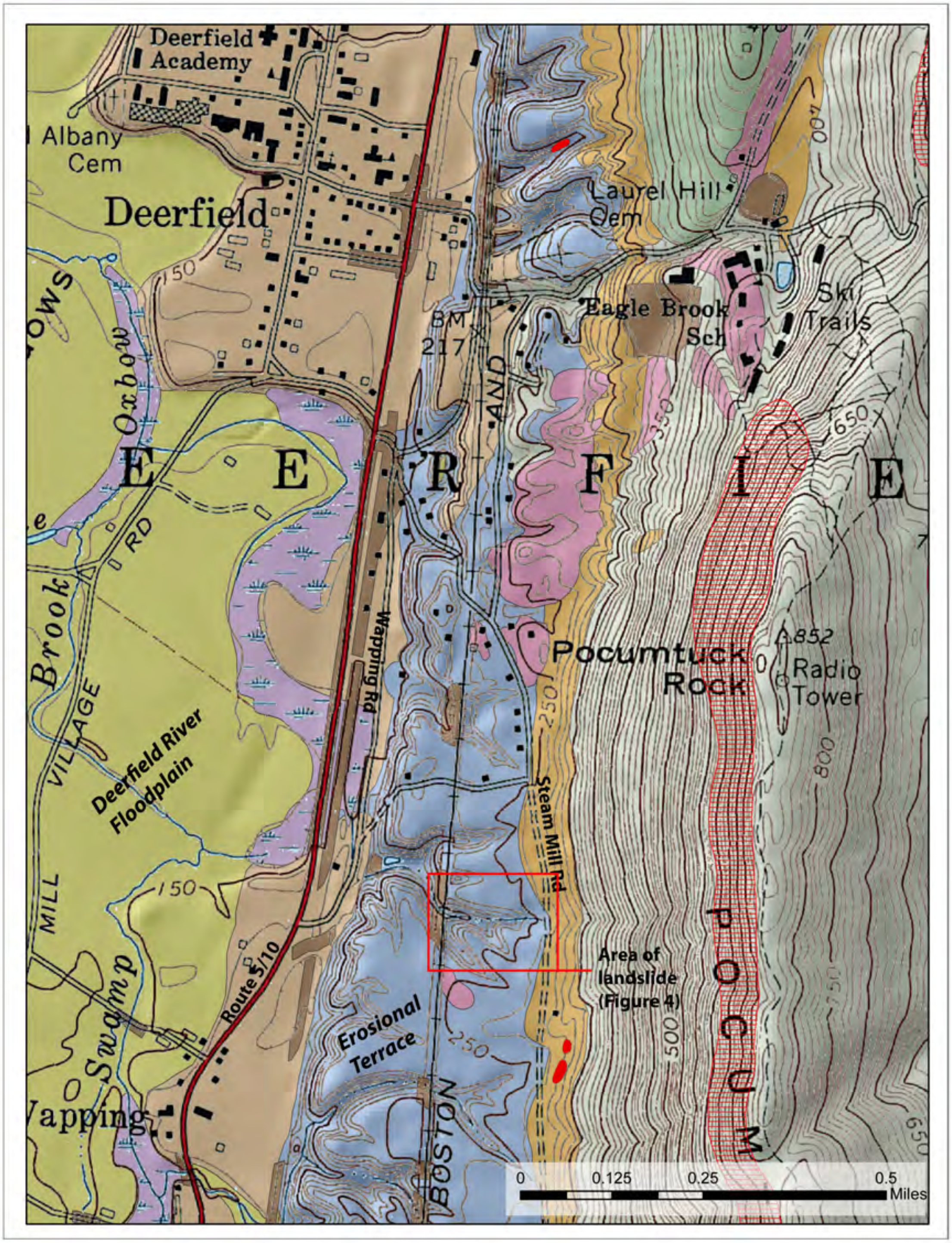

Figure 2A – Enlarged portion of Greenfield 7.5' topographic quadrangle (USGS, 1968) showing underlying surficial geology as mapped by Stone et al. (2010). Map legend is on next page. Hillshading obtained from MassGIS (www.mass.gov/mgis).

Figure 2B – Legend for Figure 2 describing surficial geologic units. The blue "clay and silt" comprise the erosional terrace referred to in the text.

comprising the slope, lowering its shear strength. It also increases the weight of the soil itself, increasing gravitational pull downslope. These soils are also sensitive to vibration and, if saturated, will tend to liquefy due to the high silt content. The lake-bottom sediments in the area probably rest directly on bedrock, and are inferred to be approximately 30-40 ft thick based on the location of a bedrock outcrop observed immediately east of the Pan Am Railway tracks near the slide.

Historical Landslides and Slope Erosion

Evidence of historical landslide activity, gully erosion, debris flows, and actively creeping slopes is common along the entire western edge of the terrace and along the deeply incised drainages therein (Figure 3, delineated at landslide site on Figure 4). Landslide scarps, now somewhat overgrown, debris flow scars, and curvilinear tree trunks all indicate that slopes in this area have been actively moving for a long time with repeated local slope failures.

Hydrogeology

Water flowing into the drainages and collecting in the wetlands at Wapping comes from two primary sources. During precipitation events, rainwater flows down the western slope of the Pocumtuck Ridge and collects in the drainages in regular to intermittently flowing streams. Precipitation also recharges groundwater which flows westward from the ridge through glacial sediments and discharges into the drainages as stream baseflow. The primary path for groundwater in the vicinity of the landslide is most likely along the top of the bedrock surface, underneath the clay-rich sediments. Such clay rich soil, as found at the landslide site, is relatively impermeable and drains poorly, however, the interface between the bedrock surface and clay provides a pathway, or channel, along which groundwater can flow toward the drainages.

Figure 3 (next page) – Evidence of previous landslides and actively moving slopes: A- Looking westward downstream at trees with curvilinear trunks on southern slope of drainage. Note curvilinear trunks of older trees upslope. B – Looking south from landslide site at old debris-flow scars on southern slope of drainage (locations denoted in Figure 4). White dashed lines delineate margins of flows. Arrows denote direction of past movement of material into stream channel. Photos taken by J. Kopera on November 21 and 27, 2011.


A
B

The Landslide

The landslide occurred on the north slope of the head of a small drainage cutting through the erosional terrace of lake-bottom clays (Figures 1, 2, 4). Historical (older than 30-50 years based on tree diameter) landslide and debris flow scars are abundant along the entire length of the drainage. Towards the bottom of the drainage, in the vicinity of an abandoned ice-pond dam, distinctive curvilinear tree trunks indicate incremental and continued downhill creep of the slope over time (Figure 3).

The slide is located approximately 150 feet west of Steam Mill Road along the southern edge of a hayfield between the road and the Pan Am Southern Railway (Figure 4). It is entirely within and is comprised of light gray lake-bottom silty clay (Figure 5). The topsoil at the site is made of the same material, having slightly higher silt content than the undisturbed silty clay beneath. The slide as a whole can be classified as an active rotational block slide with small debris flows present at the toe and along the western margin (Figure 6).

The area of the slope that is actively sliding is approximately 0.5 acres. It is defined on its north end by a ~400 ft long series of en-echelon open ground fissures and scarps exposed at the southern edge of a hayfield and just inside the woods at the current (post-landslide) break in slope. Individual fresh fissures are typically 50 feet or less in length, are 6 inches to a foot in width (Figures 4, 7). The ground on the southern sides of exposed scarps has dropped down between 4 inches to 3 feet with respect to the northern side (Figure 7). In several places trees have sunk vertically into ground fissures by several feet and are still standing upright (Figure 7).

A 4 ft-wide debris flow along the western margin of the slide area (Figure 8) was the probable point source for the bulk of clay and silty material that made its way downstream. The other primary source of material that was deposited into the stream is numerous seeps and minor slope failures along the base of the slide. Surface water enters newly-opened fissures, drops vertically and moves along the slip surface between the rotated block and underlying soil. As the water moves along the underside of the slide block silt and clay is removed from underneath the slide block through a process called "piping." The turbid water then emerges as a series of springs and seeps that eventually discharge to the main stream channel (Figure 9). Such seeps were still producing clay-rich water when observed on Nov 17th, but were producing clear water by November 19th. The seeps continued to produce clear water after the rainstorms on November 22-23rd and 29th.

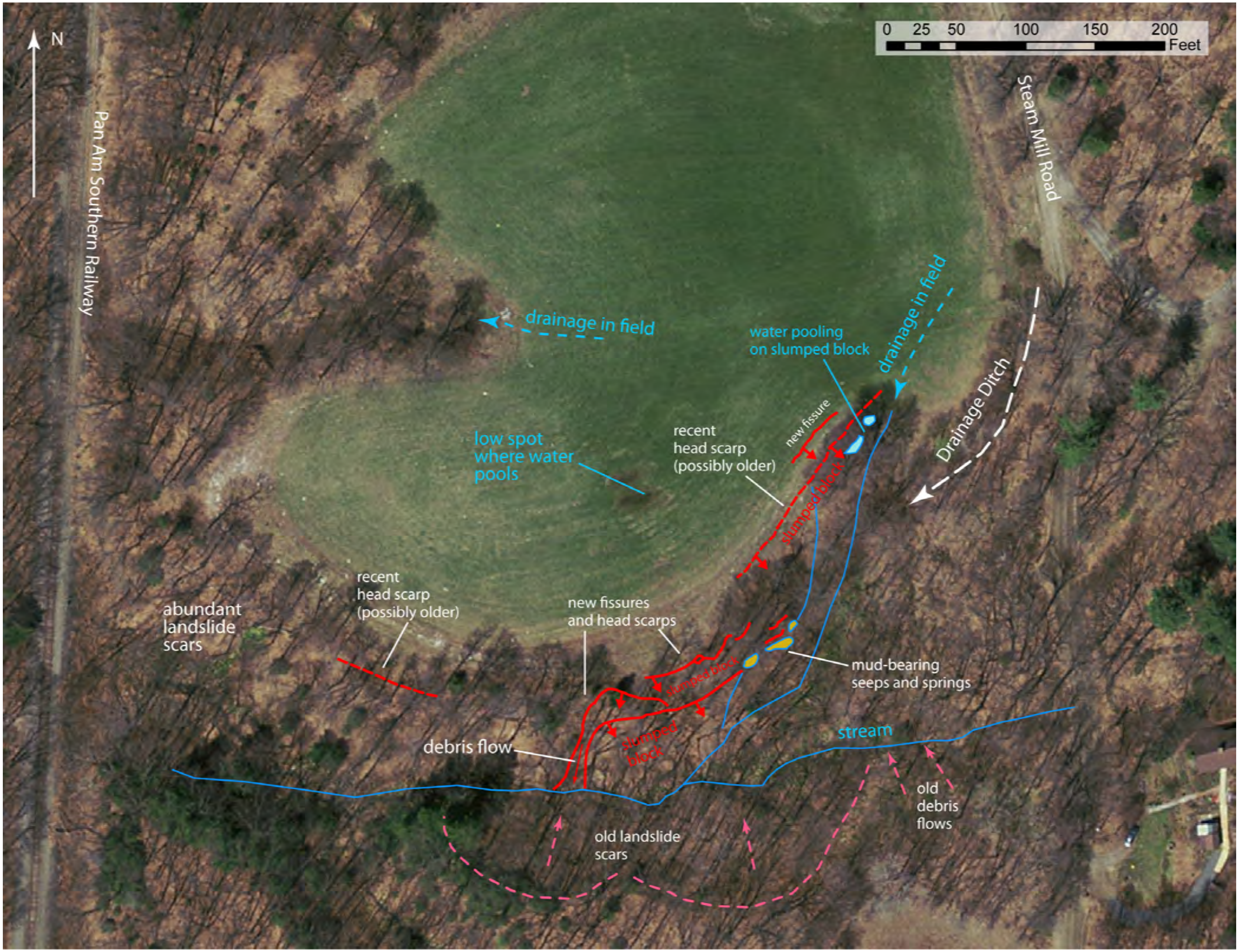

Figure 4A – Schematic map of landslide site from field reconnaissance by J. Kopera on November 21st and 23rd, 2011. Orthophoto base from MassGIS (2009).

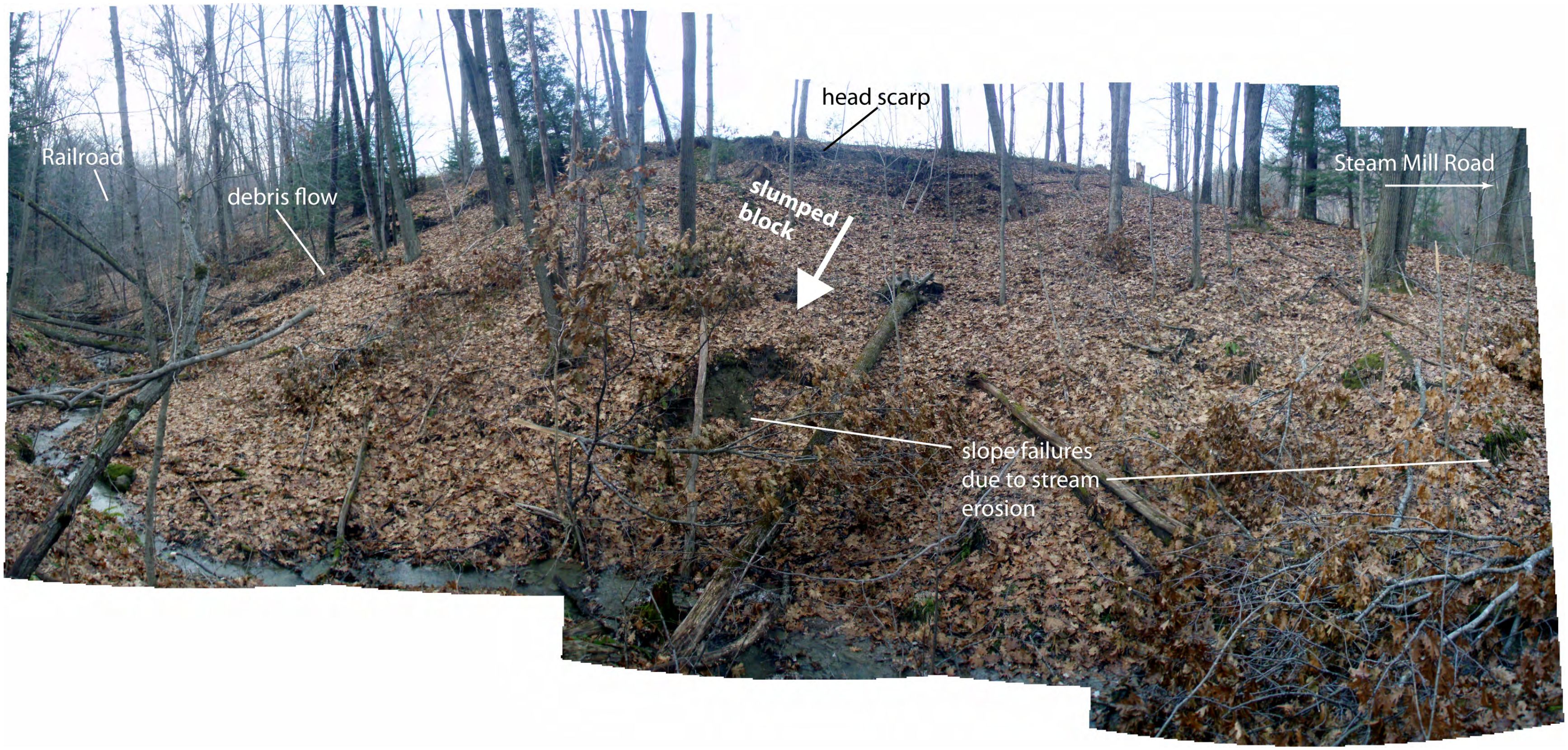

Figure 4B – Photo panorama of western portion of landslide site, looking north. Large arrow on slumped block shows approximate direction of movement downslope. Photo taken by J. Kopera on November 27, 2011.

Figure 5 – Disturbed clay-rich glacial lake bottom sediments exposed by landslide. Photo by J. Kopera, taken November 21, 2011.

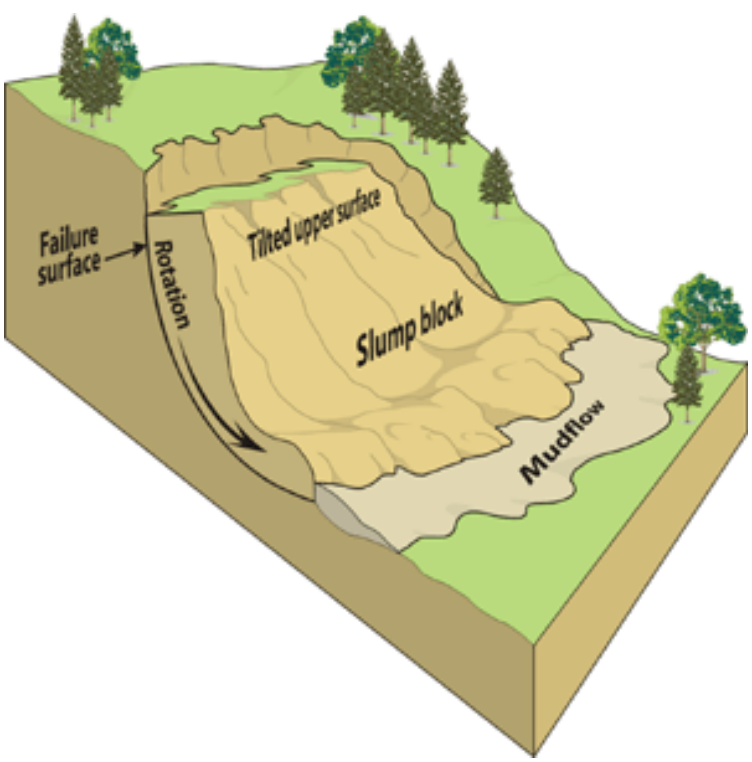

Figure 6 – Simplified schematic block diagram of a rotational block slide, similar to the one near Steam Mill Road.

Diagram obtained from http://geoscape.nrcan.gc.ca/calgary/topics/slope_e.php

Figure 7 – Examples of ground fissures and scarps at landslide site. A – Extensional ground fissure at top of landslide. Width is approximately 1 foot. B – En echelon array of ground fissures at top of slide. Orange fieldbook for scale is 7 x 4.5 inches. C – Ground fissure at top of eastern portion of slide in adjacent hay field. D – Headwall scarp of western portion of slide. Displacement is approximately 3 feet. Photos taken by J. Kopera, November 21 and 23rd, 2011.

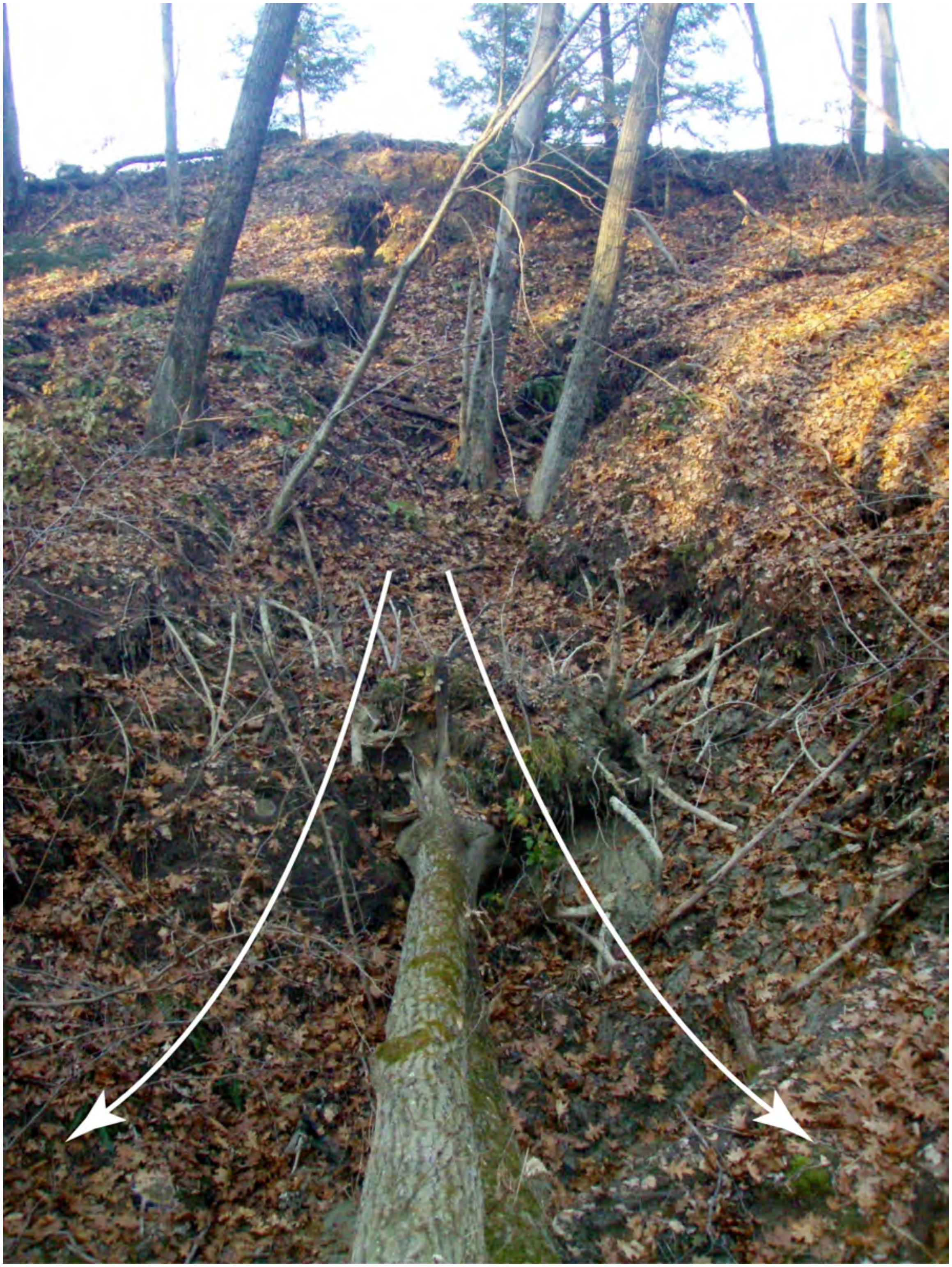

Figure 8 – Debris flow scar at the western edge of landslide area. Note down-dropped trees into gully left by flow. Arrows denote motion of movement of material into stream channel. Photo looking north and upslope towards hayfield. Photo taken by J. Kopera on November 21, 2011.

Figure 9 – Seeps and springs at the base of the landslide. A – Clay rich mud discharging from spring at base of eastern landslide block. The clay is transported from the base of the block by a process called "piping."

B – Series of mud-filled pools at east side of landslide (see Figure 4) fed by newly-formed springs at base of landslide. Photo looking south across drainage. Photos taken by J. Kopera on November 21, 2011.

Figure 10 – A- Enhanced streambank erosion at base of northern slope of drainage, and steepening of base of slope, due to recent high streamflow, presumably during hurricane Irene. Photo looking west, downstream. B- Small debris flow at base of slide caused by streambank erosion. Photo looking north. Photos taken by J. Kopera, November 21 and 23, 2010.

Estimation of the exact amount of material released into the watershed after November 13th is difficult due to the lack of detailed data on the configuration of the slope immediately prior to the landslide. Roughly 1500 to 3000 cubic feet (55 to 110 cubic yards) of material is estimated to have been removed from the slope via the debris-flow at the western flank of the slide. An unknown amount of material was also released from seeps and small failures at the base of the slide.

Probable Causes

Most landslides investigated by the Massachusetts Geological Survey in western Massachusetts have occurred during or directly after a major precipitation event. This landslide is unusual in that it occurred well after major events in the region.

A combination of abnormally high rainfall for much of 2011 has led to high water tables, high groundwater flows, and saturated soils throughout western Massachusetts. These conditions contribute significantly to the instability of steep clay-rich slopes in the following ways:

1) Increased water content raises the fluid pressure in the soil, which in turn reduces the shear strength, the main force that resists gravitational slope movement and holds the slope together.
2) The saturated soil conditions also adds extra weight to the soil which has the effect of increasing the forces that tend to drive the soil downslope,
3) High stream flow during Hurricane Irene led to substantial streambank erosion in the drainage where the landslide is located. Several small (2-3 feet high) slope and bank failures related to high stream flow can be found along the length the stream channel (Figure 10), especially along the base of the landslide. Removal of this material during extended precipitation events oversteepens the toe of these unstable slopes ultimately decreasing the forces needed to resist sliding. These factors conspire to cause the slope to slide. These landslides tend to be slow moving events that continue to move as long as wet conditions persist.

The October 30 snowstorm was, most likely, the triggering event for this landslide given the pre-existing conditions discussed above. High stream flow from this event possibly caused further erosion of the base of the slope. Several windfallen trees, also towards the base of the slope, most likely contributed to further destabilization by removing the stabilizing network of tree roots from the soil. It is possible that delayed pulses of high groundwater flow from Irene and the snowstorm reached the landslide site in the weeks prior to November 13. Such pulses, combined with the above conditions, could also have been the triggering mechanism for the slide.

Future Risk

The landslide is still considered active over the long term by the authors. During field investigation the length and width of ground fissures and displacement along scarps increased incrementally over the span of approximately 1 week: evidence that the slope is still moving and settling. Pending any major precipitation events, the possibility of further discharge of mud and material from the slide itself in the immediate future (weeks to months) is low.

Over the long term (months to years), however, the slide will most likely continue to release material into the watershed during discrete events that may be related to storms and high streamflow. Newly opened ground fissures at the top of the slide allow for increased infiltration of water into and under the slide. Freeze-thaw during the early and late winter may continue to open such fissures, increasing infiltration of water into and under the slide. Both can contribute to further destabilization of the slope.

Steep-sided drainages within the glacial lake terrace (Figures 1 and 2) and the western slope of the terrace itself have a moderate to high probability of landslide recurrence over the long term. Evidence of numerous past landslides along the entire slope, the steepness of the slopes due to natural processes and, locally, quarrying (Jahns, 1966), and the poorly-drained, clay-rich materials that make up the terrace contribute to this probability. The probability for landslides along the entire erosional terrace, described above, is especially high during wet years such as 2011 where frequent extreme precipitation events are coupled with already saturated soils. While we cannot predict precisely when or where a landslide may happen next, the probability in future years is expected to increase as New England is projected to experience warmer, wetter winters with earlier ice-out dates and frequent extreme precipitation events (Hayhoe et al., 2006).

Recommendations

The primary ongoing problems posed by the landslide near Steam Mill Road are clogging of culverts east of and under Route 5/10 and loss of floodwater storage due to the partial filling of the wetlands by clay and silt.

The following are some general recommendations that may help in reducing the probability and detrimental effects of further slope movement at the landslide near Steam Mill Road:

- Intercept and convey any surface water away from the top of the terrace through lined swales and drain pipes. Do not allow concentrated flow to enter slope area.
- Do not allow surface water to pond at the top of the terrace.

- Consider placing tarps or otherwise covering and stabilizing exposed lake bottom sediments to prevent direct contact of precipitation with exposed soil.
- Stabilize and armor the toe of the slope to reduce undercutting and oversteepening during high rainfall events.
- Consider replacing existing culverts with much larger ones that can accommodate high streamflows while being partially clogged with silt.
- Consider redesigning former ice pond as a sedimentation basin with flashboard weir and filter berm to capture silt and mud and allow it to settle out before it reaches the wetlands in Wapping. This, however, will require ongoing maintenance to remove silt as it accumulates.

Cited References

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