NEW YORK STATE
DEPARTMENT OF TRANSPORTATION

SCOBY HILL LANDSLIDE REPORT

SCOBY HILL LANDSLIDE
ROUTE 219, SECTION V
SPRINGVILLE, NEW YORK

PREPARED BY
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NYSDOT

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INTRODUCTION

The Route 219 (Section V) project involves construction of a 4-mile segment of expressway on new alignment, from Peters Road to Route 39. This report describes:

- The geotechnical investigation for the initial design
- The ground movement during initial construction
- The geotechnical investigation and analysis of the landslide
- The horizontal drain test program
- Analysis of mitigation options
- The selected mitigation option
- The permanent instrumentation monitoring program

GEOTECHNICAL INVESTIGATION FOR THE INITIAL DESIGN

The geotechnical investigation for this project followed the Department's standard practice used for large earthwork projects, which is a terrain reconnaissance followed by subsurface explorations. This effort by the Department's geotechnical staff included the review of air photos, the analysis of digital terrain models, and a review of soil boring logs. It also included a review and analysis of test results performed on soil samples obtained from those borings, i.e., standard penetration tests, moisture content determination, and soil visualization. The subsurface investigations for design followed standard protocols as to their depth. Borings for the cut sections were taken to five feet below the proposed soil cut depth, and borings for the fill sections were made to a depth approximately twice the height of the proposed embankment. In addition, because the presence of high groundwater was anticipated, borings were taken more frequently than standard procedures dictate and water observation wells were drilled to define the groundwater condition more accurately.

Borings were taken more frequently than standard procedures would dictate, however, and additional borings needed to better define this condition. The subsurface explorations did not indicate unusually poor soil conditions.

The existing valley sides have gentle slopes, approximately 8º in angle from the bluff at the top of the slope down to the edge of Cattaraugus Creek. The soil borings and tests revealed clayey soils typical of the Buffalo area. These soils, while not of high strength, do stand on slopes as steep as 15º and are stable. Therefore, the Department geotechnical experts concluded that standard earthwork design and construction procedures would apply. Ponds and springs were also evident, and the contract plans included measures to address the expected surface sloughing and seepage typically encountered in this area as a result of these conditions.

CONSTRUCTION AND GROUND MOVEMENT

The new alignment traverses a side-hill portion of the Cattaraugus Creek valley. **Figure 1** shows a plan view of the proposed alignment. During construction of the new Route 219 expressway south of Springville, a partial embankment was placed north of Scoby Hill Road up to a height of 6 m (20 ft) by the beginning of June 2007. During the embankment construction, a landslide was triggered and cracks developed in the east side of the embankment fill. Seepage was evident near the areas of the largest cracks, and with no sign of other movement farther down the slope, it was initially believed that the movement was shallow, local, and due to excessive water in the soil. In an attempt to drain this water and arrest the movement, drainage trenches were cut on the east side of the proposed highway and filled with stone. While these trenches drained significant amounts of water, the movement continued. The Department then installed instruments to determine the depth of the movement. The first of these slope inclinometers to be installed were too shallow to locate the plane of movement. It wasn't until additional inclinometers were installed to much greater depths that the failure plane was detected approximately 30 m (100 feet) below the ground surface.

Ground movement surface survey monitoring was initiated on June 22, 2007. Embankment placement north of Scoby Hill Road was suspended on June 23, 2007 due to the progressive ground movements. Placement of fill continued south of Scoby Hill Road until similar cracks were discovered in that area on August 6, 2007.

A significant portion of the fill material was removed in October 2007. The net effect of unloading was a reduction in the rate of slide movement, particularly in the middle of the new highway corridor. East cut slopes made during early summer 2007 experienced cracking and slumping, particularly within the soft to medium-stiff, clayey, silt soils that make up the majority of the soil profile in this area. These soils continue to move.

The landslide at present is approximately 1,000 m (3,300 ft) wide measured parallel with the highway alignment and 400 m (1,300 ft) long measured perpendicular to alignment.

GEOTECHNICAL INVESTIGATION OF THE LANDSLIDE

Once the extent of the ground movement was realized, and due to the scope and breadth of this landslide, the Department consulted with geotechnical experts from the Federal Highway Administration (FHWA) and also hired a specialty consultant, Landslide Technology, Inc. to provide assistance. The Department also immediately assembled a landslide mitigation work team, which met weekly. The team, composed of project, Regional Design and Construction staff, and Main Office staff worked to identify and resolve project issues related to the landslide.

Additional geotechnical drilling and more extensive surface surveys were initiated (see **Figure 2**) to quantify slide movements and geometry. Instruments to measure subsurface movement and ground water pressure were installed across the slide area to detect the depth and magnitudes of landslide shear displacement and the levels of groundwater. The movement instruments (slope inclinometers) verified that basal landslide movement was deep, approximately 30 m (100 ft) below the original ground surface in the construction area. The water pressure instruments (piezometers and standpipe observation wells) indicated high groundwater levels, typically within two meters (six feet) of the ground surface.

The slide area is located within unusually complicated, multi-glacial-era soil deposits. Letters from the State Geologist in October and December 2007 prompted by this event reinforced the fact that this geologic condition is very unusual for New York and revealed that the details of the deposit were not known even to their office. In the letters, they requested the assistance of the Department in gathering additional data on the nature of these unusually old soils. These soil deposits include an overconsolidated layer of hard gray clayey silt, 30 m (100 ft) thick, with scattered gravel and outwash soils on the surface. This layer is underlain by stiff, silty clay, which has been remolded in the basal shear zone. Numerous springs and ponds exist throughout the site, which are probably related to groundwater discharging from the upper glacial outwash deposit and from the underlying clayey, silt layer.

The failure plane, located in the basal shear zone, was not detectable through ordinary subsurface explorations. The subsurface exploration borings taken for design purposes did not reach this layer, and would not have detected the unusual nature of this layer even if they had. The soils at the failure plane were similar in appearance and moisture content to the other soils in the area. The basal shear zone only revealed itself through ground movement, and its location was determined by using slope inclinometers installed after the cracks appeared on the grade. This basal shear zone is possibly the result of an ancient landslide, which disturbed and remolded the soil at this great depth.

Special soil tests (ring shear tests) were performed to determine a range of residual shear strengths in the upper slide mass and at the basal shear zone. The results showed that the remolded shear strength of the upper clayey silt soil had an internal strength of 26°, which is a typical value for the Buffalo-area clays. However, the remolded strength of the silty clay in the shear zone was only 12° to 14°. These unexpectedly low values are significantly lower than shear strengths of the Buffalo and Lockport clays previously tested by the Department and prevalent in the area.

LANDSLIDE ANALYSIS

Detailed analyses were then performed using these new data to evaluate the existing stability and to back-calculate residual soil shear strength. Analysis of the current slide indicates that the area was marginally unstable prior to construction. The slide area is composed of a series of separate failure surfaces. **Figure 3** shows an oblique view of these surfaces. **Figure 4** depicts a cross-sectional view.

The shifting of earth loads during the 2007 construction season (initial embankment placement and subsequent removal of this fill) over different areas of the slide has demonstrated the delicate balance that currently exists at this site. Any change to the geometry, including changes that normally would increase slope stability, can result in movement in other locations. This system complexity made designing a solution especially difficult. The addition of fill material in this area is likely to cause movement, and even the removal of earth at certain locations can worsen the slide.

The complexity of the conditions causing the landslide and its large size make finding a reasonable balance between stability and economy key to choosing the best mitigation plan for this site. Portions of the area are still creeping, and it is still possible for the landslide to enlarge beyond existing observed cracks (retrogress uphill).

HORIZONTAL DRAIN TEST PROGRAM

The landslide analysis indicates that high water pressures in the deep soils contribute to the ground movement. Installing deep horizontal subsurface drainage pipes, drilled into the soils on the slopes of the slide, can sometimes intercept zones of permeable layers in the slide shear zones and slide mass to draw the water levels down. This treatment is a common one, and in the right soil conditions, can significantly improve stability at relatively low cost. Therefore, the Department agreed that the cost of a test program to investigate the possible effectiveness of horizontal drains was worthwhile.

A horizontal drain test program was conducted in November and December 2007 to determine installation feasibility and whether reduction of groundwater pressure could be achieved. The test program consisted of 19 horizontal drains installed in November and December 2007. The test demonstrated that horizontal drains could be installed with moderate difficulty. Over 90 percent of the installed horizontal drains have produced discharge water. Flow rates are low, but consistent with horizontal drain experience in clayey soils. As of April 2008, most of the original construction drains are still discharging water. Several of the piezometers appear to have responded to the horizontal drains. One piezometer showed a drawdown of 3.1 m (more than 10 ft) as of the end of March 2008. A reduction in the rate of slide movement was observed in December 2007, which corresponds with the results from the horizontal drain test program.

ANALYSIS OF MITIGATION OPTIONS

The general, commonly used landslide mitigation options are:

- **"Build As Designed" Approach –** Construct the highway as originally designed. This option has little to no chance of success. In the Scoby Hill situation, this construction would destabilize existing conditions, resulting in large slide movements and possible slide retrogression uphill. Assuming that the roadway could survive construction, it would be anticipated that significant and frequent repair would be necessary. This option would likely have a low initial cost with minor right-of-way (ROW) and substantial environmental impacts.
- **Avoidance Approach -** Considers abandoning or relocating the facility, or selecting a method to cross the landslide without touching it. Crossing a landslide could consist of a

bridge or a tunnel, but such options become extremely expensive and technically challenging for larger landslides.

- **Full Stabilization –** Mitigation designed to produce a high degree of stability for an entire landslide area, both on and off the ROW, primarily through earthwork that reduces forces driving the slide. This option typically has a very high cost and substantial ROW and environmental impacts.
- **Selective Stabilization –** Mitigation designed to produce a high degree of stability for a highway alignment, primarily through ground modification, while the remainder of the slide (off the ROW) continues to have marginal stability. This option typically has high cost but possibly reduced ROW and environmental impacts.
- **Balanced Approach-** Implement a combination of stabilization methods designed to reduce landslide movements, thereby improving safety to the facility and its users. Under this approach, further ground movements may occur, with the possible need for ongoing maintenance and repair. This option typically has a moderate cost with minor ROW and environmental impacts.

The selection of an appropriate mitigation option is based on an assessment of the probability of continued soil movement, overall uncertainty, possible consequences, constructability, contractor capabilities, environmental impacts, and costs. Other factors that should be considered in the selection of the chosen mitigation option include the effect on the current construction schedule, future impacts to this proposed corridor, and the need to acquire additional property for certain geotechnical options, which might require re-assessment of environmental and real estate impacts.

The specific mitigation options for this location were reviewed to determine those that appeared most geotechnically effective. A total of 20 options were considered. Four options were selected for further evaluation. All four options required the removal of the original fill placed by the contractor and eliminating the bridges over Scoby Hill Road, due to potential for structure distress.

In analyzing the four options, the Department consulted with the Associated General Contractors and the Deep Foundations Institute to include the expertise of their members in assessing the problem and determining the most feasible solutions. The Department had conversations and a meeting with some of their specialty contractor members. The Department used this input to refine its recommendations. See **Figure 5** for a cross-sectional view of each option.

The four options considered in detail were:

- **Toe Buttress Option** – This full stabilization option combines construction of large earth fills at the bottom of the slide (far off the ROW) with shear keys and/or stone columns to provide a buttress for the upper slide mass. The highway could experience some subsidence until the upper slide stabilizes. This option could have major environmental impact due to significant tree removal from slope and filling of wetlands above the Cattaraugus Creek. The approximate cost of construction would be about $35 to $40 million, not including ROW acquisition.

This full stabilization option was dismissed earlier by the Department because, although the construction cost would be moderate compared to other alternatives, it would cause significant impact to downslope private property with associated environmental and acquisition issues.

- **Stone Column Option** – This selective stabilization option employs deep stone columns within the ROW for shear strength improvement and control of excess pore pressures. This option would stabilize the upper slide, with the downslope area remaining marginally unstable. This option would be very difficult to construct and would require two construction seasons to complete. Specialty contractors agreed that this solution was at or beyond the limits of the technology and expertise available in this country. The approximate cost is about $65 to $80 million.

  This option would provide a high level of stabilization in the ROW, but the drawbacks appeared insurmountable (high cost, extreme construction difficulty, and construction delays).

- **Full Unloading Option** – This selective stabilization option lowers the highway below the original gradeline and cuts deeply into the bluff to reduce the weight on the slide headscarp, which is driving the movement. This option would stabilize the upper slide area, but provide little to no improvement of the downslope area. In addition, horizontal drains would be used to lower ground water under the highway corridor. ROW would have to be acquired east of the highway corridor, probably affecting some existing structures. This option has an approximate cost of about $35 to 45 million, not including ROW acquisition, and a substantial delay to the project.

  This option would provide the most significant reduction of slide movement of all the alternates. However, its drawbacks include significant acquisition of property, moderate construction difficulty to control groundwater during deep excavations, moderate cost, and project delay.

- **Balanced Approach Option** – This option constructs the highway at or below original ground to minimize fill placement on the landslide (landslide unloading). Drainage systems (horizontal drains and trench drains) would be included to lower subsurface water pressures. The combination of placing minimal fill and groundwater drainage is expected to avoid exacerbating slide conditions. This option also includes strengthening the subgrade using crushed stone reinforced with geotextile to minimize future cracking. This option would reduce, but not completely eliminate, slide movement. Most of the work area required for this option is contained within the existing highway corridor. Environmental and property impacts would be low to moderate. Roadway maintenance or reconstruction would be required periodically. This option has the lowest initial cost and the least impact on the project schedule.

The prime construction contractor has the necessary skills, experience, and equipment to construct the Balanced Approach and Full Unloading Options, which primarily consist of earthwork and drainage mitigation methods. A specialized subcontract driller would be needed for installing the horizontal drains. A specialty ground-improvement subcontractor would be needed for installation of stone columns for the Toe Buttress and Stone Column Ground Improvement options.

The option of Fully Unloading the upper slide zone both inside and outside of the ROW, using the Contractor's proven earthmoving expertise, offered an acceptable level of stability and was initially recommended by the Geotechnical Engineering Bureau as the best geotechnical solution. However, this option generates a large amount of waste soil, requires substantial ROW takings, requires re-evaluation of the Environmental Impact Statement, is significantly more expensive, and would considerably delay the project, thereby adding cost. This option, therefore, was rejected by the Department.

SELECTED MITIGATION OPTION

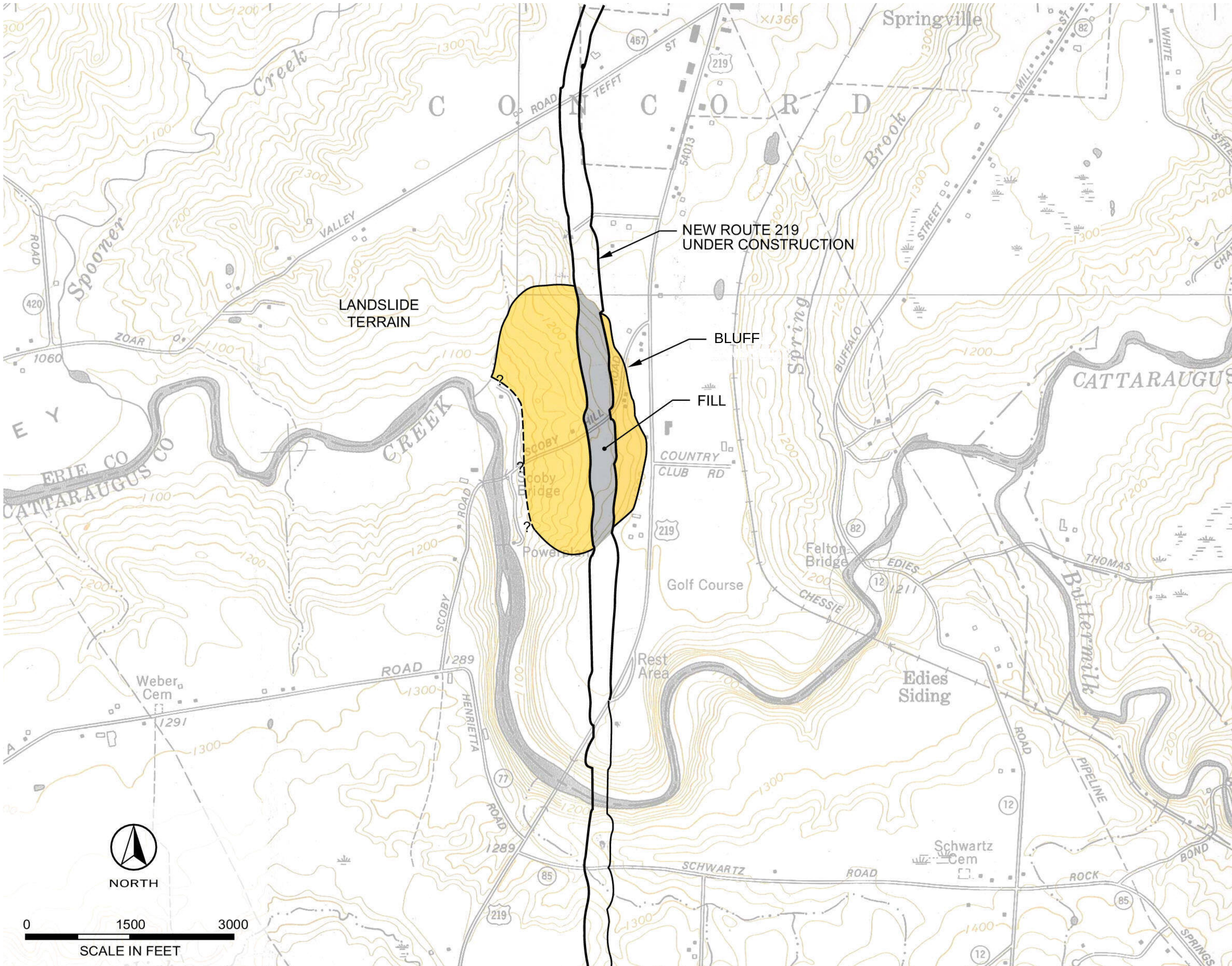
After discussions with the many stakeholders, the Department selected the **Balanced Approach Option** because it provides the means to cross the landslide area using practical construction methods at a reasonable cost and within the construction schedule, while providing some measures to reduce landslide movements.

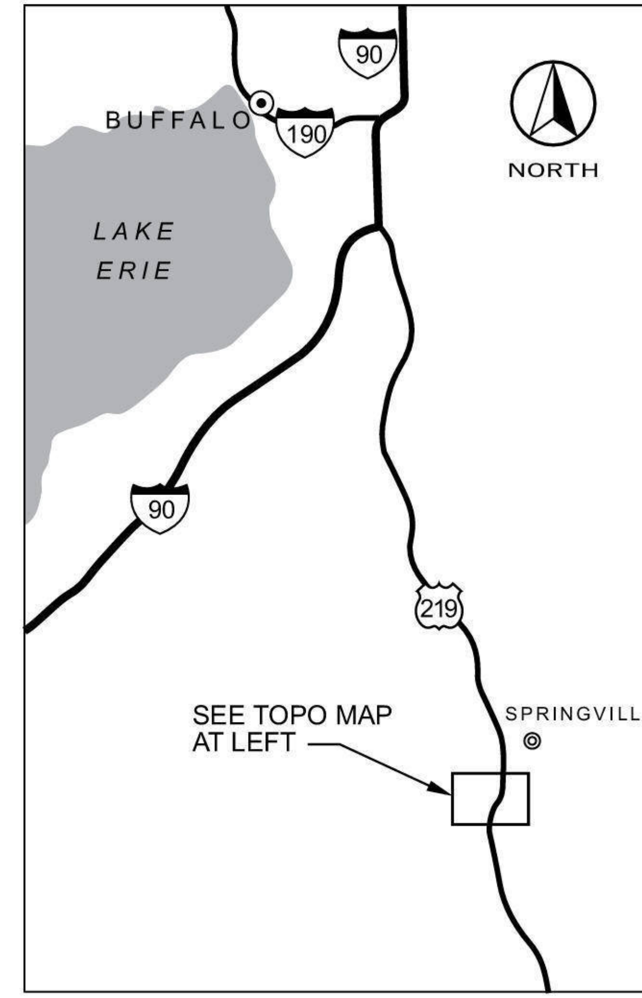
The probability of some continued gradual soil movement is relatively high, but no sudden movement is expected. Pavement cracking and irregular subsidence are anticipated to continue over the long term, but the degree of roadway distress should be manageable and repairable, resulting in a safe and serviceable highway. The use of horizontal drains is recommended for reducing these expected movements. Accessory components to help mitigate movements further include cut slope protection, trench drains, tensile-reinforced culverts, and pavement subgrade reinforcement. The cost to construct the lowered roadways plus the projected cost of potential repairs are considered to be substantially less than the life-cycle costs of the other mitigation options considered. The combined lower first cost and ongoing maintenance associated with the balanced approach will be less expensive than the other alternatives.

Environmental and private property impacts would be moderate since horizontal drains would be installed just to the west of the highway corridor, and would only require a small amount of space for protection of subsurface drain pipes and small discharge areas. The current construction contractor has the necessary skills, experience, and equipment to construct the Balanced Approach Option because it primarily consists of earthwork and drainage. The majority of work necessary under this option will be completed this year, with project completion scheduled for 2010. Highway drainage pipes will need to be designed to tolerate earth movements, and such systems will need periodic inspection.

PERMANENT INSTRUMENTATION MONITORING PROGRAM

An expanded instrumentation system will be developed to measure slide movements and groundwater levels accurately during construction and over the life of the highway. This system also will help the Department anticipate construction and long-term needs better and will provide early warning of any significant changes.



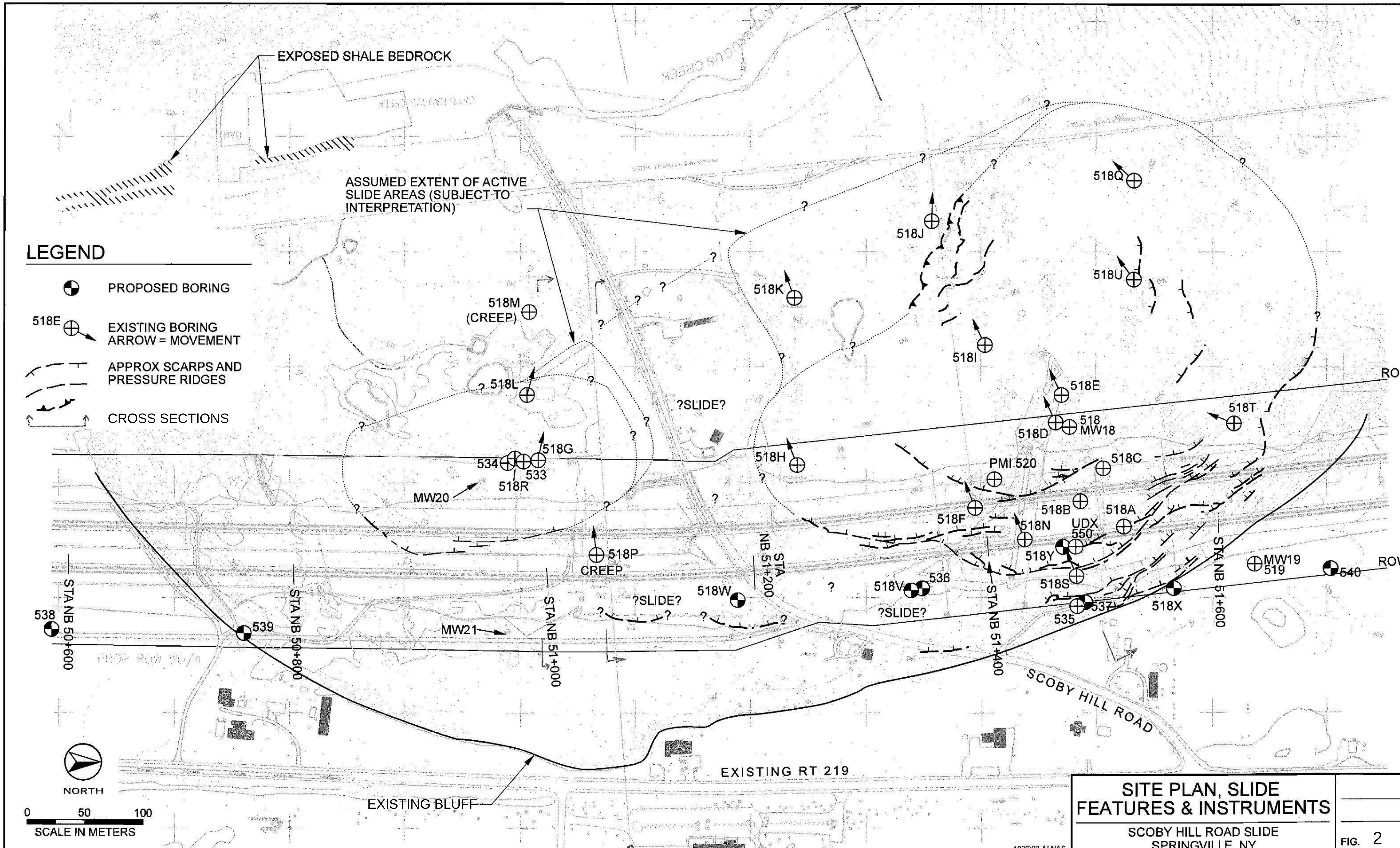


VICINITY MAP

VICINITY MAP
AND TOPO MAP

SCOBY HILL ROAD SLIDE
SPRINGVILLE, NY

FIG. 1

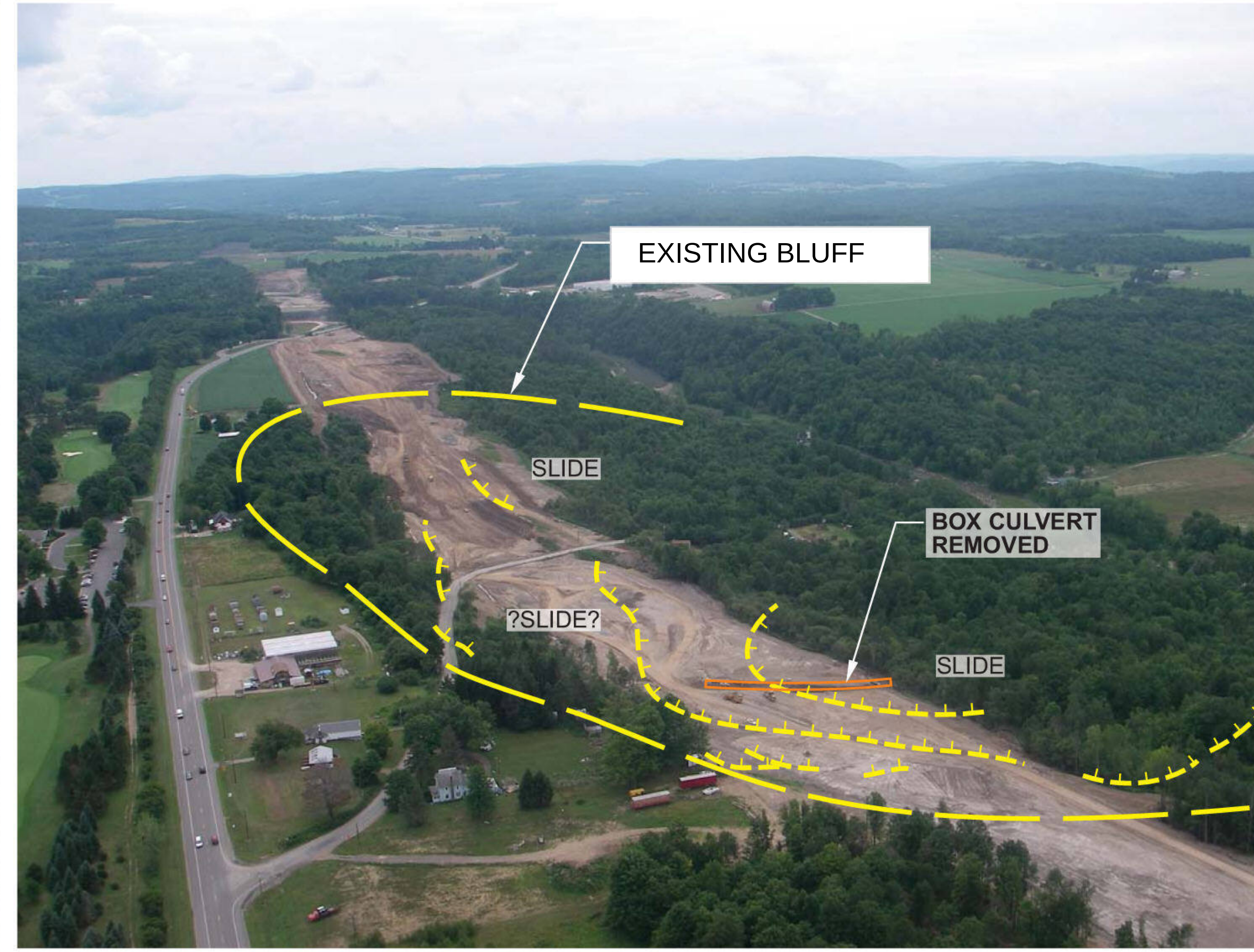


SITE PLAN, SLIDE FEATURES & INSTRUMENTS

SCOBY HILL ROAD SLIDE
SPRINGVILLE, NY

FIG. 2

EXISTING BLUFF LIMITS (LOOKING NORTH EAST)



ACTIVE SCARP CRACKS (LOOKING SOUTH)

OBLIQUE AIR PHOTO IMAGES	
SCOBY HILL ROAD SLIDE SPRINGVILLE, NY	FIG. 3

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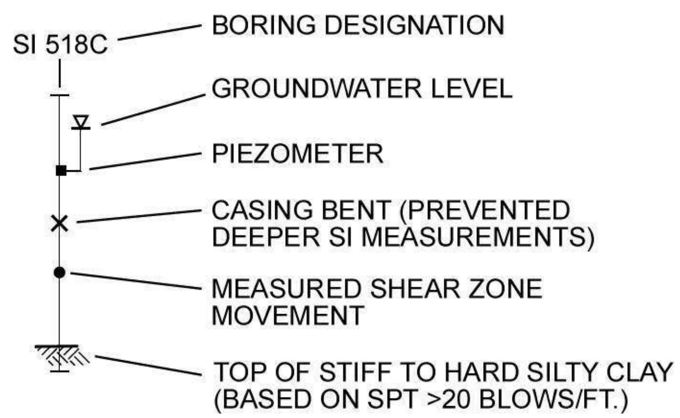
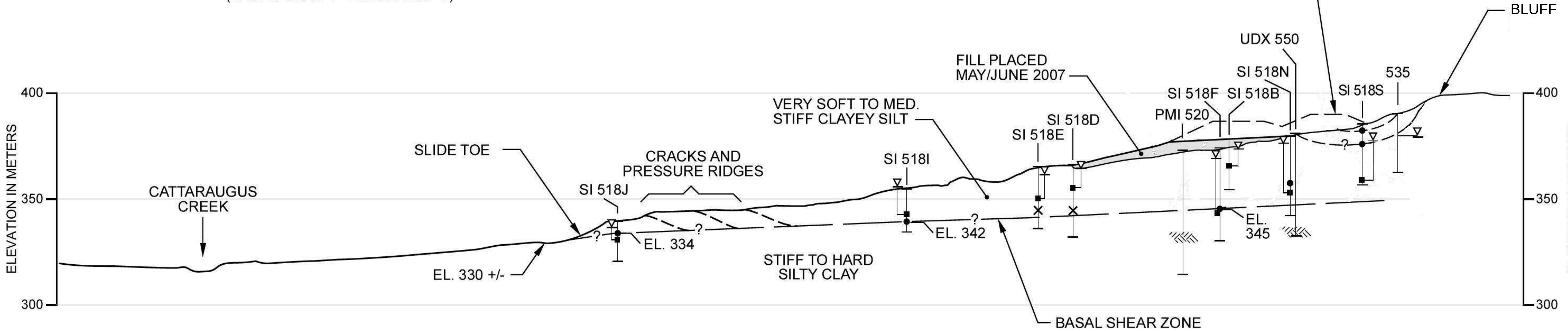
LEGEND





NOTES:

BORINGS ARE PROJECTED ON CROSS SECTION

SEE SITE PLAN, FIGURE 2 FOR ORIENTATION OF CROSS SECTION.

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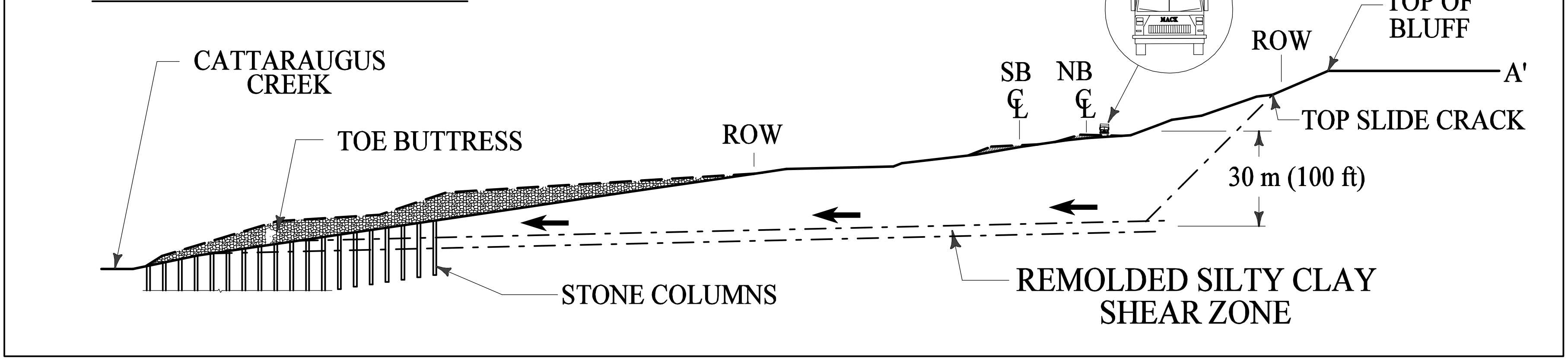
INTERPRETED GEOLOGIC SECTION, NORTH SLIDE AREA

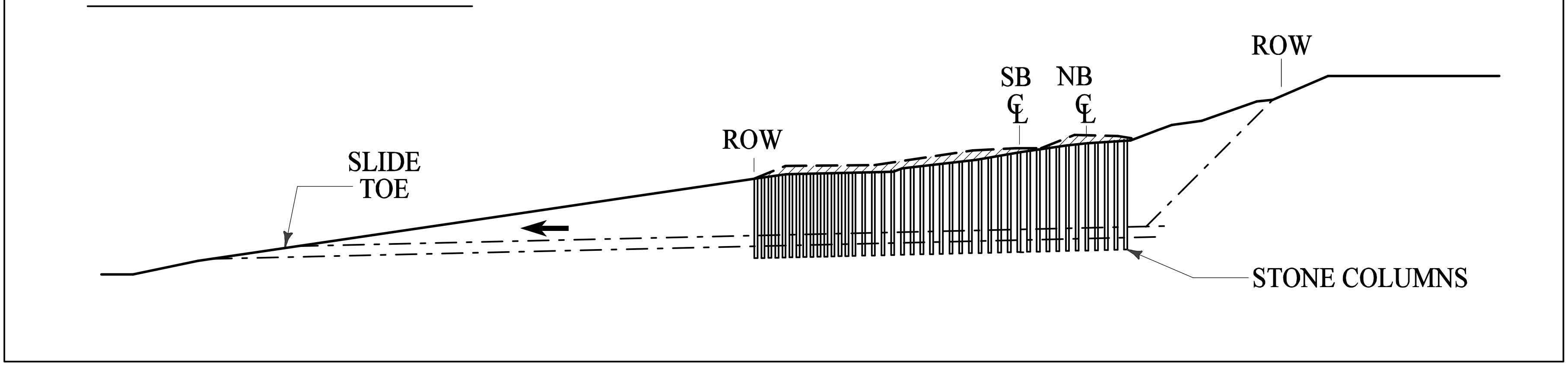
SCOBY HILL ROAD SLIDE
SPRINGVILLE, NY

FIG. 4

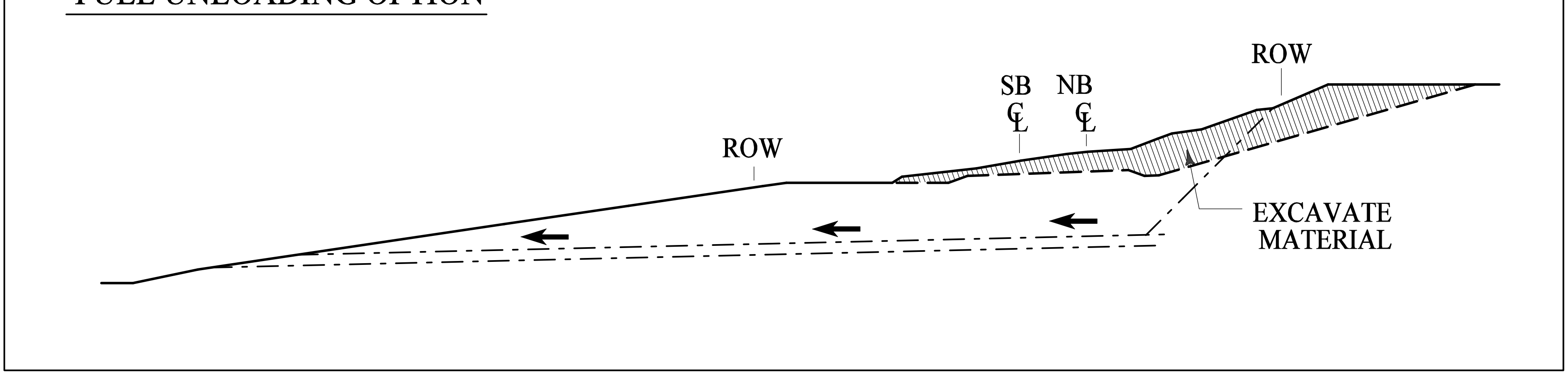
TOE BUTTRESS OPTION



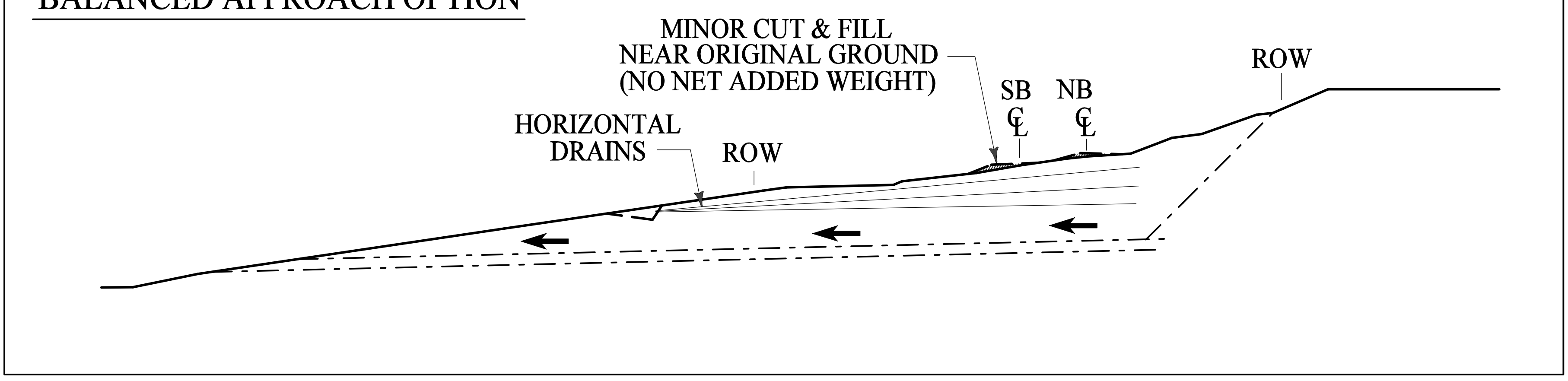
STONE COLUMN OPTION



FULL UNLOADING OPTION



BALANCED APPROACH OPTION



OPTION FIGURES	MAY 14, 2008
	FIG. 5
SCOBY HILL ROAD SLIDE SPRINGVILLE, NY	NOT TO SCALE