# SELECTED PROBLEMS OF ENVIRONMENTAL GEOLOGY IN CHAUTAUQUA COUNTY, NEW YORK

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## LAKE ERIE SHORELINE EROSION

The problems of shoreline erosion in the Lake Erie basin as well as the other Great Lakes have received wide publicity during the past two years. As Table 1 indicates, the highest monthly averages of levels of Lake Erie on record were observed during 1973 (9 months) and 1972 (3 months). These record-high lake levels have a significant effect on the intensity of wave erosion and are probably the primary cause of the extensive erosion which has been observed during the last 2 years. At the time this paper is being written (June, 1974) the Chairman of Chautauqua County Civil Defense Unit is attempting to have the lake shore area of Chautauqua County declared a national disaster area. He suggests that there is a potential of $14 million damage to private property by lakeshore erosion.

Although the problem of erosion along the shoreline is very complex, several important variables can be demonstrated by the simple model indicated in Figure 1. Note that at times of normal lake levels, the water at the shoreline is in contact with bedrock which has a very low erosion rate under normal circumstances. The lake bottom area over which the wave energy is dissipated (indicated by X in Fig. 1.) is very large. This condition produces a stable beach and wave erosion is not a serious short-term problem. In contrast to this, however, a high-water lake level will result in much more rapid erosion. In many places along the Lake Erie shore in Chautauqua County, the water level is presently very close to the top of the bedrock and is in contact with till in many others. As the lake level reaches this till-bedrock contact, and the waves can attack the unconsolidated till, the rate of erosion increases very rapidly. The wave action is now directed at the steepest portion of the shore zone and the lake bottom area over which wave action is dissipated reaches its lowest value (indicated by Y in Fig. 1). These factors combine to produce intensified erosion in the most easily-eroded materials exposed along the shoreline.

However, this is not the whole story. Figure 2 illustrates an additional factor which must be considered when trying to understand the increased rate of erosion along the shore. Notice in Figure 2 that the undisturbed (stillwater) level indicates that water will be in contact with bedrock and therefore result in low rates of erosion. This may be true for a given shore area even if the stillwater level is at a record high. However, short-term

TABLE 1. Summary of Average and Extreme Level of Lake Erie at Cleveland, Ohio. (Modified from data published by U. S. Department of Commerce NOAA - National Ocean Survey, Lake Survey Center, Detroit, Michigan.)

| Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTHLY AVERAGE FOR PERIOD 1860 THRU 1970 | | | | | | | | | | | |
| 569.85 | 569.81 | 570.02 | 570.56 | 570.90 | 571.05 | 571.01 | 570.83 | 570.54 | 570.21 | 569.95 | 569.88 |
| MONTHLY AVERAGE FOR PERIOD 1900 THRU 1970 | | | | | | | | | | | |
| 569.61 | 569.58 | 569.80 | 570.37 | 570.70 | 570.84 | 570.80 | 570.61 | 570.32 | 570.00 | 569.72 | 569.64 |
| MONTHLY AVERAGE FOR PERIOD 1960 THRU 1970 | | | | | | | | | | | |
| 569.61 | 569.73 | 569.97 | 570.46 | 570.78 | 570.87 | 570.83 | 570.68 | 570.39 | 569.99 | 569.78 | 569.78 |
| HIGHEST MONTHLY AVERAGE (1860-1973) WITH YEAR | | | | | | | | | | | |
| 573.39 (1973) | 572.53 (1973) | 572.88 (1973) | 573.50 (1973) | 573.25 (1973) | 573.51 (1973) | 573.34 (1973) | 573.03 (1973) | 572.51 (1973) | 571.95 (1972) | 572.17 (1972) | 572.35 (1972) |
| LOWEST MONTHLY AVERAGE (1860-1973) WITH YEAR | | | | | | | | | | | |
| 567.62 (1935) | 567.49 (1936) | 567.65 (1934) | 568.20 (1934) | 568.43 (1934) | 568.46 (1934) | 568.46 (1934) | 568.36 (1934) | 568.23 (1934) | 557.95 (1934) | 557.60 (1934) | 557.53 (1934) |

INTERNATIONAL GREAT LAKES DATUM (1955)

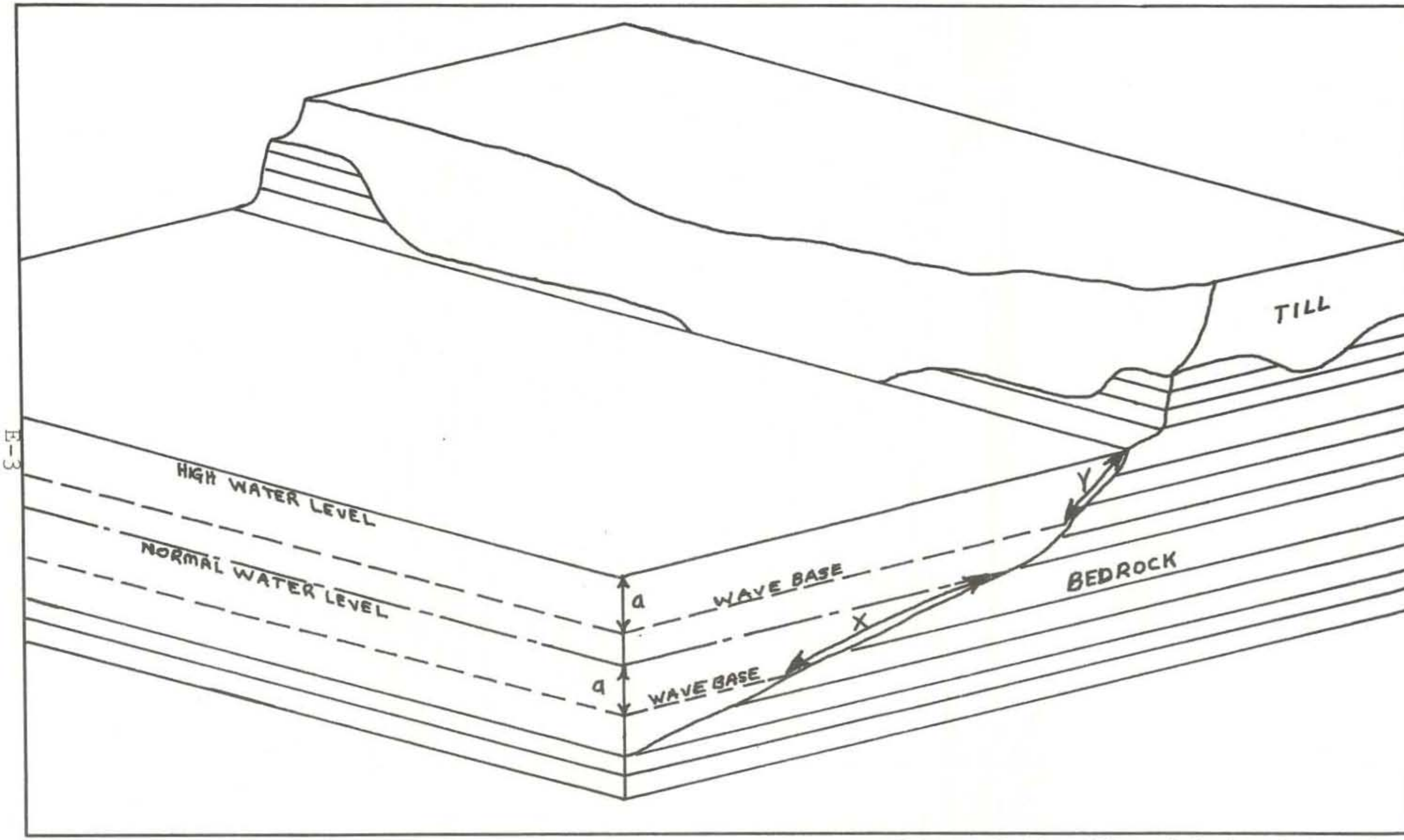


Figure 1. This diagram illustrates a hypothetical lake shoreline. Both till and bedrock are in contact with the water. Both normal and high water lake levels are illustrated. The effective wave depth is the same in both cases and indicated by the letter a. The area over which the wave energy is dissipated at the normal lake level is indicated at x while the area at the high water level is indicated at y.

meteorological activity such as rapid barometric changes and storms may cause strong, prevailing winds to develop in the lake basin. This will result in a phenomenon called setups which causes the water to pile up on one side of the lake and the surface of the water to tilt in the basin. This is known as the storm setup. The amount of setup observed at any time varies with such factors as the intensity of the storm, the length of fetch associated with the prevailing winds, the bottom topography and the depth of water. The maximum setup values for Lake Erie are not constant, but they generally range from about 1.5 feet near Cleveland, Ohio to nearly 6 ft. at Buffalo. (Corps of Engineers, 1973).

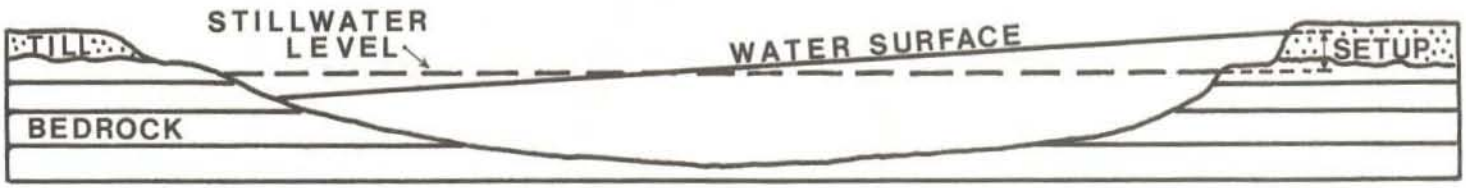


Figure 2. This diagram illustrates the tilted water surface that develops during prolonged prevailing wind conditions. The increase in the elevation of the water surface on the windward shore is called the setup. Note that in this case the stillwater surface is in contact with bedrock while the setup surface is in contact with the much more easily eroded till.

With record-high water levels, a storm which results in the maximum setup for a given area is generally accompanied by large waves with amplitudes greater than 5 ft. These large waves, in combination with the high water levels, can result in extremely rapid shoreline erosion.

When the lake water levels are at the maximum, as we presently observe them, the higher intensity waves erode the sand on the beach and carry these sediments offshore. The beaches are narrowed by both the encroachment of the water and the removal of the sand to the offshore beach area. When the lake levels return to normal, this sand should be pushed back onto the beach by the lower energy waves.

FLY ASH AND BOTTOM ASH DISPOSAL

One of the major problems facing all municipalities today is the disposal of solid wastes and cities in Chautauqua County are not exceptions. However, there is an additional problem here. Two bituminous coal-fired electric generation plants located in the county produce substantial quantities of ash which add considerably to the total solid waste tonnage that requires disposal.

According to a study by Havens and Emerson (1971), the total solid wastes produced in Chautauqua County during 1970 exclusive of ash amounted to 189,900 tons. The total ash produced during the same year was approximately 163,000 tons, or 46 percent of the total solid wastes produced in the county.

The principle ash source is the Niagara Mohawk electrical generation plant located in Dunkirk, New York. This is a 600 megawatt installation which is fired by bituminous coal. The total ash which is being produced at the present time is significantly greater than the figures quoted above for 1970. In 1973, new and more efficient electrostatic precipitators were installed on all the stacks at this plant. While this resulted in a very desirable and commendable improvement in the air quality, it also greatly increased the amount of fly ash that was trapped by the precipitators. Presently the plant burns 4000 tons of coal daily and produces 250 tons of bottom ash and 550 tons of fly ash (Leo O'Sullivan, Plant Superintendent, Dunkirk, NY, personal communication. During the spring of 1974, Niagara Mohawk announced plans to construct within 15 miles of Dunkirk, NY an additional 1700 megawatt generating plant also to be fired by bituminous coal. It is clear that the problem of the disposal of these wastes will increase as this new plant begins operation in 1979 or 1980.

In order to assess the current trench-and-fill method of ash disposal, the present landfill site was visited during the spring and early summer of 1974. Samples of water were taken from several locations on the site itself as well as from an adjacent abandoned disposal area. The stream which drains both areas was sampled approximately 1,000 ft. downstream from the landfill. We were interested in determining the concentration of several ions which were expected to be high in leachate derived from the fly ash deposits. Low concentrations of these ions would suggest that the leachate was being contained on-site, whereas high values downstream would indicate that this method of ash disposal was not successful in containing the leachate on-site. We were also interested in comparing the relative quality of the water from the present operation with that of the abandoned area located adjacent to the present site. Finally, all of these measurements were compared to data taken from Canadaway Creek which was the nearest stream that could be used as a control. All these data are summarized in Table 2.

The data demonstrate that the artificial pond (Location 1, Fig. 3) constructed in 1973 has significantly lower values of iron and manganese than Canadaway Creek. The conductivity of the water in the pond is almost twice as great as the creek but this may be related to the fact that the pond is primarily recharged by

TABLE 2. Conductivity and Ion Concentrations From Fly Ash and Bottom Ash Disposal Sites

| Location | Conductivity mhos | Mn g/L | Fe g/L | Cd g/L |
|---|---|---|---|---|
| Location 1: Artificial Pond Surface Sample West End | 615 | 18 | 70 | 22 |
| Location 2: Leachate from former landfill operation | 3514 | 7300 | 96600 | 32 |
| Location 3: Ponded Leachate adjacent to Fredonia Airport runway | 602 | 2600 | 3100 | 35 |
| Location 4: Surface water downstream from former landfill | 1216 | Not determined | Not determined | Not determined |
| Canadaway Creek: averages for entire drainage basin June 13, 1973 | 287 | 91 | 660 | Not determined |

Unpublished data from W. M. Barnard and R. A. Levey with permission

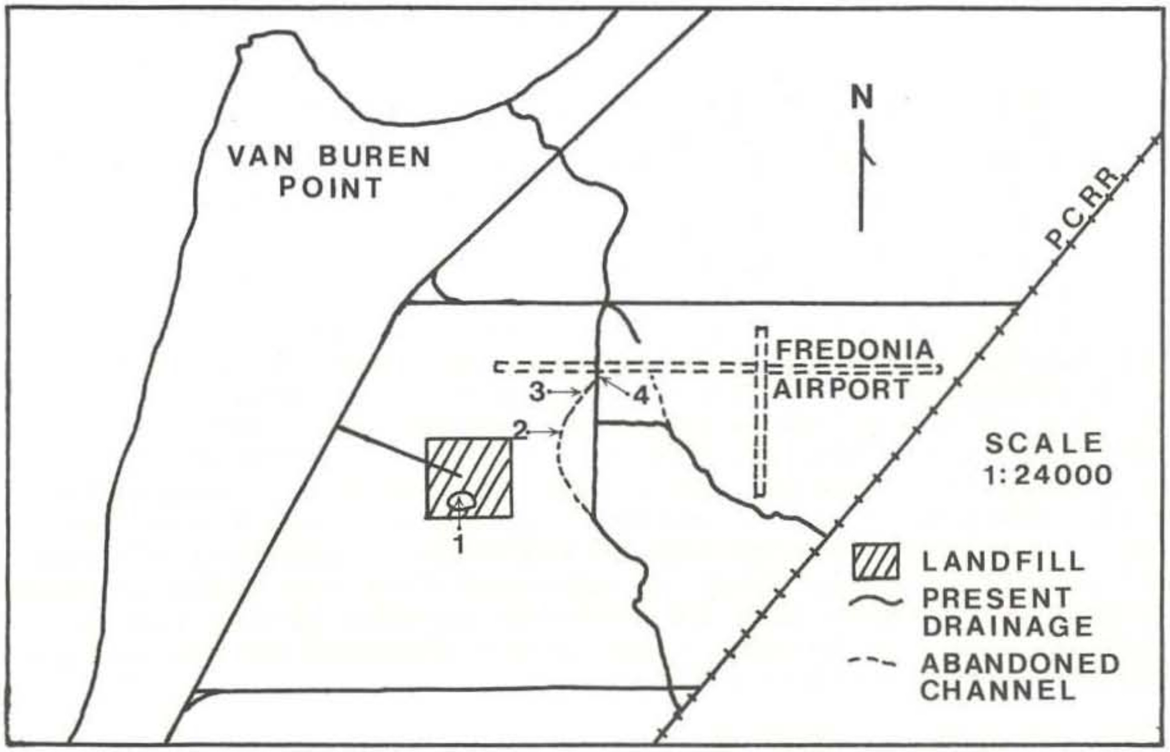


Figure 3. Map showing the location of the numbered sample sites listed in Table 2. Base map is USGS Brocton 7½' quadrangle.

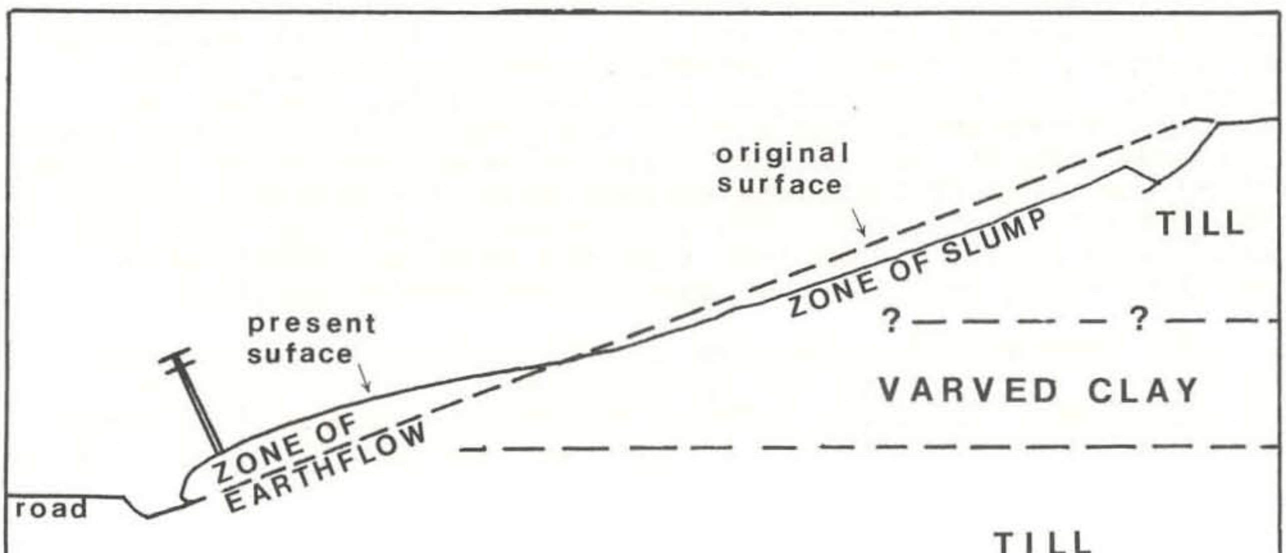


Figure 4. Morphology of the landslides along Route 60 near Laona, NY. The diagram indicates the relative position of the zone of slumping and the zone of earthflow. The generalized glacial stratigraphy is indicated at the right.

groundwater which typically has higher ion concentrations than surface water. From this information it appears that for the relatively short period of the pond's existence, the disposal methods currently being employed at this site are controlling the concentrations of ions in the groundwater moving away from the site. However, the leachate which was taken from the abandoned site (Location 2) represents a completely different situation. In the water drainage from this site, there is approximately 300 times the concentration of iron and over 100 times the concentration of manganese as is found in the pond. The increased concentration of these ions represents the partial solution of the improperly-buried fly ash and the lack of containment of this leachate within the disposal site. The intermediate conductivity reading at Locations 3 and 4 (Table 2) which are downstream from Locations 1 and 2 are interpreted to represent a physical mixture of normal runoff with the leachate produced from the older disposal site. Continued efforts must be directed towards proper burial of the ash so that the present area is not degraded to the level now observed at the abandoned site.

## LANDSLIDES AND BADLAND EROSION

The section of NY highway 60 which is affected by landslides was completed in 1958. The cut, which is approximately 0.3 mile long, was excavated through a series of glacial deposits which include a varved proglacial lake deposit which is both underlain and overlain by till (see Fig. 3). The material removed from the excavation was incorporated into a large fill which spans the valley immediately south of the cut. Before the fill was brought up to grade, considerable instability was experienced in this material. As a consequence of this instability, the fill was partially re-excavated and some of the proglacial lake clays and till were brought back to the north and deposited on the hillside behind the crest of the ridge on each side of the road. Within the road cut itself, the sides were graded to an even slope and seeded with grass. Since that time the area has served as an excellent model for both mass wasting and erosion studies.

The generalized morphology of a typical slide can be seen in Figure 4. Typically, two different areas can be distinguished on each slide. The upper portion behaves like a classical slump. The material moves downslope along a well-defined plane of dislocation.

The moving mass remains coherent for the most part and often displays the characteristic backwards rotation of slumps. During the spring rains, small ponds of water are often formed in these low areas contributing to the continued wetting of the downslope material. Over a period of 5 years scarps as much as 15 feet in height have been produced.

The lower portion of the slide behaves as a non-coherent, flowing mass typical of an earthflow. The first movement generally occurs at, or very near, the lower till-varved clay contact. The lower edge of the flow is marked by sod rolls which extend across the entire front of the portion of the hill undergoing mass movement. The flows move at rates which have been measured between 2 and 10 ft. per year. Most of the movement occurs as a more-or-less continuous event during the spring thaw.

The next transfer of material downslope is more rapid in the upper portions of the earthflow-slump. This movement results in a bulge of the surface of the ground wherein the surface is actually raised above the original elevation (see Fig. 3). Most of the flow of the soil material occurs below the rooted grass. Initially, the grass cover may not be disturbed as the flow begins. However, as the movement progresses, the sod is stretched and discontinuous bare patches of soil appears in the grass. As the amount of soil material is added to this area by flow from upslope and the bulging reaches a maximum, prominent areas of bare soil appear on the entire upper surface of the flow.

During May, 1970, a flow on the southwestern side of the roadcut moved downslope to the point that it reached a utility pole near the base of the hill. The earthflow initially flowed around the pole, but within two days the pole began to tilt outward towards the highway. The utility lines were relocated along the top of the hill where they are seen today. The State Highway Department became concerned that the flow would block off their drainage ditch at the roadside so they began an active program to remove the toe of the slide. This oversteepened the slope again and increased the potential for greater upslope activity. This readjustment is still continuing at the present time.

At the top of the cut on either side of the road good exposures exist of the excavated material that was "redeposited" by the contractor after it began to fail in the valley fill. These deposits are composed principally of till. But the significance of this location lies in the nature and extent of the soil erosion in this area that can be observed in the redeposited materials at this spot. The area represents a true badlands-type of topography that is primarily the result of construction activity. Grasses have failed to grow in this oversteepened area and erosion is very extensive.

The sediment which is being removed from this area is flowing into a tributary which eventually flows into the Fredonia water supply reservoir. This is obviously a problem area that offers good examples of man's interaction with environmental geology.

REFERENCES CITED

Corps of Engineers, 1973, Help yourself; a discussion of the critical erosion problems on the Great Lakes and alternative methods of shore protection: Department of the Army, Corps of Engineers, North Central Division, Chicago, Illinois.

Havens and Emmerson, 1971, Solid wastes in Chautauqua County; a comprehensive planning study: Havens and Emmerson, Consulting Engineers, Cleveland, Ohio.

TRIP E - ENVIRONMENTAL GEOLOGY OF THE FREDONIA-DUNKIRK AREA

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| Total Miles | Miles from last point | Route description |
|---|---|---|
| 0.0 | 0.0 | Leave the Fredonia campus at the Temple Street exit. Turn right (NW) onto Temple Street. |
| 0.3 | 0.3 | Intersection with Brigham Road; turn right (N). |
| 0.8 | 0.5 | New York State Thruway overpass. Route travels over lake bottom sediments of glacial Lake Warren. |
| 1.5 | 0.7 | Entering the city of Dunkirk. |
| 2.7 | 1.2 | Junction with Lake Shore Drive West (Route 5). Turn left (W). At this point on the north side of the road the Niagara Mohawk electrical generation plant can be observed. Power is produced by burning bituminous coal. The problems related to the disposal of the fly ash and bottom ash produced here will be discussed at STOP 3 of this trip. |
| 4.0 | 1.3 | Cross Canadaway Creek bridge. |
| 5.8 | 1.8 | Enter the parking area of the South Shore Motor Lodge. Walk north 150 yards to the lake shore. |

STOP 1. Lake Shore Erosion Problems (Brocton, NY, 7½' quad.): This area allows a comparison of the extent of erosion between areas which have sea walls with those areas without any erosion control. In one unprotected zone over 10 feet of embankment has been eroded away during the past 20 months. One house which will be visited is seriously threatened by the active erosion which has been intensified by the high lake stages.

Return to the bus.

| Total Miles | Miles from last point | Route description |
| --- | --- | --- |
| 5.9 | 0.1 | Return to Route 5. Turn right (W) and proceed towards Van Buren Point. |
| 7.8 | 1.9 | Bear right onto Van Buren Bay Road at gas station. |
| 8.0 | 0.2 | Bear left at junction. |
| 8.1 | 0.1 | Junction with Van Buren Point private road. Turn right. |
| 8.4 | 0.3 | Intersection with Park Street. Turn right. |
| 8.6 | 0.2 | Pull well off road onto right shoulder in front of flood control wall. |
| | | STOP 2. Flood control structure and shoreline erosion problem (Brocton, NY 7½' quad): The project you are examining was completed in the Spring of 1973 by the Corps of Engineers as a flood control measure to prevent the flooding of the low lying areas near the cottages along this portion of the beach. To the North of the wall, the elevation of the land is sufficient not to justify flood control. However this area is not protected from wave activity and rapid erosion is now taking place in that area. |
| | | Return to the bus. Turn around and return along Park Street. |
| 8.8 | 0.2 | Intersection with Central Street. Turn left. |
| 9.1 | 0.3 | Junction with Van Buren Bay Road. Turn right. |
| 9.2 | 0.1 | Intersection with Route 5. Turn right (W). |
| 9.6 | 0.4 | Junction with unnamed dirt road. Turn left. |

| Total Miles | Miles from last point | Route description |
| --- | --- | --- |
| 9.7 | 0.1 | Park in pull-off area at the left of the road before the gate. Walk into disposal area.<br><br>STOP 3. Fly ash-bottom ash disposal site (Brocton, NY, 7½' quad): You will observe a trench and fill operation in relatively imperveous lake bottom sediments which overlie till. The fly ash is dumped first and later covered with coarser bottom ash to prevent blowing of the very fine particulates. The ash is then covered over by the soil and glacial deposits removed in the original excavation. Attempts to control and monitor leachate will be observed including an on-site measurement of the conductivity of the water entering the pond.<br><br>Return to the bus. Turn around and leave the disposal site. |
| 9.8 | 0.1 | Junction with Route 5. Turn left (W). |
| 10.4 | 0.6 | Junction with Berry Road. Turn left. |
| 10.5 | 0.1 | Keep left at junction with The next segment of the trip will traverse a significant variety of glacial deposits and features. The highlights are noted in the log. At this point the bus is driving over lake bottom deposits of Glacial Lake Warren. |
| 11.6 | 1.1 | Penn Central railroad crossing. |
| 12.4 | 0.8 | Thruway overpass. |
| 12.9 | 0.5 | Junction with Farrel Road. Turn right. |
| 13.1 | 0.2 | To the left and front of the bus note the line of poplar trees in the distance. They mark the location of the Lake Warren II beach. |
| 13.6 | 0.5 | Driving up the front face of the Warren II beach. |

| Total Miles | Miles from last point | Route description |
|---|---|---|
| 13.7 | 0.1 | To the right of the bus observe the inactive sand and gravel pit. When in operation this pit is a good location to note the nature of the sediments and bedding characteristics of an ancient beach deposit. |
| 13.9 | 0.2 | Junction with Route 20. Jog to the right and continue on Farrel Road. |
| 14.2 | 0.2 | Unnamed, poorly defined beach ridge. |
| 14.5 | 0.3 | Driving up the front face of the Lake Whittlesey beach. This is the highest proglacial stage recognized in Chautauqua County. |
| 14.6 | 0.1 | Junction with Webster Road. Turn left (E). Webster Road follows the crest of the Lake Whittlesey for the next mile on the trip route. |
| 15.7 | 1.1 | Bear right to follow Webster Road. |
| 15.8 | 0.1 | Intersection with Chautauqua Road. Continue straight ahead on Webster Road. |
| 16.9 | 1.1 | Penn Central railroad (abandoned). |
| 17.8 | 0.9 | Intersection with the Fredonia-Stockton Road. Turn right (S). For the next 2 miles, the bus will travel over Lake Escarpment ground moraine as we gain elevation on the escarpment. |
| 19.3 | 1.5 | Penn Central Railroad (abandoned). To the right of the bus observe the deep gorge which was used as the railroad right of way. This is a glacial meltwater channel formed during the deglaciation of this area when the ice blocked the normal outlet downslope to the north. |
| 19.7 | 0.4 | Junction with Glasgow Road. Turn left. This intersection marks the approximate northern boundary of the Lake Escarpment end moraine complex. |

| Total Miles | Miles from last point | Route description |
|---|---|---|
| 21.0 | 1.3 | Penn Central railroad (abandoned). |
| 21.3 | 0.2 | Junction with Darby Switch Road. Turn left. |
| 21.4 | 0.1 | Pull off onto the far right shoulder of the road. Follow fence line down to the creek. |

STOP 4. Agnes flood erosion and stream channelization problems (Cassadaga, NY, 7½' quad.): A very large landslide induced by greatly accelerated erosion during the Agnes Flood (1972) runoff is seen. The abundant supply of silt and clay from this material caused a serious siltation problem in the Village of Fredonia's Water Supply Reservoir located approximately 1.4 miles downstream. Agnes flood relief money allowed stream channelization upstream from this point to be completed in the summer of 1973. Since that time, extensive down-cutting on this stream has occurred which has contributed greatly to further siltation problems in the reservoir.

Return to the bus. Proceed straight ahead on Darby Switch Road.

| Total Miles | Miles from last point | Route description |
|---|---|---|
| 22.0 | 0.6 | Junction with Spoden Road. Turn left into parking area of New York State Highway Department. Leave the bus and walk 50 yards down Spoden Road. |

STOP 5. Stream contamination problems (Dunkirk, NY, 7½' quad.): Two sources of water contamination are apparent in this area. The first includes clay and silt which is being dumped down the embank-ment by the highway department. The second involves the unprotected pile of bottom ash and salt which is locally used for ice and snow removal on the highways during the winter. The small stream is tributary to the Village of Fredonia water supply.

Return to the bus. Leave the parking area and turn right onto Spoden Road. Proceed uphill.

| Total Miles | Miles from last point | Route description |
|---|---|---|
| 22.5 | 0.5 | Junction with Route 60. Turn left (N). The bus is now traveling over a series of deposits that include clays deposited in proglacial lake. They will be observed at the next stop. |
| 23.3 | 0.8 | Pull off the road to the far right. Leave the bus and proceed up the right hand embankment. |
| | | STOP 6. Landslides and badland erosion (Dunkirk, NY, 7½' quad.): This section of Route 60 was completed during 1958 and since that time a combination of slumping and earthflows have affected both sides of this cut. The glacial deposits involved in the slides are proglacial varved clays and at least two tills. The highway department has removed much material at the base of the slope which has caused further instability problems. At the top of the hill an extensive "badlands" has developed where the soil has been removed or covered with clays taken from the road cut excavation. These clays are being washed into a tributary to the Village of Fredonia water supply reservoir. |
| | | Return to the bus. Continue north along Route 60. |
| 24.4 | 1.1 | Semistabilized landslides in similar deposits. |
| 25.6 | 1.2 | Junction of Liberty Street and Route 60. Turn left and enter Laona, NY. |
| 26.1 | 0.5 | Entering Fredonia. |
| 26.6 | 0.5 | Bear right on Water Street and cross bridge over Canadaway Creek. |
| 26.8 | 0.2 | Intersection with Route 20. Continue straight ahead. |
| 27.3 | 0.5 | Temple Street entrance to the Fredonia Campus |
| | | END OF TRIP |