HISTORIC BLUFF RETREAT AND STABILIZATION AT FLAG HARBOR, CHESAPEAKE BAY, MARYLAND

Inga Clark, Curtis E. Larsen, Michele McRae, U.S. Geological Survey, Reston, VA

OBJECTIVE

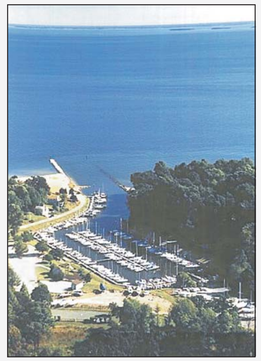
Studies of bluff erosion and slope stability along the western shore of Chesapeake Bay suggest relative evolution from steep, eroding cliffs to stable slopes over decades. The present study estimates relative time required for eroding bluffs to reach stability.

STUDY

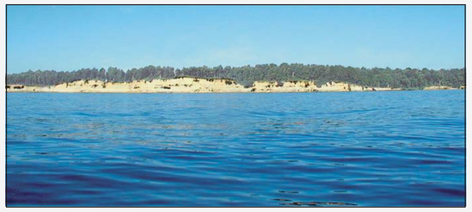
Flag Harbor study area is located on the western shore of Chesapeake Bay in Calvert County, Maryland. This section of shoreline is comprised of cliffs cut into Miocene sediments -- non-lithified clays, silts and sands. Cliffs are continually eroded by wave action, landslides, groundwater seepage, freeze/thaw action and weathering. The recession rates measured over 1848 -- 1942 period vary from 0.7 to 1.3 meters per year (fig. 1).

Development in this area started in 1930's. At present, except for the Flag Ponds State Park, shoreline supports privately owned communities. In 1947 a pair of small harbor structures were constructed on Calvert Beach Run entering the Bay to maintain a dredged channel to the Flag Harbor marina. Between 1950 -- 1980 several additional groins were built to slow down cliff erosion around residential development. Construction of groins and riprap at the bases of bluffs altered natural erosion pattern. Updrift deposition behind the northern jetty at the Flag Harbor marina and jetty at Kings Creek progressively created protective beaches along the toes of the bluffs. Thus, undercutting of cliffs by wave action was eliminated in the areas nearest to the jetties. Under these conditions, bluffs continually degraded to form stable, vegetated slopes. Slope angles progressively steepen to the north and to the northern limit of sand bodies where cliffs are no longer protected by beach deposits. Beyond these are eroding bluffs standing at angles of 60 - 70 degrees.

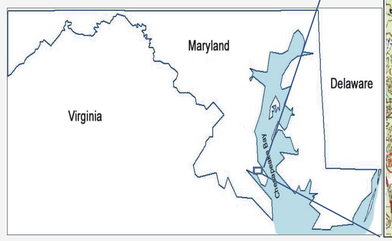
The object of this study was to define the rates of slope changes in the Flag Harbor area. We measured slope angles at intervals northward from the jetty at the marina for a distance of 1700 meters. In addition, we constructed a schematic profile of accumulated sand bodies in the study area based on the following measurements: the width of the beach from the toe of the bluff to the water edge; distance between the groins; and total length of each groin. The relative time required for eroding bluffs to reach stability was estimated by interpolating the distance and time for the stable slopes to prograde northward since construction of the jetty.



View of the marina at Flag Harbor. Updrift deposition behind the northern jetty (on the left) created beach that protects cliffs nearest to the marina from wave erosion.



View of Calvert Cliffs



Map showing location of the study area

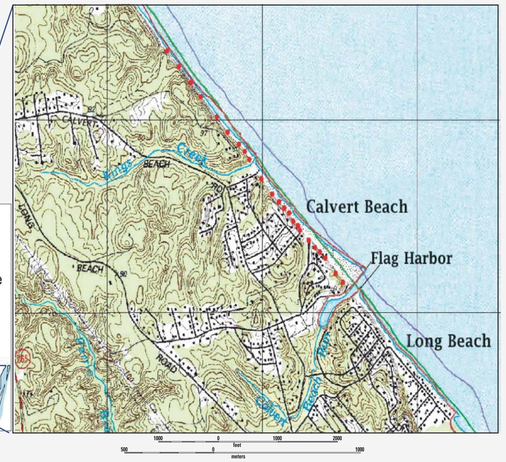
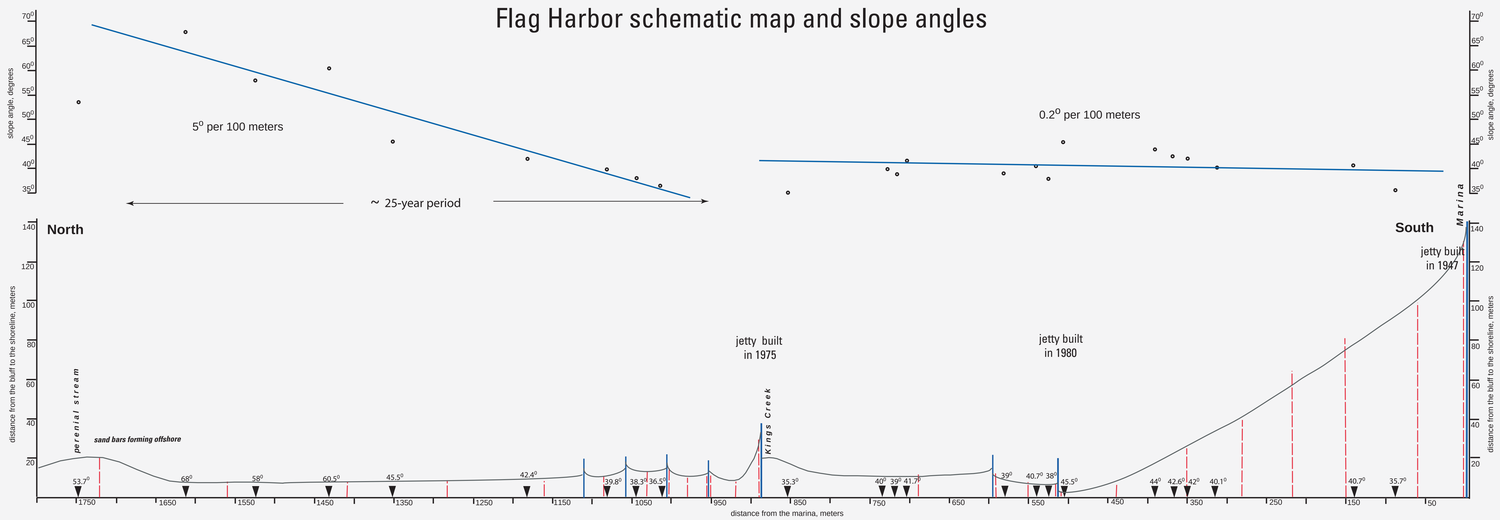
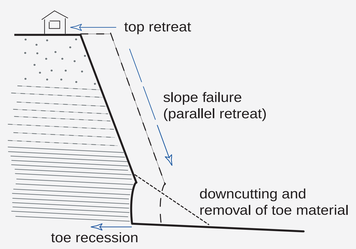


Fig. 1 Location of profile stations and historical migration of the Chesapeake Beach shoreline (courtesy of the Maryland Geological Survey) : blue line - 1848; green line - 1942; red line - 1993. Topography - 1981. Construction of two jetties at Flag Harbor in 1947 altered the natural pattern of erosion. Parallel retreat of shoreline in this area subsided and finally changed to the deposition of beach sediments.

STUDY RESULTS



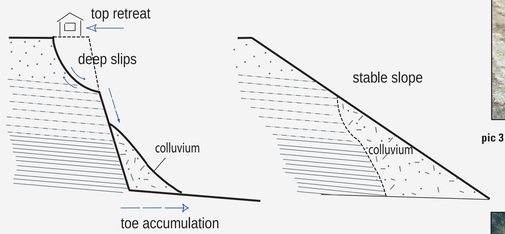
CLIFFS ACTIVE EROSION AND STABILIZATION



pic 1 Eroding cliffs to the north of the study area

pic 2 General view of Calvert Cliffs north of Kings Creek.

At actively eroding bluffs, wave action erodes intact material at the toe of a bluff. Failure of the slope face and top retreat take place in the form of translational slides and free degradation. Degradation material at the toe of the bluff is removed by waves (pic. 1 - 4)



pic 3 Actively eroding cliff. Colluvial material slides to the toe of the bluff and is removed by waves at high tide.

pic 4 Actively eroding cliff. Rotational slides at the top of the bluff created by oversteepened slope

Bluffs protected by a beach progressively attain a uniform stable slope. Rotational slides or slumps propagate from the top of the bluff (pic 5 - 7). Colluvial material is accumulated at the base of the bluff and forms an 'accumulation zone'. Ultimately the slope profile reaches the stable angle equal to the effective angle of shearing resistance of the soil (pic 8).

pic 5 Bluff protected by the beach. Vegetated scarp of an old landslide can be seen on the foreground.

pic 6 Slope in the process of stabilization. Pile of rocks at the edge of the cliff designed to enhance drainage and wood wall prevents soil slumping

A least squares regression of slope angle vs. distance showed progressive decrease in angle from north to south. On this section of shoreline, bluffs closest to the marina were protected for a longer period of time than the bluffs behind the Kings Creek jetty. Thus, the change in angle for these slopes is only 0.2° per 100 meters while it is 5° per 100 meters for the later ones. A relationship between time and distance along the shore allowed us to estimate a stabilization time for this location. Construction of the jetty at the Flag Harbor marina in 1947 and at Kings Creek in 1975, created conditions for the deposition of sand bodies that protected cliffs to the north of it. When undercutting at the toe of the bluffs was eliminated, slope recession still continued until stable slope angles were reached. Actively eroding 60 - 70 degree bluffs gave way to vegetated, but slumping slopes, and finally to stable slopes at angles of 35 - 40 degrees at the north side of the jetties. Bluffs at the distance of 250 -- 300 meters to the north of a jetty attain stability in less than 25 years. The shortness of this time scale allows us to suggest that attempts to artificially stabilize eroding bluffs along this coast is not a simple task of protecting the toes of the slopes from wave action. Once shoreline retreat ends, sloughing of sediment from bluff faces gives way to longer-term landslide processes. The bluff top recedes until a stable 35-degree slope is attained. Thus, simple shoreline protection methods do not preserve property at the bluff edge.

pic 7 Bluff protected by the beach. Mass of sliding material can be seen on the left. Slopes flatten towards the jetty at the marina seen on the background.

pic 8 Bluff protected by the beach. Bags filled with sand were placed to protect the toe of the slope from wave action. Logs at the center of the picture are the remnants of an old stucture designed to prevent soil from sliding.

U.S. Geological Survey Open-File Report 02-331