WOODS HOLE GROUP

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December 11, 2012

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Sent via email and US mail: gsourati@souratigroup.com

RE: Shoreline analysis for Shifter property

Dear George,

Woods Hole Group has completed an analysis of historical shoreline change and coastal geomorphology for the south facing shoreline of Chappaquiddick Island, Edgartown, MA. The purpose of the analysis was to gain a more in-depth understanding of historical shoreline evolution and geomorphologic development of the area as a way to predict future changes. We understand that the Shifter property, which is located at the southeast corner of Chappaquiddick Island near Wasque Point, has eroded significantly over the past few years. The wide beach and dune resources that once existed have completely eroded, and recent erosion since August 2011 has caused a loss of 120 to 150 ft of coastal bank. When the Shifter residence was initially completed in 2006 the top of coastal bank was approximately 200 ft away from the building, however recent erosion has brought the bank to within 73 ft of the residence. Given these alarming losses the property owners are considering relocating the residence to a more landward location. Woods Hole Group was contracted to complete a historical shoreline analysis and to provide information on potential future changes.

Shoreline Analysis

The Shifter property is part of a larger coastal system that includes the beaches and dunes on the southeast side of Martha's Vineyard, the barrier beach that separates Katama Bay from the Atlantic Ocean, Katama Bay itself, and the upland areas of Chappaquiddick Island. Review of historic information indicates that the system follows a three (3) stage pattern of geomorphologic evolution. Each stage is described below; details regarding the frequency and longevity of each stage are included as well as the impacts to shoreline change at the Shifter property.

- *Stage 1: Inlet Breaching* - Katama Bay is separated from the Atlantic Ocean by a narrow low lying barrier beach. The beach is subject to breaching during storms as increased wave energy and elevated water levels act on vulnerable spots in the barrier beach. Historically these storm-generated breaches have developed into semi-permanent inlets that allow tidal exchange between Katama Bay and the Atlantic Ocean. Immediately after the breach forms, barrier beaches remain on either side of the inlet; west of the inlet Norton Point extends to Katama, while east of the inlet the barrier beach connects to the southwest corner of Chappaquiddick Island (Figure 1). Inlet breaches typically form near the center of Katama Bay, although slight

variations east or west have occurred. Over the past 75 years storm-induced breaches have developed into semi-permanent inlets on three separate occasions: 1938, 1953, and 2007. Other cuts through the barrier have also occurred; however these have been short lived.

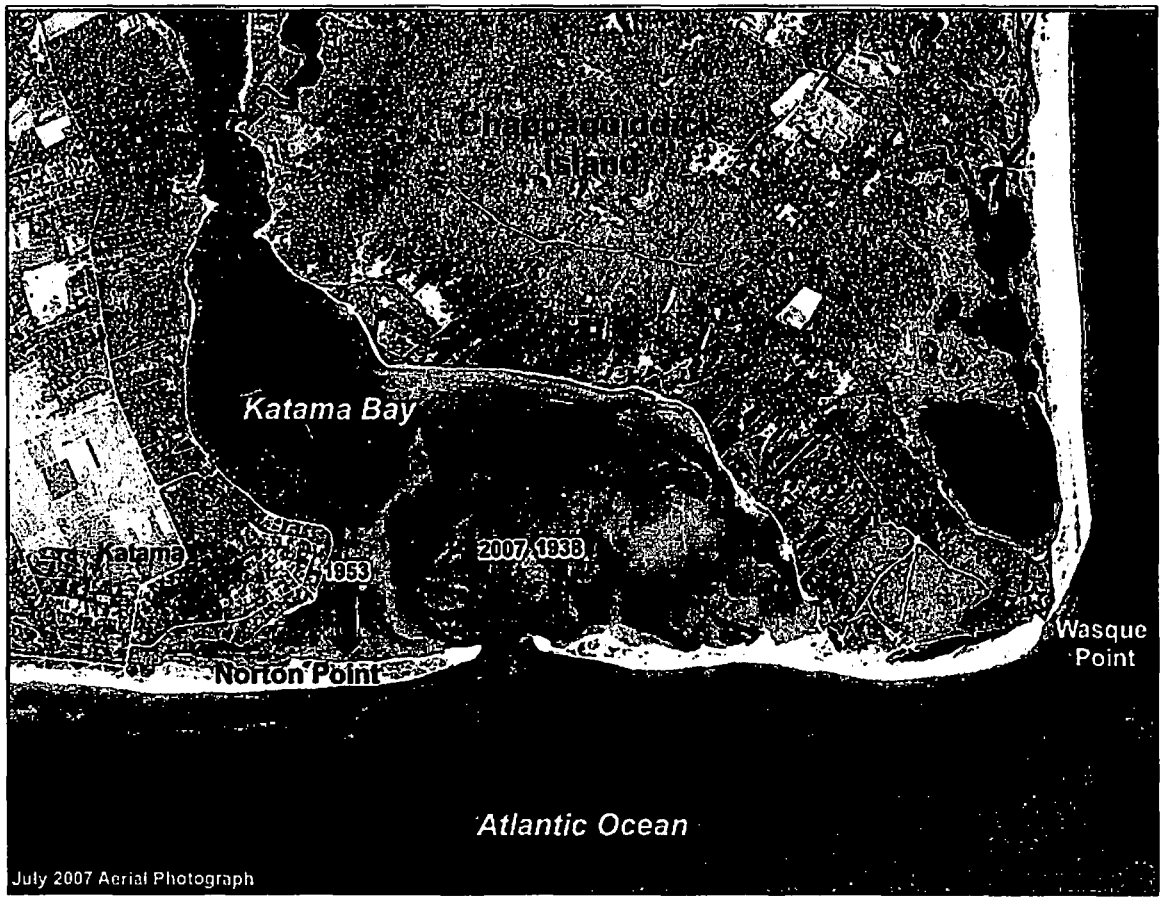

Figure 1. July 2007 aerial photo showing Stage 1: Inlet Breaching geomorphology. Historical locations of inlet breaching in 1938 and 1953 (estimated) are also shown.

- *Stage 2: Spit Growth and Channel Elongation* – During Stage 2 the inlet begins to migrate towards Chappaquiddick Island as the dominant easterly flowing longshore transport causes the spit at Norton Point to grow. As the spit extends to the east, the barrier on the opposite side of the inlet tends to shorten and erode. Often the eastern barrier will also rotate north into Katama Bay as incoming tides push sediment into the Bay (Figure 2). During the early phase of Stage 2 the shoreline along the south side of Chappaquiddick Island is relatively stable to slightly eroding. This is true as long as the eastern barrier spit is intact and can supply sand to the south side of the Island. Figure 2 shows this early phase of Stage 2 during 1961 (yellow shorelines) and more recently during 2008 (aerial photo). Both time periods show the barrier spit extending off the southwest corner of Chappaquiddick Island as well as a relatively wide beach/dune system along the south facing shoreline of the island. At times, the beach/dune system at Wasque Point has also contained an elongated pond, known as a "cat-eye pond". The pond is located at the landward edge of the beach/dune deposits near the base of the coastal bank. The site of this pond has migrated landward over the years as the shoreline has retreated; an indicator of the dynamic nature of the Chappaquiddick shoreline.

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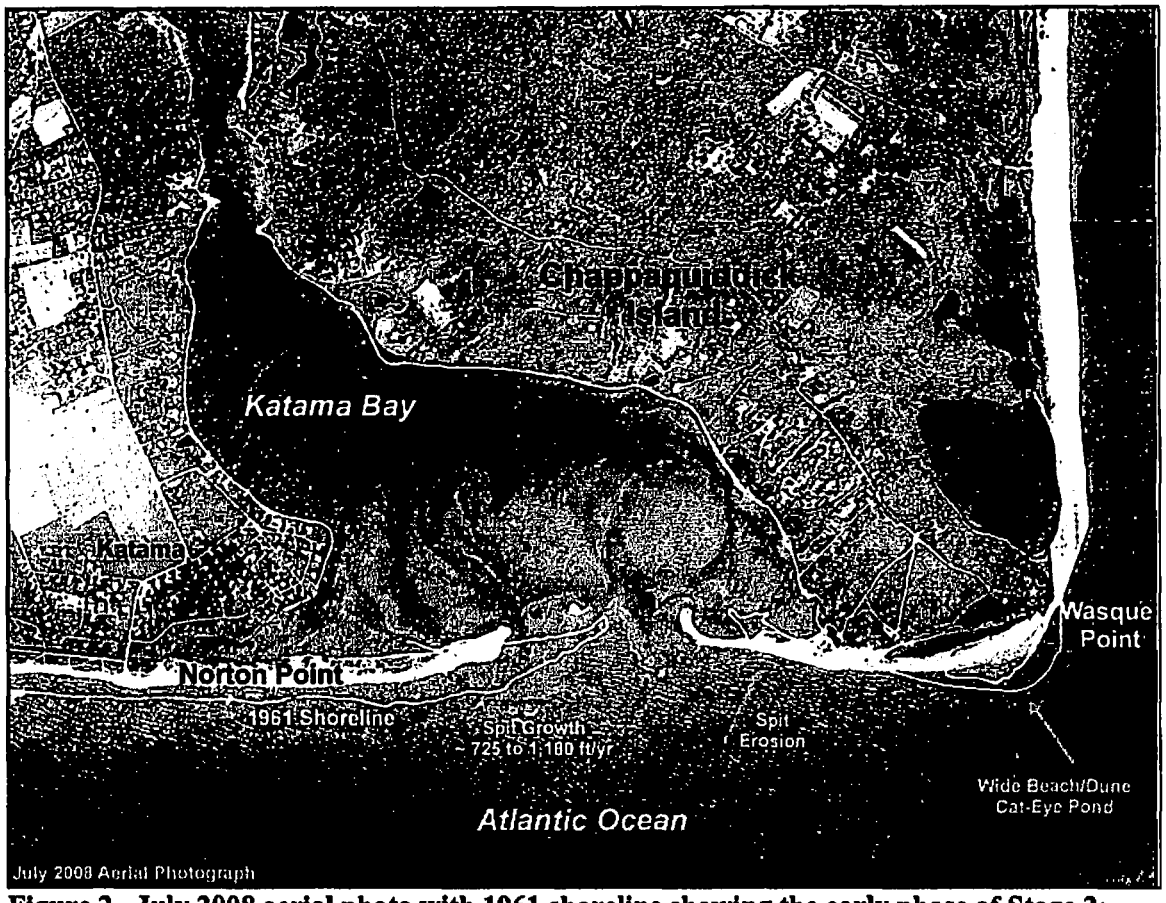

Figure 2. July 2008 aerial photo with 1961 shoreline showing the <u>early</u> phase of Stage 2: Spit Growth and Channel Elongation geomorphology.

The process of easterly inlet migration and barrier spit growth occurs until the eastern barrier is completely eroded and Norton Point begins to overlap the southwest corner of Chappaquiddick Island. During this middle phase of Stage 2, the absence of a sediment source from the west in combination with tidal currents directed against Chappaquiddick Island, cause rapid erosion of the south facing shoreline (Figure 3). Initial erosion removes the modern day beach/dune deposits and the cat-eye pond, until the upland portions of Chappaquiddick are exposed as an eroding coastal bank. Continued erosion causes retreat of the bank and loss of upland. The system is currently at this stage of geomorphic evolution.

Figure 3 shows three examples of the middle phase of the Stage 2 evolutionary cycle over the 63 year period from 1949 to 2012. The green line shows the position of the shoreline in 1949 as Norton Point overlaps the western end of Chappaquiddick Island. The 1949 shoreline at Wasque Point represents the approximate location of the coastal bank, with the beach/dune and cat-eye pond deposits having eroded during the years leading up to 1949. A similar cycle of inlet breaching, spit growth, inlet closure, and shoreline erosion occurred over the next 20 year period, and by 1969 the coastal bank had retreated an additional 550 ft (Figure 3; yellow dashed line). Most of this bank erosion occurred during the last few years of the cycle, between 1961 and1969. Starting in 2007 the system began a new cycle of inlet breaching, spit growth, and shoreline erosion. As in previous cycles, erosion at Wasque Point started with removal of the beach/dune and cat-eye pond deposits, followed by erosion of the coastal bank

and upland areas. Since August 2011 the bank at the Shifter property has retreated between 120 and 150 ft (Figure 3; blue dashed line). Until the system reaches the end of the Stage 2 evolutionary cycle, continued erosion of the bank can be expected.

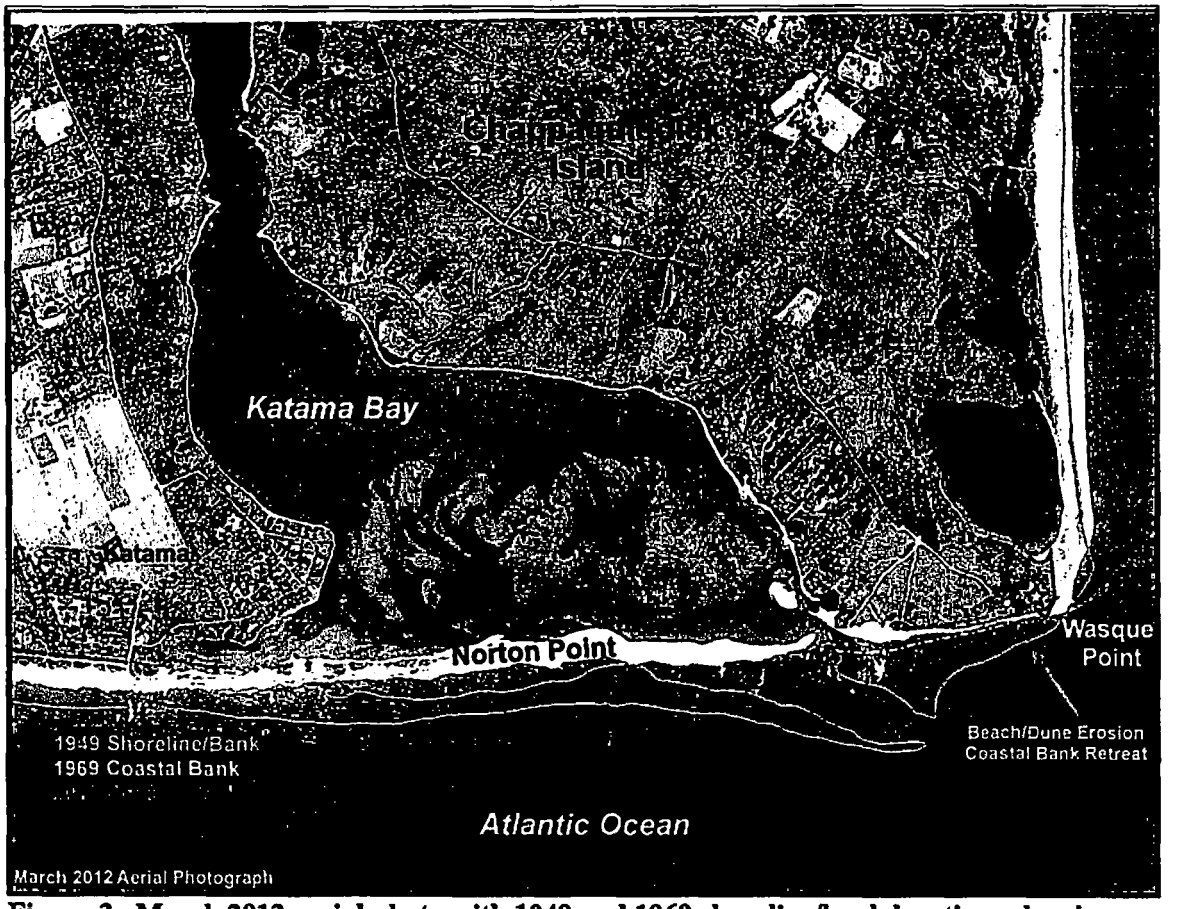

Figure 3. March 2012 aerial photo with 1949 and 1969 shoreline/bank locations showing the middle phase of Stage 2: Spit Growth and Channel Elongation geomorphology.

During the late phase of the Stage 2 evolutionary cycle, Norton Point extends to the southeast corner of Chappaquiddick Island at Wasque Point. The Norton Point barrier beach runs parallel to the Chappaquiddick shoreline, separated from the island by a narrow tidal channel that connects Katama Bay to the Atlantic Ocean (Figure 4). At this point the south facing shoreline of the island is protected from wave activity by the Norton Point barrier beach, and erosion of the coastal bank is essentially halted. Over the past 75 years the system has reached the late phase of Stage 2 on two separate occasions: 1938 and 1969. Figure 4 shows the 1969 shoreline (yellow line) near the end of Stage 2, where the Norton Point spit is approaching Wasque Point and the tidal channel leading to Katama Bay is along the south shoreline of Chappaquiddick Island.

- *Stage 3: Inlet Closure* – During Stage 3 the tidal channel connecting Katama Bay to the Atlantic Ocean closes. The channel from Katama Bay to Wasque Point is long and hydraulically inefficient, and the inlet at Wasque Point eventually closes as tidal currents are not strong enough to flush sediment from the opening. Waves gradually push the Norton Point barrier spit to the north and the beach eventually welds onto the Chappaquiddick

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shoreline. The site of the previous tidal channel forms a new cat-eye pond as the barrier spit moves onto the island (Figure 5). This process results in a relatively quick and dramatic accretion along the south facing shoreline of Chappaquiddick as the beach/dune and cat-eye pond deposits weld onto the coastline. Finally, during the last part of Stage 3 the beach/dune system begins to retreat as ocean waves, tides, and currents cause erosion.

Figure 5 shows the Stage 3 evolutionary cycle since the last period of inlet closure in 1969. The cat-eye pond in the aerial photograph marks the location of the tidal channel formed during the previous Stage 2, and the 1978 shoreline (yellow line) shows the extent of accretion caused by welding of the barrier spit to the island. Subsequent to 1978 there has been a trend of gradual erosion, shown by the 1994 shoreline (green line) and 2005 shoreline (aerial photograph) which are progressively closer to upland areas of Chappaquiddick Island. The process of beach/dune retreat continues through Stage 3 until a new breach in the Katama Bay barrier forms and then the cycle starts over with Stage 1.

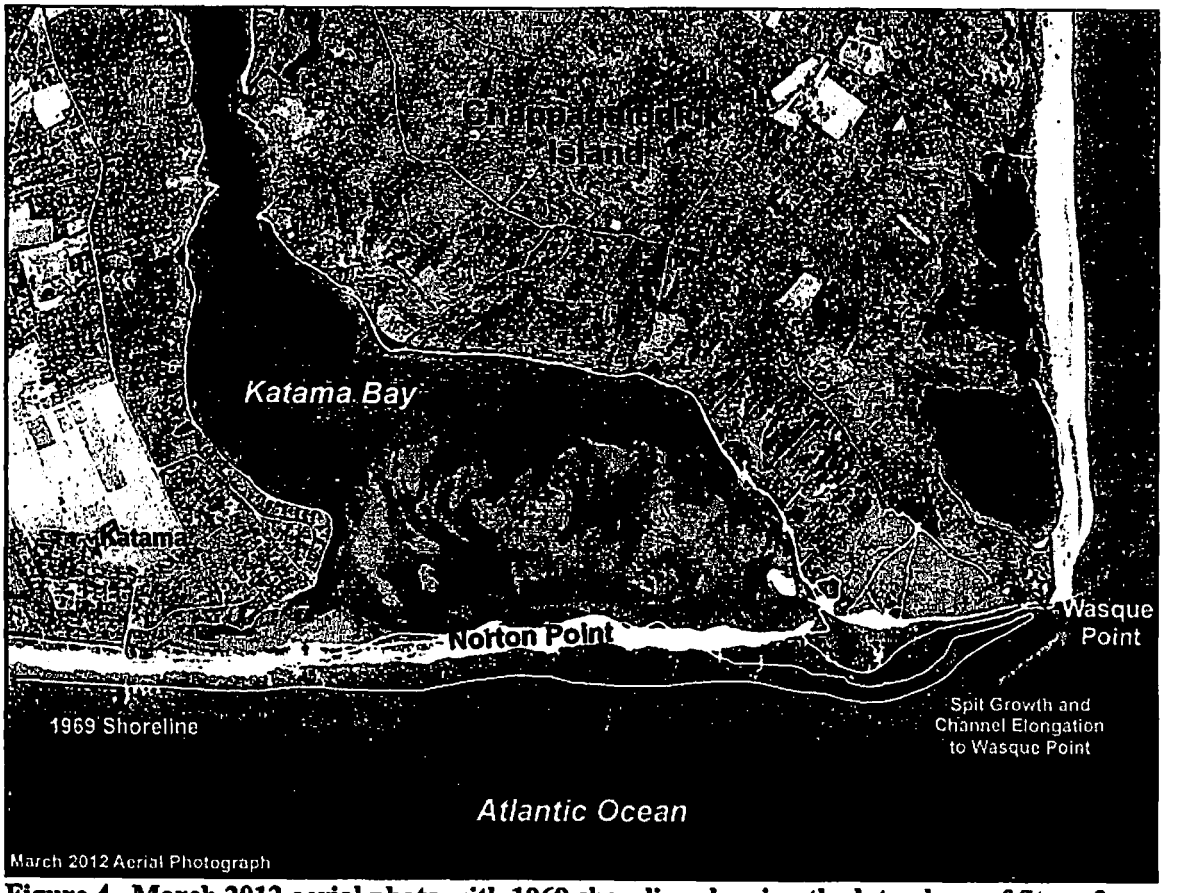

Figure 4. March 2012 aerial photo with 1969 shoreline showing the <u>late</u> phase of Stage 2: Spit Growth and Channel Elongation geomorphology.

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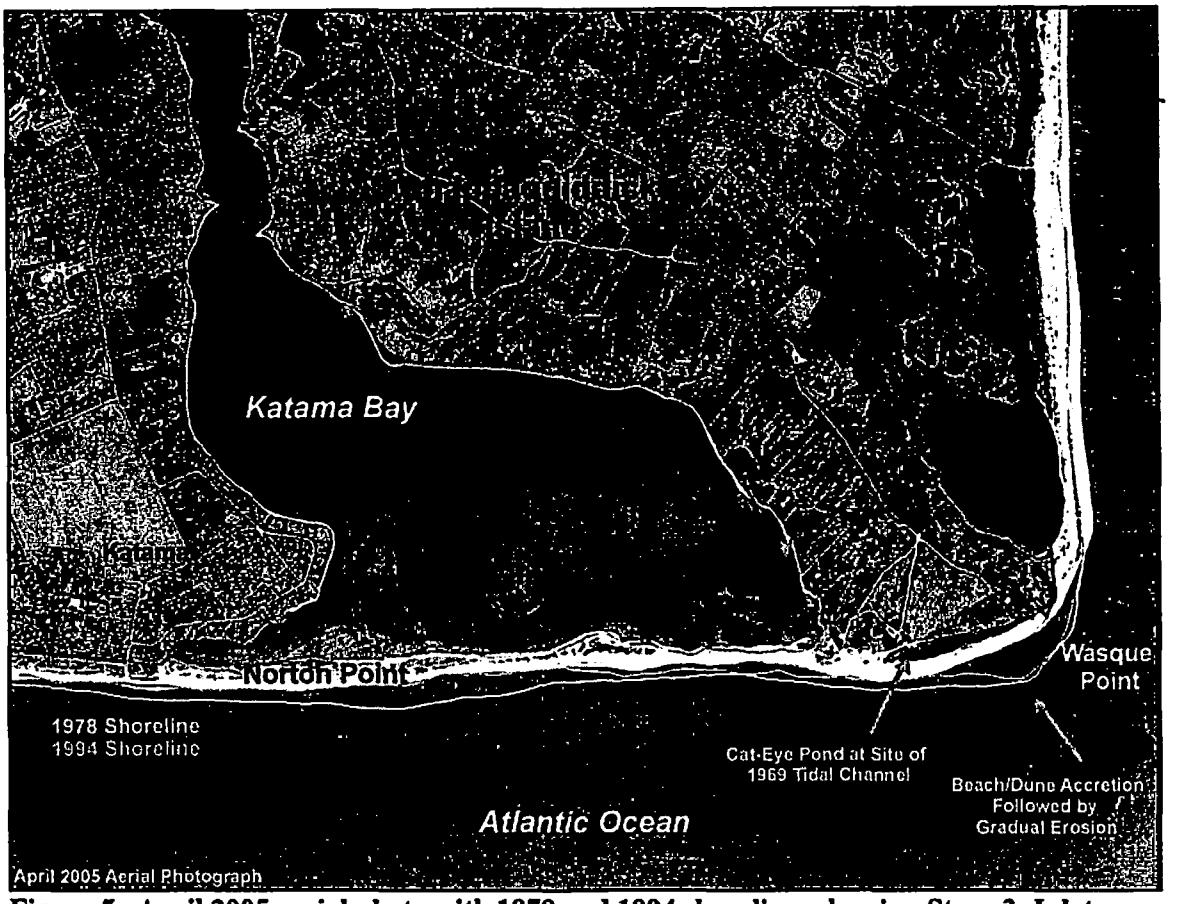

Figure 5. April 2005 aerial photo with 1978 and 1994 shorelines showing Stage 3: Inlet Closure geomorphology.

A summary of the various Stages of geomorphic evolution is provided in Figure 6. These data show that since 1938 the system has experienced three (3) cycles of evolution from Stage 1 to Stage 3 as follows:

- 1938 to 1950-1953
- 1953 to ~1970
- 2007 to present (middle phase of Stage 2)

At the Shifter property these coastal processes have resulted in periods of beach/dune accretion followed by erosion of both the beach and coastal bank. Although the natural evolution of the coastline causes the beach/dune to come and go depending on the Stage of evolution, the location of the coastal bank is always retreating. While it is difficult to predict how much further the bank will retreat during this middle phase of Stage 2, an estimate of potential erosion can be made using the historical data.

First it is necessary to determine how much longer it will take for the system to reach the late phase of Stage 2 when the Norton Point barrier spit grows to Wasque Point and protects the coastal bank at the Shifter property from wave-induced erosion. Calculations on past migration rates of Norton Point in combination with known durations of Stage 2 suggest that this phase will be reached sometime between 2016 and 2023. Until this time however, the bank will continue to erode.

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The magnitude of further bank erosion can be estimated from the previous cycles of evolution. For example, during the 1953 to 1970 cycle the bank along the southeast side of Chappaquiddick Island eroded at an average rate of -27 ft/yr. During the current period, which started in 2007 when the inlet breached, the average rate of bank erosion has been approximately -31 ft/yr. It should be noted that these values represent average rates of bank erosion computed over the duration of the evolutionary cycle. Using the more recent average, it is estimated that the coastal bank could retreat another 124 ft by the end of 2016. If the late phase of Stage 2 does not occur until 2023, the bank could retreat approximately 310 ft beyond its current location. These rates do not take into account the shore protection measures currently being constructed at the site. As long as the coir bags are in place they will help to protect the bank from erosion; however, as the adjacent unprotected bank areas retreat, there will be erosion and flanking of the Shifter shore protection.

This report is based on historical data and documented trends in the geomorphologic evolution of Katama Bay, Norton Point, and the south facing shoreline of Chappaquiddick Island. The data show a cyclic evolution which involves inlet breaching, spit growth and channel elongation, and inlet closure. We have applied the science of shoreline change and inlet dynamics to develop a more in-depth understanding of the historical shoreline evolution and geomorphologic development. The best available information was used to develop rates of spit growth, bank erosion, and expectations for future shoreline evolution. While all information in this report is presented to the best of our understanding, there is no crystal ball that can be used to predict future shoreline and bank locations with any greater degree of accuracy.

If you have any questions or require additional information, please do not hesitate to contact me at (508) 495-6225.

Sincerely,

Leslie Fields

Leslie Fields
Coastal Geologist

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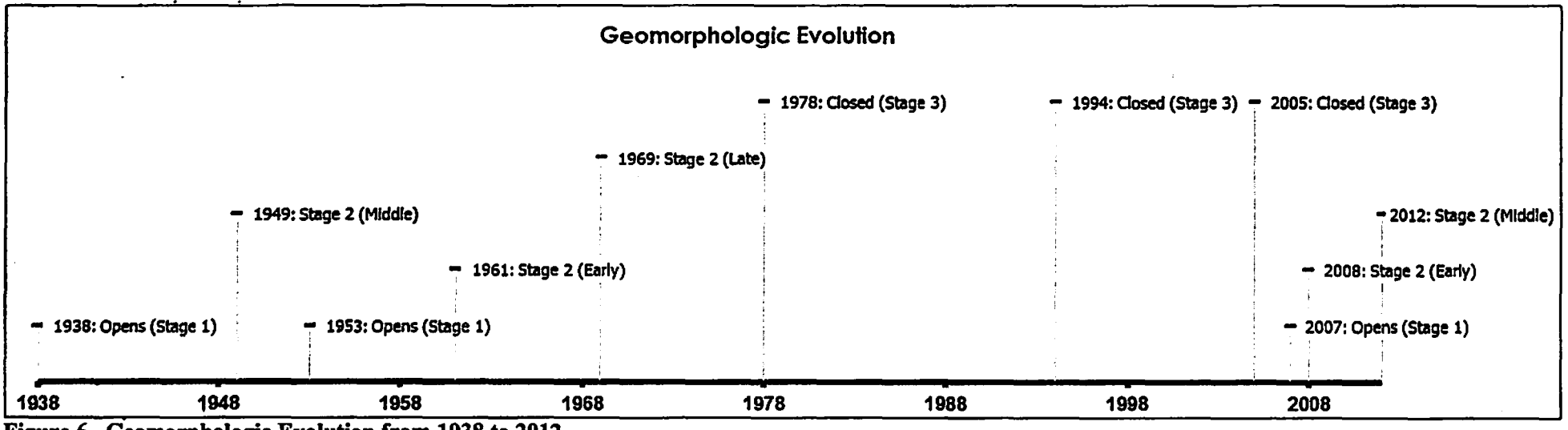

Figure 6. Geomorphologic Evolution from 1938 to 2012.