An Update of Coastal Erosion in Puerto Rico

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Introduction

This is an update of a 1978 survey of coastal erosion in Puerto Rico (Morelock, 1984). Since the time of the 1977 photographs, several storms and hurricanes have passed close enough to Puerto Rico to cause higher than normal wave impingement on the shoreline of Puerto Rico. This has left large areas of the north coast a beachrock shoreline instead of sand (Figure 1). Sites from the original study were surveyed for changes in shoreline position between 1977 and 1999, using the same photographic techniques described in the first study.

Figure 1. Beachrock on the north coast of Puerto Rico exposed after Hurricane Georges

Continued research confirms that the rate of erosion in these beaches is not constant with time; there are accelerations, decelerations and even reversals from erosion to accretion. The effects of winter storms and occasional hurricane wave events exert a strong influence on erosion rates compared to the normal wave regime. Aerial photographs taken several years apart will not provide information on episodic changes in erosion rates, but will allow a determination of net shoreline change.
If we look at the net changes of shoreline position, they are relatively slight (Figure 2). The immediate response to erosion in areas where property appears to be threatened is hard stabilization (Figure 3). This has created more problems that the original erosion event.

The sites surveyed in this study and the prior publication are Arecibo, Punta Salinas, Isla Cabras and El Tuque (Figure 4). An additional site, Añasco has been added. The following discussion summarizes the shoreline changes since the prior study.
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**Arecibo**

From 1940 to 1977, the shoreline at Arecibo underwent continuous retreat at an average rate of 1.5 to 1.7 meters per year (Morelock, 1984), resulting in a net loss of more than 55 meters of shoreline. From 1977 to 1985, the shoreline was stable except for changes at the mouth of the old river channel. The stability of the coast for this eight-year period may indicate that the shoreline adjusted to the changed conditions that led to the original erosion, which were:

- damming of the river upstream, with reduced sediment carried to the beach
- construction of the harbor breakwater and a change in the wave regime
- harbor dredging and removal of bottom sediments
- changes in position of the river mouth

In 1980, construction was started on a small jetty north of the relict river mouth, and the channel was dredged for access to the Arecibo Yacht Club. The work was completed in 1982. The shore north of the jetty is almost 30 meters seaward of the 1977 shoreline (Figure 5). By 1987, there was only minor accretion and erosion when compared to the 1977 photo. The stability was upset by the jetty between 1987 and 1999 and the resultant erosion begins just south of the channel and spreads westward (Figure 6). Field observations showed that high waves accompanying Hurricane Gladys have started this process.
Studies of the beach sediments showed a shift from mixed terrigenous and biogenic beach sand to terrigenous sand in the 1990’s (Barreto, pers. obs.). After the passage of Hurricane George in 1998, the beach showed an extreme change in sediment composition from the back beach to the swash zone.
Terrigenous sediments with a high magnetite content (90 to 98% insoluble material) were found along the beach. Heavy flooding and a river crest of more than 5 m flushed sediment from behind the dam on the Río Arecibo and carried it to the coastline. Field observations seven months after the hurricane showed the amount of magnetite was reduced, possibly indicating return to stable conditions after the hurricane effects.

Punta Salinas

The 1977 to 1981 photographs showed a continuing retreat of the east shoreline at Punta Salinas of almost two meters per year. This is almost the same as the 1950 to 1977 rate. In 1981, the entire east shore was protected with rock riprap (Figure 7). The 1977-1987 photographs show that the conversion from beach to a rock shoreline has stopped the erosion. The change from 1987 to 1999 has been accretion north of the riprap, but a beginning of erosion south of the riprap (Figure 8).

Figure 7. Boulder riprap on the east side of Punta Salinas.

Figure 8. Shoreline changes at Punta Salinas.

The addition of riprap has cut off the source of sand to the Levittown shoreline of Bahia de Boca Vieja. This area eroded appreciably between 1950 and 1971, but was stable from 1971 to 1977. The jetties in the
western portion of the bay were impounding sand until 1981, but are now being emptied since the sand source provided by erosion of Punta Salinas's east beach has been eliminated. This loss of sediment supply may result in renewed erosion in the Levittown area.

The west shore of Punta Salinas tombolo was eroding at about two meters per year. The construction of a jetty at the north end of the beach was begun in June 1981. Fill excavated from within the tombolo was added to the berm and beach to extend the shoreline seaward almost 50 meters. This work was completed in 1982. The jetty blocks and alters the wave and current regime which should change the pattern of sediment transport. The 1987 photograph shows the shore position at the south end of the beach at the 1977 shore position and at the north end it is beyond the 1971 position. The beach south of the park was not eroding prior to the jetty construction but between 1987 and 1999 the southern beach has begun eroding.

An increase in the magnetite content of the west shore may indicate changing land use and deforestation in the upper reaches of the Río El Cocal and Río La Plata (Barreto, pers. obs.). The geology of the lower reaches of the river is limestone, biogenic sandstone and alluvial deposits. Volcanic rocks with abundant magnetite are only found in the mountains of the Cordillera Central.

**Isla Cabras**

Erosion of the east side of Isla Cabras began between 1971 and 1977 with the loss of more than three meters of shoreline per year at the south end of the east shore. From 1977 to 1981, there was little additional erosion, but between 1981 and 1985 another episode of erosion occurred north of the original area of erosion. Almost 20 meters of shoreline were removed in a four year period (Figure 9). This continued until the entire area of erosion was enclosed with a breakwater to create a public swimming area (Figure 10).

![Figure 9. Shoreline changes on the east side of Isla Cabras. Almost half of the width was lost.](image-url)
In 2000, rebuilding was required on the breakwater. Exposed coconut palms and damage to the breakwater showed continuing erosion.

**El Tuque**

This beach was modified by engineering activities several times after 1960. Between 1962 and 1987 the pattern was accretion on the northwest beach and erosion on the southeast beach. The measurement of accretion beween 1978 and 1987 was a result of beach replenishment in 1979. The fill was to restore the shoreline to its 1960 position. This fill was stabilized by a shore-connected groin and an offshore breakwater (Figure 11). Beach profiling and sand size analysis in 1992-1993 showed that the coarse sand fill was lost and fine sand and mud formed the adjusted beach. Comparison of the 1987 and 1999 aerial photographs show a return to shoreline retreat (Figure 12).
Figure 11. El Tuque breakwater and groin.

Figure 12. Shoreline change at El Tuque.
Añasco

Complex shoreline changes happened at Añasco beach from 1936 to 1993. Two main areas were defined based on net shoreline changes. These were: 1) net accretion from stations 7 to 13; and 2) a net erosion to the south close to the Rio Grande de Añasco mouth. Shifts between erosion and accretion were observed between the two sections. These were major shoreline changes close to the river mouth (Figure 13). Changes were related to variation in magnitude and occurrence of flood events in the Rio Grande de Añasco Valley.

Accretion occurred in the northward beach from stations 5 to 12 during 1936 to 1950. Moderate erosion rates were measured from 1950 to 1964. An increase in erosion rates was observed in all stations during 1964-1971. The severe erosion rates were related to both storms and flooding which occurred during this period. Human activities, such as the construction of the Yahuecas and Guayo water reservoirs during 1956, were also responsible for the reduction in the local sediment supply to the beach.
Accretion was measured for 1971 to 1977. The added sand was from the major flood during tropical storm Eloisa in 1975. These accretions can be seen on the comparisons of the 1973 shoreline to the 1975 shoreline.

Accretion continued from 1977 to 1993, but severe erosion occurred on the south beach close to Rio Grande de Añasco from 1987 to 1993. Loss of sand was caused by floods during the period and the construction of beach facilities on and near the beach and related activities.

**Summary**

Certain patterns and common elements can be seen in the erosion of the shoreline in Puerto Rico. At many locations, the initiation of rapid erosion commences suddenly, after a period of very little or no erosion. After a period of erosion, a shoal (usually rock underlying relatively thin beach sands) may become exposed in front of the eroding beach, resulting in a great reduction in the rate of erosion, as seen at north shore, beachrock and eolianite ridges may contribute to beach protection. In some areas, the shoreline has adjusted to the altered wave and current regime and the reduced sediment supply from rivers, and a new equilibrium has been established.

The shorelines at Isla Cabras and Punta Iglesia have both shown a great increase in erosion since 1971. The eastern shoreline of Isla Cabras was rebuilt to restore the prior shoreline position. Erosion has slowed drastically at Levittown with the development of a protective shoal (beachrock ridges) in front of the beach. At Arecibo, the beach system had established a new equilibrium, which was changed by shoreline construction. At Punta Salinas, the beach may have been stabilized with construction of a jetty on the west shore and emplacement of riprap on the east shore. But, this riprap has resulted in problems at the Levittown beach.

Erosion is fairly widespread in Puerto Rico (Morelock and Trumbull, 1985). Changes in the wave regime of the winter storms, erosion of natural barriers, loss of reef and mangrove protection, and reduced sediment input from the rivers (all rivers in Puerto Rico now have dams) may be contributing factors to the prevalence of erosion. There is evidence that the shoreline may establish a new equilibrium after a period of erosion. The shoreline of Puerto Rico that shows no erosion or even accretion is generally fronted by mangrove forest and extensive reef tracts on the shelf.

Changes in the beach sands to higher terrigenous content have occurred in the last ten years (Barreto, pers. obs.). This probably resulted from urban expansion south and west of the San Juan Metropolitan Area. The vegetated mountain areas have been populated along the river basins resulting in increased land erosion and sediment production.

**References**

