of maps and the social survey may be explained by the different perspectives provided by these datasets. Shoreline positions from maps, because they were derived from aerial photographs, provide a snapshot of the area during a specific time only — that is, when the aerial photo was taken. On the other hand, the observations of the locals span a longer period of time. However, errors may arise in the respondents estimate of distances, which vary from person to person. This can be tested by checking how a particular change at a particular time was consistently quoted by the respondents in a *barangay*. Nonetheless, the general trends derived from the maps and from anecdotal accounts are consistent.

Changes in bathymetry during the past decades confirm the abovementioned results. Along coastal segments where significant erosion took place, deepening occurred in the immediate vicinity. This is exhibited off Payocpoc Sur through Wenceslao, Samara, Alaska, and Sta. Rita Sur through San Manuel Norte, where as much as 4 m of deepening occurred. Likewise, San Fernando Bay generally deepened, except for its central part which underwent shallowing. Maximum deepening of about 8 m took place in the narrow passage of the mouth of San Fernando Bay. Conversely, shoaling occurred where progradation is considerable. This is seen adjacent to the mouth of Bauang and Aringay River. In Bauang, the offshore area fronting Parian Oeste and Payocpoc Norte/Oeste became shallower by 3 to 9 m. The same amount of shoaling took place in front of the Aringay River mouth, whereas offshore Dulao through Sta. Rita West, water depth shallowed by 5 m. Shoaling of approximately 4 m in the offshore area shows two along-coast elongate pattern originating in front of the Bauang River mouth and extending south, 3 km off the coast of Santiago Sur. A similar pattern is observed south of Aringay River. The area of shallowing close to the coast, however, extends only in front of Sta. Rita West whereas the more distal area of shoaling reaches about 1 km offshore Baybay. These spatial variations in bathymetric change indicate sites where sediments are being removed and where they are being deposited. The trends observed in the study area show that in general, sediments that are eroded from the coast are delivered offshore. Furthermore, materials coming from the rivers are mostly deposited to the south, which is consistent with the predominant southward longshore drift in the area.

Response to coastal changes

Individually or as a community, the people of La Union responded to the prevalent erosion either by temporarily evacuating, relocating, building ripraps or sandbags, or if funds are available, by constructing seawalls (Fig. 3). Short-term erosion that occurs during storms or typhoons prompts affected communities to temporarily evacuate to a safer place; nevertheless, when conditions return to normal and partial or full beach recovery occurs, residents go back and restore whatever s left of their properties. In a lot of cases, however, beach recovery does not happen and people are forced to relocate, usually just several meters inland. Relocating has become frequent for many, especially for those living in persistently eroding coastal segments. In the case of Pilar in Bauang, residents have transferred five times already since 1975. To protect properties and infrastructures from erosion, private individuals and some communities resorted to building structures like ripraps, sandbags and seawalls. The ripraps and sandbags, according to the locals, were not effective in preventing erosion and maintaining them became costly in the long run. Those who have more resources, such as along Carlatan in San Fernando, construct more robust structures.

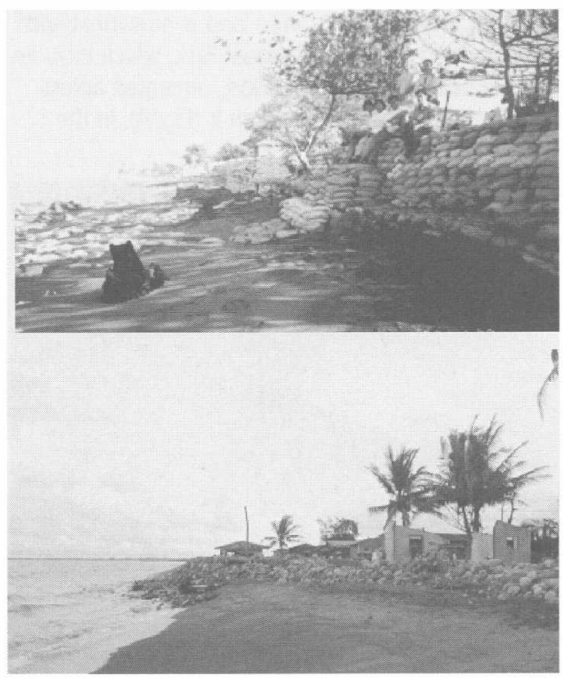
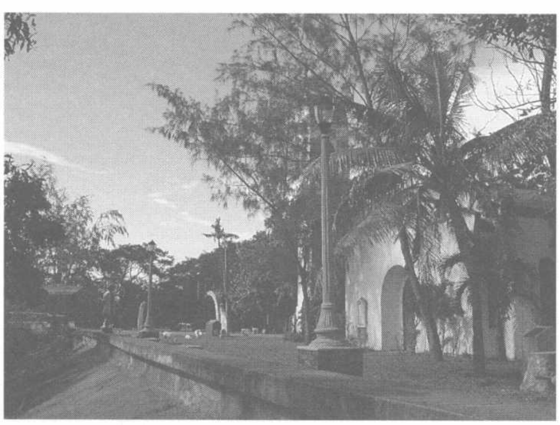


Figure 3. Cheaper alternatives to the more expensive coastal protection structures: sandbags in Wenceslao (top) and ripraps in Alaska (bottom). In the long run, however, maintaining these structures also becomes costly.

On the Government's part, huge funds have been allocated to construct coastal engineering structures to counter erosion. In 1980, a 1.5 km-long seawall was built in Sta. Rita to protect the Agoo-Damortis National Park. The entire structure was completed in 1988; however, its southern end had to be repaired periodically due to weak foundation. The 1990 earthquake further damaged the base of the seawall, which prompted the construction of its second layer. This, and the original construction of the Sta. Rita seawall over a period of 14 years, from 1980 to 1994, cost approximately PhP250 M. Since 1984, a series of groins and bulkheads have been put up to protect the Agoo-Sto. Tomas coast. Initially built to protect the pavement just south of Agoo Playa compound, groin construction was further extended to San Julian Norte, Agoo in the north and to Sto. Tomas in the south. At present, more than 60 groins, costing around PhP57 M, dot the Agoo to Sto. Tomas coastline. More groins are being proposed for construction to arrest the erosion of areas downdrift of these structures.

On the contrary, new coastal lands formed by progradation are promptly occupied and even titled, though by law it should be public land (Commonwealth Act 141, Chapter IX). In Sta. Rita Central, Aringay, shoreline prograded by approximately 350 m from 1940s to 1970s. This newly-accreted land is now inhabited and the Agoo-Damortis National Park, which includes a basketball court, church, resort, cemented access road and the seawall, is built on it (Fig. 4). In the past 30 years, another 450 m of land was added to this coastal stretch and is also being slowly occupied (Fig. 4). This prompt occupation of newly-formed land leads to a lot of problems later on: in Caba, for example, progradation in the late 1930s until 1960s lured people to settle in, but were later forced to relocate several times because of the subsequent erosion that took place (Siringan and Jaraula, 2002). This led to loss of properties. Thus, the local government should be prompt in declaring accreted land as public property to avoid a similar scenario.



Causes

Changes in shoreline position along the southern coast of La Union during the 60-year period can be attributed to natural and anthropogenic factors. Natural causes of erosion include local forcings such as waves, earthquakes and shifting position of river mouth. Constant wave action on the coast brings about erosion by removing materials from the beach and by wearing away hard materials that it cannot carry. Hence, coastal segments where wave energy is high are more prone to erosion than those in more protected settings. The general north-south orientation of La Union's shoreline renders it open to waves originating from South China Sea. Wind data from observations in Poro Point, San Fernando indicate predominant winds coming from the northwest. Typically, waves with significant height of less than a meter are generated at wind speed ranging from 2 to 6 m/s during normal conditions but, at wind speed of 10 to 20 m/s, can reach as high as 3 m (Woodward Clyde, 1999). Furthermore, waves during storms, in the form of storm surges, can be even higher; documented storm surge height in Ilocos Sur, north of the study area, ranges from 3 to10 m (PAGASA, 2002).

Figure 4. In 1980, a 1.5-km long seawall was constructed to protect communities and the Agoo-Damortis National Seashore Park in Sta. Rita (left). At present, however, approximately 450 m of land accreted in front of the structure (below) due to the natural southward drift of sediments coming from Aringay River, 5 km north of the area.

In July 16, 1990, a 7.8-magnitude earthquake rocked central Luzon. This devastating earthquake caused several areas in La Union, specifically along the coasts of Aringay, Agoo and Sto. Tomas to subside instantaneously due to liquefaction: 1 to 2 m in Alaska (anecdotal account), 0.5 m in San Nicolas West, 1 to 2 m in Cabaroan, 1 to 3 m in Narvacan (Geomatrix, 1995), among others. Widespread inundation accompanied the lowering of coastal lands; the most severely-affected area is Alaska, wherein residents recounted about 1 km of sea encroachment (Fig. 5). After the earthquake, the locals in Sto. Tomas observed slight shoreline progradation; but because the land is now lower, it became more prone to erosion. Torres et al. (1994) attributes liquefaction in La Union and in the neighboring provinces to the nature of the underlying material: relatively unconsolidated and water-saturated sands. Aringay sits on a delta, which is built by rapid and continuous deposition of materials from Aringay River. Agoo and Sto. Tomas, are atop very young sandy deposits formed by accumulation of sediments transported by the longshore current.

In contrast to the large shoreline retreat that occurred in Alaska, the coastal stretch to the south, in Dulao and Sta. Rita, experienced rapid land accretion after the earthquake (Fig. 4). These areas are at the receiving end of the eroded materials from Alaska and the sudden influx of sediments from the rivers due to earthquake-induced mass wasting in the upstream. Rapid progradation south of the Bauang River is ascribed to the southward migration of the river mouth coupled with the south-directed longshore currents. However, because these lands are relatively new, they are also likely to experience liquefaction in the future. Furthermore, because these segments are very close to the river, future shifts in river course may lead to rapid erosion. The northern flanks of the deltas, although seemingly "stable" at present, may also be at risk of rapid erosion as shifting of the rivers northwards is also probable. A more northerly position of the river mouths in the distant past, no longer covered by the period with maps, is indicated by scars of previous stream positions, which can be seen in aerial photographs.

On the global scale, widespread erosion can be ascribed to the effects of global warming: decreased precipitation, increased storminess and sea-level rise. El Nino Southern Oscillation (ENSO) record for the past several decades indicates a shift from a La Nina-dominated to El Nino-dominated climate in the 1970s. With El Nino occurring more frequently, the amount of precipitation decreases, hence, river discharge to the coast also goes down. Peak annual discharge data from 1946 to present of the two major rivers in the study area indicate a decline (Streamflow data 1980-2000, 2001), which may be related to the observed shift in climate regime.

Storms and typhoons in the Philippines are very frequent and cause the greatest damage to properties and the most number of lives lost among all the other natural disasters (ADRC, 2002). Residents of La Union attribute about 5 to10 m of erosion to typhoon passage. In the past several decades, the locals observed that the beach is able to recover almost after every typhoon; however, the series of strong typhoons that hit the area in the 1990s hindered the shoreline from returning to its pre-storm position. Typhoons such as Trining (International Code Ruth; October 24, 1991), Mameng (Cybil; September 27, 1995) and Feria (Utor; July 3, 2001) caused significant destruction to the coastal communities of La Union. Should storm frequency continue to increase due to climate change, erosion would accelerate because the affected coastal segments are not able to recover to pre-storm conditions.

Figure 5. Present shoreline of Barangay Alaska is littered with tree stumps indicating that trees used to thrive along the coast. During the July 1990 earthquake, a large area of Alaska subsided by 1 to 2 m as a result of liquefaction. According to the locals, prior to the earthquake, the shoreline was approximately 1 km farther offshore.