

Characteristics of a Chronically, Rapidly Eroding Beach:

Long Key, Pinellas County, Florida

by

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Characteristics of a Chronically, Rapidly Eroding Beach:
A Case Study of Long Key, Pinellas County, Florida

Alyssa L. Saint John

ABSTRACT

Long Key, on the central western coast of Florida, has been nourished repeatedly since 1975. Following nourishment, the beach has rapidly eroded. This study documents rates, processes, and mechanisms for the rapid erosion. To better understand the beach performance, it is crucial to quantify the background erosion rate when artificial beach fill is at its minimum. This year long study from February 2003 through March of 2004 provides a detailed examination of the performance of a natural beach experiencing intense erosion.

The primary objective is to analyze the performance of Long Key through detailed investigation of shoreline and beach-volume changes at a time when the effects of the most recent nourishment in the summer of 2000 are a minimal influence, and the natural performance of the beach, i.e, the background erosion/accretion rate, can be determined. This study also examines, in detail, shore-parallel and cross-shore sediment properties in an attempt to link erosional, stable and accretional areas to sediment grain-size composition. Finally seasonal variations of the near shore morphology and sediment properties of the Long Key beach were determined to identify the significance of seasonal variations on long-shore and cross-shore sediment transport. This

study was conducted using monthly beach profile data and monthly sediment samples.

Net long shore sediment transport at the eroding north end (Upham Beach) is to the south at a rate of 34,000 cubic meters per year. Eighty-five percent of this sediment is deposited on the central and southern portions of the island, mainly in the central portion. This is an elevated sediment transport rate as compared to the generally accepted rate of 15,000 to 20,000 cubic meters per year, which explains the rapid erosion at the north end. The greatest volume loss occurs in the winter months, ostensibly due to the passage of winter storms. There is also no significant cross-shore sediment transport in the northern portion of Long Key; beach profile results demonstrate a stable shape. However, there is slight cross-shore sediment transport in the central and southern regions of the island. At location LK 3 in the north end of the island lost 35 meters of shoreline above NGVD and 25 meters below NGVD. At location LK 11 in the south end there was a gain of 3 meters above NGVD and 15 meters below NGVD. Based on detailed sediment analysis, it is not possible to determine distinctive and persistent temporal or spatial sediment characteristics, nor are the sediment properties of Long Key indicative of long shore sediment transport.

INTRODUCTION

Beach erosion on the western coast of Florida has been a significant problem for decades. Pinellas County is no exception, with erosion in the region generally paralleling the rapid increase in development that followed World War II (Davis et al, 1993). One of the most persistent beach erosion problems is demonstrated along Upham Beach at the northern end of Long Key. Tidal inlets often play a significant role in influencing beach erosion. For the case of Upham Beach, Blind Pass, just north of Upham Beach, was stabilized with jetties, and seawalls were erected to promote further development along the coast. The consequences of these hard stabilization measures have resulted in depletion of sediment supplies to the downdrift beach, and therefore extreme erosion at the north end of Long Key at Upham Beach (Figure 1). There have been several nourishment projects conducted over the past decades that have provided a temporary solution, but the beach returns to nearly its pre-nourishment condition within the first two years, and sometimes even within one year of a nourishment project. Nourishment projects have been constructed approximately every five years since 1976 (Loeb, 1994) in order to maintain Upham Beach. The two most recent projects, in 1996 and 2000, have eroded rapidly, increasing the rate at which renourishments must be conducted. The most recent nourishment project scheduled to begin construction in July of 2004, along with construction of T-head groin structures, however this nourishment occurs after the termination of

this study. This study encompasses one year of data, from February 2003 through March 2004.

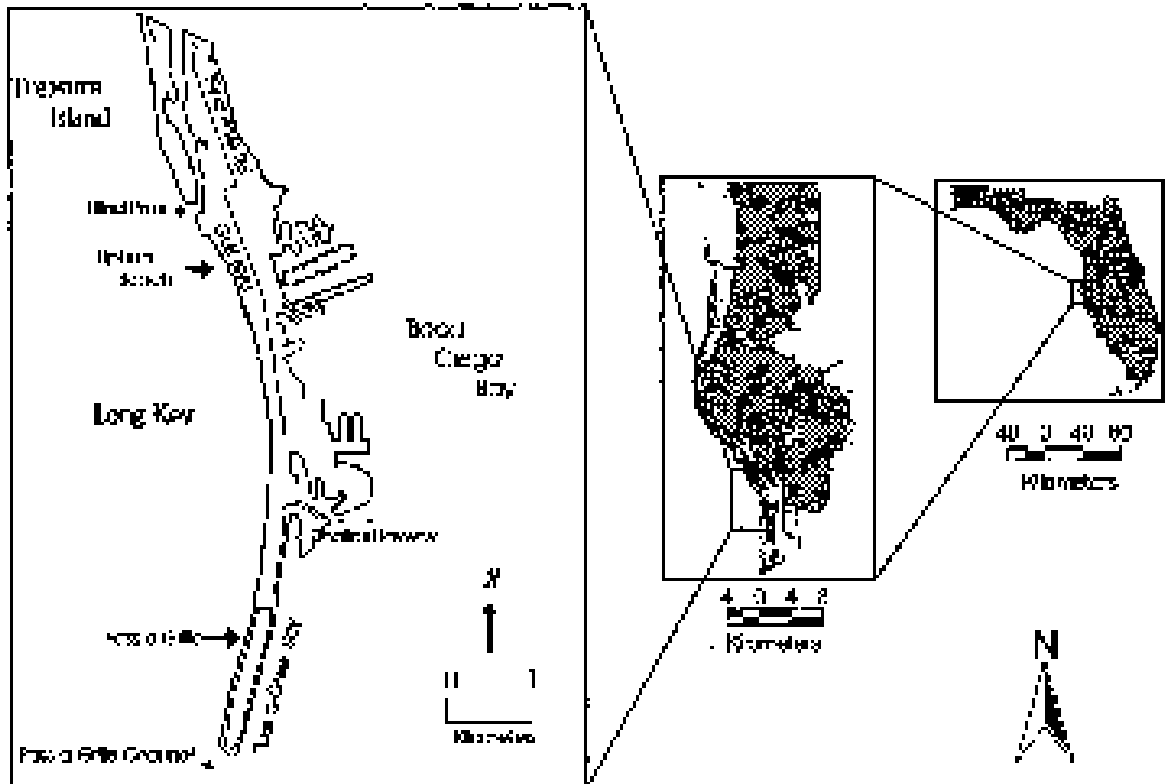


Figure 1: Study Area, Long Key, Pinellas County, Florida

Objectives and Significance

The objectives of this study are threefold. The primary objective is to analyze the performance of Long Key through detailed investigation of shoreline and beach-volume changes at a time when the effects of the most recent nourishment in the summer of 2000 are a minimal influence, and the natural performance of the beach, i.e, the background erosion/accretion rate, can be

determined. This aspect of the study will address two questions: 1) if cross-shore sediment transport is a significant factor in the erosion of Upham Beach, and 2) if there are seasonal variations influencing the beach morphodynamics. The second objective is to examine, in detail, shore-parallel and cross-shore sediment properties. Specifically, this aspect of the study is an attempt to link erosional, stable and accretional areas to sediment grain-size composition. This will determine if sediment properties can be used as indicators of longshore sediment transport. The third objective is to determine seasonal variations of the nearshore morphology and sediment properties of the Long Key beach. This information enables the determination of the significance of seasonal variations on long-shore and cross-shore sediment transport.

While several studies have been conducted to determine the effect of nourishment projects on Pinellas County (Elko, 1999, Herrygers, 1990), there is a lack of studies conducted when there is minimal nourishment influence. To better understand the beach performance, it is crucial to quantify the background erosion rate when artificial beach fill is at its minimum. This study will provide a detailed examination of the performance of a natural beach experiencing intense erosion. For the course of this study, the term natural refers to a beach that has been stripped of nourishment material and other temporary beach stabilization measures. The results of this study will be valuable for understanding the natural dynamic processes at work on Long Key, and will aid coastal planners and engineers in the development of new technology for future nourishment projects, development and conservation practices.

Regional Climate and Seasonal sediment transport patterns

Florida lies in the subtropical climatic belt characterized by seasonal and bimodal weather patterns. The spring and summer months (April through October) are dominated by the Bermuda High, an anticyclonic circulation pattern which brings winds from the southeasterly direction. These weather patterns cause severe late afternoon/early evening thunderstorms (Davis, 1989), which account for most of the annual rainfall. However, there is little effect of these storms on beach processes due to their very short duration (Davis, 1996). An afternoon seabreeze often develops in the summer months. This breeze is due to the development of a pressure gradient that develops between the relatively low pressure over the land, and the higher pressure over the ocean. This pressure gradient causes an onshore flow of air (Hsu, 1988). The seabreeze typically results in slightly higher waves in summer afternoons.

Most beach modification along the west-central coast of Florida occurs during the winter and fall months (October through March). Significantly elevated waves coincide with the passage of winter frontal systems. Southwesterly winds precede fronts that move easterly toward the west coast of Florida. The frontal storms bring strong northerly winds and high wave energy with their passage (Davis, 1989). Prior to the passage of the storms, barometric pressure decreases and the winds are from the southwest. The strong northerly winds generate waves from the northwest and a longshore current that flows to the south. These high waves instigate most of the erosion along the west coast,

although some erosion is the result of infrequent tropical cyclones that occur from June through October.

Hurricanes are relatively infrequent along the west coast of Florida, except the historical hurricane year of 2004. The cyclones enter the Gulf of Mexico from the Caribbean Sea and usually move to the north or northwest direction. These storms usually make landfall along the north or western Gulf of Mexico (Davis and Andronaco, 1987), e.g., along the Florida Panhandle, Texas or Louisiana. However, there have only been eleven hurricanes to pass through the western peninsula of Florida in the last century and make landfall (Heath and Conover, 1981).

Any hurricane that passes less than 100 kilometers of the west central Florida coast will have an effect on the coastline. This is due to storm surge, waves, tide and high winds (Davis, 1989). A hurricane in 1921 caused storm surge of almost three and a half meters above mean sea level. This caused extensive storm damage in the form of property destruction, and created Hurricane Pass and Redfish Pass (Davis and Andronaco, 1987). The contributions of these low-frequency tropical events have not been significant to the chronic erosion of Upham Beach (with 2004 as an exception), at least not during the present study period.

Study Area

Long Key lies in the municipality of St. Pete Beach in southern Pinellas County (Figure 1). It is a highly developed drumstick barrier island that is

concave seaward, with the orientation of the shoreline changing from northwest to north-south, to south-west in the southern portion of the island. There are two public beaches that are locally popular—Upham Beach at the northern end, and Pass-a-grille at the southern end. The island is bordered to the north by Blind Pass and Treasure Island, to the west by the Gulf of Mexico, to the south by Pass-a-Grille and a large ebb-tidal delta, and to the east by Boca Ciega Bay (Figure 1). Blind Pass is a wave-dominated inlet that has been stabilized on both sides to maintain the navigability of the channel and control sand accumulation in the inlet channel. This waterway is used mainly by recreational boaters traveling between Boca Ciega Bay and the Gulf of Mexico, and has provided the sand source for many of the nourishment projects at Upham Beach, including the 2000 project. Pass-a-Grille channel and a series of low mangrove-dominated islands separate Long Key from Mullet Key to the south (Doyle et al, 1984).

Long Key demonstrates a classic drumstick barrier island shape. There is a short, wide, northern end with a northwest orientation, and a long, narrow, southern end with a north-south trend. The north end of Long Key, where Upham Beach is located, is completely developed with several businesses and condominiums along the coast. The most severe erosion is a threat to many high rise condominiums that were built when the north end was stable (Davis, 1989). The south end is less densely populated with mainly residential homes. Figure 1 shows the location of Long Key on the coast of Florida.

On August 10, 1993, approximately 32,000 gallons of mixed light fuels and 330,000 gallons of #6 fuel oil were discharged into Tampa Bay area following the

collision of three vessels (Urquhart-Donnelly et al, 2000). Immediately following the collision there was some oiling of exposed beaches, seagrass bed and mangroves in lower Tampa Bay, but prevailing winds and currents carried most of the oil into the Gulf of Mexico. However, there was a strong storm front on August 14th and 15th, which brought the oil onto the sandy beaches of the barrier island communities, and through the inlets into Boca Ciega Bay. Some of this oil sank, and formed mats on submerged sediments in offshore depressions, Boca Ciega Bay, and in passes such as Blind Pass (Urquhart-Donnelly et al, 2000), located just to the north of Upham Beach and Long Key.

Blind Pass was dredged in January of 2000 for sand placement on Upham Beach and Long Key. During this dredging project, small pockets of oil were found, with an estimated volume of 50 gallons. Dredging was halted, and the Coast Guard initiated cleanup and oil containment procedures. Samples of these oil pockets were found to be a match to the #6 oil spilled in Tampa Bay in 1993 (Urquhart-Donnelly et al, 2000).

Several locations along the length of Long Key, particularly the northern end, show remnants of the oil emplaced during the 2000 nourishment project. The sediments form bands of cohesive material that exhibits a vague fuel odor. These dark bands of oily cohesive material are seen most clearly in the scarp. These bands are seen in Figure 2, a photograph taken in January 2004, at profile location LK 4. There are also large clumps of material in the swash zone, which are seen in Figure 3, a photograph taken in August 2003. An attempt to remove the oily material was made in April 2003, and the beach was graded to a gentle

slope after the removal. However, following the procedure the cohesive material persisted, as shown in Figures 2 and 3, and the slope of the beach returned to the pre-graded position within two weeks with minimal longer-term influence.



Figure 2: Photograph of oily, cohesive band of material found at Location LK 4. This picture was taken January 15, 2004.



Figure 3: Photograph of clumps of oily cohesive material in the swash zone at profile location LK 4A, looking southward, August 2003.

History and Development

While Long Key demonstrated typical drumstick barrier island morphology, it is not demonstrating typical such beach performance. Typical drumstick barrier islands have a large “bulge” at the updrift portion of the island, which is attributed to waves refracting around the ebb-tidal delta (Davis and Fitzgerald, 2004). Figure 5 is a representation of a drumstick barrier island and the processes that form them (Hayes, 1975). At Long Key, this bulge should be represented by the northern end, as the dominant longshore current is to the south. The downdrift portion of typical drumstick islands is narrow and formed through spit accretion (Davis and Fitzgerald, 2004). This is represented by the southern part of Long Key. On Long Key, the northern end is eroding very rapidly (Davis, 1989), while the southern end is relatively stable. There is some accretion shown in the central portion of the island. This unusual trend is due to the human development in the area. Human development, combined with natural processes, caused the loss of the ebb tidal delta of Blind Pass. Natural processes include the hurricane that opened John’s Pass to the north of Blind Pass. John’s pass captured a large portion of the tidal prism of Boca Ciega Bay, resulting in a dramatic prism decrease at Blind Pass. The building of causeways and dredge-and-fill construction further decreased the tidal prism of Blind Pass, which resulted in the

diminishing of the once substantial ebb-tidal delta. These in turn starved the down-drift beaches of the north end of Long Key of sediment supply.

Blind Pass was once a well-developed tidal inlet with a large ebb tidal delta and channel-margin linear bars. These morphological characteristics are seen in early maps from 1873 and aerial photographs from 1926, one of which is shown in Figure 6. These maps and photos also show Long Key exhibiting a classic drumstick barrier shape. The wider, north end formed as waves refracted around the ebb delta and deposited on the north end as swash bars that migrated onshore. This was caused by a local reversal in sediment transport from the dominant long shore sediment transport to the south (Hayes, 1975).

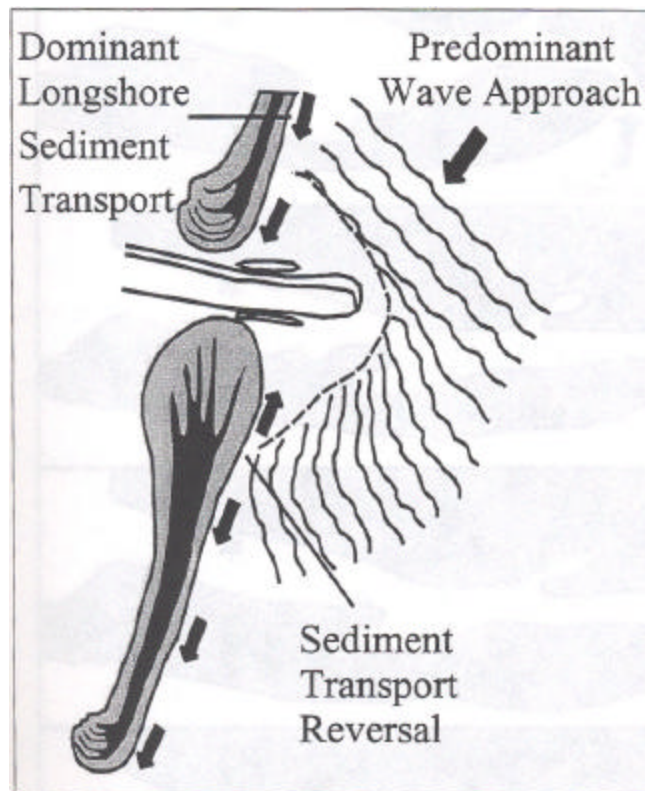


Figure 4: Process-response model of a drumstick barrier island (revised: Hayes, 1975)

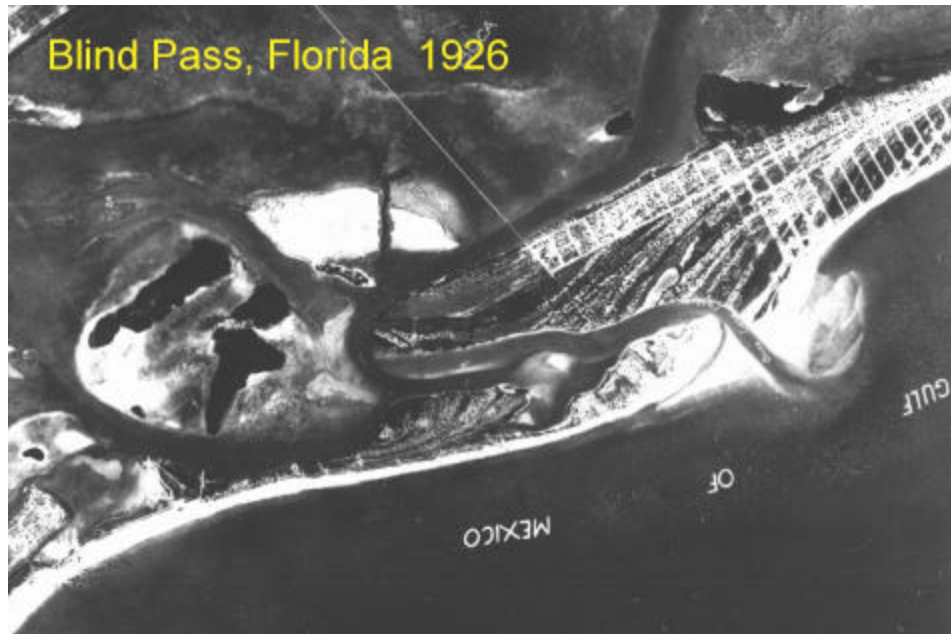


Figure 6: Aerial photograph of Blind Pass and Upham Beach, 1926.

These swash bars introduced a prograding beach ridge complex to the updrift end of the barrier island. This led to sediment starvation of the southern end, as is typical of most drumstick barrier islands. Figure 5, from Hayes and Kana, 1976, models sediment transport and deposition as a function of wave refraction around the ebb-tidal delta.

When John's Pass was opened in 1848, most probably by a hurricane, Blind Pass lost a large portion of its tidal prism and became wave dominated (Mehta, 1976). This diminished tidal prism caused Long Key to lose much of its sediment source, and the northern end of Long Key stopped accreting. The opening of John's Pass also catalyzed the southerly migration of Blind Pass.

Since the 1920s, the tidal prism has been further reduced by the construction of causeways and dredge-and-fill construction. This construction accelerated the diminishment of Blind Pass's tidal prism and overall cross-

sectional area of the inlet (Davis, 1989). However, Blind Pass was already on its southerly migration course before this human intervention (Figure 6). In 1936, in order to halt the southerly migration, the southern side of Blind Pass was stabilized with a 27-meter jetty. Over all, the inlet moved 1.6 kilometers from 1873 to 1936. This is an average of 28 meters per year (Mehta et al, 1976).

Dredge-and-fill construction was very popular in the development boom following World War II. This construction involves depositing dredged sediment on the lagoon side of the barrier to create fingers of land for residential property (Davis, 1989). Dredge-and-fill construction decreased the size of Boca Ciega Bay from $2.8 \times 10^7 \text{ m}^2$ in 1929 to $2.1 \times 10^7 \text{ m}^2$ in 1969 and increased the size of Long Key (Mehta, 1976). The combination of anthropogenic activity and natural events so reduced the tidal prism of Blind Pass that the ebb tidal delta no longer exists, and north Long Key became starved of its sediment source due to the diminishing of sediment bypassing across Blind Pass.

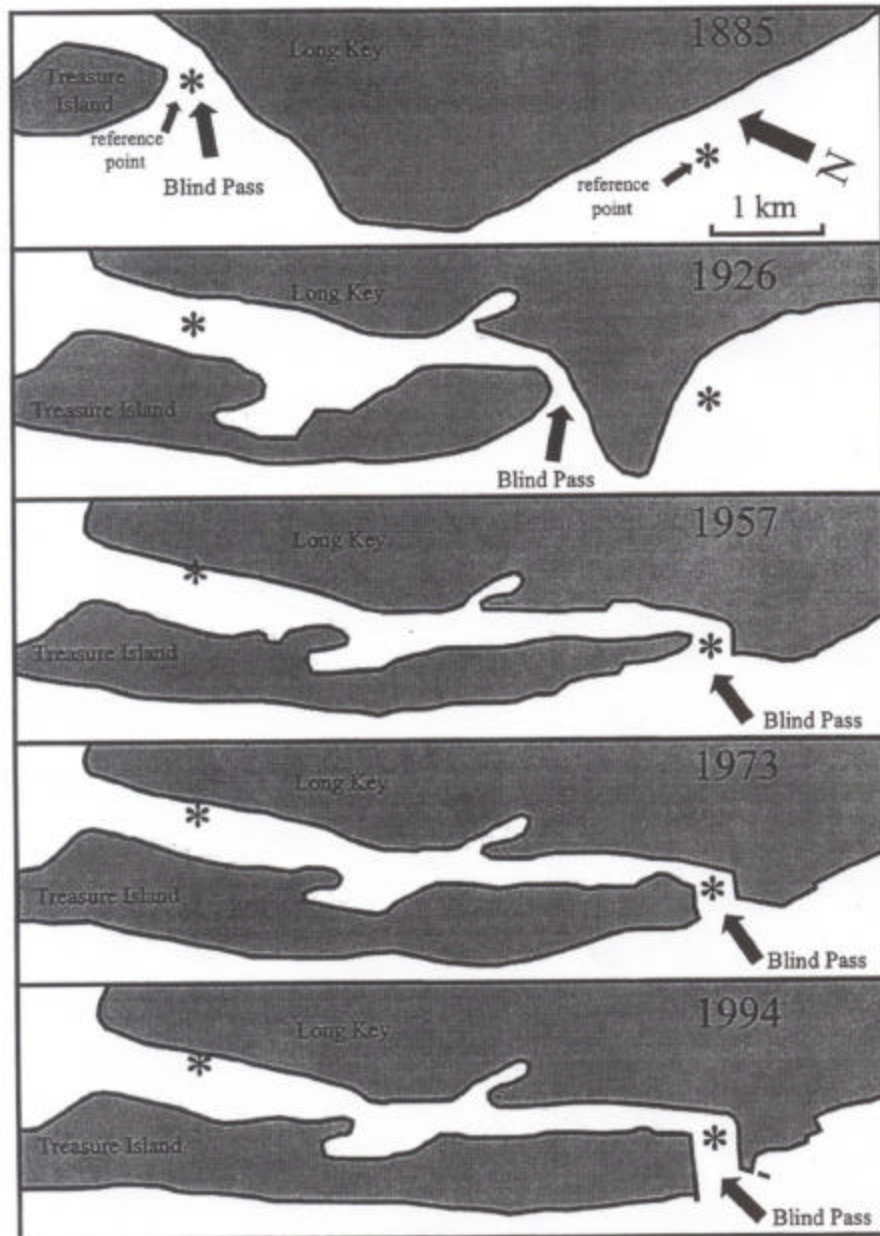


Figure 6: Time series map outlining the southerly migration of Blind Pass and stabilization (Barnard, 1998)

Significant development continued in the 1960s with the construction of a 110-meter jetty on the north side of Blind Pass to prevent shoaling in the channel. In 1975, the opposite jetty was extended to 80 meters during a

nourishment project. However, these efforts were not enough to keep Blind Pass open, and it was closed completely in 1978. In response to this closing and to attempt to slow the shoaling, the north jetty was extended to 160 meters in 1983, and the south jetty was extended to 96 meters in 1986. The cross sectional area of Blind Pass stabilized following the jetty construction in 1986. These construction projects have made Blind Pass the most artificially controlled inlet on the west coast of Florida (Bernard, 1998). The pass still needs to be dredged periodically, since the shoaling rates remain as high as 57,000 meters³ per year (Loeb, 1994).

Anthropogenic activity in the form of dredge-and-fill construction and stabilization projects has caused the previously well-defined ebb-tidal delta of Blind Pass to vanish. This lack of delta removes the local reversal and wave refraction, causing the swash bars to disappear. With no sediment supply, there was no way for the updrift end of Long Key to continue progradation, as it once did. Thus, the north end of Long Key is now experiencing severe erosion, with progradation of the southern end of the island. Figure 7 is an aerial photograph taken in 2000 to illustrate the distinctive differences between 1926 and present. There is clearly no large ebb tidal delta seen in the 2000 photograph. When Figure 7 is compared to Figure 5, the ebb-tidal delta is much smaller, as are the beaches of Long Key.

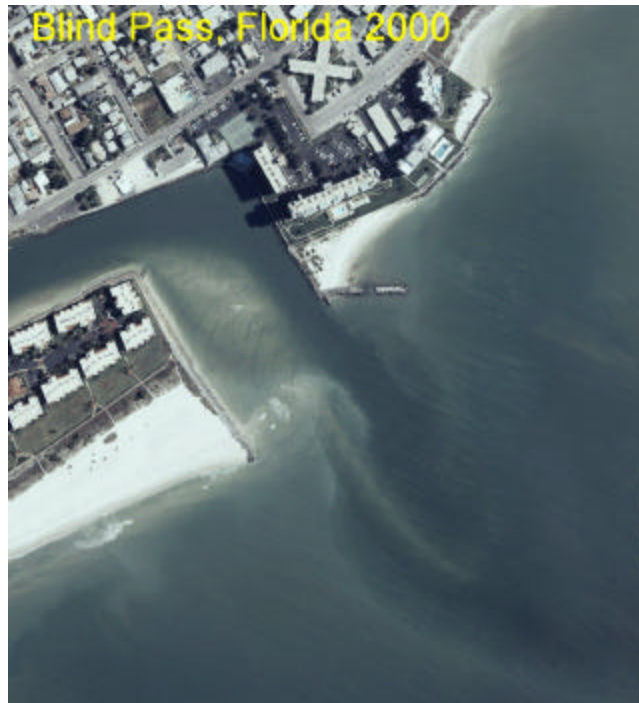


Figure 7: Aerial photograph of Blind Pass and Upham Beach, 2000, showing current structures and the lack of a well developed ebb-tidal delta.

There are two main sources of sediment for the central portion and southern end of the island—littoral sediment that would have been trapped in the ebb tidal delta if it persisted, and sediment from the northern end nourishment projects. This combination of sediments has stabilized the south end. Between 1950 and 1960, groins, a seawall, and a rubble-mound jetty were installed at Pass-a-Grille. This area has been stabilized since 1992, with no nourishments necessary. The history of development on Long Key is listed in Table 1.

Table 1: History of construction on Long Key (Mehta et al, 1976, Loeb, 1994, Elko, 1999).

Year	Construction	Site	Total Length
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1936	Jetty	South Blind Pass	30 m
1950	Groins, seawall	Pass-a-Grille	
1959	Rubble mound jetty	Pass-a-Grille	
1960	Bulkhead	Upham Beach	280 m
1962	Jetty	North Blind Pass	130 m
1962	Extended jetty	Pass-a-Grille	
1974	Extended jetty	South Blind Pass	80 m
1976	Extended jetty	North Blind Pass	110 m
1980	Sand breakwater	South of Blind Pass	
1986	Extended jetty	South Blind Pass	96 m
1989	Dune planting and sea oat fencing	Pass-a-Grille	

The nourishment history of Long Key is extensive. Since 1975, there have been six nourishments (Table 2). As seen in the table, the initial nourishment was supplied by sediment dredged from Blind Pass. Over the course of 25 years, the sediment source has changed, but the rate of necessity for these projects, as well as the amount of sediment needed for these projects has steadily increased.

For the most recent nourishment project in 2000, material from Blind Pass was removed to enlarge the cross-sectional area of the inlet and maintain the

channel. This dredged material was placed along the northern-most 725 meters of Long Key. The first of these nourishment projects began in 1975 with 57,000 cubic meters of sediment (Mehta et al, 1976). The nourished area extends from Blind Pass to the south end of the seawall located at the south end of Upham Beach. This sediment was fully eroded within two years, and the pre-nourishment position was re-established. The Army Corps of Engineers monitored the rate of erosion following the 2000 nourishment. Figure 8 illustrates the rapid initial rate of erosion following the nourishment in 2000, showing volume loss over the two years following the project. These figures illustrate the intense rate of erosion, which can be seen by the loss of approximately 50% of the entire project within the first two years.

Table 2: History of Nourishment on Long Key: (Mehta et al, 1976; Loeb, 1994; Trembanis and Pilkey, 1998; Elko, 1999)

Year	Site	Sediment volume (m ³)	Length (m)	Source
1975	Upham Beach	57,000	725	Blind Pass
1980	Upham Beach	194,000	725	Blind Pass
1986	Upham Beach	74,000	725	Pass-a-Grille Channel
1991	Upham Beach	176,000	725	Blind Pass
1996	Upham Beach	193,000	725	Egmont Channel
2000	Upham Beach	236,000	725	Blind Pass
	Upham Beach Total	930,000		

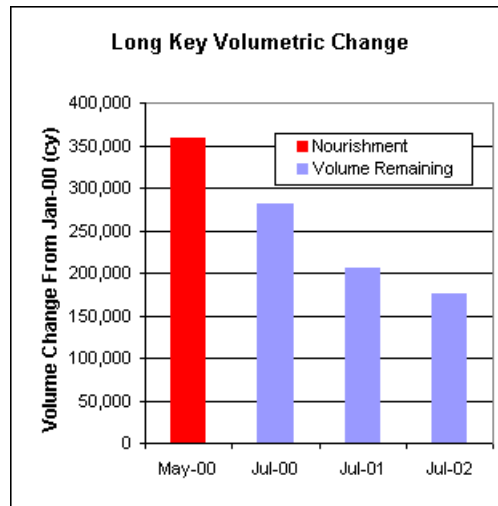


Figure 8: Volume change on Long Key following the 2000 nourishment project, showing a 50% loss in two years (USACE, 2002).

Coastal Processes

The west central Florida coast is a mixed energy region with a combination of wave-dominated and tidally influenced barriers. Pinellas County beaches illustrate the barrier island patterns by forming in chains, and extend for tens of kilometers in each direction from the ebb tidal delta near the mouth of Tampa Bay. (Davis, 1989) These islands demonstrate considerable range in shoreline orientation (Davis, 1991). These beaches are characterized by a tidal range of less than one meter, and a mean annual wave height of approximately thirty centimeters (Tanner, 1960; Davis, 1988). According to the National Ocean Survey, the spring range is 0.76 meters at Blind Pass and 0.64 meters at Pass-a-Grille. This is a microtidal system, and the tides are a combination of diurnal and semi-diurnal.

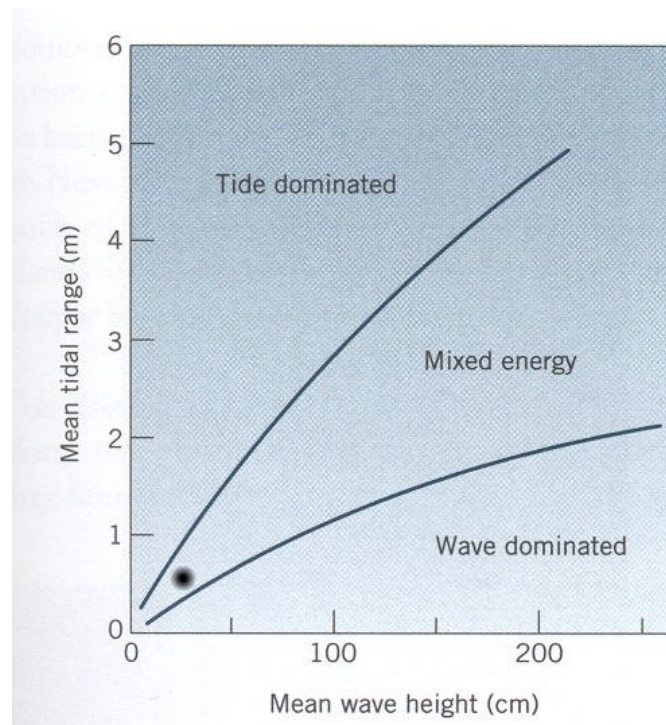


Figure 9: Depositional coastlines separated into three major types based on wave and tidal energy (Hayes, 1975). Long Key is designated with a dot.

This system is classified as a mixed energy coast. This is shown in Figure 9, where Long Key is designated with a dot. Since barrier islands fall almost exclusively into the wave-dominated or mixed energy regime, the position of Long Key is as expected. For this classification, both wave and tidal processes are crucial to shaping the beach. Barriers on mixed energy coasts, like Long Key, tend to be drumstick shaped, with a greater number of tidal inlets than seen in wave-dominated coasts (Davis and Fitzgerald, 2004).

The indigenous sediment on Long Key is bimodal with fine-grained quartz sand mixed with various amounts of shell (U.S. Army, 1985). Beach quality sand is concentrated in the ebb-tidal deltas and in linear ridges found on the inner shelf (Hine et al, 1986). No new terrigenous sediment is being introduced to the west coast of Florida (Brooks et al, 1998); however there is a small amount of carbonate production from organisms.

Distribution of sediment is controlled mainly by littoral transport, with migration between inlets (especially ebb-tidal deltas), beaches, and near shore bars. Net littoral transport is to the south, with very little net cross-shore transport evident except in the vicinity of tidal inlets. Estimates of longshore sediment transport range from 19,000 cubic meters per year (Walton, 1976) to 57,000 cubic meters per year (Loeb, 1994).

PREVIOUS STUDIES

Performance of nourished beaches

Many beaches have been nourished since the 1930s, however most of these nourished beaches have been inadequately monitored and documented (Stauble and Nelson, 1983). Usually, the information collected is restricted to the time period just prior to and following a nourishment project. Long Key is an example of this lack of complete data collection. Ideally, data from the entire time period between nourishments should be collected.

There have been several studies conducted on the island of Long Key. McKenna (1990) examined nearshore gradients, the effects of wave, climate, and sediment removal rates. It was determined that Upham Beach demonstrates seasonality in the deposition of sediment, with a summer progradation of approximately 10 meters (McKenna, 1990). The summer progradation may have come from a local reversal of littoral drift. This summer progradation was confirmed by Hogue (1991), which supported the erosional nature and seasonality of Upham Beach.

Elko (1999) conducted a comprehensive study of the performance of Long Key prior to the most recent nourishment project. That study incorporated beach profile data with climate data, sediment budgets for the island and a model for wave refraction. It was determined that Upham Beach lost three times the

historic rate of sediment from 1997 to 1998. Most of that volume loss can be attributed to winter storms and the El Nino storms of 1998. Elko also determined that sediment eroded faster than previous nourishment projects, and future nourishment projects will continue to erode rapidly until sediment bypassing at Blind Pass resumes.

Shell content has a distinct effect on the beach performance. It has been determined that in recently nourished beaches, sites with the highest shell content performed better than adjacent sites with lesser amounts of shell (Davis et al, 1991). This trend was also seen by Herrygers (1990) at Redington Beach, where two beaches with high shell content following a nourishment project maintained more sand than nourished beaches with lesser amounts of shell.

Sediment Characteristics

Grain size analysis at Upham Beach has consistently been shown to be bimodal, with peaks in the gravel and fine sand fractions. The gravel can be attributed to the shell content. However, while studies of sediment characteristics have been performed, a detailed study on the temporal and spatial distribution of sediment properties has not been conducted on Long Key.

Haney (1993) performed a detailed analysis of grain size characteristics at one location on the west coast of Florida. This study focused extensively on the sediment distribution in the swash zone of a shelly beach. The samples were sieved at half-phi intervals, and used a shorter than average time scale to prevent shell breakage. The shell content was also examined to determine how

density variation affected the hydrodynamic properties of the sediment over the course of tidal cycles.

Elko (1999) also performed grain size analysis on the sediments at Long Key. However, the study was conducted using a settling tube to determine mean grain size and standard deviation of the sand fraction. According to Folk, 1974, grain size of sediment determined that way is generally less accurate; especially when there is a large variation of grain shape, although can be conducted more rapidly.

METHODOLOGY

This study encompasses data collected in the field, and analysis in the laboratory. Beach profiles were surveyed to analyze beach performance, and to determine volume and shoreline change. It is also possible to evaluate cross-shore sediment transport from the change of profile shapes. Sediment samples were collected to determine if sediment characteristics could be used as indicators of longshore sediment transport, as well as being a determinant of seasonal variations.

Field Methods

Beach Profiles

The Florida Department of Natural Resources has placed 192 monuments spaced 300 meters apart along the Pinellas County coastline. Of these, 28 are located on Long Key (Figure 10). These monuments are denominated with the prefix R, and are numbered R139-R166 starting from the north end of the island. While the Florida Department of Environmental Protection (FDEP) has performed irregular monitoring of these sites in the past, the most comprehensive studies done the in the last few years are the work of the Coastal Research Laboratory at the University of South Florida.

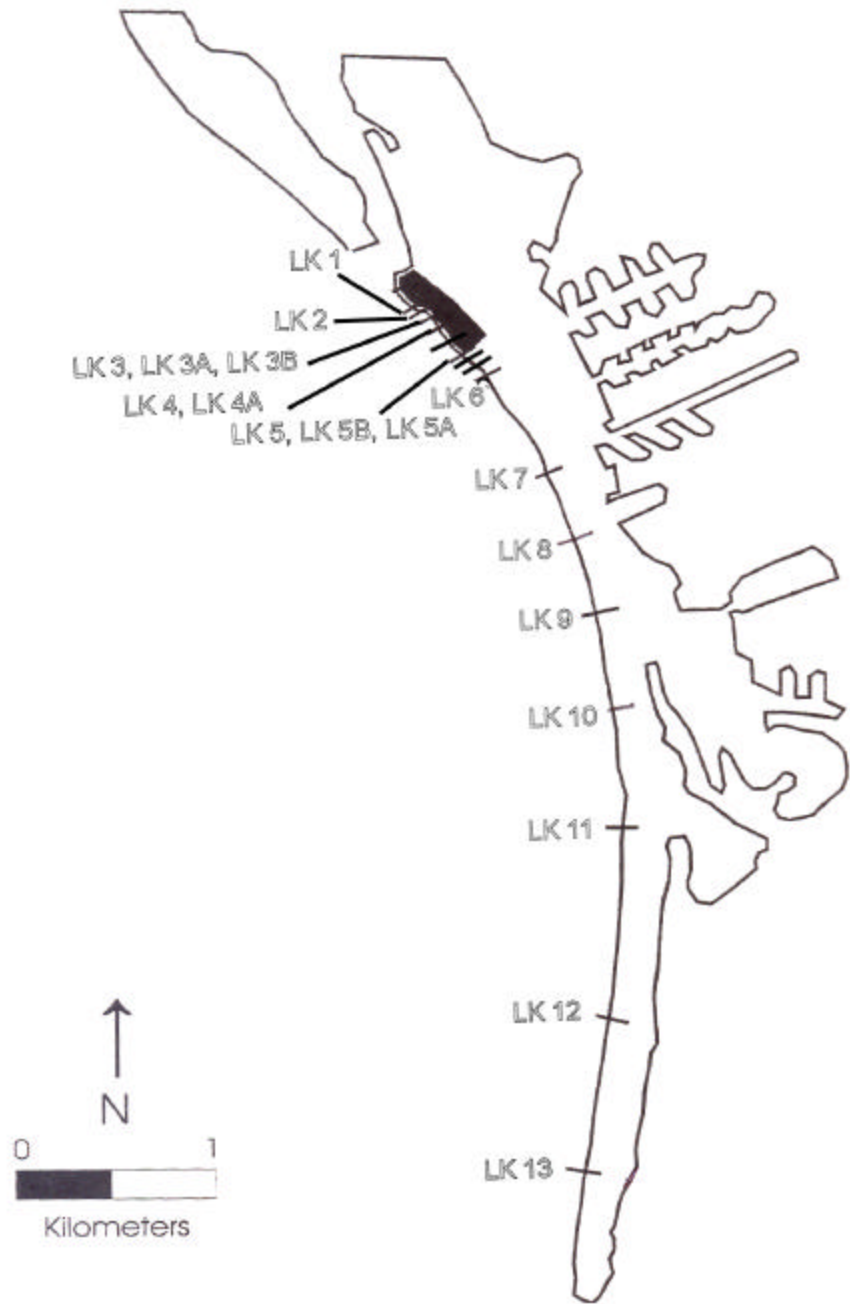


Figure 10: Profile locations on Long Key

Upham Beach is experiencing the most intense erosion, and is thus the recipient of a more clustered monitoring scheme (Figure10: Long Key). In

Order to obtain a clear vision of the beach's variation over the course of the year, several additional monuments at the north end of Long Key were established. Those are labeled LK-BP (Long Key-Blind Pass) and were established by the Army Corps of Engineers. These markers are used by the Coastal Research Laboratory for surveying, in addition to the FDEP markers (Table 3). The monuments were combined in this study for the convenience of discussion, and the names used in this study are also listed.

For the course of this study, ten of the previously mentioned monuments were concentrated on the north end of Long Key to monitor Upham Beach. Eight more monuments are spaced at larger intervals to cover the central and southern portions of Long Key. These monuments are used to study beach morphodynamics through time series beach profile surveys over the course fourteen months, beginning in February 2003 and concluding in March of 2004. Three of these profiles (LK 5, LK 5B and LK 5A) are focused on the region with the most remnant oily material. The surveys are conducted using a Sokkia electronic theodolite and survey rod with a reflecting prism following the standard level and transit survey procedure. This equipment is accurate to ± 0.002 meters. Shore-normal profiles are surveyed to an average water depth of 1.5 meters below NGVD (roughly 15 centimeters below mean sea level in this area). Distance and elevation measurements at significant topographical changes along an established azimuth were surveyed. This azimuth is perpendicular to shore, and measured with a compass to ensure the integrity of the measurement.

Profile information was temporarily stored in a data logger, then downloaded and analyzed in the laboratory.

Table 3: Long Key profile names, with benchmark elevations and azimuths

MONUMENT	NAME	BENCHMARK ELEVATION (m)	AZIMUTH (°)
NEAR 139	LK1	6.54	210
NEAR 139	LK2	6.11	220
LK3	LK3	8.7	220
NEAR LK3	LK3A	7.76	220
NEAR LK3	LK3B	7.97	225
LK4	LK4	9.245	230
NEAR LK4	LK4A	7.69	230
LK5	LK5	6.11	230
NEAR LK5	LK5B	6.12	225
NEAR LK5	LK5A	7.03	235
147	LK6	7.36	230
149	LK7	8.08	240
151	LK8	5.35	255
153	LK9	7.5	255
155	LK10	6.20	260
157	LK11	14.69	270
160	LK12	9.36	270
163	LK13	9.66	275

Sediment Samples

Sediment samples were collected at each site along Long Key. Samples were collected monthly in order to determine the temporal variation of grain size composition along the severely eroded northern end, and the stable southern end. Variation due to the mixing of several nourishment projects from several sediment supply locations was examined at each location along Long Key. There are at least four sources of sediment that have become well dispersed over time. Each sampling location along the profile (back beach, the top and bottom of the scarp when present, mid beach when the scarp is absent, and in the swash zone) has different mixing processes so it is important to examine the characteristics of each, and how they differ to fully understand the characteristics of Long Key. High concentrations of shell will be noted, since it has been proven that shell content has an influence on beach nourishment performance (Davis et al, 1991). This may allow us to determine the contribution of sediment characteristics in determining why some beaches along Long Key are apparently stable, while others are retreating rapidly. The areas of most intense study (Upham Beach) were sampled monthly, while the entire length of Long Key was sampled bi-monthly. For each location, approximately 200 grams of sediment was collected, placed in a plastic sample bag, and labeled for analysis.

Samples for two months, October 2003 (end of summer) and March 2004 (end of winter), were collected to determine spatial change along Long Key.

Samples for these months were collected at each profile location, at the back beach, the high tide line, the swash zone and at an approximate depth of 1 meter to determine the foreshore beach characteristics. This sampling regime was used to determine sediment characteristics for the entire length of Long Key under identical weather conditions.

Laboratory Methods

Beach-Profile Analyses

Profile data were initially stored in an electronic notebook while in the field and then downloaded in the laboratory. The data were then analyzed using the Army Corps of Engineers Software Beach Morphology Analysis Package (BMAP). BMAP is a program that allows for entry, processing, and analysis of the survey data, making it possible to determine the volume change over a year of nourishment-free beach behavior, and interpret shoreline movement. It is also possible to create average profiles by digitizing the selected profiles using stepwise linear interpolation, then creating an average profile with data points every 3.05 meters. This processing allows for seasonal averages to be determined, with eight winter profiles, and six summer profiles used to create these averages. Winter months are October through March, and summer months are April through September. Because the study began in February 2003 and concluded in March 2004, there is an overlap (February and March, 2004), which explains the larger amount of winter months. An average profile for both winter and summer was calculated, as well as a yearly average.

BMAP also allows beach profiles to be examined at monthly intervals, as well as multiple months simultaneously. This display makes it possible to see seasonal variations and changes in slope throughout the entire course of the study. It is also possible to divide the profile into several sections, and determine volume change in the foreshore, near shore and backshore. This program allows us to clearly illustrate and interpret the changing face of the shoreline.

Sediment Samples

Each sample was rinsed in distilled water to eliminate the salt, then dried in an oven at 120° Fahrenheit. The entire sample of about 200 grams was then sieved. Because a considerable number of samples contained large shells, the weight percentage of individual size fractions could be skewed toward the gravel fraction by one or two large shell pieces, if only a small amount of sediment is sieved.

Each sediment sample was sieved in a Ro-Tap with 20-centimeter mesh sieves at .25 phi intervals ranging from -3.00 +4.00, for a total of 28 sieves. After 7 minutes, the sediment was retrieved from each sieve and the catch pan, weighed and recorded. The time interval was selected in an attempt to reduce breakage of the shell fragments, while allowing the sediment fractions to go through the sieves. The recorded results were then entered into a spreadsheet to determine mean grain size, standard deviation, skewness, and kurtosis based on the moment method. The spreadsheet results were then graphed as size

fraction (ϕ) vs. weight percentage. This procedure is consistent with that of Folk (1978).

The ultrasonic cleaner was used after every 20 samples were completed, to remove sediment possibly clogging the smaller diameter sieves. This minimizes the possibility that larger sample sizes will influence the overall trend.

Classifications of sediment grain-size distribution characteristics were then developed. These classifications were determined by several parameters, such as gravel percentage and overall shape of the grain size distribution. These classifications, in addition to the overall grain-size parameters (e.g., mean, standard deviation, skewness, and kurtosis), were established to investigate the trends of sediments characteristics along the island.

RESULTS AND DISCUSSION

This study investigates the beach performance on Long Key through two different mediums. Sediment characteristics were used to determine in detail the sediment properties of the island in an attempt to link erosional, accretional, and stable areas to sediment grain size composition. Beach profiles are used to determine trends of beach erosion and accretion, their seasonal variations, and the influence of seasonal variations on the overall performance of the beach. Finally, both of these studies are used to determine the performance of Long Key at a time when the most recent nourishment is a minimal influence, and only permanent structures are a factor.

Sediment Characteristics

Monthly sediment samples were obtained from February of 2003 through March of 2004. These samples were collected to investigate the grain size distribution along the entire length of the island. Because the present study is conducted three years after a beach nourishment, when most if not all of the nourishment material has been removed, valuable information on the distribution along the island of the nourished material may be acquired from the sediment analysis. Since longshore sediment transport is to the south, the original hypotheses was that fine grain sediment should dominate the south end, while

coarse material that is not as easily transported should be more concentrated at the north end.

The purpose of analyzing these samples was to determine how the various sedimentological regimes of the island (erosional, accretional, and stable) differ, and to determine seasonal trends along the island. Also, these distributions represent the mixing of sediment from several sources, with sediment at each location mixing differently. To further examine this aspect of Long Key, sediment was examined both temporally and spatially.

Classification of Sediment Characteristics

Following the sieving, the results were graphed on a plot of size fraction (ϕ) vs. weight percentage. Overall, two distinctly different particle distribution patterns were distinguished. These shapes, classified as Particle Distributions A and B, are used to discuss characteristics of sediment distribution.

Particle Distribution A is dominated by one large mode of greater than 25% weight. This distribution is indicative of low shell content, and is dominated by fine sand (Figure 11). This distribution pattern is seen throughout the entire island, and is the dominant particle distribution on Long Key. To allow detailed examination of grain-size distribution patterns, several sub-types were identified in Particle Distribution A.

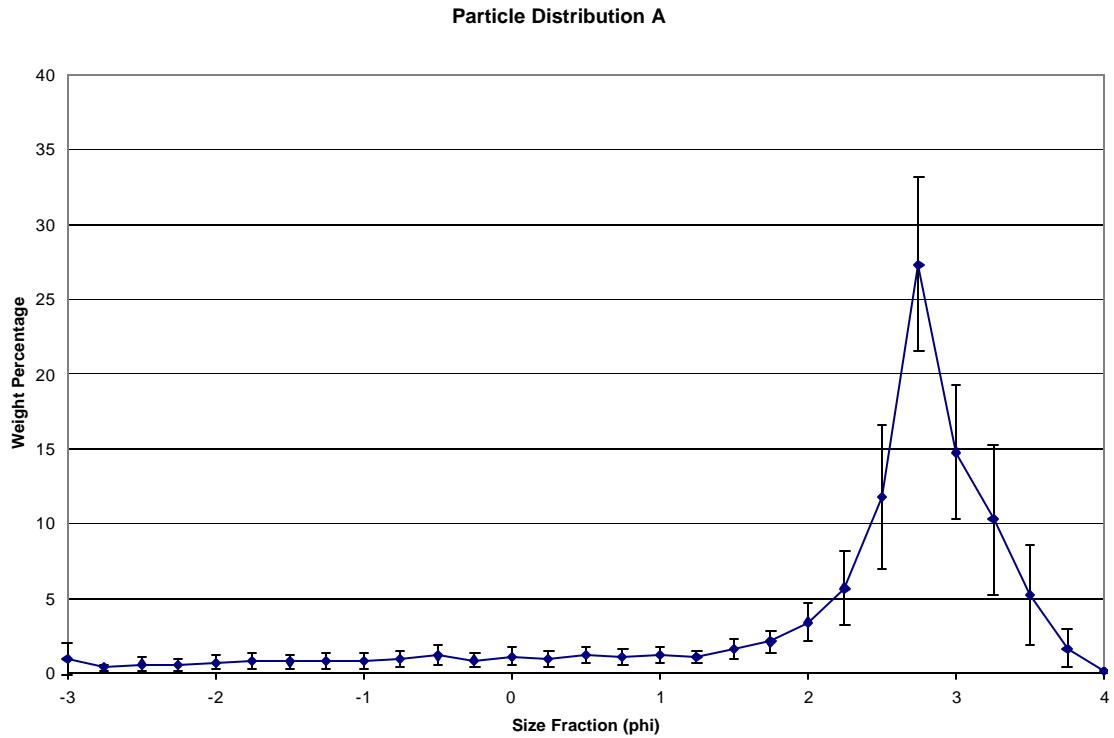


Figure 11: Particle Distribution A, dominated by fine sand, with very little gravel

Particle distribution B occurs much less frequently on the island. There is not one dominant mode; weight percentage is almost evenly dispersed throughout each size fraction (Figure 12). There is one slightly elevated mode at 2.75 phi. This distribution has high gravel concentration, as well as high fine sand concentration, however this distribution is dominated by coarse material.

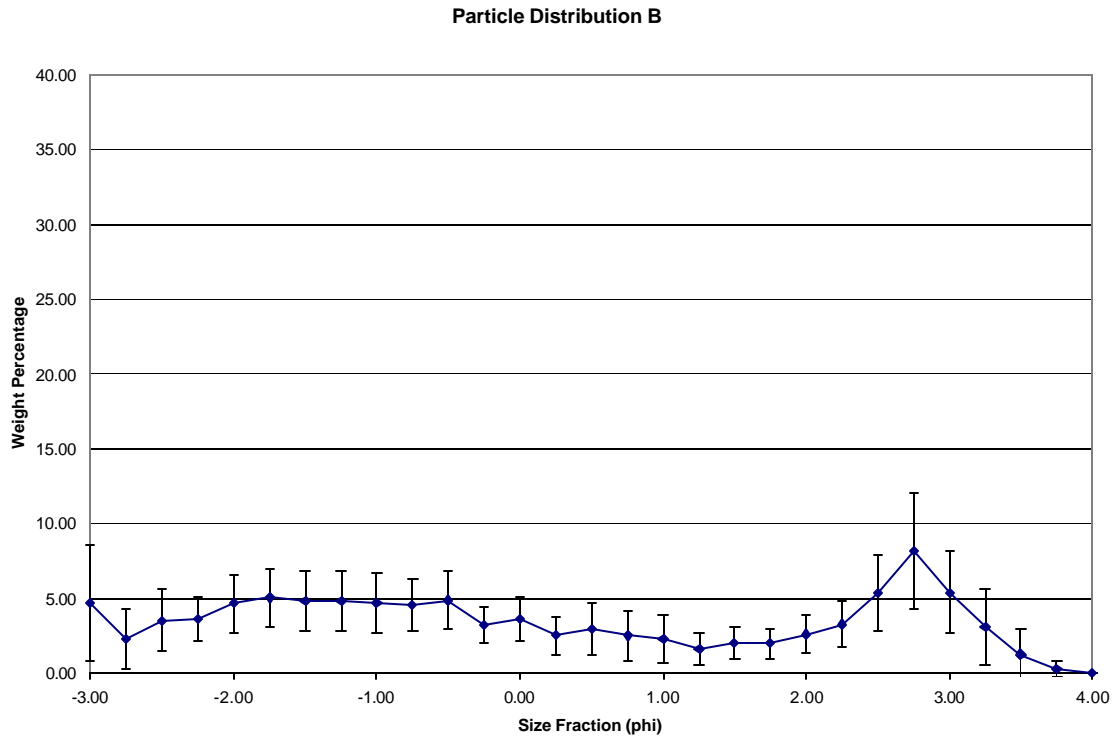


Figure 12: Particle Distribution B: high gravel, with no dominant phi size

Although a large amount of effort was invested in examining the detail grain-size distribution pattern, no convincing trend of particle distribution along the Long Key study area could be identified. Every sampling location, (back beach, top of the scarp, bottom of the scarp, mid beach, high tide line, swash zone and one meter depth) is dominated by particle distribution A. There is a higher frequency of particle distribution B in the swash zone, almost 20%, and there are rare occurrences in the back beach, at the bottom of the scarp, and at the high tide line (Figure 13). Careful examination of various sub-types also failed to reveal any convincing trends indicating a concentrating fine component toward the southern end and coarse component toward the northern end, as

previous hypothesized. In addition, no persistent cross-shore trend could be identified.

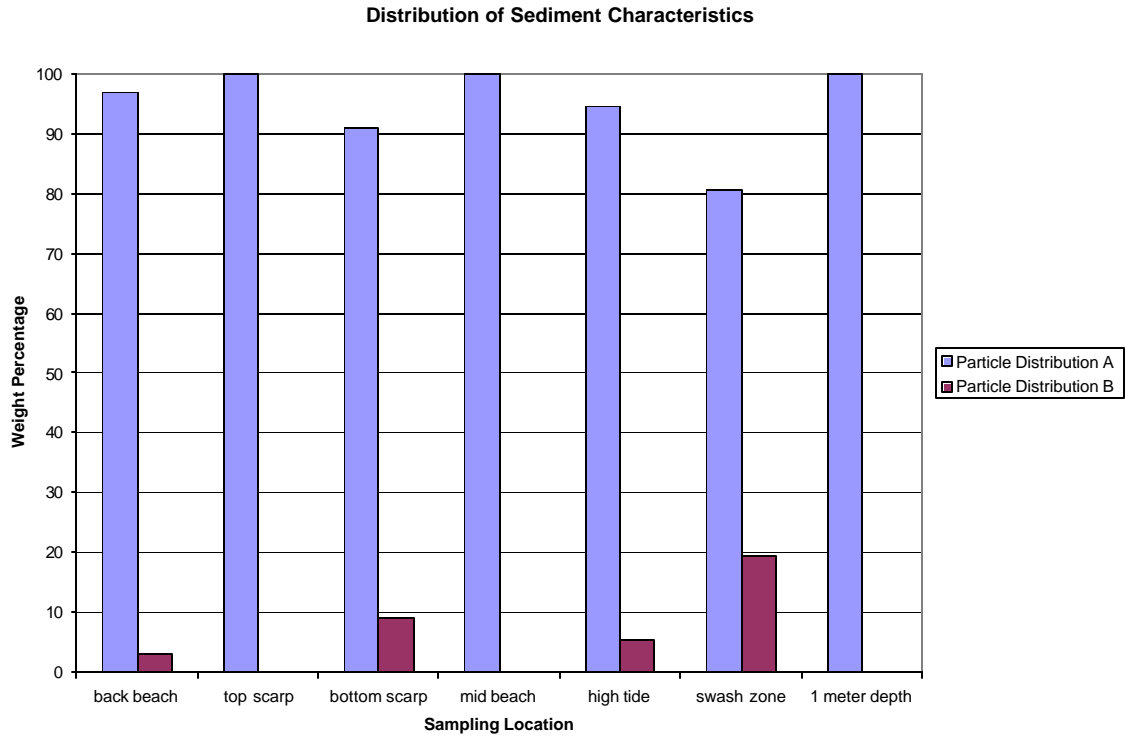


Figure 13: Comprehensive table illustrating where Particle Distribution A and Particle Distribution B are distributed over the seven sampling locations: back beach, top of the scarp, bottom of the scarp, mid beach, high tide, swash zone and at 1 meter depth.

Temporal Distribution of Sediment Characteristics

Sediment samples were collected monthly, with sampling concentrated on the Upham Beach, north Long Key region of the island. Because Upham Beach is experiencing the most radical erosion, the northern most region is the subject of the most interest. However, the southern stable end is also examined to determine characteristics of a stable beach, and to serve as a comparison. This

study was designed to determine how the mean grain size changes over the course of the year as well as how the grain size characteristics adjust over the changes in season. This aspect of the study was performed to determine if longshore sediment transport can be traced by grain size characteristics.

Temporal Sediment Characteristics of Northern Long Key

The northern area of Long Key is best characterized by LK 4. This is a profile with a great amount of erosion, so change in sediment size could correspond with the rapid retreat. The samples analyzed for this study were taken in February, June, September, and October 2003, and January 2004. This is a total of three winter samples, and two summer samples.

The mean grain size of the sediments retrieved from the back beach and the top of the scarp remains very similar throughout the course of the study as is expected (Figure 14). Variation at the bottom of the scarp is only seen in the sediment from January 2004, which is most probably a result of deposition by winter storms or as a lag deposit following winter storms. The swash zone sediments are the only sediments to show variation, with a higher mean grain size seen in the summer months.

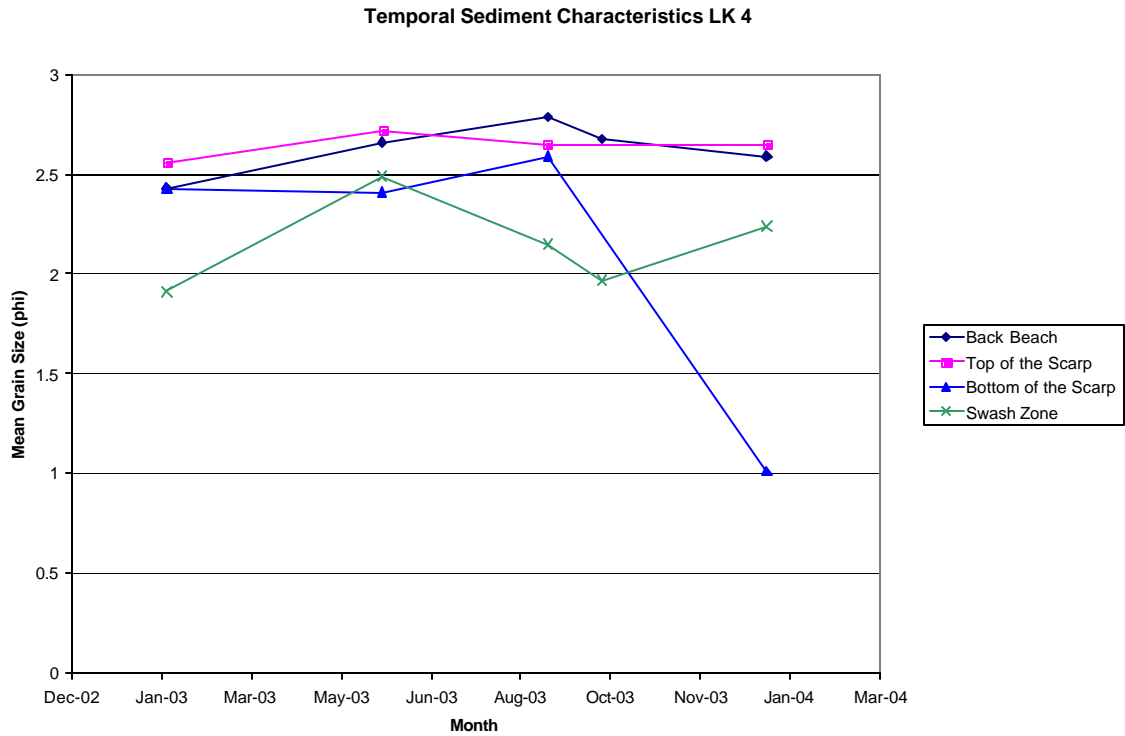


Figure 14: Temporal Sediment Characteristics of profile location LK 4. LK 4 represents the northern region of Long Key.

Temporal Sediment Characteristics of Southern Long Key

The profiles in the southern end of Long Key show slight accumulation, especially in the winter months. These profiles show very different trends than those of the northern half of the island, where erosion is the greatest contributor to sediment characteristics. These results are shown in Figure 15.

Like the sediments in the north end, the samples taken in the southern end portray the same characteristics in the back beach. There is very little variation between summer and winter months. The mid beach samples show slight variation, with mean grain sizes between 1.5 and 2.5 phi. The mean grain size of the swash zone is similar to the mid beach, however in October there is a large drop to less than 0 phi mean grain size. This is indicative of very coarse

sediment, which is not seen anywhere else on the profile. Also, this result was different from the situation at the northern end of the island, where coarser sediment was encountered in January.

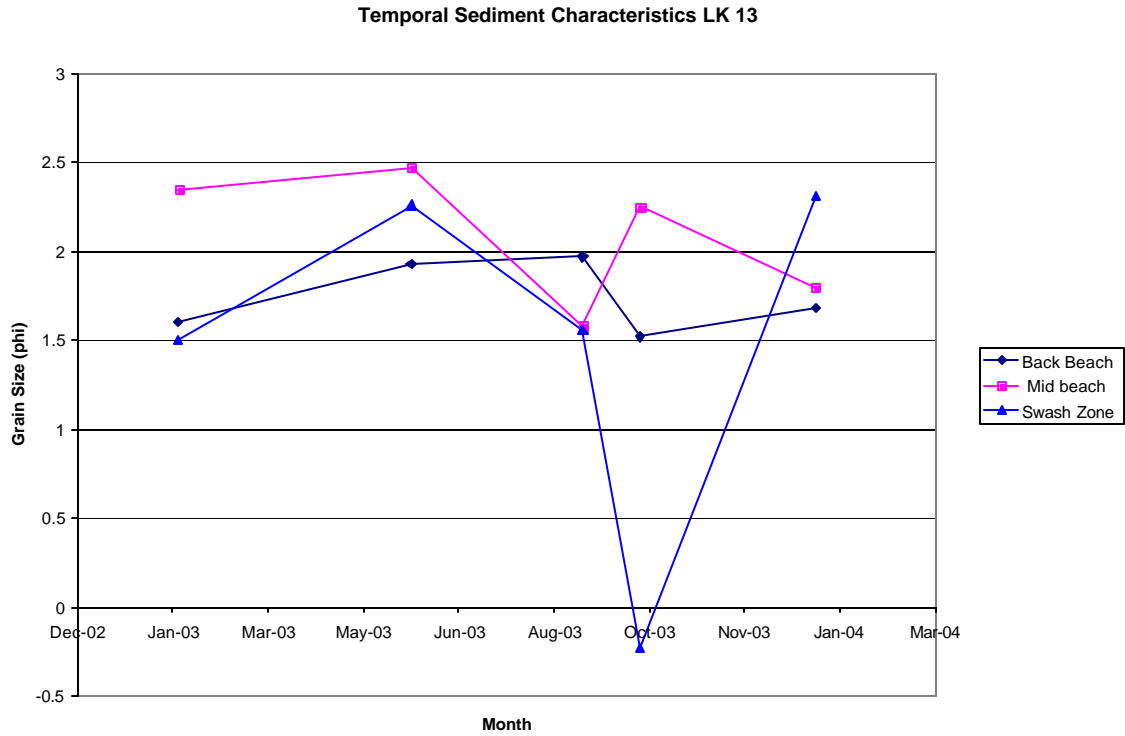


Figure 15: Temporal Sediment Characteristics at profile location LK 13. LK 13 represents southern Long Key.

In summary, sediment characteristics remain similar over the year on the back beach due to the lack of action, as expected. Some temporal variations were observed in the swash zone, although no convincing trend could be identified. Field observations indicate that very short-term, e.g., day to day, process variations seemed to play a significant role in determining local sediment properties.

Spatial Variations of Sediment Characteristics

This aspect of the study was conducted on October 24, 2003. Sediment samples were collected at all 18 profiles, with locations in the back beach, the high tide line, the swash zone, and in one meter of water depth. These samples were taken to examine the sediments at a time of consistent wave energy, weather conditions, and sampling consistency.

The back beach and one meter depth sediments show very little variation in gravel percentage along the length of the island. There is a slight increase in the gravel percentage in the central part of the island; however, the highest gravel is still less than 20%. The swash zone shows great variation in gravel percentage, with the highest amount in the southernmost part of Upham Beach, and in the central portion of the island. This is most likely due to the orientation of the island; the change in wave angle could have created larger waves, thus transporting larger sediment sizes. Finally the high tide sediments have a rise in gravel percentages in the southernmost profiles of Upham Beach, with a large increase in the central part of the island, before having minimal gravel percentages in the southernmost profiles of the island. The spatial scale collaborates well with the data from the temporal data, showing no persistent trend other than a slight coarseness in the central portion of the island.

Overall, sediment properties varied considerably both temporally and spatially. However, at temporal and spatial resolutions applied in the present study, no convincing trend of change can be identified. Sediment properties

cannot be applied to infer patterns of sediment transport, longshore or cross-shore (Figure 16).

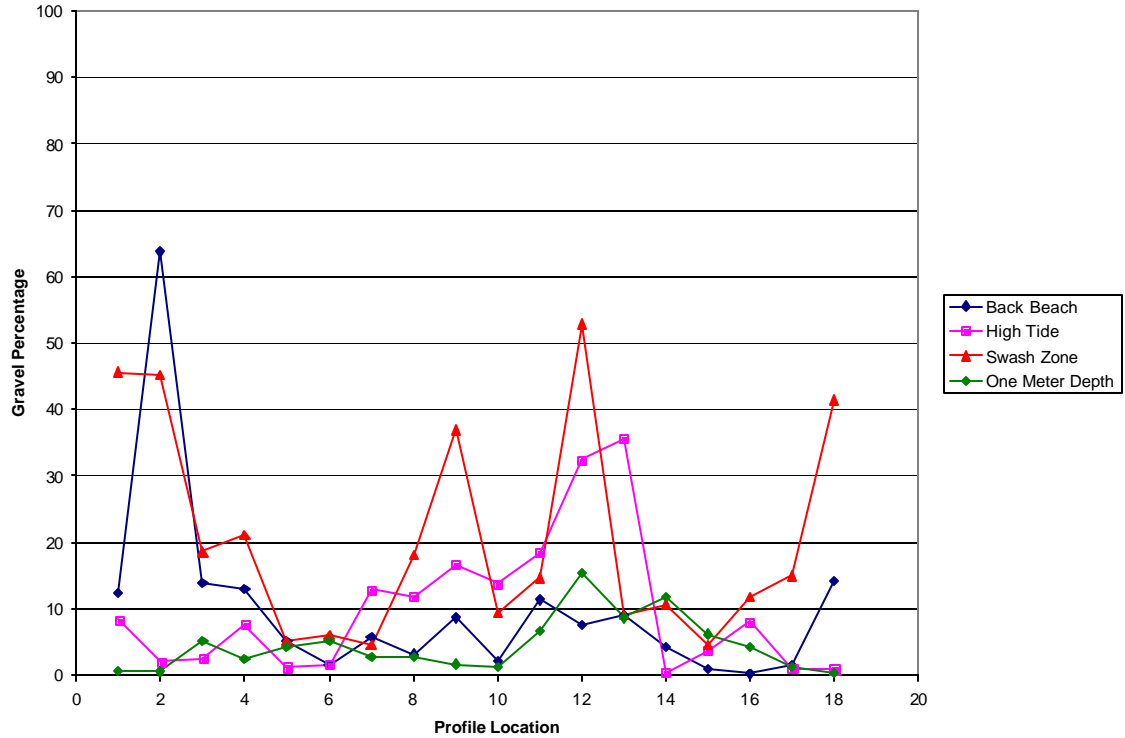


Figure 16: Spatial variation of gravel percentage at back beach, high tide, swash zone and one-meter depth, samples taken October 24th, 2003.

Beach profiles

Monthly beach profiles (Figure 10) were surveyed to illustrate the changing shape of the beach at each of the 18 locations. The time series profiles are a way of determining volume change over the course of the study, and provide an excellent means of understanding the processes at each location. These profiles also serve as a means of comparison between locations, and characteristics of each section of Long Key—the eroding north end, the accreting

central part, and the stable south end. Figure 10 shows the location of all profile locations.

Characteristics of Individual Beach Profiles

LK 1 and LK 2

LK 1 and 2 (Figures 17, 18, 19, and 20) show very little change over the course of this study. These locations are both on a small beach in front of a local condominium. Blind Pass is located immediately to the north. There is a weir jetty just seaward of the end of the southern jetty of Blind Pass that contributes minimally as a protection measure. These profiles can be deemed as stable, because there is no variation over the course of the year. This stability is seen in Figures 17 and 18 depicting the monthly profiles from February and September of 2003 and March of 2004. The minimal change concurs with the seasonal averages, however there is a small profile variation visible in the profile comparison that is not visible in the season average comparison. There is one major difference in the two adjacent profiles however. While LK 1 is virtually shell-less in the back beach and foreshore, LK 2 is almost exclusively shell.

The yearly average profile is almost identical to the seasonal averages, with only a small offshore bar developing in the summer months at LK 1 (Figure 19) that is also seen at LK 2 (Figure 20). In fact, when seasonal averages and the yearly average are overlain, there is virtually no distinguishable difference in the shape of the back beach, the foreshore and near shore profile. It is only at approximately 90 meters distance from shore at LK 1 and 60 meters at LK 2

(Figure 18) that the differences in the profiles become apparent. A possible reason for the bar development is the reversal of wind direction between summer and winter. The locations of LK 1 and 2 are in a quasi-cove that shelters the profiles from strongest effects of the longshore sediment transport to the south. The angle of the cove allows for sediment transport to deposit when the winds are from the south.

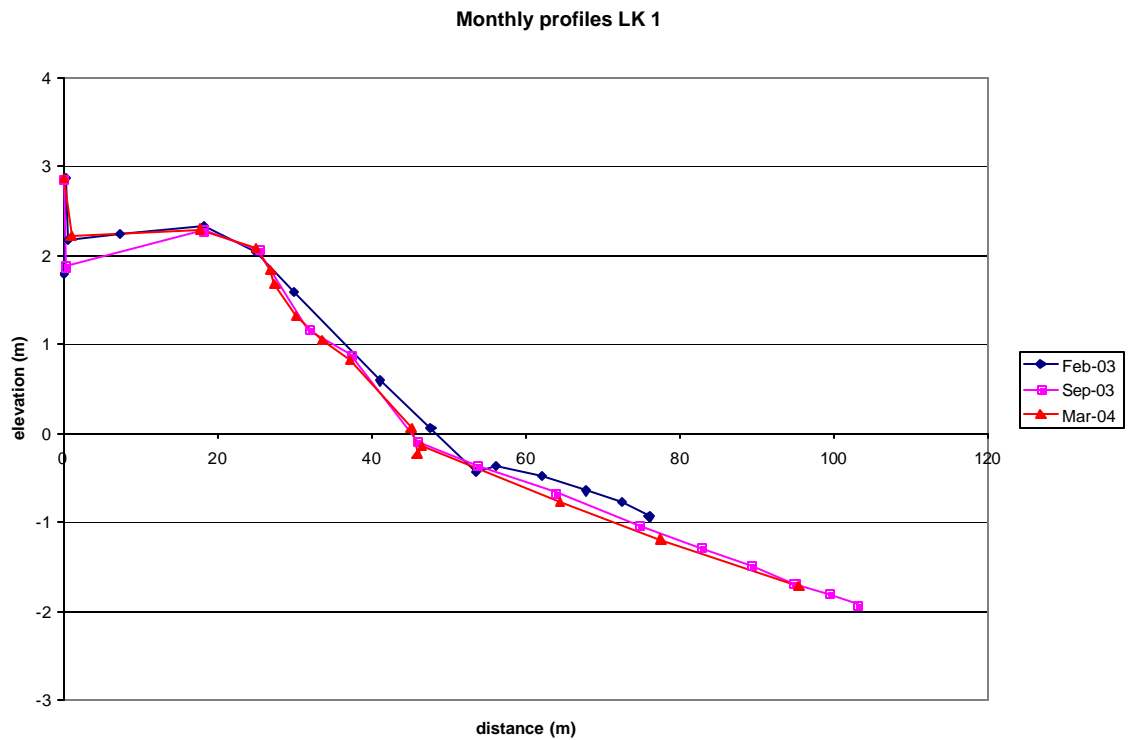


Figure 317: Monthly profiles at LK 1, taken in February and September 2003 and March 2004.

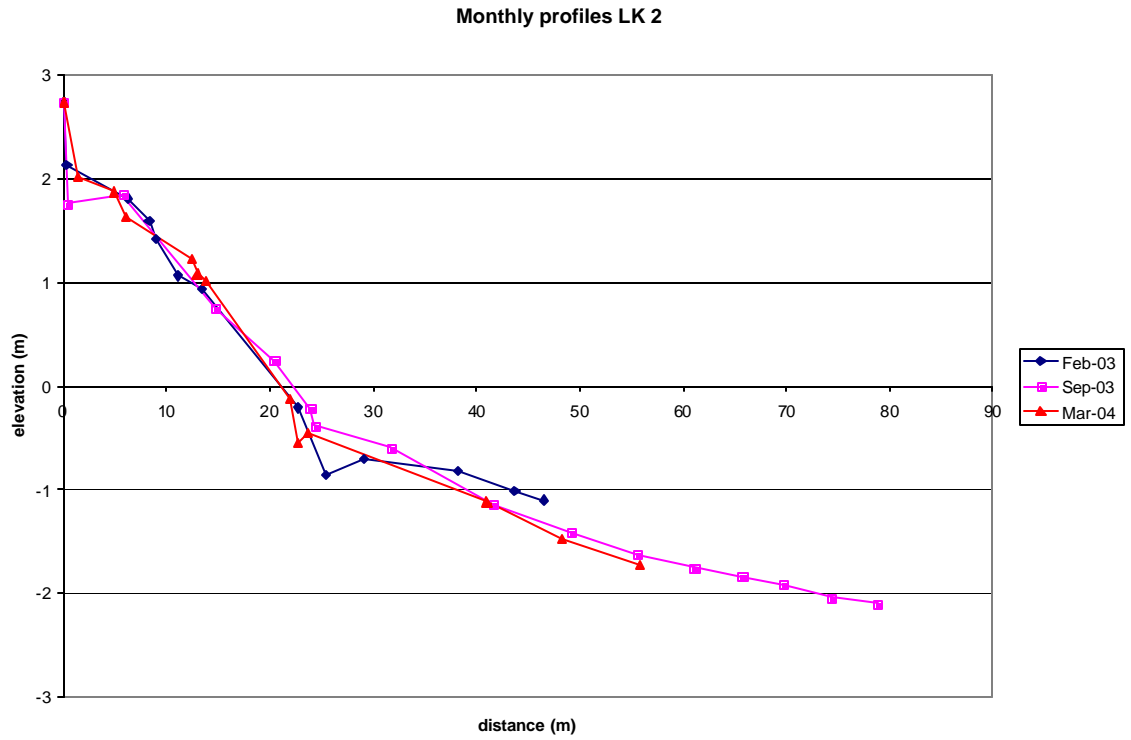


Figure 18: Monthly profiles at LK 2, taken in February and September 2003 and March 2004.

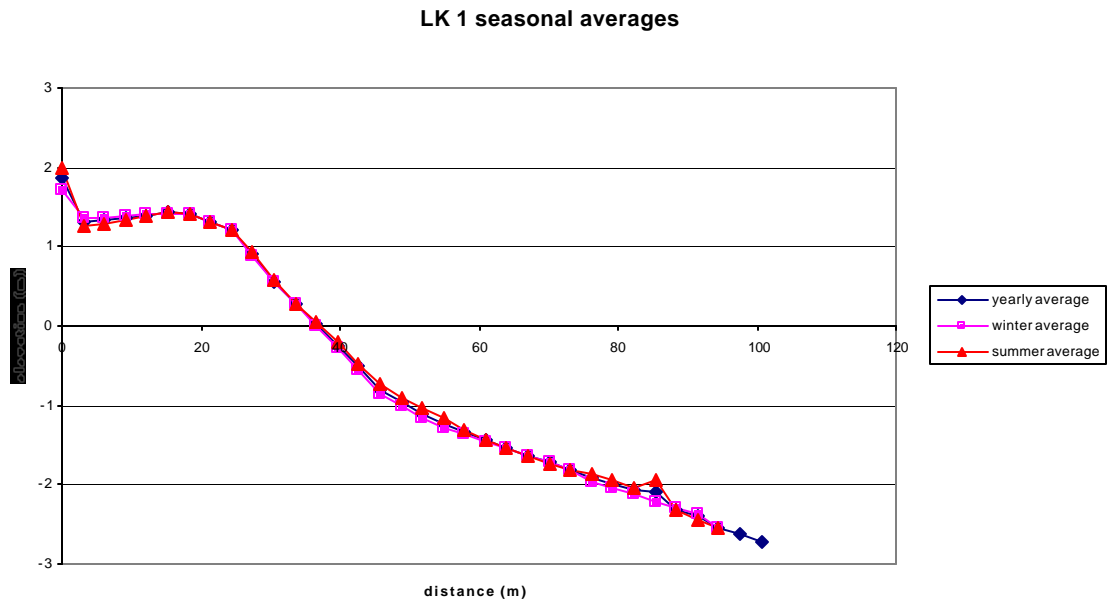


Figure 19: Seasonal averages of LK 1: yearly, winter (October through March) and summer (April through September)

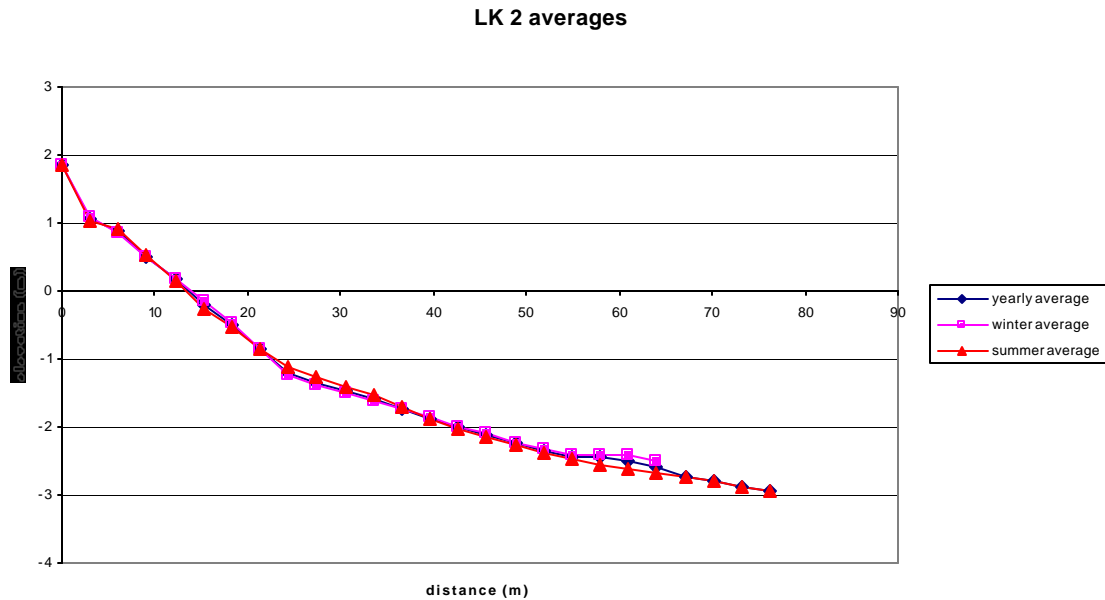


Figure 20: Seasonal averages of LK 2: yearly (February 2003 through March 2004, winter (October through March) and summer (April through September)

LK3, LK 3A, and LK 3B

Upham Beach is the northern end of Long Key, and is represented by monuments LK 3, LK 3A and LK 3B. This profile has additional sites added to obtain a denser sampling pattern, as this is the site of most severe erosion. Just to the north of this location there is a seawall designed to protect a local condominium. This seawall induced substantial erosion of the beach immediately downdrift, which is represented by LK 3 by blocking the longshore sediment transport to the south. Upham Beach has been the recipient of nourishment projects, however the sediment was not retained. During the last nourishment project, remnant oil from a spill was part of the sediment dredged from Blind Pass. The sediment was cleaned, however, some oily material persisted and was placed on the beach as part of the nourishment. This allowed

for cohesive bands of oily material to form, which were unearthed as the scarp retreated. These patchy oily cohesive sediment bands did not have noticeable influence on the beach erosion at these locations.

These beaches maintain an erosional scarp throughout the entire year, which indicates the ongoing erosion (Figure 21). With the lack of sediment influx from Blind Pass, all of the profiles at Upham Beach continue to erode rapidly. The profiles from north to south are LK 3, then LK 3A, then LK 3B, which is located at a beach access ramp.

The profiles LK 3, LK3A and LK3B maintain the same shape while continuing to lose sediment. There is an extreme retreat visible at these locations as seen from February 2003 to March 2004. The greatest retreat occurs between September 2003 and March 2004, which indicates winter storms most likely increased the rate of retreat, with LK3A illustrating the highest rate of winter erosion. However, the rate of erosion at LK 3B is fairly constant over the course of the year, which indicates a lesser winter storm effect. Most importantly, there is no sign of accretion at any point during the course of the study at these locations, including both summer and winter. The reason for the lack of sediment accumulation in the summer time with southerly incident waves is not clear.



Figure 21: LK 3, LK3A, October 2003, looking north. Note the erosional scarp to the left, as well as clumps of oily material at the bottom of the scarp. Also, the shape of the scarp was not influenced by the oily material.

The profiles at Upham Beach are the first to show the erosional scarp (Figure 21). The erosional scarp is formed by wave energy breaking down the bottom of the scarp causing instability. When a threshold is crossed the top of the scarp collapses, and the process begins again. The average summer profile at the scarp is slightly steeper than that of the average winter scarp profile at all of these locations, but the overall shape is very similar. There is also no evidence of offshore seasonal bars as seen in previous profiles.

Figures 22 and 23 illustrate the shape of the beaches at the beginning, middle and conclusion of the study. The scarp is the steep part of the beach

where there is a decline of almost a meter between two data points. These graphs show very clearly the significant retreat of the scarp, almost eliminating the back beach. The seasonal averages are shown in Figure 23 in order to determine seasonal erosional trends from north to south. The summer average was formulated using data from April through September, and the winter averages were formulated with data from October through March. The shapes of the seasonal averages remain nearly identical, indicating no net cross-shore sediment transport.

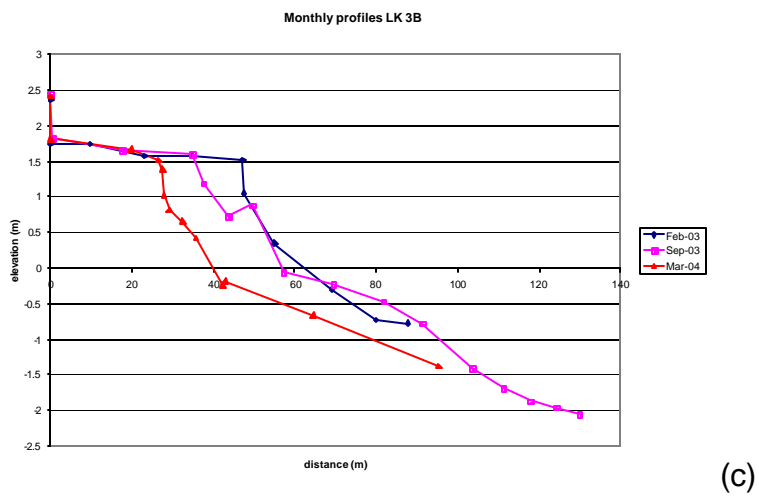
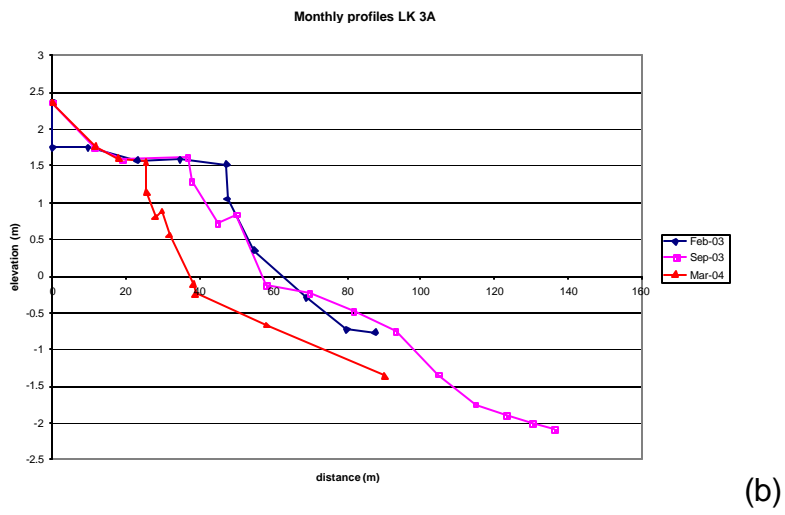
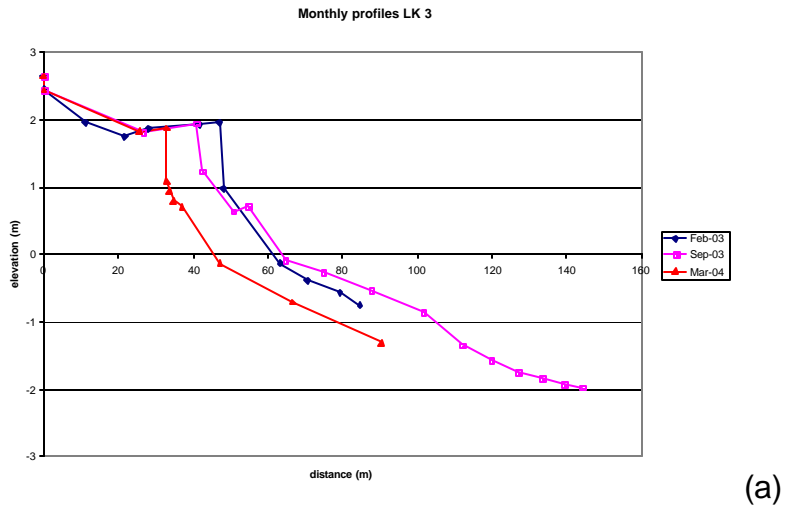
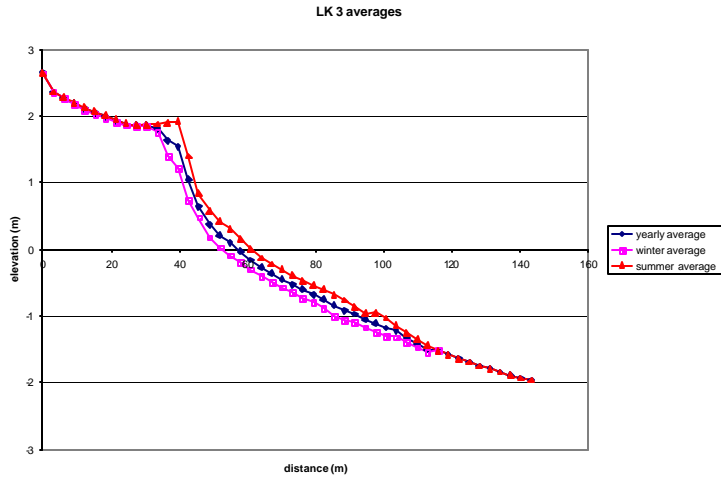
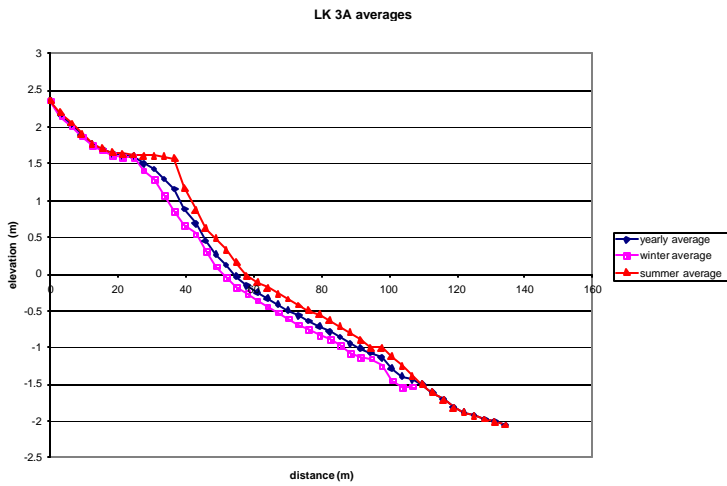


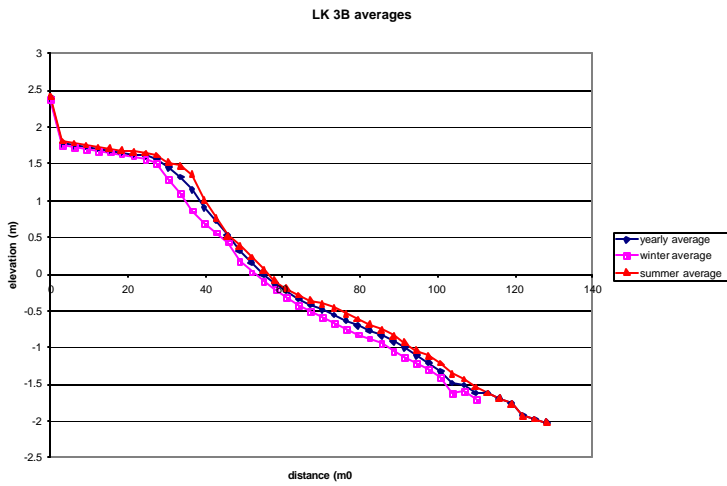
Figure 22: Monthly profiles at a LK 3, b. LK 3A, and c. LK 3B, taken in February, September 2003 and March 2004



(a)



(b)



(c)

Figure 23: Seasonal averages of a. LK 3, b. LK 3A and c. LK 3B: yearly, winter (October through March) and summer (April through September)

LK4 and LK 4A

LK 4 is located in the low dunes south of location LK 3B, and LK 4A is located just south of LK 4, also in the low dunes. Most of these dunes are vegetated, with only a narrow strip of beach remaining before the scarp. The scarp is characterized by large bands of oily sediment as seen at LK 3, LK 3A and LK 3B.

At the onset of the study, there was a larger back beach that has been almost completely obliterated over the course of the year by the scarpal retreat. Also, the slope of the scarp is more gradual in September, while in February and March is very steep. In September, the profile also accretes slightly in the offshore portion of the profile. All of this offshore accretion is removed by March however. The slope of the March profile closely matches that of the September offshore profile. LK 4 is shown in Figure 24 and LK 4A is shown in Figure 25.

The yearly and seasonal averages display none of the characteristics of the single month profiles. Instead, the profiles are very similar in slope and appearance, indicating that these small profile variations are not persistent over time, e.g. the entire summer or winter seasons. Figure 26 is the seasonal averages of LK 4, and Figure 27 is the seasonal averages of LK 4A. The similar seasonal shapes indicate minimal net cross-shore transport on a seasonal basis.

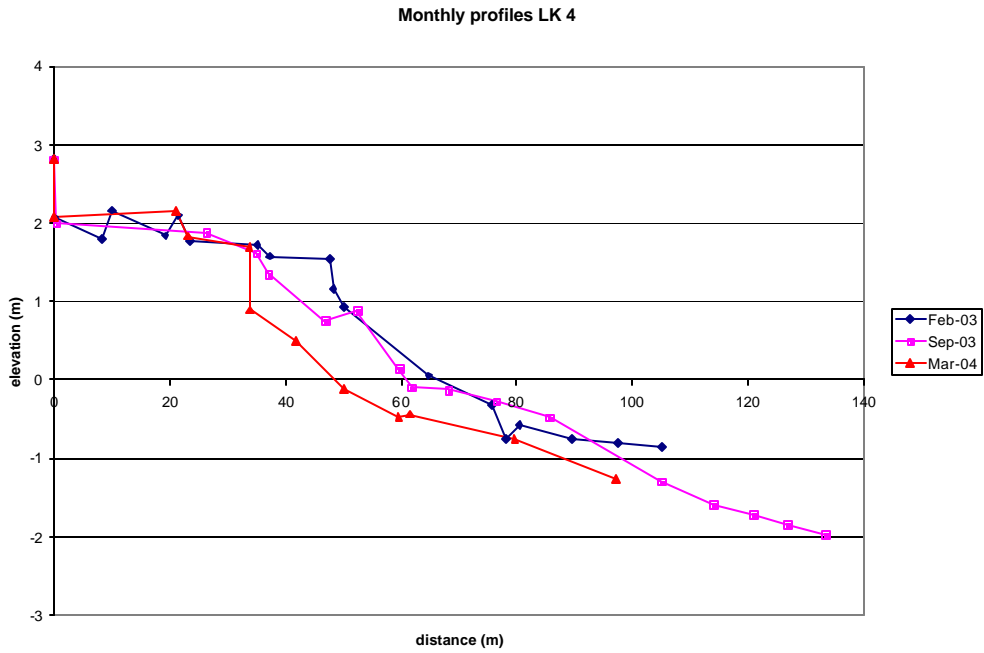


Figure 24: Monthly profiles at LK 4, taken in February, September 2003 and March 2004

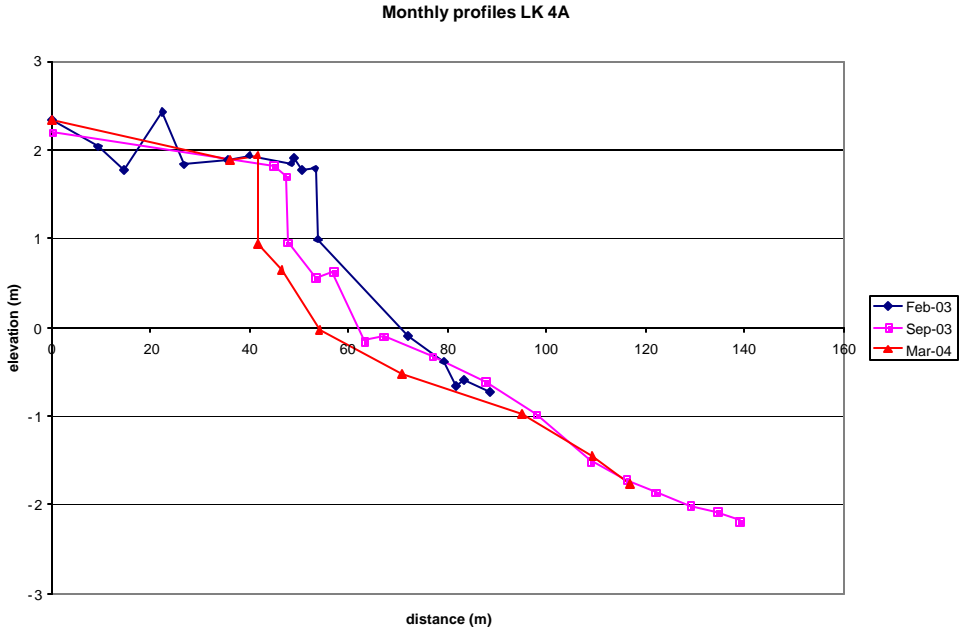


Figure 25: Monthly profiles at LK 1, taken in February, September 2003 and March 2004

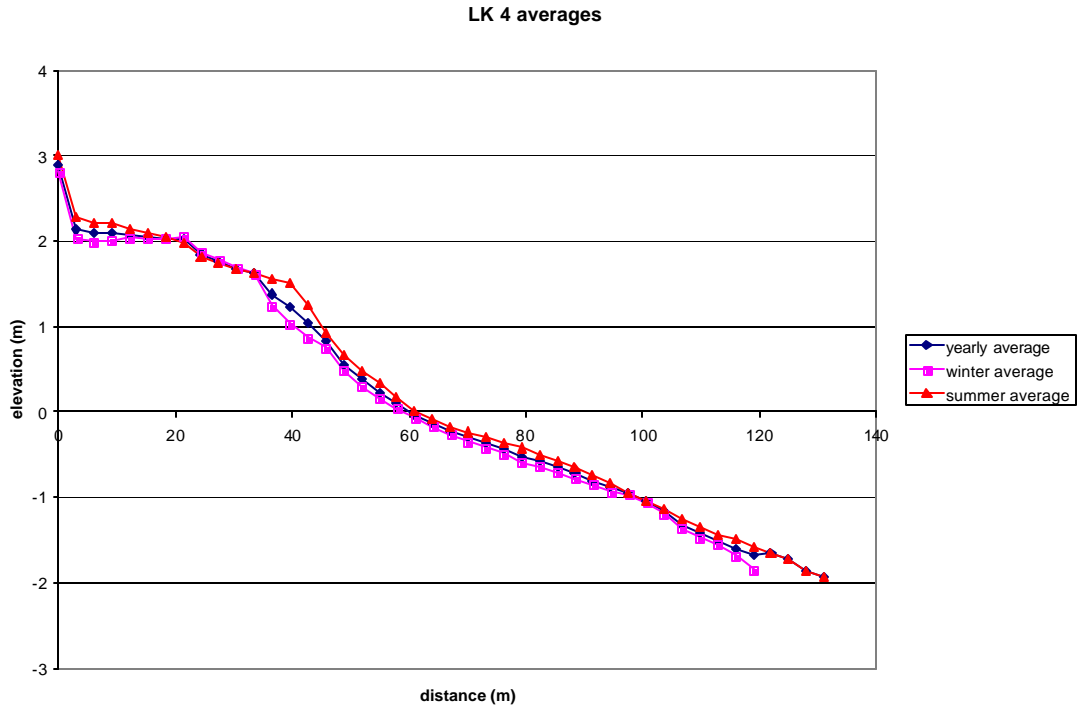


Figure 26: Seasonal averages of LK 4: yearly, winter (October through March) and summer (April through September)

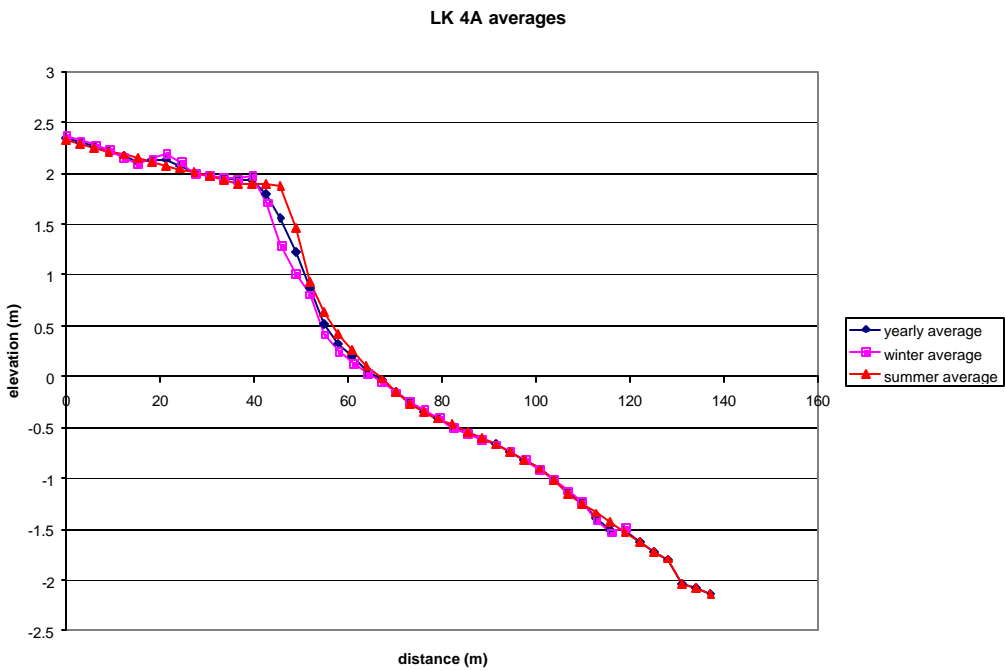


Figure 27: Seasonal averages of LK 4A: yearly, winter (October through March) and summer (April through September)

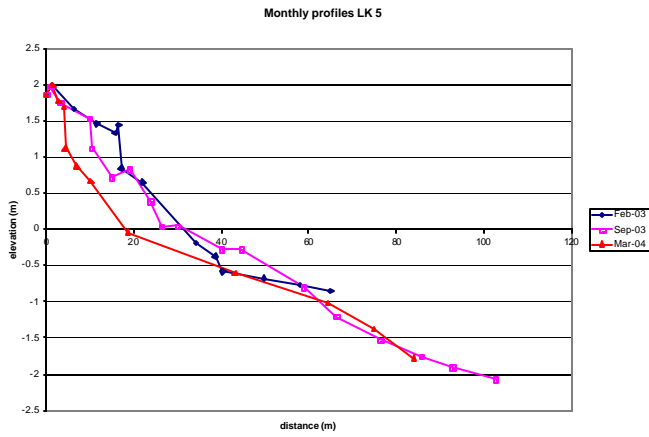
LK5, LK 5B and LK 5A

LK 5, LK 5B and LK 5A are located on a seawall that also has rip rap present to help strengthen the structure. Rip rap is a term applied to various sizes of boulders used in different arrangements or in combination with other structural material to provide protection (Davis and Fitzgerald, 2004). This profile shows the worst of the tarry sediment at LK 5B that was emplaced during the last nourishment project. There are large mounds of this cohesive material present in the swash zone, and large bands of the material visible throughout the height of the scarp. In April 2003, oily material was removed, and the slope of the beach gentled. Similar to the situations at other profiles, the cohesive oily material did not result in any irregularities of the scarp sharp or beach erosion rate.

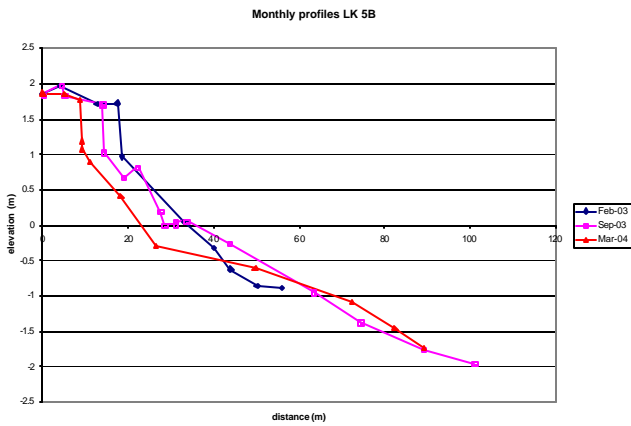
These profiles are characterized by a gentle back beach, followed by a steep scarp eroding at a seemingly constant rate throughout the year. The scarp has a very steep one meter drop, succeeded by a gentle slope to the Gulf of Mexico. Some accretion is seen in the first 50 meters offshore from February to September 2003. This deposition was removed prior to the survey done in March 2004, most likely due to winter storms. The slope of the offshore portion of the profile also changes from September to March, becoming gentler. These trends are shown in Figure 28.

There is very little seasonal variability in the profiles. The summer and winter average profiles show similar overall shape indicating no noticeable

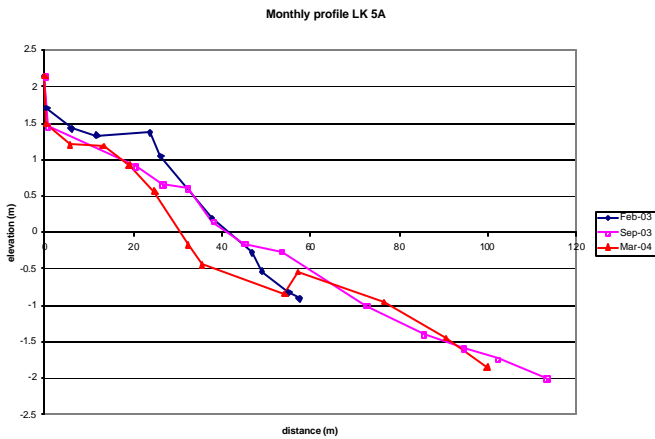
seasonal net cross-shore sediment transport. There is no presence of an offshore bar remaining for any length of time (Figure 29).



(a)

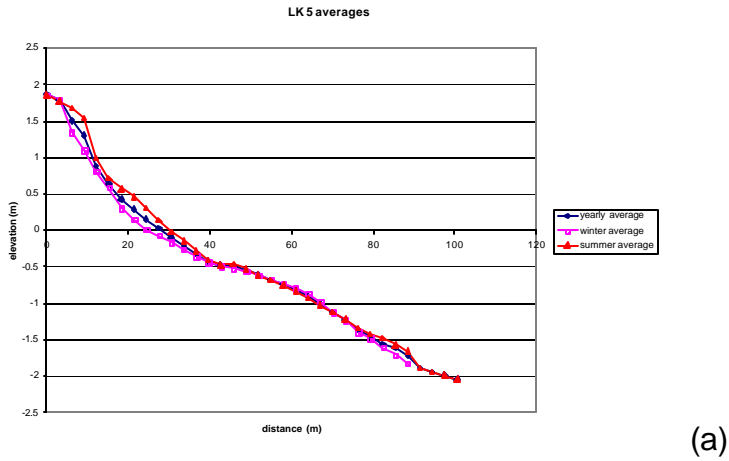


(b)

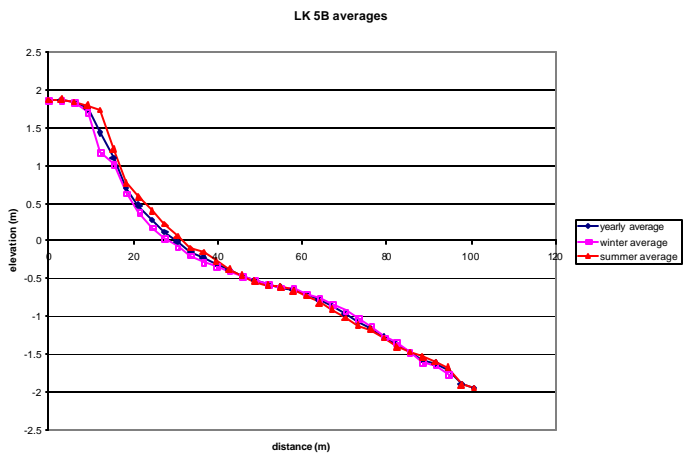


(c)

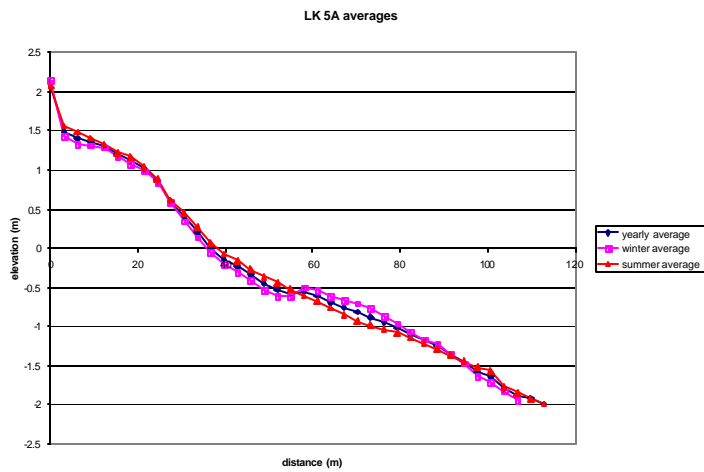
Figure 28, Monthly profiles of a. LK 5, b. LK 5B, and c. LK 5A taken in February, September 2003 and March 2004:



(a)



(b)



(c)

Figure 29: Seasonal averages of a. LK 5, b. LK 5B and c. LK 3A: yearly, winter (October through March) and summer (April through September)

LK6, LK 7, and LK 8

The profiles in the central and southern portions of Long Key are spaced differently as compared to the profiles in the northern section. These profiles are more widely spaced, with at least 1000 meters between each. Since these regions are experiencing a much less dramatic volume change, the need for intense study is not as high.

LK 6 is located just south of the end of the seawall that makes up all three LK 5 locations. It is a long profile starting at the end of a parking lot and extending almost 200 meters. This profile is located on a nourished beach that has maintained the integrity of the slope without the scarping. This profile is the beginning of a much different environment than those to the north, it is a relatively stable profile instead of the drastic intense erosion witnessed just to the north. LK 7 is also a very long profile, and exhibits many of the same characteristics as LK 6.

The back beach and foreshore are very similar in appearance throughout the year at LK 6 as expected (Figure 30). There is a slight amount of erosion seen in the foreshore, which is countered by deposition in the offshore portion of the profile. LK 7 however shows slight deposition in the foreshore over the course of the year. The March profile of LK 6 shows erosion over the winter months from the position in September, but there is deposition shown farther offshore. LK 7 shows further deposition in both the swash zone and offshore (Figure 31), likely resulting from the sediment supplied from the eroding Upham Beach to the north.

The profiles of the yearly average, and both seasonal averages show very minimal differences in shape. The offshore profiles show minor visible differences, however. The winter profile shows some accumulation in the form of an offshore ridge, while the summer profile shows a marked absence of this ridge (Figure 32). This is dissimilar to the results seen in the stable profiles LK 1 and LK 2, where the summer profile showed an offshore bar. LK 7 shows a large offshore bar, that changes shape over the course of the year (Figure 33). The bar first appears at the end of the summer, and accretes almost .25 meters from September, 2003 to March, 2004.

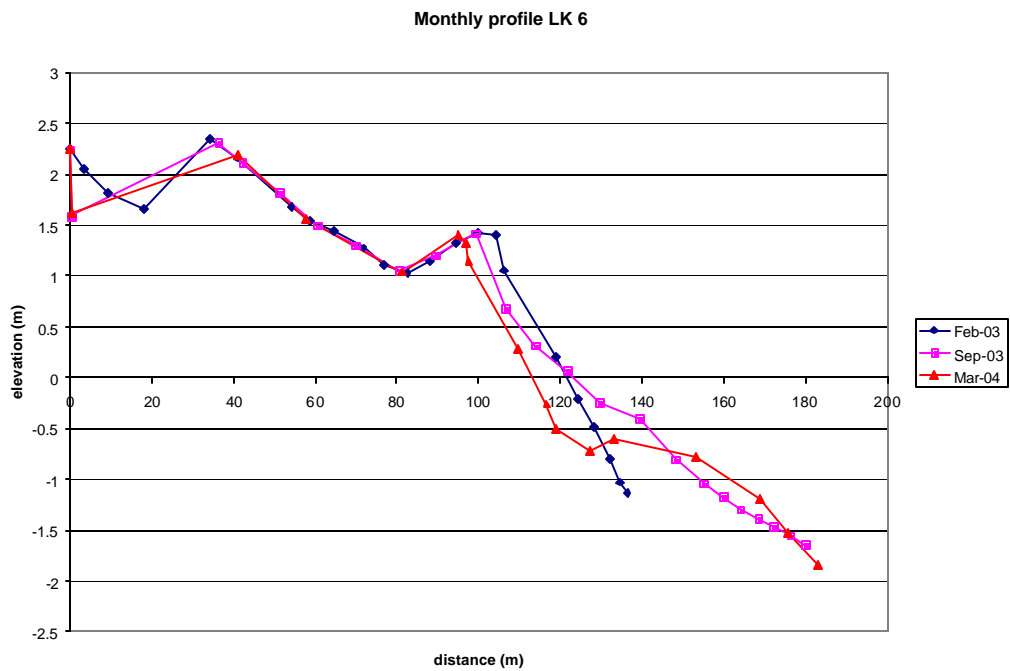


Figure 23: Monthly profiles of LK 6, taken in February, September 2003, and March 2004.

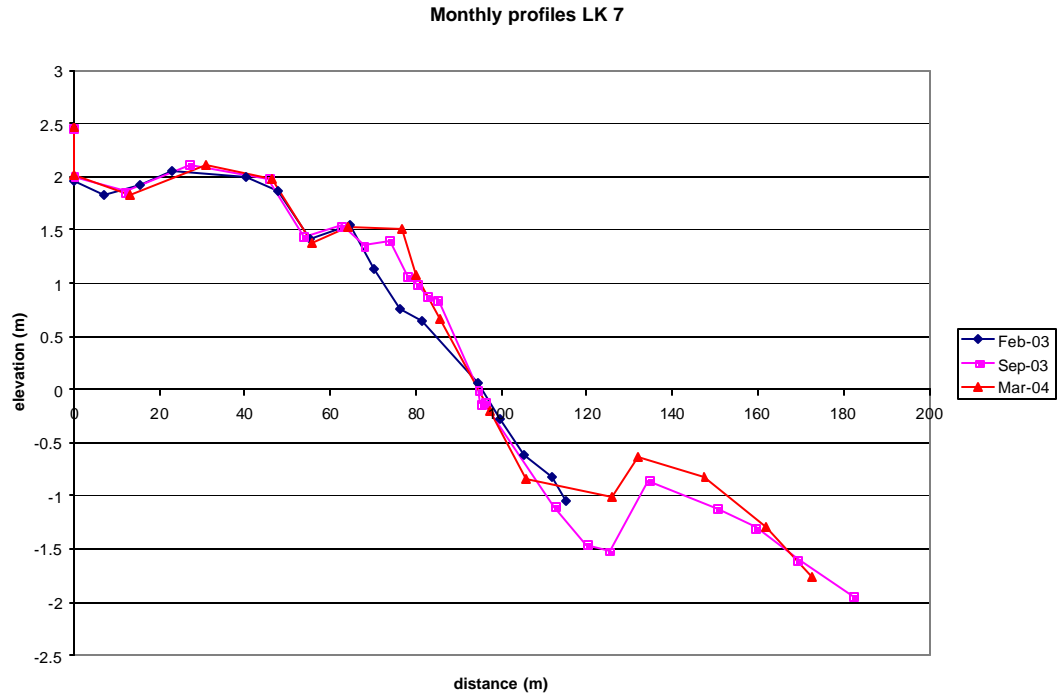


Figure 42: Monthly profiles of LK 7, taken in February, September 2003, and March 2004.

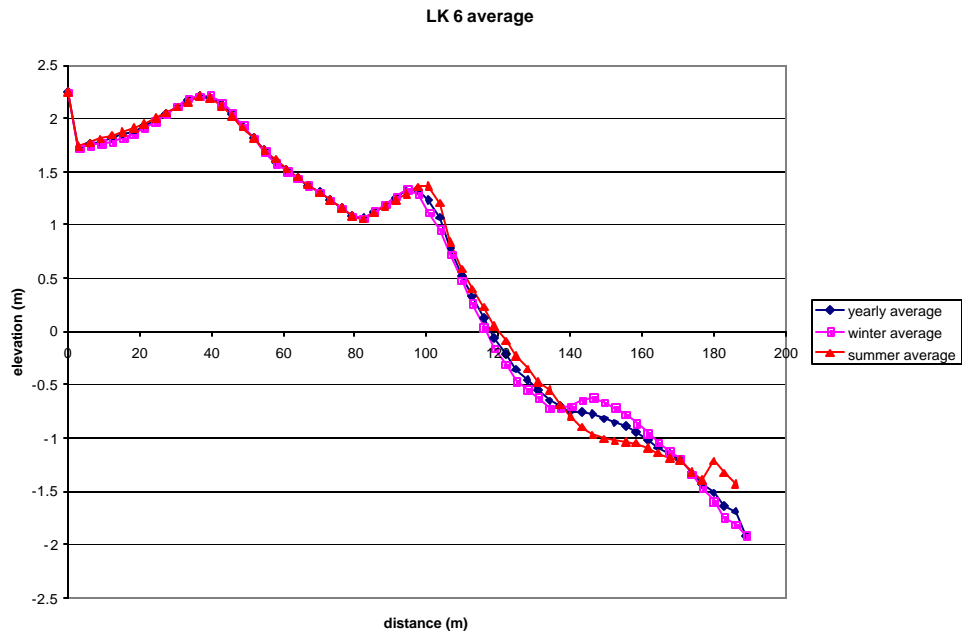


Figure 32: Seasonal averages of LK 6: yearly, winter (October through March) and summer (April through September)

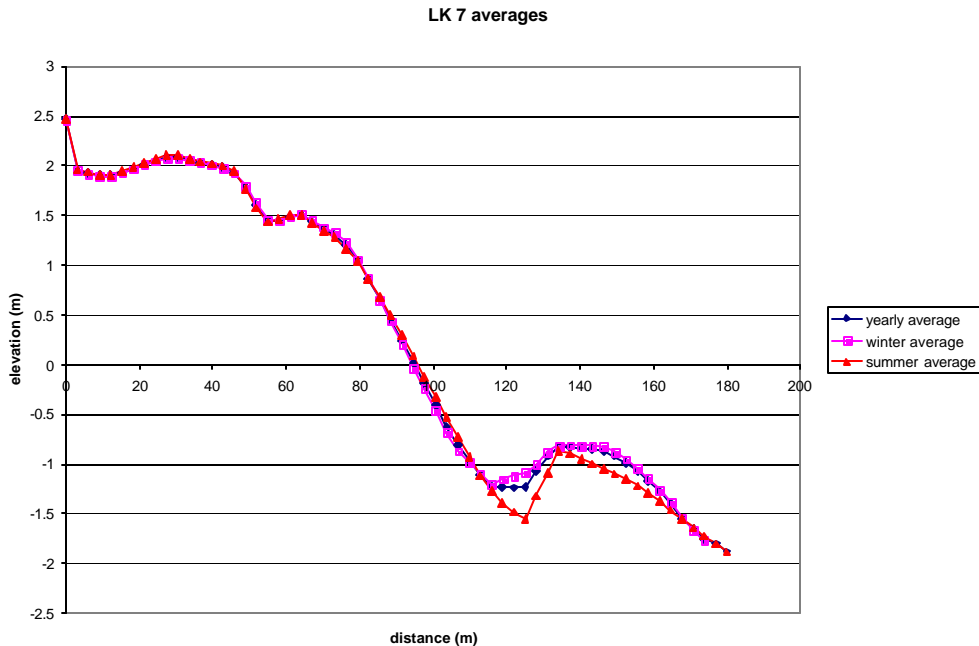


Figure 33: Seasonal averages of LK 7: yearly, winter (October through March) and summer (April through September)

LK 8 is located to the south of LK 7. This is another very long profile, with an extensive back beach that is relatively flat. This is similar to LK 7 and characterizes the central part of Long Key quite well. This profile is also accreting in the offshore portion of the profile in a similar manner to that of LK 7. There is also a movement of the offshore bar closer to shore from September to March (Figure 34).

This profile is also accreting, lending credibility to the hypothesis that the central part of Long Key is not experiencing the intense erosion that is attacking the northern end. It is probable that the sand eroding from the north end of Long Key is depositing on the central profiles due to longshore transport (Figure 35).

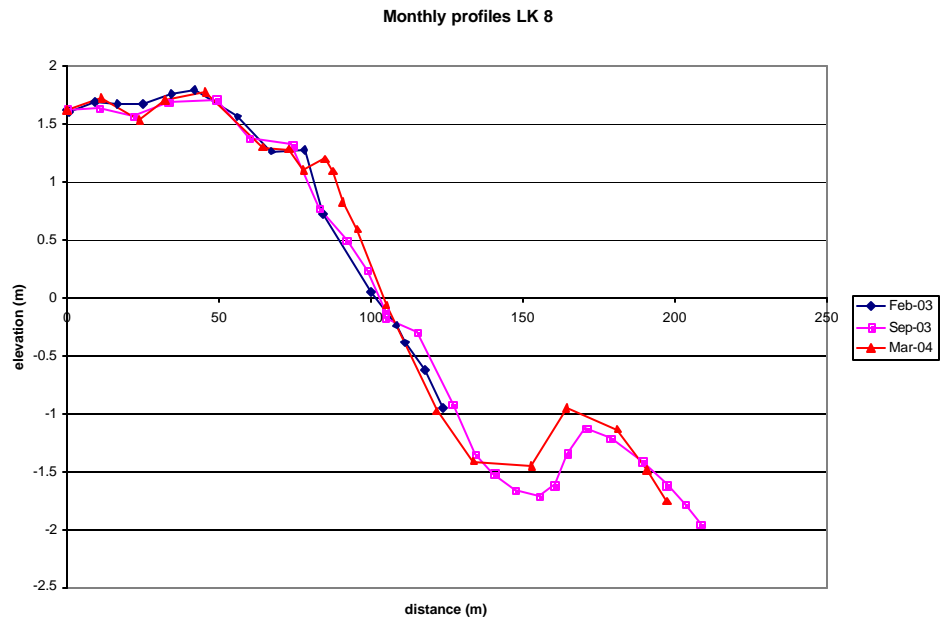


Figure 34: Monthly profiles of LK 8, taken in February, September 2003, and March 2004.

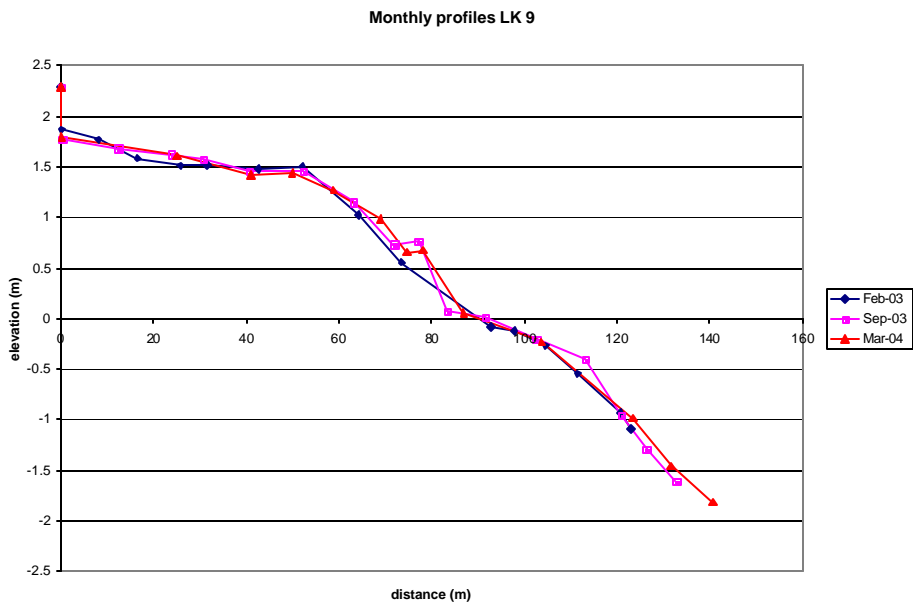


Figure 35: Monthly profiles of LK 6, taken in February, September 2003, and March 2004.

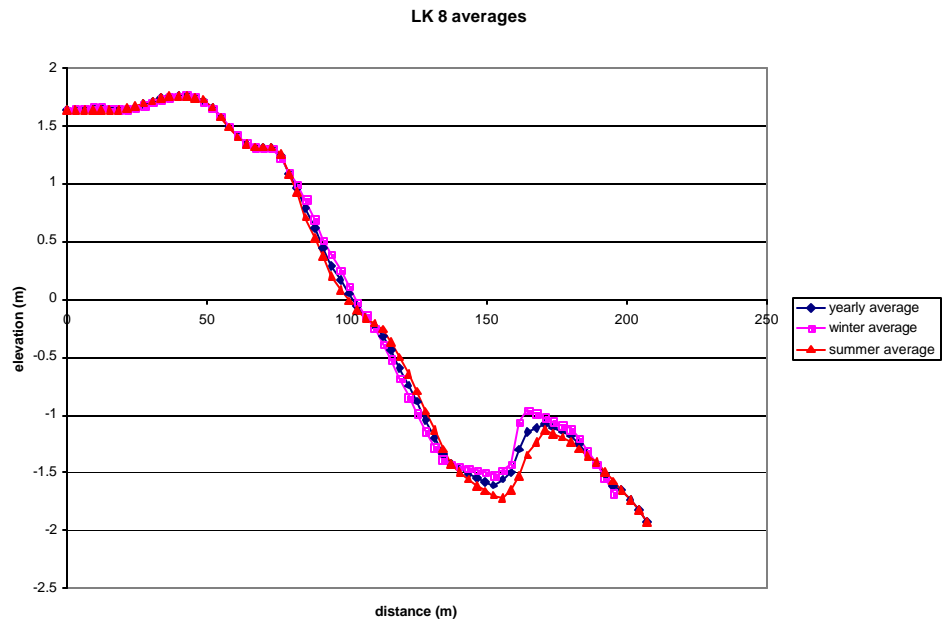


Figure 36: Seasonal averages of LK 8: yearly, winter (October through March) and summer (April through September)

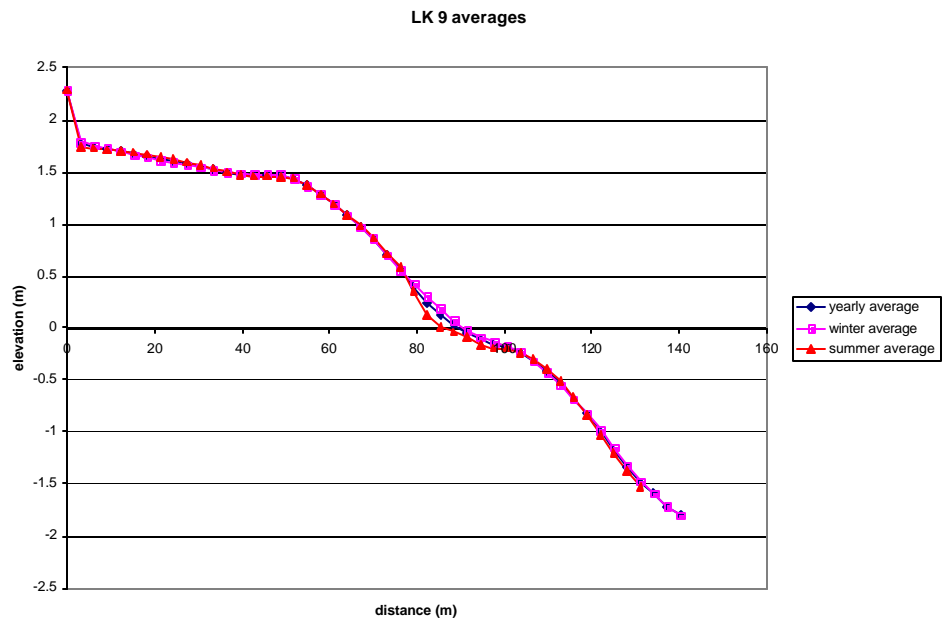


Figure 37: Seasonal averages of LK 9: yearly, winter (October through March) and summer (April through September)

LK 9, LK 10, LK 11, LK 12, and LK 13

LK 9 is an almost completely stable profile. There is slight sand accumulation in the winter months, and slight erosion in the summer months. There is virtually no offshore bar at any point during the year, and the offshore portion of the profile is almost identical at each month during the year (Figure 35). Neither the winter nor summer average profile shows any seasonal changes. This is different from the profiles in the northern portion of the island, which supports the idea that there are multiple depositional regimes on the island (Figure 37).

Location LK10 is found near monument marker 155. The benchmark is found in the dunes behind the back beach, which drop abruptly to the back beach. This part of the profile shows variation throughout the course of the year; however this variation is caused by the survey operation because the time-series surveys re-occupy the same survey lines but not the same survey points. Each time the survey was performed, the point was taken at a different place in the dunes. This is a common survey artifact, and is seen in Figure 38. Field observations indicate that the dune field is very stable over the course of the study. This profile is stable, with little variation over the course of the year. There is some accretion in the foreshore part of the profile. However, the offshore and swash zone portions of the profile are almost identical.

The winter profile average is slightly shallower than the summer profile (an artifact of the averaging, however the slope is almost identical. Also, in the

foreshore portion of the profile, the summer profile extends slightly further seaward prior to the downward slope to the Gulf of Mexico (Figure 38).

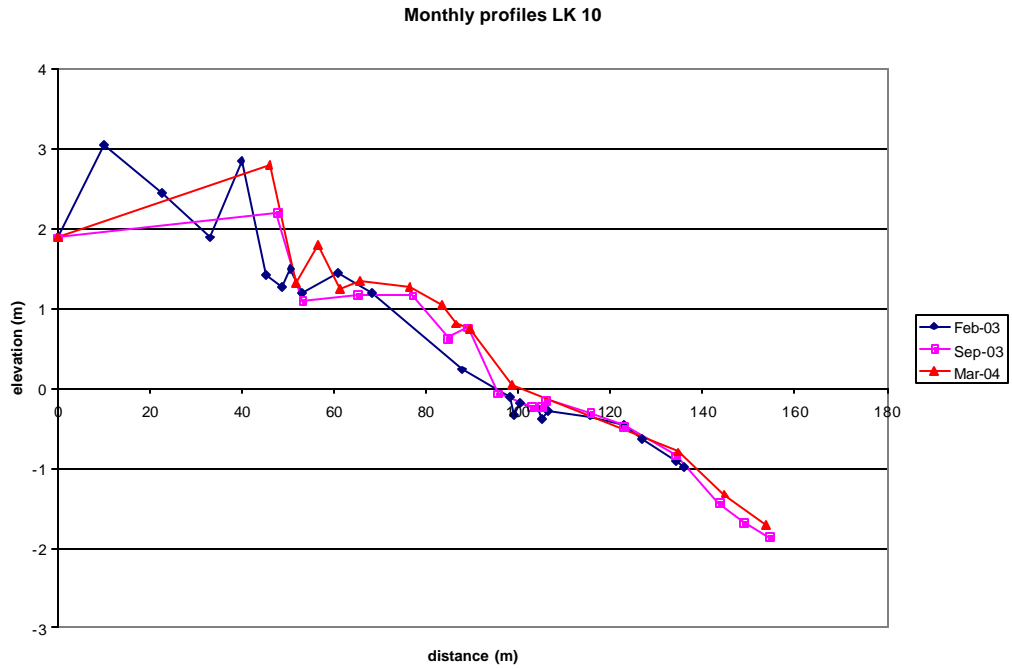


Figure 38: Monthly profiles of LK 10, taken in February, September 2003, and March 2004.

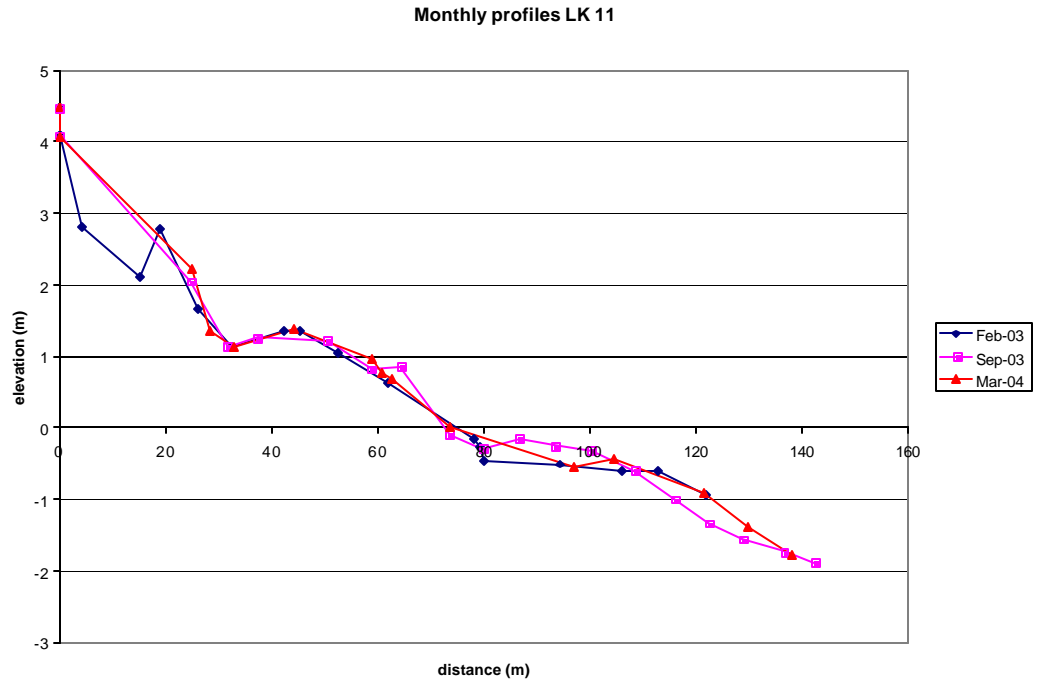


Figure 39: Monthly profiles of LK 11, taken in February, September 2003, and March 2004.

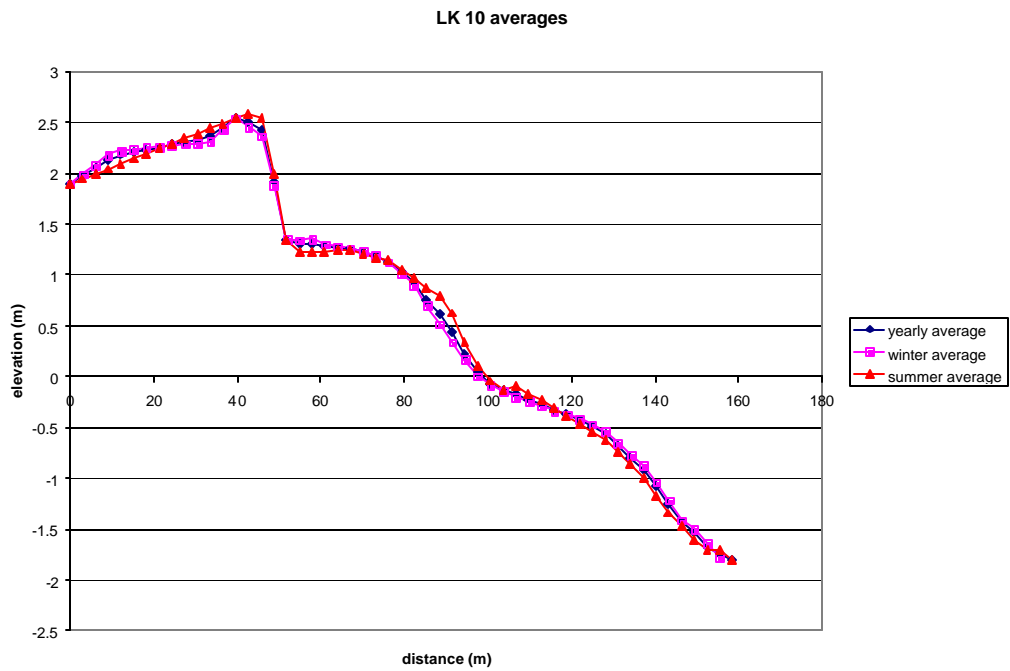


Figure 40: Seasonal averages of LK 10: yearly, winter (October through March) and summer (April through September)

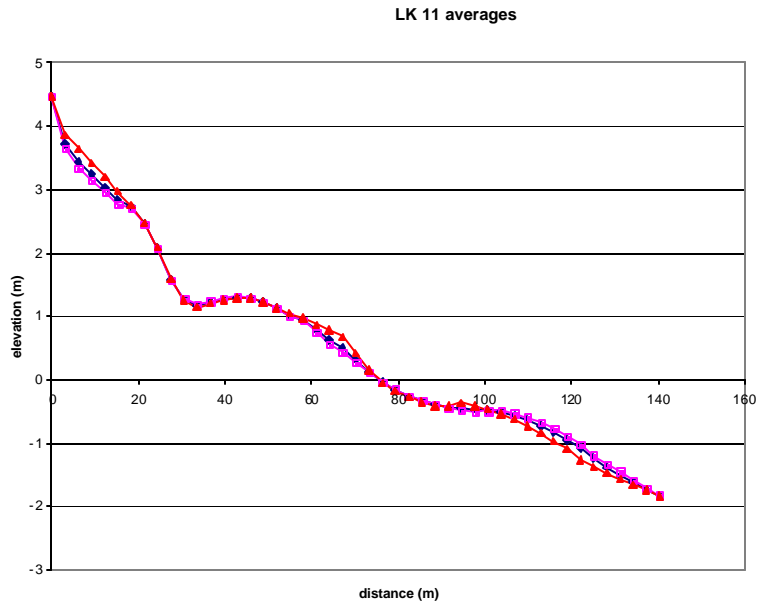


Figure 41: Seasonal averages of LK 11: yearly, winter (October through March) and summer (April through September)

LK 11 is also exhibiting the trend of the south end of Long Key. It is a stable profile, with little to no volume loss over the course of the year (Figure 40). The shape of the profile remains the same in both summer and winter, which indicates an equilibrium state with the surroundings (Figure 41). This profile is characterized by a shallow offshore profile, with an almost horizontal submerged profile for the first 100 meters. This is different than the previous profiles, which tend to drop off more abruptly. This does not alter the equilibrium, stable state at which the profile exists however.

This profile is located near to Pass-a-Grille Channel. It was hypothesized that sand from the Upham Beach area of the study was supplying the beaches of Pass-a-Grille with sediment. The profile does appear to be gaining a small

amount of sediment, however the lack of sediment accretion in the adjacent profiles to the north implies that most of the sediment is depositing on the central portion of the island instead. Instead this is a stable profile that appears to be in an equilibrium stage. This beach has remained in this state since the 1992 nourishment (Elko, 1999).

Profile LK 12 is almost identical to that of LK 11. The only difference in shape occurs in the first 50 meters of the profile, where there is a steep drop in elevation at LK 12 that is lacking in the profile of LK 11 (Figure 42). Both exhibit a horizontal area of approximately 50 meters found from 100 to 150 meters from the origin of the profile. This is then followed by a gradual drop to the Gulf of Mexico, which is in turn followed by another horizontal area.

LK 13 is the southern-most research site in the study. This profile is also exhibiting accretion. While the previous profile showed accretion along the entire length of the profile, LK 13 shows accretion in the first 150 meters of the offshore region, and erosion in the last 100 meters offshore. The September profile shows the most erosion, with the January 2004 profile showing accretion from September. This accretion does not equal or exceed the February 2003 state (Figure 43).

Unlike the previous profiles in the southern end of Long Key, this profile shows some variation in profile from winter to summer (Figure 44). The summer profile is at a higher elevation in the back beach, then rapidly becomes deeper than the winter profile in the foreshore, i.e., the profile is steeper in the winter than in the summer. This trend continues throughout the offshore portion of the

profile. Another difference is found in the offshore portion—a small sand bar is seen in the winter months that is completely lacking in the summer months.

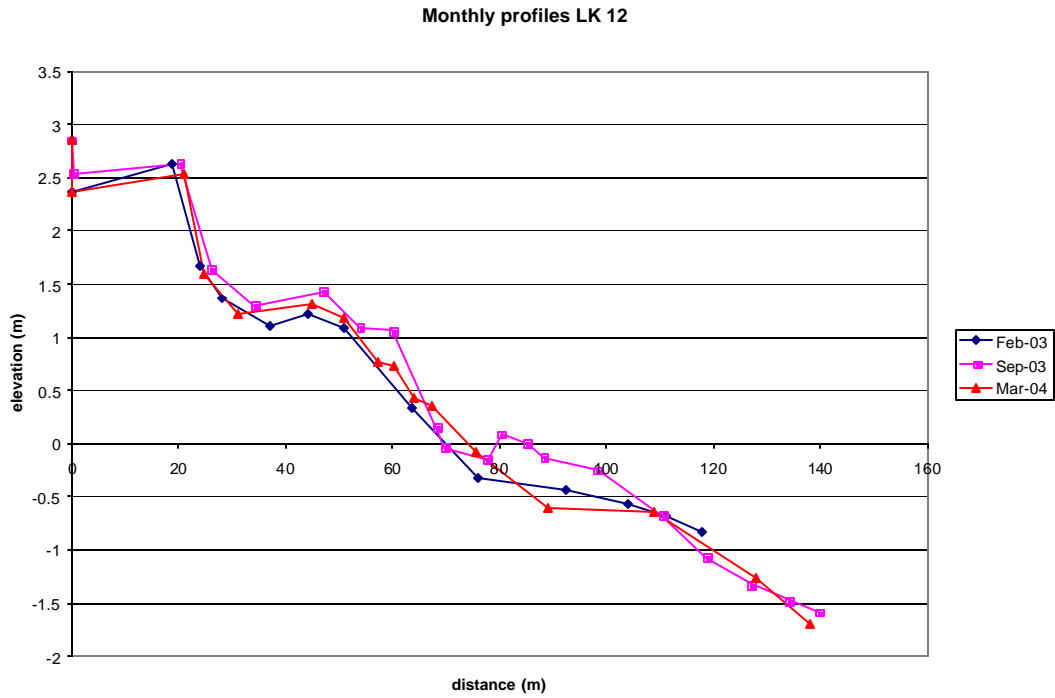


Figure 42: Monthly profiles of LK 12, taken in February, September 2003, and March 2004.

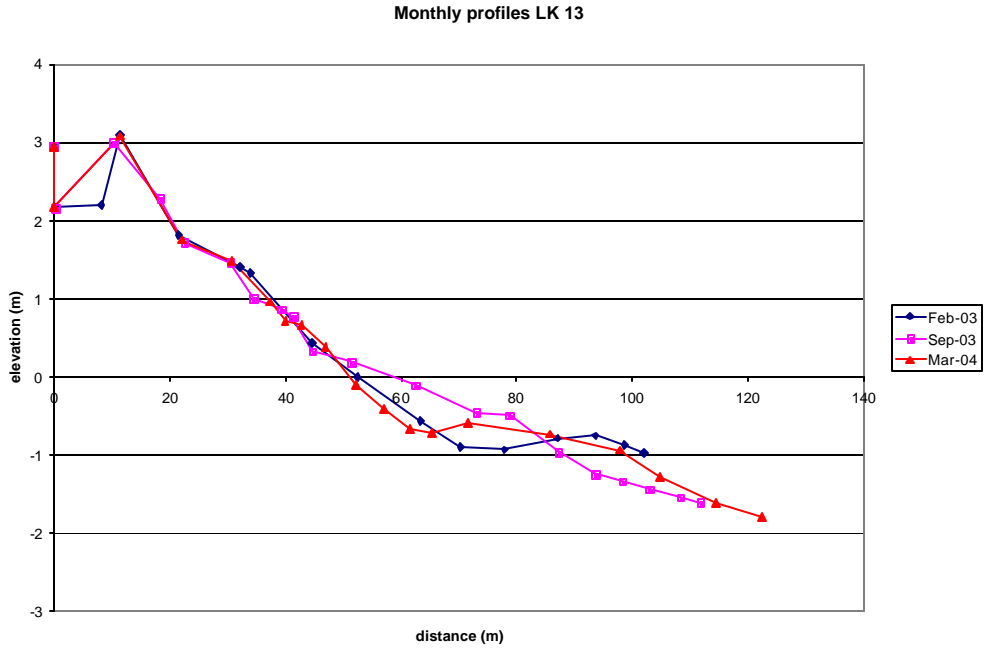


Figure 43: Monthly profiles of LK 13, taken in February, September 2003, and March 2004.

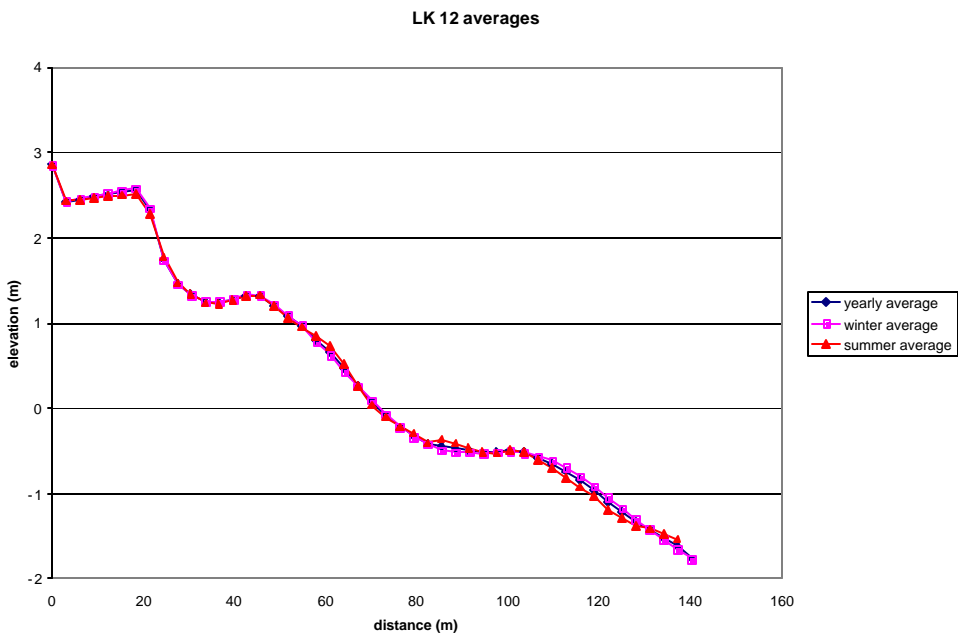


Figure 44: Seasonal averages of LK 12: yearly, winter (October through March) and summer (April through September)

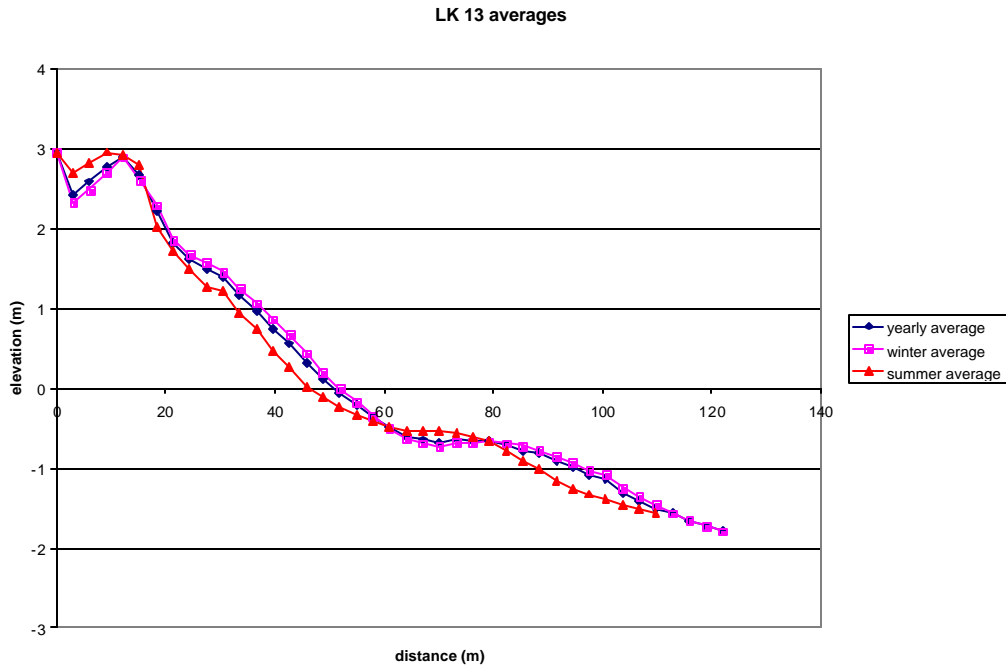


Figure 45: Seasonal averages of LK 13: yearly, winter (October through March) and summer (April through September)

Beach Volume Change along Long Key

Beach volume changes over the entire study period were calculated for both the subtidal zone, and the aerial zone. These calculations were done by calculating the area at the initiation of the study, then subtracting the area at the conclusion of the study. As shown in figure 46, the most erosion of the back beach and foreshore is taking place in the northern portion of the island. The most intense erosion above NGVD is occurring at the scarp, which is seen in the northern portion of the island, LK 3 through LK 5A. Sediment loss decreases southward on the island, with accretion shown in the central and southern parts. The greatest loss of sediment is seen at LK 3A, which lost more than 30 cubic

meters during the slightly more than 12 month period. The greatest accumulation is seen at LK 10, which adds more than 10 cubic meters per meter. LK 1 and LK 2 show very little volume change, which is explained by the protective cove that slows erosion due to longshore sediment transport to the south. LK 7 through LK 12 show significant but variable volume accretion of at least 5 cubic meters per meter. LK 13, which was the only profile in the southern region of Long Key to display seasonality shows a very slight loss of sediment over the year, less than one cubic meter per meter over the year.

In the northern profile locations, the substantial beach volume loss also occurred below NGVD. The subtidal region of LK 3A lost the greatest amount of sediment per year, although the volume loss is slightly less at slightly greater than 25 cubic meters per meter. LK 1 and LK 2 also lost sediment, which is different since there was very little change in the region above NGVD. The remaining profiles in the northern region show comparable volume loss to that seen above NGVD. The central portion of the island shows more consistent variation in volume change. LK 7 through LK 11 have volume gain less than 5 meters per year. Volume change at LK 12 is minimal, however volume change at LK 13 is very similar to the change seen at LK 8 (Figure 47).

It is apparent that volume loss is the greatest at the scarp region of the northern end of Long Key, while beach volume gain was measured at both the central and southern ends of the island. The offshore region of the beach profiles demonstrated a somewhat different trend. The greatest volume loss is still occurring in the northern profiles, but with a steeper decreasing trend

southward but the central portion of Long Key is accreting more due to seasonal offshore bars. The southern end of the island shows slight accumulation at each location. This supports the idea that the sediment from north Long Key and Upham Beach are supplying the central portion of the island with sediment, with much lesser amounts being delivered to the far southern profiles.

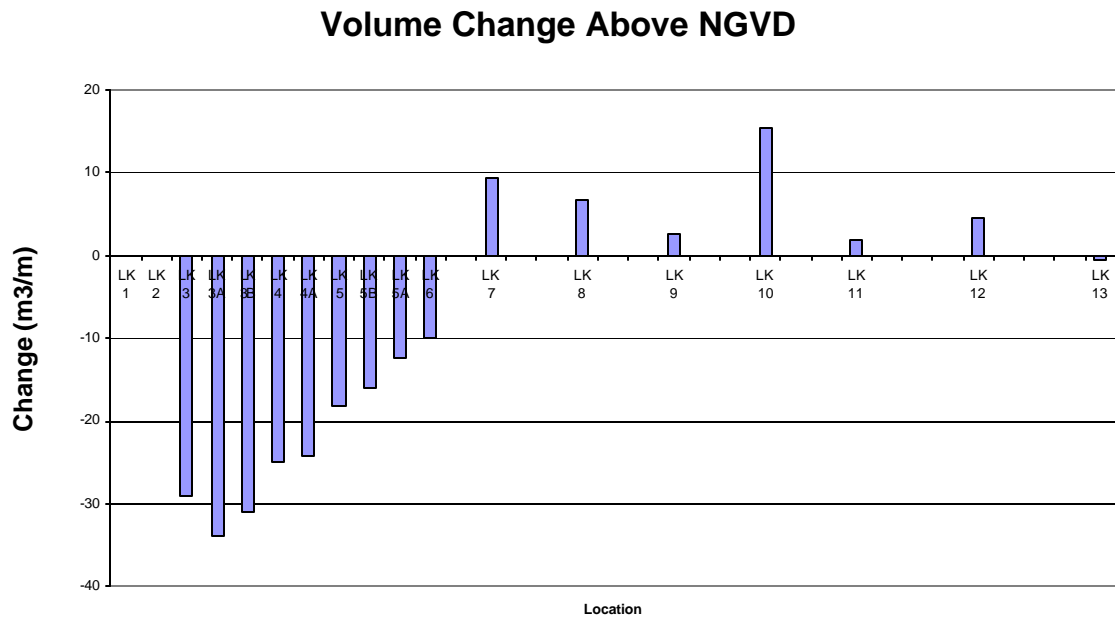


Figure 46: volume change above NGVD at all profile locations over the course of the year.

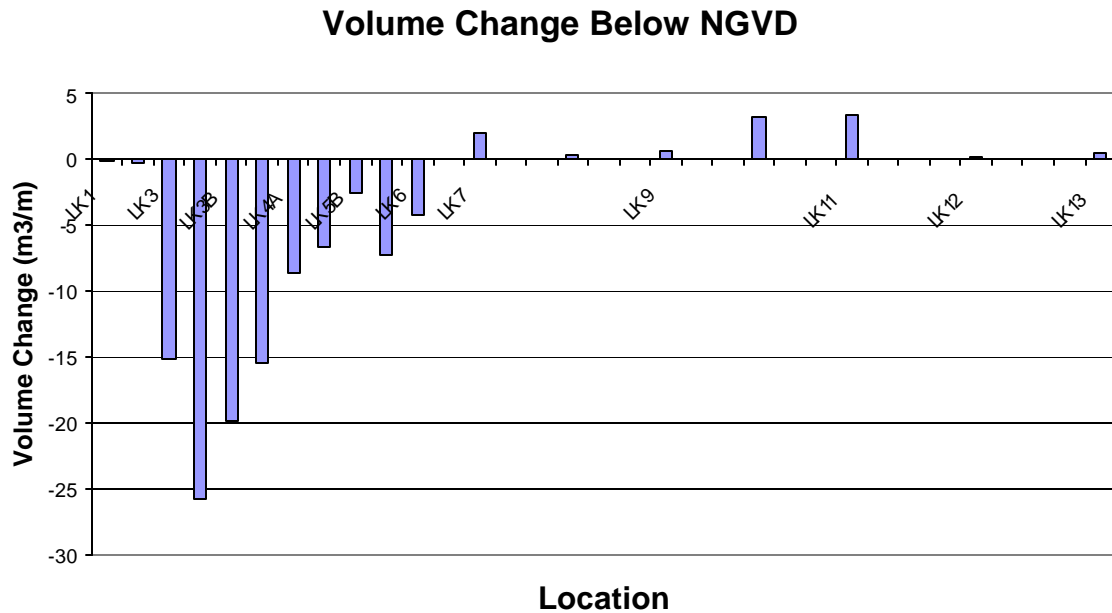


Figure 47: Volume change below NGVD at all profile locations over the course of the study

Sediment Budget along Long Key

A volume balance was calculated by combining the volume change above and below NGVD. An average beach volume loss was calculated for LK 3 through LK 6 because the distance between each profile is approximately 100 meters apart and the trend is approximately linear. The profiles LK 6 through LK 13 are spaced further apart, so the trapezoid rule was used to determine volume change.

The total volume change above NGVD in the northern end of Long Key is a loss of 22,000 cubic meters. Total volume change for the same profiles below NGVD is 12,000 cubic meters loss. Combined there is a total volume loss of 34,000 cubic meters per year.

Volume change in the southern profiles was calculated using the trapezoid rule. An average of two adjacent profiles was taken, then multiplied by the distance between the profiles. Volume change above NGVD in the central and southern portion of the island is 24,000 cubic meters, and volume change below NGVD is 5,000 cubic meters. This is a total volume gain of 29,000 cubic meters per year.

The volume gain in the central and southern portions of the island accounts for 85% of the volume loss at Upham Beach. This is an indication that most transport at Long Key is longshore sediment transport. The remaining 15% sediment could be transported offshore, or further down shore, or simply cannot be accounted for with present survey resolution.

Shoreline Change

Shoreline change at three contour levels at each profile was also examined. This was done to determine change at the mean low tide line, the mean high tide line, and the middle of the scarp/mid beach region. By examining the change (in meters) it is possible to quantify the consequences of beach-volume changes. For example, how much the shoreline (or the contour lines) retreat has been caused by the beach-volume loss at Upham Beach, and how much shoreline gain, if any at all, has resulted from the volume gain in the central and southern portions of the island. As shown in Figure 48, the greatest loss of shoreline is at profile location LK 3A. This is consistent with the profile data discussed earlier, with the most accretion shown at LK 10.

The northern part of the island shows consistent erosion at each profile location. As previously discussed, location LK 1 and LK 2 are sheltered by a weir jetty, which diminishes the effect of longshore sediment transport. Thus, some sediment is lost, but the loss is less than the remaining profiles in the northern section of the island. The greatest shoreline loss is seen at LK 3A, LK 3B and LK 4. LK 3 shows slightly less shoreline erosion than those adjacent to the south, but has very similar results to LK 4A. These profiles all show similar trend at each contour level, with variation less than 5 meters. However, at LK 7 and LK 8 there is greater variation, which is due to the disappearance of the scarp.

The central and southern portions of the island, with the exceptions of LK 6 and LK 7, are gaining shoreline. This shoreline increase is a result of the sediment being eroded from the northern part of the island. It was thought that the sediment was being deposited on the southern-most profiles, however, it is clearly being deposited on the central part of the island as well, and in slightly greater amounts. The variation at each contour level was considerably different influenced by the lack of the erosional scarp and the presence and movement of an offshore bar.

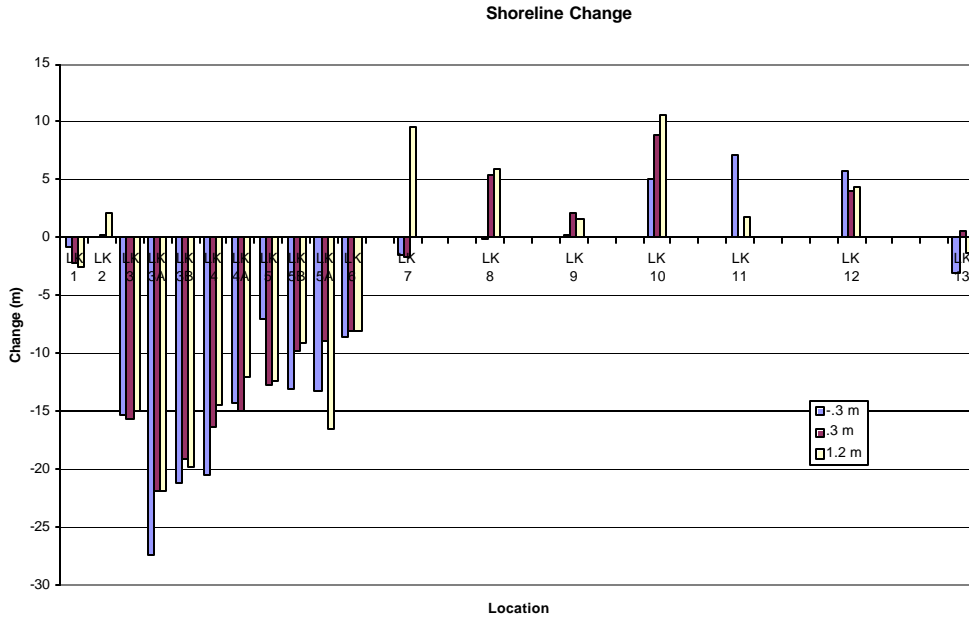


Figure 48: Shoreline change at -0.3 m, 0.3 m, and 1.2 m by location.

CONCLUSIONS

Beach and near shore profiles at 18 locations on Long Key, Pinellas County have given insight into the processes affecting a chronically rapidly eroding beach. Sediment samples have contributed further to the understanding of this constantly changing system. Volume calculations and distance-elevation graphs were used to determine shoreline change and trends. These data were evaluated, leading to the following conclusions:

1. The northern end is experiencing rapid erosion while the central portion is accreting and the southern end is relatively stable.
2. The most volume change is seen during the winter months, ostensibly due to the passage of winter storm fronts.
3. Total beach volume loss at Upham Beach was 34,000 cubic meters during the 12 month study period, roughly equal to total volume gain of 29,000 cubic meters (85%), mainly in the central part of Long Key.
4. The 34,000 cubic meters agrees well with sedimentation rates of Blind Pass, immediately updrift of Upham Beach indicating a background long shore sediment transport rate of approximately 34,000 cubic meters per year..

5. This long shore transport rate is considerably higher than the generally accepted 15,000-20,000 cubic meters per year.
6. This elevated rate of transport explains the rapid erosion of Upham Beach, given that the sediment supply from the north is blocked by the heavily structured Blind Pass.
7. Based on the analyses of 154 sediment samples, no persistent or distinctive temporal or spatial patterns in sediment characteristics can be identified.
8. No significant cross-shore sediment transport was found at Upham Beach by this study, however there is slight cross-shore sediment transport in the southern end of Long Key.
9. Sediment properties at Long Key are not indicative of longshore sediment transport. No convincing trend can be seen either along the coast or seasonally.

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Appendices

Appendix A: Temporal Sediment Characteristics

Date	Location	Mean Grain Size	% Gravel	% Sand	% Silt
2/23/2003	LK 3 BB	1.75	11.41	88.04	.55
2/23/2003	LK 3 TS	1.62	12.51	86.94	.54
2/23/2003	LK 3 BS	1.66	10.84	88.9	.26
2/23/2003	LK 3 SZ	1.73	6.24	93.74	.01
2/23/2003	LK 4 BB	2.43	4.07	95.16	.77
2/23/2003	LK 4 TS	2.56	.13	99.7	.17
2/23/2003	LK 4 BS	2.43	1.99	97.87	.14
2/23/2003	LK 4 SZ	1.91	5.40	94.59	.02
2/23/2003	LK 5 BB	2.16	7.57	90.78	1.64
2/23/2003	LK 5 SZ	1.68	8.77	91.20	.03
2/23/2003	LK 5B BB	1.87	11.73	86.88	1.39
2/23/2003	LK 5B TS	1.53	15.15	84.24	.61
2/23/2003	LK 5B BS	2.25	7.97	90.78	1.25
2/23/2003	LK 5B SZ	2.34	99.98	.00	.02
2/23/2003	LK 11 BB	2.22	1.99	97.99	.02
2/23/2003	LK 11 MB	2.49	.63	99.35	.02
2/23/2003	LK 11 SZ	2.48	.33	99.64	.03
2/23/2003	LK 13 BB	1.6	6.3	93.56	.15
2/23/2003	LK 13 MB	2.35	.13	99.85	.02
2/23/2003	LK 13 SZ	1.5	6.39	93.59	.02
6/3/2003	LK 3 BB	1.93	5.87	93.87	.26
6/3/2003	LK 4 BB	2.66	1.53	97.79	.69
6/3/2003	LK 4 TS	2.72	2.10	96.36	1.54
6/3/2003	LK 4 BS	2.41	5.54	93.25	1.21
6/3/2003	LK 4 SZ	2.49	.25	99.62	.13
6/3/2003	LK 5 BB	2.22	2.98	96.55	.46
6/3/2003	LK 5 TS	2.00	8.77	90.63	.6
6/3/2003	LK 5 BS	1.88	8.71	90.67	.63
6/3/2003	LK 5 SZ	1.38	15.19	84.58	.24
6/3/2003	LK 13 BB	1.6	6.3	93.56	.15
6/3/2003	LK 13 MB	2.35	.13	99.85	.02
6/3/2003	LK 13 SZ	1.5	6.39	93.59	.02
9/17/2003	LK 3 BB	1.73	11.47	88.06	.47
9/17/2003	LK 3 TS	1.1	18.01	81.65	.34
9/17/2003	LK 3 BS	1.24	14.98	84.66	.36
9/17/2003	LK 3 SZ	2.5	3.57	96.41	.01
9/17/2003	LK 4 BB	2.79	1.02	98.27	.71
9/17/2003	LK 4 TS	2.65	2.03	97.28	.68
9/17/2003	LK 4 BS	2.59	3.37	96.32	.31
9/17/2003	LK 4 SZ	2.15	8.18	91.8	.02
9/17/2003	LK 5 BB	2.08	3.04	96.57	.39

Date	Location	Mean Grain Size	% Gravel	% Sand	% Silt
9/17/2003	LK 5 TS	1.8	10.56	88.97	.46
9/17/2003	LK 5 BS	2.56	3.95	95.21	.84
9/17/2003	LK 5 SZ	.54	20.88	79.09	.03
9/17/2003	LK 13 BB	1.97	4.07	95.87	.06
9/17/2003	LK 13 MB	1.58	16.19	83.77	.04
9/17/2003	LK 13 SZ	1.56	12.43	87.55	.02
1/15/2004	LK 3 BB	2.43	.55	99.29	.16
1/15/2004	LK 3 TS	1.48	14.3	85.37	.33
1/15/2004	LK 3 BS	.79	23.78	76.09	.13
1/15/2004	LK 3 SZ	2.29	3.58	96.4	.02
1/15/2004	LK 4 BB	2.59	.5	99.1	.4
1/15/2004	LK 4 TS	2.65	.03	99.83	.14
1/15/2004	LK 4 BS	1.01	24.04	75.44	.23
1/15/2004	LK 4 SZ	2.24	2.19	97.8	.01
1/15/2004	LK 5 BB	1.63	14.45	84.97	.58
1/15/2004	LK 5 TS	1.82	10.51	88.99	.50
1/15/2004	LK 5 BS	2.15	3.98	95.97	.05
1/15/2004	LK 5 SZ	2.34	.44	99.53	.03
1/15/2004	LK 11 BB	1.8	6.9	93.03	.06
1/15/2004	LK 11 MB	2.44	1.52	98.47	.01
1/15/2004	LK 11 SZ	2.38	1.15	98.84	.01
1/15/2004	LK 13 BB	1.68	5.23	94.65	.12
1/15/2004	LK 13 MB	1.8	8.01	91.98	.01
1/15/2004	LK 13 SZ	2.31	2.23	97.67	.07

Appendix B: Spatial Characteristics

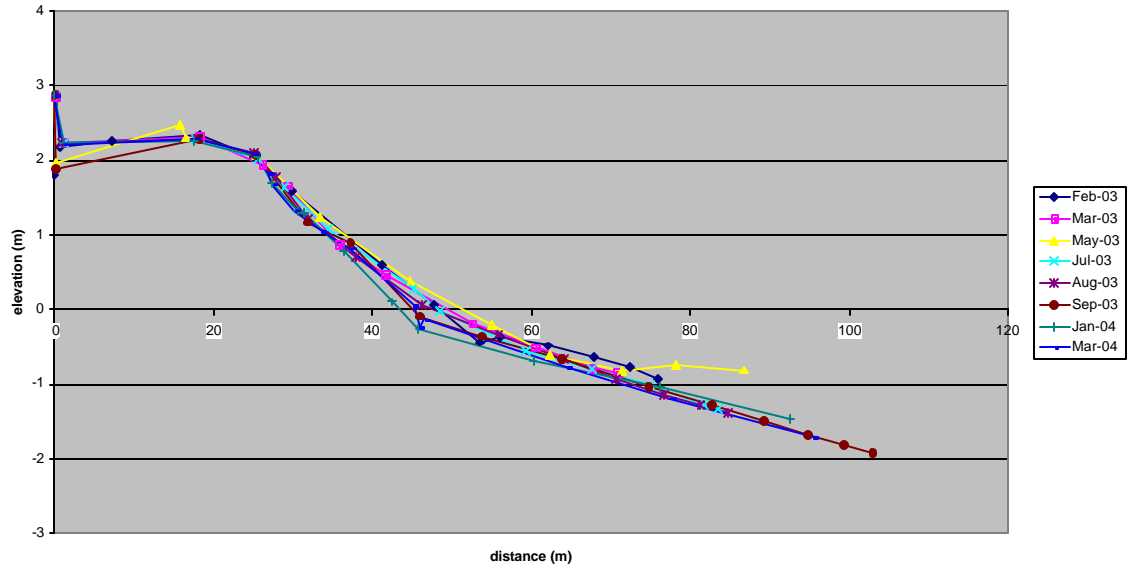
Date	Location	Mean Grain Size	% Gravel	% Sand	% Silt
10/24/2003	LK 1 BB	1.36	12.37	87.56	.07
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10/24/2003	LK 1 SZ	-.41	45.65	54.34	.01
10/24/2003	LK 1 1 METER	2.80	.71	99.08	.21
10/24/2003	LK 2 BB	-1.09	63.74	36.24	.02
10/24/2003	LK 2 HT	2.17	2.02	97.93	.04
10/24/2003	LK 2 SZ	-.38	45.23	54.75	.01
10/24/2003	LK 2 1 METER	2.84	.53	99.05	.43
10/24/2003	LK 3 BB	1.56	13.95	85.64	.41
10/24/2003	LK 3 HT	2.35	2.45	99.44	.11
10/24/2003	LK 3 SZ	1.56	18.55	81.41	.04
10/24/2003	LK 3 1 METER	2.25	5.16	94.78	.06
10/24/2003	LK 3A BB	1.78	12.93	86.59	.47
10/24/2003	LK 3A HT	1.28	7.59	92.37	.03
10/24/2003	LK 3A SZ	.77	21.08	78.91	.02
10/24/2003	LK 3A 1 METER	2.49	2.40	97.51	.1
10/24/2003	LK 3B BB	2.32	5.19	94.29	0.00
10/24/2003	LK 3B HT	2.07	1.20	98.79	0.00
10/24/2003	LK 3B SZ	1.95	5.15	94.15	.7
10/24/2003	LK 3B 1 METER	2.32	4.17	95.75	.07
10/24/2003	LK 4 BB	2.68	1.46	97.71	.83
10/24/2003	LK 4 HT	2.05	1.59	98.40	.01
10/24/2003	LK 4 SZ	1.97	6.01	93.98	.01
10/24/2003	LK 4 1 METER	2.22	5.25	94.66	.09
10/24/2003	LK 4A BB	2.36	5.81	92.99	1.20
10/24/2003	LK 4A HT	1.57	12.90	87.08	.02
10/24/2003	LK 4A SZ	2.07	4.66	95.3	.03
10/24/2003	LK 4A 1 METER	2.41	2.73	97.2	.07
10/24/2003	LK 5 BB	2.17	3.16	95.23	1.61
10/24/2003	LK 5 HT	1.47	11.84	88.14	.02
10/24/2003	LK 5 SZ	1.17	18.09	81.88	.03
10/24/2003	LK 5 1 M	2.43	2.84	97.12	.04

10/24/2003	LK 5B BB	1.74	8.62	90.86	.52
10/24/2003	LK 5B HT	1.39	16.84	83.35	.02
10/24/2003	LK 5B SZ	-.14	36.93	63.02	.03
10/24/2003	LK 5B 1 METER	2.44	1.67	98.29	.04
10/24/2003	LK 5A BB	2.32	2.18	97.72	.1
10/24/2003	LK 5A HT	1.54	13.81	86.14	.05
10/24/2003	LK 5A SZ	1.56	9.37	90.62	.01
10/24/2003	LK 5A 1 METER	2.55	1.18	98.77	.05
10/24/2003	LK 6 BB	1.42	11.36	88.39	.24
10/24/2003	LK 6 HT	.95	18.46	81.52	.02
10/24/2003	LK 6 SZ	1.4	14.65	85.34	.02
10/24/2003	LK 6 1 METER	2.04	6.58	93.41	.02
10/24/2003	LK 7 BB	1.62	7.48	92.45	.06
10/24/2003	LK 7 HT	.45	32.46	67.52	.02
10/24/2003	LK 7 SZ	-.36	52.85	47.13	.02
10/24/2003	LK 7 1 METER	1.81	15.38	84.54	.09
10/24/2003	LK 8 BB	1.57	8.97	90.92	.11
10/24/2003	LK 8 HT	.55	35.66	64.3	.03
10/24/2003	LK 8 SZ	1.5	9.1	90.89	.01
10/24/2003	LK 8 1 METER	2.01	8.61	91.36	.03
10/24/2003	LK 9 BB	1.88	4.13	95.79	.08
10/24/2003	LK 9 HT	2.43	.46	99.52	.02
10/24/2003	LK 9 SZ	1.39	10.68	89.31	.01
10/24/2003	LK 9 1 METER	1.10	11.88	88.12	.01
10/24/2003	LK 10 BB	2.49	.84	99.12	.04
10/24/2003	LK 10 HT	1.96	3.72	96.26	.02
10/24/2003	LK 10 SZ	2.24	4.62	95.38	.01
10/24/2003	LK 10 1 METER	2.07	6.20	93.76	.04
10/24/2003	LK 11 BB	2.54	.22	99.73	.05
10/24/2003	LK 11 HT	2.07	8.09	91.89	.02
10/24/2003	LK 11 SZ	1.38	11.72	88.26	.02
10/24/2003	LK 11 1 METER	2.13	4.36	95.6	.04
10/24/2003	LK 12 BB	2.32	1.58	98.41	.02
10/24/2003	LK 12 HT	2.38	1.79	99.00	.01
10/24/2003	LK 12 SZ	1.23	14.95	85.03	.01
10/24/2003	LK 12 1 M	2.70	1.26	98.69	.04

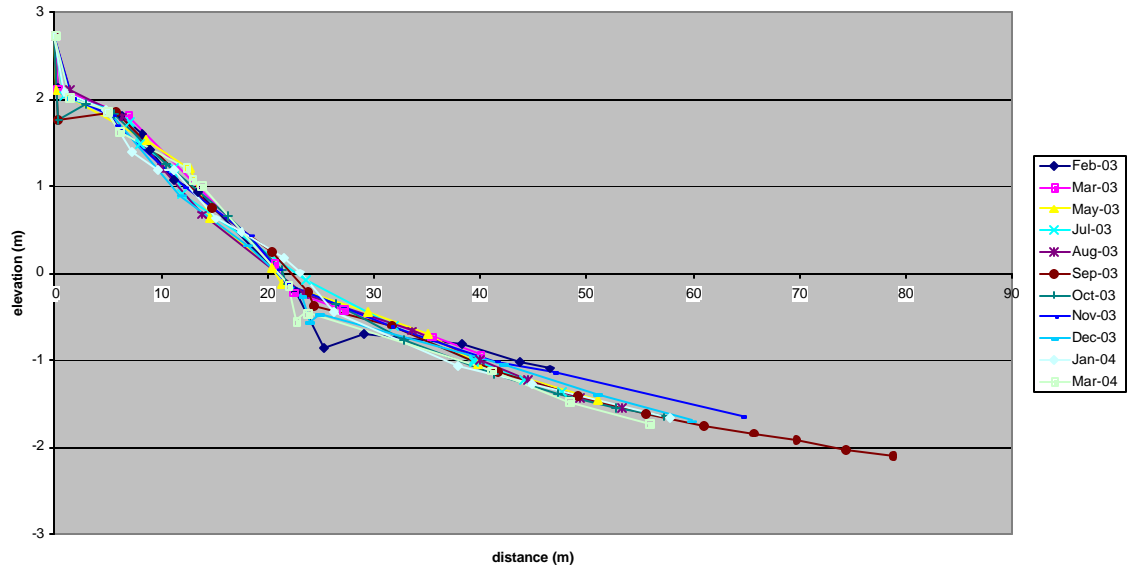
Date	Location	Mean Grain Size	% Gravel	% Sand	% Silt
10/24/2003	LK 13 BB	1.52	14.2	85.73	.07
10/24/2003	LK 13 HT	2.25	.87	99.11	.02
10/24/2003	LK 13 SZ	-.23	41.45	58.53	.02
10/24/2003	LK 13 1 METER	2.79	.38	99.56	.06

Appendix C-Monthly Beach Profiles

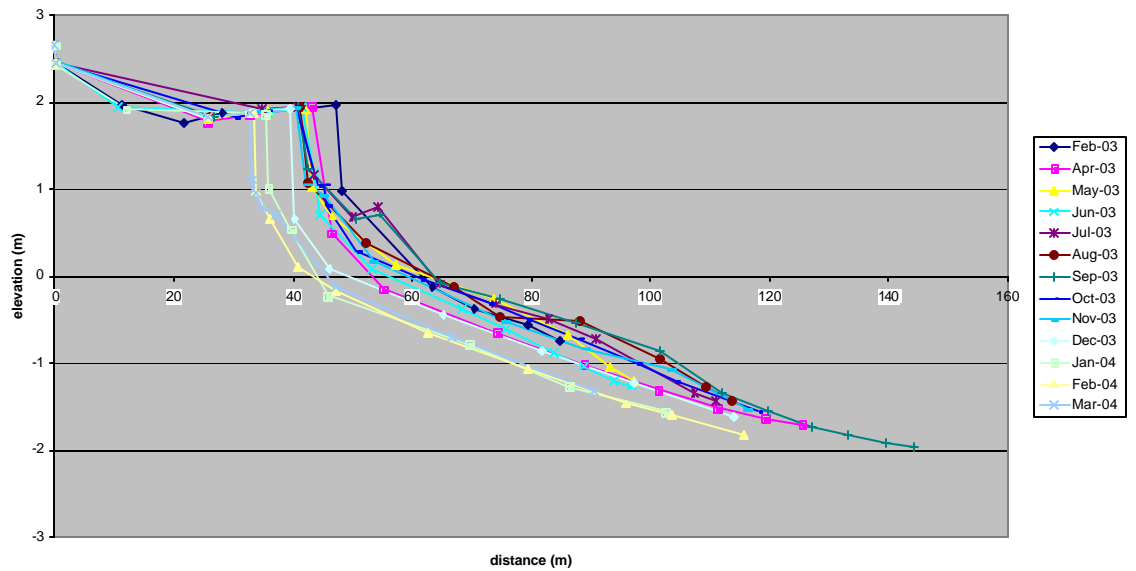
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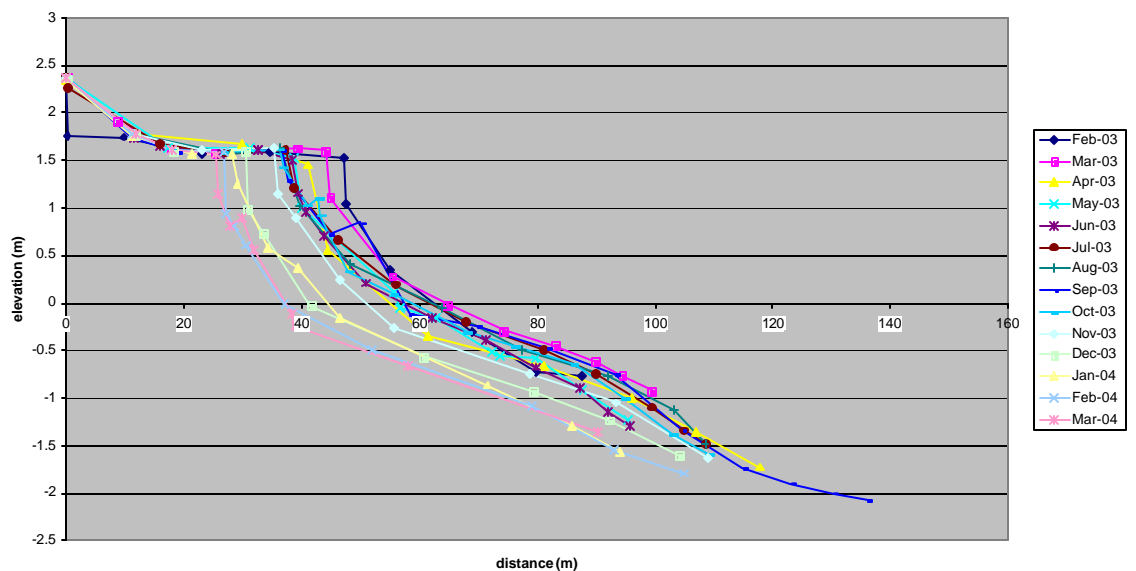
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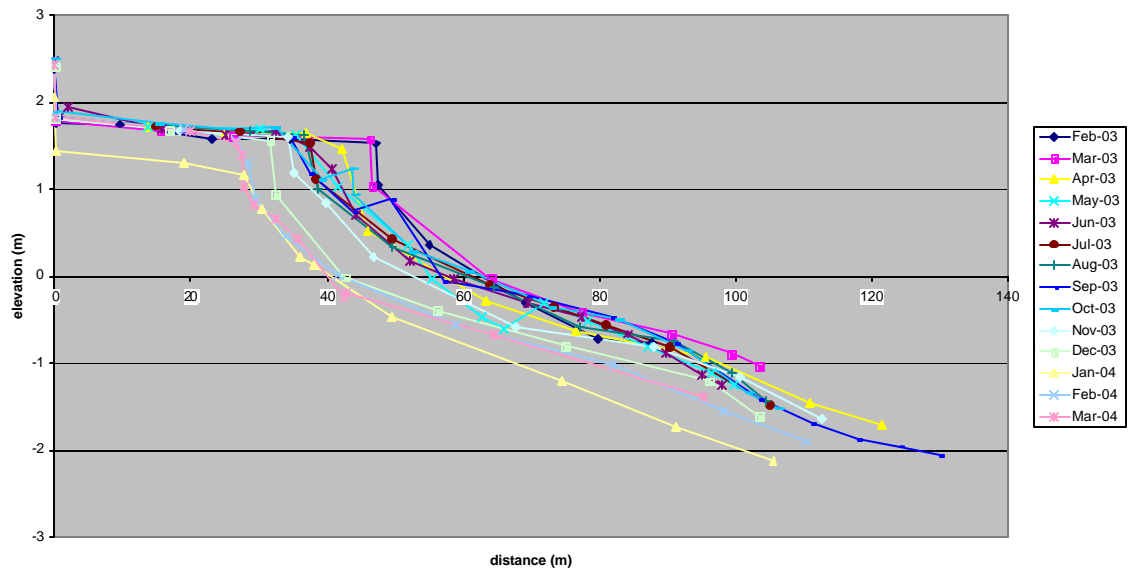
LK 3



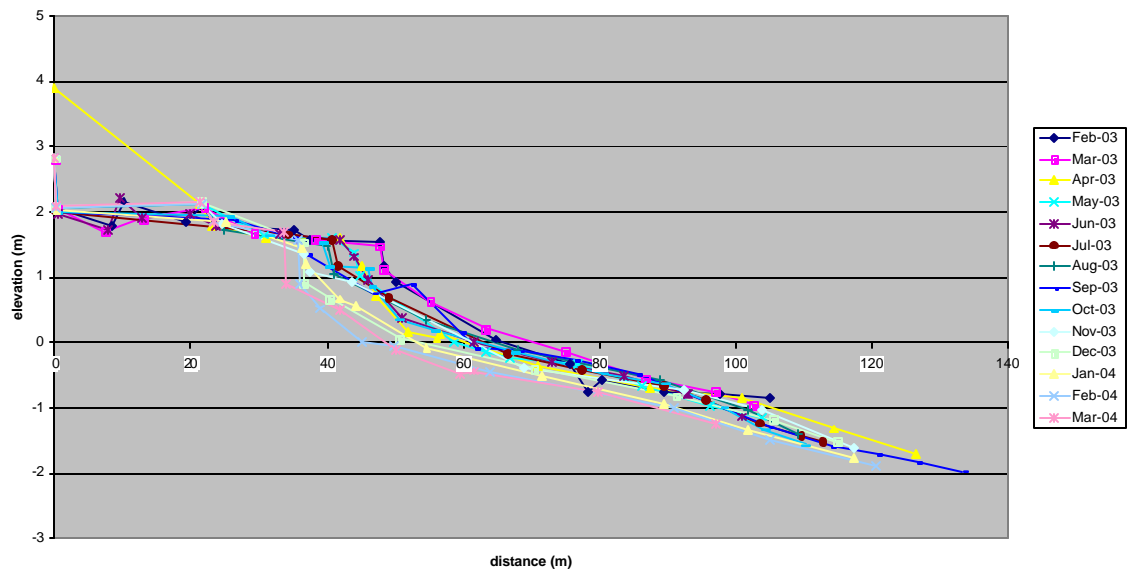
LK 3A



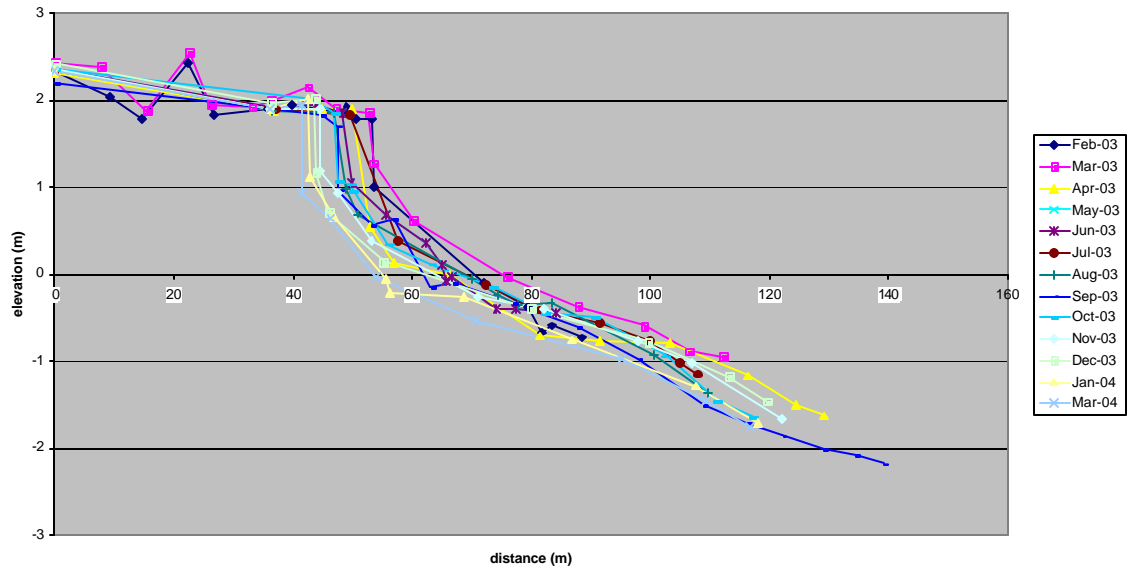
LK 3B



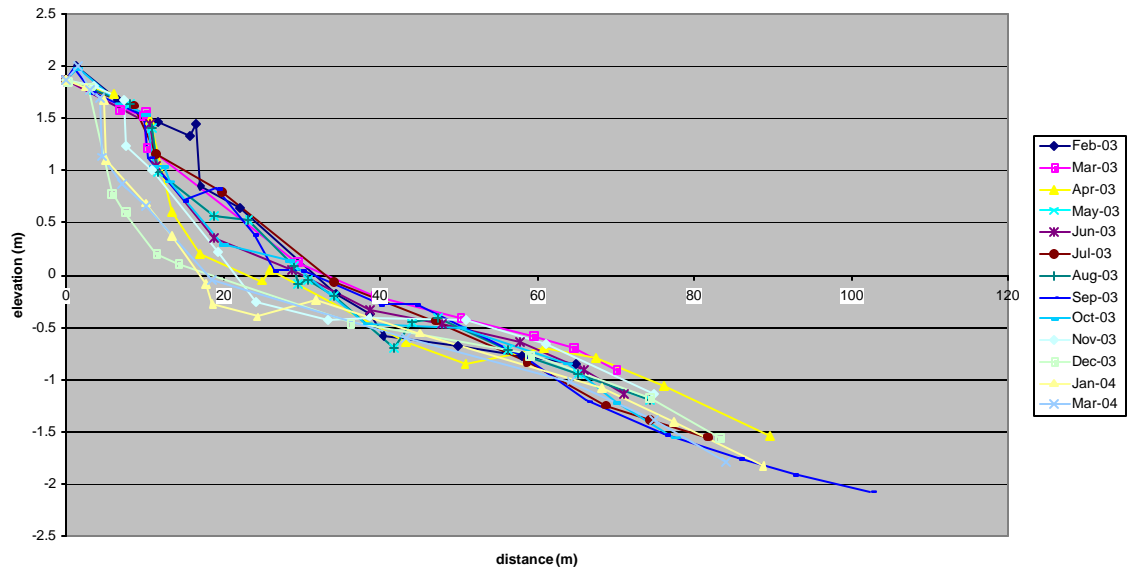
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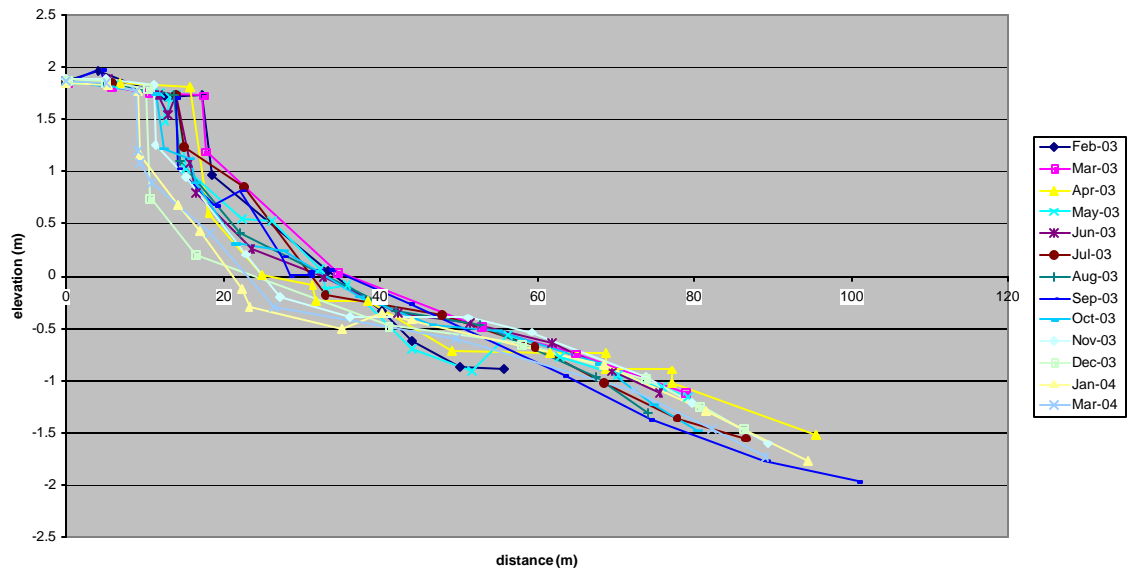
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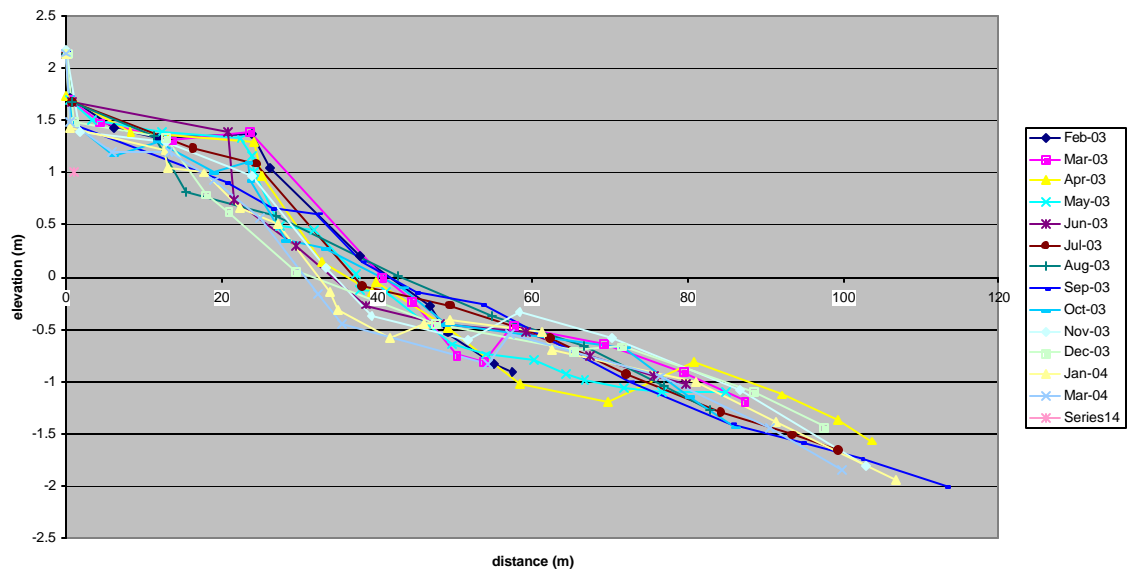
LK 5



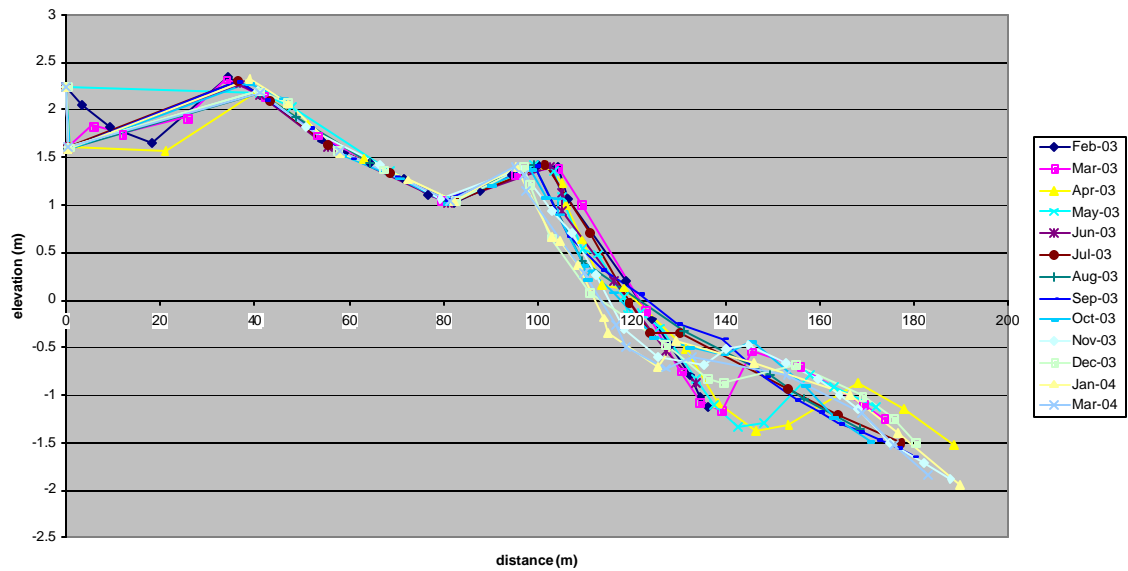
LK 5B



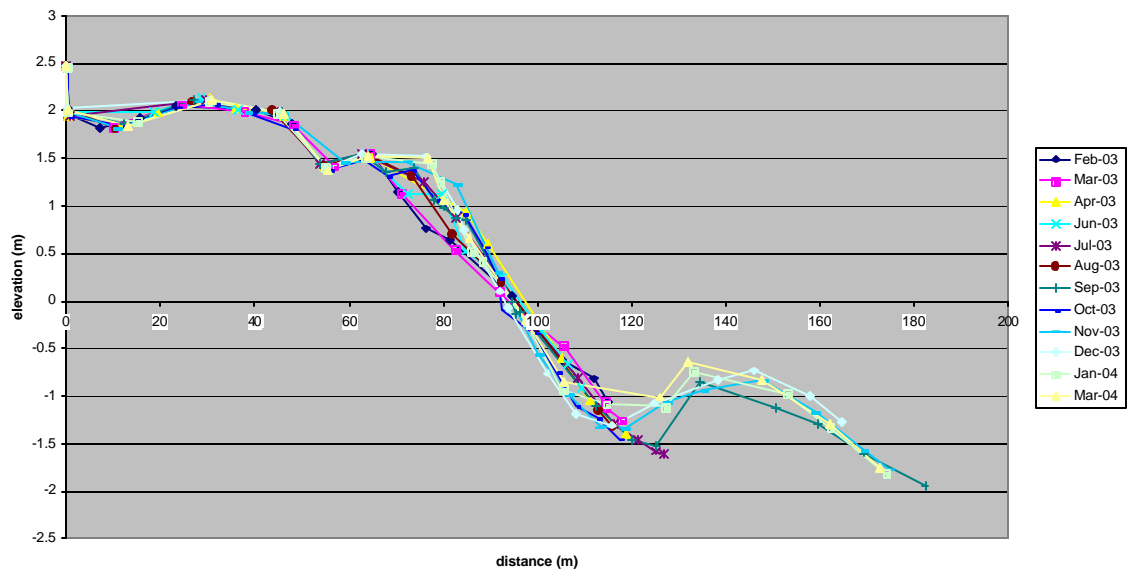
LK 5A



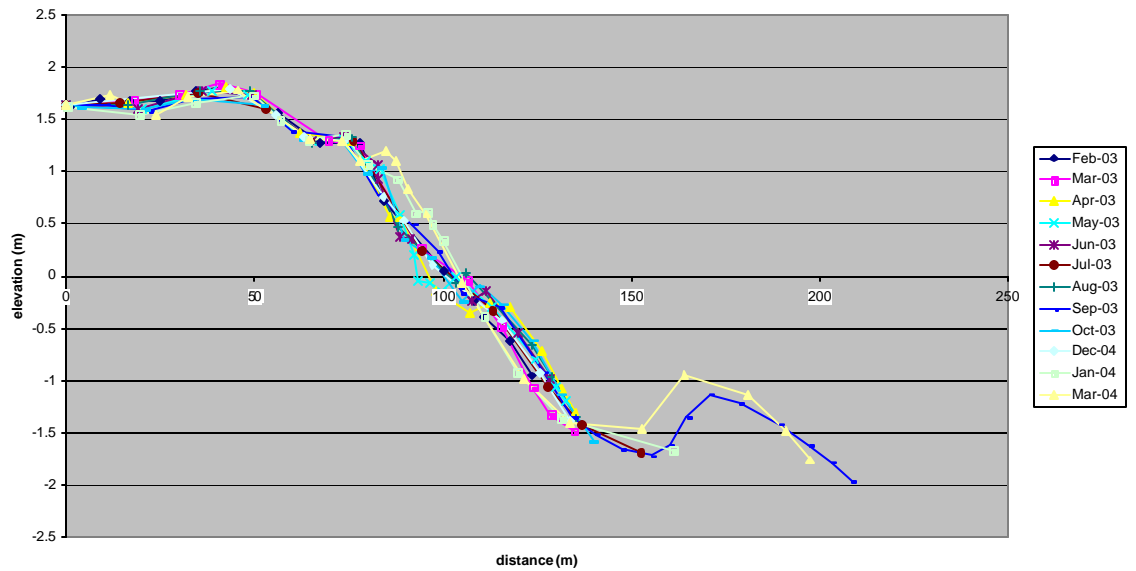
LK 6



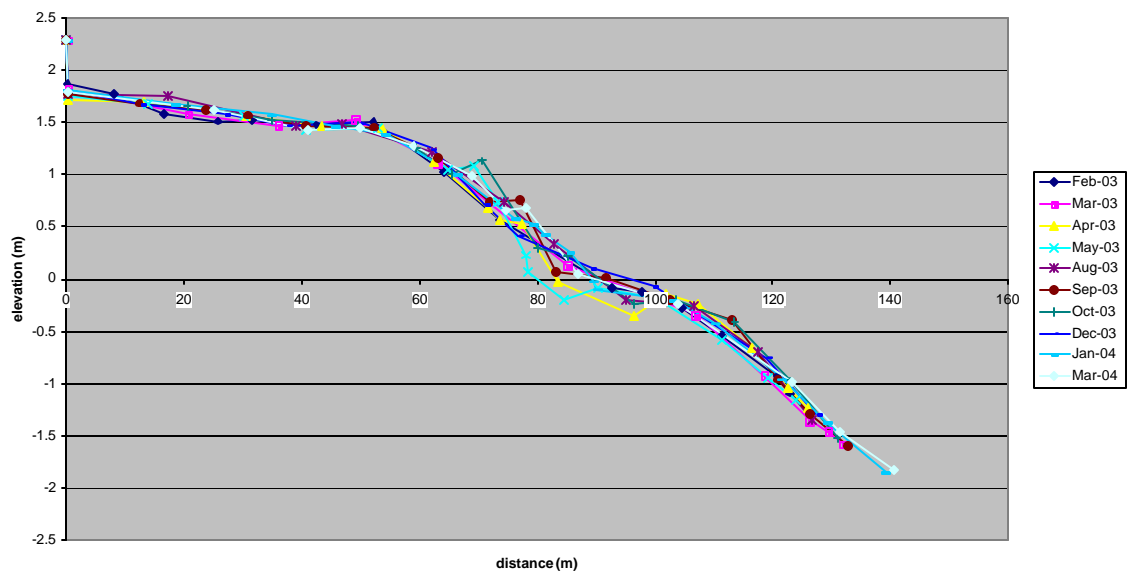
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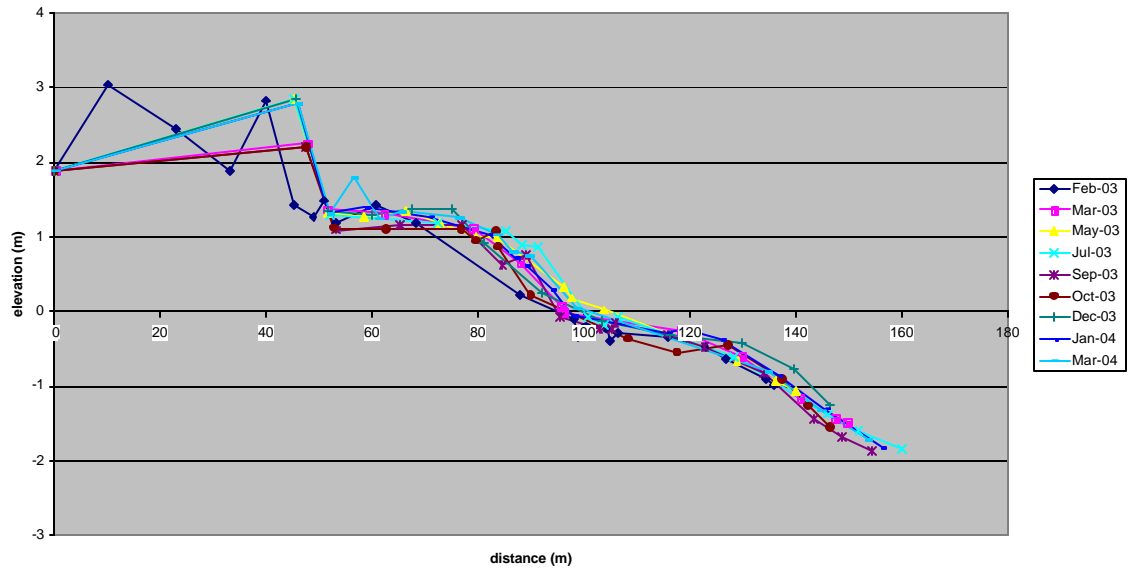
LK 8



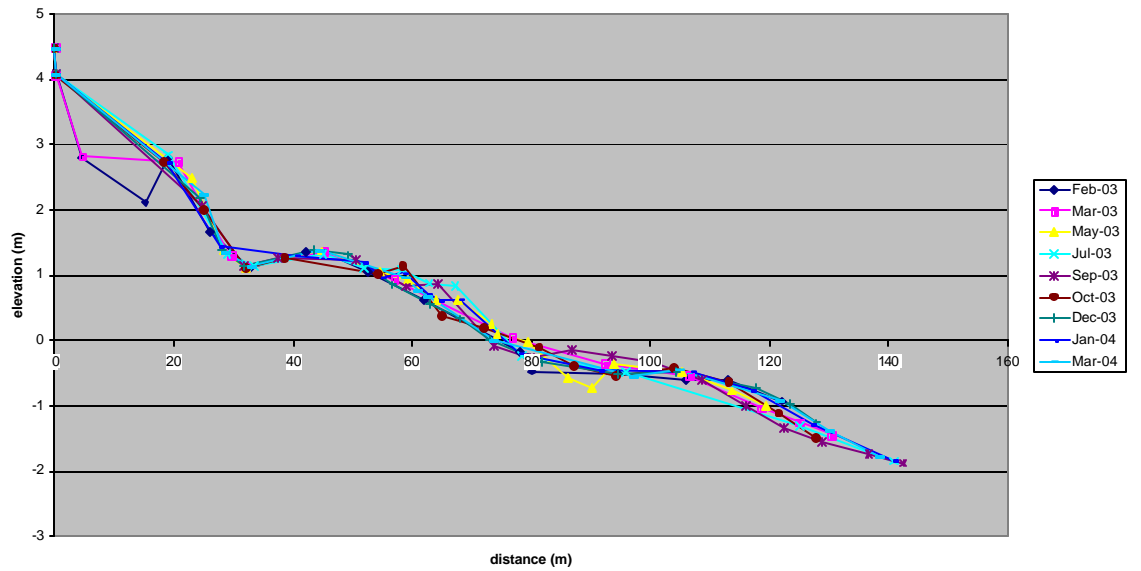
LK 9



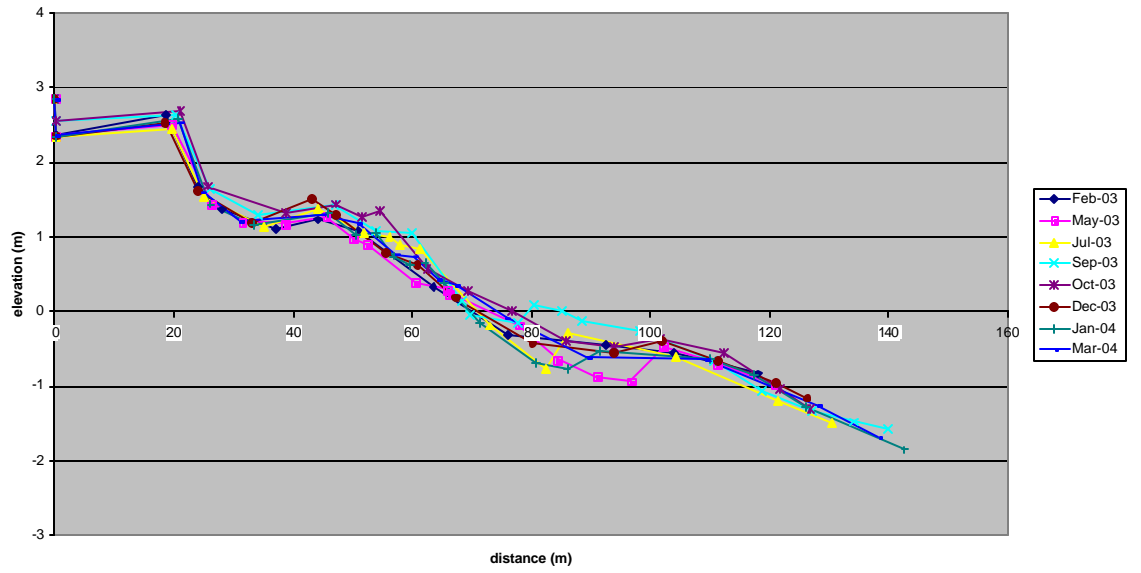
LK 10



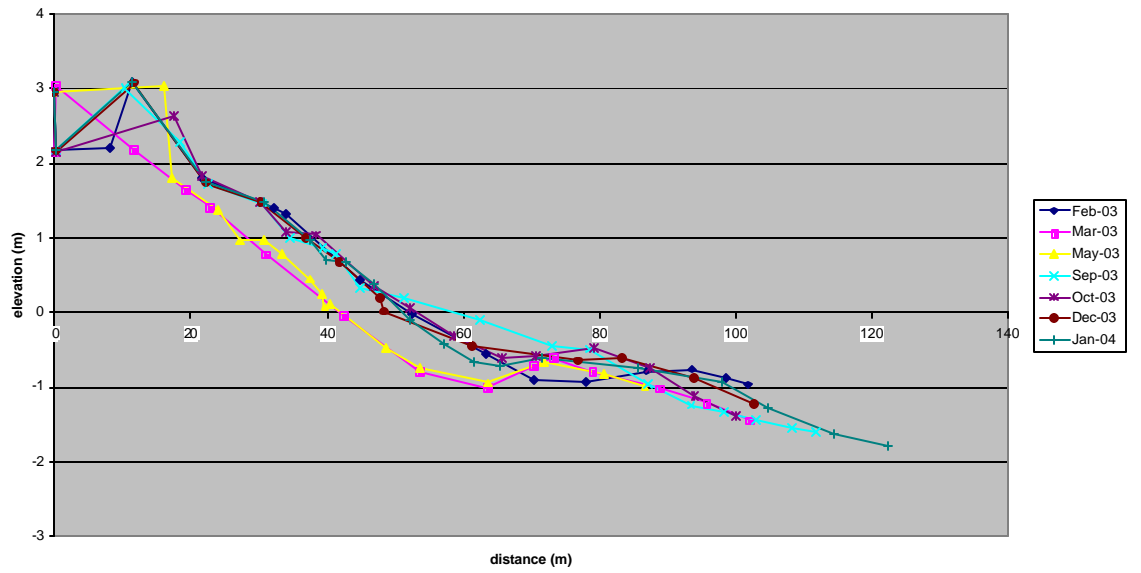
LK 11



LK 12



LK 13



Appendix D: Volume Changes

Location	Volume change above NGVD (m)	Volume change Below NGVD (m)	Distance between profile locations (m)
LK 1	-0.098	-.161	
LK 2	+0.0095	.23	91.5
LK 3	-28.98	-15.085	91.5
LK 3A	-33.993	-25.77	91.5
LK 3B	-31.074	-19.85	91.5
LK 4	-24.816	-15.46	91.5
LK 4A	-24.258	-8.59	91.5
LK 5	-18.09	-6.6875	91.5
LK 5B	-16.065	-2.4875	91.5
LK 5A	-12.279	-7.335	91.5
LK 6	-10.032	-4.2575	304.9
LK 7	+9.33	1.9825	609.8
LK 8	+6.75	.385	609.8
LK 9	+2.7	.6425	609.8
LK 10	+15.372	3.2425	609.8
LK 11	+1.866	3.3675	609.8
LK 12	+4.575	.1025	914.7
LK 13	-.651	.4325	914.7