Performance of Upham Beach T-Groin Project and Its Impact to the Downdrift Beach

Progress Report for the Period of October 2008 to April 2009

Submitted by

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EXECUTIVE SUMMARY

The field of 5 T-groins installed at Upham Beach was designed to maintain a portion of the nourished beach at this chronically eroding location without negative impacts to the downdrift beach. The T-groin project area was renourished in September 2006 and all the structures were buried. During the initial 3 months after the nourishment, rapid beach erosion at the north segment, as typical of Upham Beach, was measured. Since all the structures were buried, this rapid erosion should not be directly related to the T-groin field. The downdrift beach remained largely stable to slightly accretionary, benefiting from the sand supply from the north. No direct impact of the structures to the downdrift beach was measured during the initial 3 months.

The 2nd monitoring period from December 2006 to April 2007 represents an active winter season. The northernmost T1 became exposed at the shoreline in December 2006. T2 became exposed during January 2007. The peak volume loss of 8,000 m^3 in the T2-T3 compartment represents an increase of 20% as compared to the initial 3 months, with a corresponding average shoreline loss of 26 m. Volume losses in the T1-BP-jetty and T1-T2 compartments were 2,100 and 4,100 m^3, respectively, which was a decrease of 60 to 70% as compared to the initial 3 months. The T3-T4 compartment lost 3,000 m^3. Minimal volume and shoreline change was measured in the T4-T5 compartment during the first 7 months, along with volume gain measured at the downdrift beach.

The 3rd monitoring period from April to October 2007 represents a mild summer season. T3 became exposed in May 2007. Compared to the changes measured during the first 7 months, the overall profile-volume and shoreline changes were much smaller. No direct impact of the structures to the downdrift beach can be identified during this 6-month monitoring period.

The 4th monitoring period from October 2007 to April 2008 represents an active winter, with frequent cold-front passages. Beach erosion was measured at all the T-groin profiles, and along the immediate downdrift area. T4 became exposed at the shoreline following the passage of a strong cold front in February 2008. Overall, nearly 13,000 m^3 of sand eroded from the T-groin area, in addition to 6,000 m^3 from the immediate downdrift beach. Volume gains were measured further downdrift. The seawall along the T1-T2 compartment became exposed at the shoreline.

The 5th monitoring period from April to October 2008 represents a relatively active summer, with distal passages of 2 hurricanes late in the season. The high waves generated by the storms eroded the intertidal zone. Overall, nearly 3,400 m^3 of sand eroded from the T-groin project area, in addition to 5,600 m^3 from the downdrift beach. A gain of 27,600 m^3 was measured further downdrift from R148 to R156. The small fillet beach that had been maintained between the Blind Pass south jetty and T-groin 1 suffered some erosion due to the removal of the top layer of the T-groin 1. The erosion along the downdrift beach is likely related to the depleted sediment supply to the north as typical of the longer-term performance of the Upham Beach nourishment and not related to the T-groins. T5 did not become exposed during this monitoring period.

Overall, based on the 25 months of monthly monitoring, no clear negative impact from the T-groin field to the downdrift shoreline can be identified. Compared to the performance of the 2000-2002 Upham Beach nourishment, the 2-year sand losses from 4 of the 5 T-groin compartments were considerably less: 18% less in T1-T2 compartment, 26% less in the T2-T3 compartment, 61% less in the T3-T4 compartment, and 92% less

in the T4-T5 compartment. Slightly more sand, ~ 7%, was lost from the Blind Pass jetty and T1 compartment.

The sixth monitoring period from October 2008 to April 2009 represents an active winter season, with frequent passages of winter cold fronts. Different from the previous monitoring periods, substantial erosion was measured in the intertidal and subaqueous portions of the profile, ranging from 0.5 m NAVD88 to -2.0 m NAVD88. This resulted in an elevation loss of approximately 0.5 m over a large portion of the subtidal profile. This elevation loss resulted in considerable volume loss during the winter of 2008-2009. Overall, nearly 13,300 m^3 of sand eroded from the T-groin project area, in addition to 10,000 m^3 from the downdrift beach. A gain of 4,500 m^3 was measured further downdrift from R149 to R156. These result in an overall volume loss of 18,700 m^3 north of profile R156. This volume loss is considerably greater than the two previous summer seasons and also slightly greater than the 2007-2008 winter season with similar amount of loss in the T-groin area but slightly more loss in the downdrift area. Accelerated erosion was measured in the northern two compartments, probably due to the active interaction between the fully exposed seawall and riprap with the incoming waves. The damages to the northern two T-groins have substantially reduced their functions. Although erosion was also measured at a number of downdrift profiles, the profile-volume loss was mostly smaller than the loss within the T-groin field and is comparable to the typical rate of winter erosion at Upham Beach. This suggests that the T-groins did not have significant negative impacts to the downdrift beach. In addition, the volume loss between profile LK3 and LK5 is comparable to the loss during the previous winter season. This further supports the findings from the above 2-year comparison that the erosion rate seems to be reduced by the presence of the T-groins as compared to the previous nourishment without the structures.

Overall, based on the 31 months of intensive monitoring, no clear negative impact from the T-groin field to the downdrift shoreline can be identified. Compared to the performance of previous Upham Beach nourishment (Elko et al., 2005), the T-groins have reduced the rate of beach erosion at Upham Beach to a certain degree. However, partly due to the damage to T1 and T2 structures, the seawall and riprap north of T2 became exposed after August 2008 or about 23 months after the nourishment and the installation of the structures. Significantly accelerated rate of beach erosion was measured north of T2 after the month 23, resulting in complete exposure of the seawall and riprap. This, along with the much slower rate of erosion before the structural damage, suggests that the structures functions to a certain extent in protecting the beach landward.

Introduction

Upham Beach, at the northern end of Long Key, is a chronically eroding beach. Since 1975, Upham Beach has been nourished approximately every 4 to 5 years. The performance of several recent beach nourishment projects was examined by Elko (1999) and Elko et al. (2005). The performance of the last beach nourishment in 2004 was studied in detail by Elko (2005, 2006) and Elko and Wang (2007). The erosion at Upham Beach is caused by a significant deficit in the southward longshore sand transport. The heavily structured Blind Pass to the north prevents sand from moving into the system to replace the sand moved southward by longshore sediment transport (Elko and Davis, 2004).

In order to mitigate the rapid and persistent erosion at Upham Beach, a field of 5 experimental geotextile T-groins was installed, extending alongshore from benchmark LK1B south to benchmark LK5 (Elko and Mann, 2007). The construction of the T-groins started at the end of 2004, shortly after the completion of the 2004 Upham Beach nourishment project. The initial design was to have the T-groins buried within the nourishment project. The T-groin field would become effective once the shoreline retreated to the structure. It was expected that the T-groin field would retain a portion of the beach fill landward of the structure. The T-groin construction lasted for nearly 1.5 years and was completed in May 2006. Substantial beach erosion, especially at the northern portion of the project, occurred during the prolonged construction. At the completion of the T-groin installation, the northern 3 structures were exposed at the shoreline.

The entire T-groin project area was renourished in September 2006. The renourished shoreline extended well seaward of the T-groin field, and all the structures were buried by the renourishment.

Contracted by Pinellas County, the Coastal Research Laboratory at the University of South Florida is monitoring the performance of the T-groin field and its influence on the downdrift beach to the south. The north end of the T-groin field is bound by the south jetty of Blind Pass. The monitoring study with monthly surveys started in June 2006. The first progress report summarizes the performance of the first 6-month period from June 2006 to December 2006 (Wang and Roberts, 2007a). The second progress report summarizes the performance of the 4-month period from December 2006 to April 2007 (Wang and Roberts, 2007b). The third report summarizes the performance of the 6-month period from April 2007 through October 2007 (Wang and Roberts, 2007c). The forth report summarized the performance of the 6-month period from October 2007 through April 2008 (Wang and Roberts, 2008). The fifth report summarizes the 6-month period from April 2008 to October 2008. A summary of the 2-year performance and a comparison with a previous nourishment without the structures are also provided in the fifth report. This report summarizes the 6-month period from October 2008 to April 2009.

Because the project was renourished in September 2006 the performance before and after that time is not comparable. The performance before the September 2006 renourishment was influenced by substantial erosion during the prolonged T-groin construction. Therefore, the performance analysis focuses on the period after September 2006. This report summarizes the continuing performance of the T-groins from the 26th

to the 32nd month after the renourishment in September 2006, with comparisons to the previous monitoring periods, as well as a previous nourishment without the structures.

The Monitoring Plan

An intensive monitoring program was designed and implemented to quantify the performance of the T-groins and their impact to the adjacent beach. Monthly beach-profile surveys were conducted within the T-groin field and along the adjacent (downdrift) beach. Starting October 2008, the monthly surveys were replaced by bi-monthly surveys. Horizontal and vertical controls were established using Real-Time Kinematic (RTK) Global Positioning System (GPS). Twenty-seven beach profiles were surveyed within the T-groin field (referred to as T-groin lines in the following), in addition to 28 profiles along the entire length of Long Key (referred to as Long Key lines). The T-groin lines extend to roughly -1.5 m NAVD88. Nine of the Long Key lines are located within the T-groin field. The Long Key lines extend to roughly -3 m NAVD88, or to roughly the closure depth in this area (Wang and Davis, 1999). Level-and-transit survey procedures were followed using an electronic total survey station (SOKKIA Set 500) and a 4-m survey rod. Each T-groin survey line was marked by two PVC pipes installed in the dune or backbeach; whereas, the Long Key lines were surveyed from the traditional LK- and R-monuments.

Each T-groin structure was monitored with six survey lines: three lines that intersect the structure and three lines in the adjacent sandy “compartments”. The lines intersecting the structure included one line extending through the middle of the T along the neck, one

line extending along the south edge of the T-head, and one line extending along the north edge of the T-head. The remaining three lines were distributed evenly in the sandy compartment between T-groins. The five T-groins are oriented differently, following the trend of the shoreline orientation. The T-groin lines were aligned roughly parallel to the neck; therefore, the lines carry somewhat different azimuths. All of the survey lines within the project area are shown in Figure 1. The aerial photo is a Digital Orthographic Quarter Quad from LABINS (LAnd Boundary INformation System) taken in 2006. Three T-groin structures were exposed at the shoreline and can be seen from the aerial photo. The downdrift Long Key (LK) lines extending to R155 are shown in Figure 2, also a 2006 DOQQ obtained from LABINS. The bi-monthly beach profiles, from October 2008 to April 2008, including all the T-groin lines and Long Key lines to R156 are shown individually in Appendix I. Profiles extending 2600 m downdrift are analyzed in this report.

The survey was conducted using NAD83 State Plane (Florida West 0902) coordinate system in meters. All profile surveys are referenced to NAVD88 in meters. The elevations of the benchmarks were established using a RTK-GPS, tied to LABINS control points with Class 1 elevation. The beach volume and shoreline analyses are conducted using the software RMAP (Regional Morphology Analysis Package), developed by the U.S. Army Corps of Engineers. Based on CORPSCON (version 5.1), NAVD 88 zero equals 0.468 m NGVD 29 for this region.

Figure 1. The T-groin and Long Key survey lines within the T-Groin field project area. The northern 3 T-groins are visible on this aerial photo.

Figure 2. The downdrift Long Key survey lines. The northern nine lines within the T-groin field project area are illustrated in Figure 1. The downdrift beach analyses were extended to R156 (~300 m south of the south-most line), to 2600 m south of the project area.

Results and Discussion

Due to the large number of T-groin profiles surveyed during this study, profile nomenclature tends to be confusing. In addition, the nomenclature that is convenient for field operation is not convenient for discussion of the results. In the previous progress reports, the nomenclature used in the field operation, as shown in Figure 1, were also used in the discussion. However, to more clearly link the individual profile to the corresponding T-groin compartment, the profiles were named differently in the Appendix. In this report (and as in the last two reports, Wang and Roberts, 2008a, Wang and Roberts, 2008b), the names used in the Appendix are used in the discussion to maintain consistency. Table 1 summarizes and compares the nomenclature used in the field operation and previous reports to that used throughout this report. Several Long Key lines overlap the T-groin lines. The Long Key lines that are also used as T-groin lines are as follows: LK5 for T5N1 (T5 N. Tip), LK2 for T2N4 (T2 N. Quarter), and LK1B for T1N4 (T1 N. Quarter).

This is the sixth in a series of progressive reports. For the convenience of comparisons, the major findings from the five previous reports are summarized below, followed by the data and results for the current report. It is worth noting that the time period covered by each progress report is not identical, with the first two reports covering shorter periods of rapid changes, 3 and 4 months, respectively. The third, forth, fifth, and current reports cover 6-month periods. More rapid beach changes were expected to occur during the first few months due to initial adjustments.

Table 1. T-groin profile nomenclature. The profiles are listed from north to south. The profiles in the T-groin compartment are named based on the structure to the south.

Structure	Names used in Field operation	Names used in Reporting
Blind Pass south jetty		
BP jetty-T1 compartment	T1N4 (=LK1B)	T1 North Quarter (LK1B)
BP jetty-T1 compartment	T1N3	T1 Middle
BP jetty-T1 compartment	T1N2	T1 South Quarter
BP jetty-T1 compartment	T1N1	T1 North Tip
BP jetty-T1 compartment	T1C	T1 Center
T-groin 1 (T1)		
T1-T2 compartment	T1S	T2 North End*
T1-T2 compartment	T2N4 (=LK2)	T2 North Quarter (LK2)
T1-T2 compartment	T2N3	T2 Middle
T1-T2 compartment	T2N2	T2 South Quarter
T1-T2 compartment	T2N1	T2 North Tip**
T1-T2 compartment	T2C	T2 Center
T-groin 2 (T2)		
T2-T3 compartment	T2S	T3 North End
T2-T3 compartment	T3N4	T3 North Quarter
T2-T3 compartment	T3N3	T3 Middle
T2-T3 compartment	T3N2	T3 South Quarter
T2-T3 compartment	T3N1	T3 North Tip
T2-T3 compartment	T3C	T3 Center
T-groin 3 (T3)		
T3-T4 compartment	T3S	T4 North End
T3-T4 compartment	T4N4	T4 North Quarter
T3-T4 compartment	T4N3	T4 Middle
T3-T4 compartment	T4N2	T4 South Quarter
T3-T4 compartment	T4N1	T4 North Tip
T3-T4 compartment	T4C	T4 Center
T-groin 4 (T4)		
T4-T5 compartment	T4S	T5 North End
T4-T5 compartment	T5N4	T5 North Quarter
T4-T5 compartment	T5N3	T5 Middle
T4-T5 compartment	T5N2	T5 South Quarter
T4-T5 compartment	T5N1 (=LK5)	T5 North Tip
T-groin 5 (T5)		

*: "North End" line extends across the south tip of the structure at the north end of the compartment.

**: "North Tip" line extends across the north tip of the structure at the south end of the compartment. This is the structure used to name the profiles in this compartment.

In the following discussion, the first three months, as discussed in the first progressive report (Wang and Roberts, 2007a), is referred to as the “initial 3 months”. The second 4 month period from December 2006 to April 2007, discussed in the second report (Wang and Roberts, 2007b), is referred to as “2006-2007 winter”. The third 6 month period from April 2007 to October 2007, discussed in the third report (Wang and Roberts, 2007c), is referred to as “2007 summer”. The fourth 6 month period from October 2007 to April 2008, discussed in the forth report (Wang and Roberts, 2008a), is referred to as “2007-2008 winter”. The fifth 6 month period from April 2008 to October 2008, discussed in the fifth report (Wang and Roberts, 2008b), is referred to as “2008 summer”. Finally, the current report discusses the 6-month period from October 2008 to April 2009, and is referred to as “2008-2009 winter”.

Summary of the T-groin Performance during the Initial Three Months from September 2006 to December 2006

Detailed T-groin performance during the first 3 months after renourishment from September 2006 to December 2006 was discussed in the first progress report (Wang and Roberts, 2007a). Here, a summary of the shoreline and beach-volume changes is included for the convenience of comparison of the performance during the entire 31-month period.

During the initial 3 month period from September to December 2006, the structures remained largely buried. Rapid dry beach erosion was measured along the northern and central segments of the T-groin field, north of T-groin 3. This is a typical response of this beach following nourishment. In the south segment and downdrift of the T-groin field, a stable dry beach with deposition in the nearshore area was measured. No

negative impact of the T-groin field to the downdrift beach was measured during this period of time.

Changes of profile-volume and shoreline during the initial 3 months were calculated for all the T-groin profiles and Long Key profiles to R149. Figure 3 shows the alongshore distribution of the volume change along the T-groin profiles. Overall, profile-volume loss was measured at nearly all the T-groin profiles. A southward decreasing trend in profile-volume loss was apparent, consistent with the trend documented from previous Upham Beach nourishment projects without the T-groins (Elko, 2006). A large number of T-Groin profiles were surveyed to capture the detailed change in the nearshore zone. The profile-volume calculations for the T-Groin lines were conducted from the benchmark (on the seawall or in the dune field) seaward to -1.2 m NAVD88 (this seaward limit was increased to -1.5 m for both field survey and volume calculation from April 2007 based on FDEP comments). The Long Key profiles extended much further seaward.

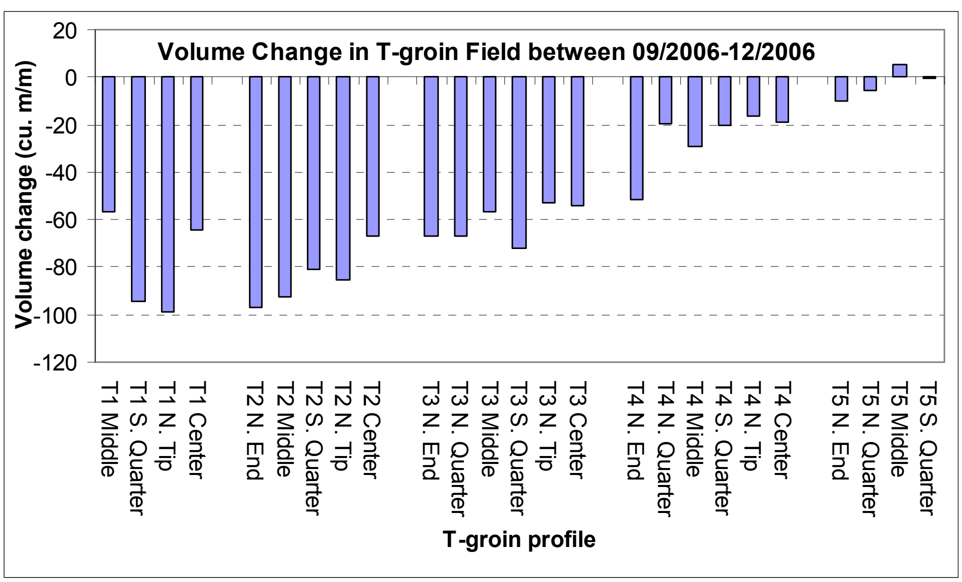

Figure 3. Profile-volume change in the T-groin field during the initial 3 months between 09/2006-12/2006.

Table 2 summarizes the spatially averaged profile-volume and shoreline changes in each T-groin compartment from 09/2006 to 12/2006. The total volume change in each compartment is obtained by multiplying the average profile-volume change by the alongshore distance of the compartment. The volume change in the T-groin compartment reflects the trend shown in Figure 3. The most volume loss of approximately 10,000 m^3 was measured in the T1-T2 compartment. The smaller volume loss in the BP-Jetty-T1 compartment to the north was due to the protection of the Blind Pass south jetty. The total volume loss in each compartment decreased to the south. Volume gain was measured at the southernmost T-groin compartment and at the downdrift beach. The T-groins were largely buried during this period of time and the above volume-change pattern largely reflects the adjustment of the September nourishment. North of T-groin 4 (T4) a total of nearly 27,000 m^3 of sand was lost during the initial three-month period. The T4-T5 compartment and the downdrift area gained more than 18,000 m^3 of sand. Overall, a net loss of slightly over 8,000 m^3 of sand was measured in the T-groin and direct downdrift areas, indicating that most of the sand eroded from the northern part of the T-groin area was deposited directly downdrift.

Table 2. Summary of profile-volume and shoreline change at the T-groin compartments and the downdrift beach during the initial 3 months from 09/2006 to 12/2006.

	Alongshore Distance(m)	Avg. Volume cu m / m	Avg. Shoreline M	Total Volume Cu m
T1 compartment	105	-65.78	-27.48	-6877
T1-2 compartment	117	-86.47	-36.02	-10159
T2-3 compartment	108	-61.69	-26.40	-6647
T3-4 compartment	119	-25.91	-10.26	-3085
T4-5 compartment	106	4.18	-1.39	443
Downdrift	812	21.93	-0.94	17809
			Volume Sum	-8515

The shoreline (defined here as NAVD88 zero) change in the T-groin field demonstrated a similar pattern as that of profile-volume change (Figure 4). Again, the T-groins were buried and this pattern largely reflected the initial beach-nourishment adjustment instead of direct functioning of the T-groins. The greatest shoreline retreat was measured in the T1-T2 compartment, averaging 36 m during these three months (Table 2). The volume gain measured at the southernmost compartment and downdrift occurred mostly in the nearshore area and did not result in shoreline gain. Slight shoreline loss was measured instead.

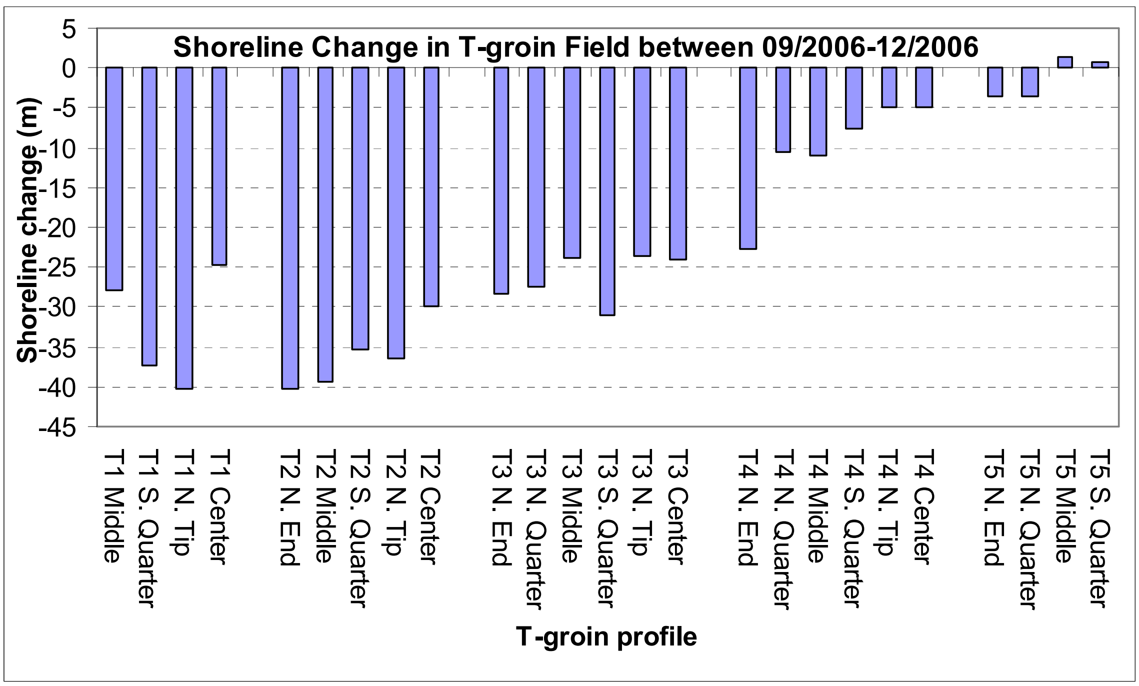

Figure 4. Shoreline change in the T-groin field during the initial three months between 09/2006-12/2006.

Figures 5 and 6 show the profile-volume and shoreline changes measured at the Long Key profiles. The Long Key profiles extended further seaward to about -3 m NAVD88, as compared to -1.2 m for the T-groin profiles. LK1B through LK5 are within the T-groin project area and LK5A through R149 are located downdrift. Profile-volume loss

was measured within the T-groin area (consistent with the T-groin lines), while profile-volume gain was measured downdrift. However, most of the downdrift volume gain occurred in the nearshore zone and did not result in any significant shoreline gain.

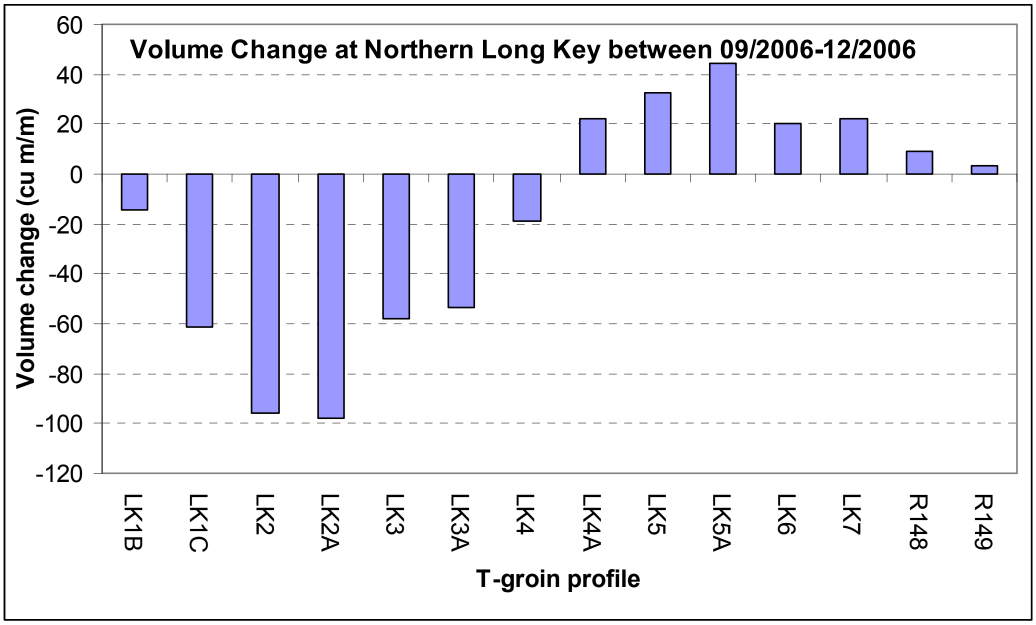

Figure 5. Profile-volume change of the Long Key profiles during the initial 3 months between 09/2006-12/2006.

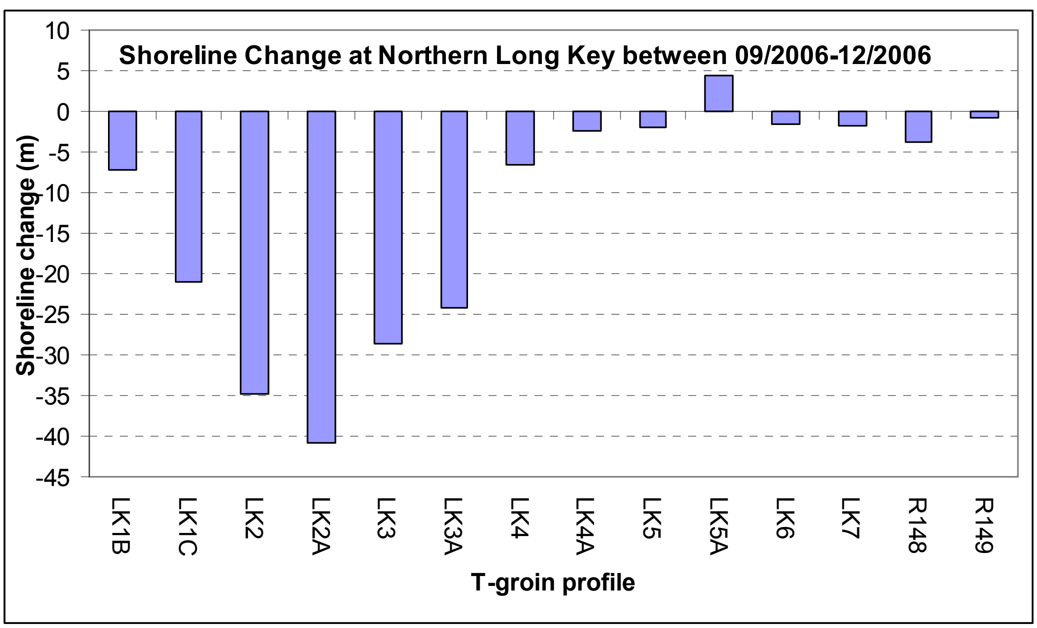

Figure 6. Shoreline change of the Long Key profiles during the initial three months between 09/2006-12/2006.

Summary of the Performance during the 2006-2007 Winter from December 2006 to April 2007

Detailed T-groin performance during December 2006 to April 2007 was discussed in the second progress report (Wang and Roberts, 2007b). Here, a summary of the shoreline and profile-volume changes is included for the convenience of comparison of the performance during the entire 31-month period.

From December 2006 to April 2007, two structures became exposed. The northern most T-groin, T1, became exposed between October and November 2006, prior to the beginning of this 4-month winter period. The T2 T-groin became exposed in January 2007 at the beginning of this period. The T3 T-groin remained buried throughout these 4 months, however became exposed during the month of May 2007.

Changes of profile-volume and shoreline during the 2006-2007 winter season were calculated for all the T-groin profiles and Long Key profiles south to R149. The profile-volume calculation was conducted from the benchmark (on the seawall or in the dune field) seaward to roughly -1.2 m NAVD88. Figure 7 shows the alongshore distribution of the profile-volume changes. Overall, profile-volume loss was measured at nearly all the T-groin profiles. The greatest volume loss occurred at the T2-T3 compartment decreasing in volume loss to the north and south of T3. Compared to the profile-volume change during the initial 3 months, between September 2006 and December 2006 (Figure 3), beach-profile volume change in the north segment decreased substantially due to a combination of depleting sediment supply and functioning of the exposed T-groin structures. In addition, profile-volume loss at the T2-T3 compartment increased considerably. The changes that occurred in the T4 and T5 compartments and the downdrift area varied slightly, but remained relatively small.

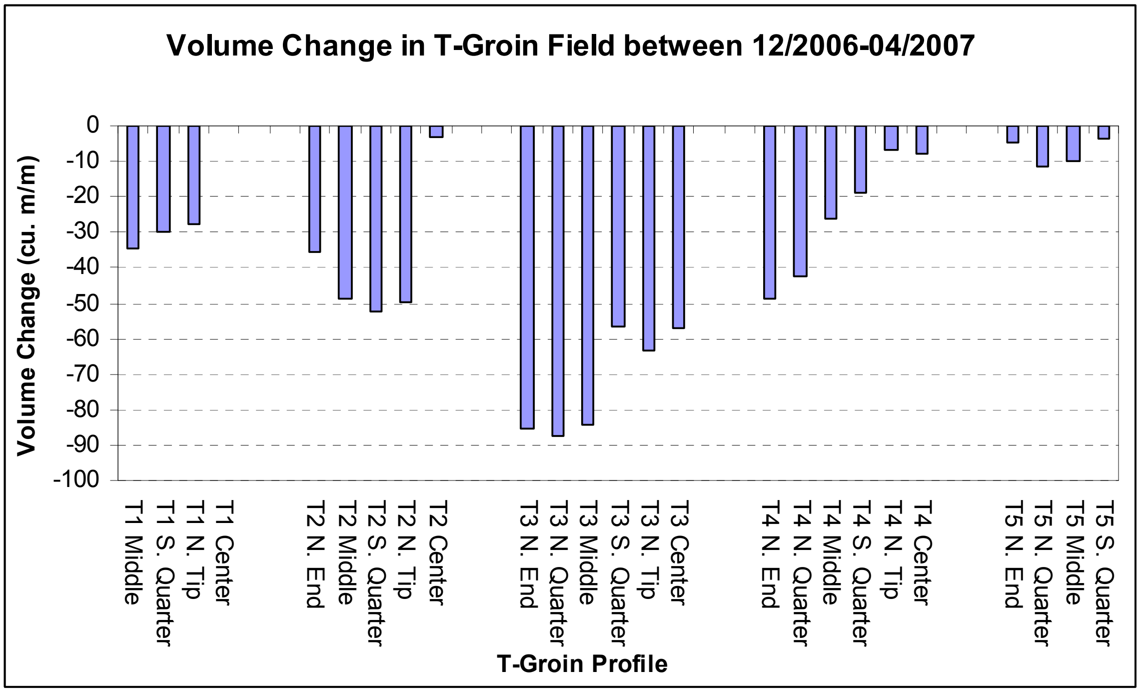

Figure 7. Profile-volume change in the T-groin field during the 2006-2007 winter season between 12/2006-04/2007.

Table 3 summaries the spatially averaged profile-volume and shoreline changes in each T-groin compartment between 12/2006 and 04/2007. The volume change in the T-groin compartment reflects the trend shown in Figure 7. The most volume loss, of approximately 8,000 m^3, was measured in the T2-T3 compartment, which represents an increase of 20% as compared to the initial 3 months. Volume losses in the northern most T1 and T1-T2 compartments were 2,100 and 4,100 m^3, respectively (Table 2), a decrease of 60 to 70% as compared to the initial 3 months. Within the T3-T4 compartment, volume loss was 3,000 m^3, similar during the two periods of time. At the T4-T5 compartment, as compared to a slight volume gain of 400 m^3 during the initial 3 months, a volume loss of 600 m^3 was measured in the following 4 months. The downdrift volume gain decreased from 18,000 m^3 to 10,000 m^3, likely reflecting the reduced sand supply from the updrift beach.

Overall for both periods of time, a net loss of approximately 8,000 m^3 of sand was measured in the T-groin and direct downdrift areas, indicating that most of the sand eroded from the northern part of the T-groin area was deposited directly downdrift. Comparing to the volume loss that occurred during the initial 3 months, the magnitude of volume loss during the 2006-2007 winter was smaller, except at the T2-T3 compartment.

Table 3. Summary of profile-volume and shoreline change at the T-groin compartments and the downdrift beach during the 2006-2007 winter season from 12/2006 to 04/2007.

	Alongshore Distance(m)	Avg. Volume cu m / m	Avg. Shoreline M	Total Volume Cu m
T1 compartment	105	-23.33	-11.25	-2439
T1-2 compartment	117	-35.29	-18.91	-4146
T2-3 compartment	108	-72.23	-25.76	-7782
T3-4 compartment	119	-25.02	-10.44	-2980
T4-5 compartment	106	-5.52	-3.88	-585
downdrift	812	12.28	-0.86	9977
			Volume Sum	-7955

Shoreline change during the 2006-2007 winter demonstrated a similar trend to that of the profile-volume changes (Figure 8). Compared to the initial 3 months, shoreline retreat in the first compartment was reduced from 28 m to 11 m. Shoreline retreat in the T1-T2 compartment was reduced from 36 m to about 19 m. The greatest shoreline retreat was measured in the T2-T3 compartment, averaging 26 m during the 2006-2007 winter (Table 3), similar to the measured retreat in the initial 3 months. Shoreline retreat in the T3-T4 compartment was 10 m, and remained about the same between the two time periods. Shoreline retreat in the T4-T5 compartment increased from about 1 m to nearly 4 m. The downdrift shoreline remained largely stable. As discussed previously, downdrift volume gain occurred mostly in the nearshore area and did not result in

shoreline advancement. Slight shoreline loss was measured instead, similar to the initial three months.

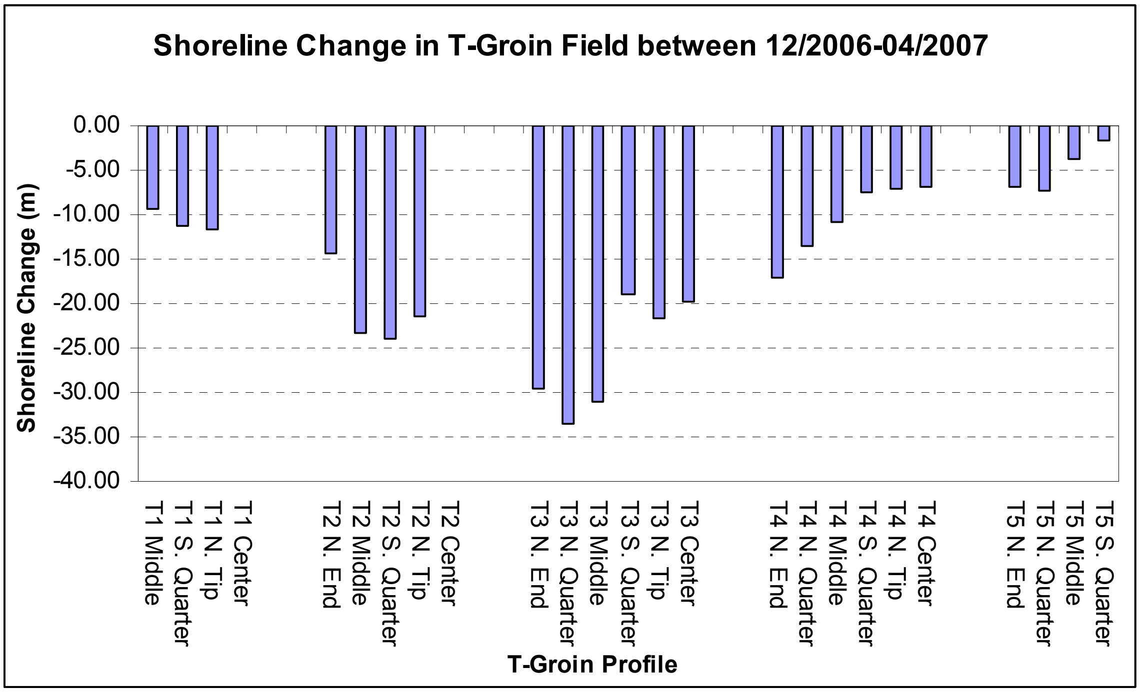

Figure 8. Shoreline change in the T-groin field during the 2006-2007 winter season between 12/2006-04/2007.

Figures 9 and 10 show the profile-volume and shoreline changes measured at the Long-Key profiles. Profile-volume loss was measured within the T-groin area (consistent with the T-groin lines), while profile-volume gain was measured downdrift. However, most of the downdrift volume gain occurred in the nearshore zone and did not result in significant shoreline advancement. As compared to the changes during the initial 3 months, the peak shoreline-volume change moved southward from the LK2A profile location to LK3.

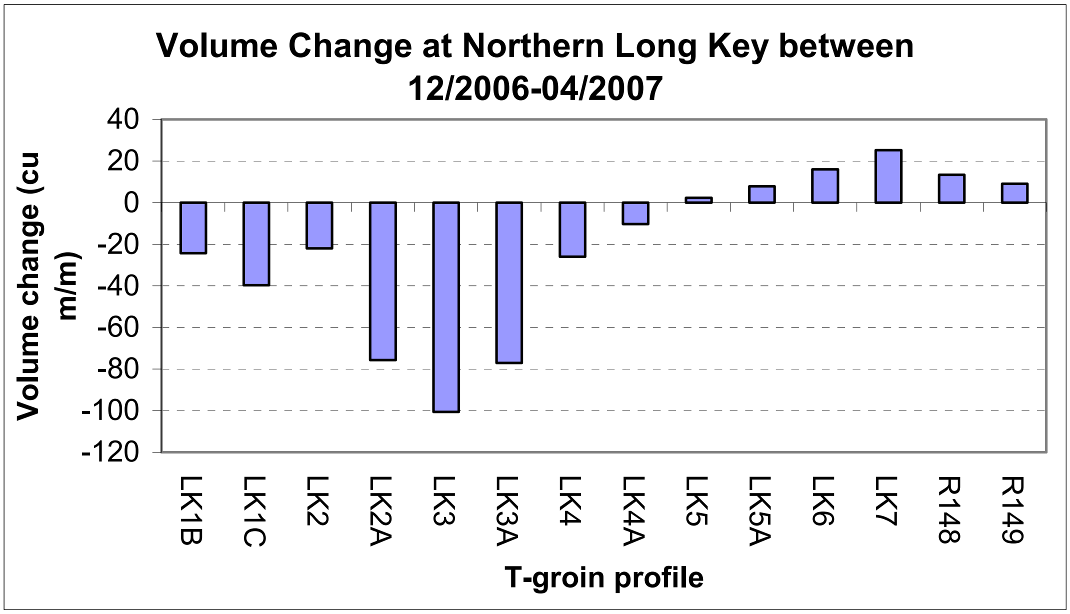

Figure 9. Profile-volume change of the Long Key profiles during the 2006-2007 winter season between 12/2006-04/2007.

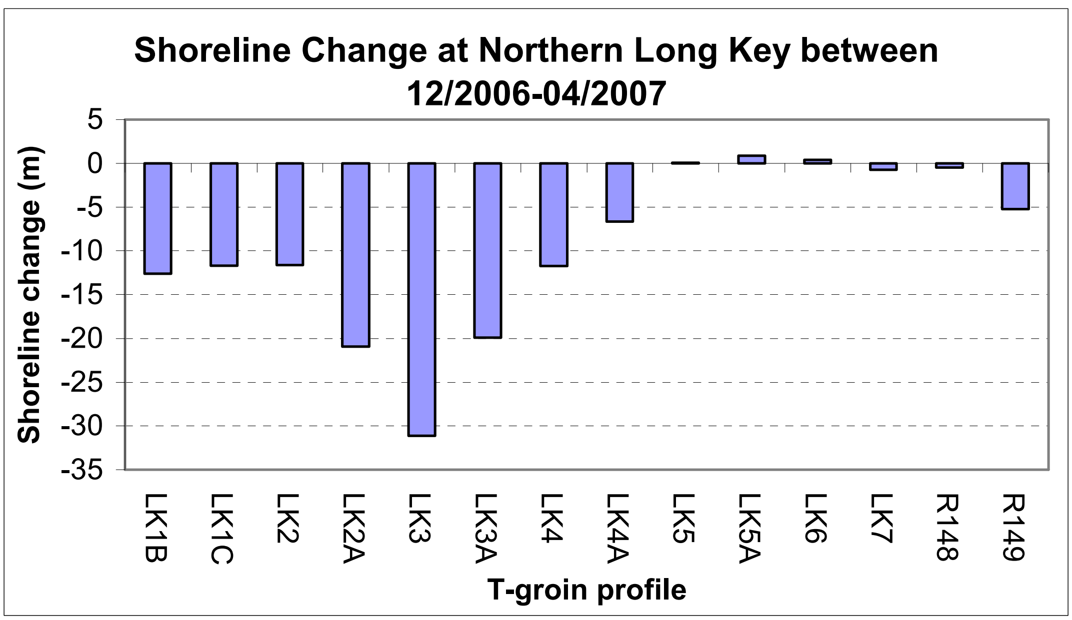

Figure 10. Shoreline change of the Long Key profiles during the 2006-2007 winter season between 12/2006-04/2007.

In summary, the erosion at the north segment was reduced substantially in the second 4-month monitoring period as compared to the initial 3-month period. In the T3-T4

compartment, the volume and shoreline changes were consistent during the first and second monitoring periods. The south compartment experienced slight erosion during the second 4-month period, as opposed to slight gain measured during the first 3 months. The downdrift beach continued to gain sand, but at a reduced rate during the second 4 months. Overall, there was volume gain in the downdrift area; however, most of the volume changes occurred in the nearshore and did not result in a shoreline advance. No negative impacts, i.e. beach volume and shoreline loss, were measured in the downdrift beach during this seven month period.

Summary of the Performance during the 2007 Summer from April to October 2007

Detailed T-groin performance during April 2007 to October 2007 was discussed in the third progress report (Wang and Roberts, 2007c). Here, a summary of the shoreline and beach-volume changes is included for the convenience of comparison of the performance during the entire 31-month period.

During this period of time, the northern-most three T-Groins (T1, T2, and T3) were exposed at the shoreline, while the southern two T-Groins (T4 and T5) remained buried. Changes of profile-volume and shoreline during the 2007 summer were calculated for all the T-groin profiles and Long Key profiles to R150. Compared to the previous reports, one more downdrift line, R150, was added to the volume and shoreline calculations to ensure that the influence to the downdrift is included. Figure 11 shows the alongshore distribution of the profile-volume change. Compared to the larger losses of up to 100 m^3/m measured during the previous periods (Figures 3 and 7), the profile-volume loss during this six months period was less than 25 m^3/m (Figure 11). The greatest volume

loss occurred at the T2-T3 compartment with decreasing volume loss to the north and south of T3, similar to the case during the 2006-2007 winter. Compared to the significant erosion during the first seven months, beach-profile volume change in the north segment (T1 compartment) decreased to roughly zero due to a combination of depleting sediment supply and the functioning of the exposed T-groin structures. Some profile-volume loss was measured in the T4 compartment, while negligible volume change was measured in T5 compartment.

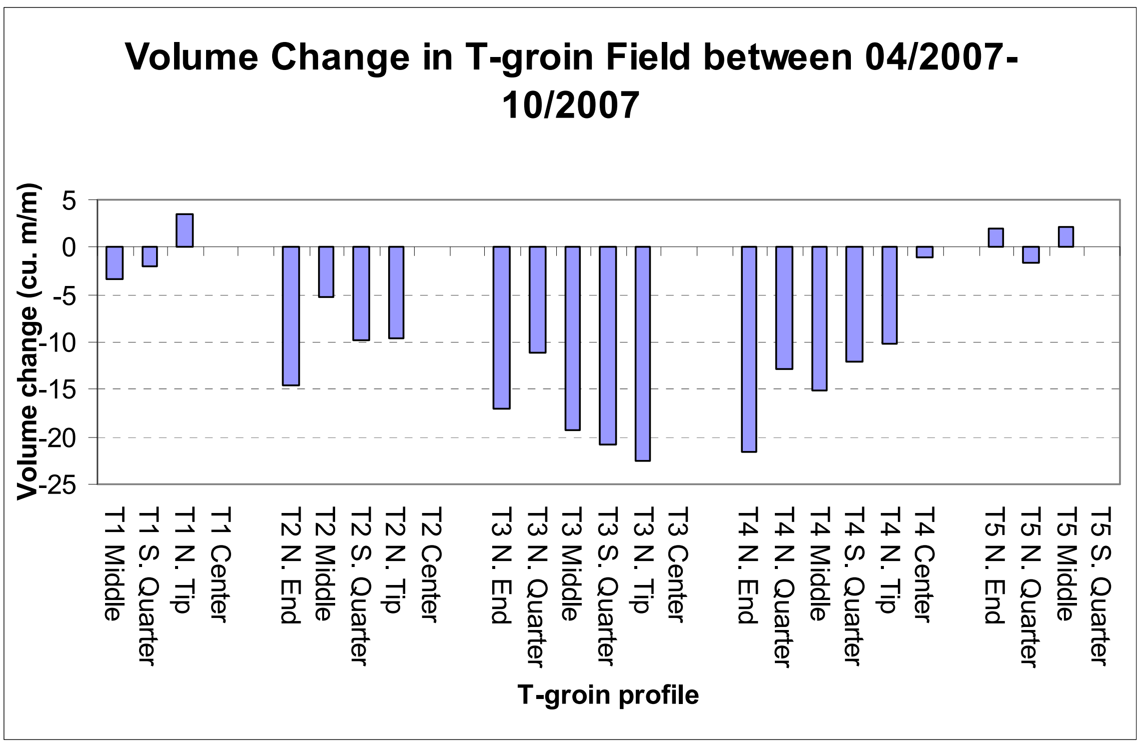

Figure 11. Profile-volume change in the T-groin field during the 2007 summer season between 04/2007-10/2007.

Table 4 summaries the spatially averaged profile-volume and shoreline changes in each T-groin compartment during the 2007 summer. The volume change in the T-groin compartment reflects the trend shown in Figure 11. Compared to the magnitude of

volume loss during the initial 3 months and the 2006-2007 winter season (Tables 2 and 3), the changes during 2007 summer season were much smaller (Table 4). The volume changes listed in Table 4 represent a period of 6 months, in contrast to 3 months in Table 1 and 4 months in Table 2. The most volume loss, of approximately 1,300 m^3, was measured in the T2-T3 compartment (Table 4). Volume losses in the northern most T1 compartment and T1-T2 compartment were less than 200 and 1,200 m^3, respectively. Negligible volume losses were measured in T4 and T5 compartments. The downdrift volume gain remained at about 10,000 m^3.

Table 4. Summary of profile-volume and shoreline change at the T-groin compartments and the downdrift beach during the 2007 summer season from 04/2007 to 10/2007.

	Alongshore Distance(m)	Avg. Volume cu m / m	Avg. Shoreline M	Total Volume cu m
T1 compartment	105	-1.37	3.15	-143
T2 compartment	117	-10.00	-3.31	-1175
T3 compartment	108	-12.18	-8.26	-1312
T4 compartment	119	-0.24	-2.98	-28
T5 compartment	106	-0.24	3.14	-25
downdrift	1112	9.15	6.61	10173
			Volume Sum	7489

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In contrast to the 8,000 m^3 of sand loss in the T-groin and direct downdrift areas measured during the initial three months and 2006-2007 winter season, respectively, volume gain of approximately 7,500 m^3 was measured during 2007 summer season between April and October of 2007. The much reduced magnitudes of profile-volume changes are the result of 1) depleted sediment supply from the northern segments, 2) lower summer wave energy approaching mostly from the south, and 3) sand

impoundment by the groins. The sustained beach-volume gain in the downdrift region during the 2007 summer season may also be a result of fluctuations in the direction of longshore sediment transport during summer months. The beach-volume gains directly downdrift of the T-groin field may be attributable to transport from the south.

Shoreline change in the T-groin field during the 2007 summer season demonstrated a similar trend to the profile-volume changes (Figure 12). Compared to the first 7 months (Figures 4 and 8), the overall magnitude of the shoreline change was much smaller, generally less than 10 m over the entire 6 months, as opposed to nearly 40 m during the initial 3 months and the 2006-2007 winter season, respectively. Slight shoreline gain, averaging 3 m, was measured in the northern-most T1 compartment (Table 4). Shoreline retreat in the T1-T2 compartment was reduced from 19 m to about 3 m. The greatest shoreline retreat was measured in the T2-T3 compartment, averaging slightly over 8 m during these 6 months (Table 4), much smaller than the 26 m retreat in the previous 4 winter months. Shoreline retreat in the T3-T4 compartment was 3 m, also smaller than the previous two time periods. Shoreline gain of 3 m was measured in the T4-T5 compartment. The downdrift shoreline gained nearly 7 m on average during the six summer months without any substantial tropical storms.

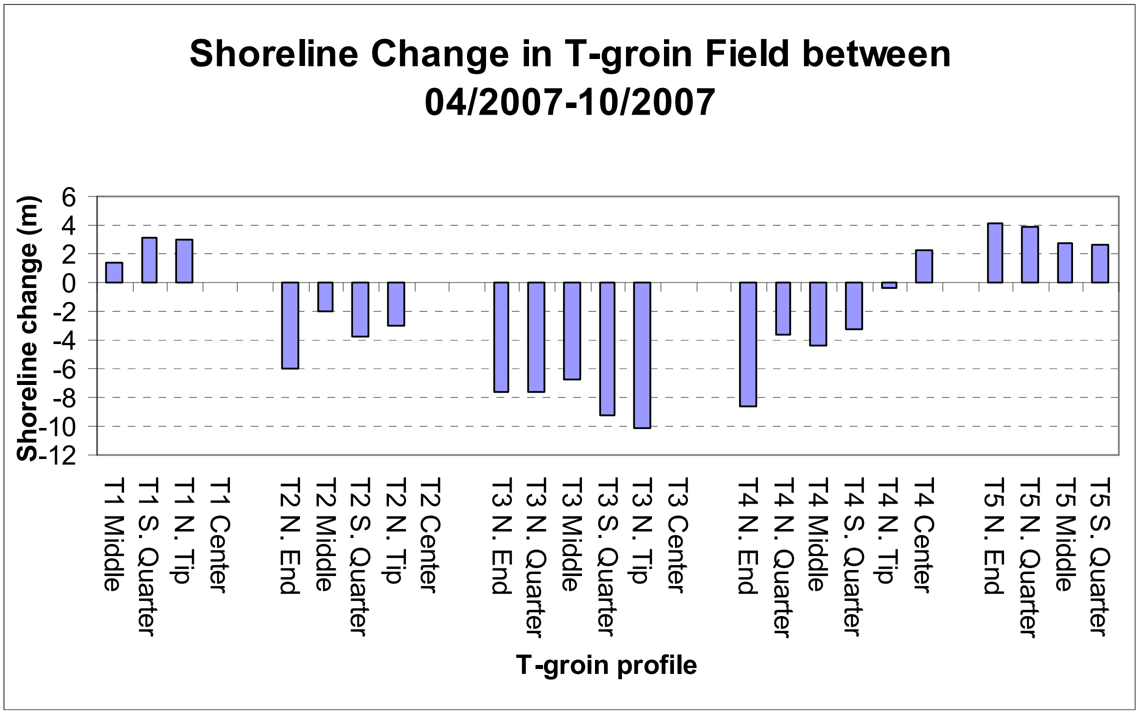

Figure 12. Shoreline change in the T-groin field during the 2007 summer season between 04/2007-10/2007.

Figures 13 and 14 show the profile-volume and shoreline changes measured at the Long Key profiles. Profile-volume loss was measured within the T-groin area (consistent with the T-groin lines), while profile-volume gain was measured downdrift. The volume loss within the T-groin area is much smaller as compared to that during the first 7 months. A relatively large profile-volume gain was measured at R150, approximately 1,100 m downdrift of the T-groin field. Different from the trend measured during the first seven months, considerable shoreline gain of up to 10 m was measured at several of the downdrift profiles (Figure 14). The large profile-volume gain measured at R150 is related to a widening of the offshore bar and did not correspond to a large shoreline gain. In conclusion, 13 months after the T-groin construction the downdrift beach continued to receive sand from Upham Beach. No erosive trend was measured.

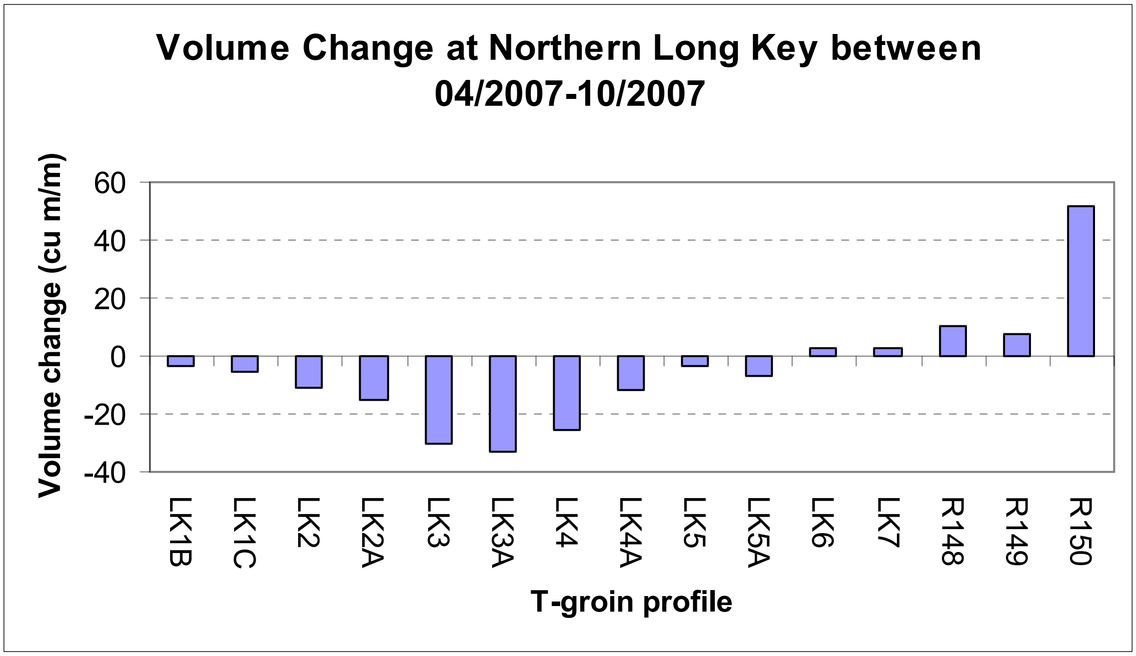

Figure 13. Profile-volume change of the Long Key profiles during the 2007 summer season between 04/2007-10/2007.

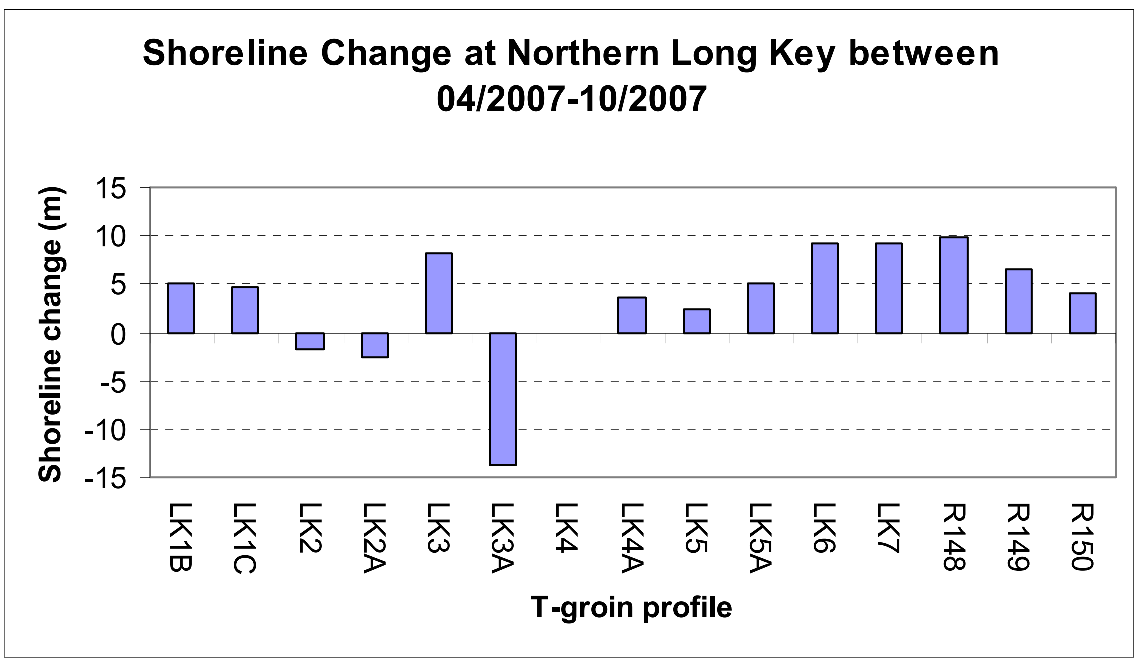

Figure 14. Shoreline change of the Long Key profiles during the 2007 summer season between 04/2007-10/2007.

Profile-volume change between -1.5 m to -3.0 m NAVD88 was also calculated to examine the exchange between nearshore and offshore sand, as suggested by FDEP. Overall, profile-volume loss was measured in the area between -1.5 and -3.0 m at nearly all the Long Key profiles except at R150 (Figure 15). This indicates an onshore trend of sediment transport during the summer months, consistent with the observed onshore migration of the offshore bar formed during the April storm and in most cases shoreline gain over the 6-month period.

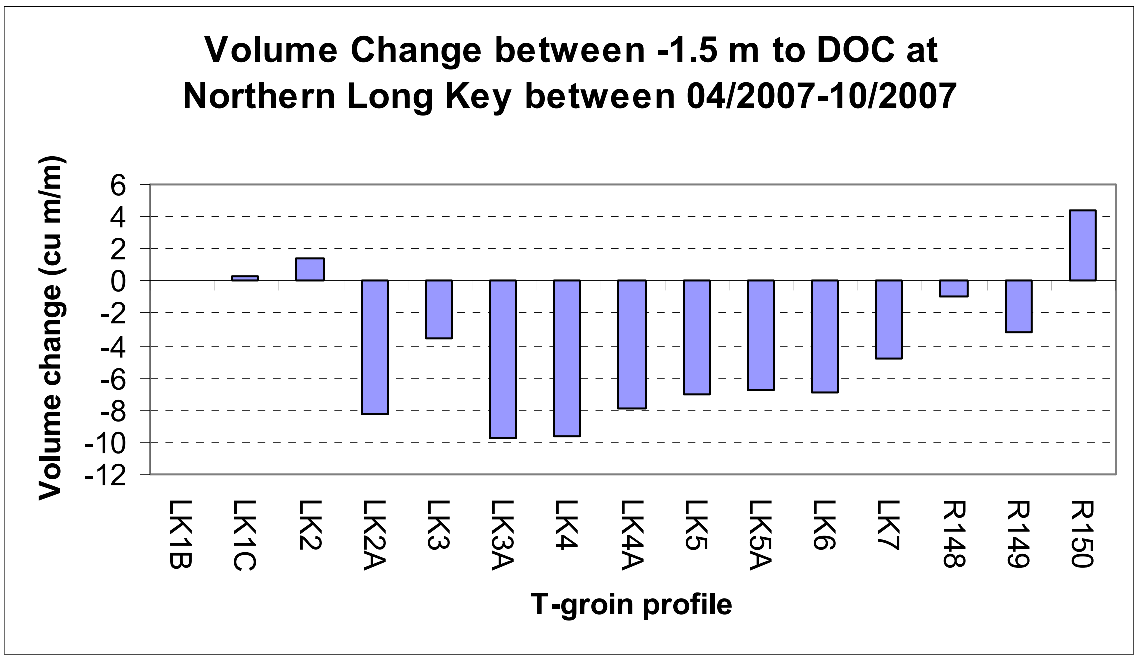

Figure 15. Volume changes between the Depth of Closure (DOC) and -1.5 m NAVD 88 at the Northern Long Key profiles during the 2007 summer season from April 2007 and October 2007.

In summary, the third monitoring period from April 2007 to October 2007 represents a mild 2007 summer season, with no significant impact of tropical storms. Compared to the changes measured during the first 7 months, the overall magnitude of beach-profile volume and shoreline changes were smaller during the 6 summer months. Erosion, although at a much reduced rate, was measured in the T-groin area with a peak at the T2

and T3 compartments. The northernmost T-groin compartment reached quasi-equilibrium, with a narrow beach maintained in front of the seawall. Volume gain of approximately 10,000 m^3 was measured in the downdrift area, along with considerable shoreline gain, benefiting from an onshore trend of sediment transport and possibly sediment transport from the south during the summer season. An onshore migration of the offshore bar was measured at nearly all the downdrift profiles.

Summary of the Performance during the 2007-2008 Winter from October 2007 to April 2008

Detailed T-groin performance during October 2007 to April 2008 was discussed in the third progress report (Wang and Roberts, 2008a). Here, a summary of the shoreline and beach-volume changes is included for the convenience of performance comparison over the entire 31 months.

During this period of time, the north three T-Groins (T-Groins 1, 2, and 3) remain exposed at the shoreline. The fourth T-groin became exposed toward the end of February, while T-Groin 5 remained buried. Considerable erosion, both on the dry beach and in the nearshore zone, was measured in the entire project area during the 2007-2008 winter season. This resulted in a large portion of the seawall between T-groins 1 and 2, or the T2 compartment, to become exposed at the shoreline, effectively anchoring the shoreline location. Compared to the first seven months, i.e., the initial 3 months and the 4 months during the 2006-2007 winter season (Wang and Roberts, 2007a and 2007b), the magnitudes of profile-volume loss and shoreline change were much smaller. This may be attributed to the completion of the initial rapid beach-profile equilibration and longshore

spreading (Elko and Wang, 2007), decreasing sediment supply at the northern segments, and the functioning of the T-groins.

Changes of profile-volume and shoreline during the 2007-2008 winter months were calculated for all the T-groin profiles and Long Key profiles to R156. Compared to the previous reports, six more downdrift lines, R151 through R156, were added to the profile-volume and shoreline calculations to ensure that the influence to the downdrift is included. Figure 16 shows the alongshore distribution of the profile-volume change. Compared to the dramatic losses of up to 100 m^3/m measured during the initial 3 months and the following 4 months (Figures 3 and 7), the profile-volume loss during these 6 winter months was relatively smaller, less than 45 m^3/m (Figure 16). As expected, the profile-volume loss was greater than during the 2007 summer (Figure 11). Different from the previous monitoring periods, the greatest volume loss occurred at the T3-T4 compartment with decreasing volume loss to the north and south of T4. In addition, considerable profile-volume loss occurred in the T4-T5 compartment, in contrast to slight volume changes measured during the previous periods. This reflects the depletion of sediment supply from the northern portion of the project area. Overall, profile-volume loss was measured across the entire project area.

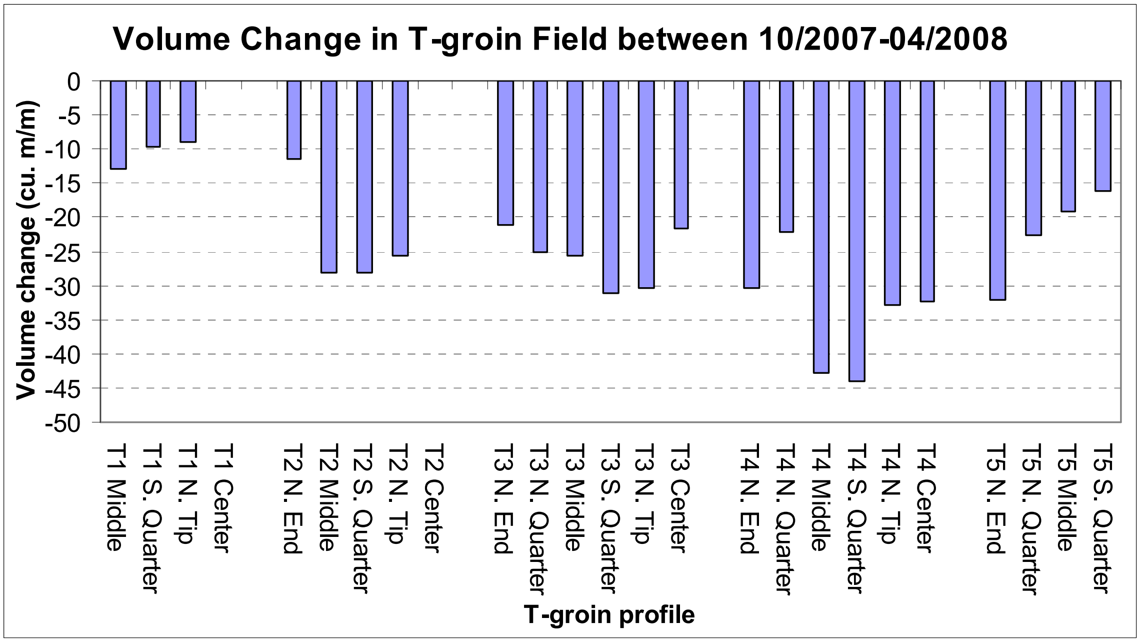

Figure 16. Profile-volume change in the T-groin field during the 2007-2008 winter season between 10/2007-04/2008.

Profile-volume changes measured at the Long Key lines within the project area (Figure 17) demonstrate a similar trend of volume loss as that of the T-groin profiles, with a peak of roughly 50 m^3/m in the T3-T4 compartment. In contrast to the previous 13 months, continued profile-volume loss was measured at the downdrift lines extending to LK6. Profile-volume gain was measured further downdrift from R149 to R154, followed by a loss further downdrift at R155 and R156

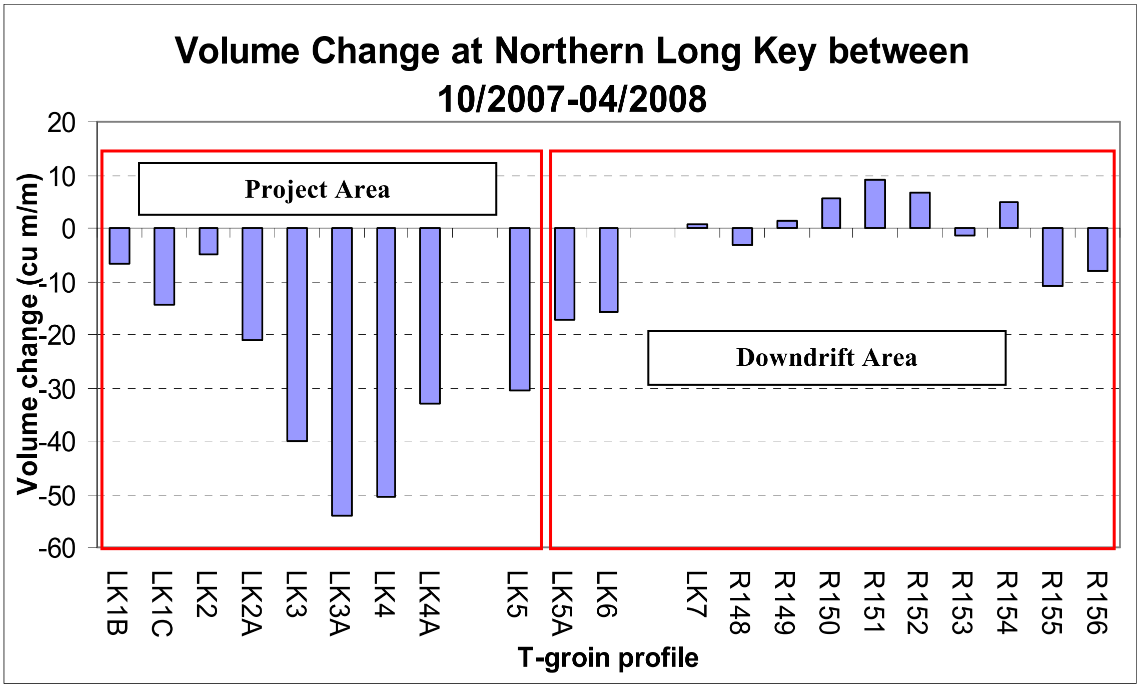

Figure 17. Profile-volume change of the Long Key profiles during the 2007-2008 winter season between 10/2007-04/2008.

Table 5 summarizes the spatially averaged profile-volume and shoreline changes in each T-groin compartment during the 2007-2008 winter season. The volume change in the T-groin compartment reflects the trend shown in Figure 16. Due to the significantly different change in patterns along the downdrift beach as compared to the previous monitoring periods (Figure 17), it was necessary to examine the downdrift changes in more detail. The downdrift beach was divided into three sections: 1) downdrift-1: including LK5, LK5A, and LK6; 2) downdrift-2: including LK6, LK7, and R148; 3) downdrift-3: including R148, R149, R150, R151, R152, R153, and R154. In addition, the downdrift profile changes were calculated to the landward slope of the offshore bar; in other words, the offshore bar volume is not accounted for in the volume-change calculations for the newly included profiles, R151 through R156. The distance from the

bar to the shoreline increases progressively southward, along with an increase in water depth in the trough, as part of the larger-scale Long Key morphology.

Table 5. Summary of profile-volume and shoreline change at the T-groin compartments and the downdrift beach during the 2007-2008 winter season from 10/2007 to 04/2008.

	Alongshore Distance(m)	Avg. Volume cu m / m	Avg. Shoreline m	Total Volume cu m
T1 compartment	105	-9.58	-3.30	-1001
T1-T2 compartment	117	-19.66	-5.12	-2309
T2-T3 compartment	108	-25.82	-2.54	-2782
T3-T4 compartment	119	-34.12	-11.26	-4063
T4-T5 compartment	106	-24.12	-7.86	-2557
downdrift-1 (LK5-LK5A-LK6)	200	-21.17	-3.76	-4235
downdrift-2 (LK6-LK7-R148)	288	-6.19	-2.22	-1782
downdrift-3 (R148-R154)	1841	3.32	-0.10	6118
			Volume Sum	-12611

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Compared to the magnitude of volume loss during the first three monitoring periods (Tables 2, 3, and 4), the changes during the 2007-2008 winter season were smaller than what was measured during the initial 7 months, but larger than during the 2007 summer (Table 5). The most volume loss, of approximately 4,000 m^3, was measured in the T3-T4 compartment (Table 5). Volume losses in the northern most T1 compartment and T1-T2 compartment were roughly 1,000 and 2,400 m^3, respectively. Although these volumes are relatively small compared to the loss in the initial 7 months, they comprise a relatively large percentage of the sand remaining on the beach. The profile-volume loss in the T2-T3 compartment was about 2,800 m^3, more than twice the amount in the

previous 6 summer months. Nearly 2,600 m^3 of sand loss were measured in T4 and T5 compartments, in contrast to the minimal changes during the first 3 monitoring periods.

A major difference measured during this 6-month winter season, as compared to the previous 13 months, was the considerable amount of erosion measured along the downdrift beach. Over 4,200 m^3 of sand eroded along the stretch of the beach extending from LK5 to LK6, in addition to 1,800 m^3 eroded from LK6 through R148. A volume gain of 6,100 m^3 was measured from R148 through R154. As discussed earlier, the above volume gain was measured between the shoreline (NAVD88 zero) and the trough, with no significant corresponding shoreline and dry beach gain.

In contrast to the overall 7,500 m^3 of sand gain in the T-groin and direct downdrift areas measured during the previous 6 months (summer), a volume loss of approximately 12,600 m^3 was measured during the 2007-2008 winter season between October 2007 and April 2008. The increased magnitudes of profile-volume changes were the result of northerly approaching waves associated with the passages of winter cold fronts. Sand volume loss was smaller during the 2007-2008 winter, as compared to the 2006-2007 winter season. This was attributed to the reduced sand supply and the impoundment at the exposed T-groins. It was not clear whether the rate of erosion was greater than the background rate without the T-groins. Since most of T-groin 4 and all of T-groin 5 remained buried, it was not likely that the T-groins accelerated the downdrift erosion 19 months after their installation.

Shoreline (defined here as NAVD88 zero) change in the groin field during the 2007-2008 summer season demonstrated a similar trend to that of the profile-volume changes (Figure 18). Compared to the first 7 months (Figures 4 and 8), the overall magnitude of

the shoreline change was smaller, with the maximum shoreline retreat of nearly 16 m measured in the T3-T4 compartment, as opposed to nearly a 40 m maximum during the initial 3 months and the 2006-2007 winter season, respectively. The greatest shoreline retreat was measured in the T3-T4 compartment, averaging slightly over 11 m during these six months (Table 5). This was slightly greater than the 10 m retreat measured in the initial 3 months and the 2006-2007 winter, and much greater than the 3 m retreat measured during the 2007 summer. An average shoreline retreat of 8 m was measured in the T4-T5 compartment, as compared to shoreline gain measured during the previous periods. The shoreline change patterns (Figure 18) revealed the designed crenulate-bay shoreline between the T-groins.

In contrast to the shoreline gain measured directly downdrift of the groin field during the previous monitoring periods, shoreline gain was not measured until R152 (Figure 19). The shoreline change pattern measured at the Long Key lines in the T-groin field was similar to that measured at the T-groin profiles, as expected. The slight profile-volume gain measured at R149, R150, and R151 occurred mostly in the nearshore zone and did not result in corresponding shoreline gain. Overall, the magnitude of shoreline changes downdrift of the T-groin field were small, less than 5 m during the 6-month of 2007-2008 winter season.

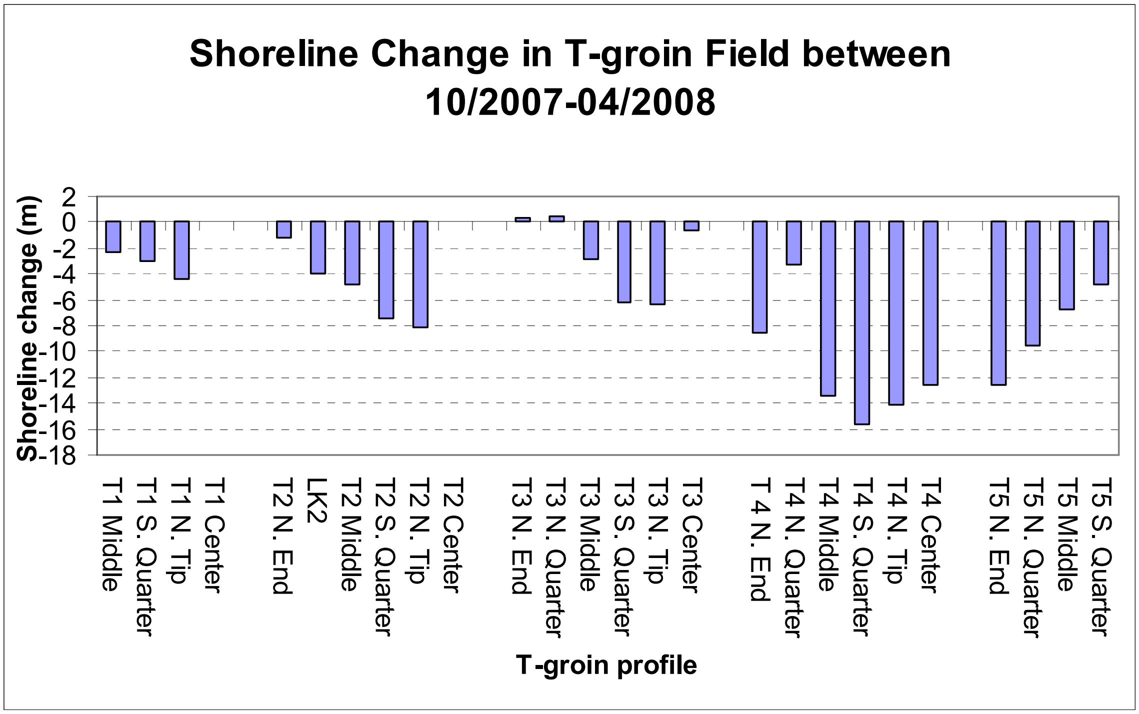

Figure 18. Shoreline change in the T-groin field during the 2007-2008 winter season between 10/2007-04/2008.

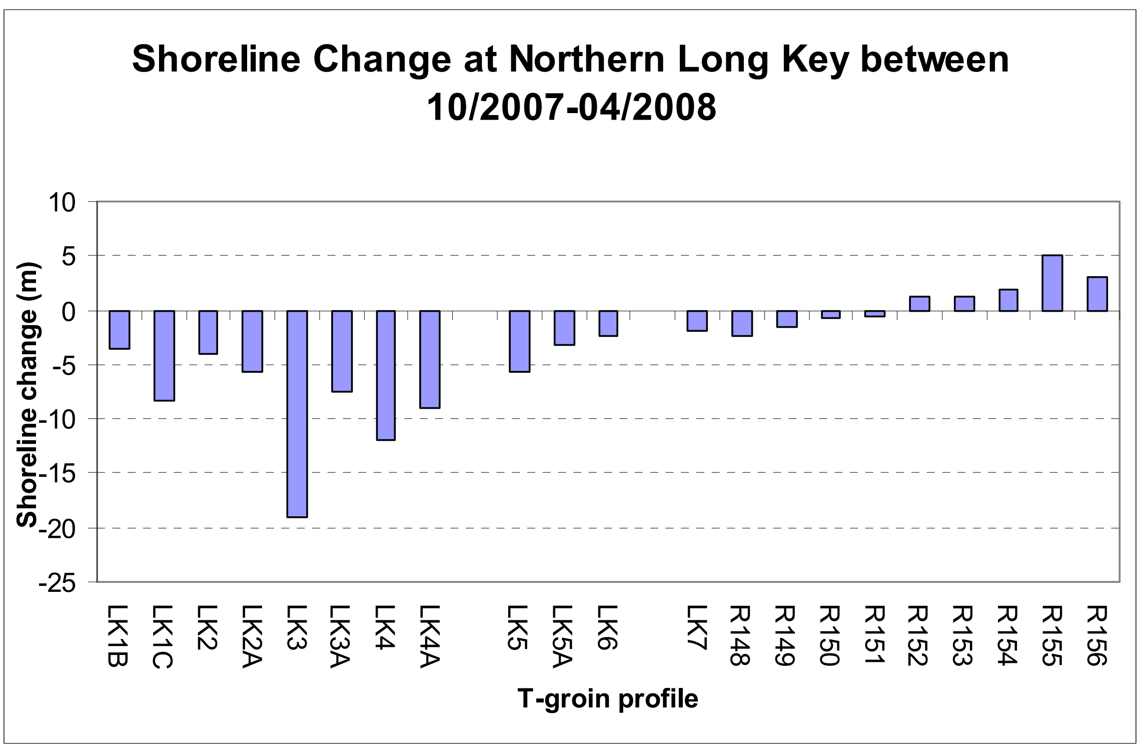

Figure 19. Shoreline change of the Long Key profiles during the 2007-2008 winter season between 10/2007-04/2008.

Overall, profile-volume loss was measured in the area between -1.5 m and the relative DOC at most of the Long Key profiles north of LK7 (Figure 20). Most of the profiles did not have an offshore bar. The profile-volume loss was likely related to the southward longshore sand transport. The overall profile-volume gain in the offshore area south of LK6 was also attributed to the southward longshore sand transport (Figure 20).

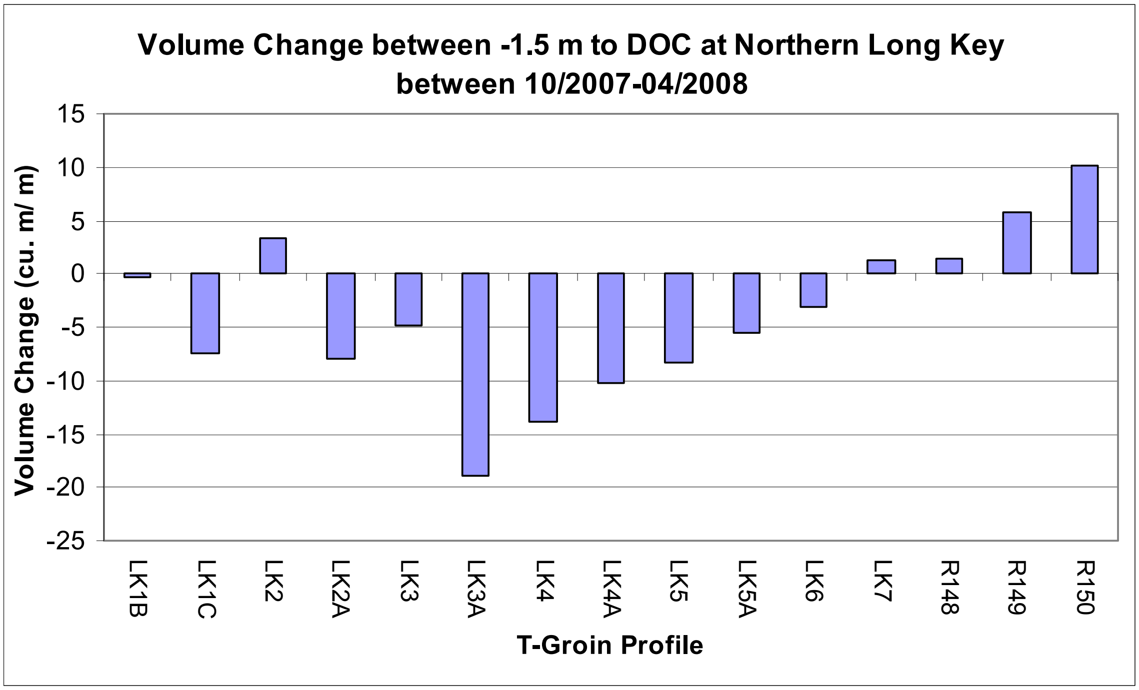

Figure 20. Volume changes between the Depth of Closure (DOC) and -1.5 m NAVD 88 at the Northern Long Key profiles during the 2007-2008 winter season from 10/2007-04/2008.

During this monitoring period, significant changes to T-groins 1 and 2 were observed on March 10, 2008. A long, straight cut (~10 ft) was observed across T1 from seam to seam and perpendicular to the shore. T1 began losing material immediately due to this tear. In addition, severe subsidence was observed at the north end of the shore-parallel head of T2. Upon further inspection, the second-tier geotubes had both been sliced at the water line starting on the seaward side of the seaward bag. The cut

continued around the north end of the T-head and along the landward edge of the landward second-tier bag. This cut resulted in sand loss from the second-tier bags that caused the top tube of T2 to slump. On June 2, 2008, a burned beach towel and a 1-ft diameter burn hole were observed on the landward portion of the shore-perpendicular stem of T1.

In summary, the fourth monitoring period from October 2007 to April 2008 represented an active 2007-2008 winter season, with frequent cold-front passages especially late in the season. Beach erosion was measured at all the T-groin profiles, as well as along the immediate downdrift area. The fourth T-groin became exposed at the shoreline following the passage of a strong cold front in February. The greatest beach-profile erosion and shoreline retreat was measured in the T3-T4 compartment, with a sand volume loss of slightly over 4,000 m^3 and an average shoreline (NAVD88 zero) loss of 11 m. Overall, nearly 13,000 m^3 of sand eroded from the T-groin project area, in addition to 6,000 m^3 from the immediate downdrift beach. Profile-volume gains were measured further downdrift from R148 to R154. The seawall along the T1-T2 compartment became exposed at the shoreline during this 6-month winter. A small fillet beach was maintained between the Blind Pass south jetty and T-groin 1. The erosion along the downdrift beach was likely related to the typical longer-term performance of the Upham Beach nourishment. It was not clear whether the downdrift erosion was accelerated by the T-groin structures; however no clear negative impact from the T-groin field to the downdrift shoreline was identified. Some damage to the geo-textile tubes occurred during March and April of 2008, resulting in substantial reduction of the T-

groin elevation at the northern end of T2, which may have had some influence on beach performance.

Summary of the Performance during the 2008 Summer from April 2008 to October 2008

Detailed T-groin performance during April 2008 to October 2008 was discussed in the third progress report (Wang and Roberts, 2008b). Here, a summary of the shoreline and beach-volume changes is included for the convenience of performance comparison over the entire 31 months.

Changes of profile-volume and shoreline during this 6-month monitoring period months were calculated for all the T-groin profiles and Long Key profiles to R156. The profile-volume change was calculated from the benchmark seaward to roughly -1.5 m NAVD88 for T-groin lines and to roughly -3 m NAVD88 (or short-term DOC) for Long Key lines. Figure 21 shows the alongshore distribution of the profile-volume change. Compared to the dramatic losses of up to 100 m^3/m measured during the initial 3 months and the following 4 months (Figures 3 and 7), and the previous winter season, the profile-volume loss during this monitoring period was smaller, less than 25 m^3/m (Figure 21). The greatest volume loss occurred at the T2-T3 and T3-T4 compartments with less volume loss to the north of T2, and in the T4-T5 compartment. Low profile-volume losses at the northern-most two compartments can be attributed to the depleting sediment supply.

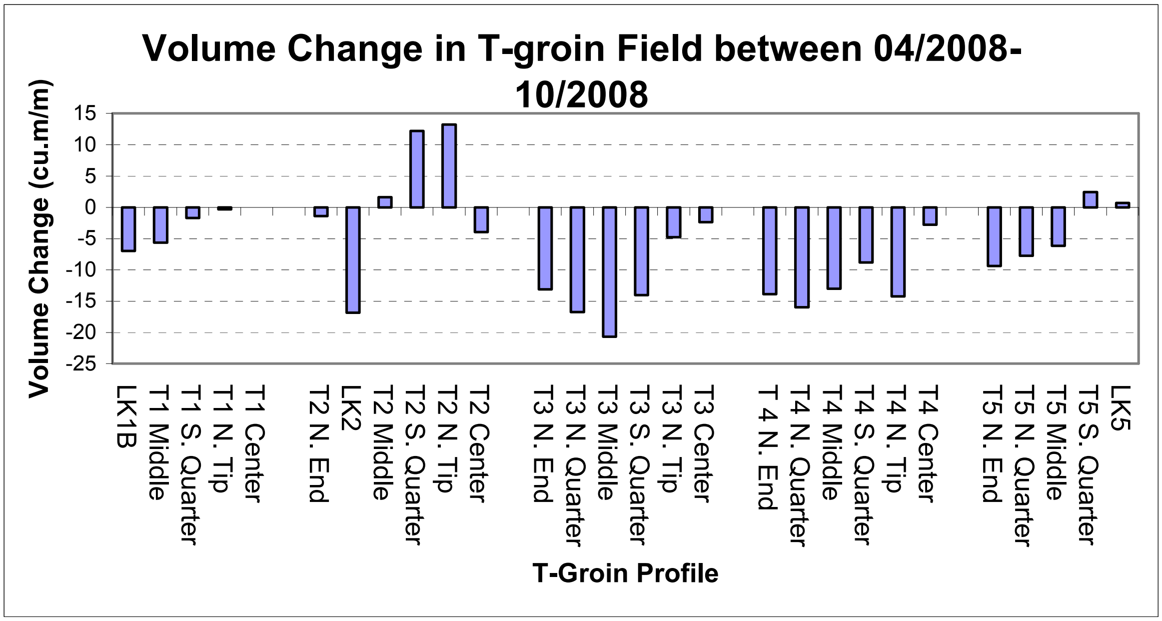

Figure 21. Profile-volume change in the groin field during the 2008 summer season between 04/2008-10/2008.

Profile-volume changes measured at the Long Key lines within the project area (Figure 22) demonstrate a similar trend of volume loss as that of the T-groin profiles, with a peak of roughly 45 m^3/m in the T3-T4 compartment. Downdrift erosion, extending to LK6, that was measured during the 2007-2008 winter, was also measured during this monitoring period and has extended further south to R149. Profile-volume gain was measured further downdrift from R150 to R156.

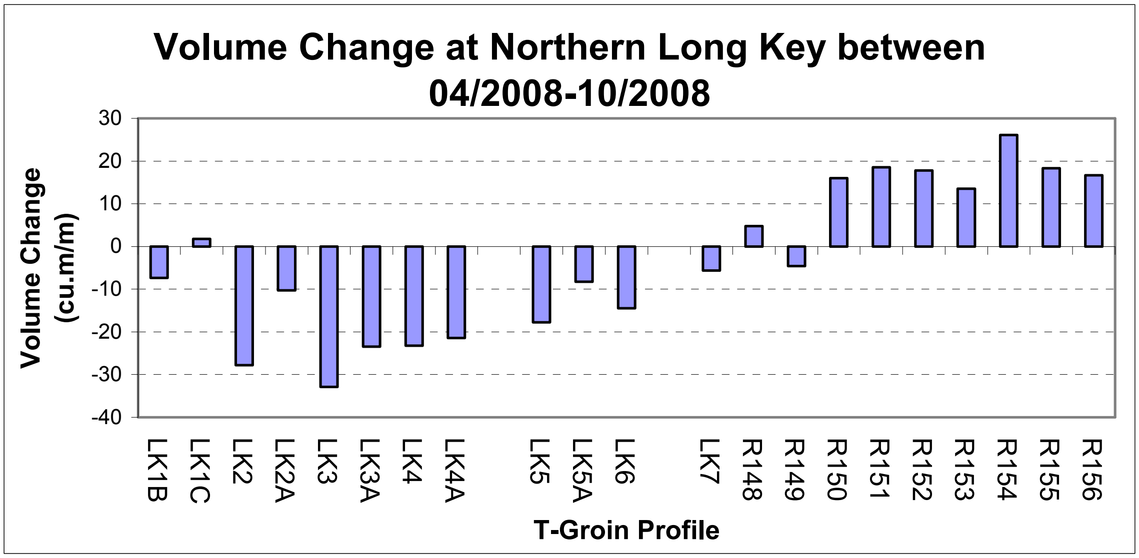

Figure 22. Profile-volume change of the Long Key profiles during the 2008 summer season between 04/2008-10/2008.

Table 5 summarizes the spatially averaged profile-volume and shoreline changes in each T-groin compartment during the 2008 summer. The total volume change in each compartment is obtained by multiplying the average profile-volume change by the alongshore extent of the compartment. The volume change in the T-groin compartment reflects the trend shown in Figure 21. The downdrift beach is divided into three sections: 1) downdrift-1: including LK5, LK5A, and LK6; 2) downdrift-2: including LK6, LK7, R148, and R149; 3) downdrift-3: including R149, R150, R151, R152, R153, R154, R155 and R156. The distance from the bar to the shoreline increases progressively southward, along with an increase in water depth in the trough.

Table 6. Summary of profile-volume and shoreline change at the T-groin compartments and the downdrift beach during the 2008 summer season from 04/2008-10/2008.

	Alongshore Distance(m)	Avg. Volume cu m / m	Avg. Shoreline M	Total Volume cu m
T1 compartment	105	-3.67	-0.89	-384
T2 compartment	117	0.82	1.38	96
T3 compartment	108	-11.95	-4.45	-1288
T4 compartment	119	-11.45	-2.30	-1363
T5 compartment	106	-4.02	0.00	-426
downdrift-1 (LK5-LK5A-LK6)	200	-13.49	0.70	-2698
downdrift-2 (LK6-LK7-R149)	588	-4.99	-2.23	-2931
downdrift-3 (R149-R156)	2100	13.15	0.49	27624
			Volume Sum	18629

Compared to the magnitude of volume loss during the first four monitoring periods (Tables 2, 3, 4, and 5), the changes during the 2008 summer were smaller than that measured during the initial 7 months and the 2007-2008 winter, but larger than that during 2007 summer (Table 6). The most volume loss in the T-groin field, of 1,363 m^3, was measured in the T3-T4 compartment (Table 6). Volume losses in the northernmost T1 compartment and T1-T2 compartment were small. Similar to the 2007-2008 winter months, a considerable amount of erosion was measured along the downdrift beach.

In contrast to the previous 6 winter months when the T-groin and direct downdrift areas lost 12,600 m^3, volume gain of approximately 18,600 m^3 was measured during this monitoring period. As compared to the gain of 7,500 m^3 during the 2007 summer, this larger volume gain may be attributable to more profiles being included in the downdrift analysis region. Most of the downdrift profiles gained sand during this monitoring period, it is not likely that the T-groins have negatively impacted the downdrift beach.

Shoreline (defined here as NAVD88 zero) change in the groin field during the 2007-2008 monitoring period season was small overall and demonstrated a similar trend to that of the profile-volume changes (Figure 23). Compared to the first 7 months (Figures 4 and 8) and the 2007-2008 winter, the overall magnitude of the shoreline change was smaller, with the maximum shoreline retreat of nearly 9 m measured in the T2-T3 compartment, as opposed to nearly a 40 m maximum during the initial 3 months and the 2006-2007 winter season and 16 m during the 2007-2008 winter. The greatest shoreline retreat was measured in the T2-T3 compartment, averaging slightly over 4 m during this monitoring period (Table 6). This is less than the 11 m retreat measured in T3-T4 compartment in the 2007-2008 winter, and similar to the 3 m retreat measured during the 2007 summer. An average shoreline retreat of 2 m was measured in the T4-T5 compartment, as compared to an 8-m retreat measured during the 2007-2008 winter.

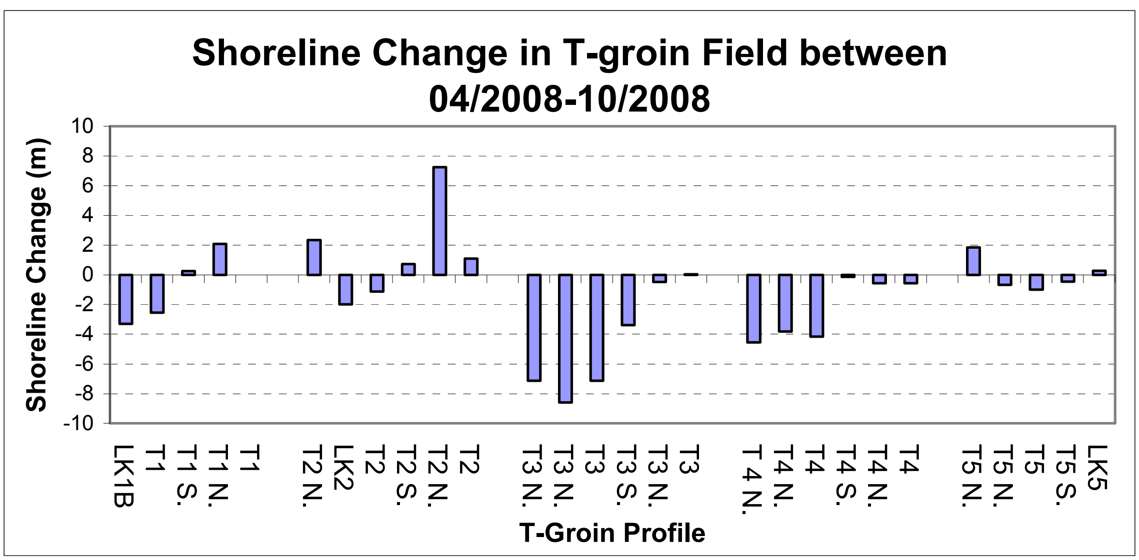

Figure 23. Shoreline change in the T-groin field during the 2008 summer season between 04/2008-10/2008.

The shoreline change pattern measured at the Long Key lines in the T-groin field is similar to that measured at the T-groin profiles, as expected (Figure 24). The slight shoreline gains measured at LK5, LK5A, LK6, and LK7 resulted from the slight net onshore transport. Net volume losses were actually measured at these profiles. As discussed above, shoreline advance is controlled by the morphology change in the dynamic intertidal zone and does not correspond with dry beach gain.

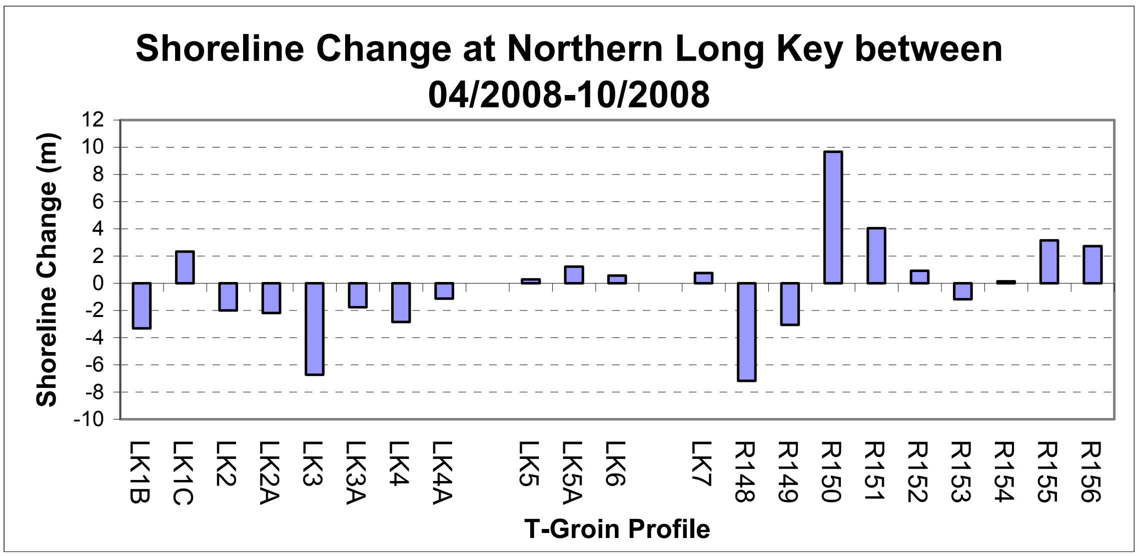

Figure 24. Shoreline change of the Long Key profiles during the 2008 summer season between 04/2008-10/2008.

Profile-volume change between -1.5 m and -3.0 m NAVD88 was also calculated to examine the exchange between nearshore and offshore regions, as suggested by FDEP. Overall, profile-volume loss of up to 20 m^3/m was measured in this area at most of the Long Key profiles north of R153 (Figure 25). A portion of this eroded offshore sand was transported onshore and deposited in the nearshore and intertidal zone and the remainder of the sand was transported alongshore. The decreasing trend of erosion south of LK 6

transitioned to profile-volume gain south of R154. It seems that the offshore sand was transported toward the south to the benefit of the downdrift profiles (Figure 25).

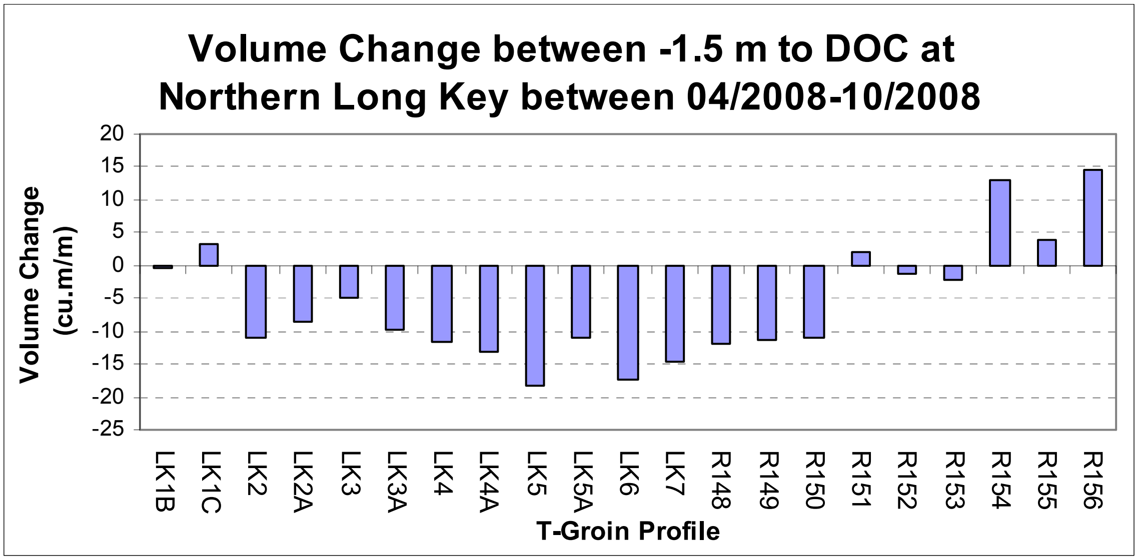

Figure 25. Volume changes between the Depth of Closure (DOC) and -1.5 m NAVD 88 at the Northern Long Key profiles during the 2008 summer season from 04/2008-10/2008.

It is worth noting that the summer of 2008 is relatively energetic with distal passages of two strong hurricanes, Gostov and Ike, generating high swell waves. These waves did not result in abnormal erosion or accretion at Upham Beach and the T-groin field, and the reminder of Long Key.

Two-Year Performance Comparison of Upham Beach Nourishments: With and Without T-Groin Structures

At the end of the fifth monitoring period, it reaches two years after the September 2006 Upham Beach nourishment with the geotextile T-groins. This provides an opportunity to compare the performance of the 2006 nourishment with the T-groin structures with the 2000 nourishment without the T-groins. Profile data collected by the

U.S. Army Corps of Engineers was used in the analysis for the volume changes for the 2000 nourishment. Data collected by the USF Coastal Research Lab was used in the analysis of the volume changes for the 2006 nourishment. Volume change one year and two years after both the 2000 and 2006 nourishments was calculated at the northern Long Key profiles to represent each T-groin compartment. The profile-volume change was calculated from the benchmark (on the seawall or in the dune field) seaward to roughly -1.5 m NAVD88 for the survey lines. Table 7 summarizes the total volume change for each compartment 1-yr and 2-yrs after the 2000 and 2006 nourishments (m^3/m), the volume change difference between the 2000 and 2006 nourishments (m^3/m) (i.e., the percent difference of the volume difference as compared to the 2000 nourishment).

During the 2006-2008 nourishment monitoring period, the beach generally eroded less with the structures as compared to the 2000-2002 nourishment monitoring period without structures. For the area where the T-groin T1 installation was completed in 2006 (compared using LK1B), the 1-year volume losses were slightly greater during the 2006-2008 nourishment monitoring period. From 2006 to 2007, the T1 compartment lost approximately 300 m^3 more sand than during 2000 to 2001, or about 7% more sediment loss. The COE survey discontinued at LK1B for the second year because no sand remained in front of the seawall (Elko, pers comm.).

Table 7. Summary of the comparison of volume changes at the T-groin compartments for the 2000-2002 nourishment without structures and the 2006-2008 nourishment performance with structures.

T-Groin Compt. (2006)	Profile		USACE Data 2000-2002 Volume Change (cu. m)	USF Data 2006-2008 Volume Change (cu. m)	Vol. Change Difference (cu. m)	% Difference	Performance
T1	LK1B	1 year	-4000	-4300	-300	-7%	Lost more
		2 year	N/A	N/A			with structures
T2	LK2A	1 year	-15000	-12800	2200		
		2 year	-2100	-1100	1000		
		Total	-17100	-13900	3200	18%	Retained more with structures
T3	LK3A	1 year	-18300	-14800	3500		
		2 year	-8400	-5100	3300		
		Total	-26700	-19900	6800	26%	Retained more with structures
T4	LK4A	1 year	-7100	-800	6300		
		2 year	-6300	-4500	1800		
		Total	-13400	-5300	8100	61%	Retained more with structures
T5	LK5	1 year	-4000	1400	5400		
		2 year	-3800	-2000	1800		
		Total	-7800	-700	7200	92%	Retained more with structures

For the T-groin compartments from T2 to T5, the 2006-2008 nourishment with the structures performed better than the 2000-2002 nourishment without the structures with less sand loss during the two-year period (Table 7). In addition, the volume change difference between the two nourishments increases southward, favoring the nourishment with structures and also suggesting the structures have not influenced the downdrift beach during the first two years. The T2 compartment retained about 18% more sand, as compared to the 2000-2002 volume change, during 2006-2008 monitoring period than

during the 2000-2002 period, increasing to over 92% more sand retained for the T5 compartment.

Performance during the 2008-2009 Winter from October 2008 to April 2009

October 2008 through April 2009 represents an active winter season, with frequent passages of cold fronts. The cold front passages tend to generate high northerly approaching waves that are crucial to the erosion at Upham Beach. Compared to the summer season in 2008, the magnitude of beach change in the 2008-2009 winter season was greater, as expected. During this period of time, the northern four T-Groins (T1, T2, T3, and T4) remained exposed at the shoreline, while T-Groin 5 remained buried. The erosion in front of the seawall between T-groins 1 and 2, or the T2 compartment, continued. The riprap in front of the seawall became completely exposed, with regular interaction with the waves nearly at all times, except at spring low tide. Bi-monthly beach profiles and tabulated beach-profile volume and shoreline changes are listed in Appendices I and II.

North segment (North of T-groin 2)

The T-head of T1 was removed by September 2008 and the seaward tube in the top layer of the stem of T1 was removed in October 2008 (Figure 26). The wave energy reduction by the T1 head was substantially reduced due to the removal of this portion of the structure. This is clearly reflected in the erosion of the narrow beach in front of the seawall that was protected by the structure, as also discussed in the previous report

(Wang and Roberts, 2008b). As shown in Figure 27, a 15-m retreat of the shoreline was measured during this 6-month winter. The seawall and riprap became fully exposed in the intertidal zone and interact with incoming waves nearly at all times. The entire profile experienced erosion over the winter, resulting in the complete erosion of the narrow dry beach and an elevation decrease of approximately 0.5 m over the subaqueous portion of the profile. Significant erosion occurred during the first and last two months of the winter.

Figure 26, a) July 2008: T-head deteriorating, b) September 2008: T-head essentially removed. Seawardmost tube in top layer of stem intact, and c) October 2008: Seawardmost tube in top layer of stem deteriorated.

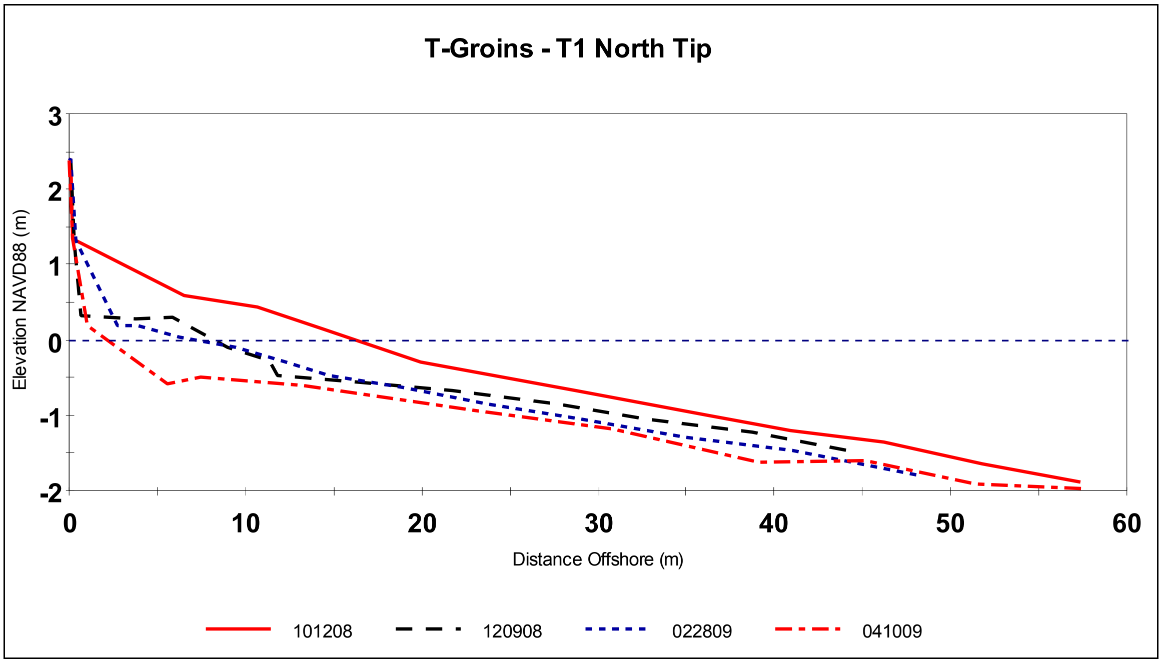

Figure 27. T-groin profile T1 North Tip, profile changes between October 2008 to April 2009 (full sized graph and adjacent profiles are listed in Appendix I).

In the compartment between the first and second T-groins (T1 and T2), a similar trend of beach profile change, as compared to the T1-BP-south-jetty compartment (Figure 27), was measured (Figure 28). The narrow dry beach was completely eroded exposing the seawall and riprap along the shoreline. The entire profile was eroded with an approximate 0.5 m elevation loss during the first two winter months. A slight difference of this profile (Figure 28) and the previous profile (Figure 27) is that the erosion during the last two winter months was not as severe. Scour in front of the riprap was measured. The morphologic response, especially the complete erosion of the narrow dry beach, in both compartments may be attributable to the removal of the T-head from T1.

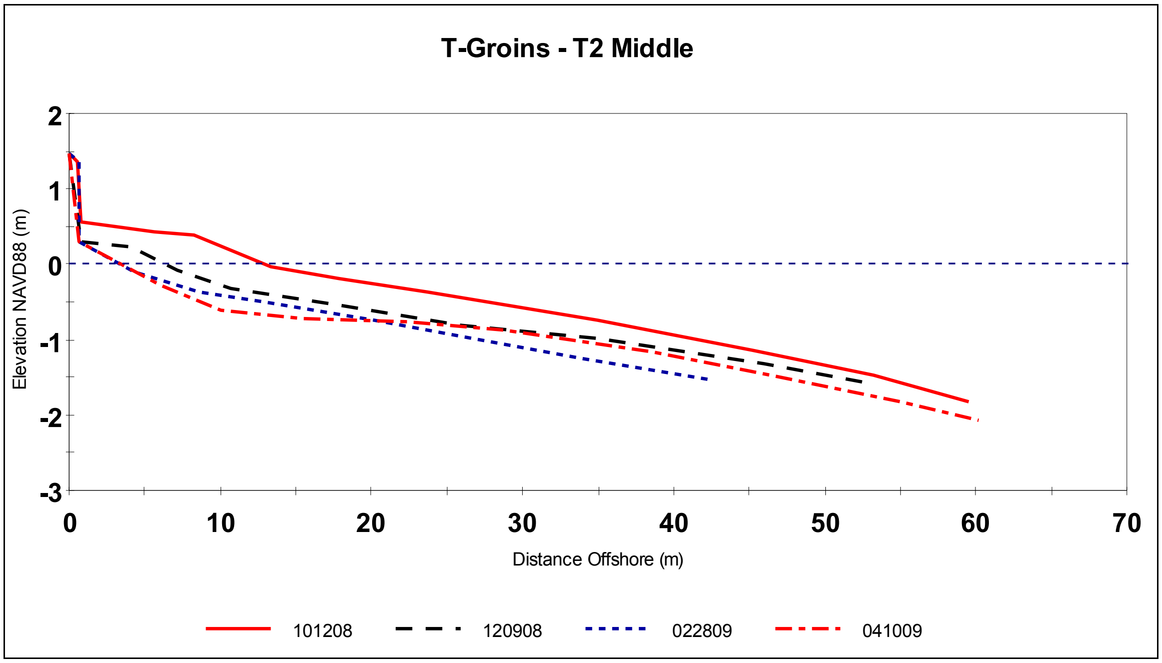

Figure 28. T-groin profile T2 Middle, profile changes between October 2008 and April 2009 (full sized graph and adjacent profiles are listed in Appendix I).

<u>Central segment (between T-groins 2 and 4)</u>

The central segment, including compartments T2-T3 and T3-T4, demonstrated a similar pattern of beach-profile changes, as compared to the compartments to the north, during this winter season. Figure 29 shows the Long Key profile, LK3, extending roughly across the middle of the T2-T3 compartment. The dry beach and berm remained relatively stable during this energetic winter season. However, the intertidal and subaqueous portions of the profile eroded, resulting in an approximately 10 m shoreline retreat along with an elevation loss of about 0.5 m. This erosion resulted in a somewhat steeper profile, as compared to the summer profile. All of the time-series profiles converged at -2 m NAVD; therefore, this profile-volume loss over the entire active profile resulted from a longshore sand transport gradient.

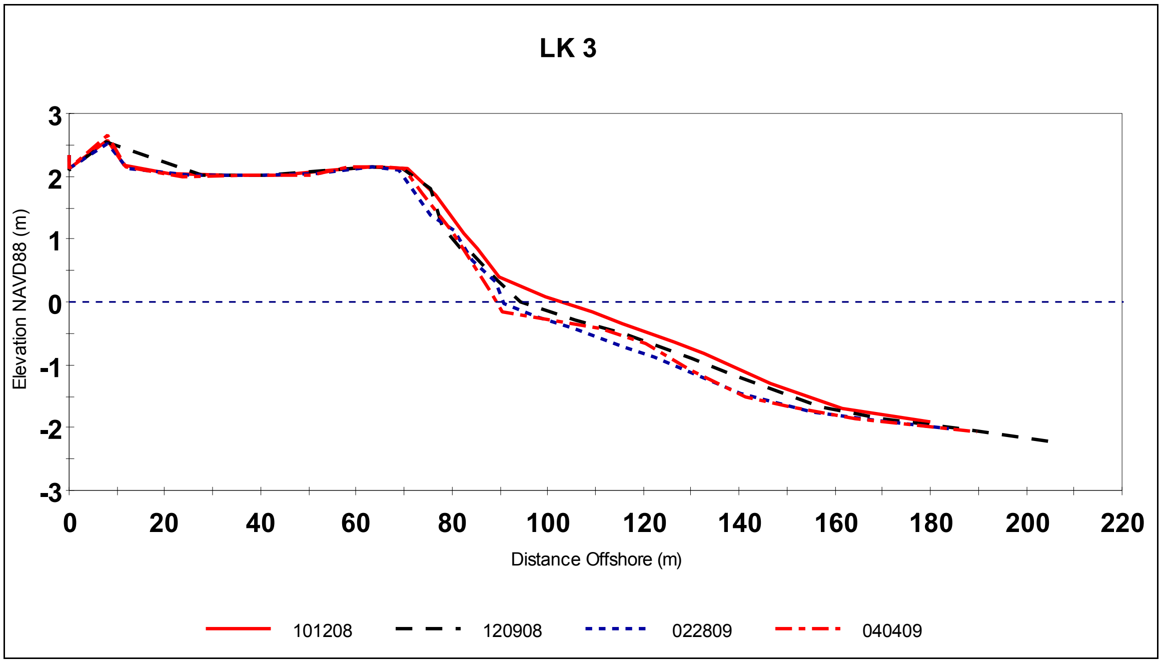

Figure 29. Long Key profile LK3, profile changes between October 2008 and April 2009 (full sized graph and adjacent profiles are listed in Appendix I).

Figure 30 shows a profile through roughly the middle of T3-T4 compartment. Both T3 and T4 remained exposed during this monitoring period. The beach changes along this profile are quite similar to LK3 shown in Figure 29, with considerable erosion over the intertidal and subaqueous profile. Overall, a nearly 10-m shoreline retreat and 0.5 m elevation loss were measured, while the dry beach and the berm remained relative stable. A 5-m berm retreat was measured.

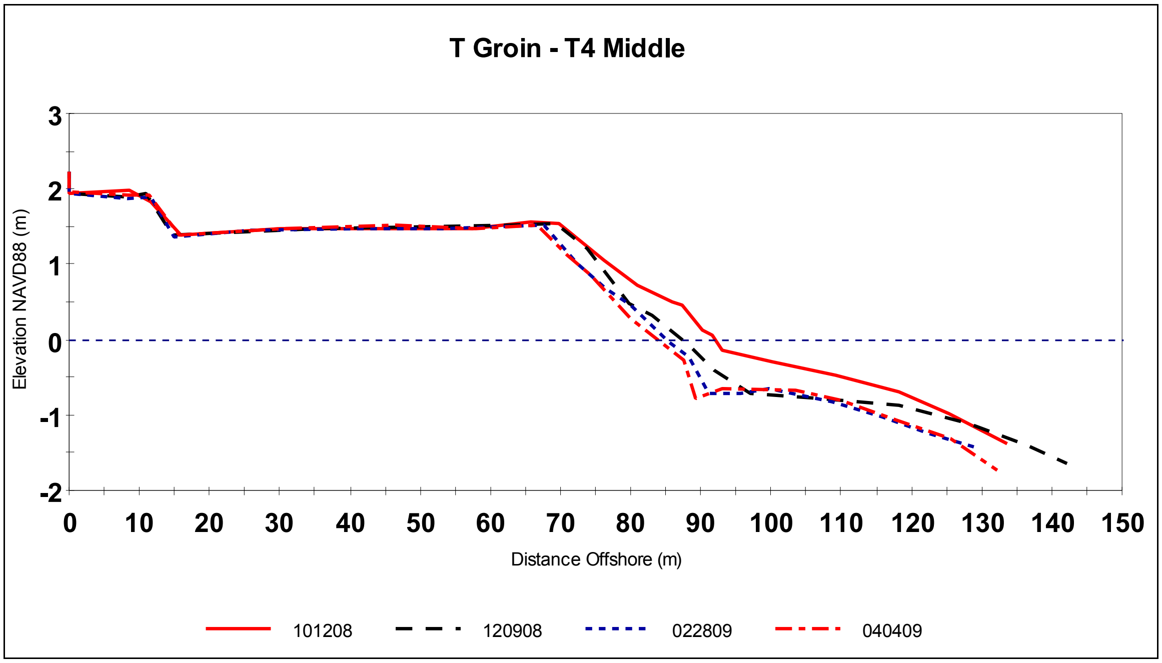

Figure 30. T-groin profile T4 Middle, profile changes between October 2008 and April 2009 (full sized graph and adjacent profiles are listed in Appendix I).

South segment (between T-groins 4 and 5)

A similar trend of profile change as measured along the profiles to the north is also measured in this segment. T5 remained buried during this monitoring period. The beach profile at the northern portion of the compartment (Figure 31) eroded along the foreshore and in the subaqueous portion of the profile, resulting in slightly over 10 m of shoreline retreat and a 0.5-m elevation loss. The entire profile shifted landward indicating that the erosion was caused by longshore sediment transport, as typically occurs during the winter season. The back beach remained rather stable.

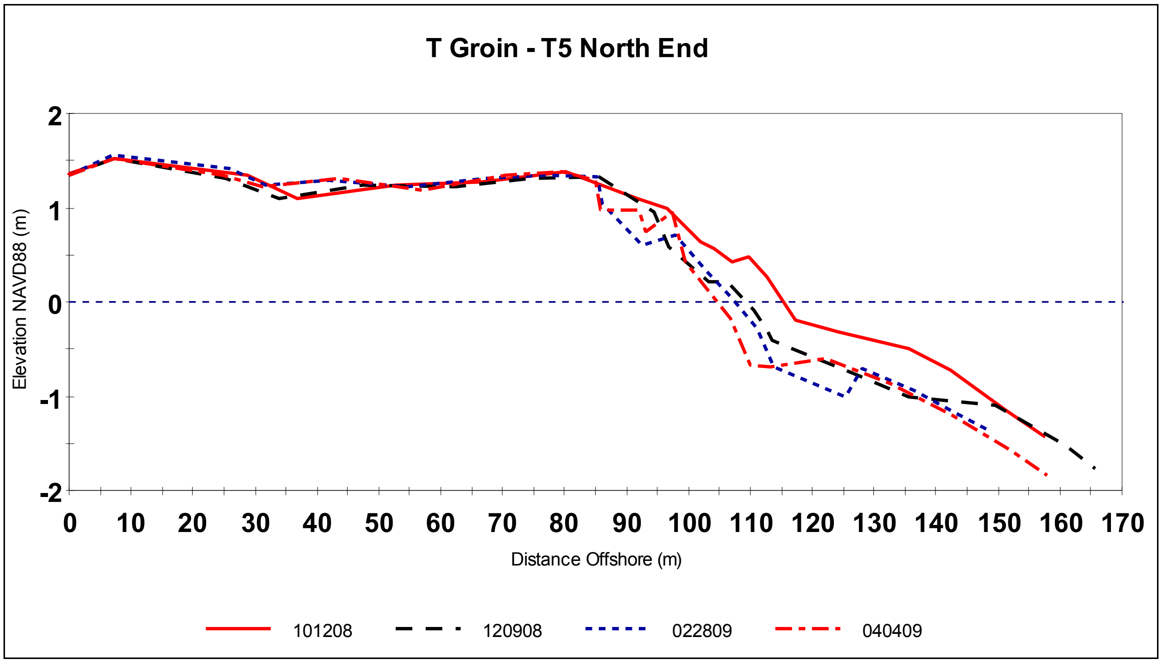

Figure 31. T-groin profile T5 North End, profile changes between October 2008 and April 2009 (full sized graph and adjacent profiles are listed in Appendix I).

Long Key profile LK5 extends across the southernmost T-groin (T5). This profile is located in the taper zone of the September 2006 renourishment, where a limited amount of sand was placed on the beach. Overall, this profile (Figure 32) showed a similar trend of change as compared to the profiles further north (Figures 29, 30, and 31). This is different from the previous monitoring periods when this profile behaved differently from the northern profiles. Profile-volume loss was measured along the foreshore and subaqueous profile, resulting in nearly 10 m shoreline retreat of about 0.2-m elevation loss. A small amount of accumulation in the offshore area was measured during the first two months of the winter, which resulted from cross-shore sand transport. This accumulation was eroded later this winter by longshore sediment transport. No nearshore bar was developed and maintained during this winter season.

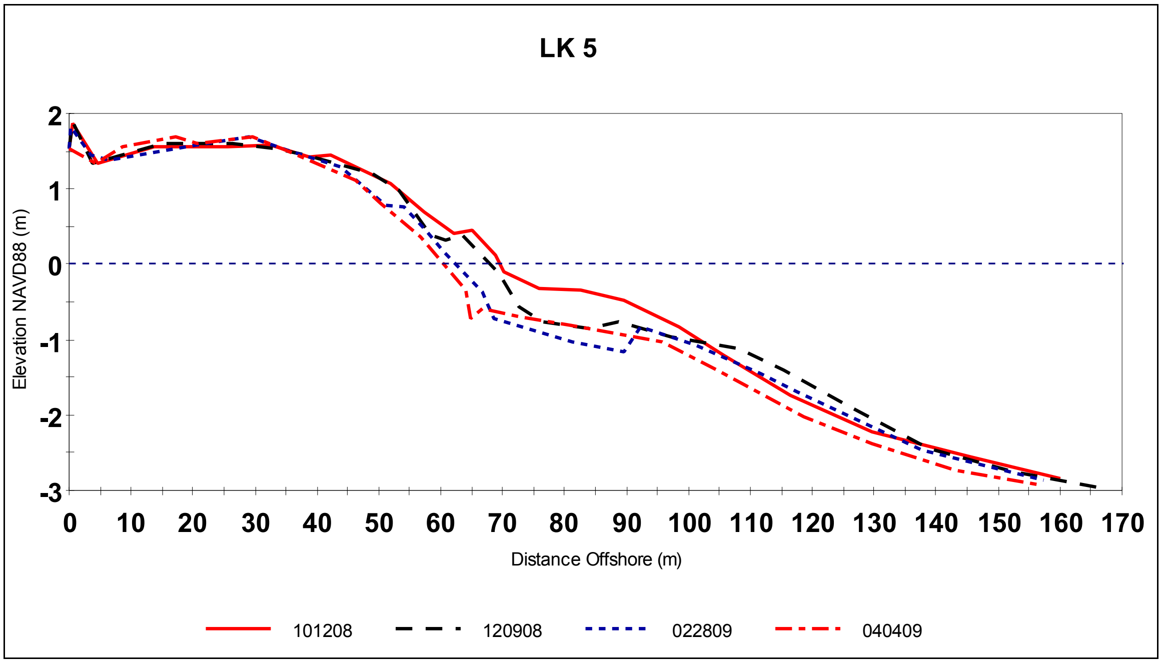

Figure 32. Long Key profile LK5, profile changes between October 2008 and April 2009 (full sized graph and adjacent profiles are listed in Appendix I).

Downdrift

Compared to the largely monotonic profiles in the T-groin project area north of LK5, the downdrift profiles are characteristic of a dynamic nearshore bar system. Figure 33 shows profile LK7, representing the trend of change at LK5A, LK6, LK7, and R148. Continuous onshore migration of the nearshore bar was measured during the last 6-month summer season, with the bar eventually merging with the intertidal zone and the profile becoming monotonic at the end of the summer. A subtle offshore bar was formed during the first two months of the winter season, resulting from the erosion in the nearshore area and deposition in the offshore area. The dry beach above mean sea level remained stable while the subaqueous profile changed substantially. The offshore bar that formed at the beginning of the winter season migrated onshore throughout the winter season. Overall, profile-volume loss was measured at this profile during this winter season, resulting from

the southward longshore transport. This erosive trend is similar to the previous summer months.

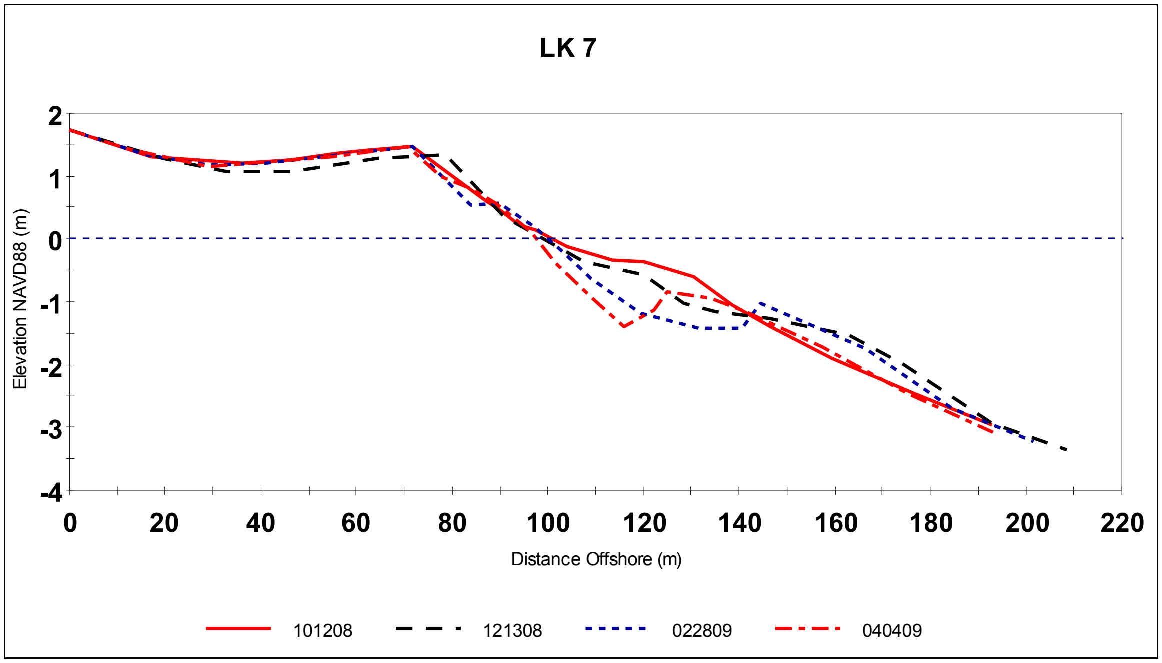

Figure 33. Long Key profile LK7, profile changes between October 2008 and April 2009 (full sized graph and adjacent profiles are listed in Appendix I).

Different patterns of profile-volume and shoreline changes were measured along the Long Key profiles further south and downdrift of R149, as compared to profiles LK7 through R149, similar to the case in the 2006-2007 winter and 2007 summer. Profile R152 is shown here as an example (Figure 34). Similar to the profiles further north (Figure 33), the dry beach remained stable and the bar migrated offshore during the first two months, followed by onshore bar migration. However, a key difference in the trend observed along these profiles is that the offshore zone seaward of the bar crest remained rather stable over this monitoring period, in contrast to erosion measured along profiles further north. Consequently, volume gain was measured over the entire profile. This can be attributed to sand supplied from the eroding profiles to the north through longshore

transport. Overall, the downdrift region eroded; however, the data suggest a typical winter beach performance and not abnormally high erosion as a result of the groin field.

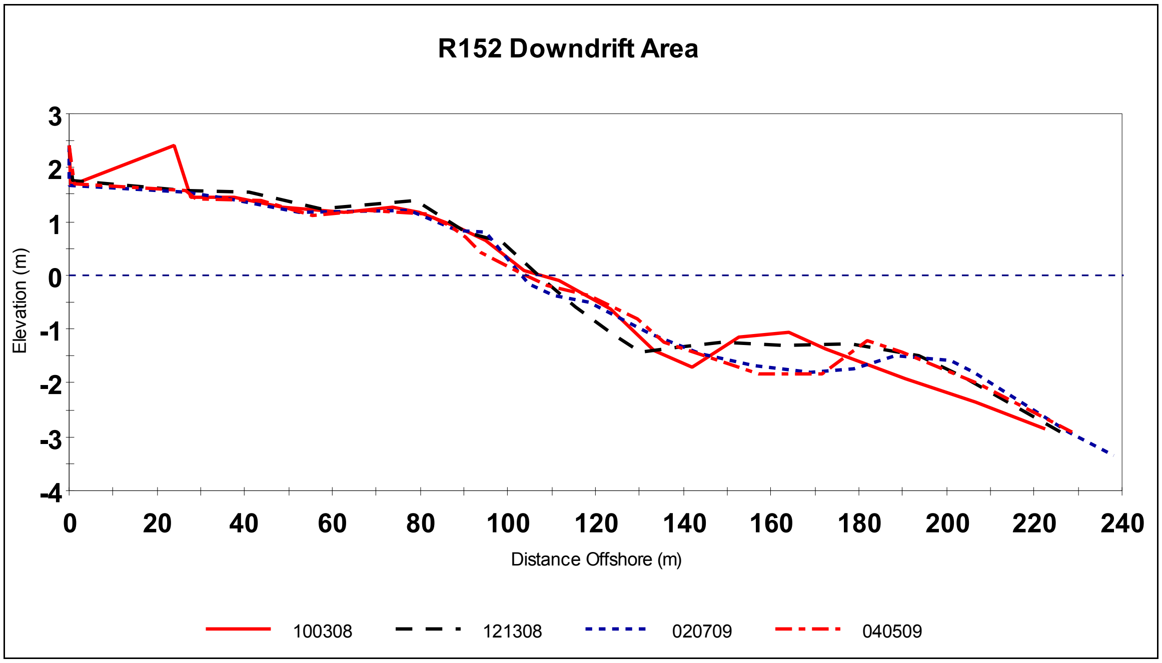

Figure 34. Long Key profile R152, profile changes between October 2008 and April 2009 (full sized graph and adjacent profiles are listed in Appendix I).

In summary, during this monitoring period, berm and nearshore zone erosion was measured in the entire project area and along the downdrift beach due to relatively high-energy waves associated with the passages of winter cold fronts. As a result of the removal of the T1 T-head, erosion of the narrow beach landward of the groin continued and the riprap in front of the seawall in the T1-T2 compartment became almost fully exposed. Furthermore, erosion in the subaqueous portion of the profile occurred resulting in an elevation loss of approximately 0.5 m. Compared to the summer of 2008 (Wang and Roberts, 2008b), the magnitudes of profile-volume loss were larger due to the erosion of the subaqueous profile. However, shoreline change was mostly less than 15

m, much smaller than that during the initial 7 months (Wang and Roberts 2007a, 2007b). This is attributed to the exposure of the seawall and riprap along the northern portion of the project. South of the exposed seawall, the T-groins may be responsible for the relatively small shoreline retreat during this high-energy winter season. No abnormally high erosion was measured downdrift of the groin field.

Volume and Shoreline Changes

Changes of profile-volume and shoreline during the 2008-2009 winter months were calculated for all the T-groin profiles and Long Key profiles to R156. The profile-volume change was calculated from the benchmark (on the seawall or in the dune field) seaward to roughly -1.5 m NAVD88 for T-groin lines and to roughly -3 m NAVD88 (or short-term DOC) for Long Key lines. The tabulated results are listed in Appendix II. Figure 35 shows the alongshore distribution of the profile-volume change. Compared to the dramatic losses of up to 100 m^3/m measured during the initial 3 months and the following 4 months (Figures 3 and 7), the changes during the 2008-2009 winter were smaller. As expected, significantly more profile-volume loss was measured as compared to the last two summer 6-month monitoring periods, i.e., 04/2207-10/2007 (Wang and Roberts, 2007c), and 04/2008-10/2008 (Wang and Roberts, 2008b). The measured profile-volume change was comparable to the last winter, 10/2007-04/2008 (Wang and Roberts, 2008a), but with a different longshore distribution pattern. A similar amount of profile-volume loss was measured in all the T-groin compartments. This resulted from the persistent erosion in the subaqueous portion of the profile, as discussed above.

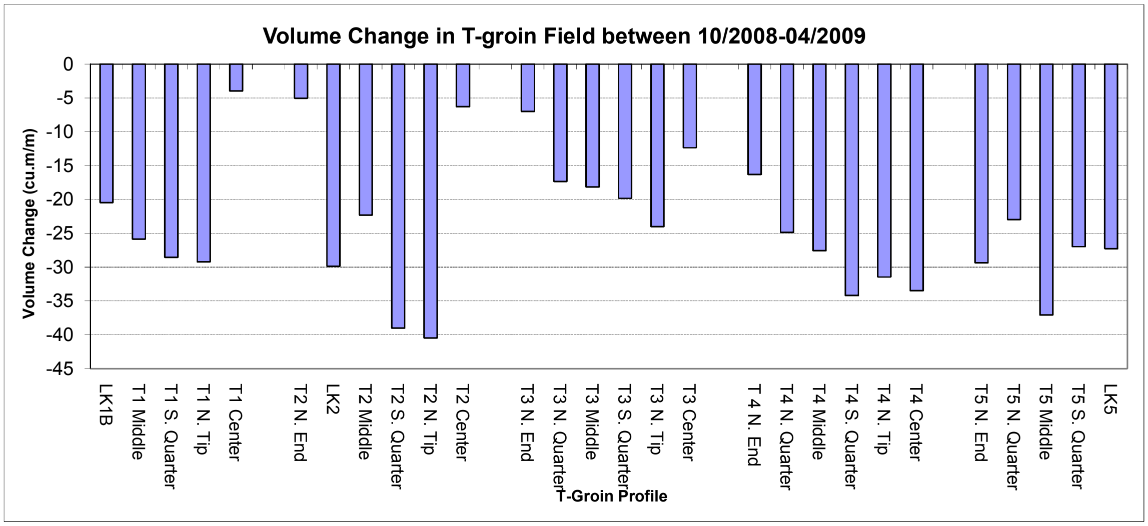

Figure 35. Profile-volume change in the groin field during the 2008-2009 winter season between 10/2008-04/2009.

Profile-volume changes measured at the Long Key lines within the project area (Figure 36) demonstrate a similar magnitude of volume loss as that of the T-groin profiles, except at LK2A where substantially more volume-loss was measured. Profile LK2A is located at the corner of a protruding seawall (Figure 1). This may contribute to the excessive erosion in the offshore portion of the profile. Downdrift erosion, extending to R148, that was measured during the 2008 summer was also measured during this winter season. However, the magnitude of the profile-volume loss did not increase during the relatively high-wave energy winter season, as compared to the summer. Profile-volume gain from R150 to R156 was minimal. Again, this suggests erosion typical of winter beach performance (perhaps even of a lower magnitude than normal due to sediment input from the north) and not abnormally high erosion as a result of the groin field.

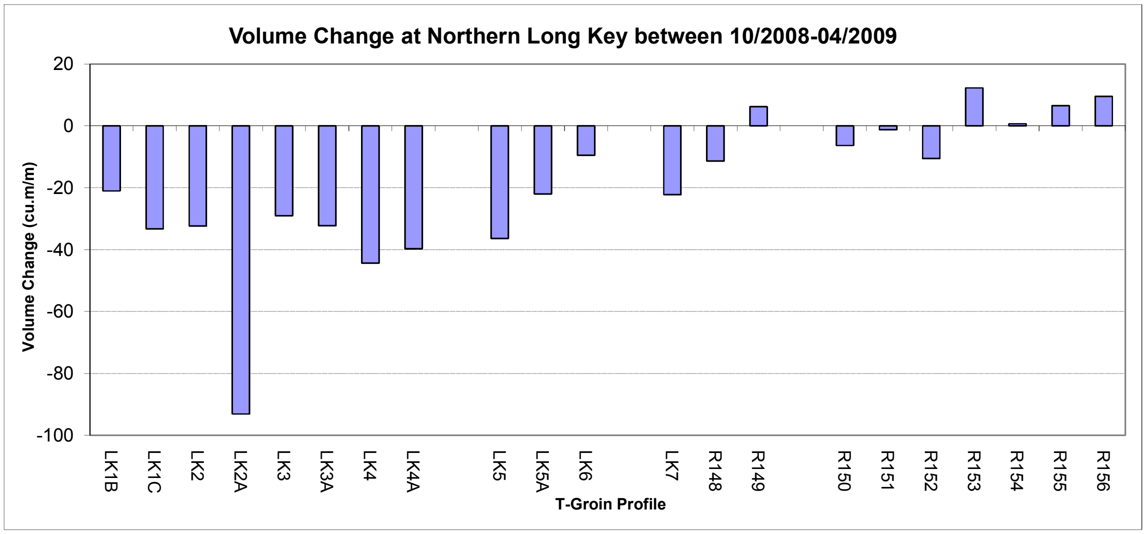

Figure 36. Profile-volume change of the Long Key profiles during the 2008-2009 winter season between 10/2008-04/2009.

Table 8 summarizes the volume and shoreline changes in each T-groin compartment during the 2008-2009 winter. The total volume change in each compartment is obtained by multiplying the average profile-volume change by the alongshore extent of the compartment. The volume change in the T-groin compartment reflects the trend shown in Figure 35. Similar to the previous two 6-month reports (Wang and Roberts 2008a, 2008b), the downdrift beach is divided into three sections: 1) downdrift-1: including LK5, LK5A, and LK6; 2) downdrift-2: including LK6, LK7, R148, and R149; 3) downdrift-3: including R149, R150, R151, R152, R153, R154, R155 and R156. Generally, the distance from the bar to the shoreline increases progressively southward, along with an increase in water depth in the trough (Appendix I).

Table 8. Summary of volume and shoreline change at the T-groin compartments and the downdrift beach during the 2008-2009 winter season from 10/2008-04/2009.

	Alongshore	Avg. Volume	Avg. Shoreline	Total Volume
	Distance(m)	cu m / m	m	cu m
T1 compartment	105	-21.61	-11.54	-2259
T2 compartment	117	-23.84	-13.71	-2800
T3 compartment	108	-16.45	-4.83	-1772
T4 compartment	119	-27.99	-9.90	-3333
T5 compartment	106	-28.74	-9.43	-3047
downdrift-1 (LK5-LK5A-LK6)	200	-22.63	-7.02	-4526
downdrift-2 (LK6-LK7-R149)	588	-9.24	1.08	-5436
downdrift-3 (R149-R156)	2100	2.14	-2.67	4501
			Volume Sum	-18672

Compared to the magnitude of volume loss during the first five monitoring periods (Tables 2, 3, 4, 5, and 6), the changes during the 2008-2009 winter season were smaller than that measured during the initial 7 months, but larger than that during the most recent three 6-month monitoring periods. The overall volume loss was considerably greater than during the previous two summer seasons (Tables 4 and 6) as expected. Slightly more volume loss was also measured, as compared to the last winter season, especially at downdrift-2 area (Table 5), reflecting the further depletion of sediment supply from the northern portion of the project. Another different trend measured during the 2008-2009 winter, as compared to the previous periods, is that similar volume was lost in all compartments, instead of having an apparent peak in a certain compartment. Both findings suggest that the longshore spreading of the most recent renourishment is complete, or has equilibrated. In addition, relatively greater volume losses were measured in the downdrift areas, as compared to the previous periods. It is worth noting that the downdrift losses are not excessive. Although the values are greater than each compartment loss, it is over a longer alongshore distance. Therefore, unit distance

volume loss is not higher, suggesting that no accelerated erosion occurred in the downdrift during the winter of 2008-2009.

In contrast to the previous 6 summer months when the T-groin and the downdrift areas to R156 gained 18,600 m^3, volume loss of approximately 18,700 m^3 was measured during this winter monitoring period. As compared to the loss of 12,600 m^3 during the 2007-2008 winter, this larger volume loss may be attributable to depleted sand supply from the updrift portion of the beach.

Shoreline (defined here as NAVD88 zero) change in the groin field during the 2008-2009 winter monitoring period demonstrated a similar trend to that of the profile-volume changes (Figures 35 and 37). Compared to the first 7 months (Figures 4 and 8), the overall magnitude of the shoreline change was smaller. However, greater values of shoreline retreat were measured during 2008-2009 winter, as compared to the 2007-2008 winter, with the maximum shoreline retreat of nearly 25 m measured in the T1-T2 compartment, as opposed to a maximum of 16 m during the 2007-2008 winter. Greater shoreline retreat was also measured in the compartment between T1 and the south jetty of Blind Pass. These are related to the structural damage of the T-groins 1 and 2 during the summer of 2008, suggesting that the structures did function to protect the landward shoreline. Shoreline retreat of up to 13 m was measured in the southern three compartments.

The shoreline change pattern measured at the Long Key lines in the T-groin field is similar to that measured at the T-groin profiles (Figure 38). However, the shoreline change pattern is considerably different from the profile-volume change pattern due to the fact that most profile-volume loss occurred in the subaqueous portion of the profiles

(Figure 36). Despite the largest profile-volume loss measured at profile LK2A, no shoreline change was measured because the shoreline was anchored by the seawall and riprap at the beginning of the 2008-2009 winter. Slight shoreline gains were measured at profiles R148 and R149 despite the overall profile-volume loss there. The slight profile-volume gains measured at profile R153, R155, and R156 did not result in any shoreline gain, instead, slight shoreline loss was measured.

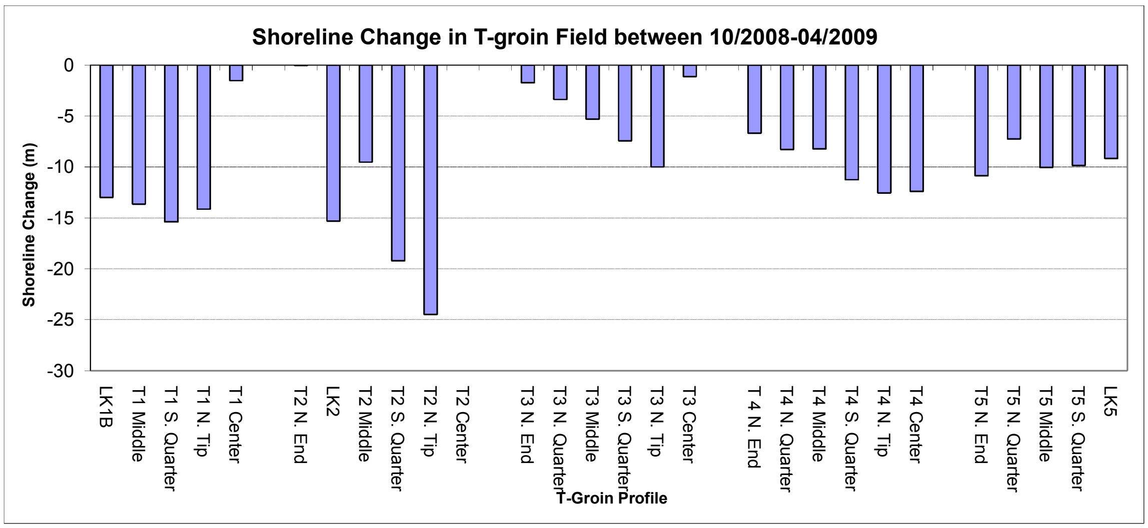

Figure 37. Shoreline change in the T-groin field during the 2008-2009 winter season between 10/2008-04/2009.

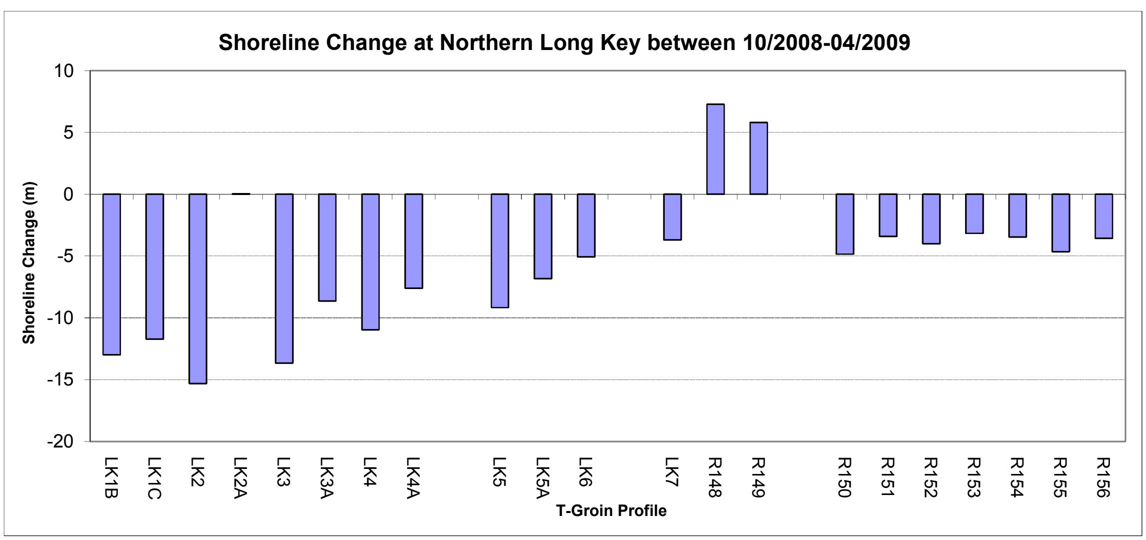

Figure 38. Shoreline change of the Long Key profiles during the 2008-2009 winter season between 10/2008-04/2009.

Profile-volume change between -1.5 m and -3.0 m NAVD88 was also calculated to examine the exchange between nearshore and offshore regions, as suggested by FDEP. Overall, profile-volume loss was measured in this area at most of the Long Key profiles north of R148 (Figure 39). Profile LK2A lost nearly 70 m^3/m, which is much greater than the rest of the profiles. As discussed earlier, the offset of the seawall at that location may be the reason of this excessive erosion. Profile-volume gain was measured at profiles south of R148. This may suggest that a considerable amount of longshore sand transport occurred between -1.5 m and -3.0 m NAVD88 during the winter of 2008 and 2009 (Figure 39).

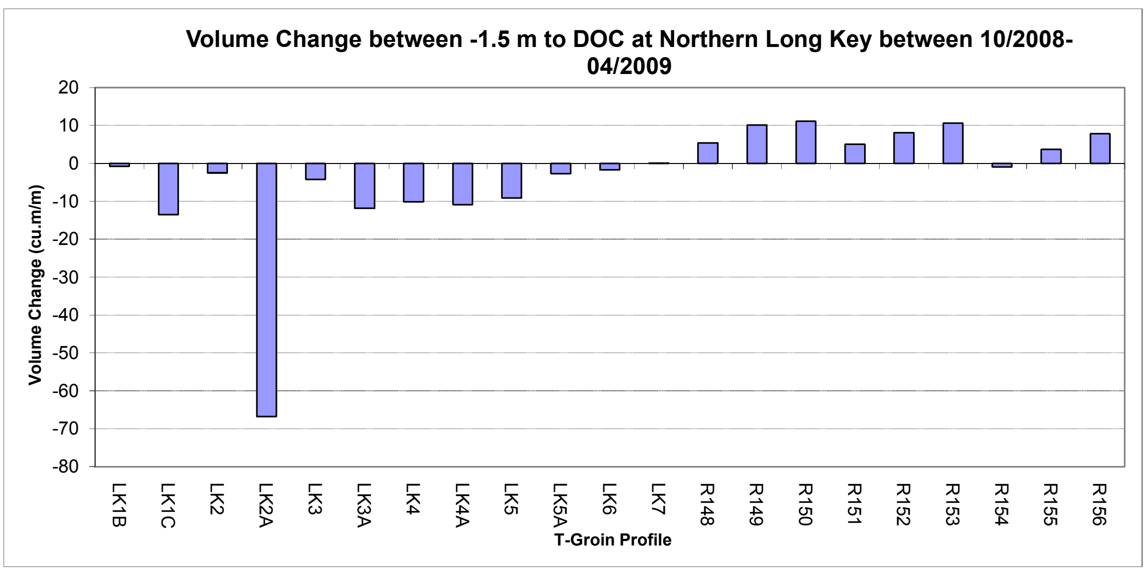

Figure 39. Volume changes between the Depth of Closure (DOC) and -1.5 m NAVD 88 at the Northern Long Key profiles during the 2008-2009 winter season from 10/2008-04/2009.

Summary

The field of five T-groins installed at Upham Beach was designed to maintain a portion of the nourished beach at this chronically eroding location without negative impacts to the downdrift beach. The T-groin project area was renourished in September 2006 and all the structures were buried. In this summary, the performance of the T-groins over the entire 31-month project period is summarized.

During the initial 3 months after the September 2006 nourishment, rapid beach erosion at the north segment, typical of Upham Beach, was measured. Since all the structures were buried, this rapid erosion was not attributed to the T-groin field. Downdrift of the T-groin area, the dry beach remained largely stable to slightly accretionary, apparently benefiting from the longshore sand supply from the north. No direct impact of the structures to the downdrift beach was measured during the initial 3 months (Wang and Roberts, 2007a).

The northernmost T-groin became exposed at the shoreline just before the December 2006 survey. The second T-groin became exposed during the month of January 2007. The third T-groin was exposed at the end of the 2006-07 winter season in May 2007. Therefore, during the 2006-2007 winter season from December 2006 to April 2007, the first two structures began to interact with the incoming waves directly. During this 4-month winter period, peak volume and shoreline changes were measured in the T2-T3 compartment as compared to the T1-T2 compartment during the initial 3 months. This reflects the function of the T-groins designed to impound and reduce southward longshore sediment transport. A delayed erosional spike along the central beach as a

result of reduced sediment supply from the north is consistent with previous studies (Elko, 2006).

The third monitoring period from April 2007 to October 2007 represented a mild summer season. Compared to the changes measured during the first 7 months, the overall magnitude of beach-profile volume and shoreline changes was much smaller during this monitoring period. Erosion, although at a much reduced rate, was measured in the T-groin area with a peak in the T2 and T3 compartments. Volume gain of approximately 10,000 m^3 was measured in the downdrift area, along with considerable shoreline gain, benefiting from an onshore trend of sediment transport and possibly sediment transport from the south during the summer season. An onshore migration of the offshore bar was measured at nearly all the downdrift profiles.

The fourth monitoring period from October 2007 to April 2008 represented an active 2007-2008 winter season, with frequent cold-front passages especially late in the season. Beach erosion was measured at all the T-groin profiles, as well as along the immediate downdrift area. The fourth T-groin became exposed at the shoreline following the passage of a strong cold front in February. The greatest beach-profile erosion and shoreline retreat was measured in the T3-T4 compartment, with a sand volume loss of slightly over 4,000 m^3 and an average shoreline (NAVD88 zero) loss of 11 m. Overall, nearly 13,000 m^3 of sand eroded from the T-groin project area, in addition to 6,000 m^3 from the immediate downdrift beach. Profile-volume gains were measured further downdrift from R148 to R154. The seawall along the T1-T2 compartment became exposed at the shoreline during this 6-month winter. A small fillet beach was maintained between the Blind Pass south jetty and T-groin 1. The erosion along the downdrift beach

was likely related to the typical longer-term performance of the Upham Beach nourishment. It is not clear whether the downdrift erosion has been accelerated by the T-groin structures.

The fifth monitoring period from April 2008 to October 2008 represents a relatively active summer season, with distal passages of two hurricanes late in the season. The relatively high-energy waves generated by the storms eroded the intertidal zone. Beach erosion, although at a reduced magnitude as compared to the winter seasons, was measured at all the T-groin profiles, as well as along the immediate downdrift area. The greatest beach-profile erosion and shoreline retreat was measured in the T3-T4 compartment, with a sand volume loss of slightly over 1,300 m^3. Overall, nearly 3,400 m^3 of sand eroded from the T-groin project area, in addition to 5,600 m^3 from the immediate downdrift beach. Volume gain of 27,600 m^3 was measured further downdrift from R148 to R156. The small fillet beach that had been maintained between the Blind Pass south jetty and T-groin 1 suffered some erosion due to the removal of the T-head of T1. The erosion along the downdrift beach is likely related to the typical longer-term performance of the Upham Beach nourishment and not related to the T-groins. T5 did not become exposed during this monitoring period.

A comparison of the 2-year performance of the 2006 nourishment with the T-groin structures was compared to the performance of the 2000 nourishment prior to the installation of the T-groins. Overall, during the 2006-2008 nourishment monitoring period, the beach retained more sand with the structures as compared to the 2000-2002 nourishment monitoring period without structures. In the T-groin compartments from T2 to T5, the 2006-2008 nourishment with the structures performed better than the 2000-

2002 nourishment without the structures. In addition, the volume change difference between the two nourishments increases southward, favoring the nourishment with structures.

The sixth monitoring period from October 2008 to April 2009 represents an active winter season, with frequent passages of winter cold fronts. Different from the previous monitoring periods, substantial erosion was measured in the intertidal and subaqueous portions of the profile, ranging from 0.5 m NAVD88 to -2.0 m NAVD88. This resulted in an elevation loss of approximately 0.5 m over a large portion of the subtidal profile. This elevation loss resulted in volume loss during the winter of 2008-2009. The volume loss is greater than the two previous summer seasons and also slightly greater than the 2007-2008 winter season. Accelerated erosion was measured in the northern two compartments, probably due to the active interaction between the fully exposed seawall and riprap with the incoming waves. Although erosion was also measured at a number of downdrift profiles, the profile-volume loss was mostly smaller than the loss within the T-groin field and is comparable to the typical rate of winter erosion at Upham Beach. This suggests that the T-groins did not have significant negative impacts to the downdrift beach. Similar to the findings from the previous report at the end of two years, the overall volume loss between profile LK3 and LK5 seems to be reduced by the presence of the T-groins as compared to the previous nourishment without the structures.

Overall, based on the 31 months of intensive monitoring, no clear negative impact from the T-groin field to the downdrift shoreline can be identified. Compared to the performance of previous Upham Beach nourishments (Elko et al., 2005), the T-groins have reduced the rate of beach erosion at Upham Beach. However, partly due to the

damage to T1 and T2 structures, the seawall and riprap north of T2 became exposed after August 2008 or about 23 months after the nourishment and the installation of the structures. A significantly accelerated rate of beach erosion was measured north of T2 after month 23, resulting in complete exposure of the seawall and riprap. This, along with the much slower rate of erosion before the structural damage, suggests that the structures functions to a certain extent in protecting the beach landward.

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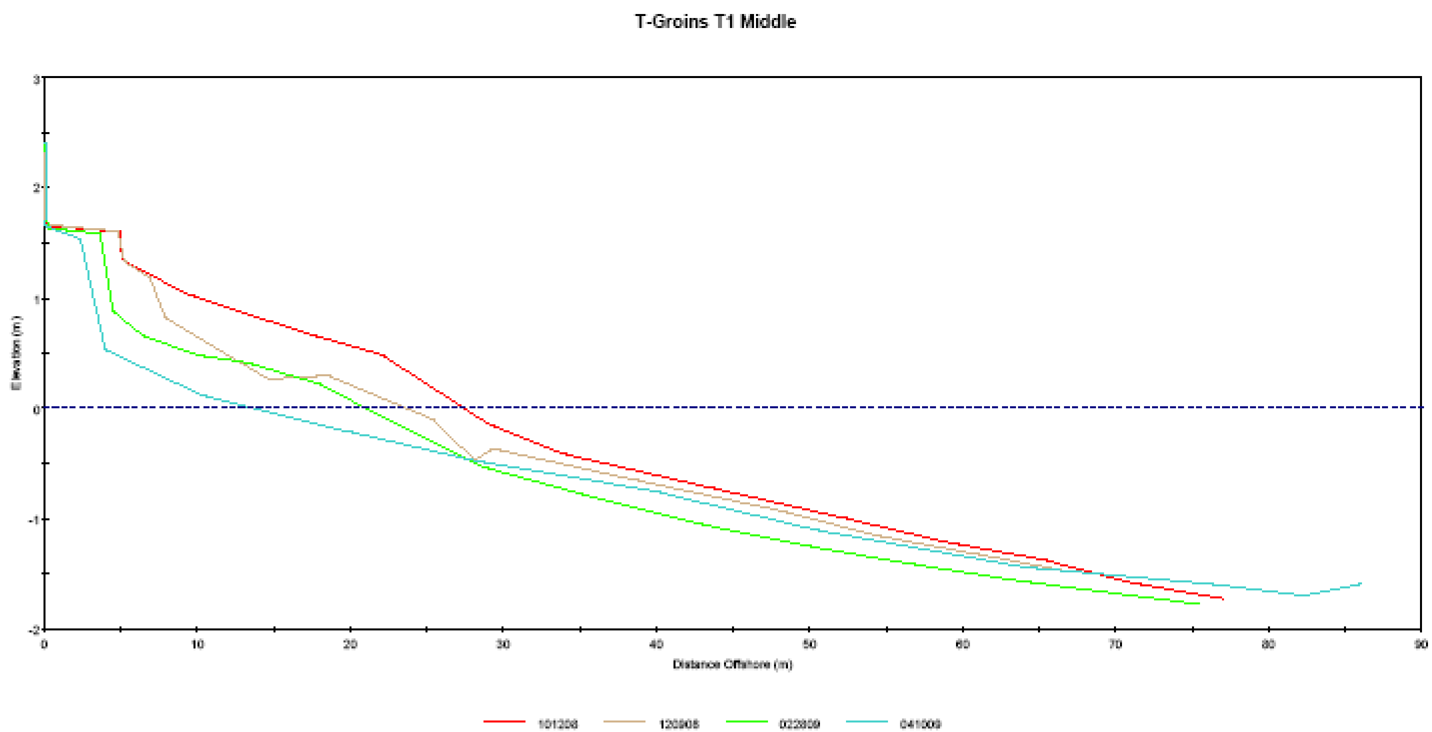
Appendix I

Monthly Beach Profiles
October 2008 - April 2009

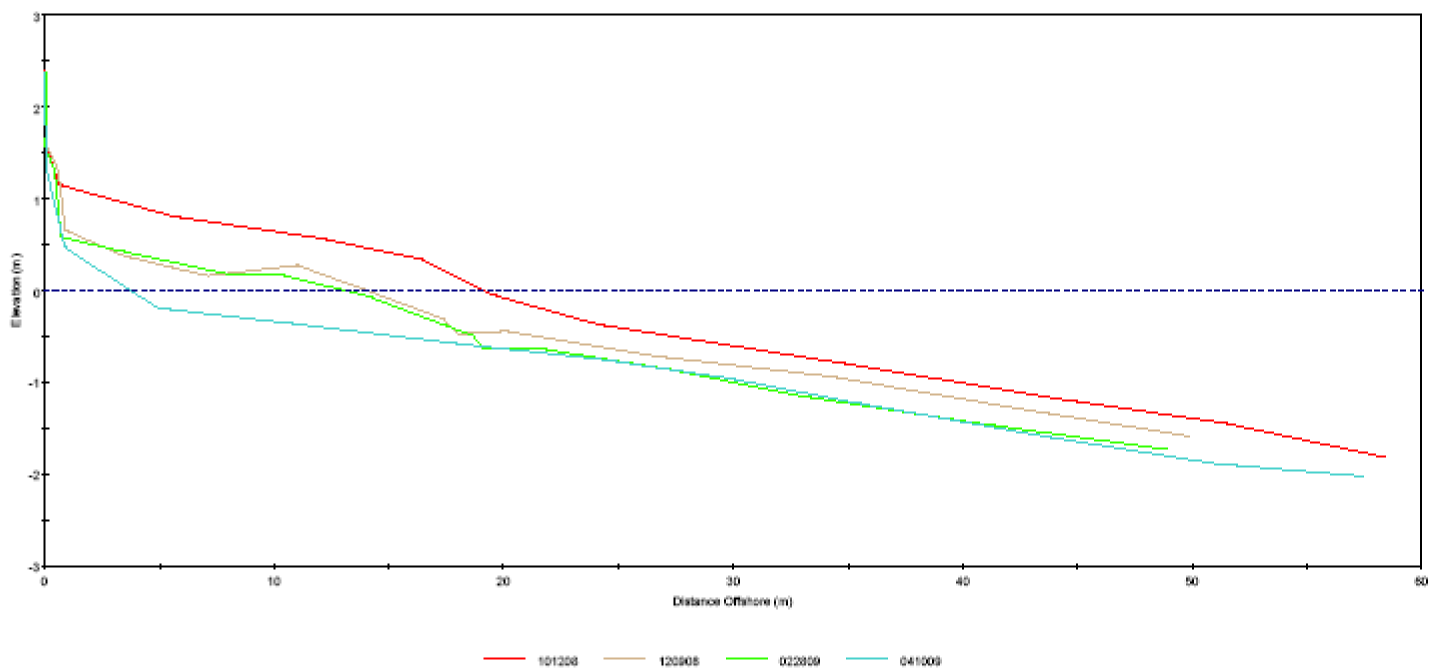
Profiles are listed from north to south. The Long Key survey lines within the T-groin field are inserted at the end of each T-groin compartment.

T-Groin 1 and the Compartment to the North

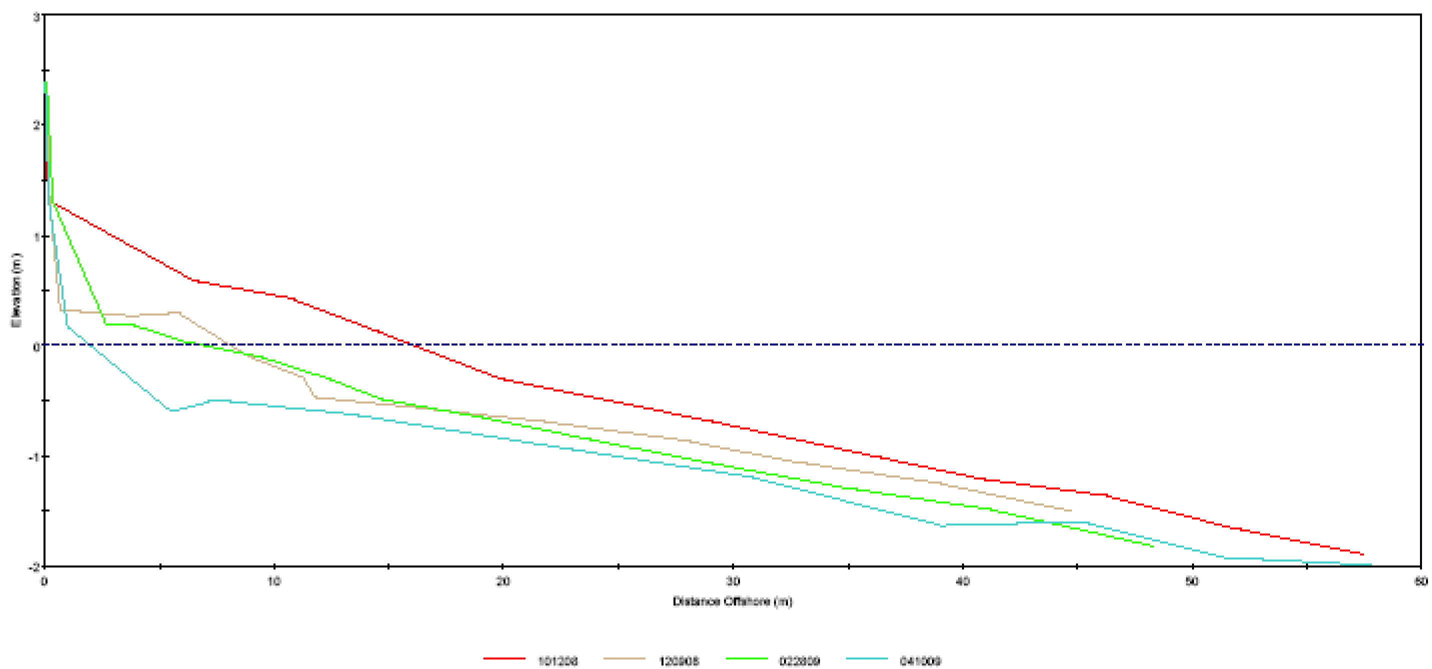


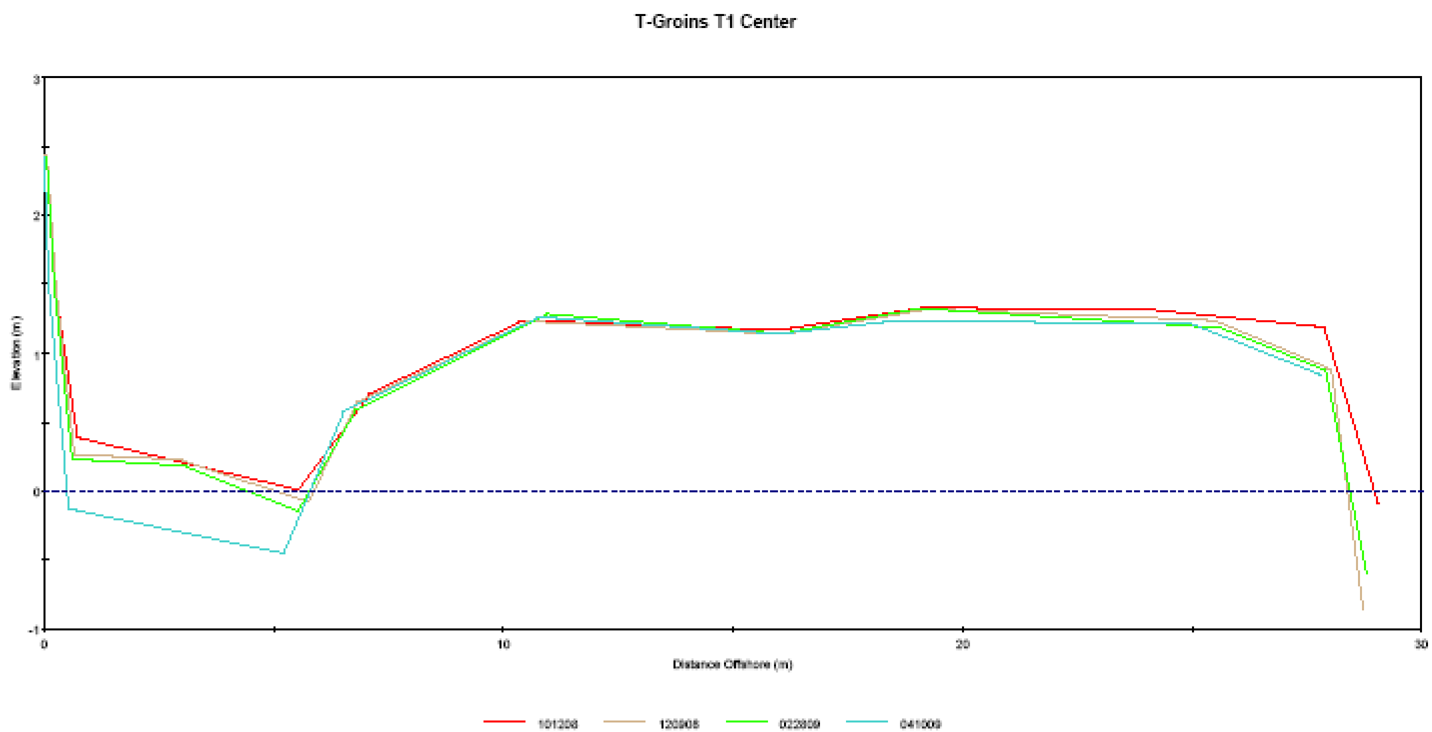
T-Groins T1 Middle
Elevation (m)
Distance Offshore (m)
3
2
1
0
-1
-2
0
10
20
30
40
50
60
70
80
90
101208
120908
022809
041009

T-Groins T1 South Quarter

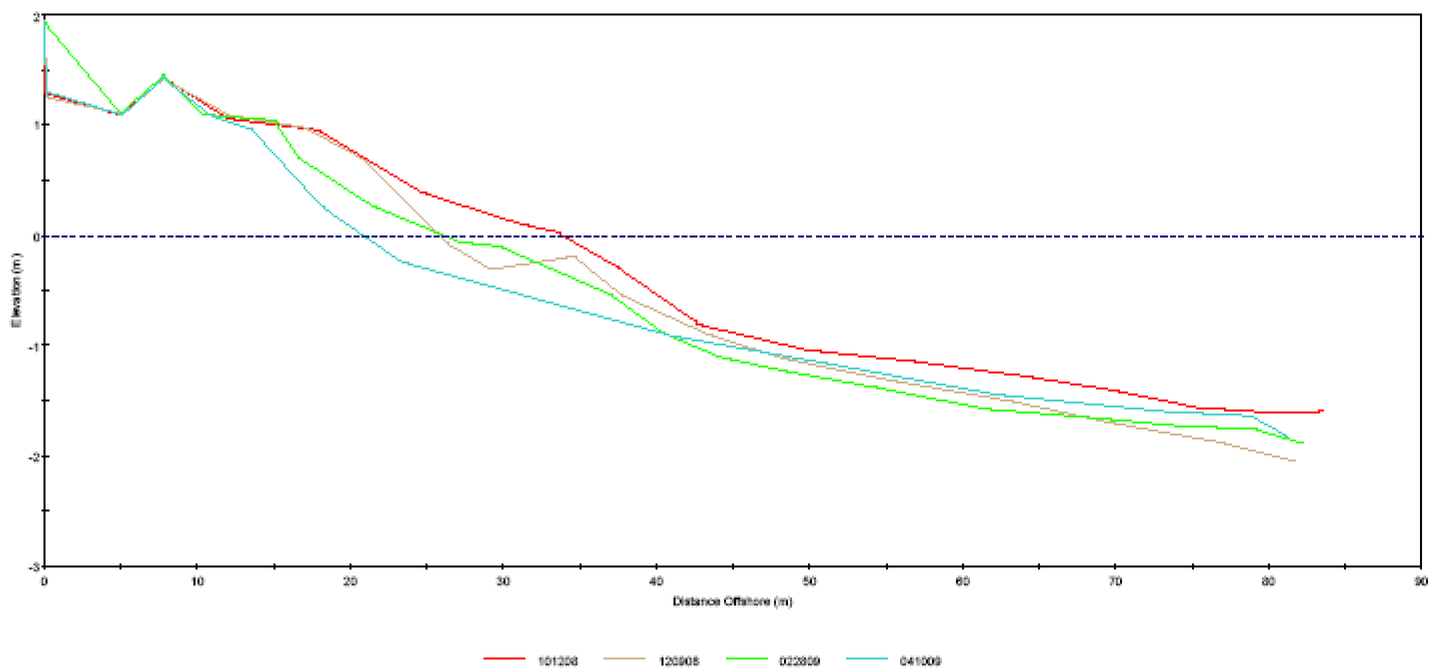


T-Groins T1 North Tip



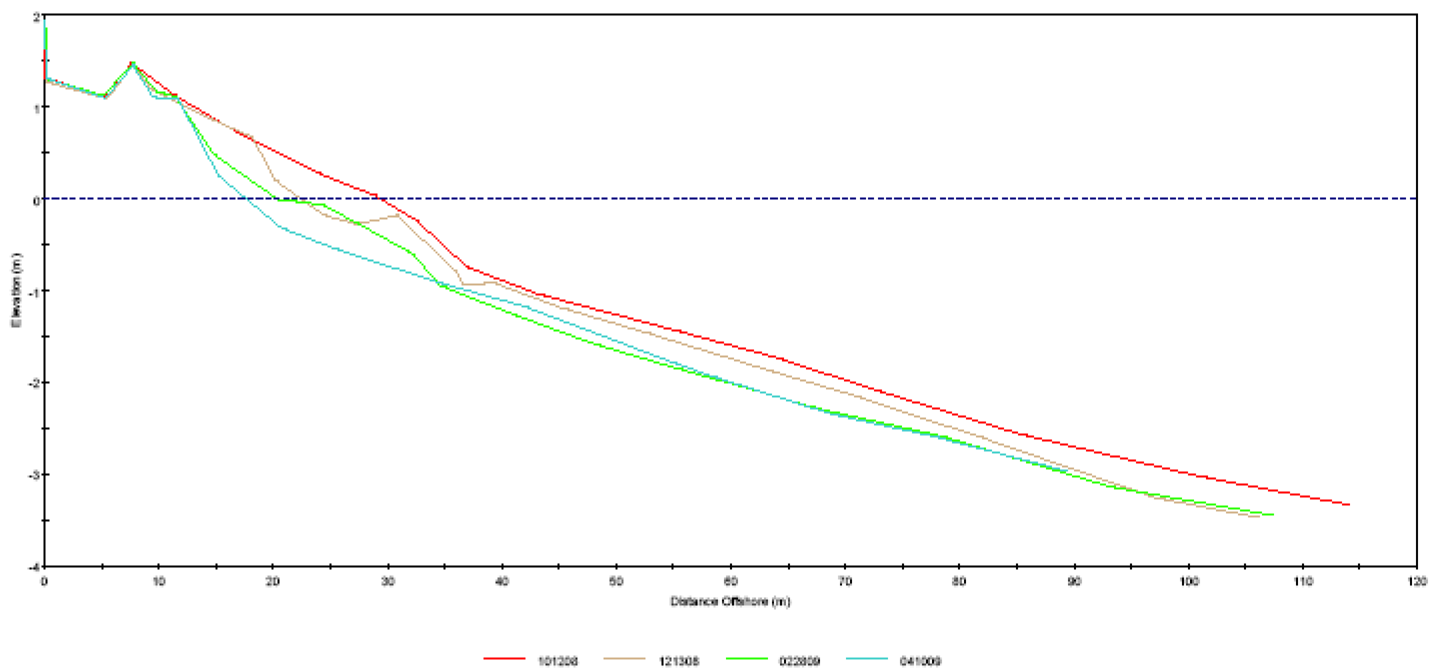

T-Groins T1 Center
Elevation (m)
3
2
1
0
-1
0
10
20
30
Distance Offshore (m)
101208
120908
022809
041009

LK1B



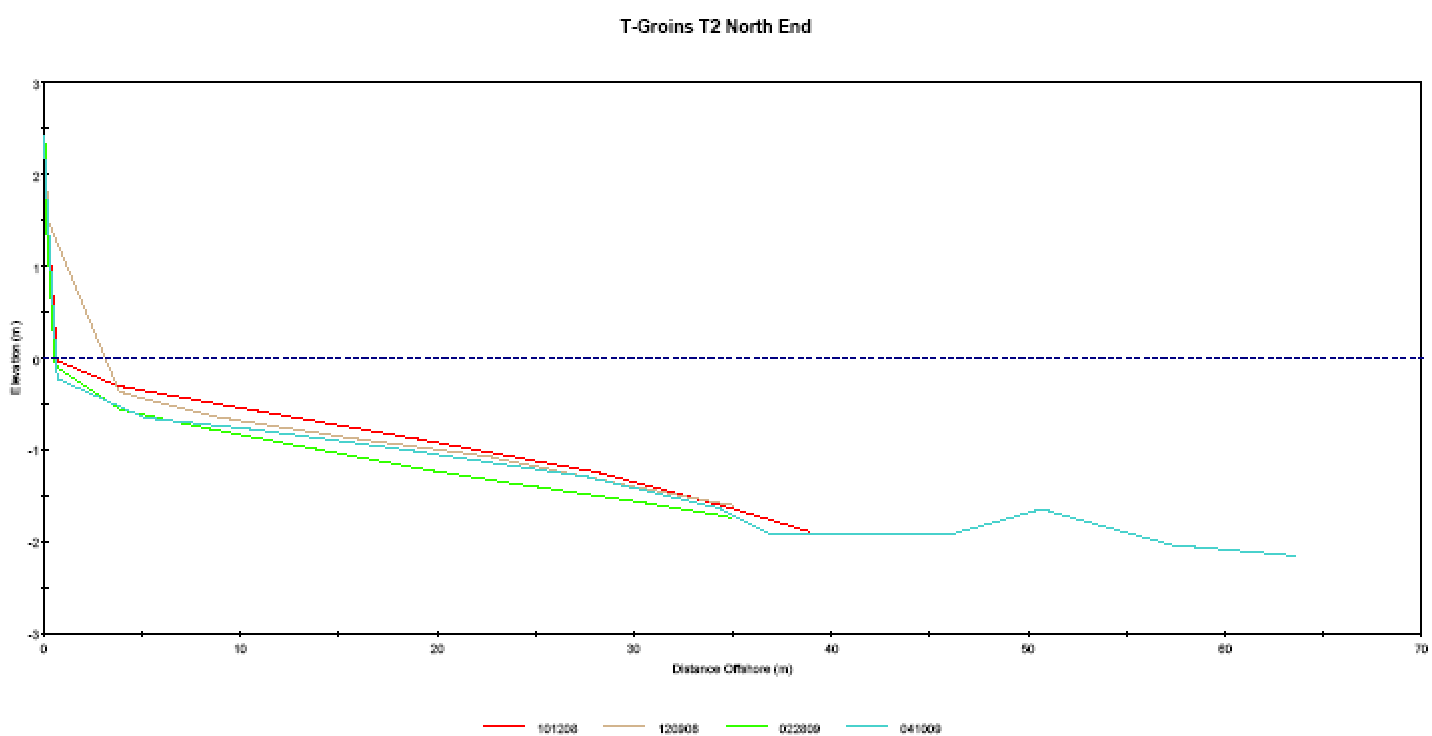
2
1
0
-1
-2
-3
Elevation (m)
0
10
20
30
40
50
60
70
80
90
Distance Offshore (m)
101208
120908
022809
041009

LK1C

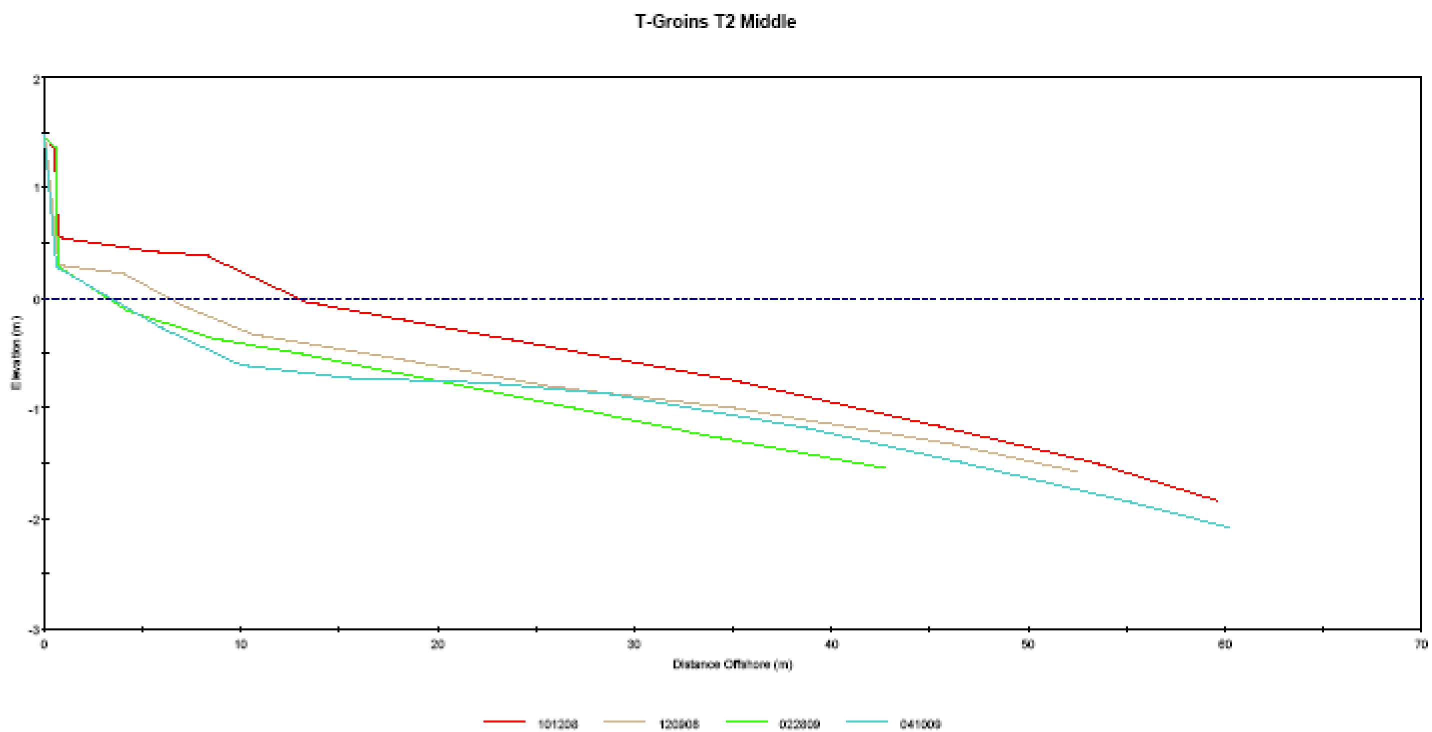


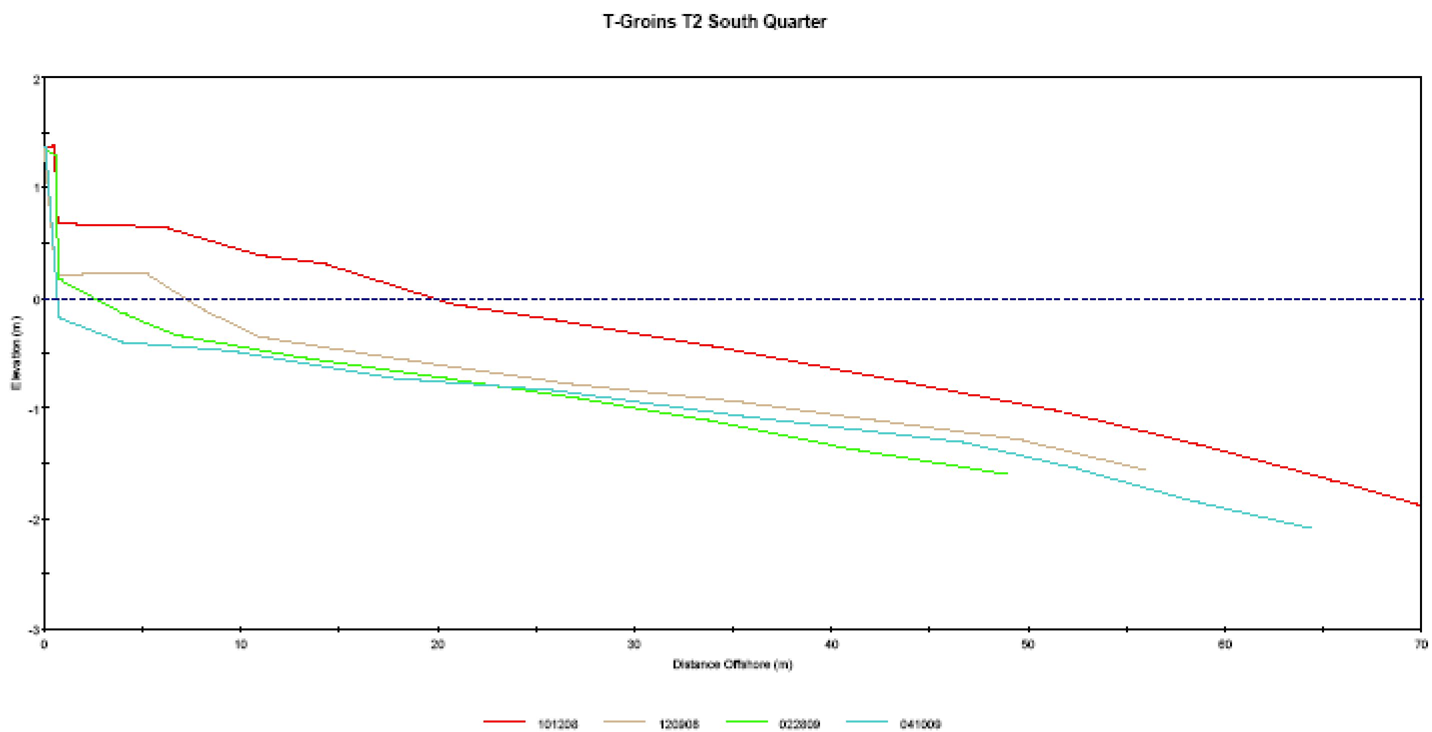
Elevation (m)
Distance Offshore (m)
101208
121308
022809
041009

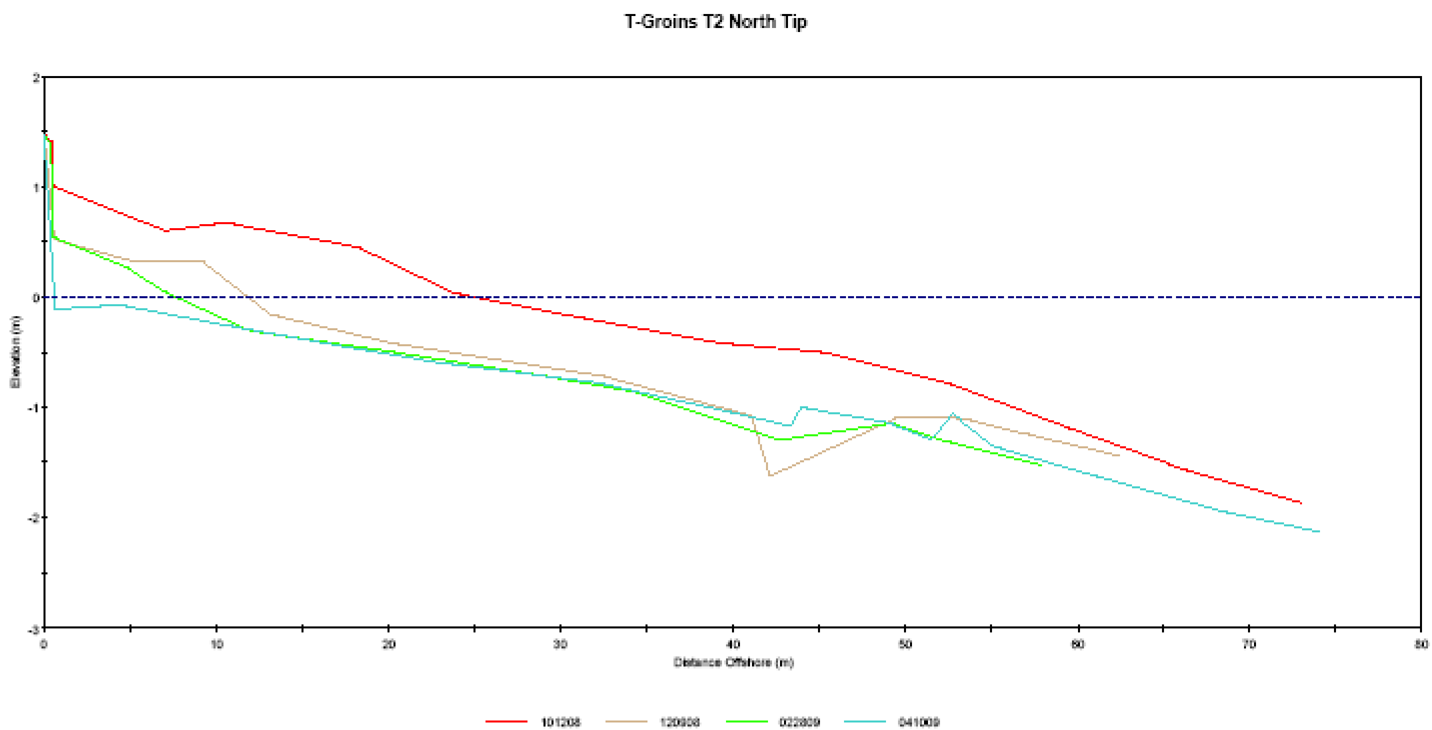
T-Groin 2 and the Compartment to the North

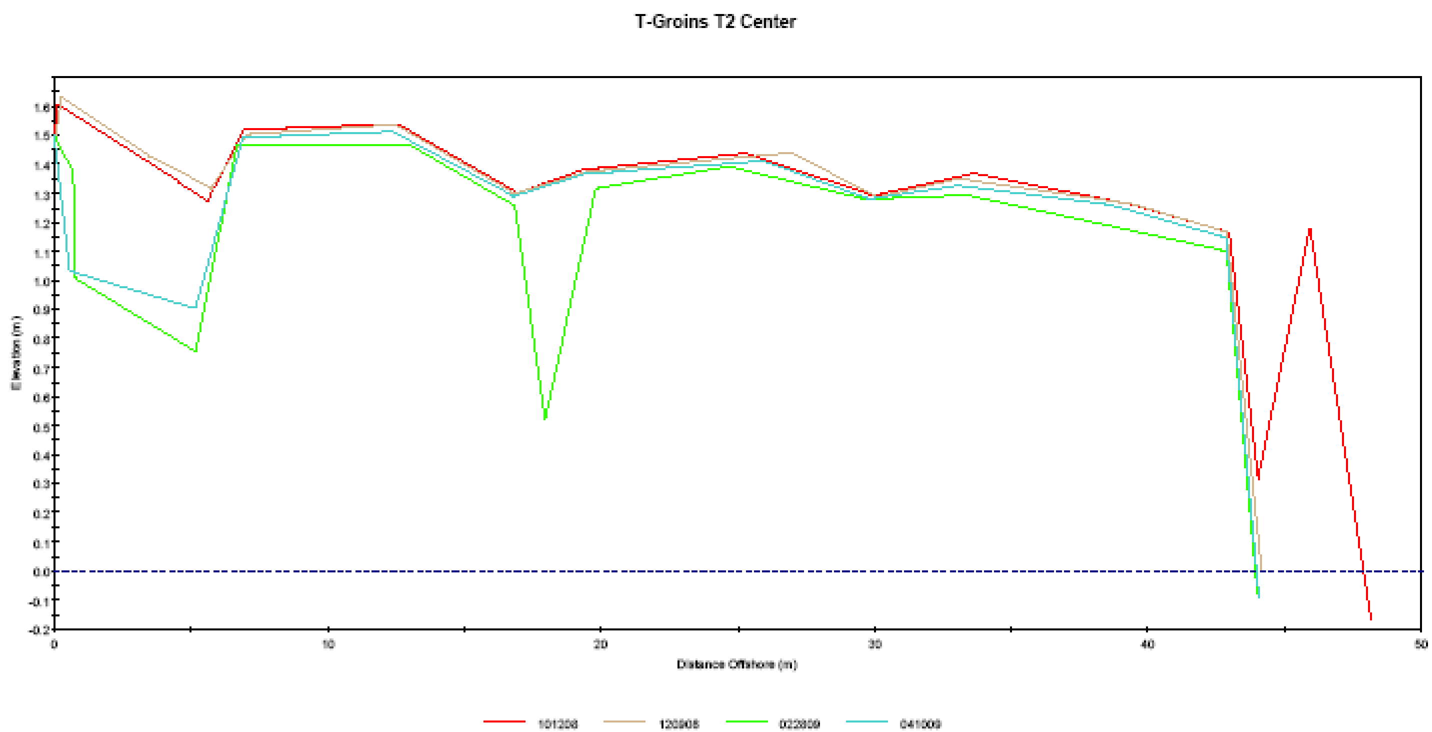


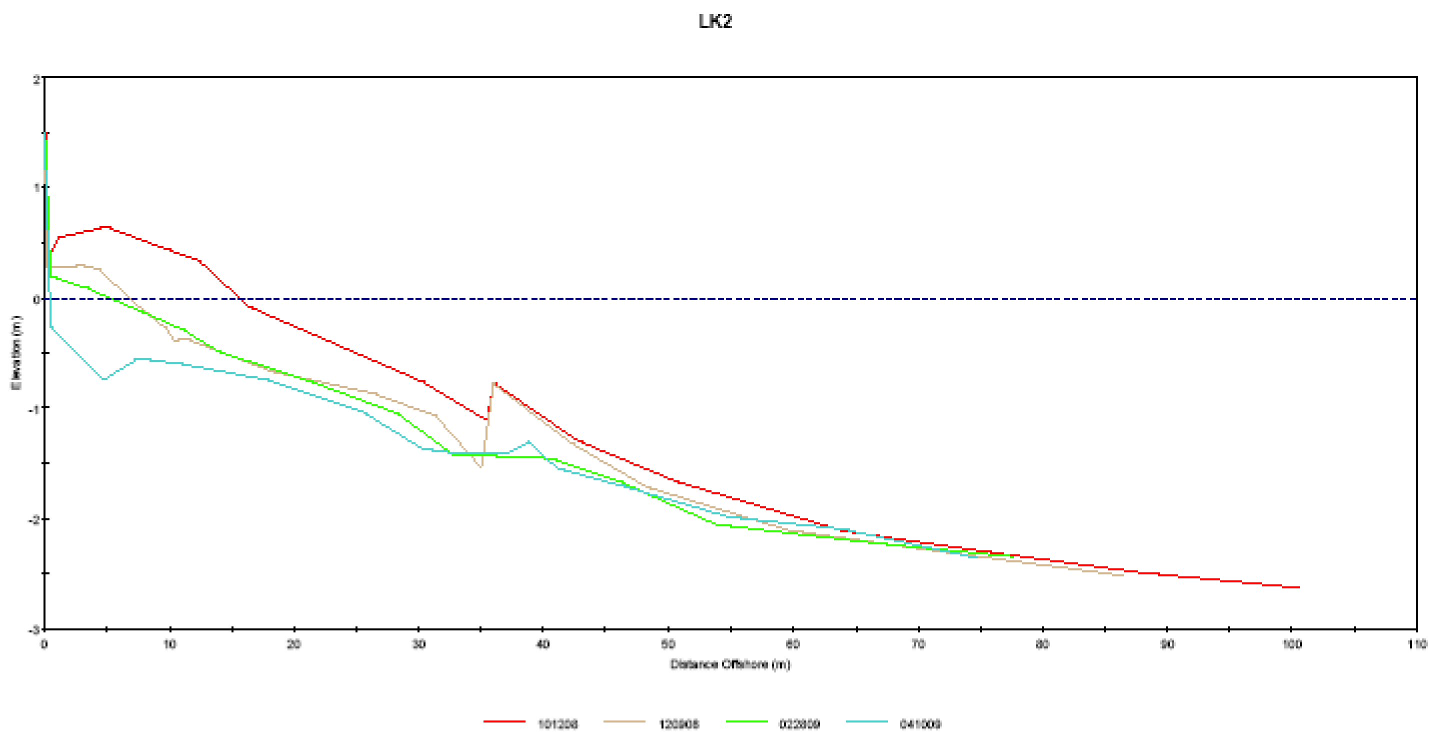
T-Groins T2 North End
Elevation (m)
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
Distance Offshore (m)
101208
120908
022809
041009

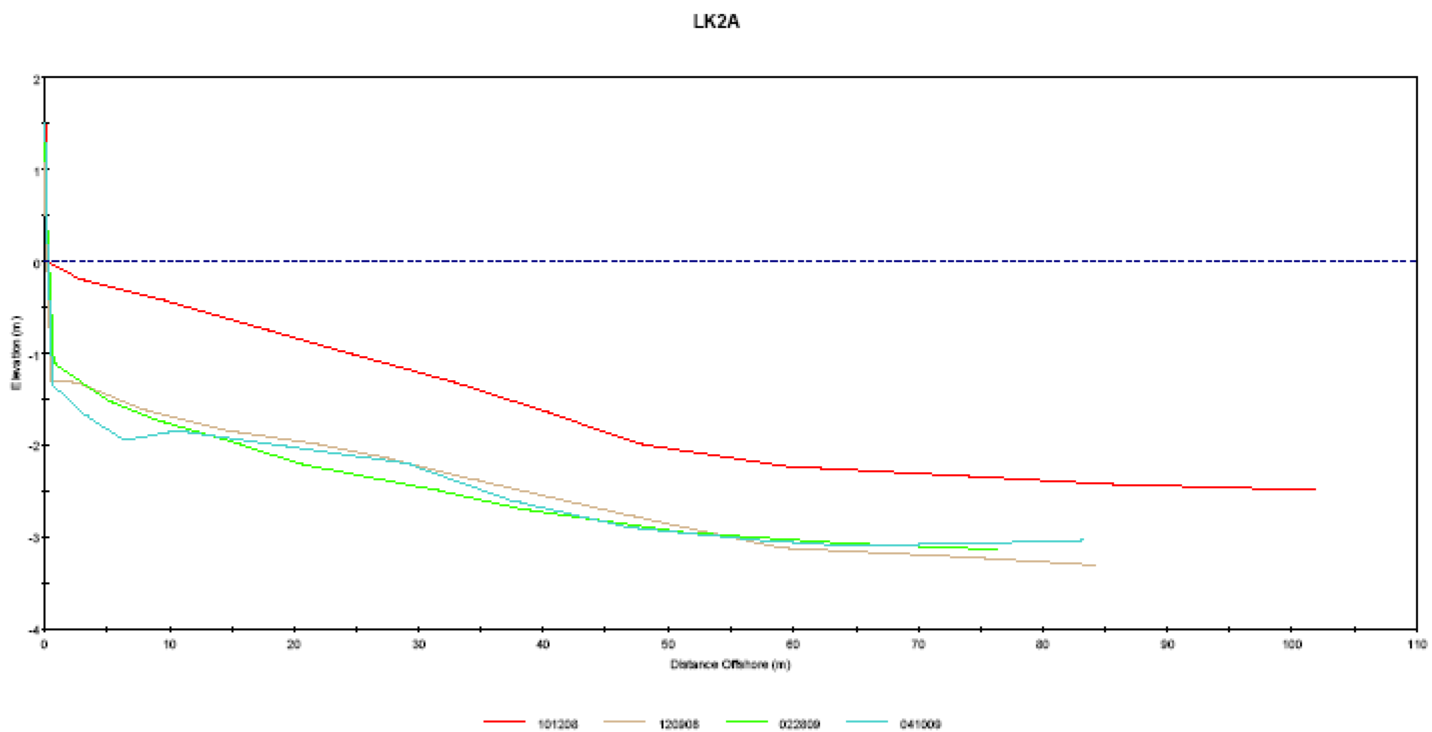

T-Groins T2 Middle
Elevation (m)
Distance Offshore (m)
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
101208
120908
022809
041009


T-Groins T2 South Quarter
2
1
0
-1
-2
-3
Elevation (m)
0
10
20
30
40
50
60
70
Distance Offshore (m)
101208
120908
022809
041009

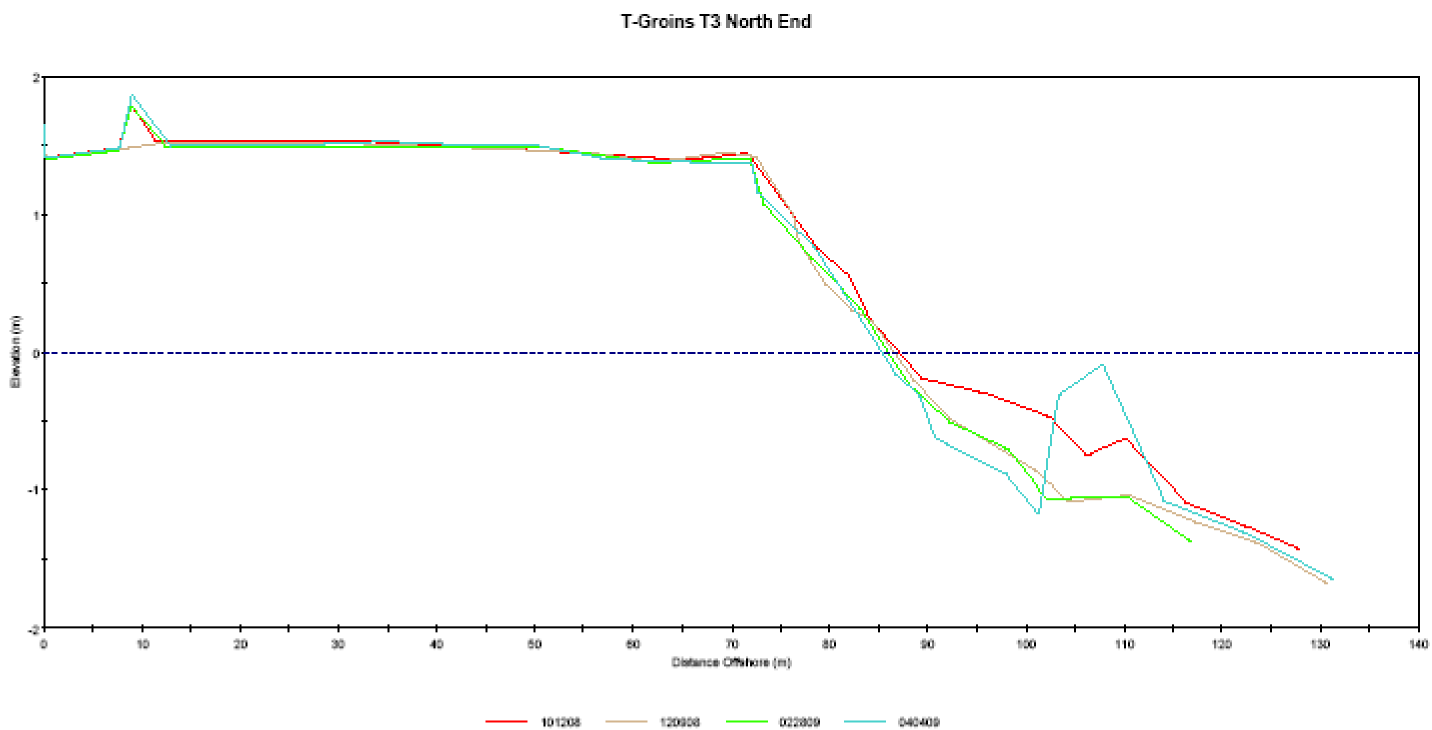

T-Groins T2 North Tip
Elevation (m)
Distance Offshore (m)
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
101208
120908
022809
041009


T-Groins T2 Center
Elevation (m)
Distance Offshore (m)
101208
120908
022809
041009

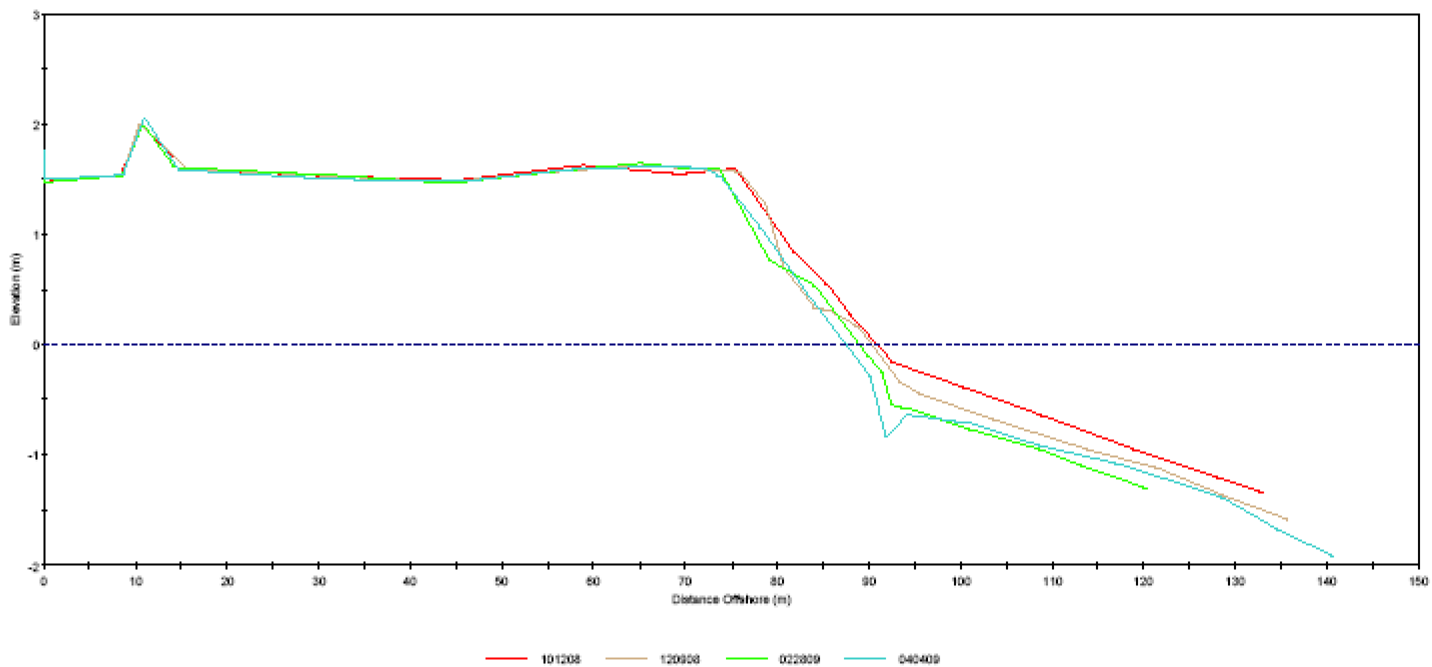

LK2
Elevation (m)
Distance Offshore (m)
101208
120908
022809
041009

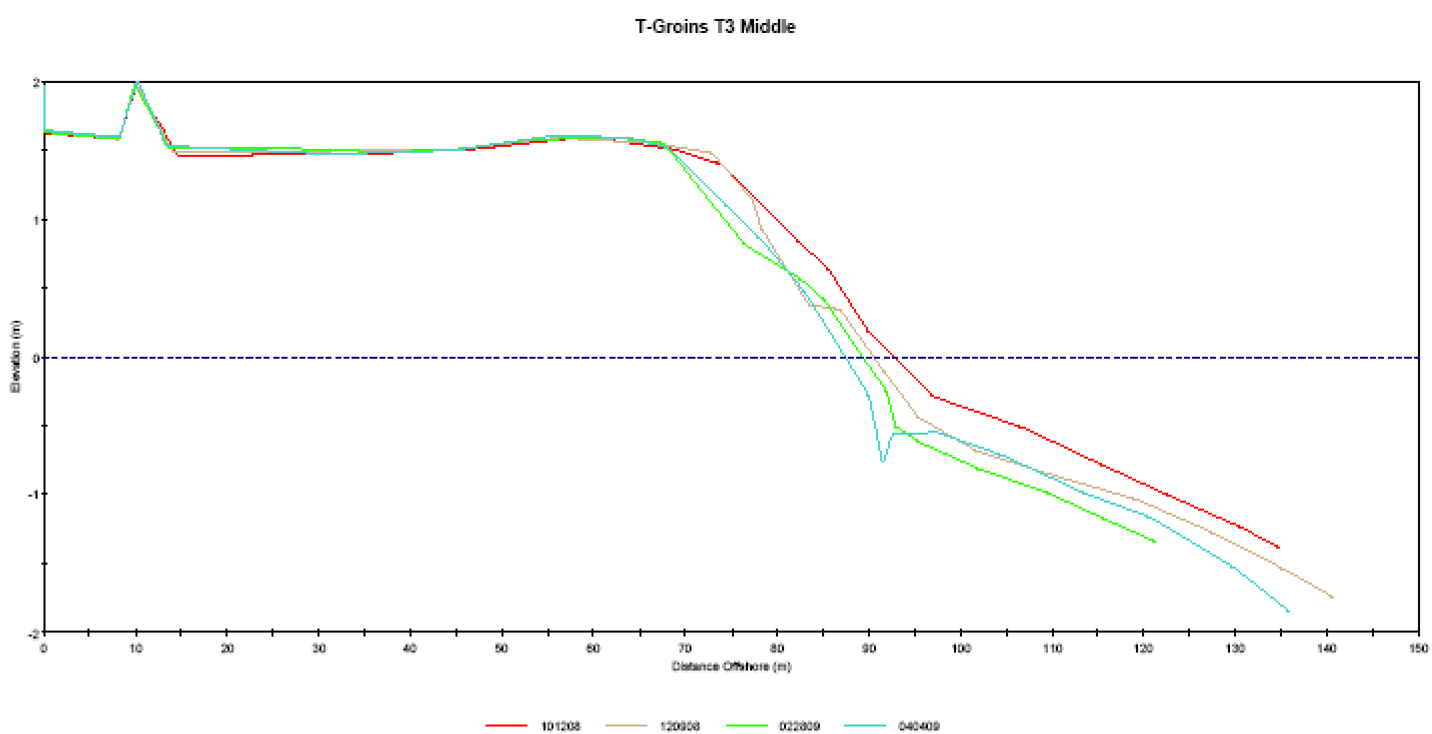

LK2A
Elevation (m)
Distance Offshore (m)
101208
120908
022809
041009

T-Groin 3 and the Compartment to the North


T-Groins T3 North End
Elevation (m)
2
1
0
-1
-2
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
Distance Offshore (m)
101208
120908
022809
040409

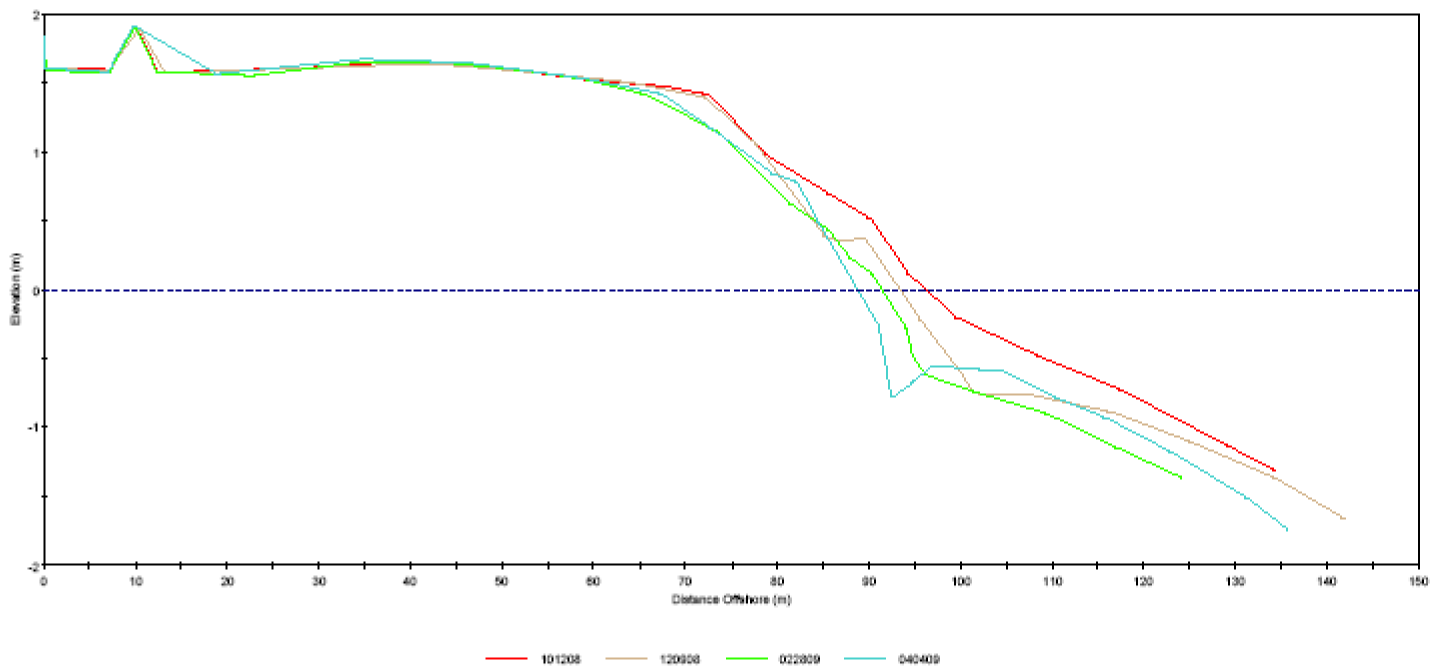
T-Groins T3 North Quarter



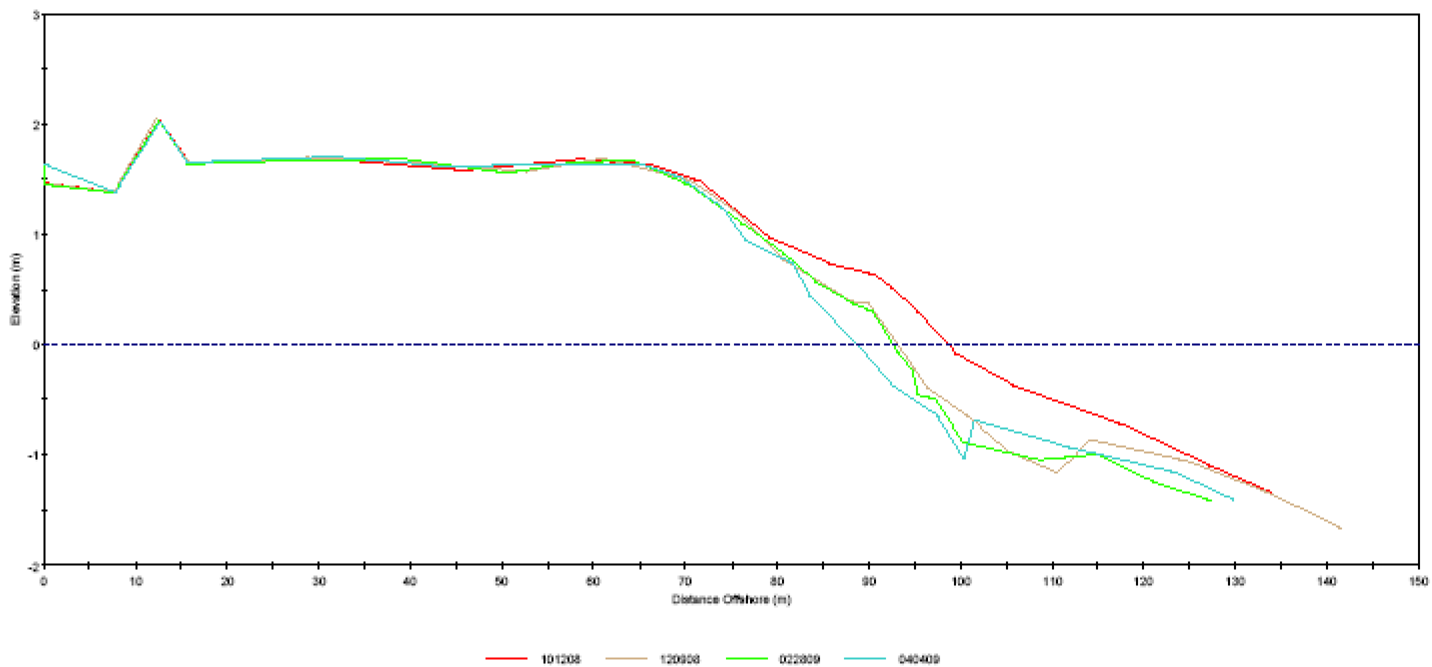


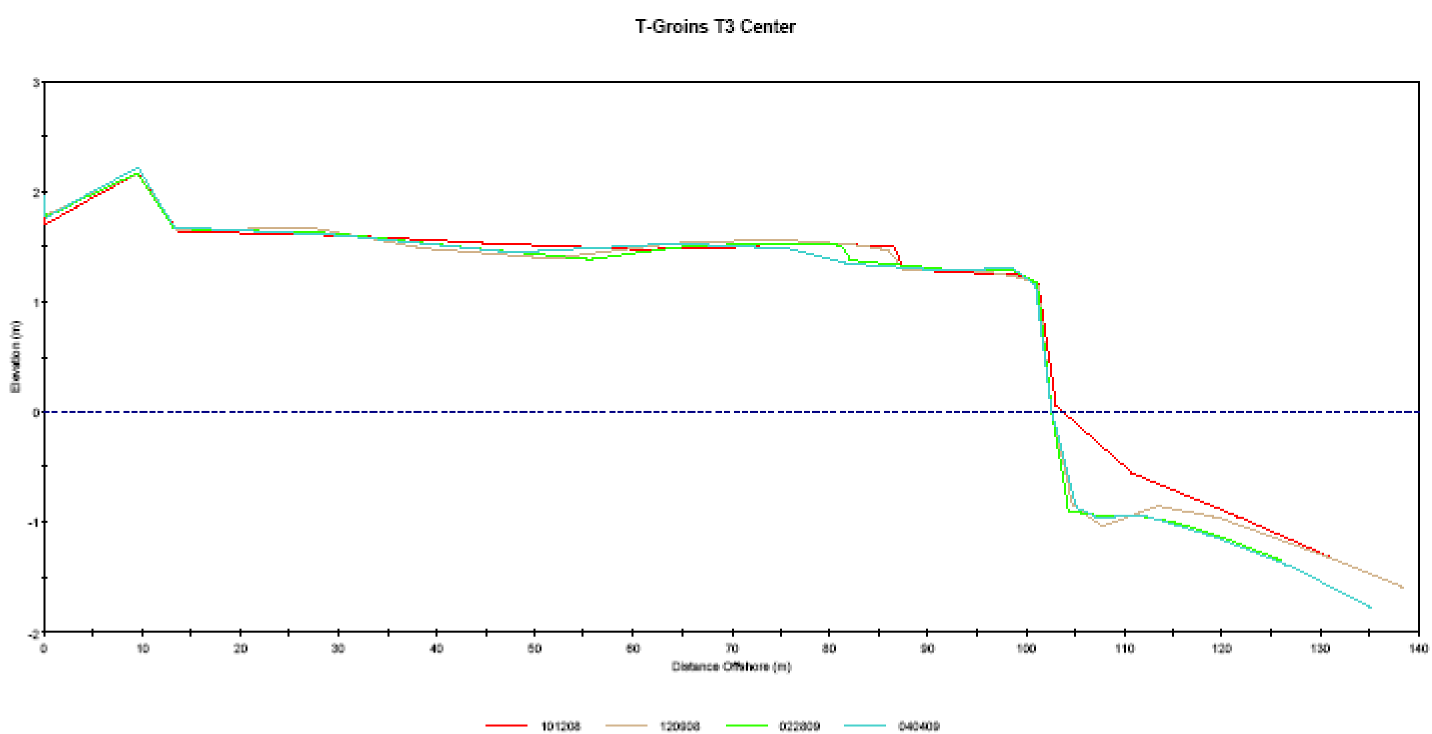
T-Groins T3 Middle
Elevation (m)
Distance Offshore (m)
101208
120908
022809
040409

T-Groins T3 South Quarter

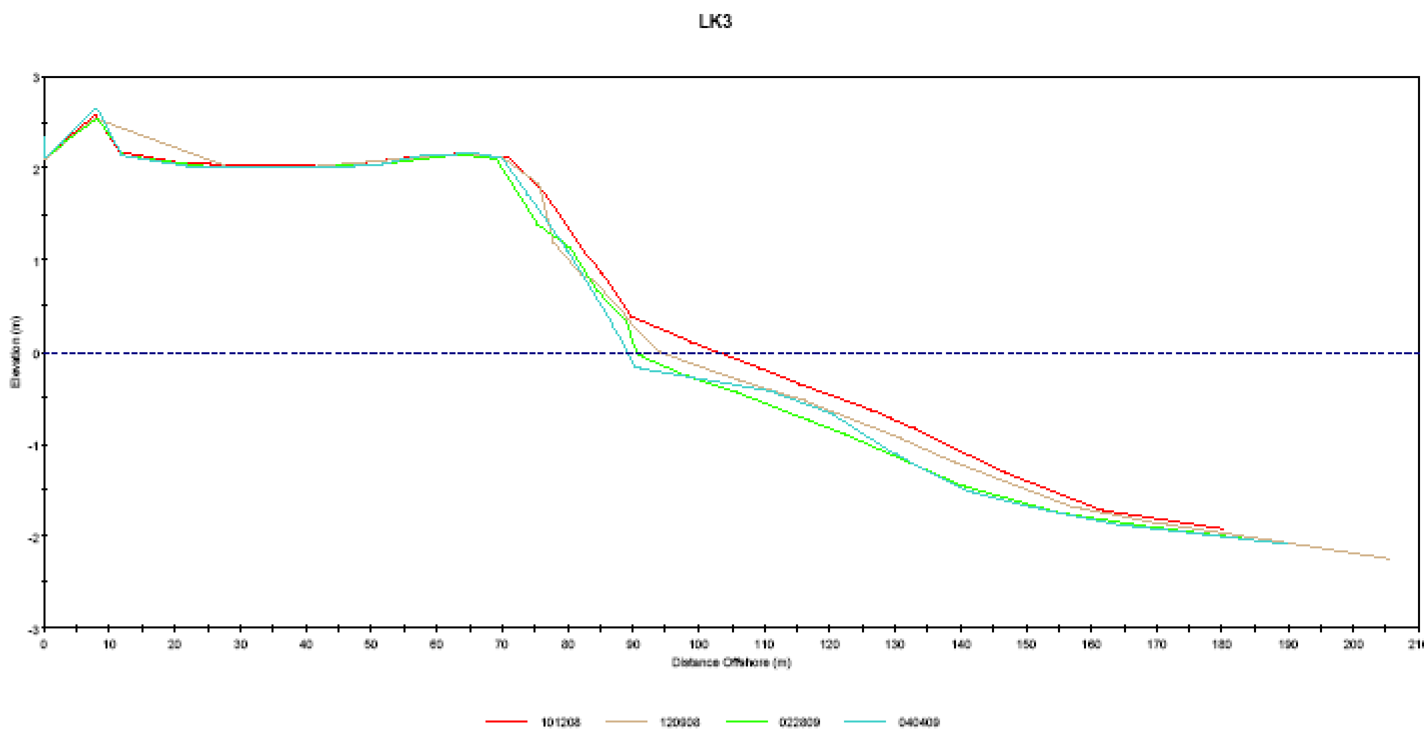


T-Groins T3 North Tip

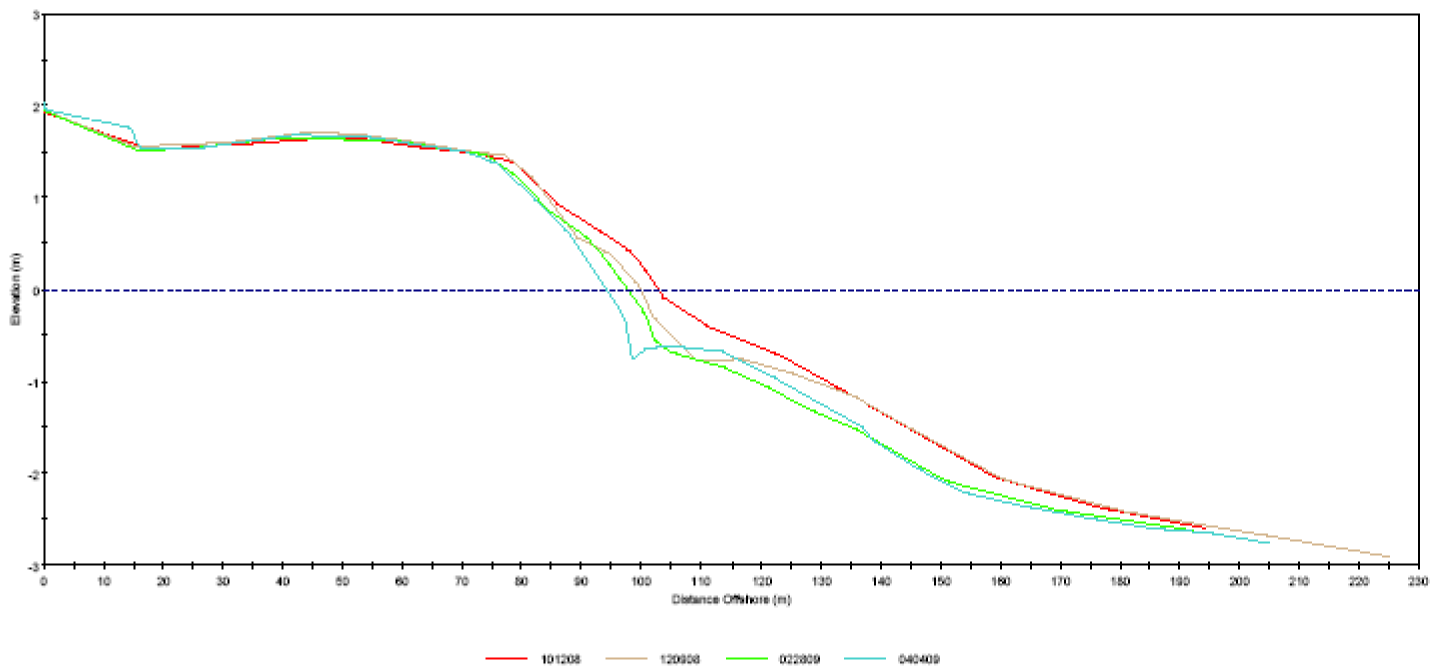




T-Groins T3 Center
Elevation (m)
Distance Offshore (m)
101208
120808
022809
040409


LK3
Elevation (m)
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
Distance Offshore (m)
101208
120908
022809
040409

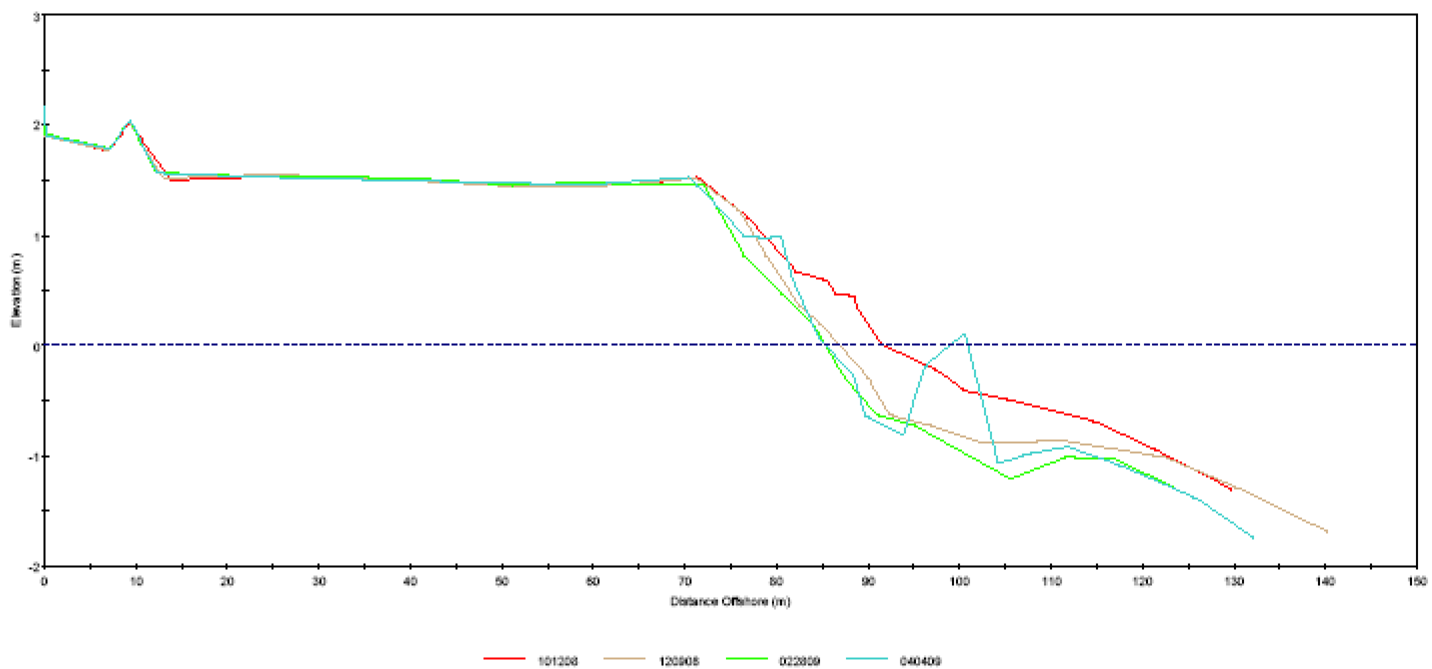
LK3A



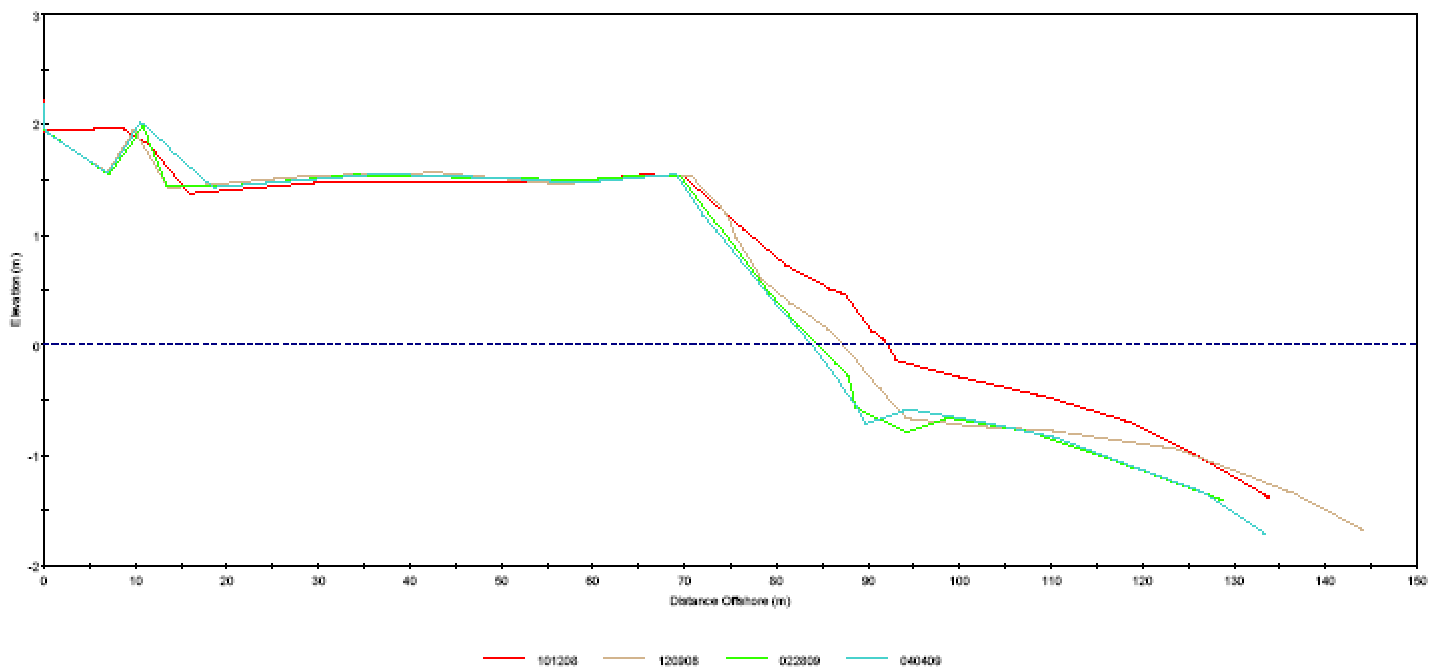
Elevation (m)
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
Distance Offshore (m)
101208
120908
022809
040409

T-Groin 4 and the Compartment to the North

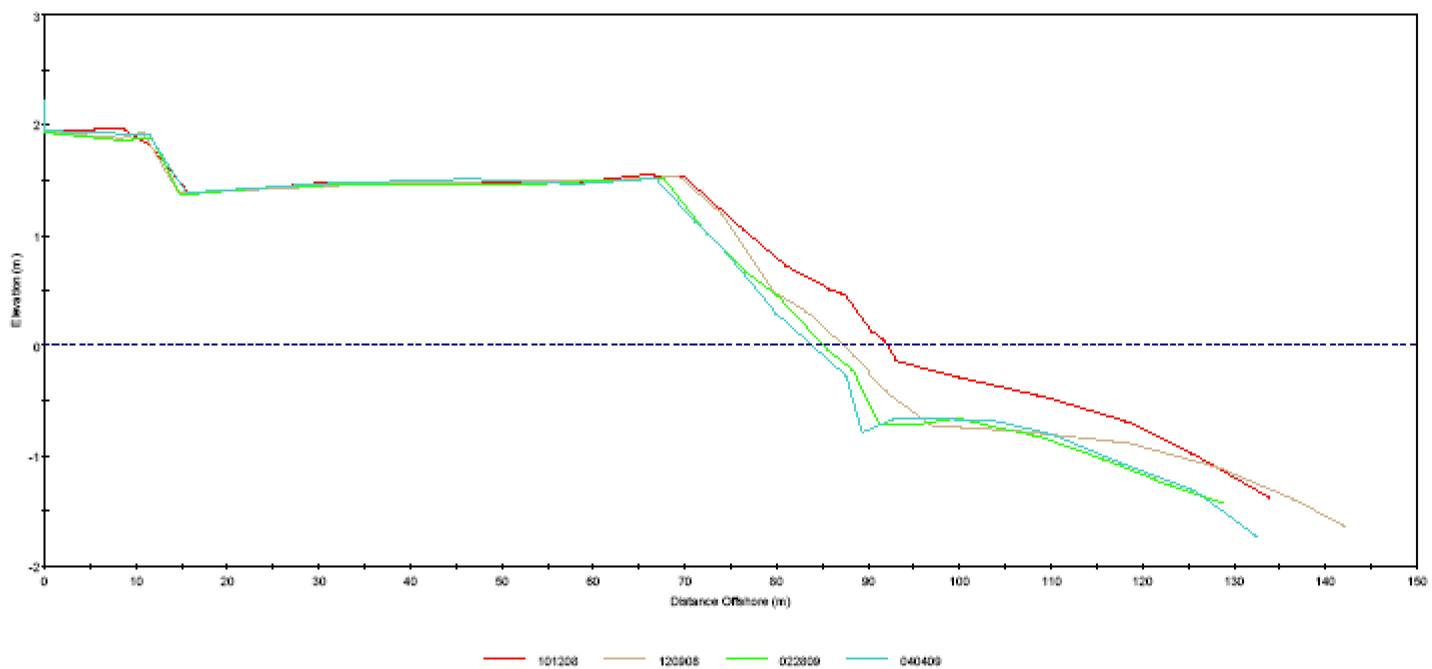
T-Groins T4 North End



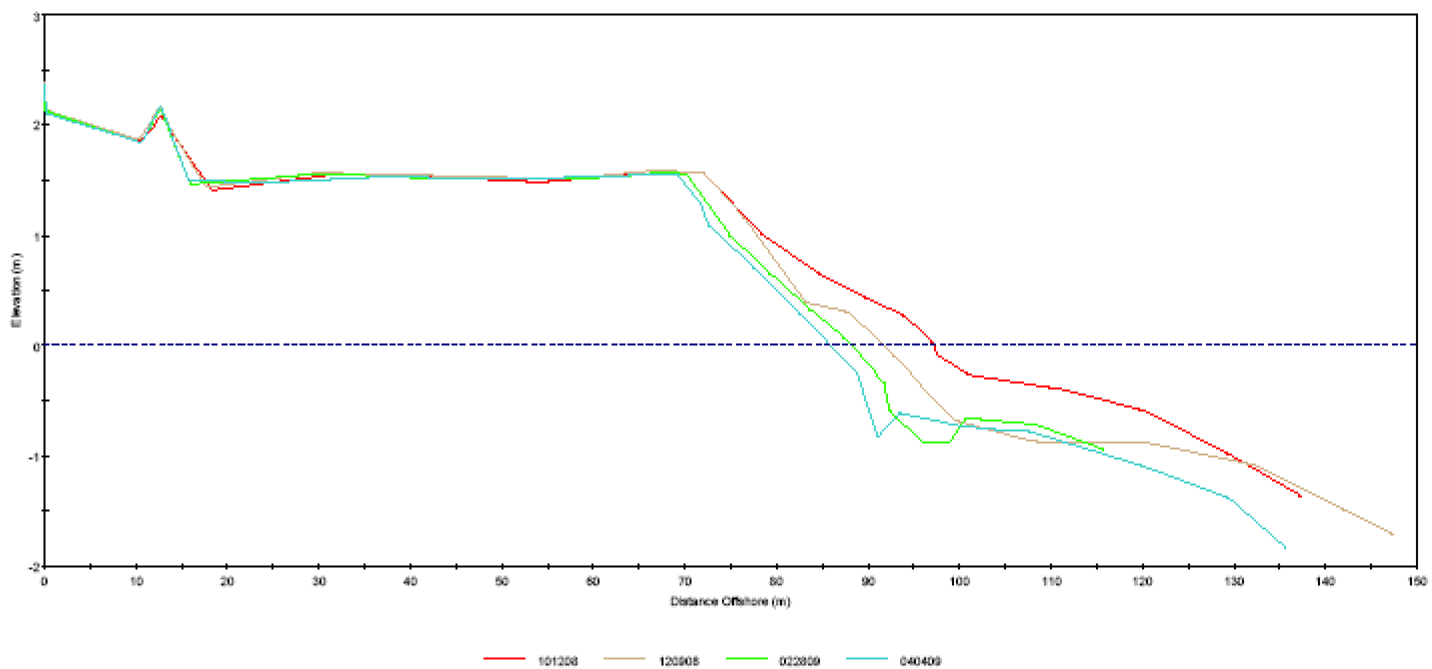
T-Groins T4 North Quarter



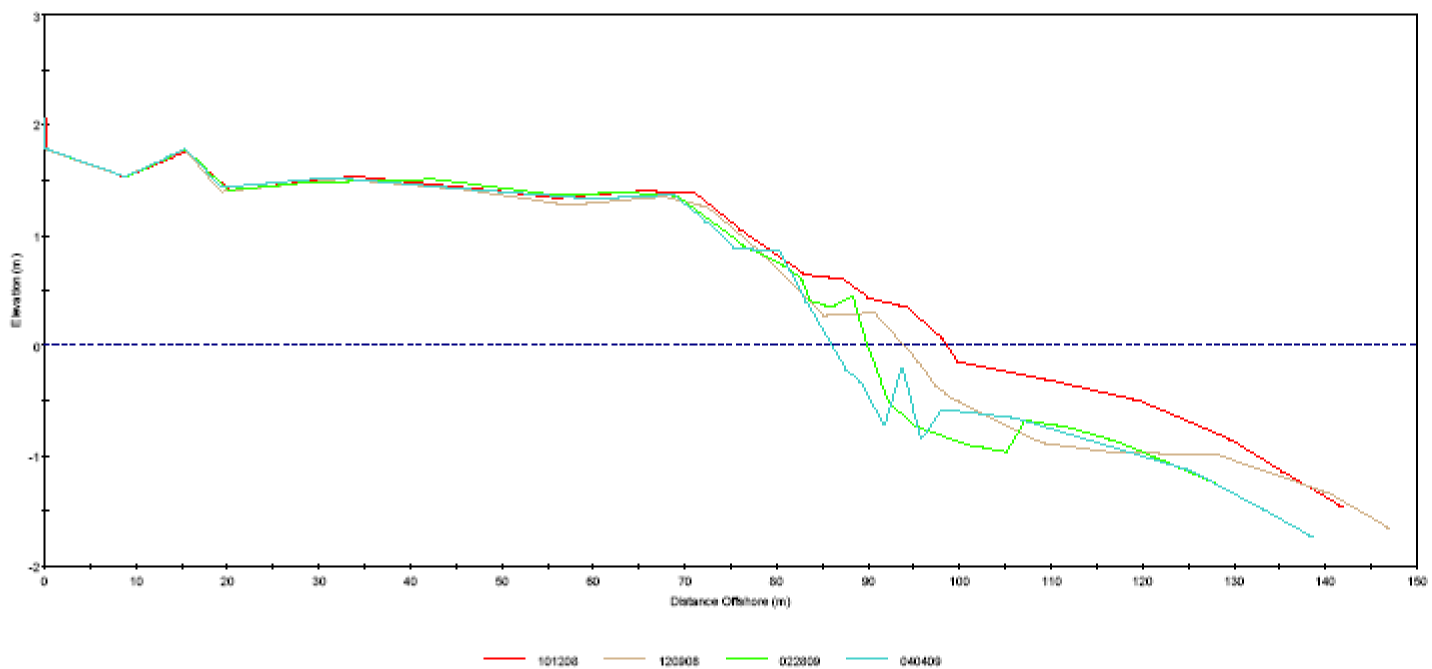
T-Groins T4 Middle



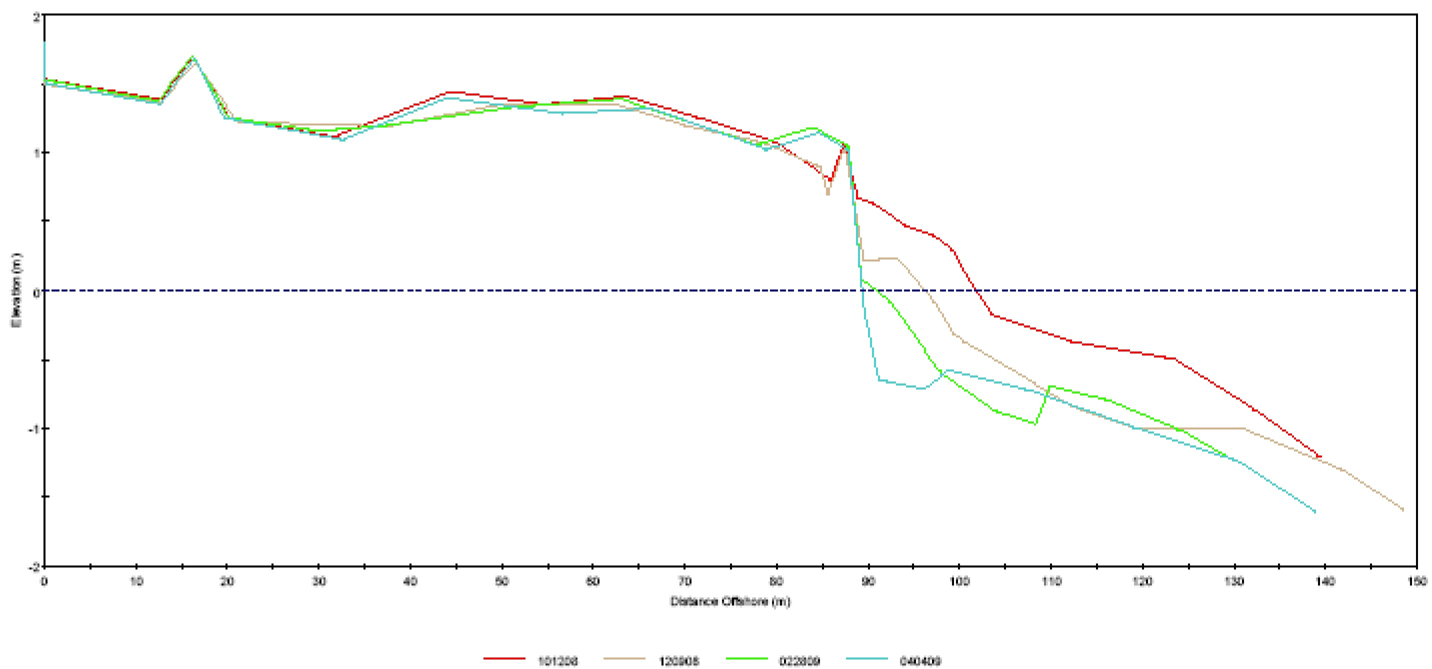
T-Groins T4 South Quarter

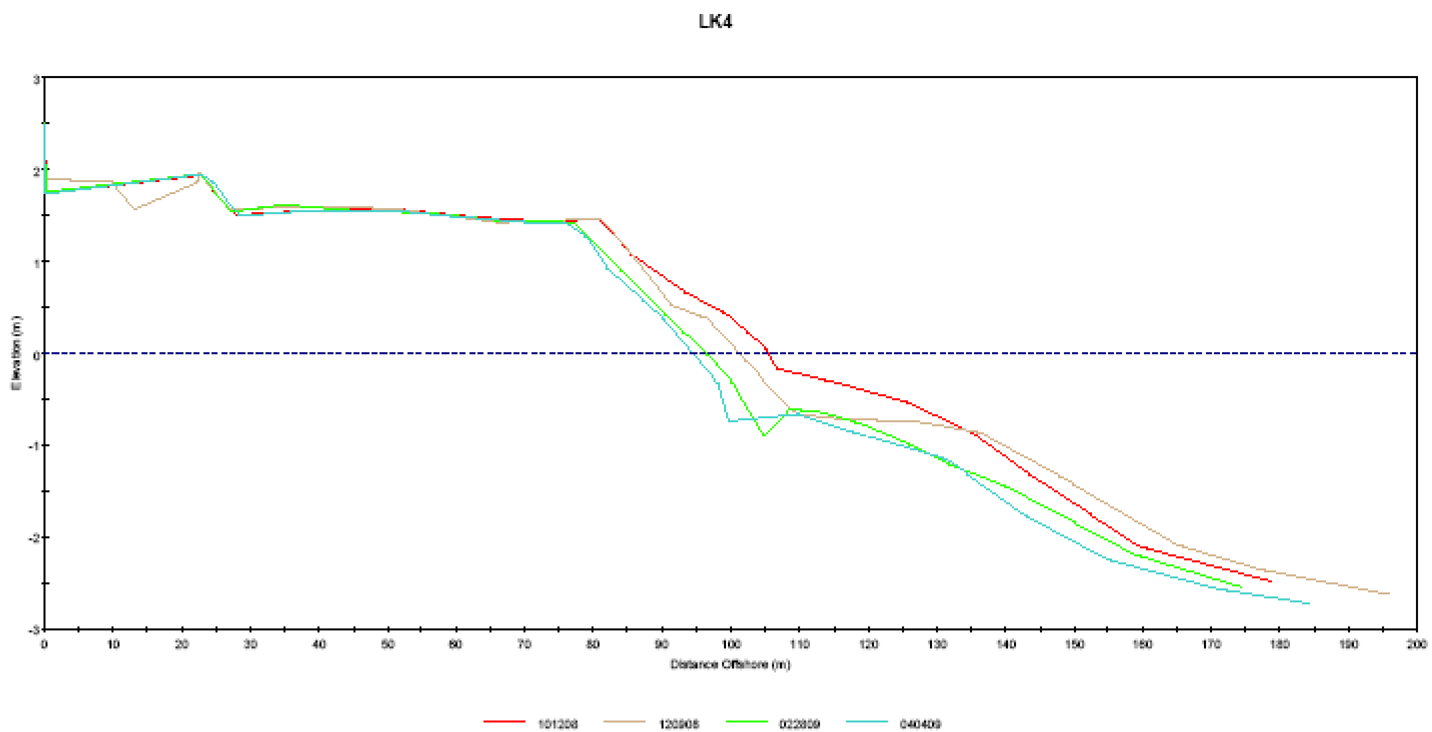


T-Groins T4 North Tip

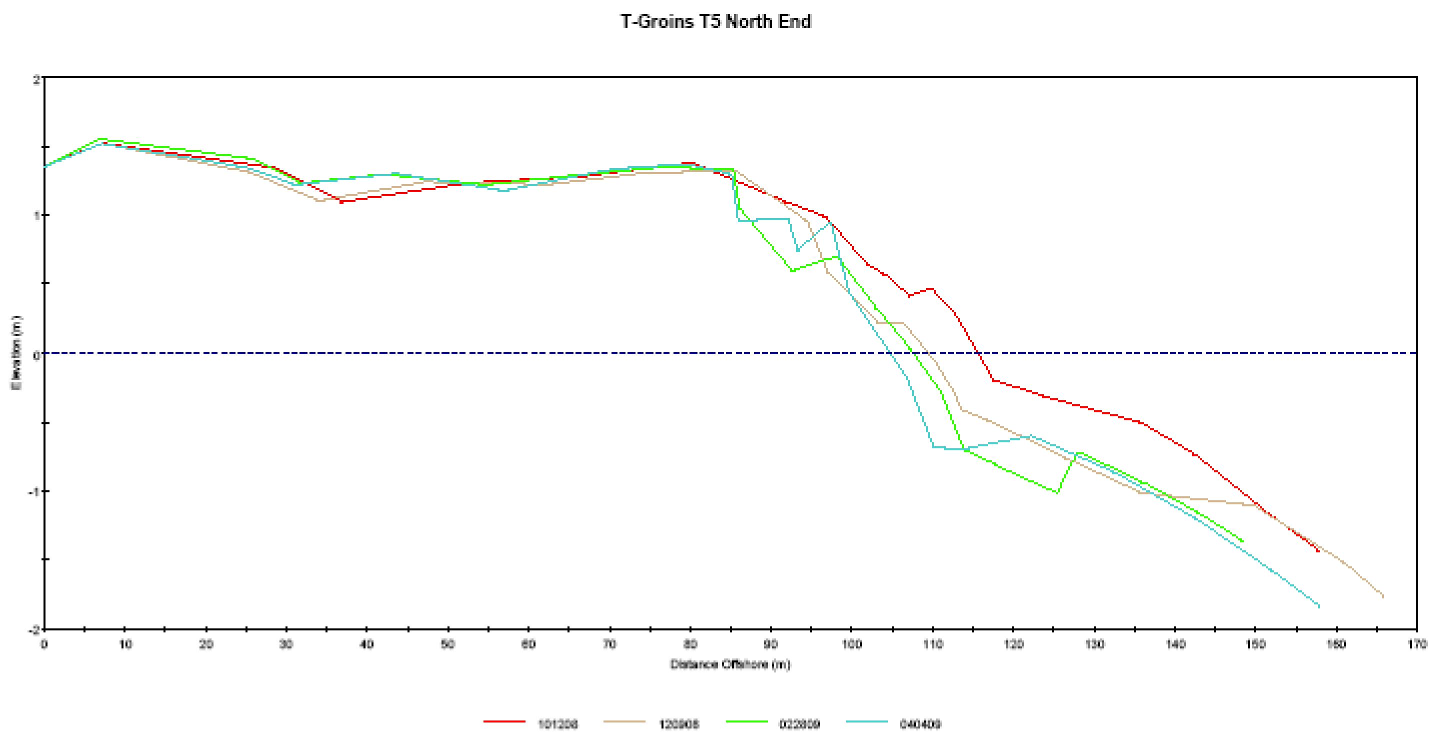


T-Groins T4 Center



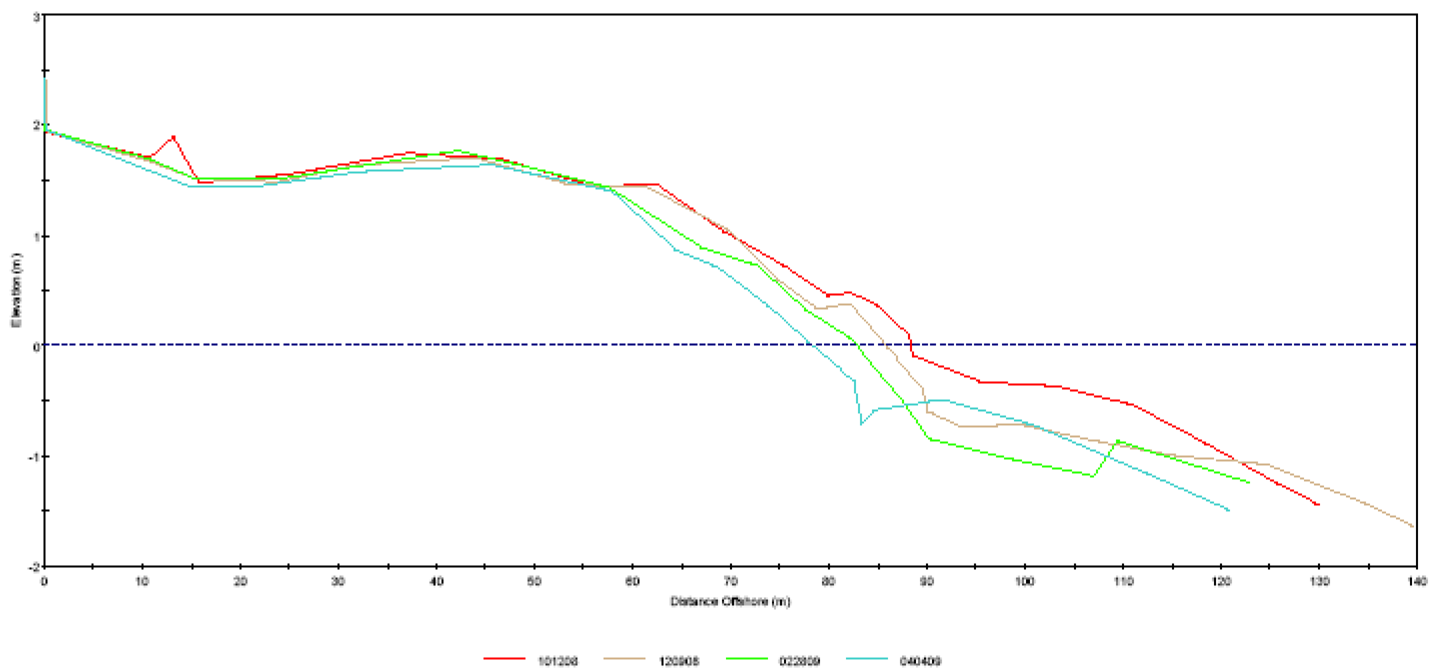

LK4
Elevation (m)
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance Offshore (m)
101208
120908
022809
040409

T-Groin 5 and the Compartment to the North

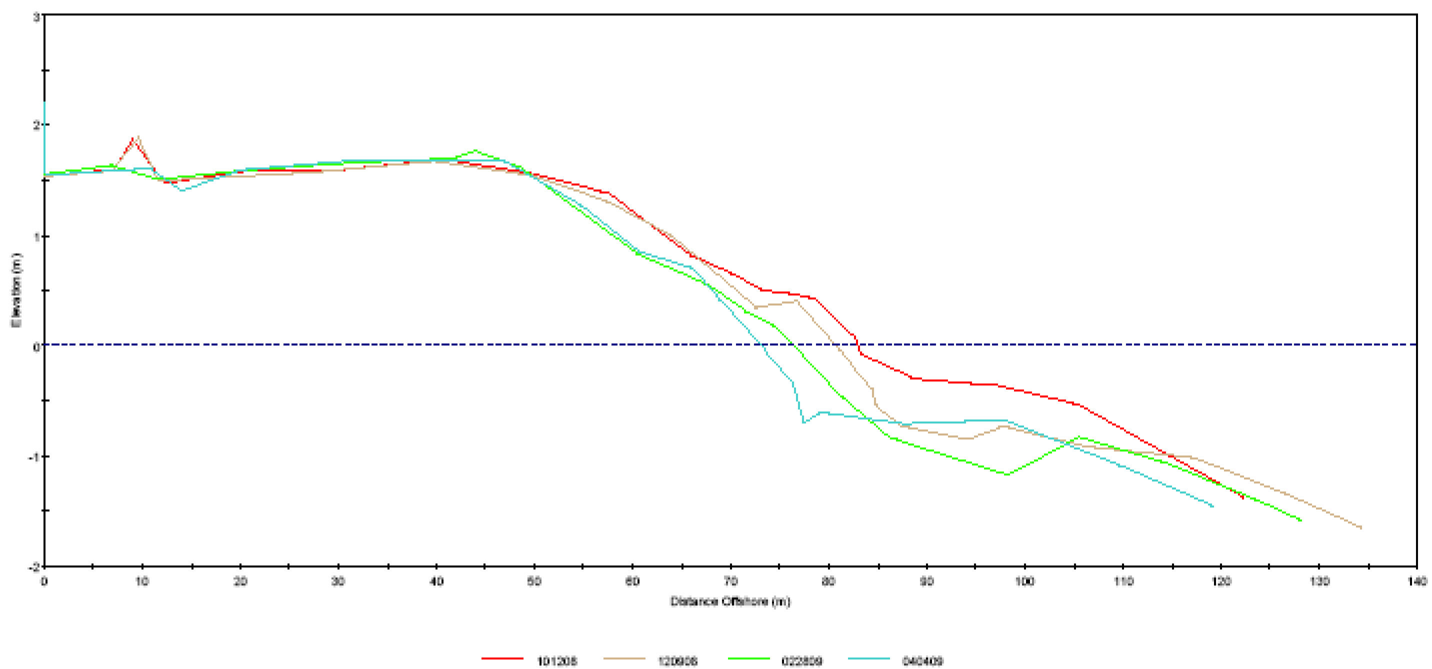


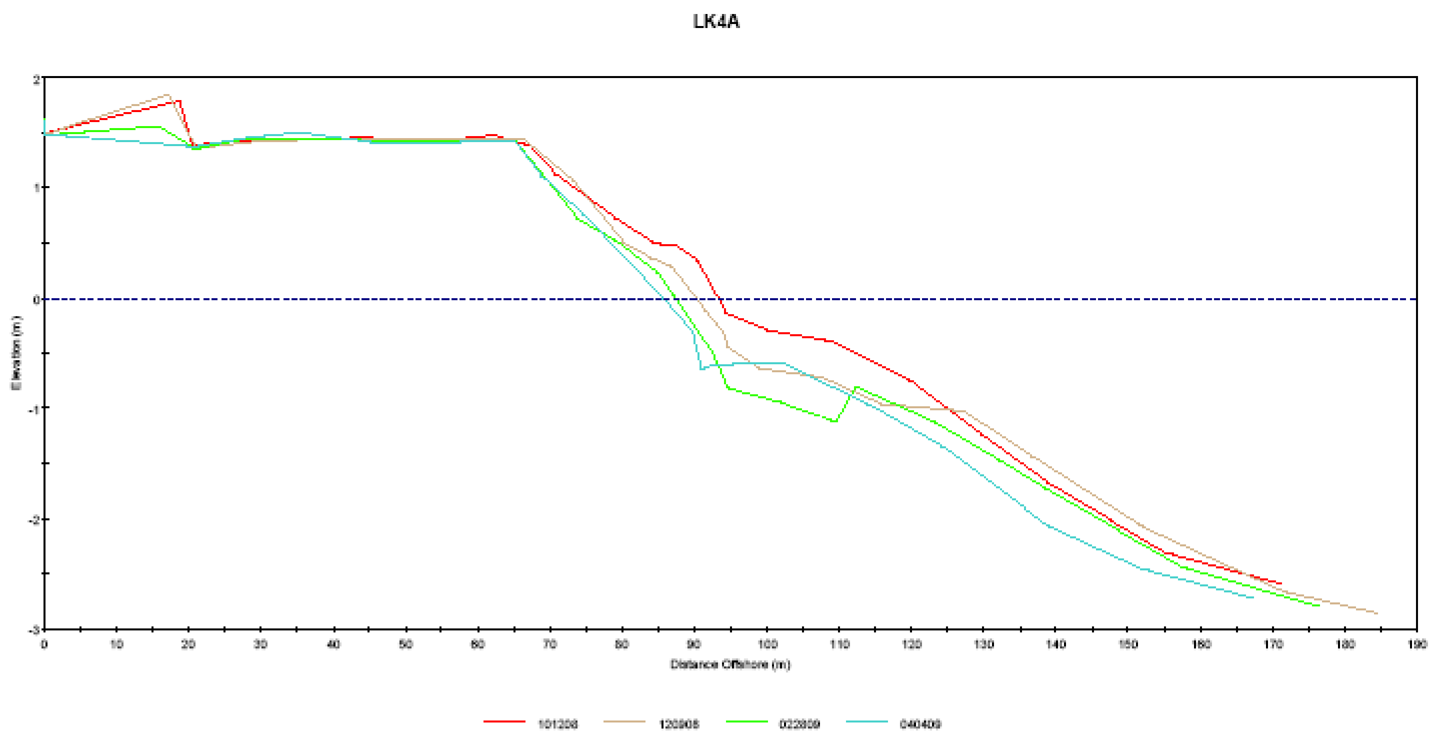
T-Groins T5 North End
Elevation (m)
Distance Offshore (m)
101208
120908
022809
040409

T-Groins T5 Middle

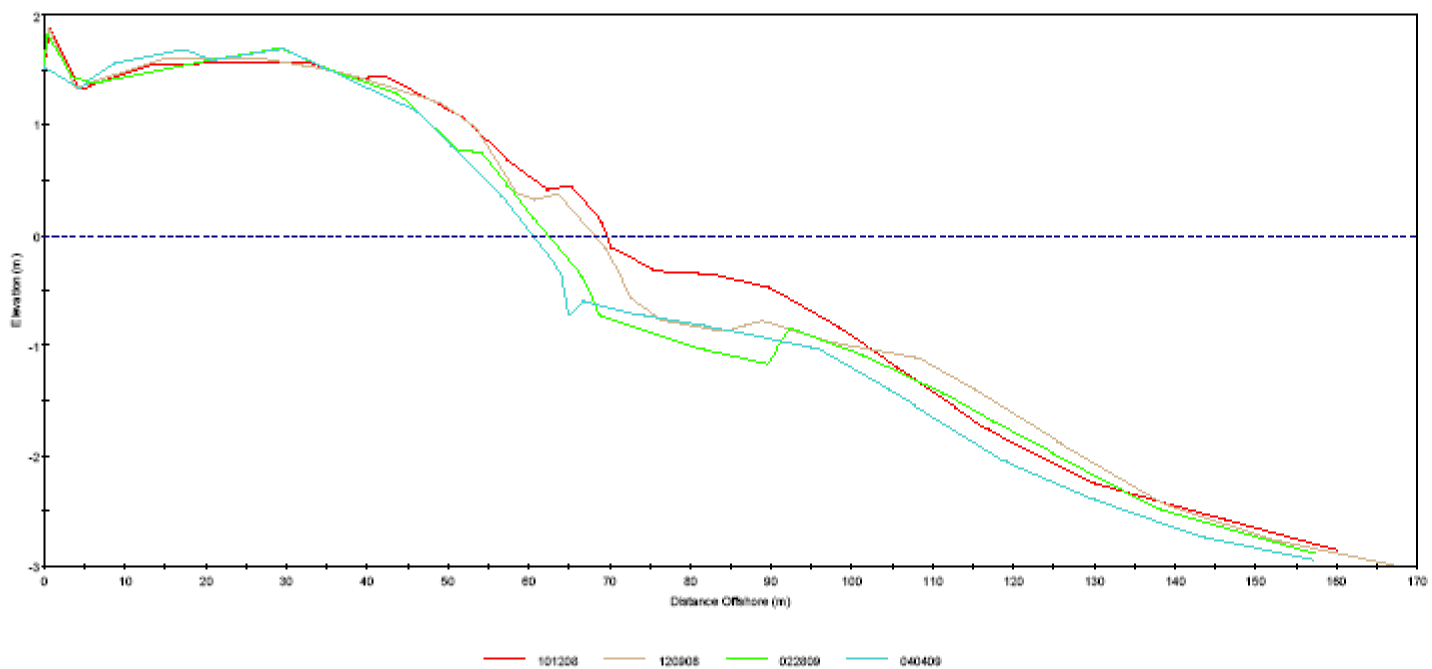


T-Groins T5 South Quarter



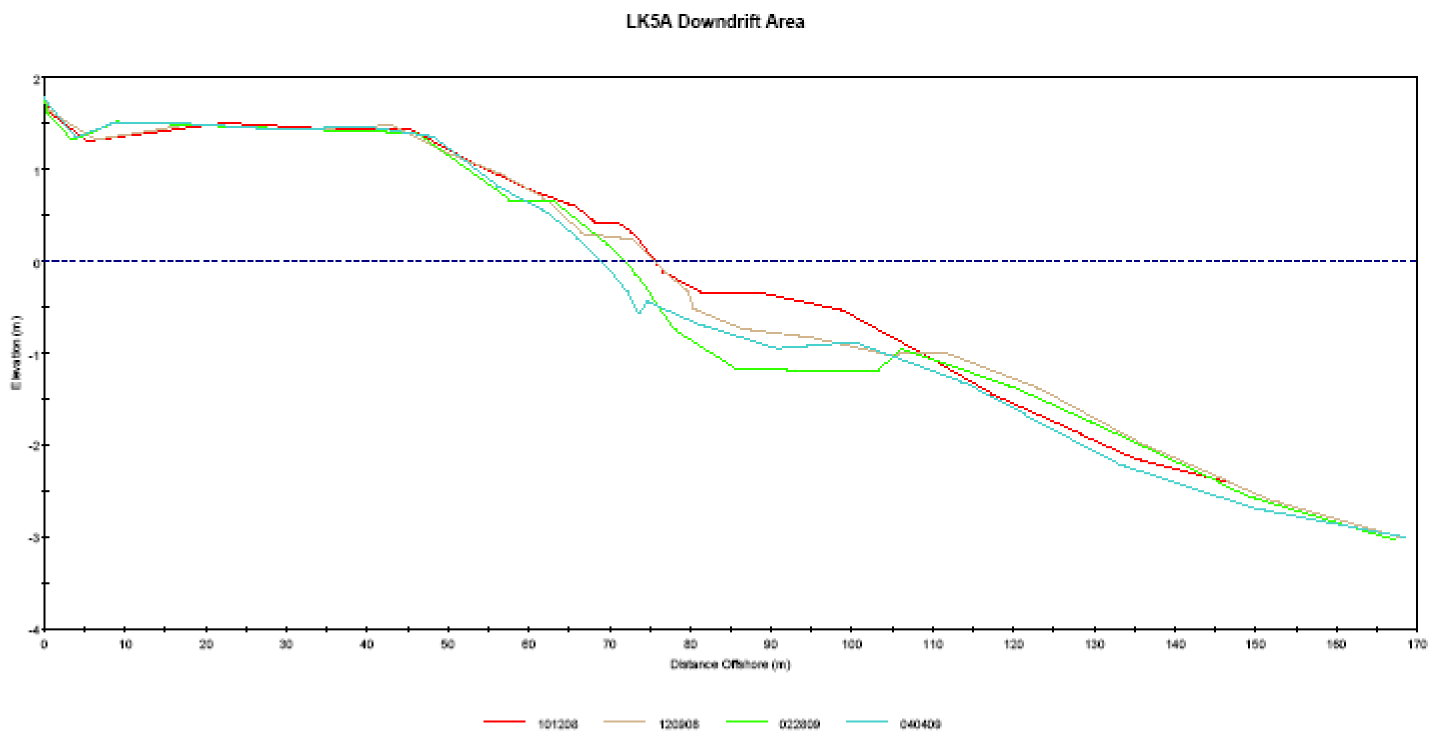

LK4A
Elevation (m)
Distance Offshore (m)
101208
120908
022809
040409

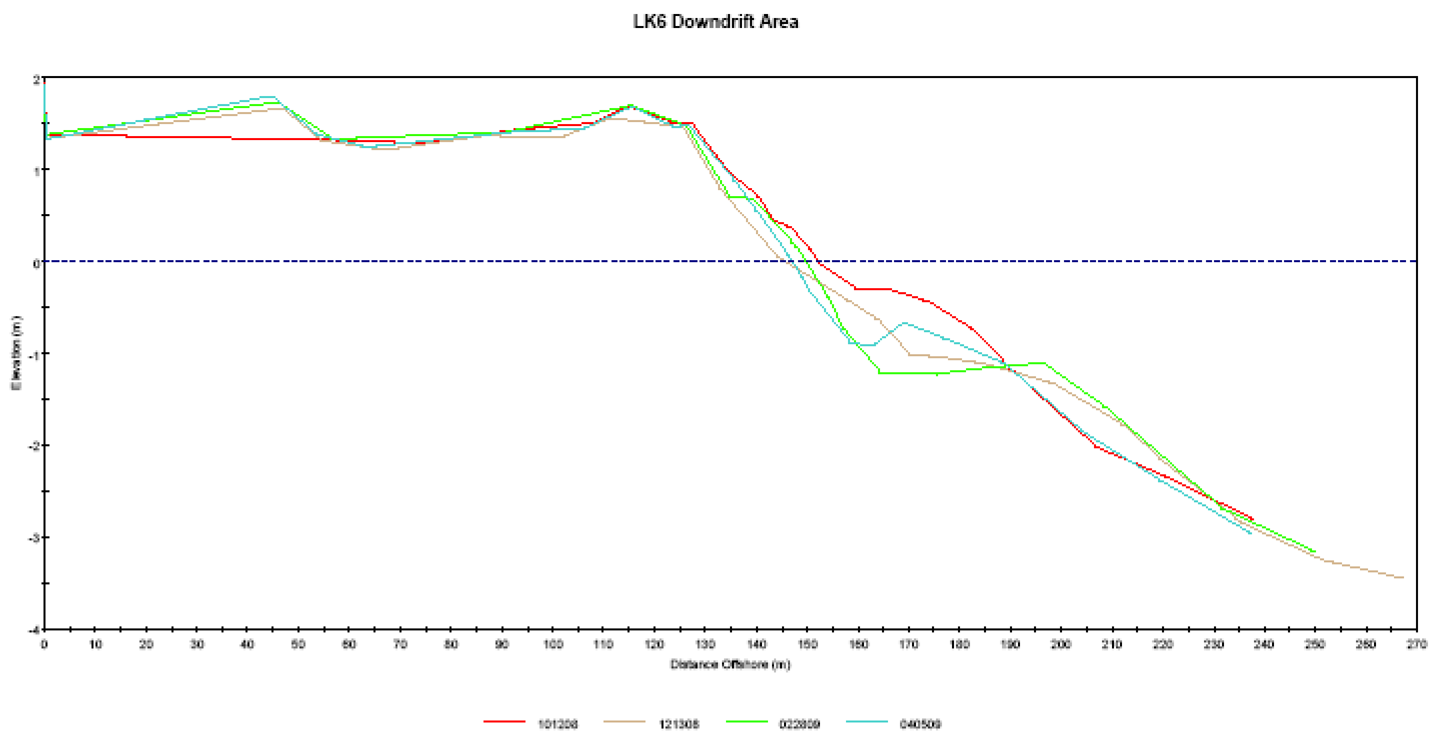
LK5



2
1
0
-1
-2
-3
Elevation (m)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
Distance Offshore (m)
101208
120908
022809
040409

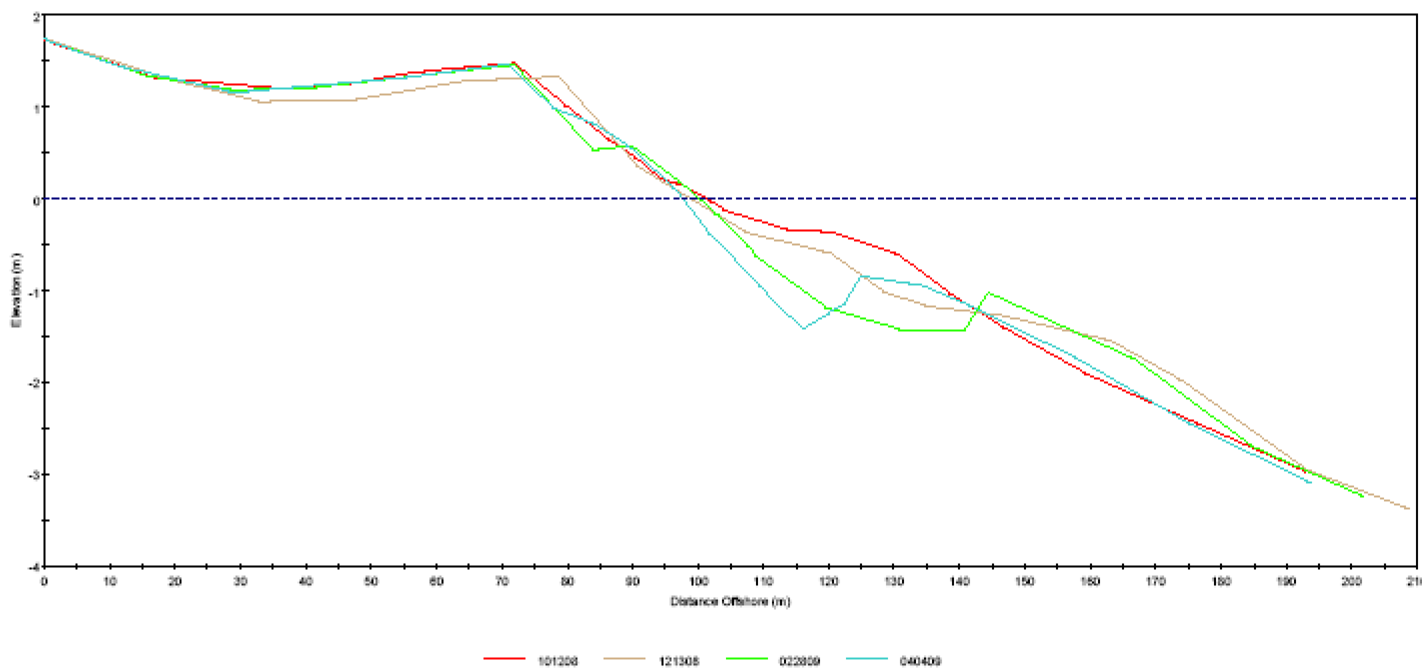
Downdrift Area of T-Groins (South of Groin Field)

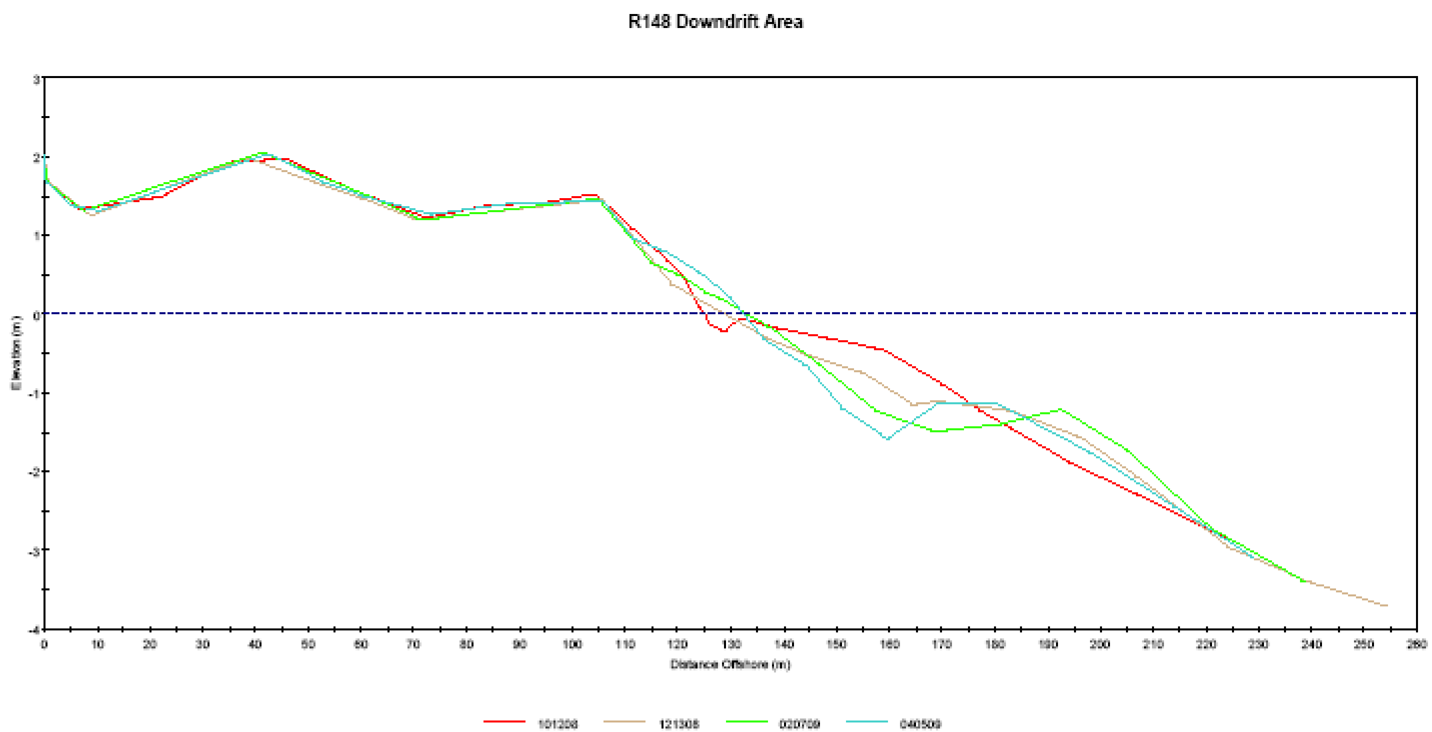

LK5A Downdrift Area
Elevation (m)
2
1
0
-1
-2
-3
-4
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
Distance Offshore (m)
101208
120908
022809
040409



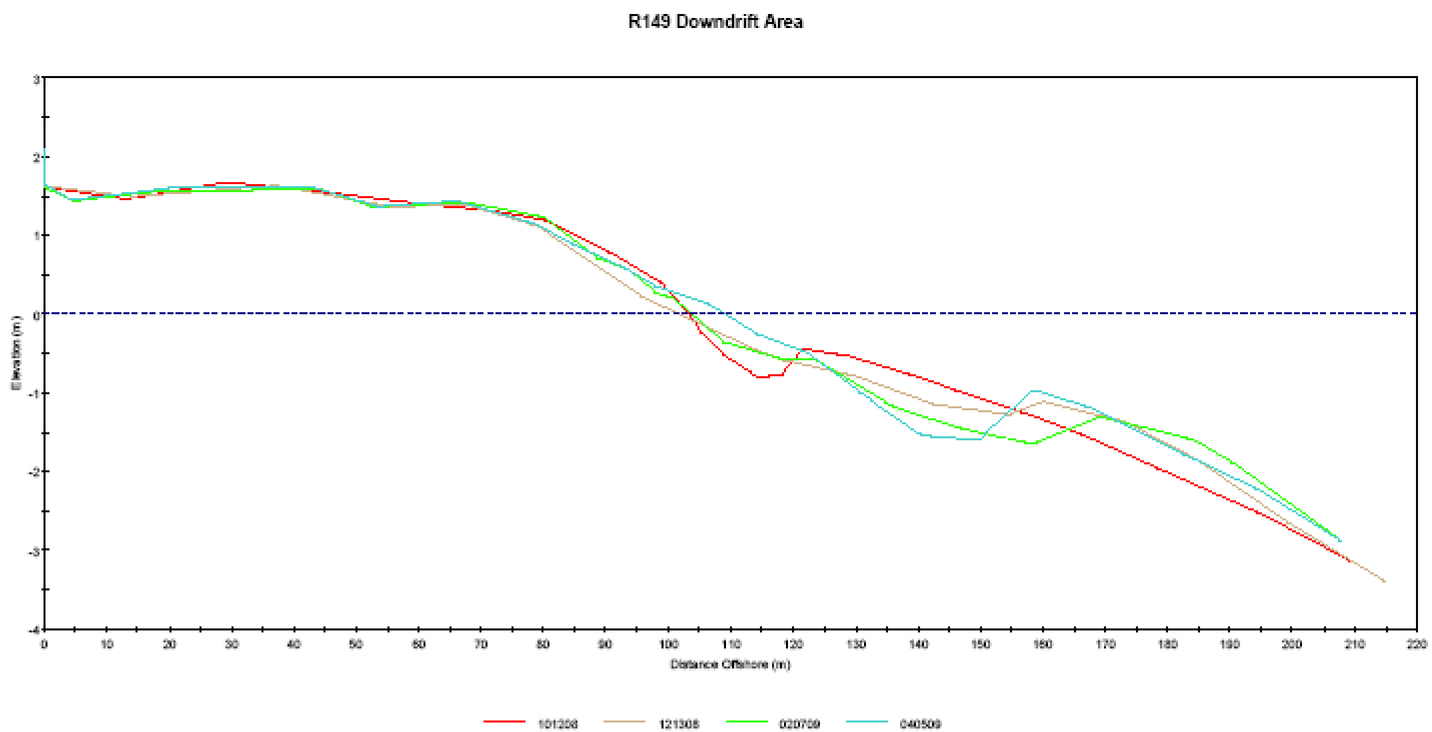
LK6 Downdrift Area
Elevation (m)
Distance Offshore (m)
2
1
0
-1
-2
-3
-4
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
101208
121308
022809
040509

LK7 Downdrift Area

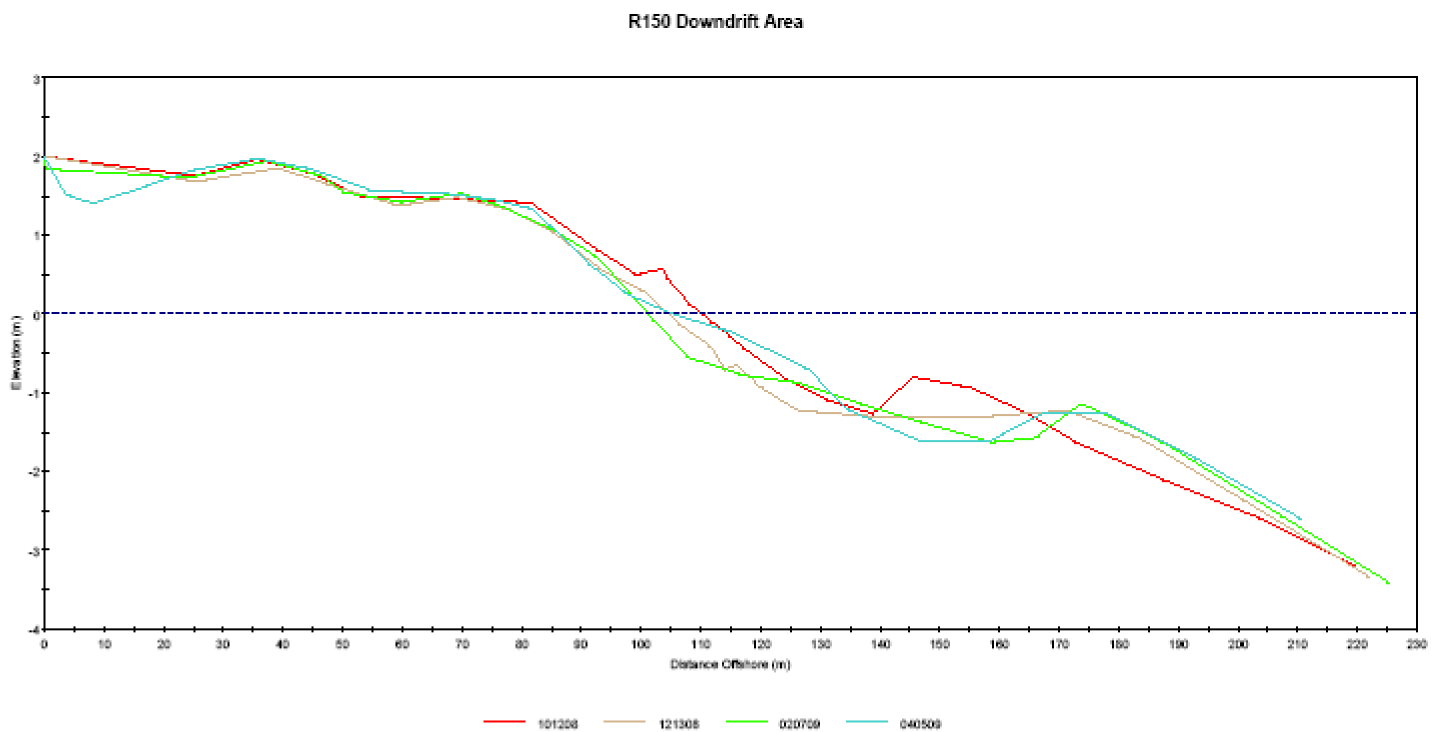


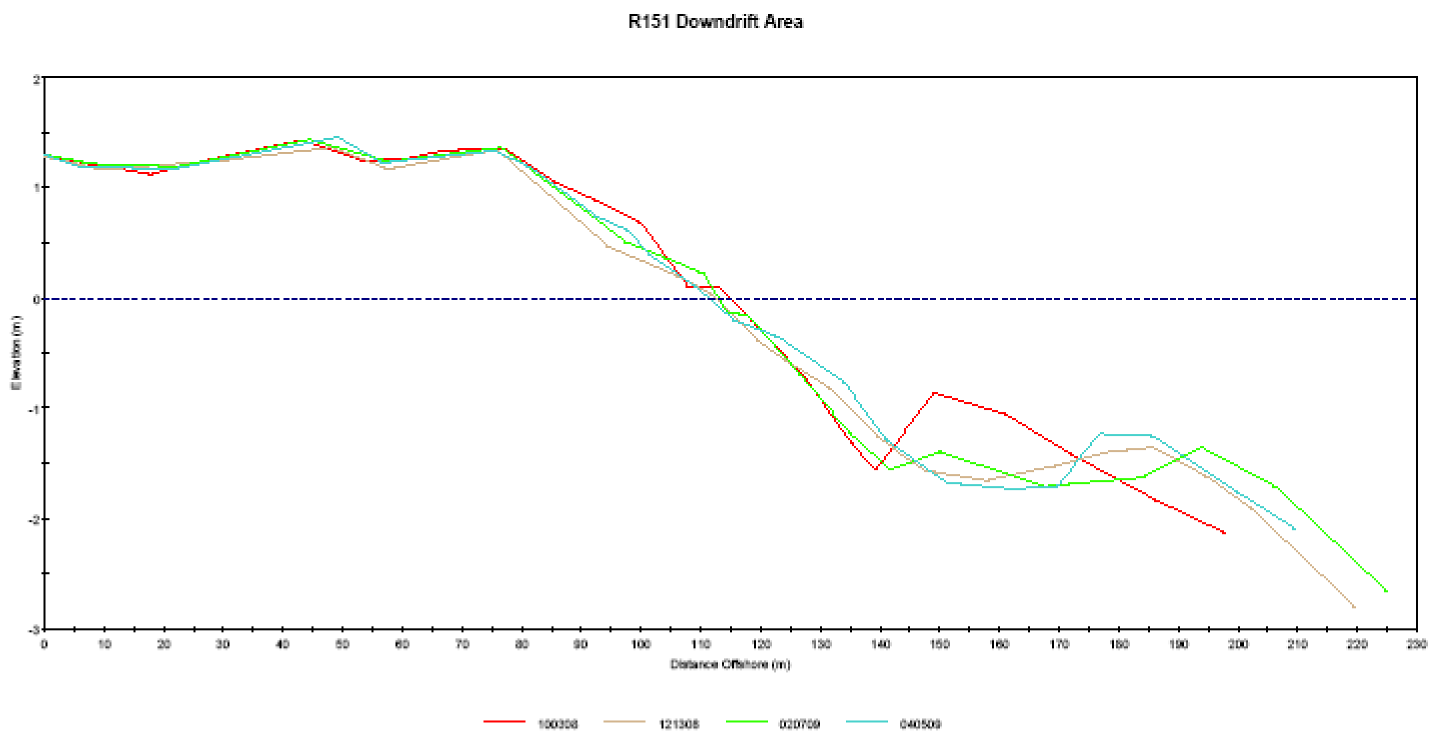


R148 Downdrift Area
Elevation (m)
3
2
1
0
-1
-2
-3
-4
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
Distance Offshore (m)
101208
121308
020709
040509

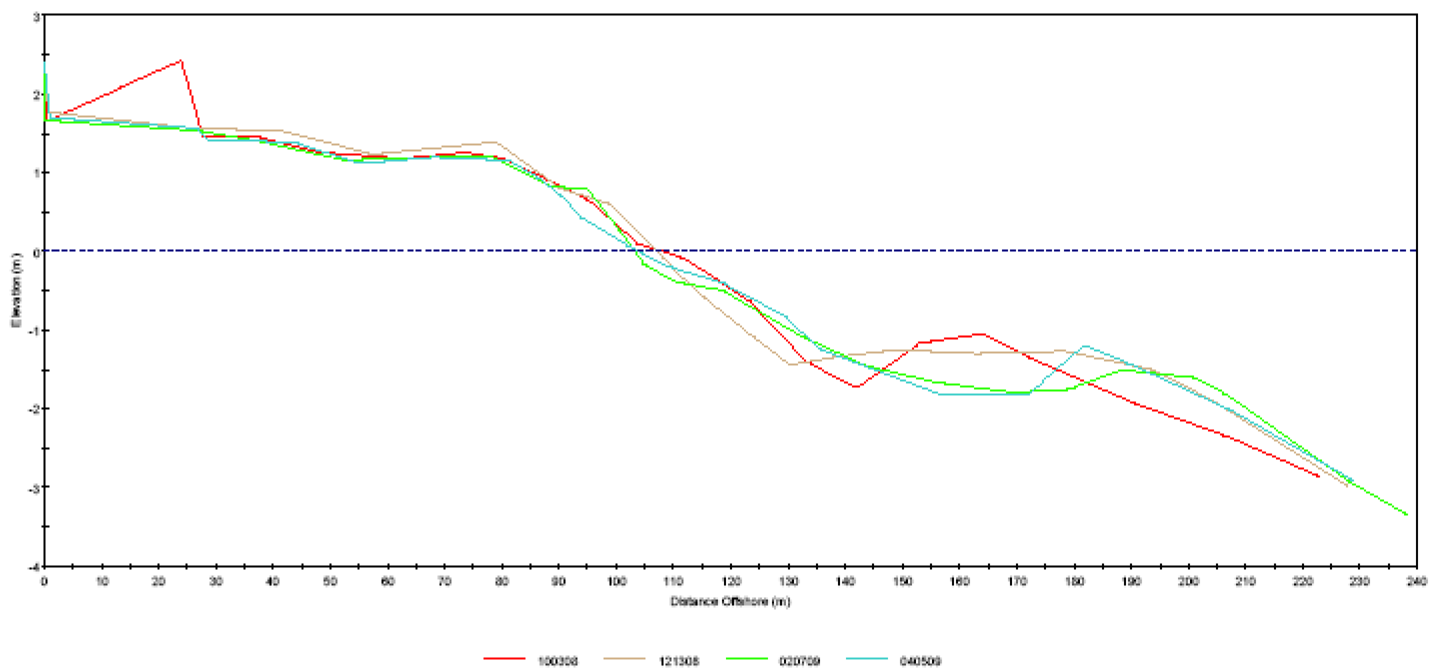


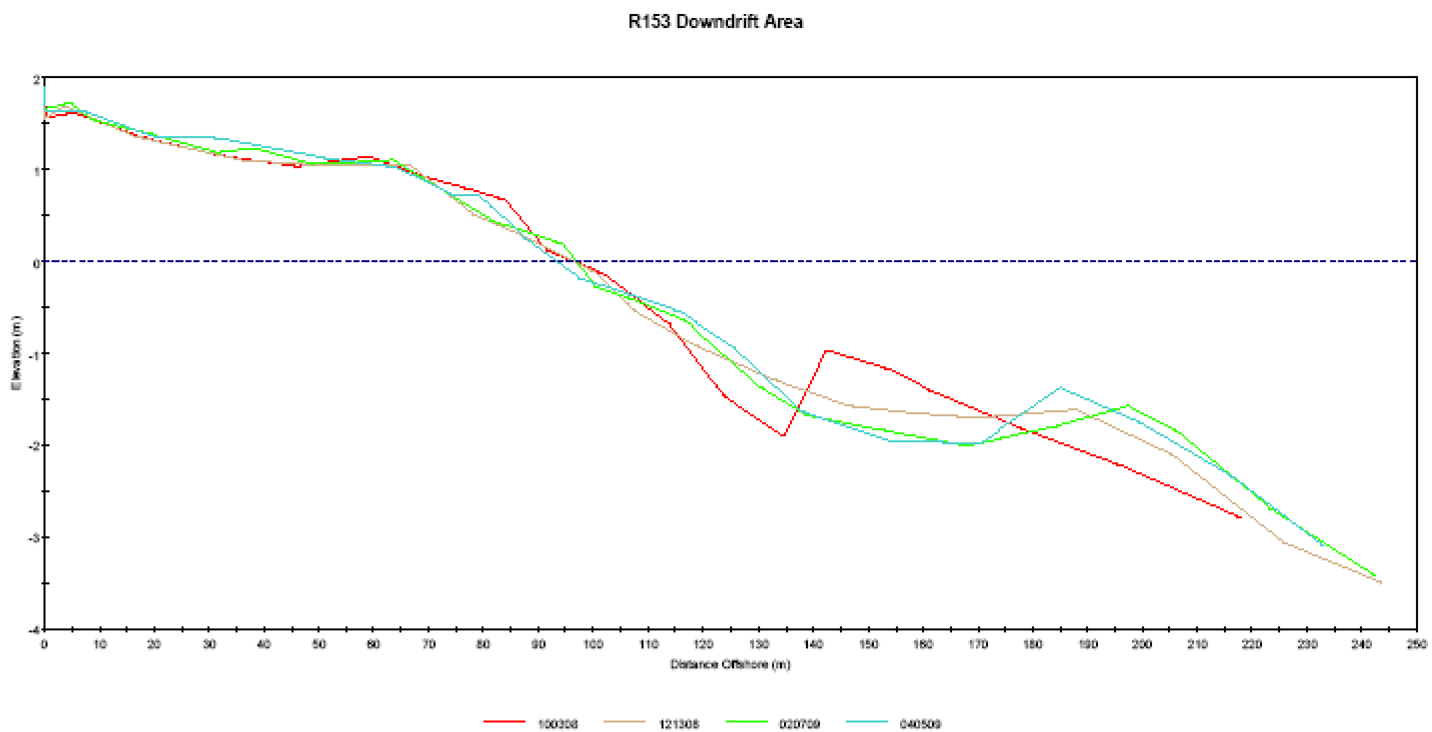
R149 Downdrift Area
Elevation (m)
Distance Offshore (m)
101208
121308
020709
040509


R150 Downdrift Area
Elevation (m)
Distance Offshore (m)
101208
121308
020709
040509

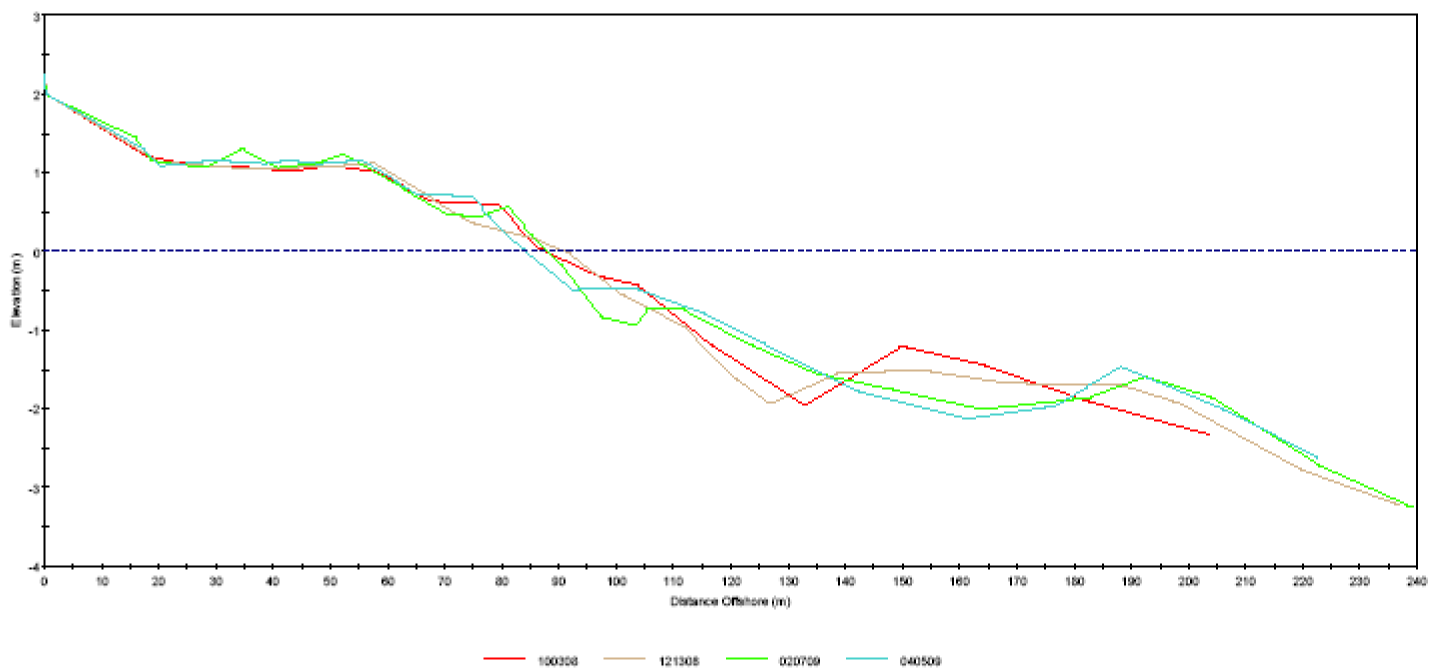

R151 Downdrift Area
Elevation (m)
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
Distance Offshore (m)
100308
121308
020709
040509

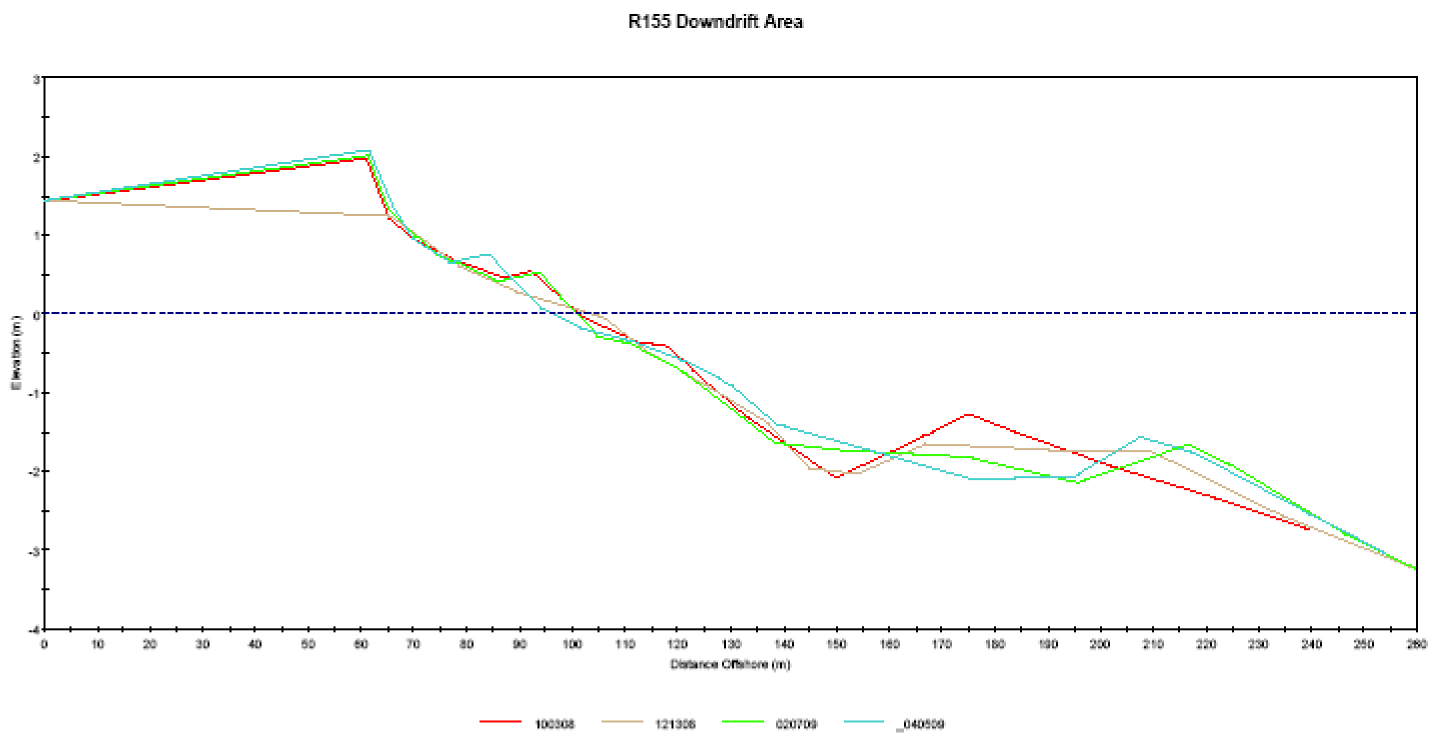
R152 Downdrift Area



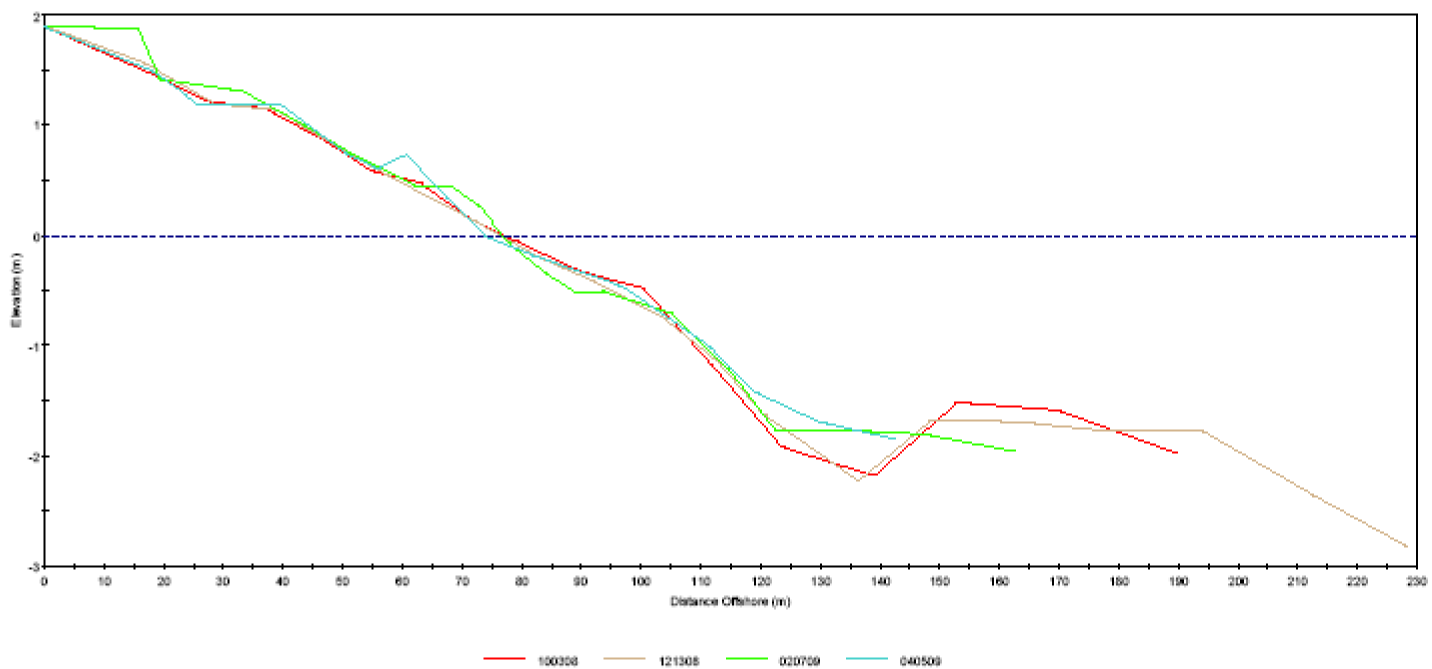

R153 Downdrift Area
Elevation (m)
Distance Offshore (m)
100308
121308
020709
040509

R154 Downdrift Area




R155 Downdrift Area
Elevation (m)
3
2
1
0
-1
-2
-3
-4
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
Distance Offshore (m)
100308
121308
020709
_040509

R156 Downdrift Area



Appendix II

Volume and Shoreline Changes between April 2008 and October 2009

Volume and Shoreline Calculations in the T-Groin Field October 2008 to April 2009

Profile (N to S)	Volume m^3	Shoreline m
LK1B	-20.46	-12.99
T1N3	-25.87	-13.65
T1N2	-28.55	-15.39
T1N1	-29.20	-14.14
T1C	-3.98	-1.52
T1S	-5.06	-0.05
LK2	-29.88	-15.32
T2N3	-22.31	-9.53
T2N2	-39.00	-19.20
T2N1	-40.47	-24.47
T2C	-6.31	0.00
T2S	-6.99	-1.73
T3N4	-17.34	-3.38
T3N3	-18.16	-5.30
T3N2	-19.85	-7.43
T3N1	-24.01	-10.00
T3C	-12.36	-1.12
T3S	-16.31	-6.68
T4N4	-24.88	-8.29
T4N3	-27.56	-8.23
T4N2	-34.20	-11.25
T4N1	-31.47	-12.55
T4C	-33.49	-12.40
T4S	-29.36	-10.87
T5N4	-22.99	-7.25
T5N3	-37.08	-10.03
T5N2	-26.98	-9.85
LK5	-27.28	-9.17

Volume and Shoreline Calculations at Northern Long Key October 2008 to April 2009

Profile (N to S)	Volume DOC m^3	Shoreline 0 m
LK1B	-21.027	-12.99
LK1C	-33.246	-11.72
LK2	-32.386	-15.32
LK2A	-93.109	0.04
LK3	-29.023	-13.66
LK3A	-32.281	-8.64
LK4	-44.389	-10.98
LK4A	-39.706	-7.61
LK5	-36.37	-9.17
LK5A	-21.994	-6.83
LK6	-9.519	-5.07
LK7	-22.273	-3.7
R148	-11.394	7.28
R149	6.208	5.8
R150	-6.342	-4.85
R151	-1.243	-3.42
R152	-10.549	-4.01
R153	12.265	-3.16
R154	0.681	-3.46
R155	6.56	-4.65
R156	9.567	-3.57

Volume Change between -1.5 to DOC at Northern Long Key October 2008 to April 2009

Profile (N to S)	DOC to -1.5 m
LK1B	-0.75
LK1C	-13.56
LK2	-2.51
LK2A	-66.77
LK3	-4.25
LK3A	-11.87
LK4	-10.14
LK4A	-10.90
LK5	-9.10
LK5A	-2.71
LK6	-1.73
LK7	0.06
R148	5.41
R149	10.14
R150	11.11
R151	5.04
R152	8.09
R153	10.58
R154	-0.92
R155	3.69
R156	7.81