WAVE HEIGHT MEASUREMENTS AT THE RACOON ISLAND BREAKWATERS DEMONSTRATION PROJECT(TE-29) : REPORT ON OCTOBER 1997 FIELD DEPLOYMENT

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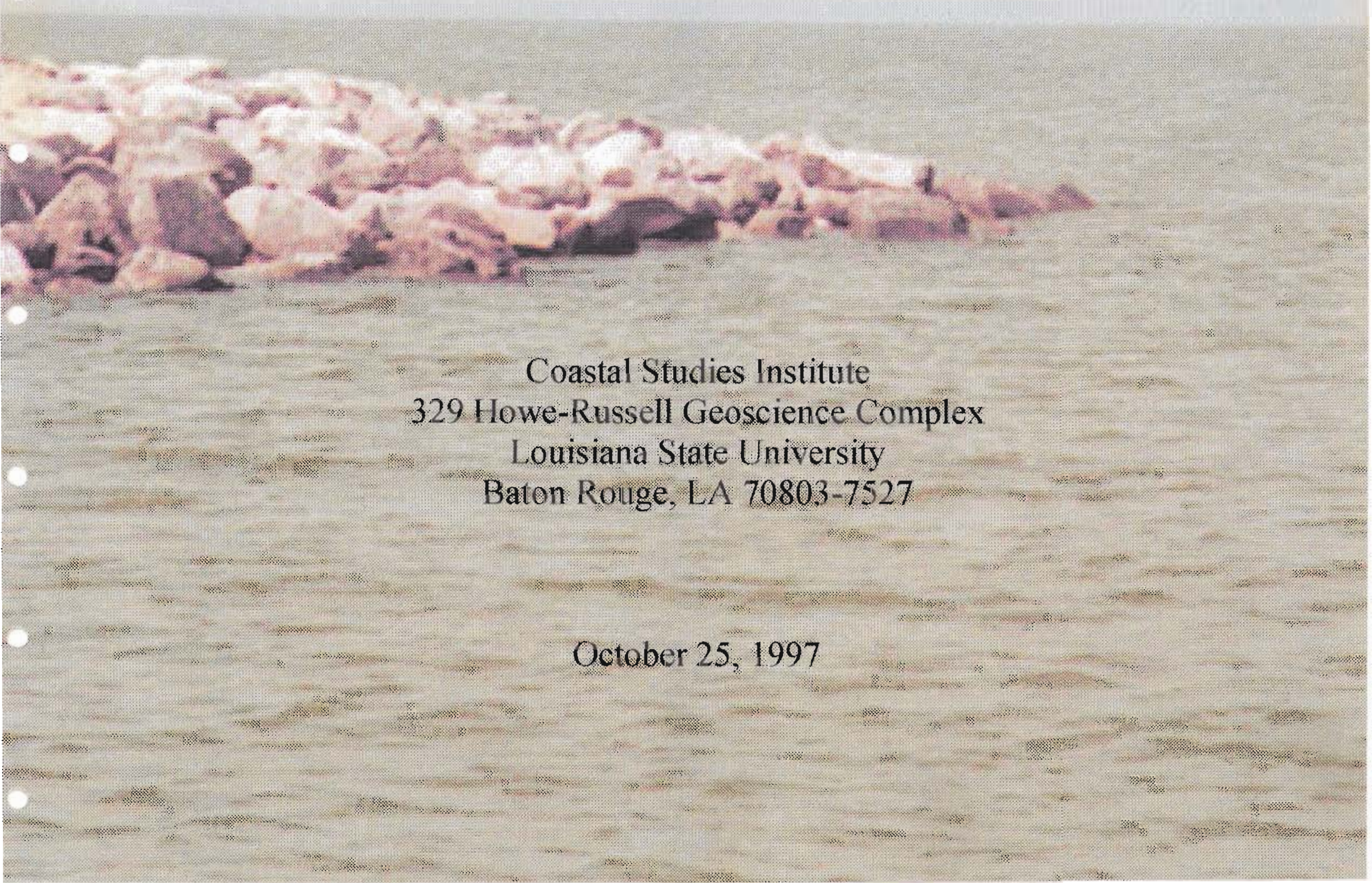

Coastal Studies Institute
329 Howe-Russell Geoscience Complex
Louisiana State University
Baton Rouge, LA 70803-7527

October 25, 1997

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INTRODUCTION

In May 1997, scientists in the Coastal Studies Institute at Louisiana State University, were contracted by the Louisiana Department of Natural Resources/Coastal Restoration Division to monitor wave conditions at the Raccoon Island Breakwaters Demonstration Project (TE-29) funded under the Coastal Wetlands Planning, Protection and Restoration Act. This is the first of a series of reports in which experimental design, field deployment, information in the form of wave statistics and spectra are presented and interpreted along with bathymetric and topographic surveys of the site.

The first wave measurement at the Raccoon Island Breakwater Demonstration (TE-29) Project was conducted on October 1^{st} and 2^{nd}, 1997. During the pre-deployment site investigation, a significant change of shoreline configuration caused by the existence of the breakwaters was observed. We decided to conduct a morphological survey in addition to the wave measurement. A series of experiments was conducted on October 1^{st} to optimize the field deployment and sampling scheme. A surveying grid composed of 10 lines perpendicular to the shoreline was established. This progress report summarizes the first wave measurement results. In addition, results from the morphological survey are also provided.

The objective of the study is to monitor the influences of the segmented breakwaters to the nearshore wave field and morphology. This progress report includes an explanation of the instrumentation and sampling scheme, a description of the sampling locations based on field observations, and a discussion of the breakwaters' influence on wave field and nearshore morphology.

INSTRUMENTATION AND SAMPLING SCHEMES

Wave height and period were measured with 3 precise, Paroscientific digital quartz pressure transducers. The pressure transducers, which record the instantaneous fluctuation of water level, are capable of 0.01% accuracy and 0.0001% resolution. For conditions at the Raccoon Island breakwaters site, the accuracy is expected to be well within 5 mm (0.2 in.). The pressure transducers were assembled by CSI personnel in a self-contained, solid-state recording package, suitable for underwater deployment. An example of the pressure sensor array is shown in Plate 1. The instrument packages are capable of sampling at a high frequency of 4 Hz.

Plate 1. The pressure transducer arrays used in the Raccoon Island breakwaters study. The pressure sensors and solid-state recorders are housed in the water-tight housing and are being tested in the Coastal Studies Institute's Wave Simulating Facility.

After a series of on-site experiments, an optimal sampling scheme, which allowed maximum temporal coverage and efficient data processing, was determined. Two thousand and forty-eight (2048) readings (one bust of 8.5 minutes) were recorded every 20 min at 4 Hz. The 4-Hz sampling allows reliable measurement of high-frequency waves with periods as low as 1 second. The 8.5-minute burst, which is sufficient enough in duration to include 100 to 150 waves of 3- to 5-second periods, yields reliable statistical analysis of wave spectra and was deemed appropriate for the objectives of this study. A total of eighteen 8.5-min bursts were recorded during the first measurement. The locations of the deployments are shown in Figure 1, and include those sites landward and seaward of the breakwaters, and the control site to the west.

Nearshore morphology was surveyed using the standard level and transit procedure utilizing a Topcon electronic total station. For the surveying range at the breakwater project, the accuracy is expected to be within 10 mm (0.4 in.) in the horizontal and 5 mm (0.2 in.) in the vertical. Ten survey lines spanning three breakwaters were surveyed, although additional surveys will be completed to cover the entire breakwater site prior to submission of the next progress report. The profile locations are shown in Figure 1. Temporary benchmarks were established using 1.5 m (5 ft) long pvc pipes. Beach posts and pipes protruding from the top of the breakwaters were used as elevation controls. A temporary relative elevation was used but will be corrected to a standard datum at a later date. The density of survey points along profile lines is a direct function of the topographic/bathymetric complexity. Significant breaks in slope associated with morphological/bathymetric features were recorded during each survey. The profile surveys start landward at the edge of vegetation, and end seaward on top of the

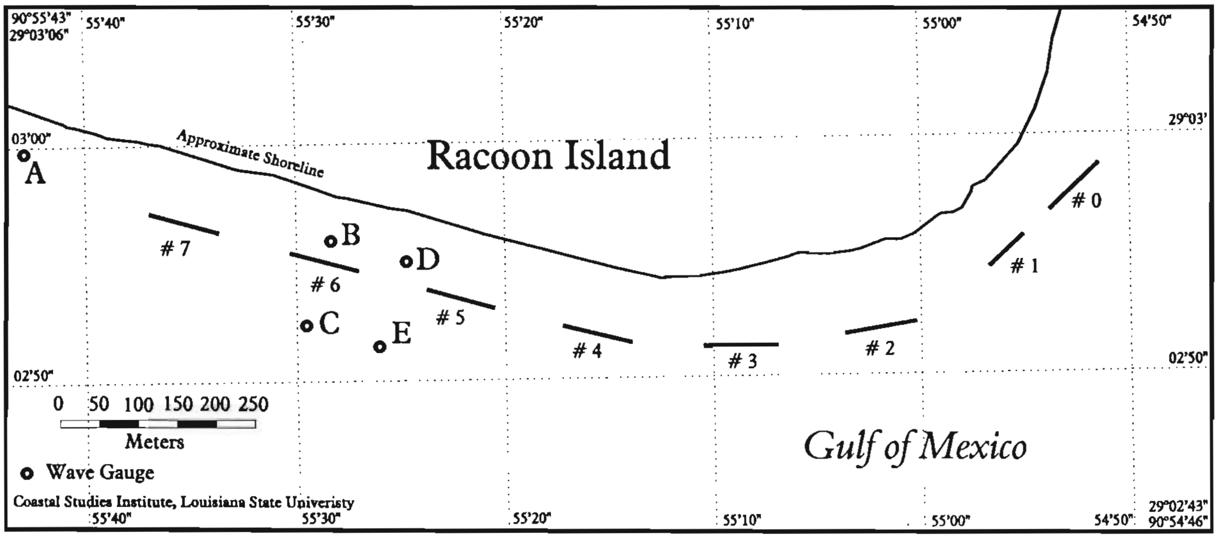

Figure 1. Study area, showing the locations of wave gages

breakwater, or at the same relative locations for the survey lines in the gaps of the breakwaters.The bathymetric and topographic surveys were conducted to determine trends associated with sedimentation/erosion induced by the segmented breakwaters. The topographic survey and nearshore morphological analysis was not part of the contract with LADNR. However, this undertaking is viewed here as being critical to a more profound comprehension of the impacts of the breakwaters on coastal processes and sediment transport at the monitoring sites. The topographic surveys will be conducted during each wave monitoring event on a quarterly basis. Nearshore morphological changes will be analyzed by comparing pre-construction, post-construction, and each of the quarterly surveys.

WAVE MEASUREMENTS

The wave measurements were conducted on October 2, 1997 from 1040 to 1640 hours. A weak cold front passed through the study area at approximately 1900 hours on October 1. On October 2, a northerly wind approximating 15 knots was measured with a hand-held anemometer, and was noted to have decreased to 8 knots in the afternoon. Wave heights were estimated visually to be 0.3 to 0.47 m (1.0 to 1.5 ft), propagating from the southeast.

Simultaneous wave measurements were conducted at 3 locations (Figure 1). Wave gage A, served as a control, and was deployed approximately 150 m (500 ft) west of breakwater #7. The average water depth at the control site approximated 1.7 m (5.2 ft). Wave gage B was deployed approximately 21 m (70 ft) landward of the center of breakwater #6 (Figure 1). Wave gages A and B were deployed the same distance of approximately 30 m (100 ft) seaward of the shoreline. The average water depth at the inside location B was 1 m (3.3 ft). Wave gage C was deployed 100 m (305 ft) seaward of the center of breakwater #6. The average water depth at location C (offshore the breakwater) was approximately 1.6 m (5.2 ft). Wave gages at sites B and C were moved to the gap (sites D and E) between breakwaters #6 and #5 at 1320 hours (Figure 1). The water depths at sites D and E were 1.0 (3.3 ft) m and 1.6 m (5.2 ft), respectively.

The control wave gage (A) remained at the same location throughout the entire sampling event. Nine bursts (burst no. 1 through 9: from 1040 through 1320 hours) were recorded with the inside (B) and outside (C) wave gages lined up across the middle of breakwater #6. The remaining nine bursts (burst no. 10 through 18: from 1340 to 1620 hours) were recorded with the inside (D) and outside wave gages (E) lined up across the gap between breakwaters #5 and #6. The inside (B and D) and outside (C and E) locations were at the same distance relative to the shoreline, respectively. The same relative distance to the shoreline at sites A (without protection), B (with protection), and D (in the gap between breakwaters) was used to ensure compatibility.

DATA ANALYSES

The objective of this monitoring project is to quantify the influence of the breakwaters on incident wave conditions. This was accomplished by comparing wave conditions measured behind the breakwaters to the conditions at the control site, with the latter being devoid of the influence of the breakwaters. Comparisons between wave conditions behind the breakwater and that in the gap also provide direct information on the breakwater influences on waves in the immediate vicinity of the tips of the breakwaters.

The raw data record of water level fluctuations was a composite of waves of different frequency (Appendix 1). In order to examine the energy contributions of each frequency, a spectral analysis is necessary. The spectra analysis of the raw data was based on the "Field Wave Gaging Program, Wave Data Analysis Standard," recommended by the Coastal Engineering Research (see Earle and McGehee, 1995 for a detailed review).

Significant wave height was calculated based on CERC's standard procedure

$$H_{mo} = 4.0\sqrt{m_o} \qquad \textbf{Eq. 1}$$

where the zero moment, m_o, is computed as

$$m_o = \sum_{n=1}^{N_b} C_{zz}(f_n)df_n \qquad \textbf{Eq. 2}$$

where $C_{zz}(f_n)$ is the power spectrum density of the *nth* frequency f_n, and df_n is the bandwidth. The power spectrum densities were calculated using the Welch method of the fast Fourier transformation (Welch, 1967).

RESULTS

The high-frequency recording allows a close examination of wave properties including significant wave height, peak wave period, and wave-energy distribution with respect to frequencies. Wave diffraction in the lee of the breakwaters was observed and had significant influence on the development of the rhythmic shoreline features.

Wave Diffraction

Wave diffraction patterns were well established in the lee of the breakwaters and had a significant influence on the patterns of wave breaking at the shoreline, and, therefore, influences on shoreline changes. Behind the center of the breakwaters towards the beach, diffraction caused convergence of the shoaling waves resulting in classic caustic zones (Appendix 2). Convergence of waves at these nodal points appeared to result in accumulation of sediment behind the center of breakwaters along the adjacent beach. Behind the gaps in the breakwaters, diffracted waves expended higher energy along the adjacent beach. Sediment was observed being transported to the east and west along the beach at these sites, resulting in the development of a vertical, beach scarp.

Significant Wave Heights

Significant decreases in wave heights were measured behind breakwater #6 (Figure 2). The average significant wave height measured seaward of the breakwater was 0.24 m (0.80 ft).

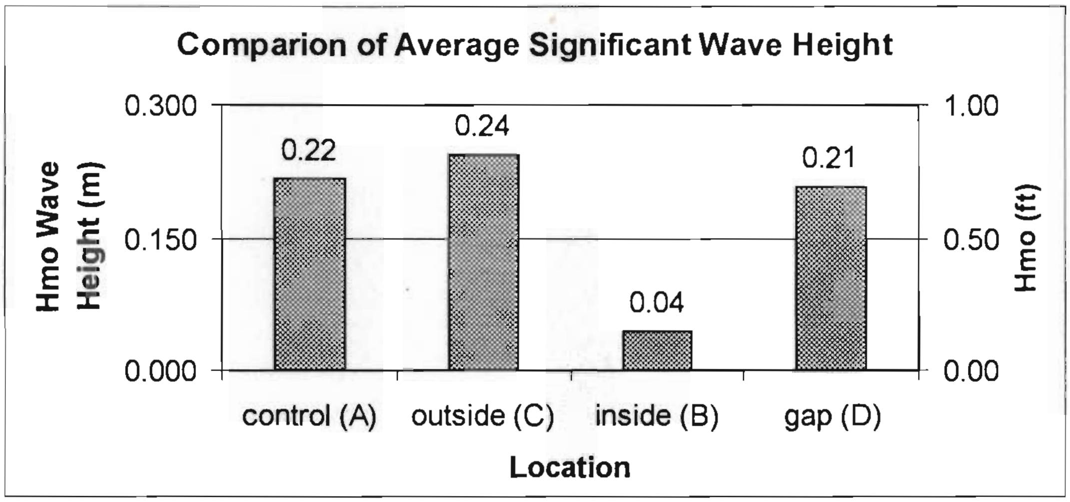

Figure 2. Comparison of significant wave heights at different locations

The average significant wave height measured at the control site was 0.22 m (0.71 ft). A wave-height reduction of 11% was measured at the control site (A) when when compared with the gage seaward of breakwater #6 (site C), due to energy dissipation as waves propagated towards the shoreline. The average wave height measured at site B behind the center of the breakwater was 0.04 m (0.14 ft). This constitutes a reduction of 83% directly attributable to wave dampening by the presence of the breakwater.

The control gage (site A, Figure 1) was deployed at the same relative location to the shoreline as the inside gage (site B). The wave conditions were significantly different with and without the protection of the breakwater. At the control site, without the protection of the breakwater, the average significant wave height was 0.22 m (0.71 ft),

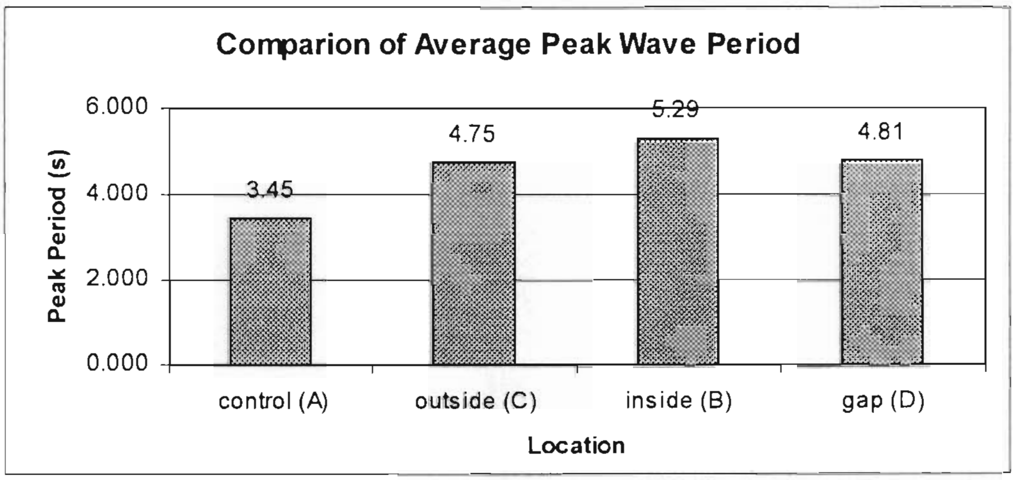

Figure 3. Comparison of peak wave periods at different locations

which was 5.5 times higher than that at the location protected by the breakwater. In terms of wave energy, which is proportional to the square of wave height, the wave energy at the unprotected beach was 30 times stronger than that at the protected beach for average wave conditions encountered during this deployment.

The average significant wave height in the gap of breakwaters #5 and #6 (site D) was 0.21 m (0.68 ft), 5.2 times larger than the wave height behind breakwater #6 (site B). The wave height in the gap was almost identical to the wave height at the control site (A), indicating that a significant amount of wave energy was being propagated through the gap in the breakwaters (Appendix 3). The rhythmic shoreline features, i.e., accumulation behind the center of the breakwaters and erosion in the gap between the breakwaters ---

discussed in detail in the following sections --- are caused by the differential energy transfer between and through the breakwaters and the wave diffraction beginning at the tips of the breakwaters.

Peak Wave Period and Wave Spectra

Peak wave period, also referred to as dominant wave period or period of maximum wave energy, is defined as the wave period corresponding to the center frequency of the frequency band with the maximum non-directional spectral density. The average peak wave period measured seaward of the breakwater was 4.75 seconds (Figure 3). The average peak period measured at the control site was 3.45 seconds. A reduction of 1.3 seconds (27%) was measured. The average peak period measured behind the breakwater was 5.29 seconds, an increase of 0.54 seconds (12%). As compared to the control site, the peak wave period behind the breakwater was 1.85 seconds (54%) longer. The average peak period in the gap between the breakwaters was 4.81 seconds, almost identical to the offshore wave period (Appendix 4).

The wave spectra of the 18 records are summarized in Appendix 5. The wave spectra illustrate the distribution of wave energy with respect to each frequency component. The peaks in the wave spectra indicate that the waves of the specific frequencies carry more energy than other frequencies. Several distinct features were observed from the October measurements:

1. The magnitudes of the wave energy for the inside wave gage (site B), as indicated by the power density, were much smaller than that of the control, the outside, and the gap gages (sites A, C, and D). These differences in the

magnitudes of power density caused the large difference in significant wave heights.

2. Almost all the wave energy was distributed between 0.1 to 0.6 Hz, or 1.7 to 10 seconds. Waves with longer than 10 seconds or shorter than 1.7 seconds period were not significant during the period of measurement.
3. Energy distribution of the offshore (sites C and E) wave was skewed to the lower frequency end, while energy distribution of nearshore waves (control, site A) was skewed toward the higher frequency end. In other words, the energy peak at low frequency measured offshore decreased, while the minor peak at higher frequency increased as the waves propagated onshore. These differences in the shape of the spectra caused the differences in peak wave period.
4. Toward late afternoon, as the wind-speed decreased, the energy from the long-period swell component increased. This caused the increase of peak periods toward the end of the afternoon.

Shoreline Morphology and Nearshore Bathymetry

The existence of the segmented breakwaters induced an obvious change in shoreline configuration. The shoreline changes correspond with the alteration of the wave field induced by the breakwaters. Shoreline features similar to beach cusps were observed along the stretch of the protected shoreline (Appendix 6). These features are commonly observed between segmented, detached breakwaters, and are often explained as the results of the intercept to longshore sediment transport due to the shadow effect of the breakwater. Our field observations indicate that the diffraction begins at the tips of the breakwaters, causing differences in the wave breaking pattern behind and in the gap of the breakwaters, thereby playing a significant role in the formation of the cuspate features.

A relatively deep trough was measured between the breakwaters and the shoreline (Appendix 7). A shallow spit existed at the east tip of breakwater #5. The water depth between breakwater #5 and #6, where the gage D was deployed (~ 21m landward), was shallow resulting in significant wave breaking at the site.

SUMMARY

The October measurements were conducted during northerly, offshore wind conditions. The overall wave height was small, with the significant wave height approximating 0.3 m (1 ft). The breakwaters functioned as effective wave energy absorbers. For these wave conditions, approximately 97% of the incoming wave energy was absorbed by the breakwaters. The level of wave energy was about 25 times lower at 21 m (70 ft) behind the breakwater than that in the gap between the breakwaters and along the open, unprotected control site. Diffraction beginning at the tips of the breakwaters had a significant influence on the shoreline configuration, causing accumulation behind the center of the breakwaters. Minor foreshore erosion was noted through the presence of a vertical scarp between cuspate features along Raccoon Island. Future bathymetric and topographic survey comparisons will allow quantification of morphological changes due to the presence of the breakwaters.

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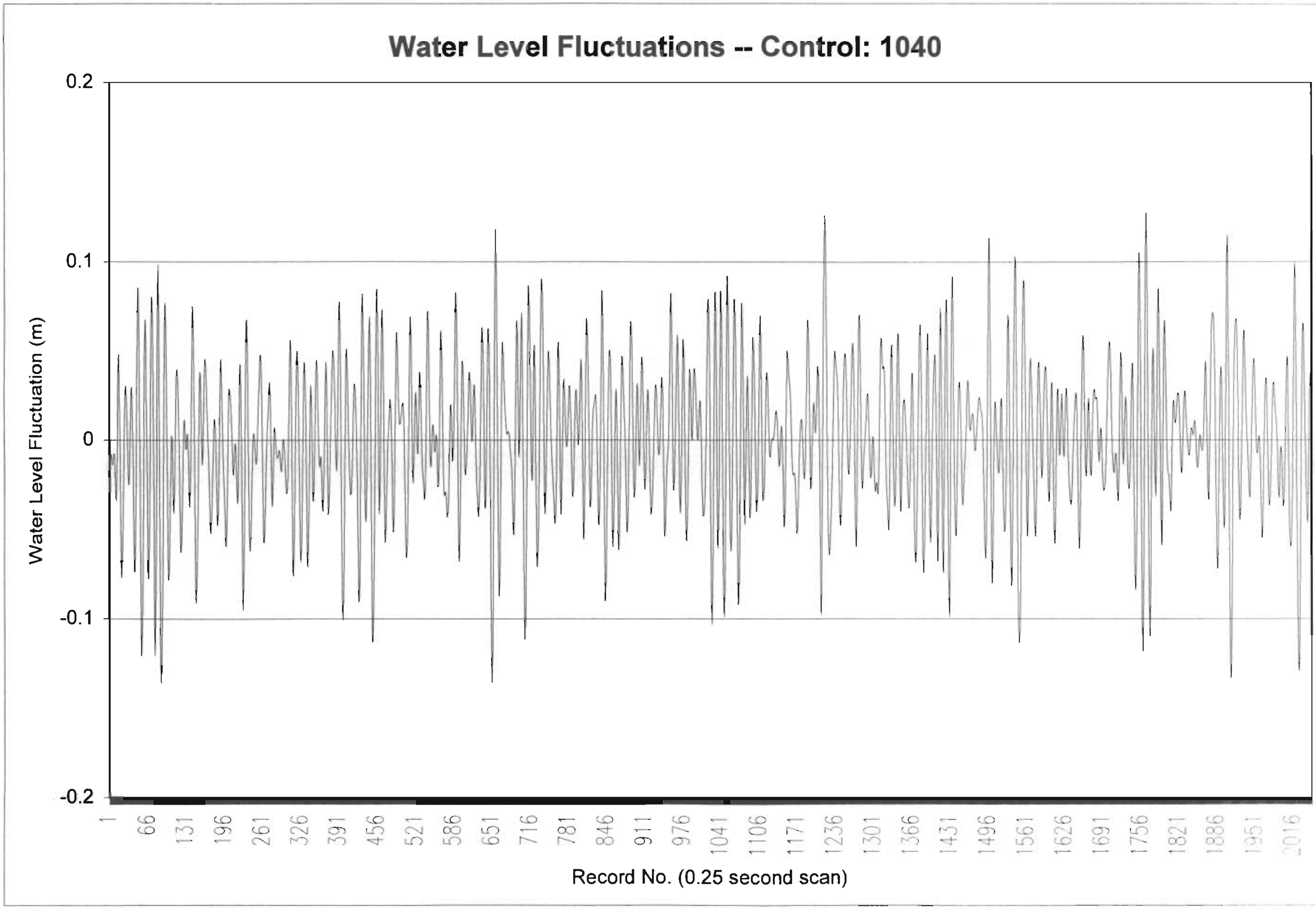
Earle, M.D. and McGehee, D., 1995. Field wave gaging program, wave data analysis standard. Instruction Report CERC-95-1, Coastal Engineering Research Center, US Army Corps of Engineer Waterways Experiment Station, Vicksburg, Mississippi.

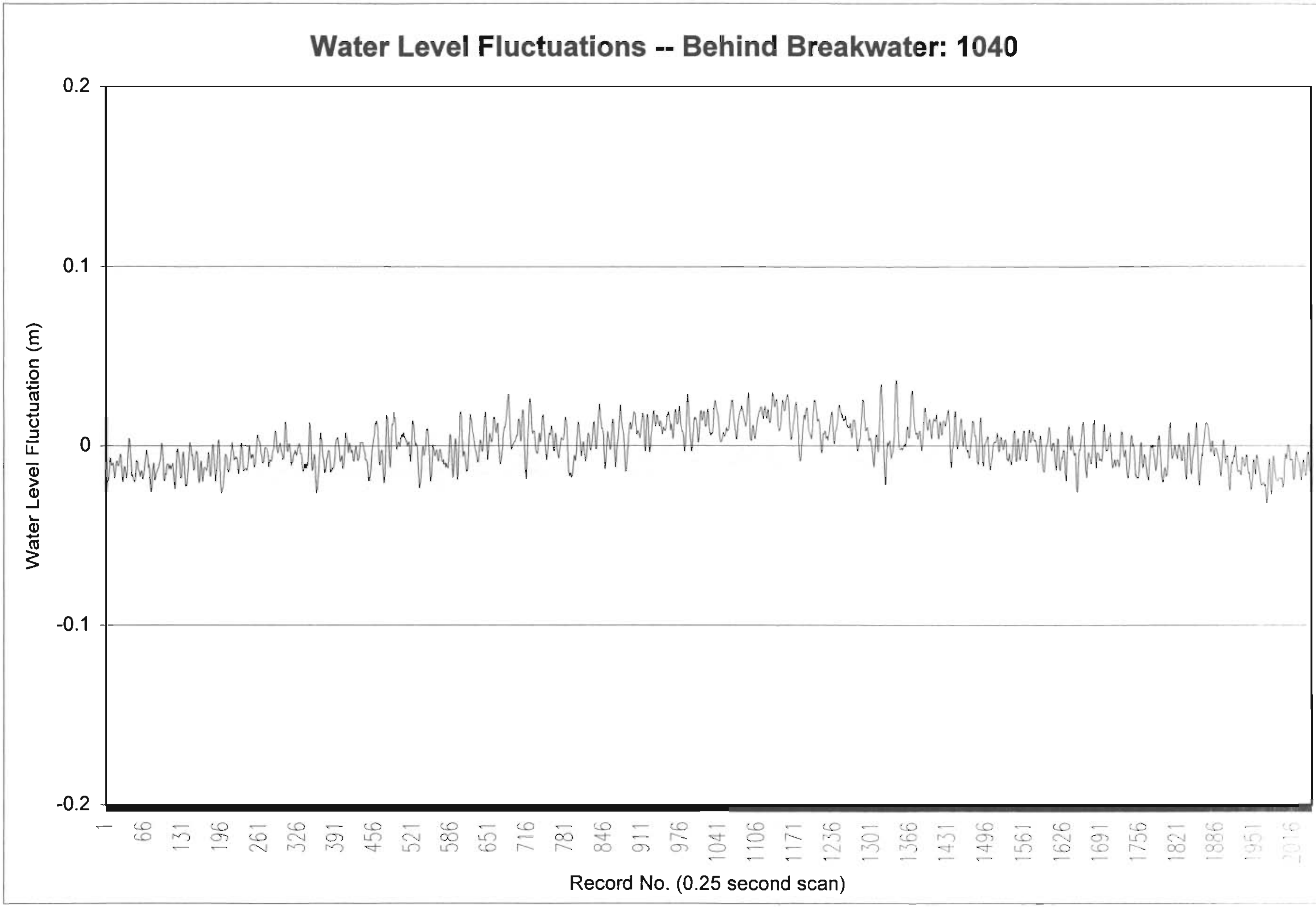
Welch, P.D., 1967. The use of fast Fourier transformation for the estimation of power spectra: a method based on time averaging over short, modified periodograms. IEEE Transactions on Audio and Electroacoustics, Vol. AU-15, 70-73.

APPENDIX 1

Examples of raw data at the study sites showing the complexity and presence of various waves at different frequencies.

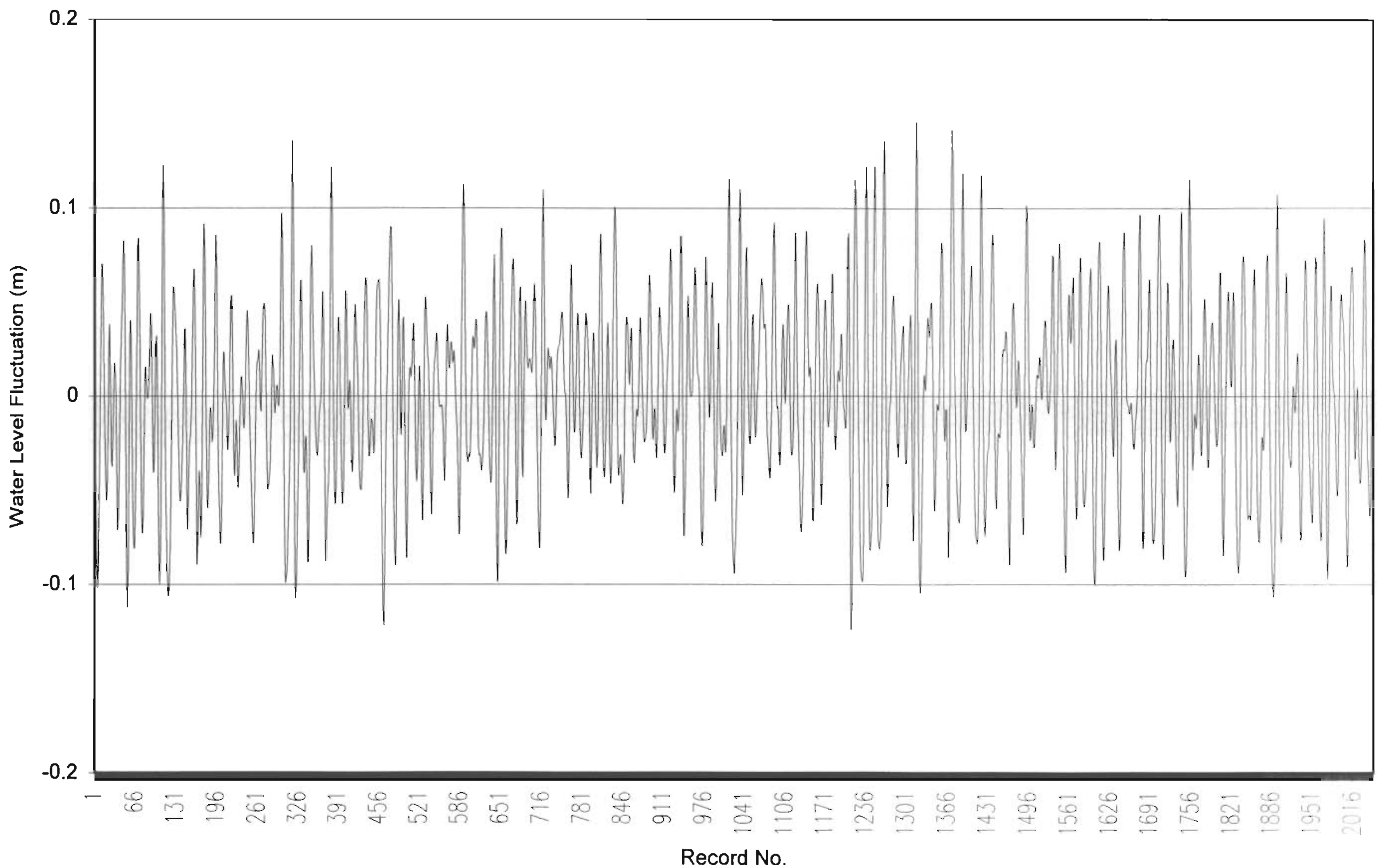


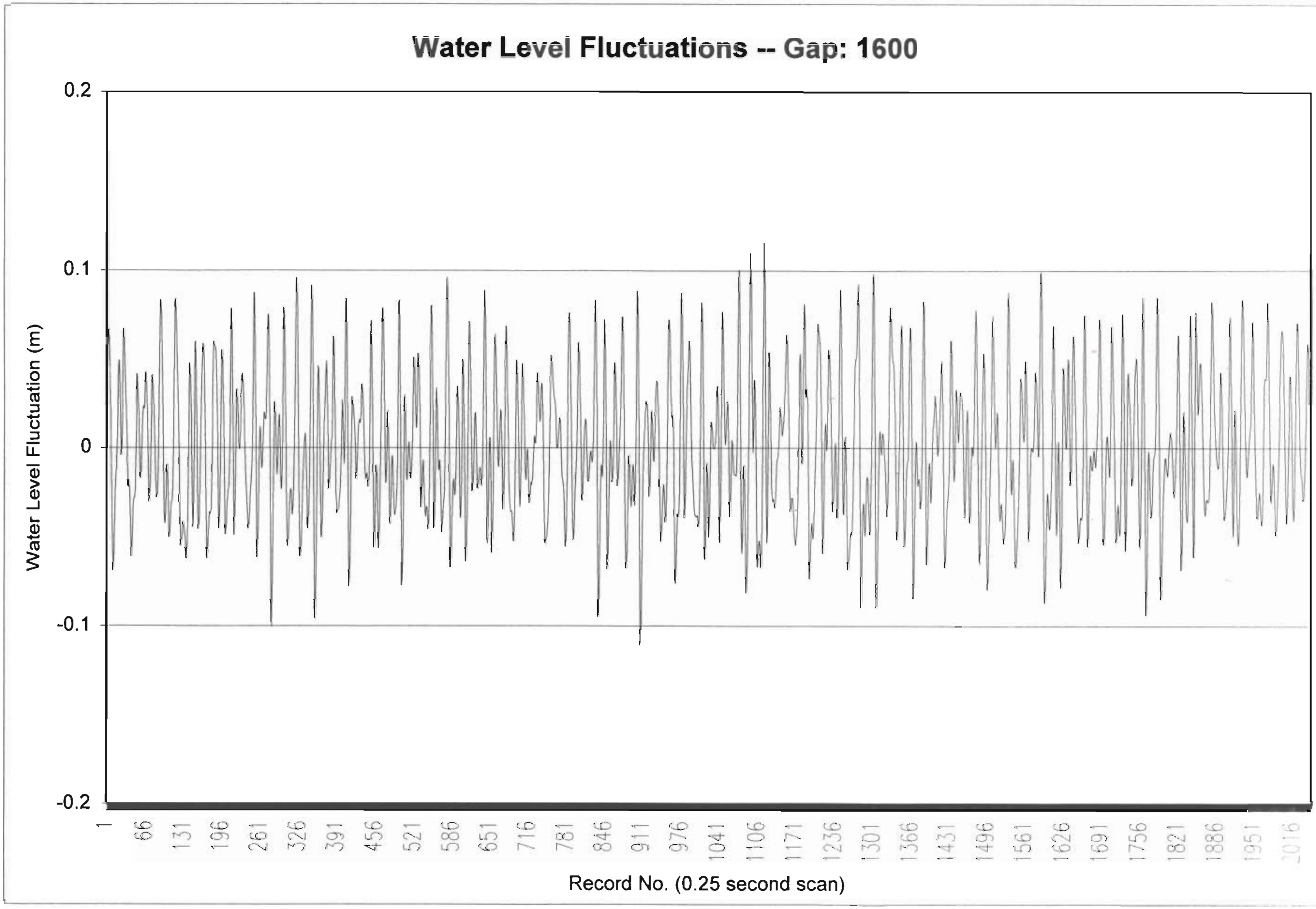
Water Level Fluctuations -- Control: 1040
0.2
0.1
0
-0.1
-0.2
Water Level Fluctuation (m)
1
66
131
196
261
326
391
456
521
586
651
716
781
846
911
976
1041
1106
1171
1236
1301
1366
1431
1496
1561
1626
1691
1756
1821
1886
1951
2016
Record No. (0.25 second scan)



Water Level Fluctuations -- Behind Breakwater: 1040
0.2
0.1
0
-0.1
-0.2
Water Level Fluctuation (m)
1
66
131
196
261
326
391
456
521
586
651
716
781
846
911
976
1041
1106
1171
1236
1301
1366
1431
1496
1561
1626
1691
1756
1821
1886
1951
2016
Record No. (0.25 second scan)

Water Level Fluctuations -- Offshore Breakwater: 1040




Water Level Fluctuations -- Gap: 1600
0.2
0.1
0
-0.1
-0.2
Water Level Fluctuation (m)
1
66
131
196
261
326
391
456
521
586
651
716
781
846
911
976
1041
1106
1171
1236
1301
1366
1431
1496
1561
1626
1691
1756
1821
1886
1951
2016
Record No. (0.25 second scan)

APPENDIX 2

A: Diffraction in the lee of breakwaters #6 and #7 resulting in well defined caustic zones along the adjacent beach on Raccoon Island.

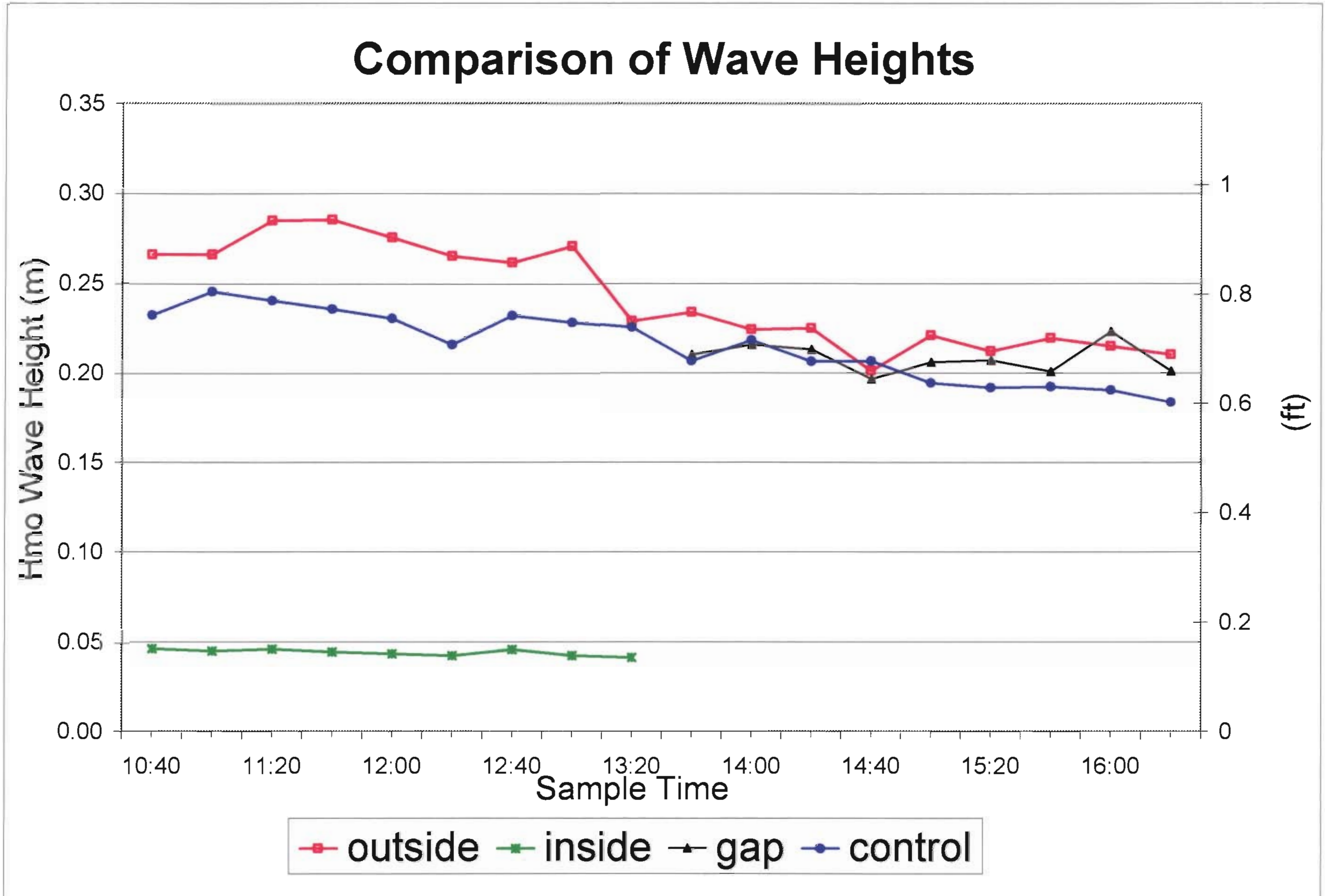
B: Wave divergence along the beach at Raccoon Island adjacent to the gap between breakwaters #6 and #7. The divergence of these waves resulted in erosion at the site with longshore sediment transport being to the east and west.

a

b

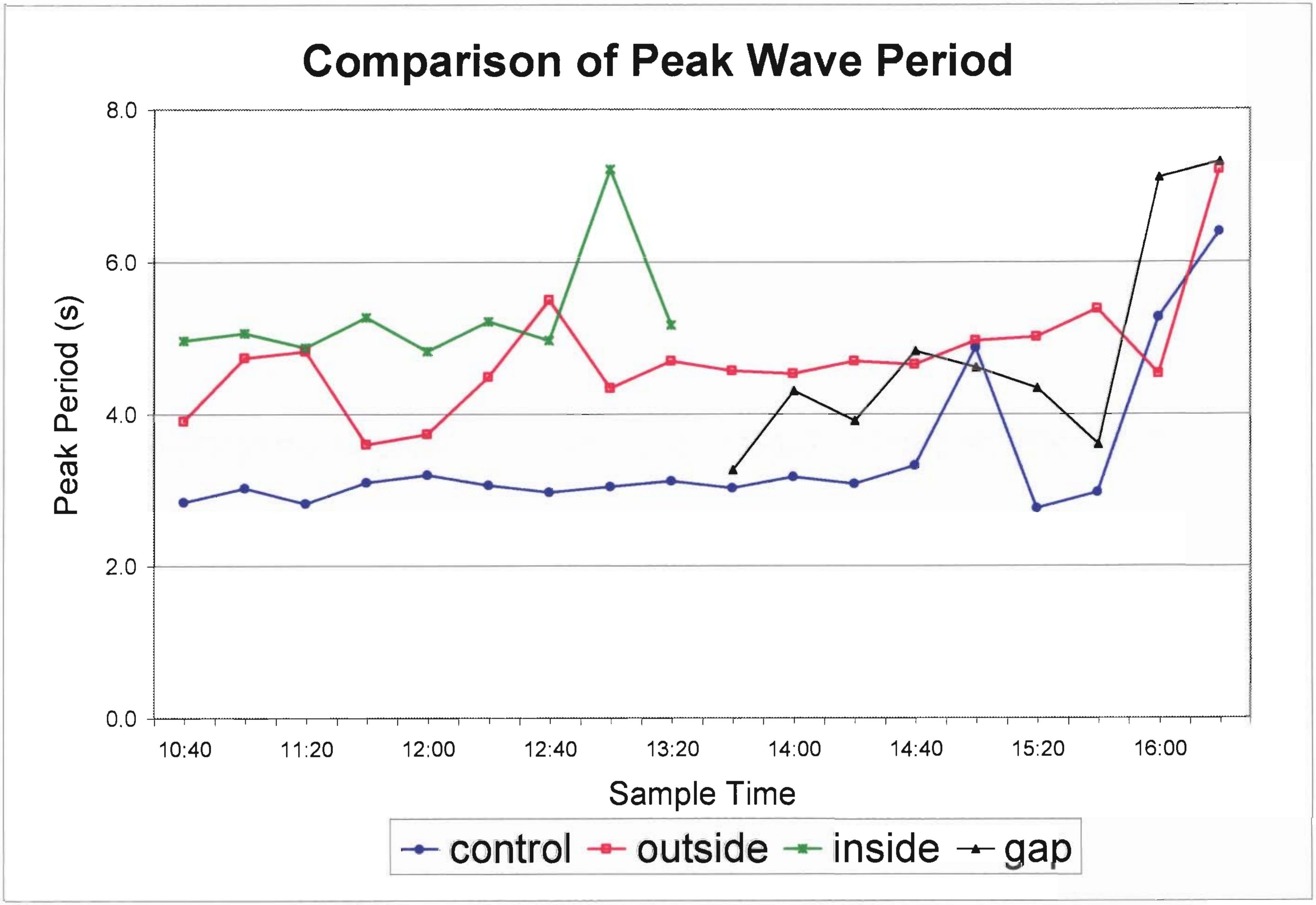
APPENDIX 3

Time-series of significant wave heights measured at control site (A), inside (B), outside (C), and in the gap (D and E) between breakwaters at Raccoon Island.


Comparison of Wave Heights
Hmo Wave Height (m)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
(ft)
1
0.8
0.6
0.4
0.2
0
10:40
11:20
12:00
12:40
13:20
14:00
14:40
15:20
16:00
Sample Time
outside
inside
gap
control

APPENDIX 4

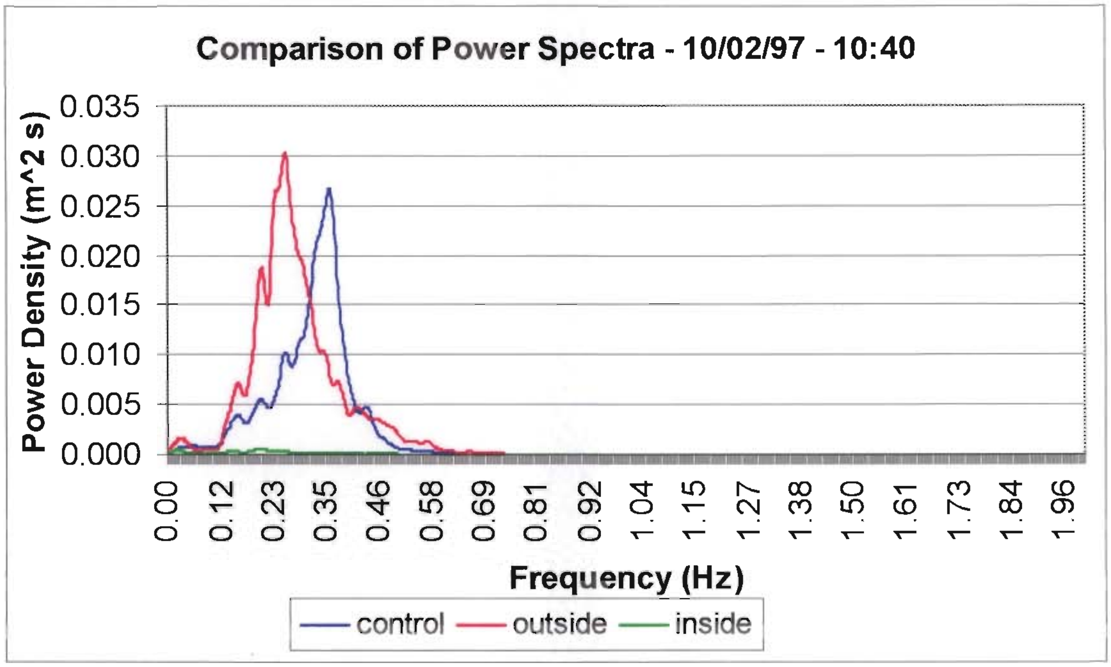
Measured peak wave periods

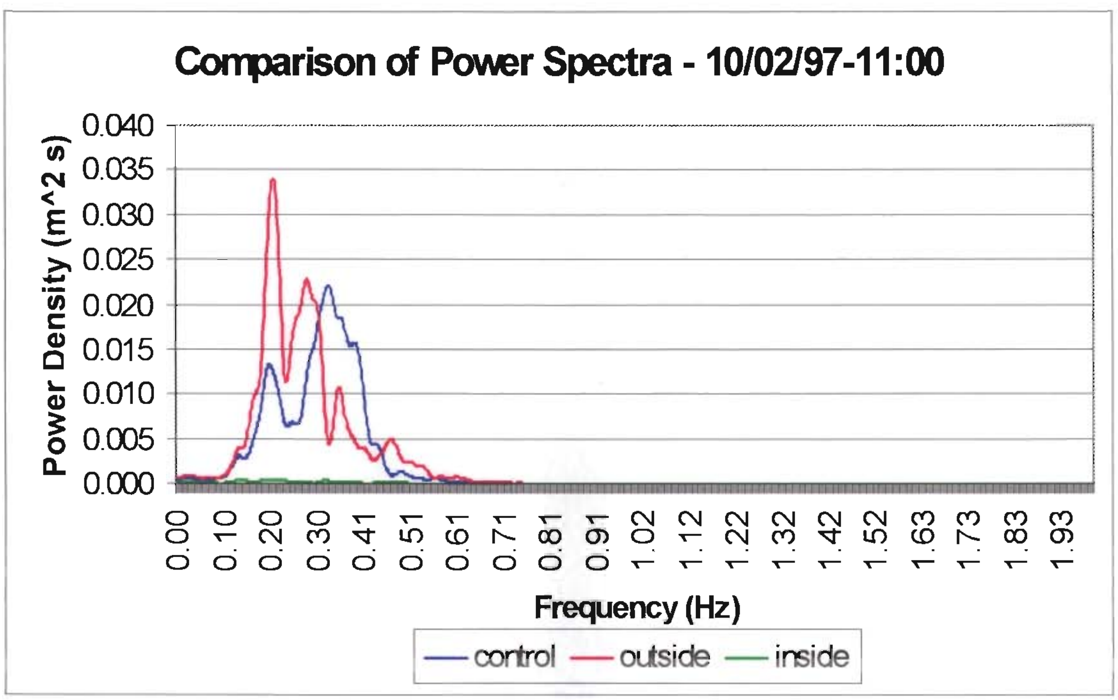


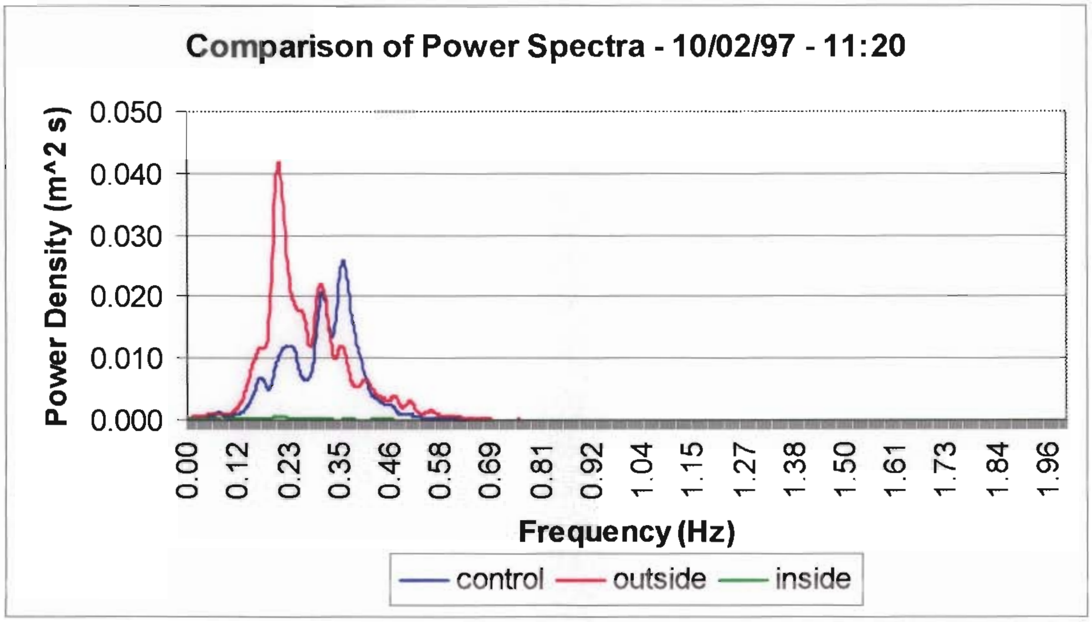
Comparison of Peak Wave Period
Peak Period (s)
8.0
6.0
4.0
2.0
0.0
10:40
11:20
12:00
12:40
13:20
14:00
14:40
15:20
16:00
Sample Time
control
outside
inside
gap

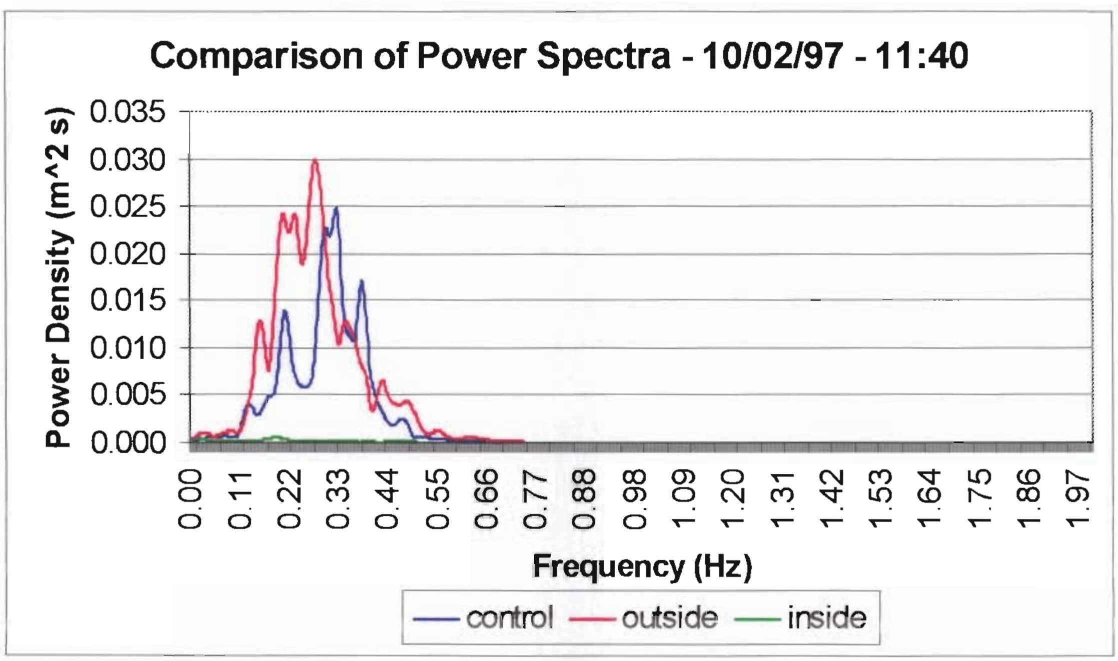
APPENDIX 5

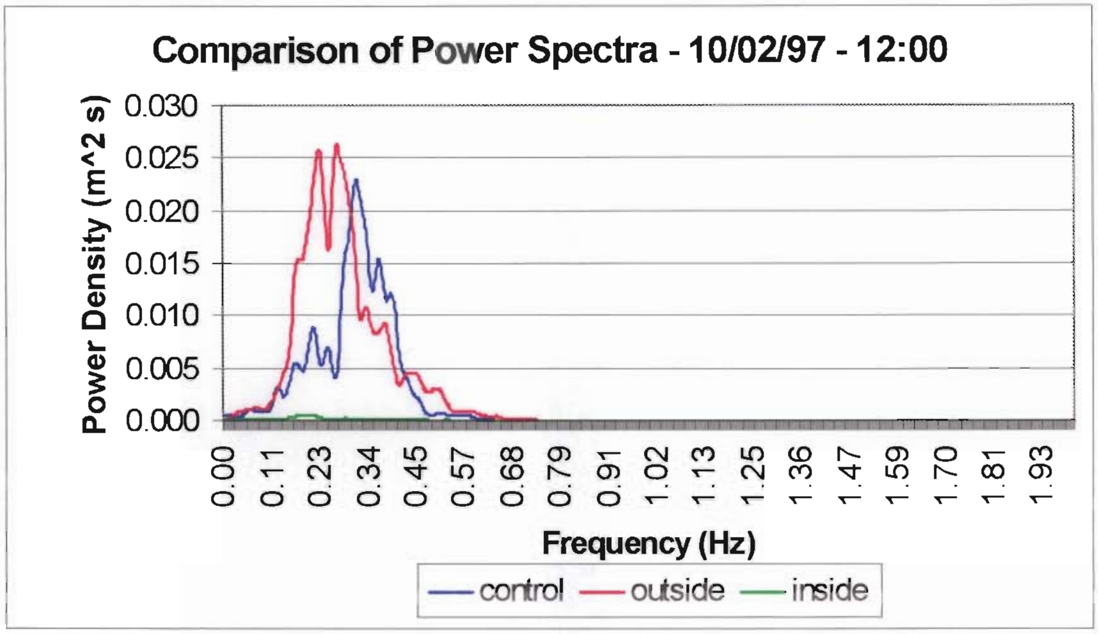
Wave spectra


Comparison of Power Spectra - 10/02/97 - 10:40
Power Density (m^2 s)
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0.00
0.12
0.23
0.35
0.46
0.58
0.69
0.81
0.92
1.04
1.15
1.27
1.38
1.50
1.61
1.73
1.84
1.96
Frequency (Hz)
control
outside
inside

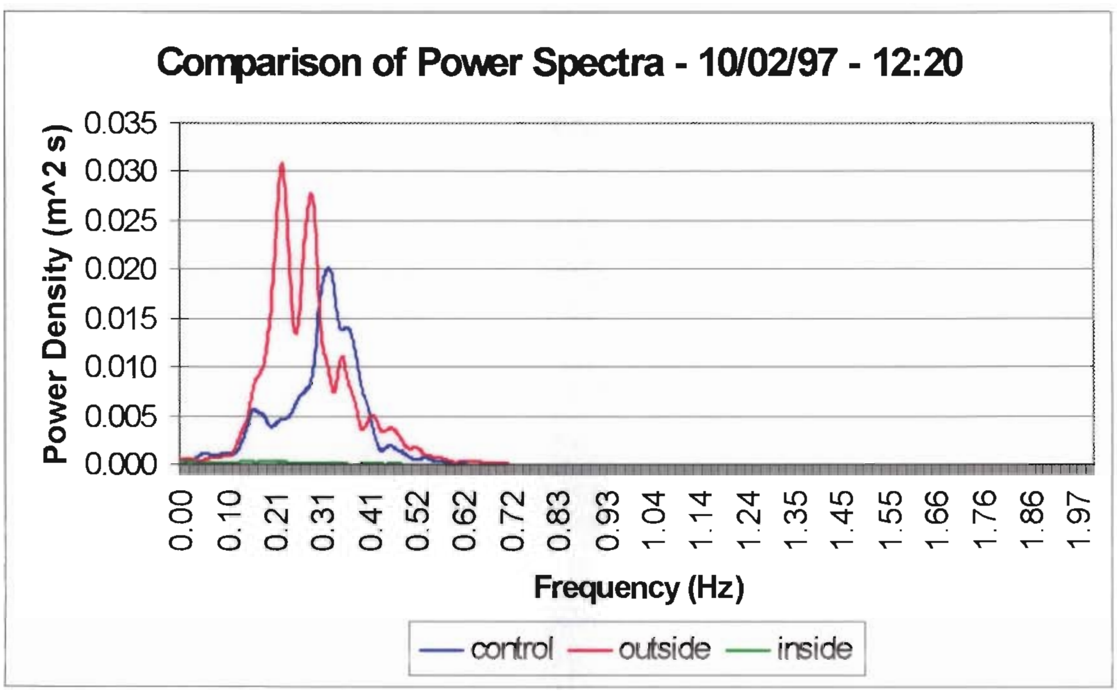

Comparison of Power Spectra - 10/02/97-11:00
Power Density (m^2 s)
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0.00
0.10
0.20
0.30
0.41
0.51
0.61
0.71
0.81
0.91
1.02
1.12
1.22
1.32
1.42
1.52
1.63
1.73
1.83
1.93
Frequency (Hz)
control
outside
inside


Comparison of Power Spectra - 10/02/97 - 11:20
Power Density (m^2 s)
0.050
0.040
0.030
0.020
0.010
0.000
0.00 0.12 0.23 0.35 0.46 0.58 0.69 0.81 0.92 1.04 1.15 1.27 1.38 1.50 1.61 1.73 1.84 1.96
Frequency (Hz)
control
outside
inside

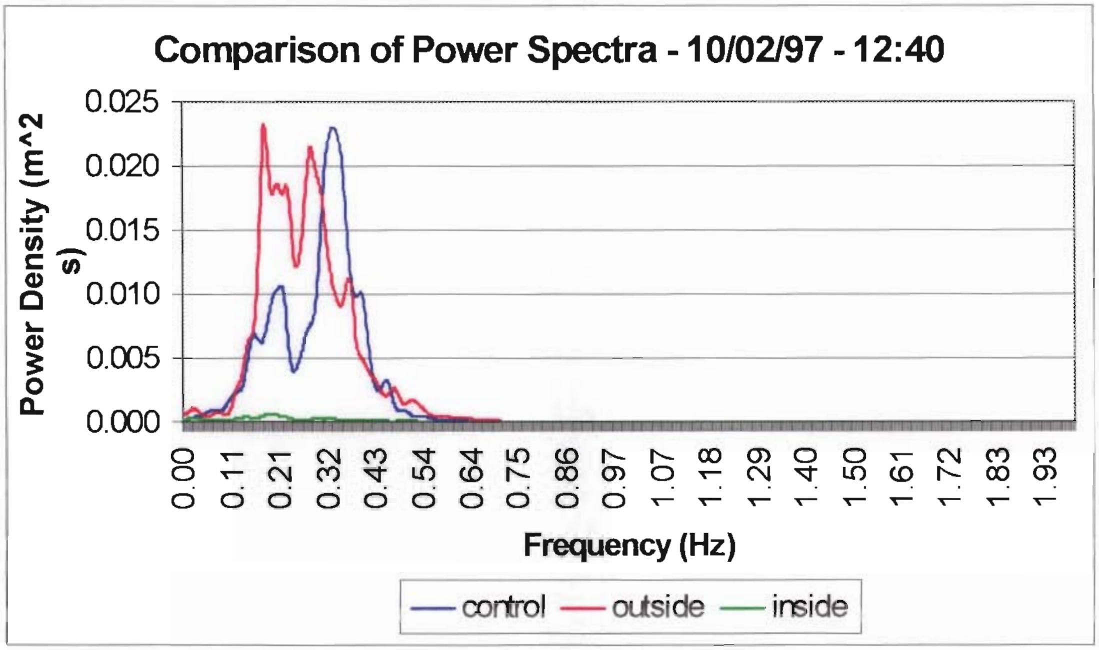

Comparison of Power Spectra - 10/02/97 - 11:40
Power Density (m^2 s)
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0.00 0.11 0.22 0.33 0.44 0.55 0.66 0.77 0.88 0.98 1.09 1.20 1.31 1.42 1.53 1.64 1.75 1.86 1.97
Frequency (Hz)
control
outside
inside

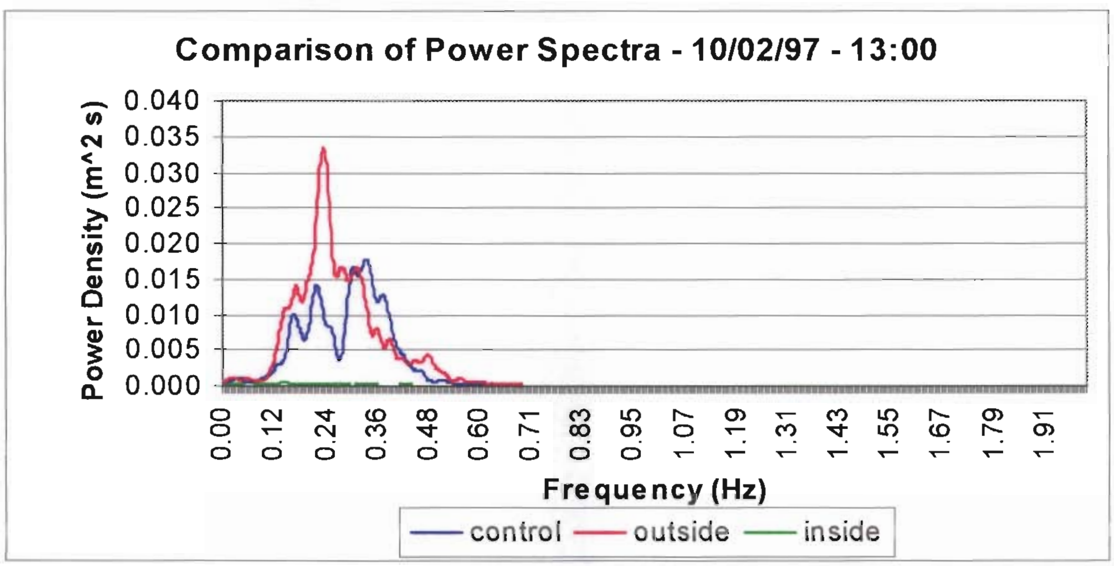


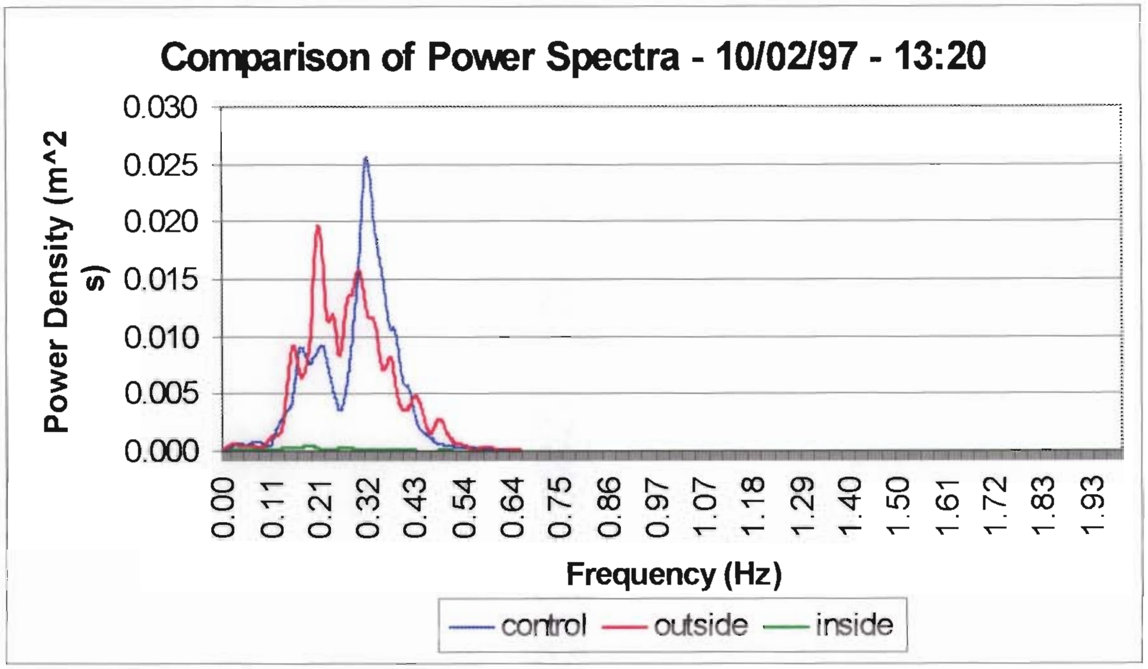
Comparison of Power Spectra - 10/02/97 - 12:00
Power Density (m^2 s)
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0.00 0.11 0.23 0.34 0.45 0.57 0.68 0.79 0.91 1.02 1.13 1.25 1.36 1.47 1.59 1.70 1.81 1.93
Frequency (Hz)
control
outside
inside

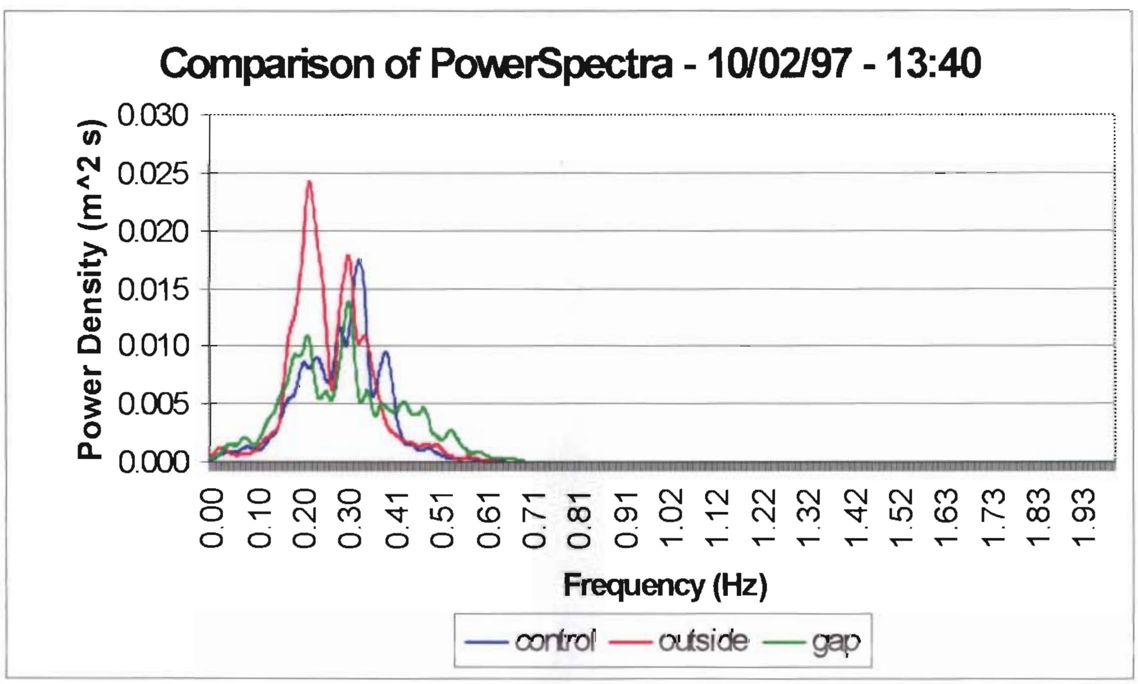


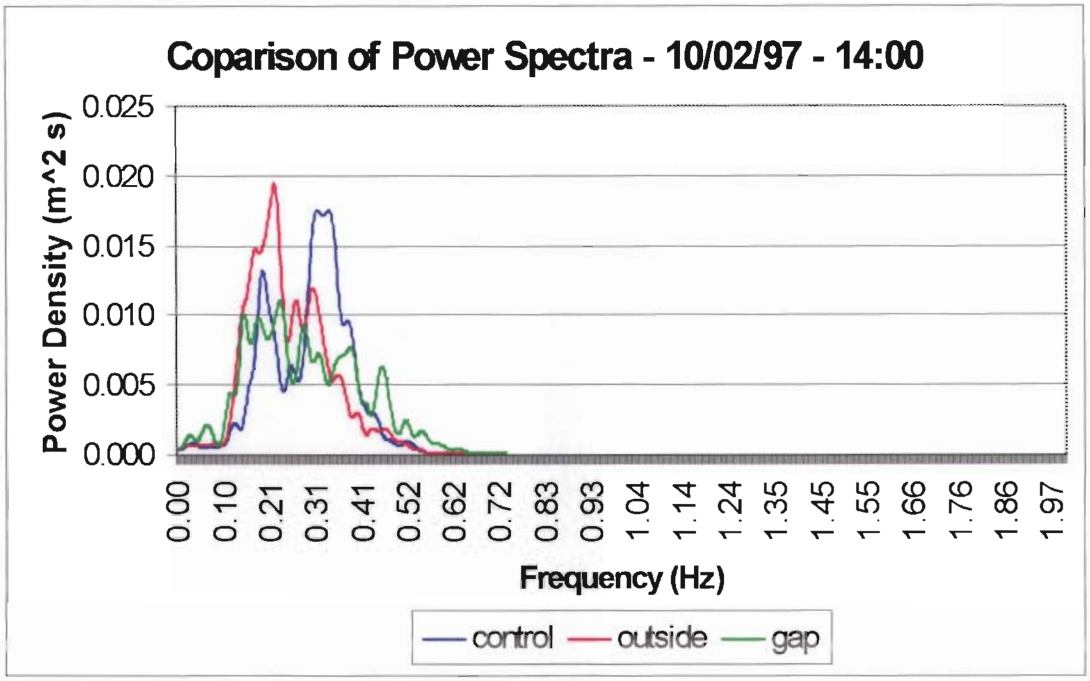
Comparison of Power Spectra - 10/02/97 - 12:20
Power Density (m^2 s)
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0.00 0.10 0.21 0.31 0.41 0.52 0.62 0.72 0.83 0.93 1.04 1.14 1.24 1.35 1.45 1.55 1.66 1.76 1.86 1.97
Frequency (Hz)
control
outside
inside

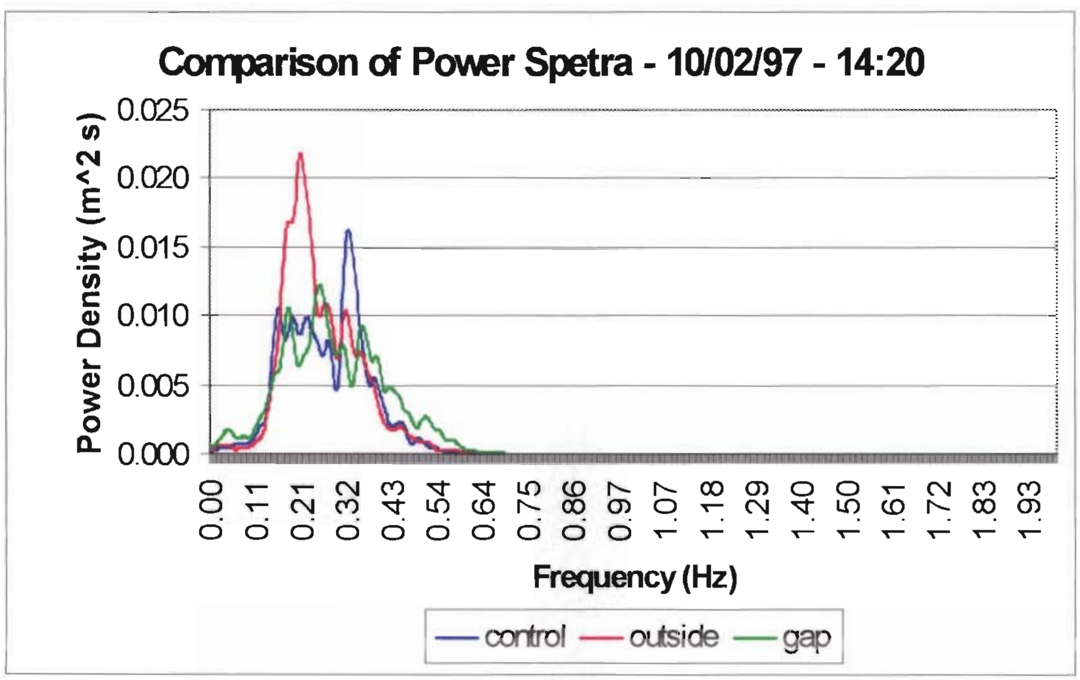

Comparison of Power Spectra - 10/02/97 - 12:40
Power Density (m^2 s)
0.025
0.020
0.015
0.010
0.005
0.000
0.00 0.11 0.21 0.32 0.43 0.54 0.64 0.75 0.86 0.97 1.07 1.18 1.29 1.40 1.50 1.61 1.72 1.83 1.93
Frequency (Hz)
control
outside
inside

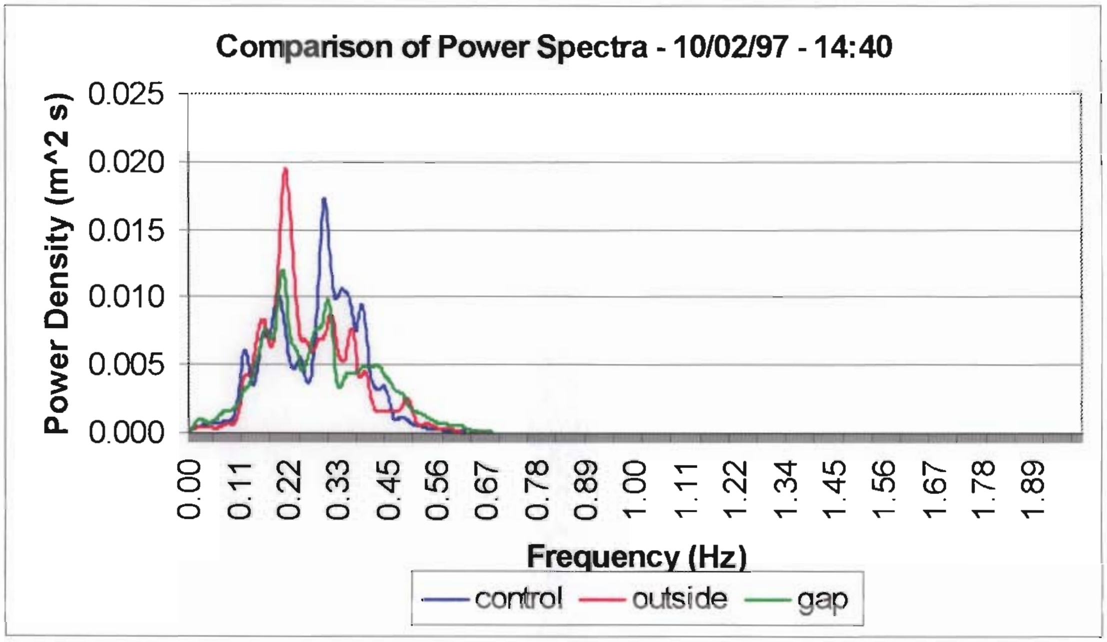

Comparison of Power Spectra - 10/02/97 - 13:00
Power Density (m^2 s)
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0.00 0.12 0.24 0.36 0.48 0.60 0.71 0.83 0.95 1.07 1.19 1.31 1.43 1.55 1.67 1.79 1.91
Frequency (Hz)
control
outside
inside


Comparison of Power Spectra - 10/02/97 - 13:20
Power Density (m^2 s)
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0.00 0.11 0.21 0.32 0.43 0.54 0.64 0.75 0.86 0.97 1.07 1.18 1.29 1.40 1.50 1.61 1.72 1.83 1.93
Frequency (Hz)
control
outside
inside

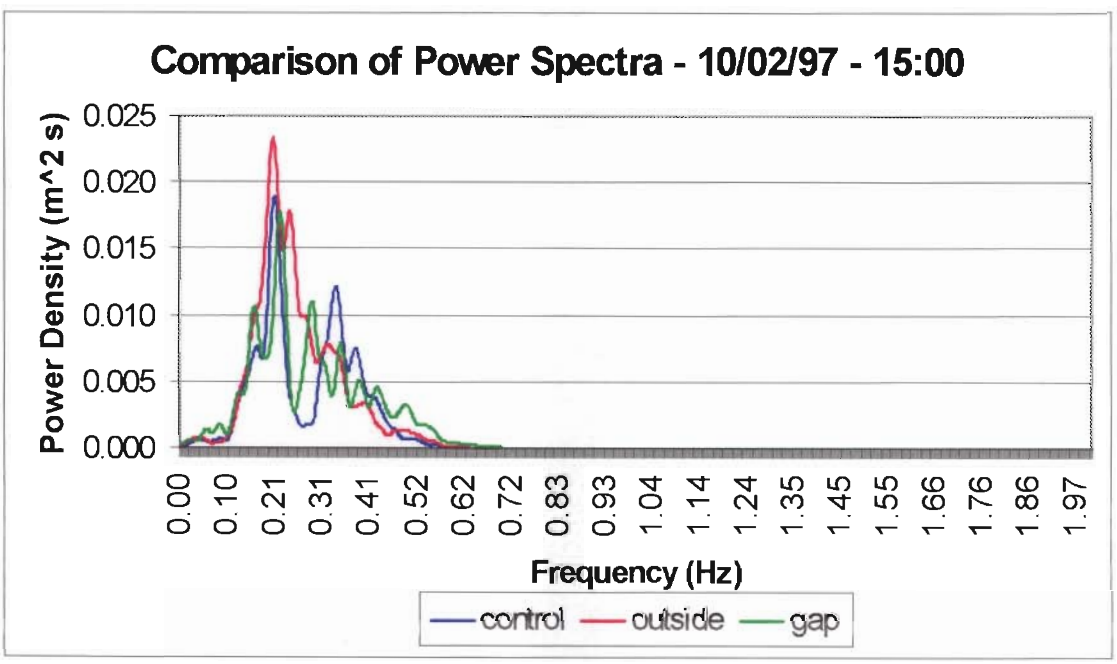

Comparison of PowerSpectra - 10/02/97 - 13:40
Power Density (m^2 s)
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0.00 0.10 0.20 0.30 0.41 0.51 0.61 0.71 0.81 0.91 1.02 1.12 1.22 1.32 1.42 1.52 1.63 1.73 1.83 1.93
Frequency (Hz)
control
outside
gap


Coparison of Power Spectra - 10/02/97 - 14:00
Power Density (m^2 s)
0.025
0.020
0.015
0.010
0.005
0.000
0.00 0.10 0.21 0.31 0.41 0.52 0.62 0.72 0.83 0.93 1.04 1.14 1.24 1.35 1.45 1.55 1.66 1.76 1.86 1.97
Frequency (Hz)
control outside gap

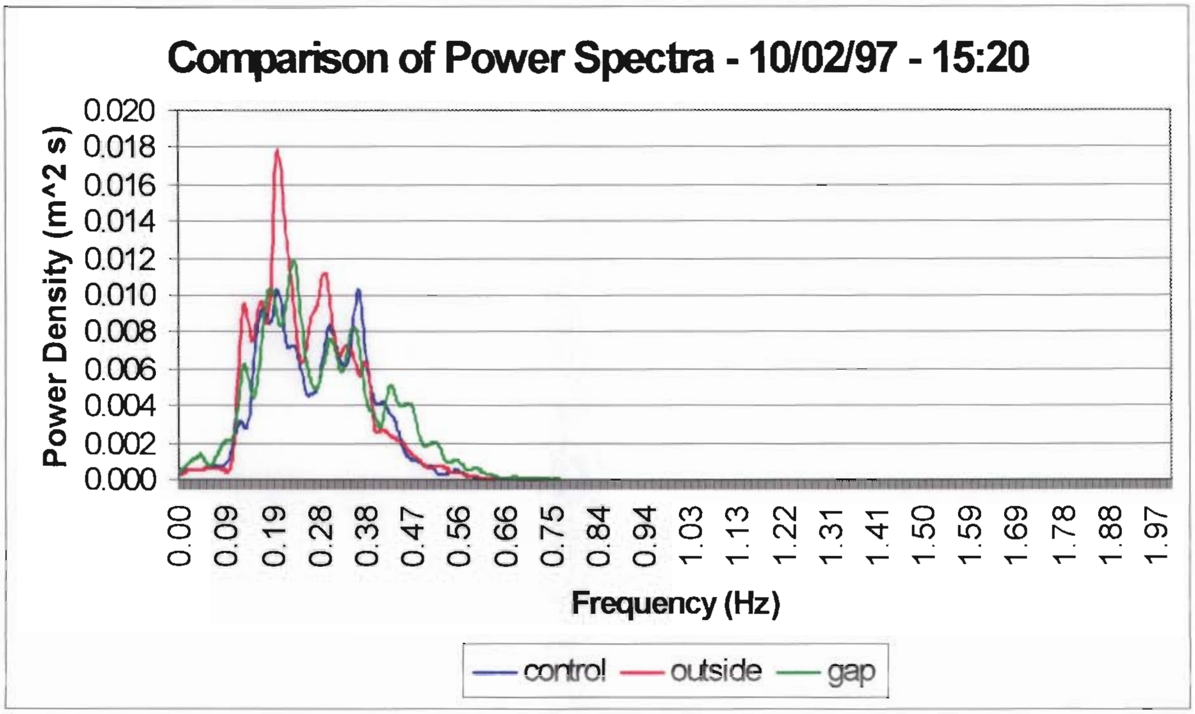

Comparison of Power Spetra - 10/02/97 - 14:20
Power Density (m^2 s)
0.025
0.020
0.015
0.010
0.005
0.000
0.00 0.11 0.21 0.32 0.43 0.54 0.64 0.75 0.86 0.97 1.07 1.18 1.29 1.40 1.50 1.61 1.72 1.83 1.93
Frequency (Hz)
control outside gap

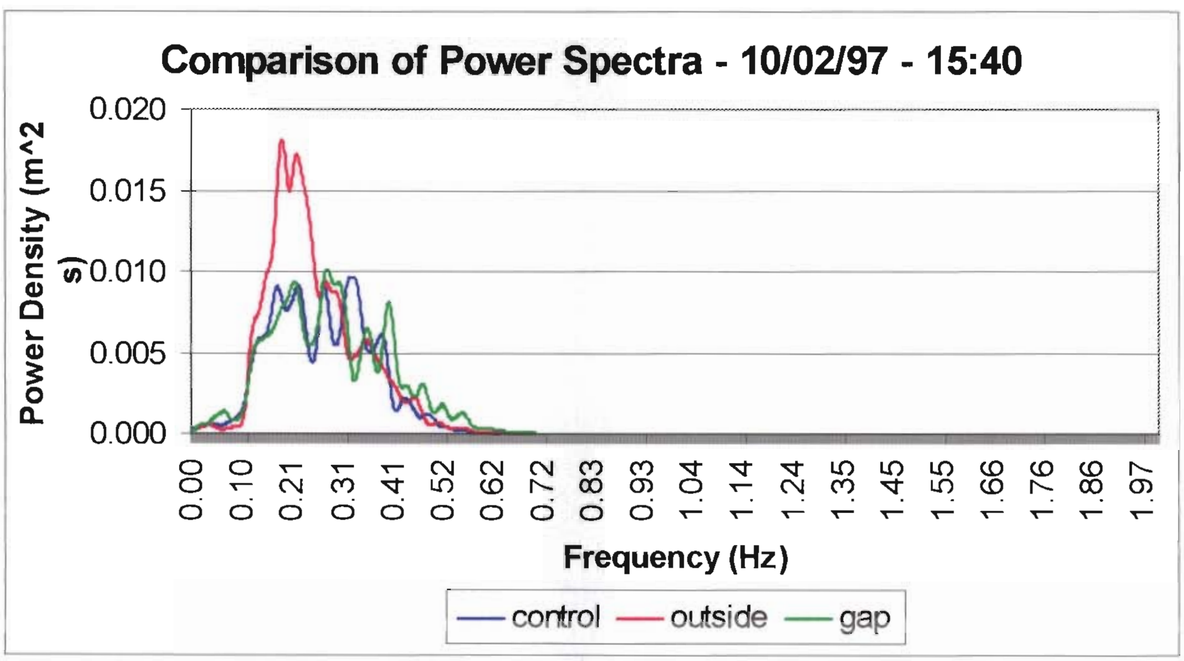


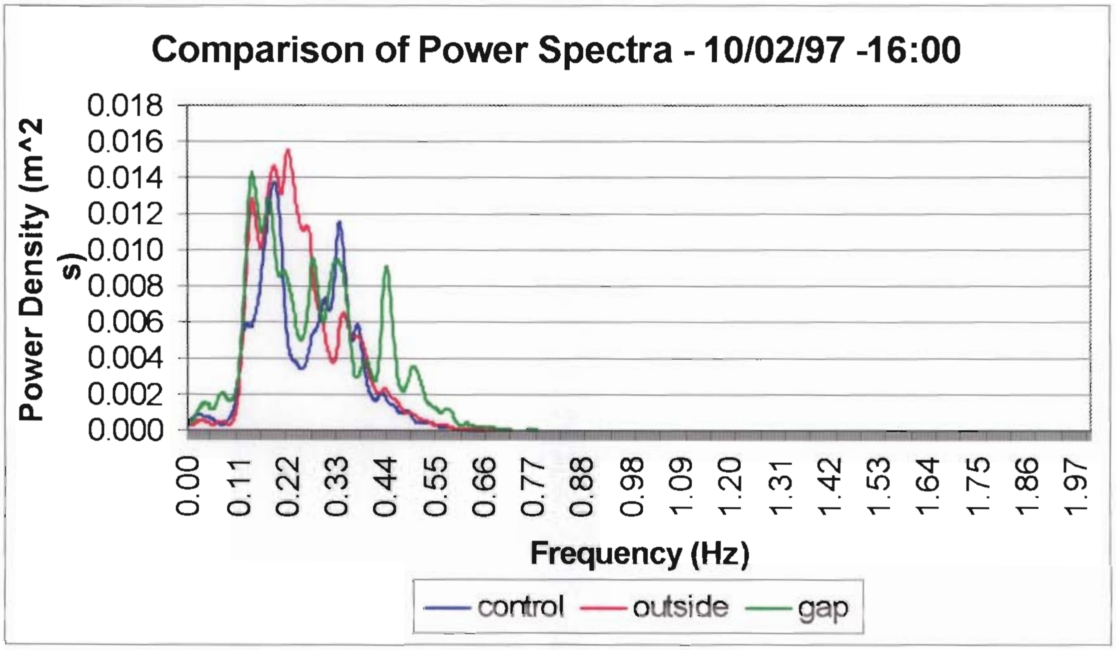
Comparison of Power Spectra - 10/02/97 - 14:40
Power Density (m^2 s)
0.025
0.020
0.015
0.010
0.005
0.000
0.00
0.11
0.22
0.33
0.45
0.56
0.67
0.78
0.89
1.00
1.11
1.22
1.34
1.45
1.56
1.67
1.78
1.89
Frequency (Hz)
control
outside
gap



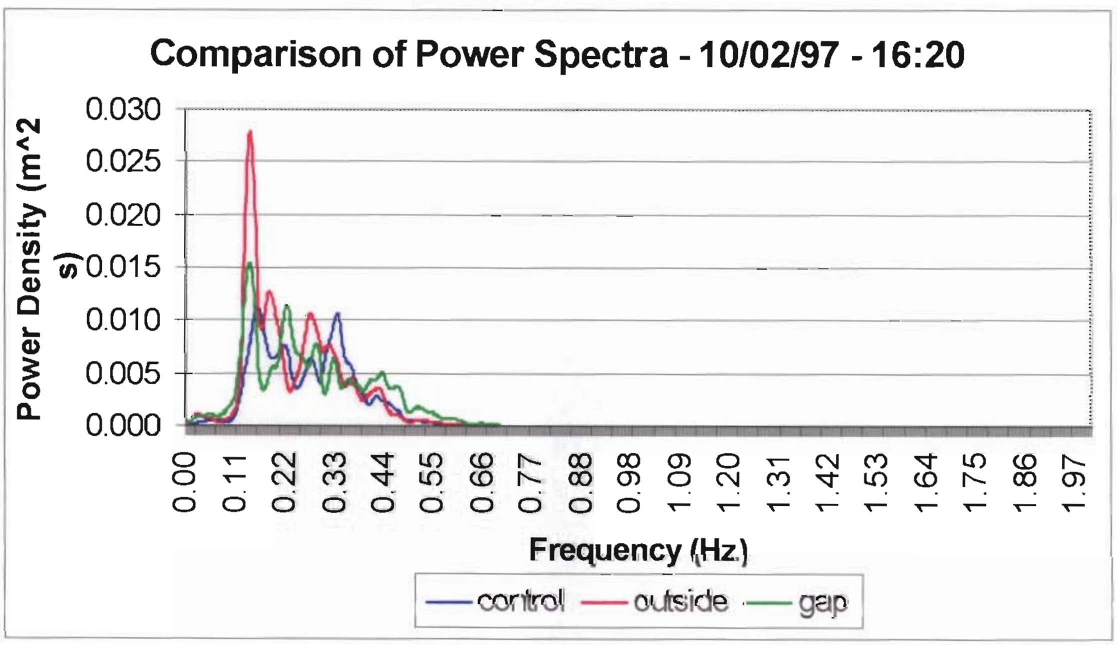
Comparison of Power Spectra - 10/02/97 - 15:00
Power Density (m^2 s)
0.025
0.020
0.015
0.010
0.005
0.000
0.00
0.10
0.21
0.31
0.41
0.52
0.62
0.72
0.83
0.93
1.04
1.14
1.24
1.35
1.45
1.55
1.66
1.76
1.86
1.97
Frequency (Hz)
control
outside
gap


Comparison of Power Spectra - 10/02/97 - 15:20
Power Density (m^2 s)
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0.00 0.09 0.19 0.28 0.38 0.47 0.56 0.66 0.75 0.84 0.94 1.03 1.13 1.22 1.31 1.41 1.50 1.59 1.69 1.78 1.88 1.97
Frequency (Hz)
control
outside
gap


Comparison of Power Spectra - 10/02/97 - 15:40
Power Density (m^2 s)
0.020
0.015
0.010
0.005
0.000
0.00 0.10 0.21 0.31 0.41 0.52 0.62 0.72 0.83 0.93 1.04 1.14 1.24 1.35 1.45 1.55 1.66 1.76 1.86 1.97
Frequency (Hz)
control
outside
gap



Comparison of Power Spectra - 10/02/97 -16:00
Power Density (m^2 s)
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0.00 0.11 0.22 0.33 0.44 0.55 0.66 0.77 0.88 0.98 1.09 1.20 1.31 1.42 1.53 1.64 1.75 1.86 1.97
Frequency (Hz)
control
outside
gap



Comparison of Power Spectra - 10/02/97 - 16:20
Power Density (m^2 s)
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0.00 0.11 0.22 0.33 0.44 0.55 0.66 0.77 0.88 0.98 1.09 1.20 1.31 1.42 1.53 1.64 1.75 1.86 1.97
Frequency (Hz)
control
outside
gap

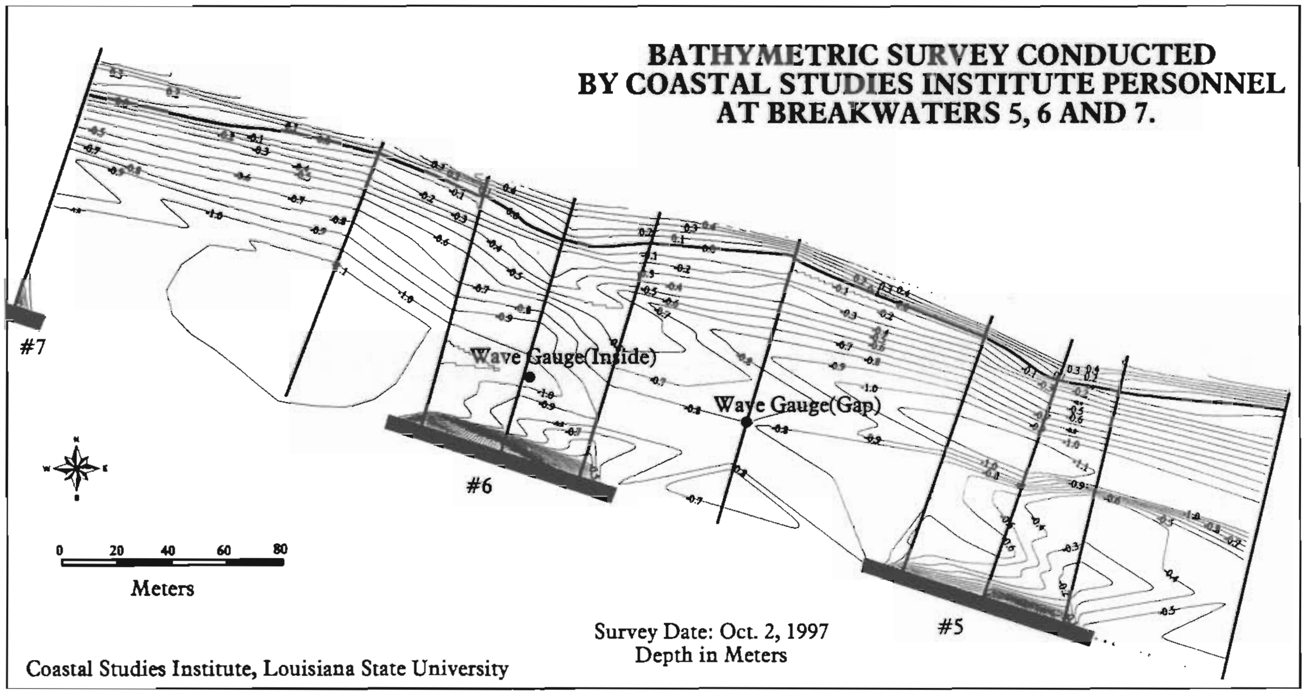
APPENDIX 6

Rhythmic shoreline patterns developed behind the segmented breakwaters

A: Photos illustrating shoreline accretion behind the center of the breakwaters and retreat along Raccoon Island adjacent to the gap between the breakwaters

B: Bathymetric map illustrating the rhythmic shoreline features.

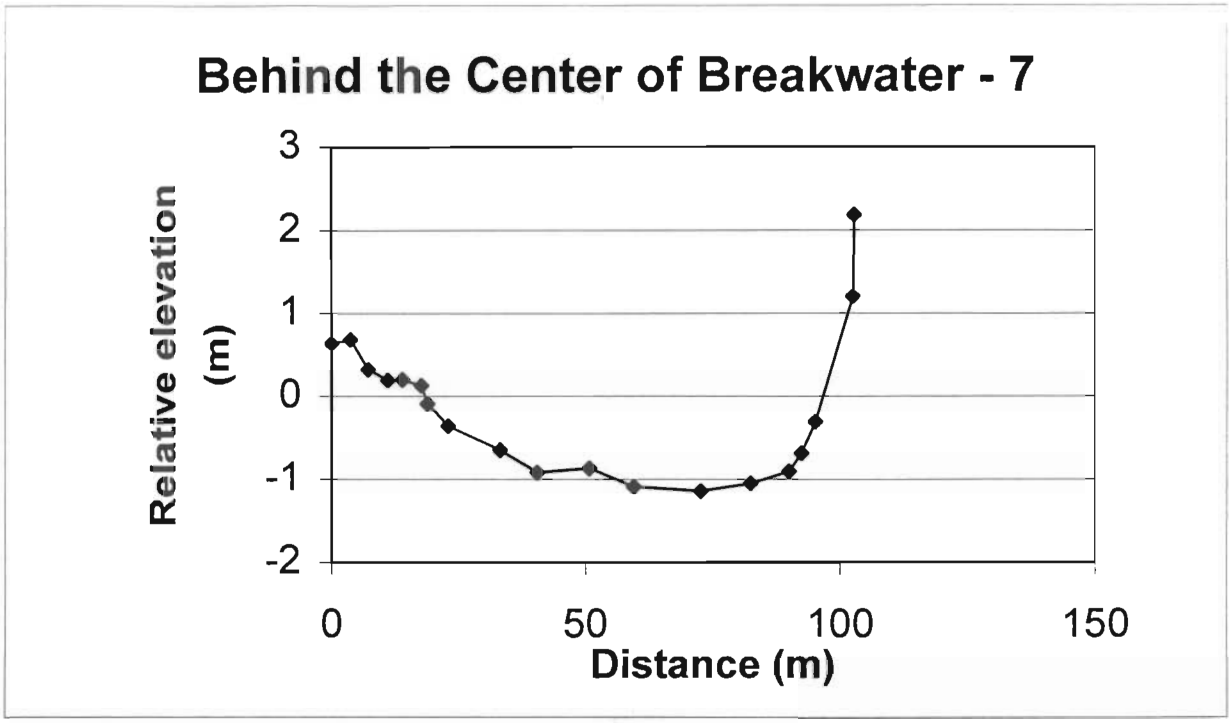
A

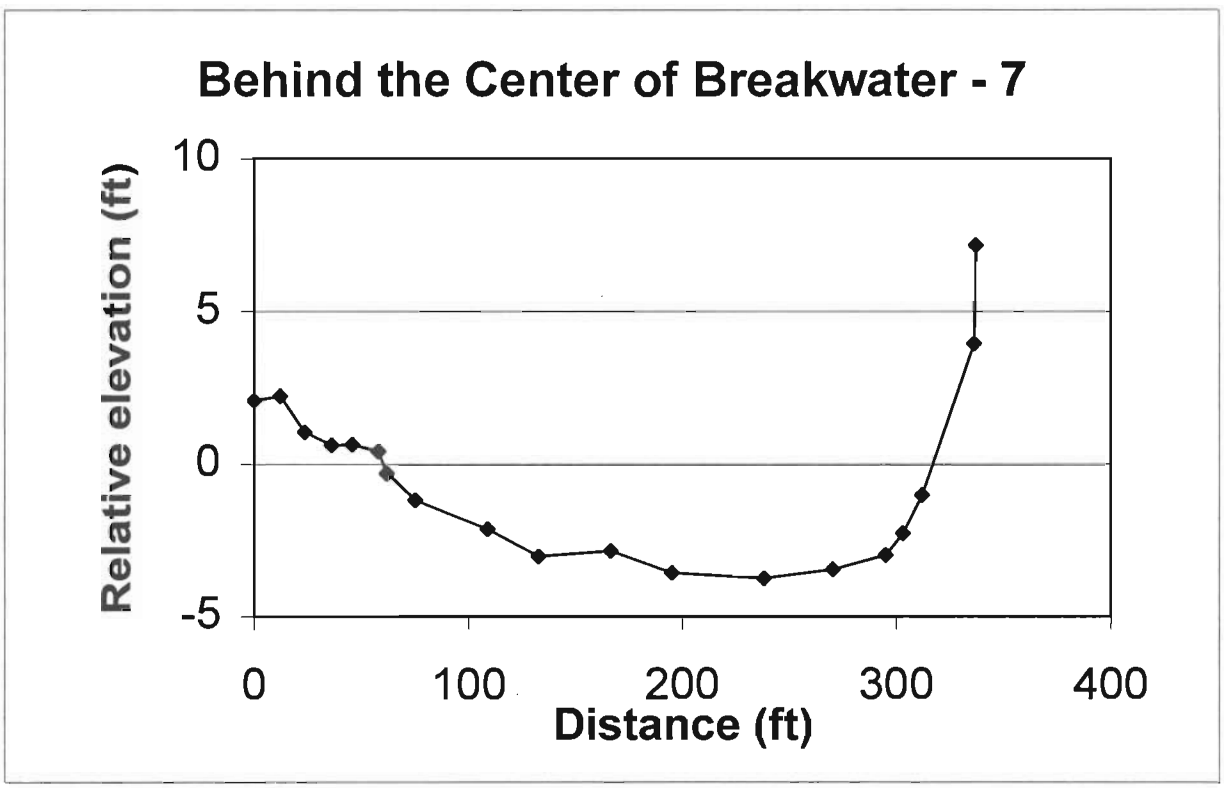

BATHYMETRIC SURVEY CONDUCTED
BY COASTAL STUDIES INSTITUTE PERSONNEL
AT BREAKWATERS 5, 6 AND 7.
#7
#6
#5
Wave Gauge(Inside)
Wave Gauge(Gap)
0 20 40 60 80
Meters
Survey Date: Oct. 2, 1997
Depth in Meters
Coastal Studies Institute, Louisiana State University

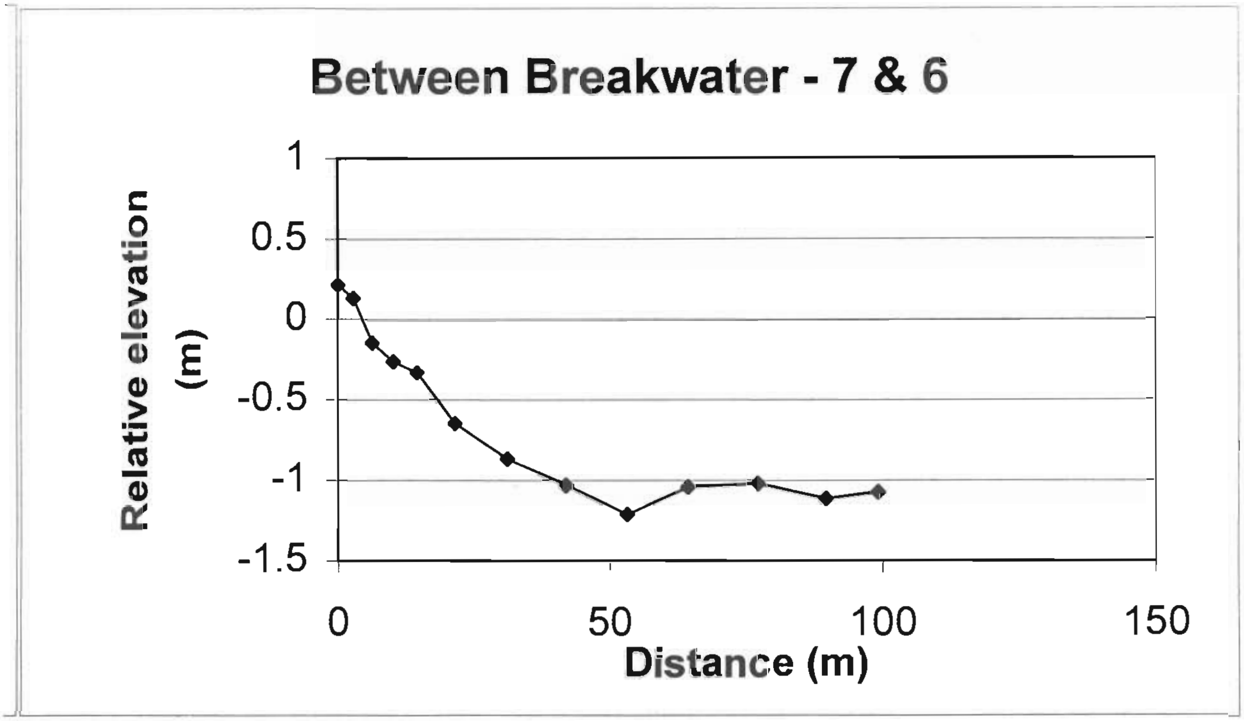
B

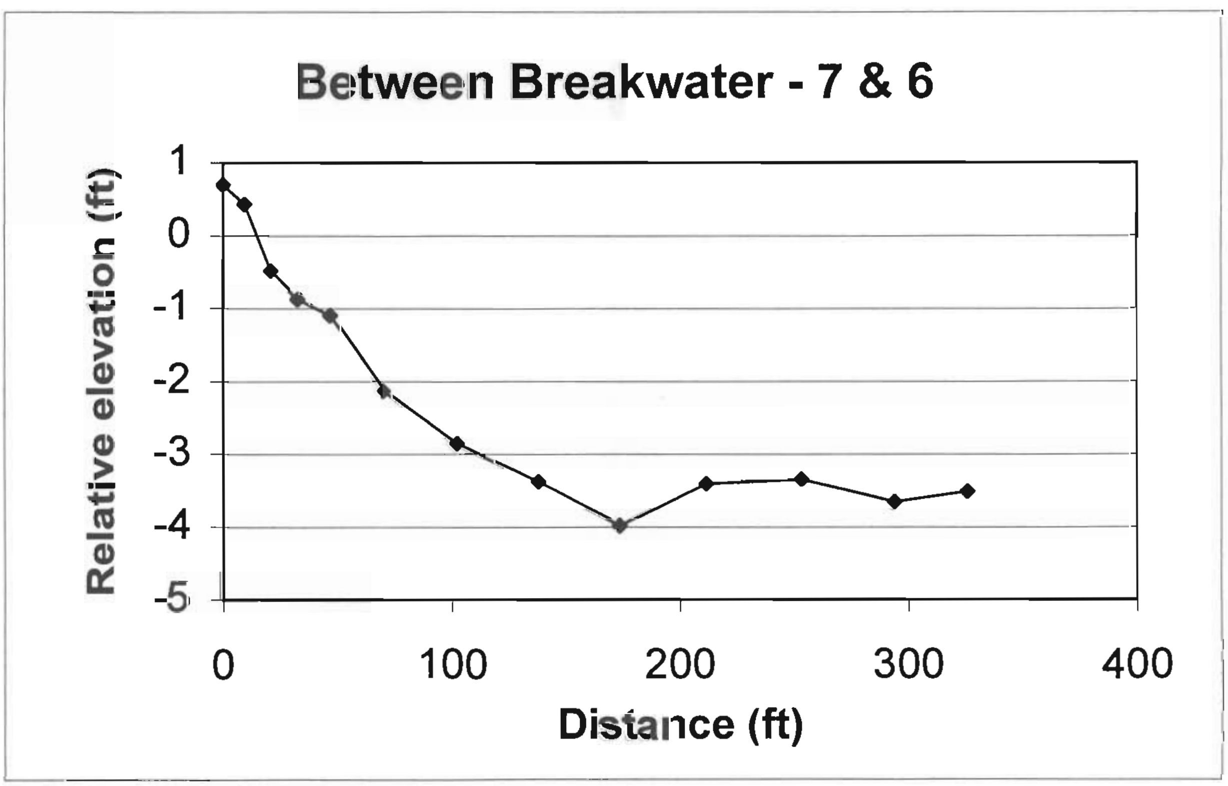
APPENDIX 7

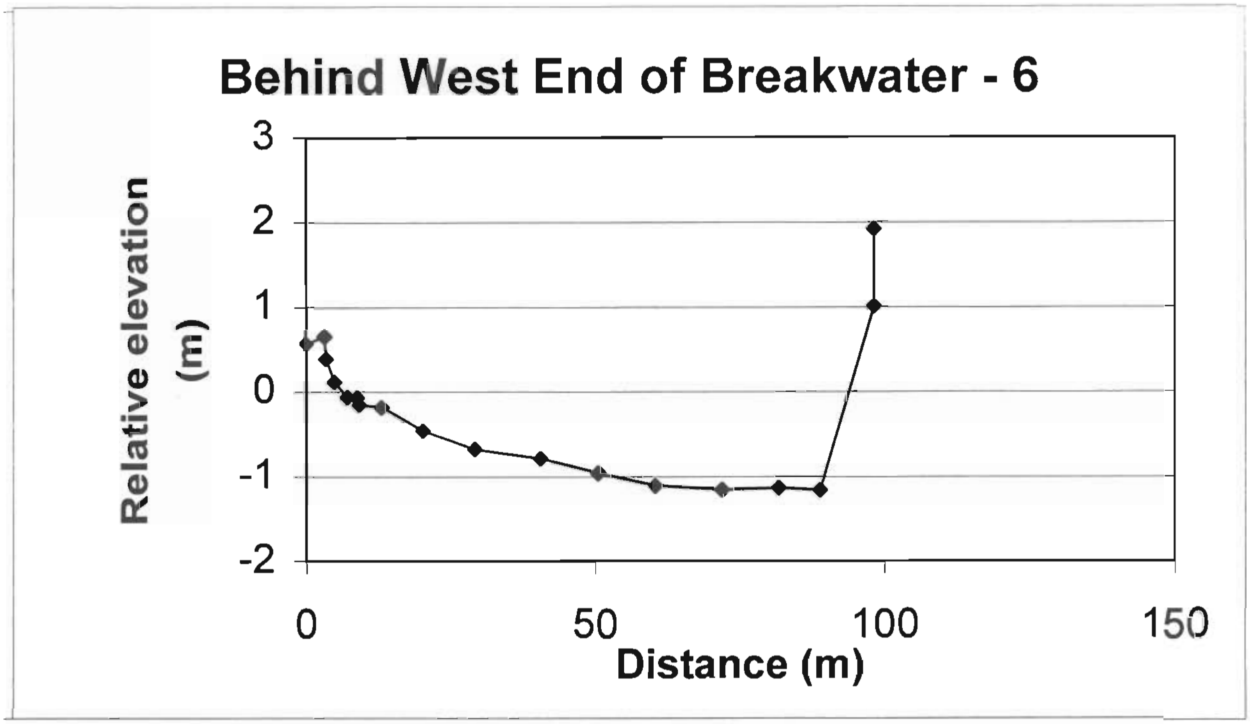
Beach profiles (profile locations are shown in Figure 1): Upper figures are in metric unites; lower figures are in English units.

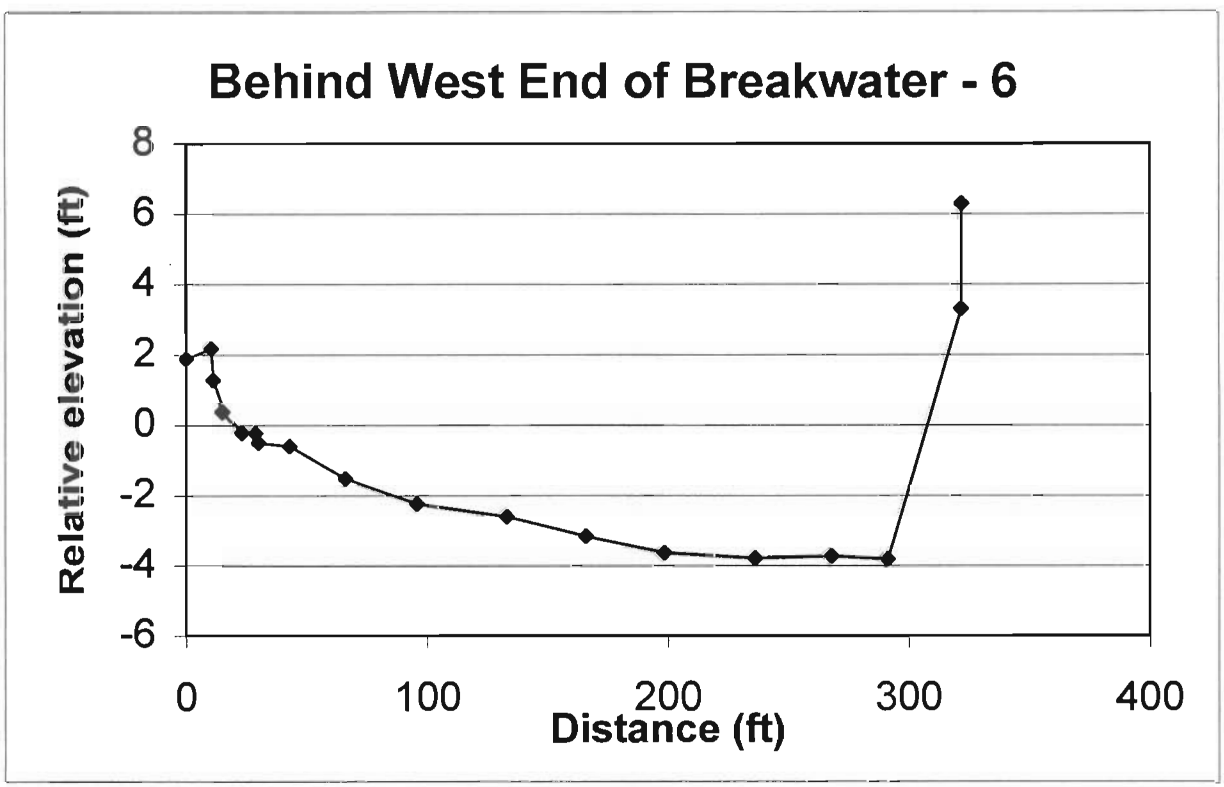

Behind the Center of Breakwater - 7
3
2
1
0
-1
-2
Relative elevation (m)
0
50
100
150
Distance (m)

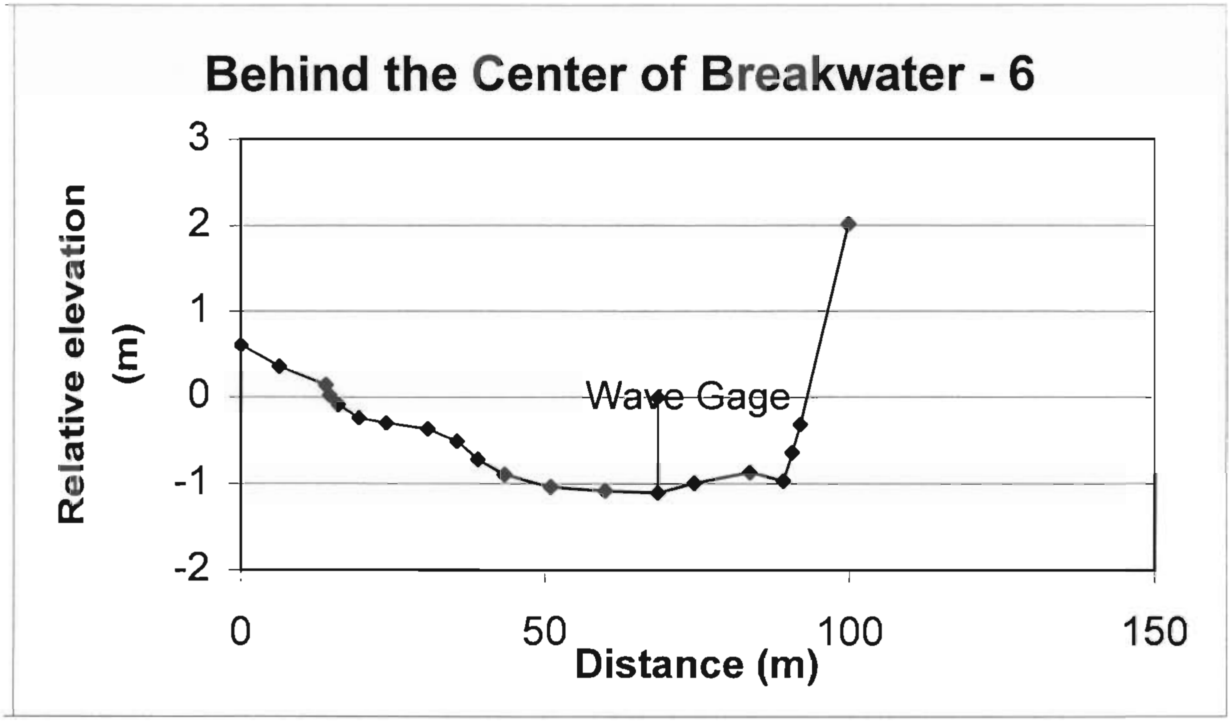

Behind the Center of Breakwater - 7
10
5
0
-5
Relative elevation (ft)
0
100
200
300
400
Distance (ft)

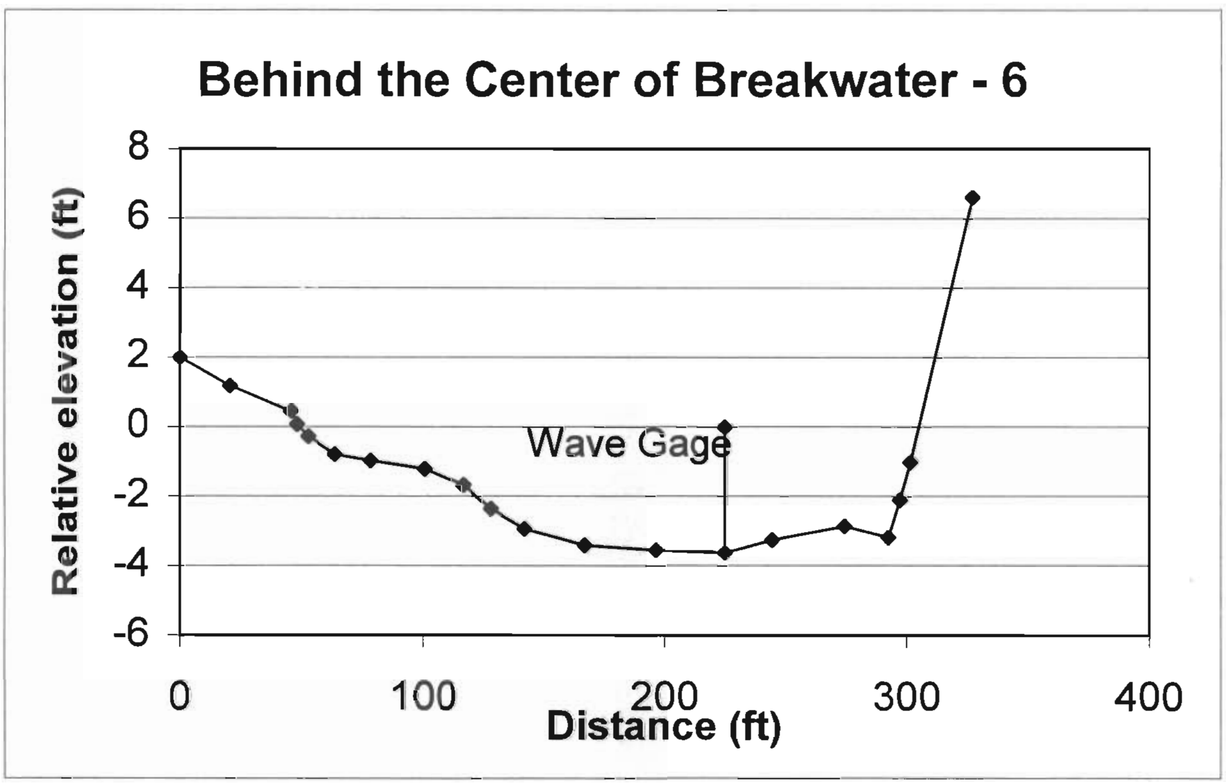

Between Breakwater - 7 & 6
Relative elevation (m)
1
0.5
0
-0.5
-1
-1.5
0
50
100
150
Distance (m)

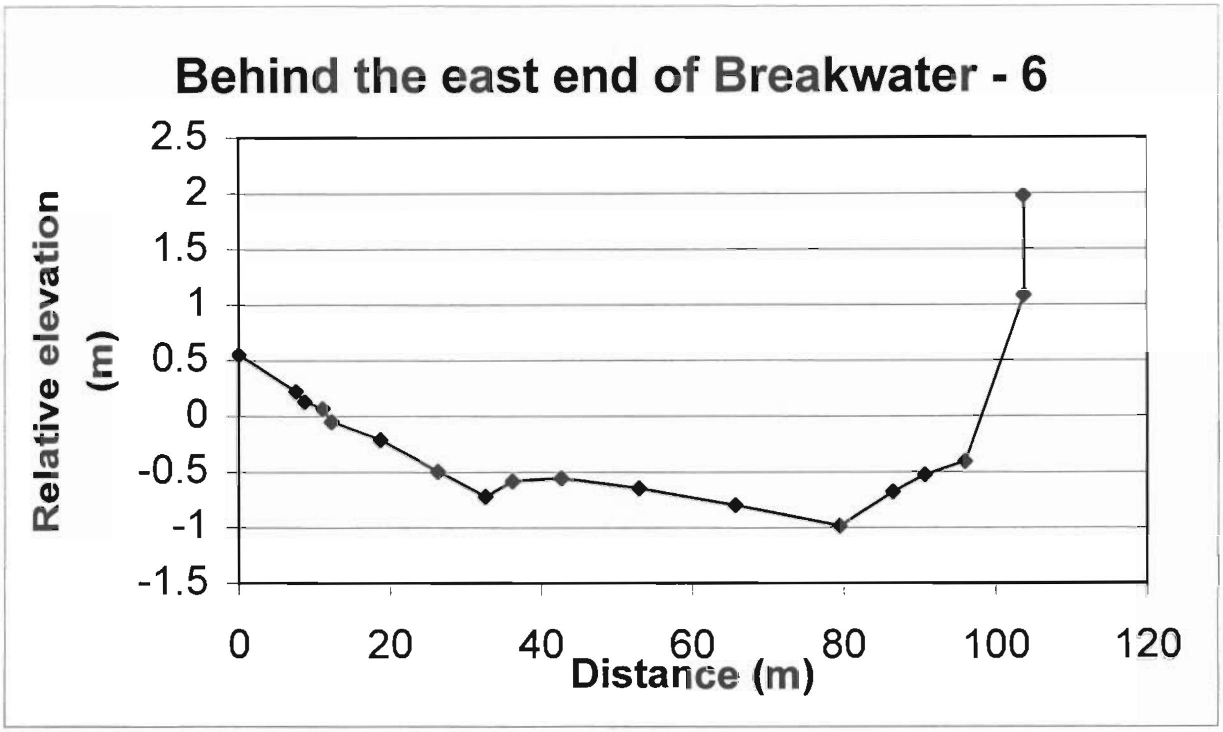

Between Breakwater - 7 & 6
Relative elevation (ft)
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
Distance (ft)

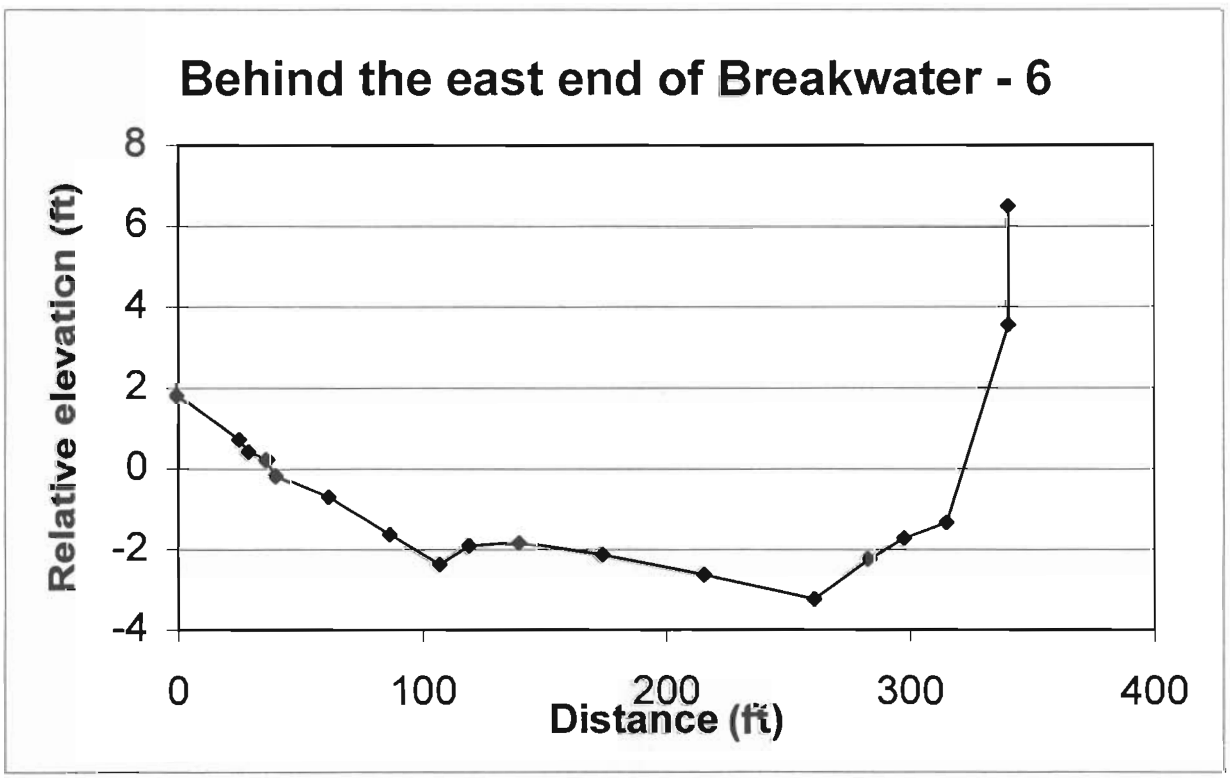

Behind West End of Breakwater - 6
Relative elevation (m)
3
2
1
0
-1
-2
0
50
100
150
Distance (m)

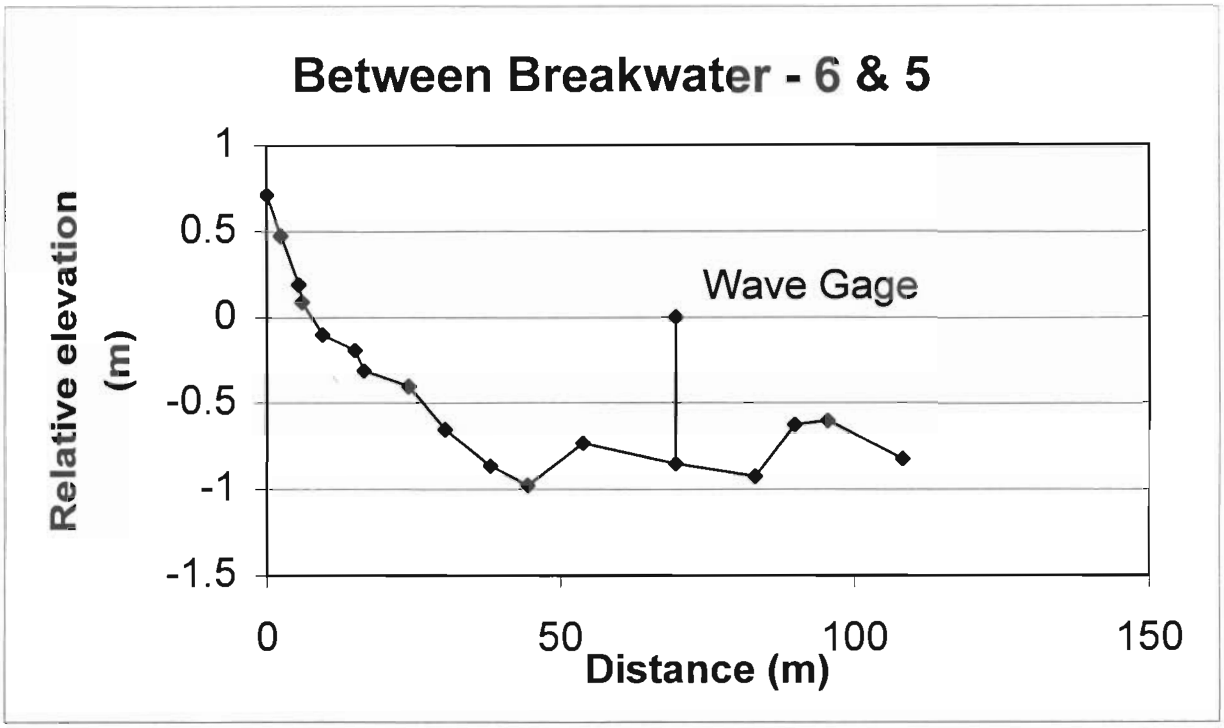

Behind West End of Breakwater - 6
Relative elevation (ft)
8
6
4
2
0
-2
-4
-6
0
100
200
300
400
Distance (ft)

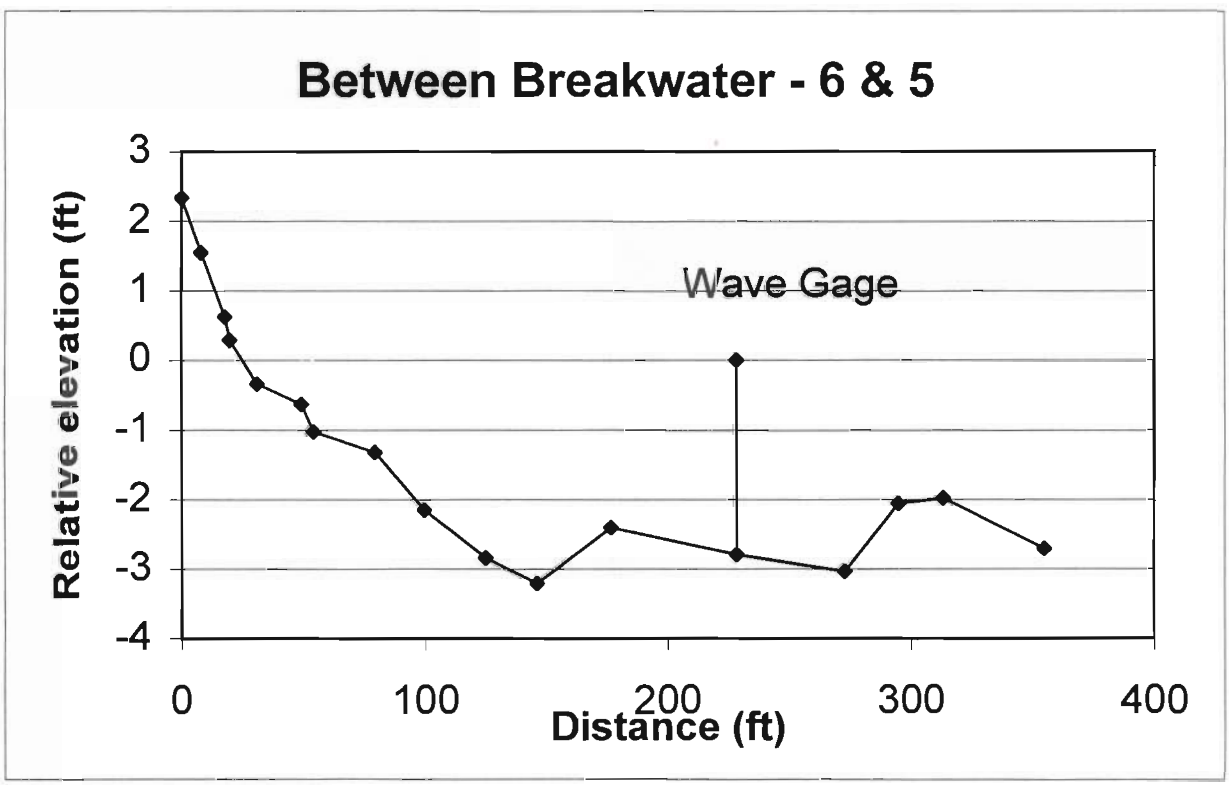

Behind the Center of Breakwater - 6
Relative elevation (m)
3
2
1
0
-1
-2
Wave Gage
0
50
100
150
Distance (m)

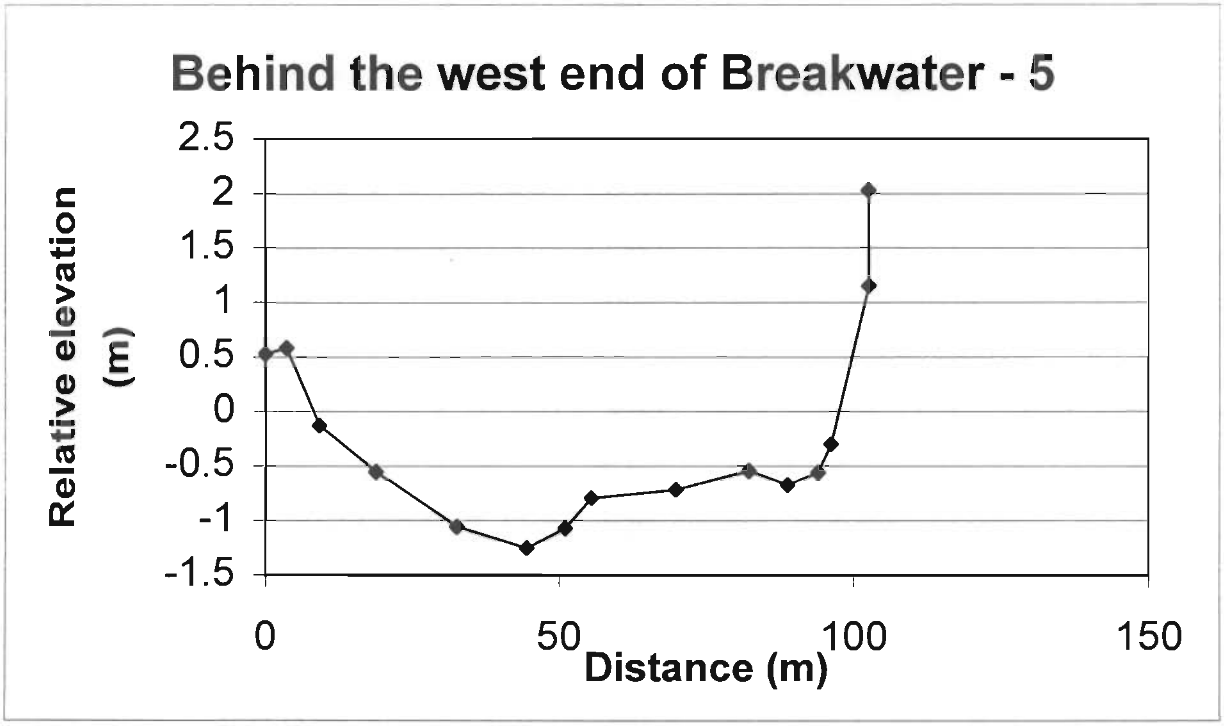

Behind the Center of Breakwater - 6
Relative elevation (ft)
8
6
4
2
0
-2
-4
-6
Wave Gage
0
100
200
300
400
Distance (ft)

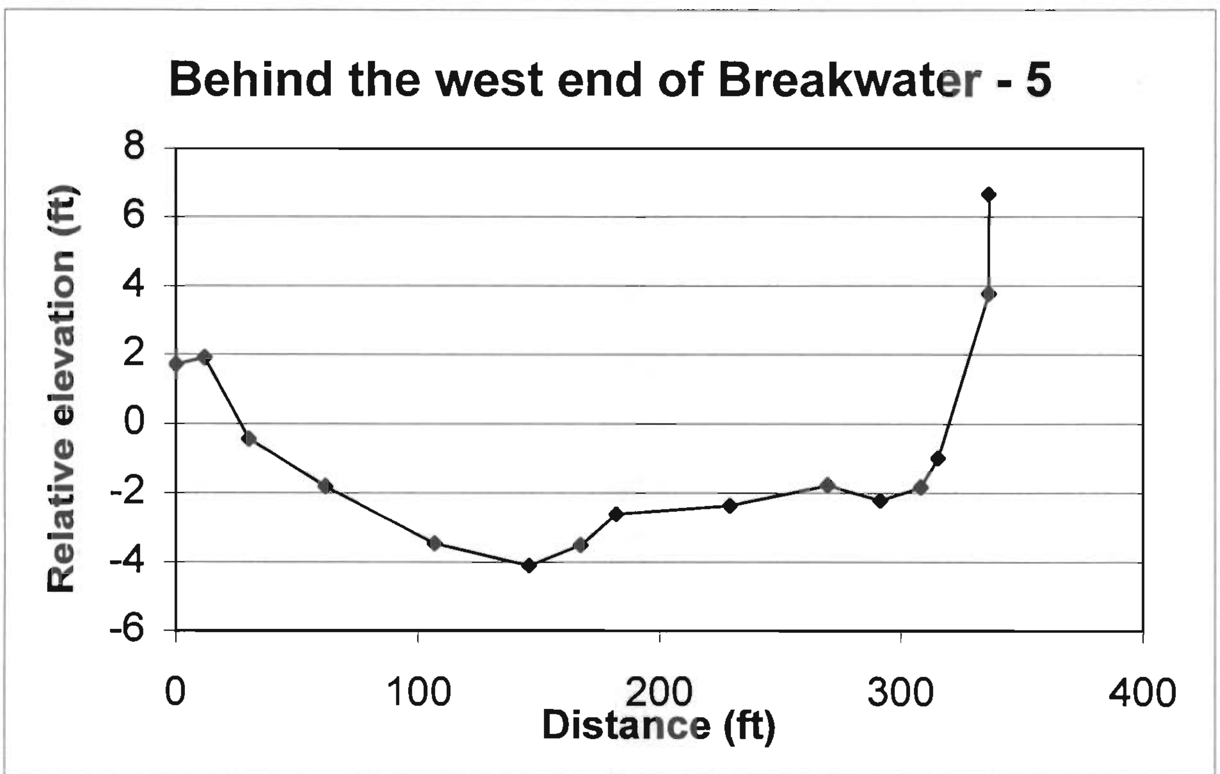

Behind the east end of Breakwater - 6
Relative elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
20
40
60
80
100
120
Distance (m)

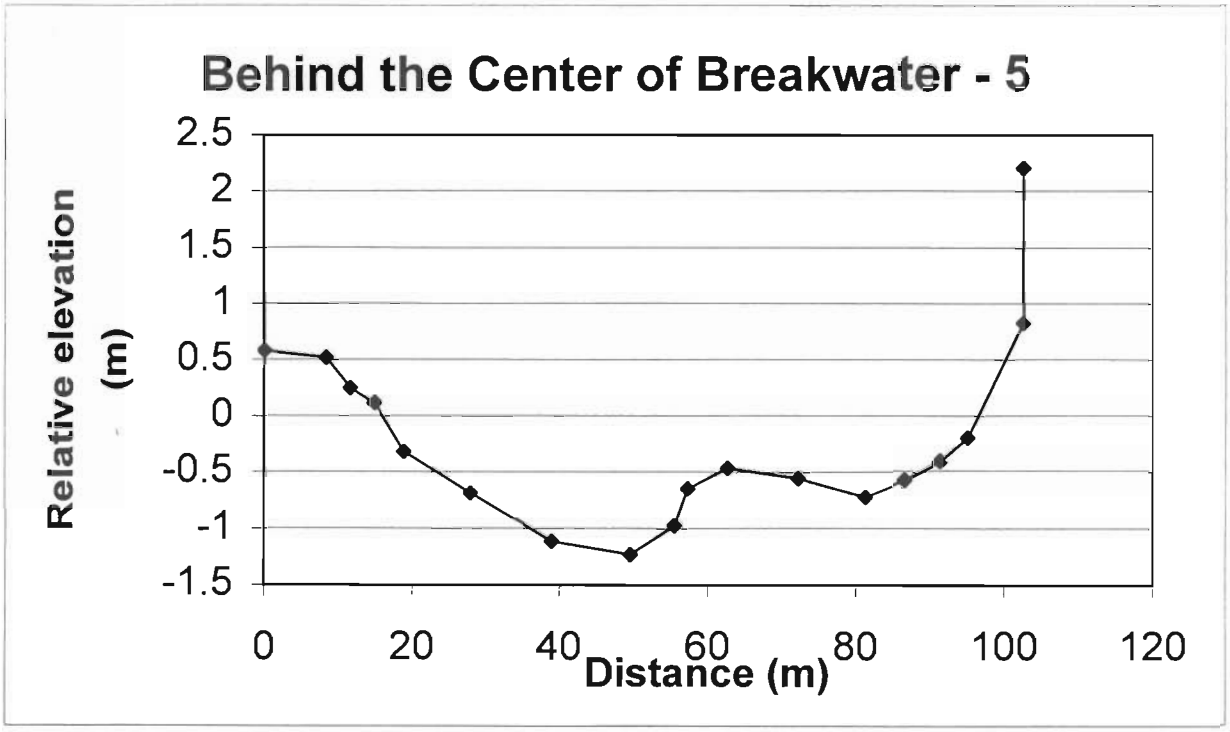

Behind the east end of Breakwater - 6
Relative elevation (ft)
8
6
4
2
0
-2
-4
0
100
200
300
400
Distance (ft)

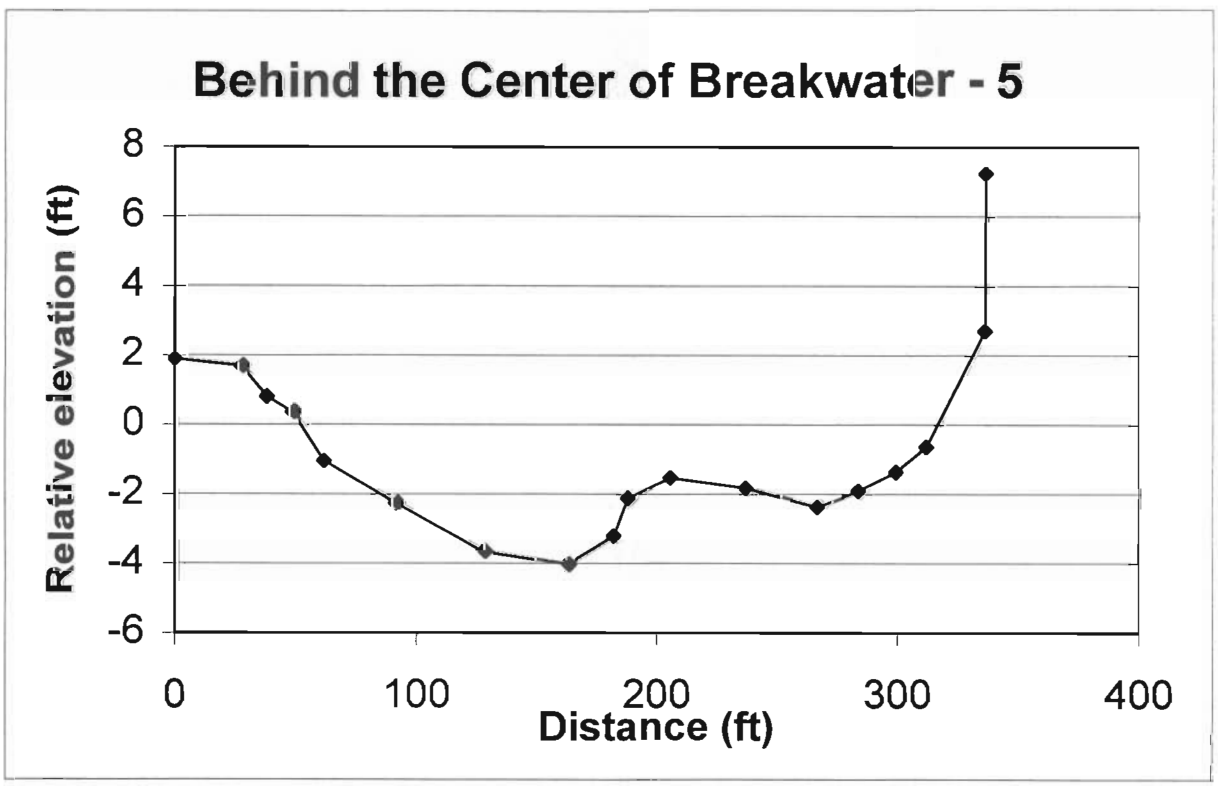

Between Breakwater - 6 & 5
Relative elevation (m)
1
0.5
0
-0.5
-1
-1.5
Wave Gage
0
50
100
150
Distance (m)

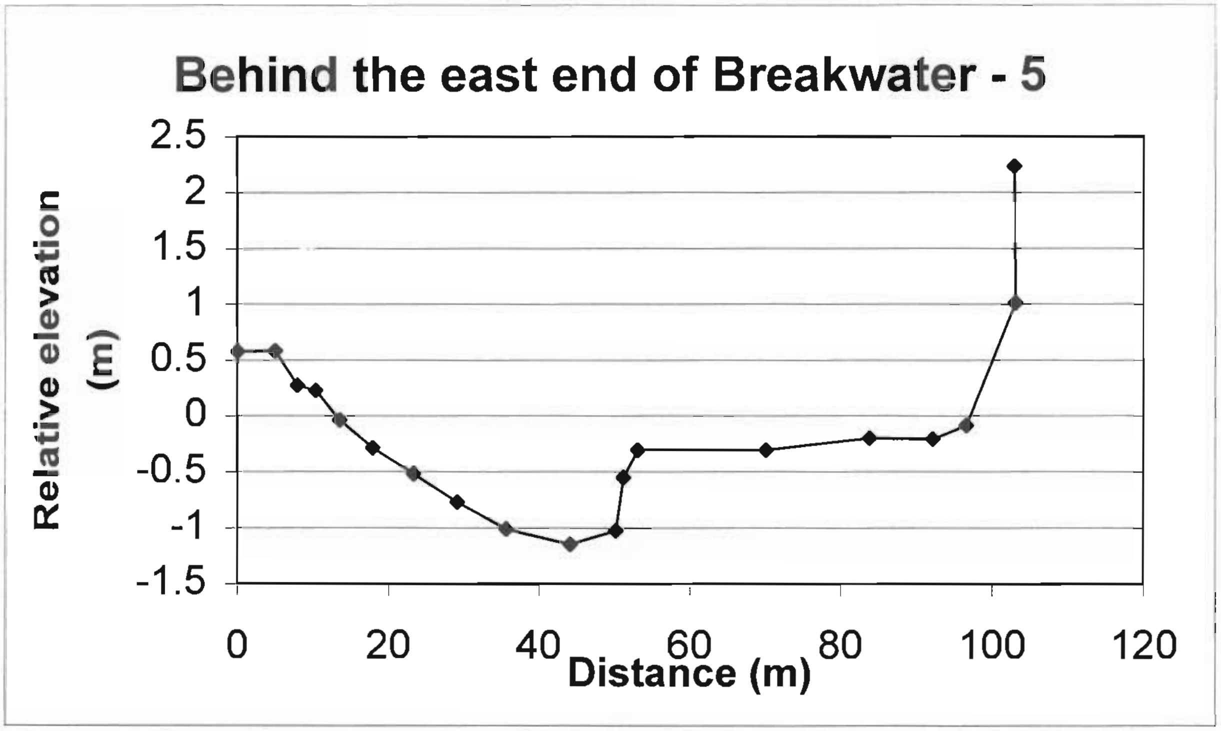

Between Breakwater - 6 & 5
Relative elevation (ft)
3
2
1
0
-1
-2
-3
-4
Wave Gage
0
100
200
300
400
Distance (ft)


Behind the west end of Breakwater - 5
Relative elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
50
100
150
Distance (m)

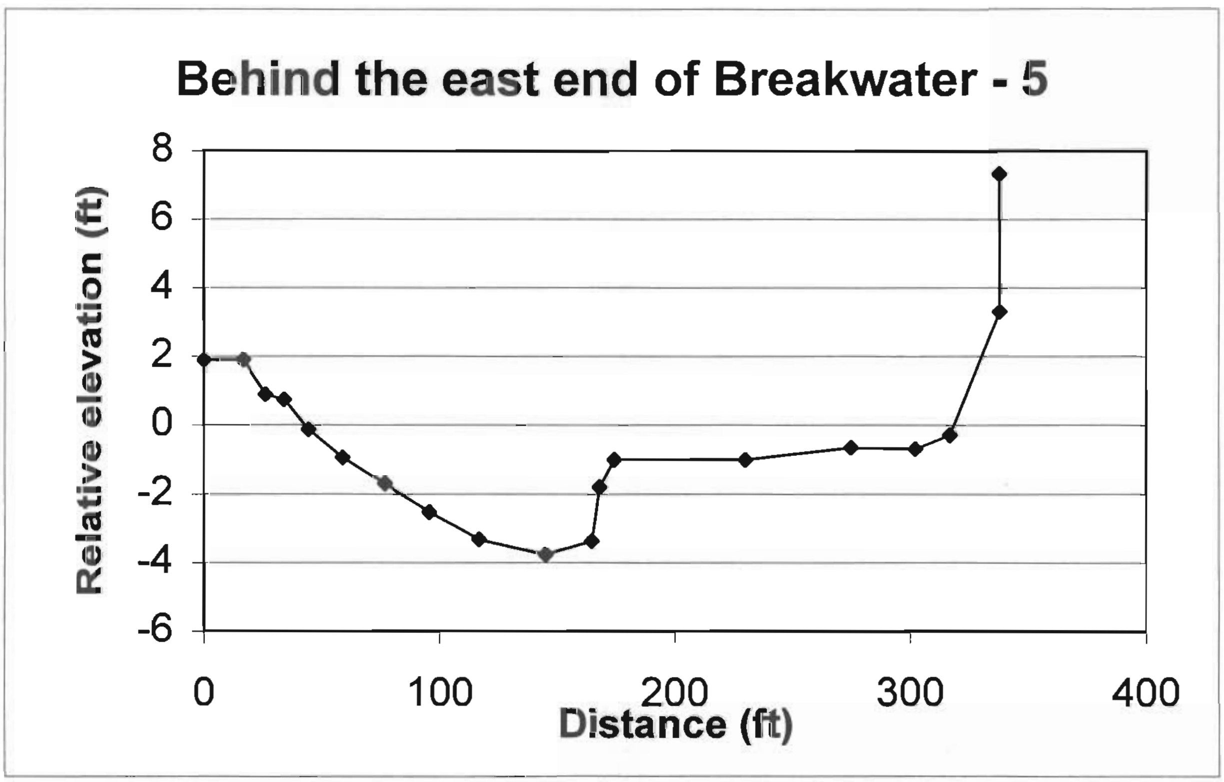

Behind the west end of Breakwater - 5
Relative elevation (ft)
8
6
4
2
0
-2
-4
-6
0
100
200
300
400
Distance (ft)


Behind the Center of Breakwater - 5
Relative elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
20
40
60
80
100
120
Distance (m)

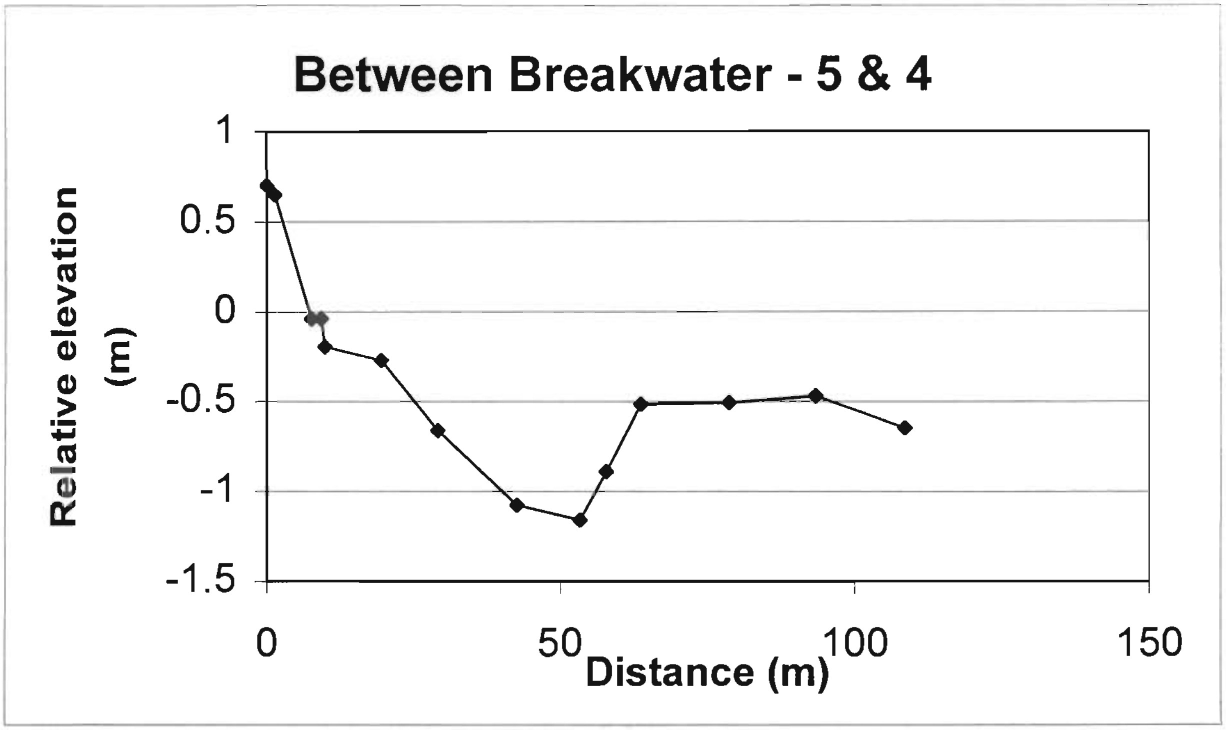

Behind the Center of Breakwater - 5
Relative elevation (ft)
8
6
4
2
0
-2
-4
-6
0
100
200
300
400
Distance (ft)



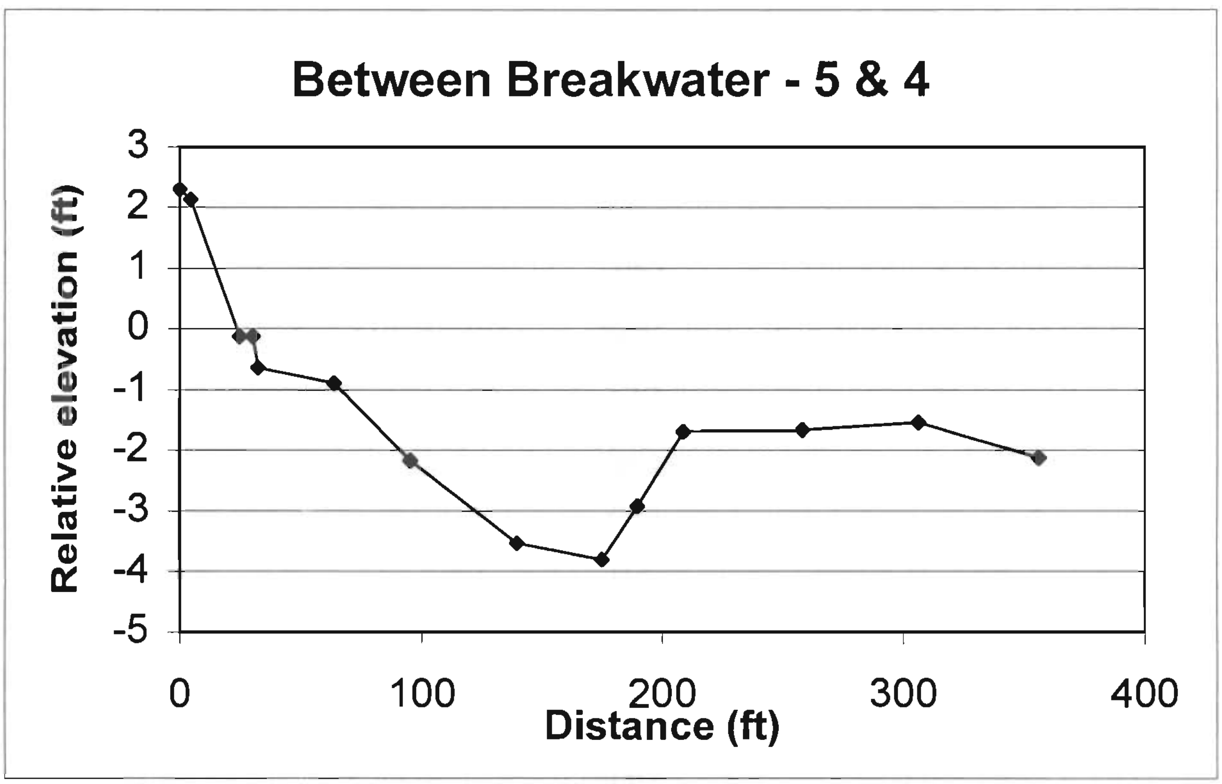
Behind the east end of Breakwater - 5
Relative elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
20
40
60
80
100
120
Distance (m)



Behind the east end of Breakwater - 5
Relative elevation (ft)
8
6
4
2
0
-2
-4
-6
0
100
200
300
400
Distance (ft)



Between Breakwater - 5 & 4
Relative elevation (m)
1
0.5
0
-0.5
-1
-1.5
0
50
100
150
Distance (m)



Between Breakwater - 5 & 4
Relative elevation (ft)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
Distance (ft)