



Beach Monitoring in the Auckland Region

Beach Profile Analysis

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Beach Monitoring in the Auckland Region: Beach Profile Analysis

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Prepared for
Auckland Regional Council

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Preface

This report analyses the beach profile records from beaches in the Auckland region (Piha, Muriwai, Campbells Bay, Milford, Takapuna, Browns Bay, Long Bay, Mangawhai, Te Arai, Pakiri, Omaha, Maraetai, Kawakawa Bay and Orere Point) and details beach status using changes in beach width and beach sediment volume for each beach profile. An accompanying review of the programme was also undertaken and is available as an Auckland Regional Council internal report (Beach Monitoring in the Auckland Region: A Review of the Current Monitoring Programme. Auckland Regional Council Internal Report: IR 2008/004 pg 21). The review outlines the strengths and weakness of the current protocols and reviews various methodologies employed in contemporary beach monitoring and the feasibility of such approaches to beach monitoring objectives. Finally a set of recommendations are provided to strengthen the monitoring programme.

Contents

Beach Monitoring in the Auckland Region	1
Beach Monitoring in the Auckland Region: Beach Profile Analysis	3
1 Executive Summary	7
2 Introduction	9
2.1 Data analysis and interpretation	9
3 Study Approach	10
4 Analysis of Beach Monitoring Records	11
4.1 Introduction	11
4.2 Study Sites	11
4.3 Methodology	12
4.3.1 Beach volume analysis	13
4.3.2 Beach width analysis	14
4.3.3 Beach envelope analysis	14
4.4 Results of Beach Profile Analysis	14
4.4.1 Browns Bay	16
4.4.2 Campbells Bay	18
4.4.3 Milford Beach	20
4.4.4 Takapuna	22
4.4.5 Kawakawa Bay	24
4.4.6 Maraetai	26
4.4.7 Orere Point	28
4.4.8 Piha	30
4.4.9 Muriwai Beach	32
4.4.10 Long Bay	37
4.4.11 Omaha Beach	39
4.4.12 Mangawhai Beach	44
4.4.13 Te Arai	47
4.4.14 Pakiri Beach	50
4.5 Summary of Beach Change	55

4.6	Value of Monitoring Records to Support Hazard Evaluation	56
4.7	Causes of Beach Change	57
4.8	Monitoring of Relevant Environmental Variables	57
5	Summary of the Coastal Monitoring Programme	59
5.1	Summary of Existing Programme	59
6	References	60
	Appendix 1	61
	Summary of Envelope of Beach Change	61

1 Executive Summary

This study was commissioned by the Auckland Regional Council (ARC) to analyse and interpret data collected for beaches in the existing ARC beach monitoring network.

The ARC's existing monitoring programme is characterized by:

- beach profiles on 16 beaches that represent 4 contrasting wave energy settings in the Auckland region,
- profiles are surveyed at six monthly or monthly intervals (at East Coast Bays beaches) complemented with post-storm surveys, and
- monitoring records that range in length from 10 years to 30 years.

This report has undertaken an analysis of the monitoring record of 14 beaches in the Auckland region (Piha, Muriwai, Campbells Bay, Milford, Takapuna, Browns Bay, Long Bay, Mangawhai, Te Arai, Pakiri, Omaha, Maraetai, Kawakawa Bay and Orere Point). In particular, protocols were established to examine beach status using changes in beach width and beach sediment volume. The envelope of beach change was also established for each beach profile.

Results show that the ARC beach monitoring programme has generated valuable information on the short-term, seasonal and inter-annual scale variability in beach morphology. It is also apparent that the magnitude of this variability differs both between beaches and within beaches. Between beach variations broadly correspond to the different coastal settings as discriminated by wave energy.

The shorter datasets (~10 years) are currently of insufficient length to determine net medium or long-term erosion or accretion trends. However, there is little sign of chronic erosion or accelerated accretion in the beach systems analysed.

The beaches with longer (>20 year) records reveal some long-term trends in beach behaviour:

- At Muriwai two profiles indicated net long-term shoreline erosion whereas other profiles indicated net beach accretion.
- There is evidence of an increase in sediment volume contained within a number of profiles at Piha. However, increases in sediment volume are only noticeable on individual profiles and are not consistent across the beach.
- At Omaha there has been a net increase in sediment volume on profiles since the 1978 storm events.
- At Pakiri long-term trends are difficult to determine due to significant short and medium-term variability. However, the beach profiles do not appear to be undergoing active erosion and are considered stable through the monitoring record.
- At Mangawhai, Pakiri, and Omaha there is clear evidence of decadal scale oscillations in beach behaviour (Figures 35, 36, 38, 39, 44, 45). However, the precise mechanisms causing beach change at these timescales is unclear.

Importantly, the existing monitoring data has defined the envelope of beach change. These envelopes provide the necessary baseline information to detect future coastal change. It is important to note that in all the beaches analysed there were no examples where the most recent survey of beach position was landward of the historic envelop of beach change.

Continued commitment to maintaining a longitudinal monitoring programme is of critical importance for expanding the value of the data to support hazard management and medium-term coastal change analysis.

In summary, valuable data has been gathered through the ARC's commitment to a beach monitoring programme. This momentum needs to be maintained through continued longitudinal surveying. However, critical thought needs to be given to the purpose and structure of these activities to ensure the most effective use of data to aid future decision-making.

2 Introduction

A foundation document and clear objective for monitoring the physical condition of the coast of the Auckland region has not been established. Furthermore, existing beach monitoring records from the Auckland region have not undergone systematic analysis and interpretation to support any management objectives. This study was commissioned by the Auckland Regional Council (ARC) in order to redress these issues.

2.1 Data analysis and interpretation

The ARC requires an analysis and interpretation of data collected for a subset of beaches in the existing beach monitoring network. It is intended that analysis should:

- a) Report basic status (beach condition) and trends in coastal profile for each beach.
- b) Discuss differences and similarities among beaches analysed.
- c) Consider the beach budget and whether the beach is in a state of equilibrium or flux.
- d) Discuss where appropriate potential causes of changes in beach profile or budget.
- e) Discuss the potential for each beach to contribute to the protection of the coastline and highlight areas where coastal erosion may require management action in the future.
- f) Examine, if possible with the current dataset, potential relationships between coastal profile and environmental variables such as changes in climate and hydrodynamics.

3 Study Approach

This study details the state of eight of the monitored beaches within the Auckland region. This study presents analysis as to the changing volume and beach width and makes assessments as to beach state over various timescales.

4 Analysis of Beach Monitoring Records

4.1 Introduction

The purpose of this section is to detail the current morphological status of a subset of the monitored beaches of the Auckland region. The section outlines the methods used in the analysis of morphological profiles, which has not been previously articulated for the monitoring records. It then provides representative volumes, widths and envelope of change of eight of the monitored beaches, which are surrogate measures of beach state.

4.2 Study Sites

The ARC currently monitors 16 beaches in the Auckland region (**Figure 1**). Fourteen beaches were selected for analysis in this study and include: Piha and Muriwai on the west coast; Orere Point, Kawakawa Bay and Maraetai on the Tamaki Strait/Firth of Thames Coast; Browns Bay, Campbells Bay, Milford Beach, Takapuna Beach and Long Bay on the East Coast Bays of the North Shore; and, Omaha, Mangawhai, Te Arai Pt and Pakiri Beach on the more exposed east coast shoreline of the Auckland region (**Figure 1**).

Figure 1 ARC monitored beaches including the eight analysed in this study (shown in bold).

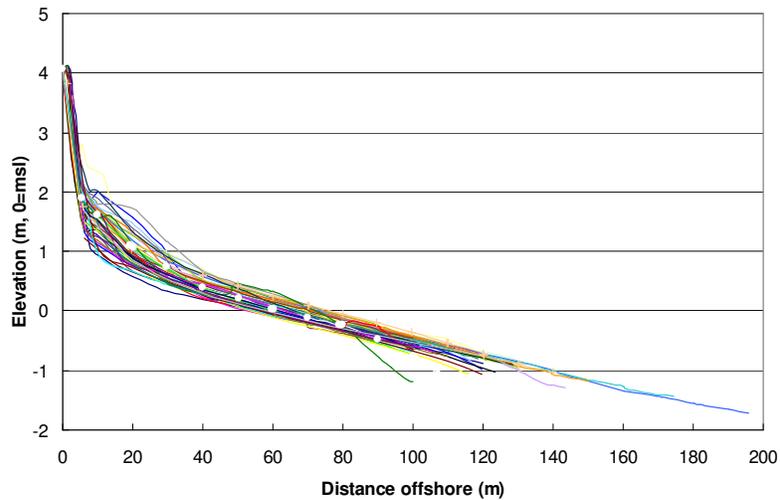


4.3 Methodology

The monitoring datasets typically include six monthly surveys (or higher frequency) over a time period of 10 to 20 years. **Figure 2** presents an example of all beach profiles for a particular location. This figure shows that beaches are changeable landforms that rapidly adjust their morphology. Such plots are difficult to interpret due to the noise associated with the number of profile lines. Furthermore, these plots provide little direct use for management purposes. Consequently, analysis procedures need to be developed to identify critical aspects of beach morphology that indicate the health and status of the beach. In lieu of any prescribed objectives it is proposed that following properties of beach morphology should be examined:

- changes in landward position of the beach,
- changes in volume of sand stored within the beach,
- changes in beach width, and
- determination of the envelope of beach change for the entire dataset for each beach.

Figure 2 Summary of beach profiles 1988 – 2007, at a beach location in the Auckland region.



As data was supplied in BMAP (Beach Morphology Analysis Package) software format subsequent analysis was undertaken using BMAP. Profile lines were loaded into BMAP and a series of horizontal and vertical limits were chosen, which constrained the boundaries of analysis.

4.3.1 Beach volume analysis

In terms of physically managing the beach sediment reservoir (e.g. nourishment) understanding the volume of material in the beach is critical. Consequently, an historical time series of change in beach volume was constructed.

The beach profiles captured by the ARC monitoring programme are two-dimensional cross section surveys of the beach surface, depicting the morphology of the beach at the time of survey. Such profiles can be used to provide an estimate of sediment volume contained within the beach by calculating the area underneath each profile. For this analysis the landward horizontal position was fixed at either the known survey benchmark location, or known location at the back of the beach (e.g. seawall). The seaward boundary was also determined as a fixed point (e.g. position of mean sea level, MSL) or for pragmatic reasons the end of the shortest profile (so that the greatest temporal comparison could be made). Ideally this type of analysis would capture the entire active beach system, extending to offshore closure depth (5-10 m below MSL), in order to evaluate the entire volume of sediment that can contribute to a beach. However, the ARC records are much shorter in extent, generally only capturing the subaerial beach and upper intertidal portion of beaches. Consequently, the practicalities of the survey data have limited the analysis to the upper portions of the active beach system (see section 4.0 for discussion on monitoring design). In this study results are reported as volume of beach material per metre length of beach. It is reasonable to assume that longshore variations in beach morphology are unlikely to induce error over a width of one metre. The output from this analysis is expressed in terms of cubic metres of sediment per metre of longshore beach width (m^3/m).

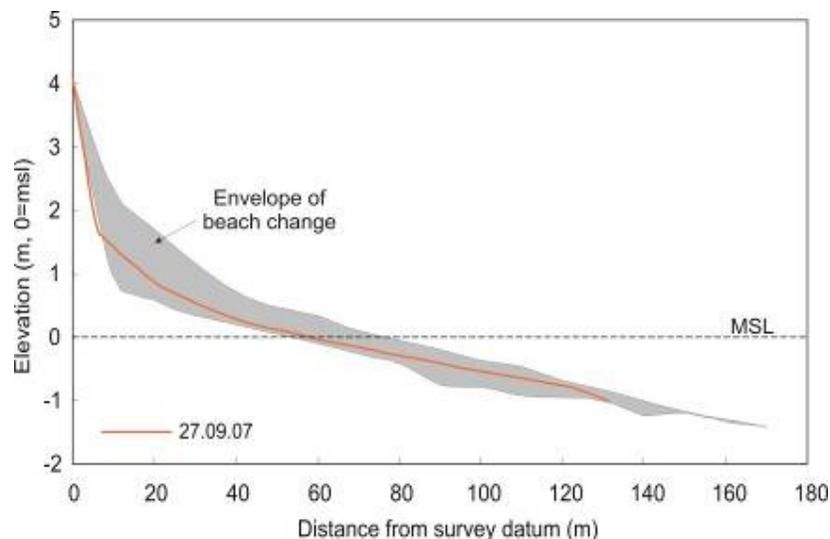
4.3.2 Beach width analysis

Beach width is another measure of the degree of beach change and can be used to gauge the available area of recreational beach above high tide or low tide. This was calculated by measuring the horizontal distance from a fixed landward position (e.g. survey benchmark) to a specified vertical level on the beach (e.g. high tide level, MSL). For the majority of analyses in this study the zero or one metre (MSL) contour was used. However, in cases where profiles do not regularly extend to this level a higher contour level was used. Construction of a time series of beach width measurements provides an indication as to whether the beach is narrowing or widening.

4.3.3 Beach envelope analysis

Of interest to managers is whether a beach profile is outside the normal range of oscillation in beach morphology. Once a sufficient number of surveys have been captured it is possible to identify an envelope of change, the area of the profile which contains all profiles. Future changes can then be assessed relative to this envelope. An example of an envelope of change is provided below (**Figure 3**). From a management perspective movement landward of the historical envelope of beach change is of utmost importance to support decisions as to whether management strategies are necessary. Envelopes are defined for each of the profiles on eight of the ARC monitored beaches (Appendix 1).

Figure 3 Example of beach envelope of change and most recent beach surveying revealing the upper section of the beach is towards the landward margins of the envelope.



4.4 Results of Beach Profile Analysis

This section presents results from the analysis of beach change on the eight study beaches. Data for each study beach is presented in Appendix 1. A summary of the changes in beach sediment volume, and beach width for each beach is presented in **Table 1**. The following sections detail the current state and dynamics of each beach and identify whether there is any seasonality or long-term trends in beach behaviour.

Table 1 Summary of beach change properties derived using BMAP analysis of beach profiles.

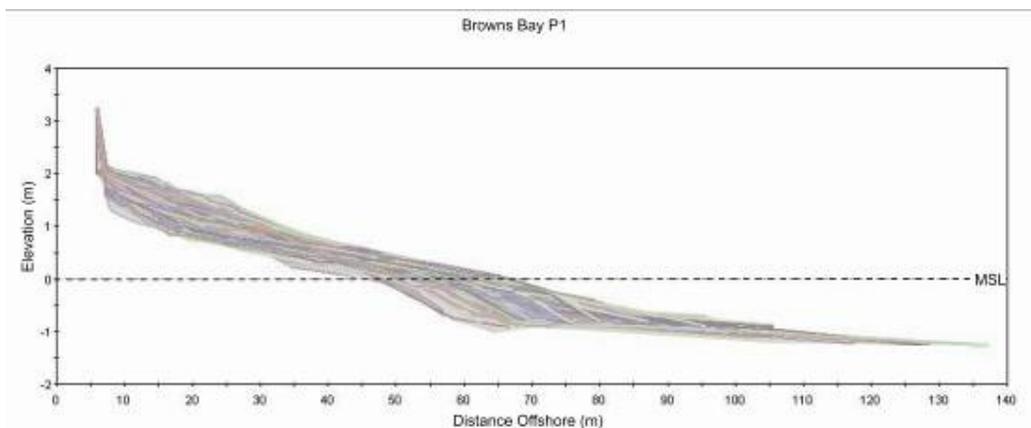
Beach	Profile	Average beach volume (m ³ /m)	Std Dev beach volume (m ³)	Average beach width (m)	Std Dev. beach width (m)
Browns Bay	P1	43.2	5.7	56.1	4.5
	P2	63.9	16.8	108.4	10.1
Campbells Bay	P1	63.5	5.5	43.5	4.1
	P2	51.4	6.7	39.9	3.8
Milford	P1	51.9	5.1	52.0	7.3
	P2	39.1	6.1	45.9	4.8
	P3	32.8	7.1	38.5	3.5
	P4	24.8	4.4	25.3	4.6
	P5	26.3	5.8	24.5	5.5
Takapuna	P1	55.7	7.0	56.2	4.4
	P2	56.8	6.0	53.2	6.7
	P3	82.6	6.5	58.2	5.3
Kawakawa	P1	17.2	1.5	16.4	2.8
	P2	13.1	1.8	16.7	2.6
	P3	12.0	1.4	15.9	3.4
	P4	12.5	3.4	15.7	4.9
Maraetai	P1	48.4	2.8	57.1	2.6
	P2	41.1	2.9	30.0	1.5
	P3	43.2	1.7	29.0	1.1
	P4	78.5	3.2	42.1	1.5
Orere Point	P1	41.4	9.3	31.2	7.4
	P2	41.2	6.9	29.2	4.5
Piha	P1	313.8	39.0	91.4	16.8
	P2	198.0	52.8	112.5	12.7
	P3	106.5	41.1	73.6	17.2
	P4	122.2	45.8	81.0	17.2
	P5	176.4	24.0	78.3	12.3
Long Bay	P1	85.0	8.5	76.4	6.2
	P2	124.0	14.6	90.1	7.2
Muriwai	P1	446.6	43.8	92.8	10.8
	P2	262.6	34.6	104.8	13.8
	P3	381.2	112.3	90.6	20.1
	P4	190.1	53.1	115.8	11.5
Mangawhai	P1	237.9	24.0	90.3	15.0
	P2	135.3	35.3	72.0	15.8
Pakiri	P1	224.1	25.9	126.0	16.0
	P2	245.0	25.7	82.4	14.1
	P4	213.8	32.8	178.1	13.5
	P5	203.5	29.3	100.4	11.3
	P6	128.7	27.9	77.9	11.9
	P7	81.8	26.1	91.9	12.2
	P8	300.5	26.8	85.0	12.2
	P9	148.1	24.1	77.0	11.7
	P3	287.6	29.2	92.4	14.6
Te Arai	P2A	131.5	47.9	63.7	16.8
	P2B	249.7	32.7	203.1	22.6
Omaha	P1	113.4	17.6	71.2	11.9
	P2	100.9	33.4	64.0	13.9
	P3	102.1	41.7	56.2	13.6
	P4	154.7	52.8	83.4	21.3
	P5	109.6	34.9	69.2	14.1
	P6	217.2	69.7	91.4	15.7
	P7	450.3	82.4	158.9	17.2
	P8	99.7	26.7	63.5	14.4
	P9	137.8	17.1	68.3	5.1

4.4.1 Browns Bay

4.4.1.1 Envelope of beach change:

The two Browns Bay profiles both show considerable spatial and temporal variability in beach morphology (**Figure 4**, Appendix 1). At both locations the zones of highest dynamism are the upper foreshore (~1 m above MSL) and lower foreshore (~-1 m MSL). However, it is apparent that Profile 2 exhibits larger morphological fluctuations than Profile 1 over the same time period. For example, vertical fluctuations in beach level at a single location on the upper beach reach up to 1.2 m and 2.5 m respectively on Profiles 1 and 2. Large horizontal distances of beach change are also evident. The MSL contour level migrates up to 25 m and 65 m on Profile 1 and 2 respectively. Of note, the latest profiles sit within the envelope of change defined in **Figure 4**. The beach envelope exhibits no significant landward movement, which indicates no net erosion of the shoreline.

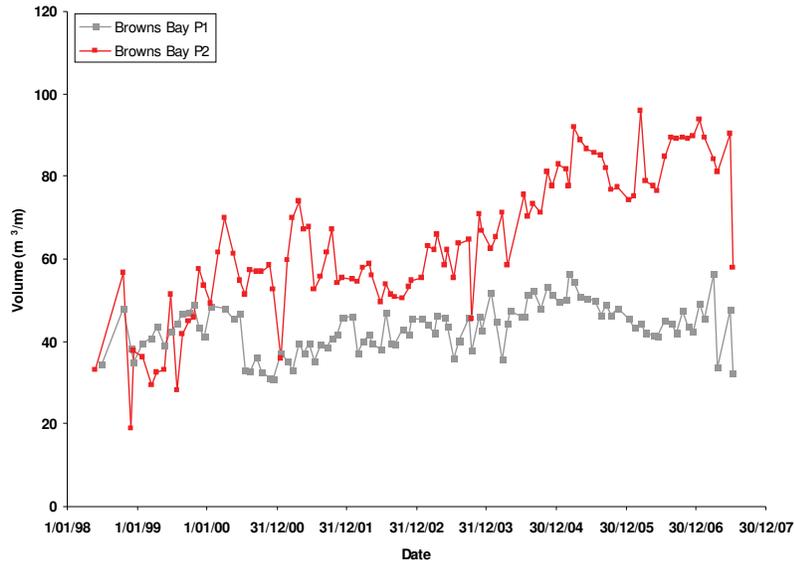
Figure 4 Browns Bay beach profiles showing envelope of change, calculated along Profile 1. Grey shaded area captures zone within which all profiles are contained.



4.4.1.2 Change in beach volume

The time series of beach volume contained under each profile (**Figure 5**) indicates significant variability across the monitoring record. At 2 to 5 year timescales the profiles exhibit periods of increasing and decreasing beach volume. There appears to be a significant increase in the volume of sediment stored within each beach profile. On Profile 2 sediment volume increased from around 35 m³/m in 1999 to a peak of approximately 95 m³/m in 2006. However, there was a sharp reduction in volume (50 m³/m) in 2007, which is likely to be the consequence of the storm event of July 2007. Profile 1 exhibits a more subdued pattern of variability ranging from 30 to 50 m³/m. It is notable that in the period from 2000 to 2006 there was a preferential increase in sediment volume at Profile 2.

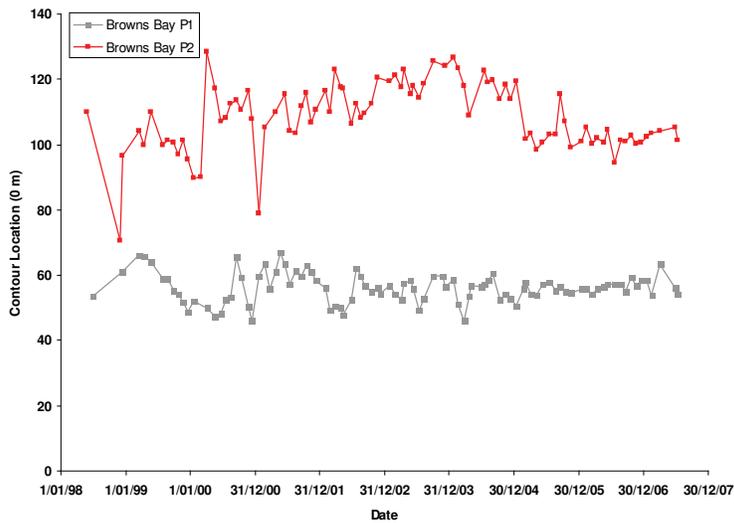
Figure 5 Time series of beach volume for sites P1 and P2 at Browns Bay.



4.4.1.3 Change in beach width

The width of the beach, which is determined by the horizontal position of the MSL contour lacks any significant trend through time (**Figure 6**). The width of Profile 1 fluctuates about a mean position (56.1 m) ranging from 45 to 66 m. Profile 2 (which is wider than Profile 1) has a mean width of 108.4 m and varies from 70 to 130 m (**Table 1, Figure 6**). Of note beach width increased to a mean value of around 110 m in the period 2000 to 2004 and has subsequently reduced to its pre 2000 width. As with other measures of beach change Profile 2 appears more dynamic than Profile 1.

Figure 6 History of beach width change at Browns Bay. Beach width defined as distance landward of mean sea level.

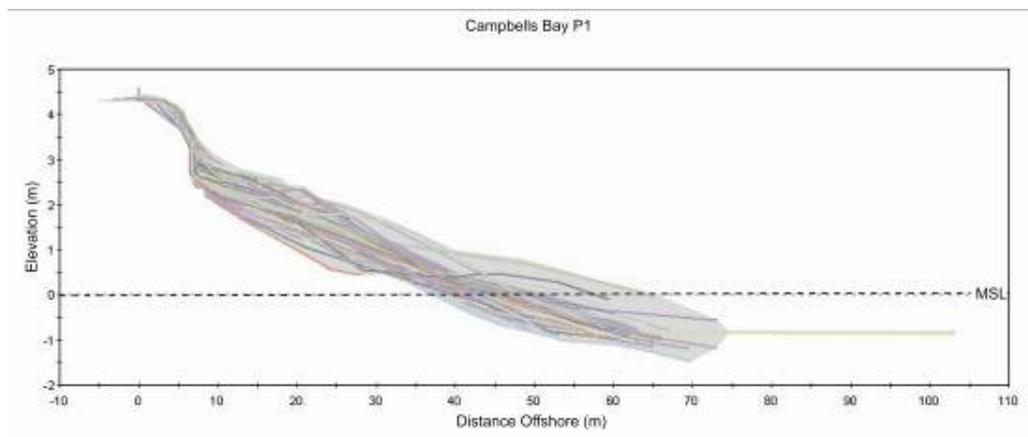


4.4.2 Campbells Bay

4.4.2.1 Envelope of Change

Both profiles show considerable variability in morphology through time (**Figure 7**, Appendix 1). As was the case at Browns Bay the most dynamic portions of the beach are the upper foreshore (~1 m MSL) and the lower foreshore (~-1 m MSL). It is apparent on both profiles that the dynamic stretch of beach extends seaward to the horizontal limit of the profiles. This indicates that while there does not appear to be a long term trend of beach erosion or accretion there is a constant readjustment of sand between the upper foreshore and the lower foreshore. Both Profile 1 and Profile 2 show similar degrees of variability, with vertical fluctuations in beach level reaching 2.0 m in some locations.

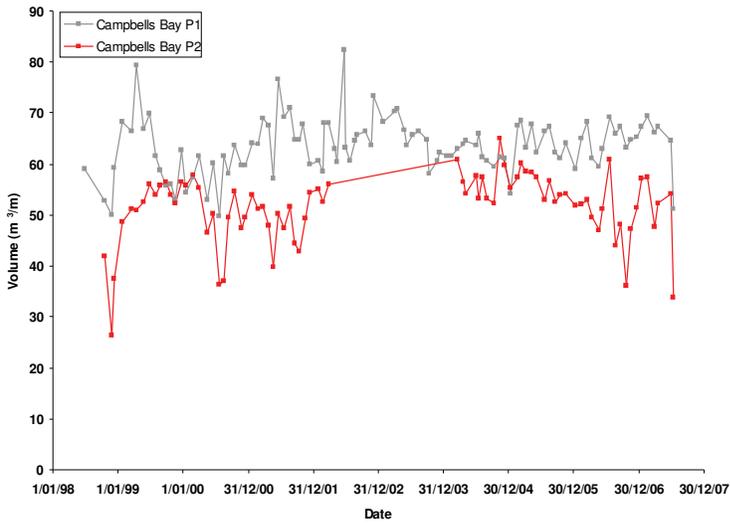
Figure 7 Campbells Bay beach profiles showing envelope of change, calculated along Profile 1. Grey shaded area captures zone within which all profiles are contained.



4.4.2.2 Change in Beach Volume

Both profiles show a significant degree of variability with regards to volume. However, there appears no underlying trend with regards to volume through time, nor does there appear to be a seasonality within the volume time series (**Figure 8**). Profile 1 ranges between 50 m³/m and 82 m³/m while profile ranges 26 m³/m and 65 m³/m. Of note, is the sudden decrease in sediment between the June 2007 and July 2007 where beach volume decreased by 13m³/m along Profile 1 and 20 m³/m along Profile 2. This is a function of a major storm event occurring between surveys.

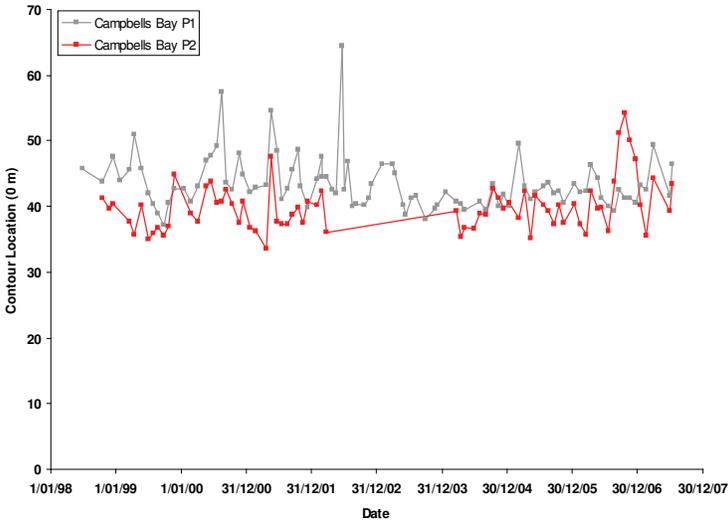
Figure 8 Time series of beach volume for sites P1 and P2 at Campbells Bay.



4.4.2.3 **Change in Beach Width**

Beach width (as determined by the zero metre contour) along both Campbells Bay profile also appears devoid of long term or seasonal trends. Short period oscillations are likely a function of periods of increased wave energy resulting from storms. Profile 1, has an average width of 43 m and ranges between 64 and 37 m (Table 1, Figure 9). Profile 2 is similar with an average width of 40 m and ranges between 54 and 34 m (Table 1, Figure 9).

Figure 9 History of beach width change at Campbells. Beach width defined as distance landward of mean sea level.

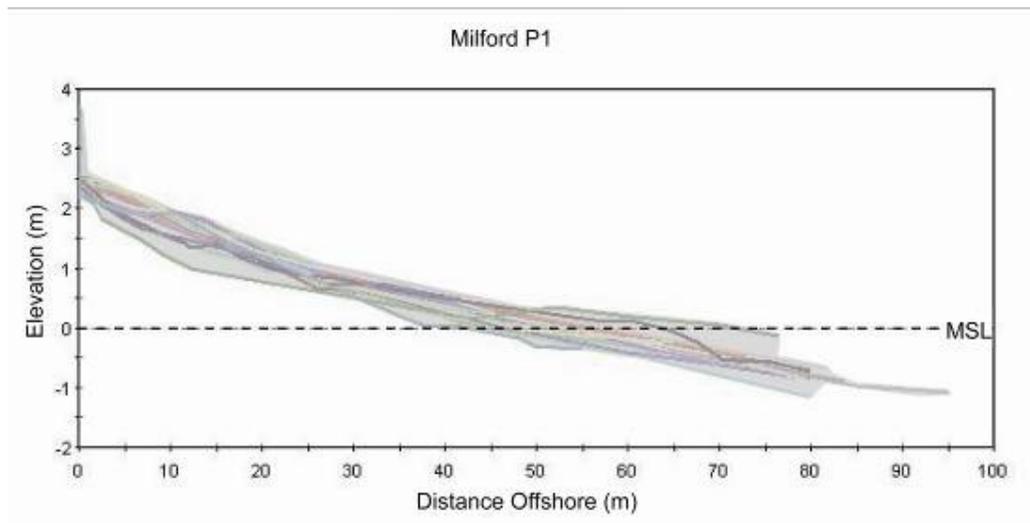


4.4.3 Milford Beach

4.4.3.1 Envelope of Beach Change

All five profiles from Milford Beach exhibit similar patterns with regards to the variability of beach levels (Appendix 1). Common throughout all five profiles is the high level of dynamism in the upper foreshore (~1 m MSL). The maximum vertical fluctuations in beach levels at a single location are in the order of 1 - 1.5 m. The lower foreshore shows a degree of variability, which is noticeably less than the upper foreshore (typically < 1 m).

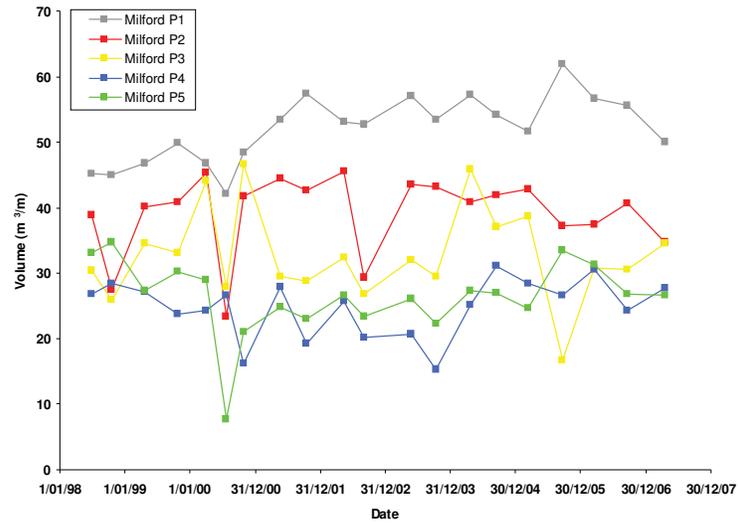
Figure 10 Milford beach profiles showing envelope of change, calculated along Profile 1. Grey shaded area captures zone within which all profiles are contained.



4.4.3.2 Change in Beach Volume

The time series of beach volume contained under each profile shows considerable variability throughout the monitoring period. This is particularly noticeable on Profiles 2, 3 and 5 which show change of up to 21.1 m³/m between successive surveys (**Figure 11**). While large variability of volume is noticeable there is an apparent absence of any underlying long-term trend within the volume time series.

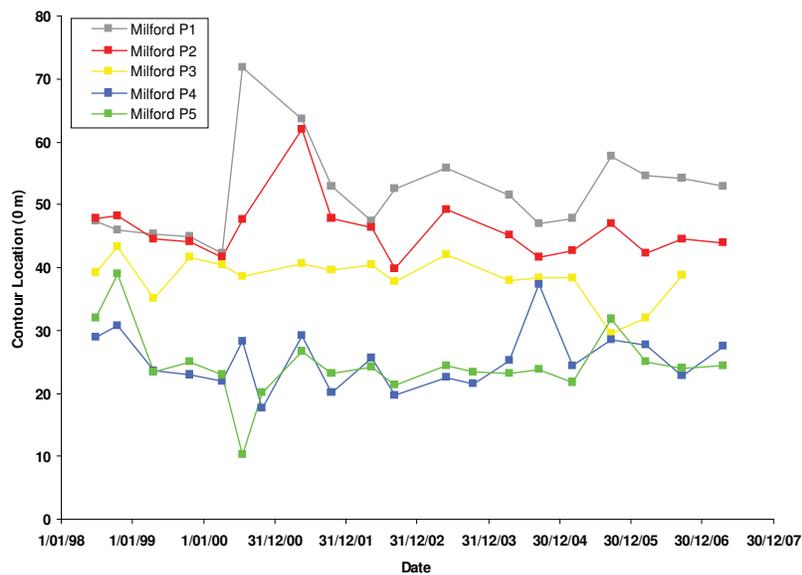
Figure 11 Time series of beach volume for sites P1 and P2 at Milford Beach.



4.4.3.3 Change in Beach Width

As with beach volume, the beach width time series at Milford shows a high degree of variability between surveys yet lacks any long-term trend (**Figure 12**). Interestingly the variability is not consistent between sites, a particular example is the period between 03/04/2000 and 21/7/2000 where Profile 1 increased from 42.3 m to 71.9 m, whereas Profile 5 decreased in width from 23.0 m to 10.2 m. This suggests that there is an adjustment in the longshore direction responsible for some of the variability seen through time and is expressed as beach rotation. It is noticeable that through time these large variations are dampened and the beach readjusts resulting in little long-term change in beach width.

Figure 12 History of beach width change at Milford Beach.

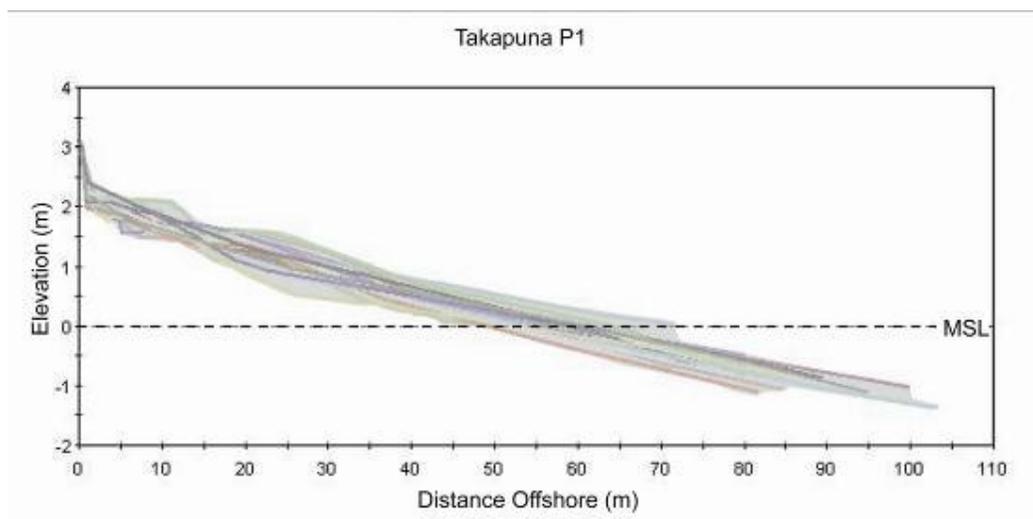


4.4.4 Takapuna

4.4.4.1 Envelope of Beach Change

The three monitored profiles at Takapuna Beach show a moderate degree of variability in beach morphology through time (**Figure 13**, Appendix 1). At all locations the area of highest variability is in the upper foreshore area where maximum vertical fluctuations at a single point are ~1 m. The amount of variation in beach morphology tends then to decrease seaward with lowest variation at beach levels below MSL.

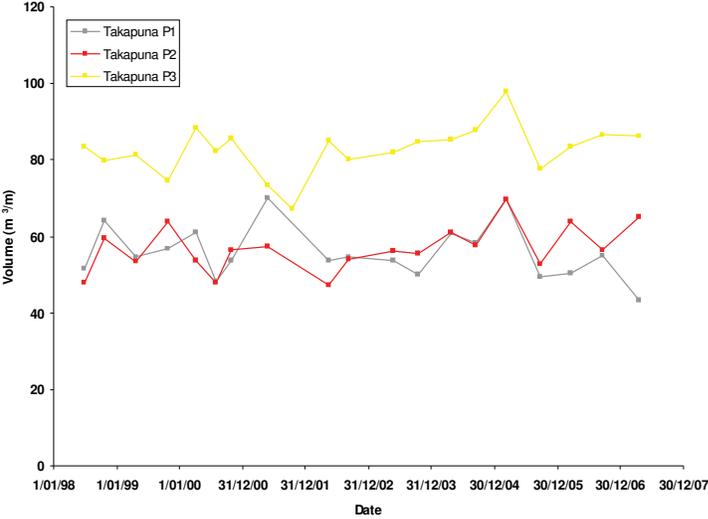
Figure 13 Takapuna beach profiles showing envelope of change, calculated along Profile 1. Grey shaded area captures zone within which all profiles are contained.



4.4.4.2 Change in Beach Volume

The time series of the beach volume contained under each profile (**Figure 14**) shows no long term trends within the dataset. Volume is stable throughout the monitoring period, with fluctuations about a mean position. There is some suggestion of a seasonality in the fluctuations with Profile 3 containing the highest volumes during March-April surveys and lowest during September-October. However, it should be noted that due to the short length of the dataset, and the degree of variability within the data that it is difficult to define consistent patterns in the data. The analysis does suggest that while the beach is stable in the long term it is likely susceptible to seasonal variations based on changes in energy conditions between summer and winter seasons.

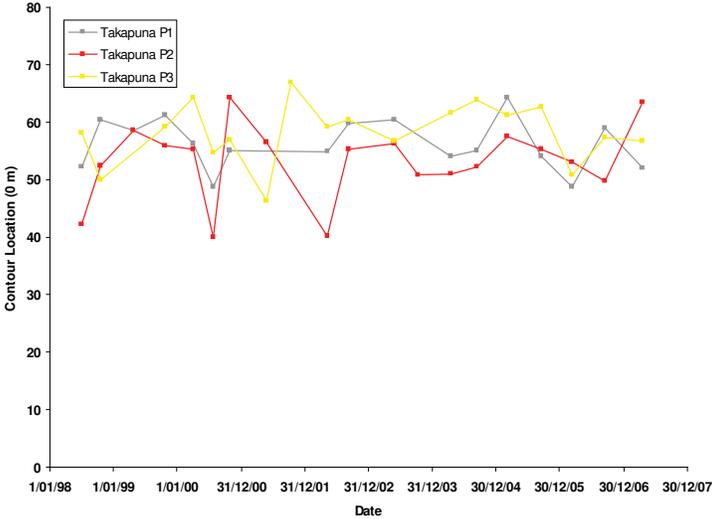
Figure 14 Time series of beach volume for sites P1-P3 at Takapuna Beach.



4.4.4.3 Change in Beach Width

As with the time series of beach volume, beach width appears devoid of any long term trend (Figure 15). The width of the beach at all three locations is similar ranging from 53.2 m along Profile 2 to 58.2 along Profile 3 with variations in width up to 24 m over time.

Figure 15 History of beach width change at Takapuna Beach.

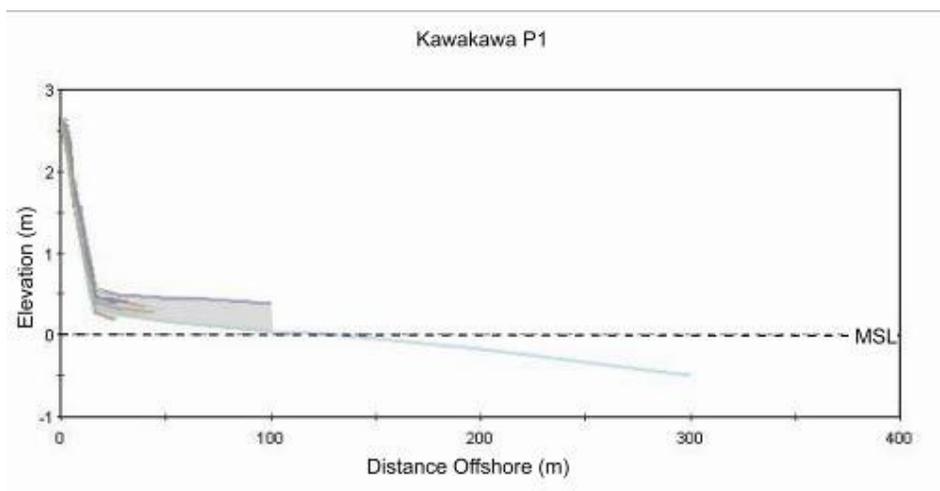


4.4.5 Kawakawa Bay

4.4.5.1 Envelope of Change

Profiles measured at Kawakawa Bay rarely extend lower than MSL (**Figure 16**, Appendix 1). Consequently, it is difficult to assess the long term variability of the beach system. However, there is adequate data in the upper foreshore regions to assess any trend apparent in the upper portions of the beach. The envelope of change shows slight variation in beach position through time, however, these vertical variations are generally less than 0.5 m.

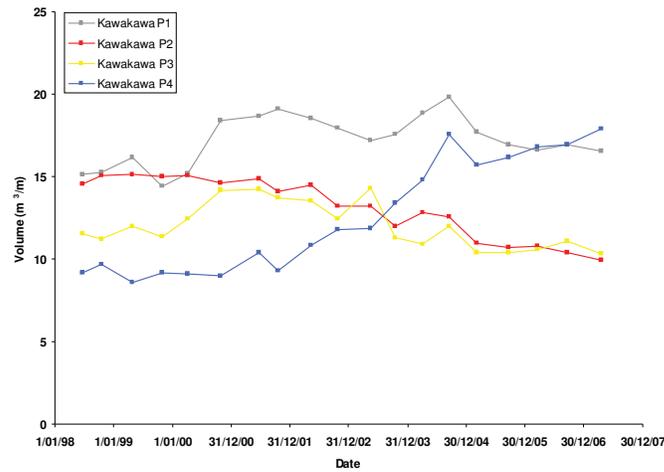
Figure 16 Kawakawa profiles showing envelope of change, calculated along Profile 1. Grey shaded area captures zone within which all profiles are contained.



4.4.5.2 Change in Beach Volume

The four profiles reveal a degree of discontinuity with respect to volume of sediment contained along the beach (**Figure 17**). The volume contained within profiles 1 and 3 show minor variations in volume about a mean, with no long term trend apparent (**Figure 17**). This is in contrast to profiles 2 and 4 which show a steady trend in volume change. Profile 2 shows a steady decrease in volume through time from 14.5 m³/m to 9.9 m³/m., whereas Profile 4 is increased in volume from 9.1 m³/m to 17.8 m³/m. This increase is particularly noticeable in the surveys after 17th Oct 2001. Different trends between profiles suggest a longshore reorganisation of sediment as opposed to a net change.

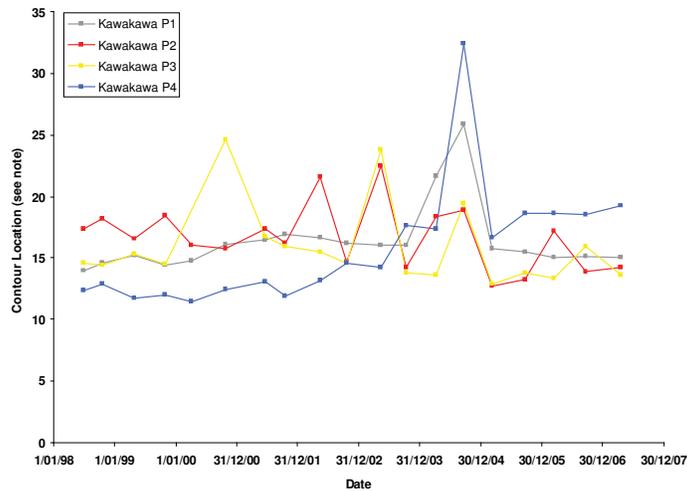
Figure 17 Time series of beach volume for sites P1-P4 at Kawakawa Beach.



4.4.5.3 Change in Beach Width

The width of beach, derived from the four profiles is remarkably consistent, with all four profiles having average widths between 15.7 m and 16.7 m through the monitoring period (**Table 1, Figure 18**). The analysis of beach width through time supports the trends observed with respect to beach volume (**Figure 17**). Profiles 1, 2 and 3 appear to fluctuate without the presence of a long term trend whereas Profile 4 shows a similar increase in beach width as was the case with beach volume. Profiles 1, 2 and 3 exhibit change in beach width of 12.0 m, 9.8 m and 11.7 m respectively, whereas Profile 4 has a much larger range of 20.9 m. The analysis of the four profile lines at Kawakawa bay is hampered by the inability to assess the dynamics of sediment in the lower foreshore. It is not possible to assess the adjustment of beach morphology as a result of onshore and offshore transport of sediment although there does appear to be a degree of variability in the longshore domain. This tends to suggest a long term alongshore variability in beach morphology.

Figure 18 History of beach width change at Kawakawa Beach.

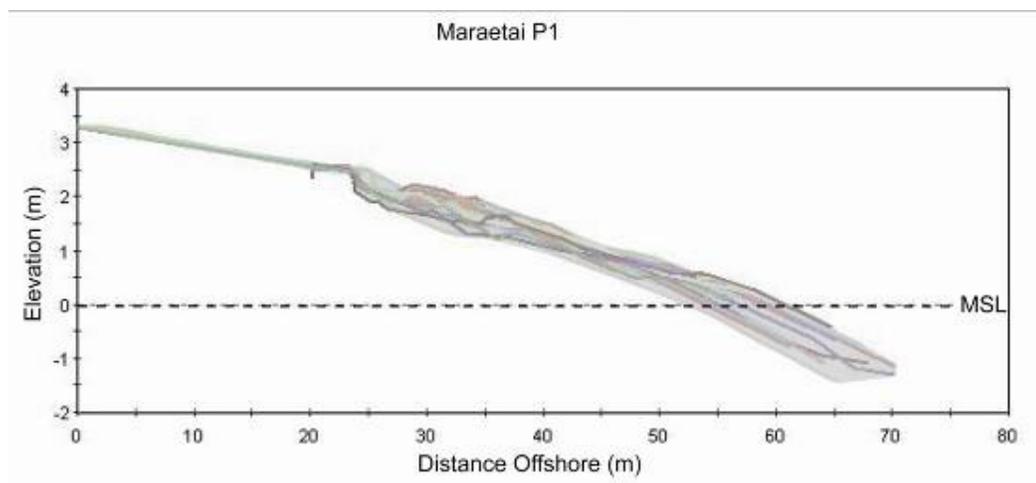


4.4.6 Maraetai

4.4.6.1 Envelope of Change

All four profiles show similar degrees of variability in beach morphology through time (**Figure 19**, Appendix 1). At all locations the envelope of change is relatively uniform, indicating dynamism across the entire beach system. The vertical fluctuations of beach level at a single location are generally low, with maximums rarely exceeding 1.0 m and generally in the order of 0.5 m. Horizontal displacement of the MSL contour is up to 20 m.

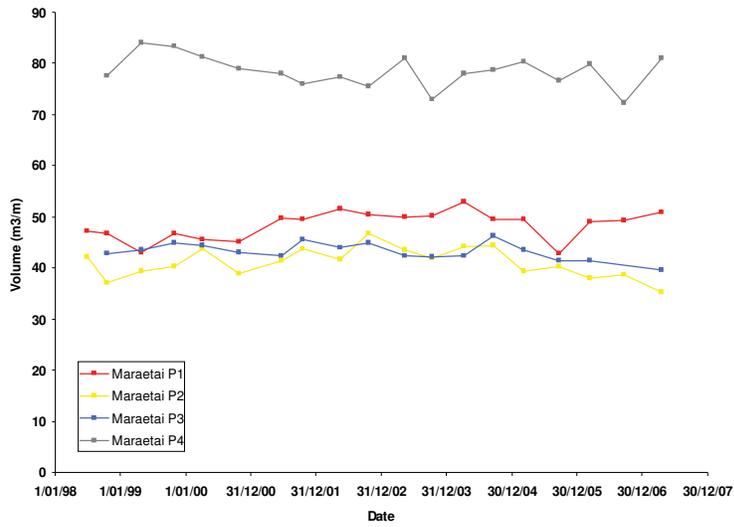
Figure 19 Maraetai profiles showing envelope of change, calculated along Profile 1. Grey shaded area captures zone within which all profiles are contained.



4.4.6.2 Change in Beach Volume

The time series of beach volume contained under each profile (**Figure 20**) indicates an absence of any significant variability. Fluctuations in volume over the monitored time period are minimal, $<10\text{m}^3/\text{m}$ (**Table 1**, **Figure 20**).

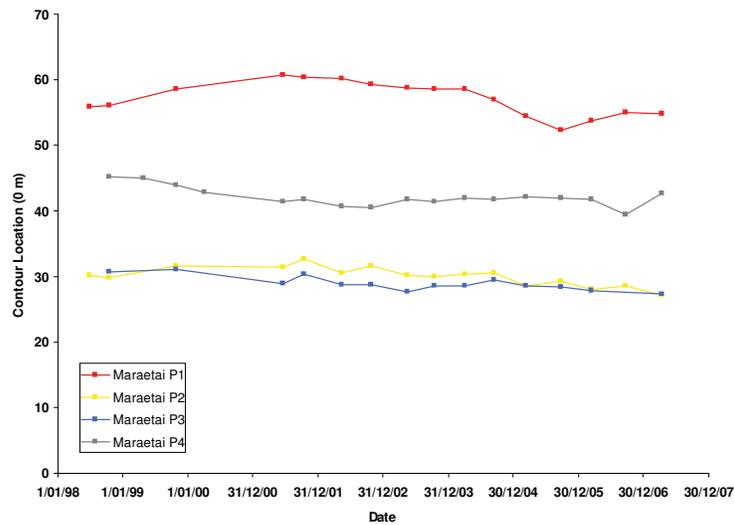
Figure 20 Time series of beach volume for sites P1-P4 at Maraetai Beach.



4.4.6.3 Change in Beach Width

The times series of beach width for all four profiles (**Figure 21**) shows the noticeable absence of any long term trend or short term variability in beach width. Variation in beach widths at all sites is small, with a maximum of 8.5 m and a minimum of 3.9 m at Profile 1 and 3 respectively. The lack of a long term trend in either beach width or beach volume indicates a high degree of stability throughout the monitoring period.

Figure 21 History of beach width change at Maraetai Beach.

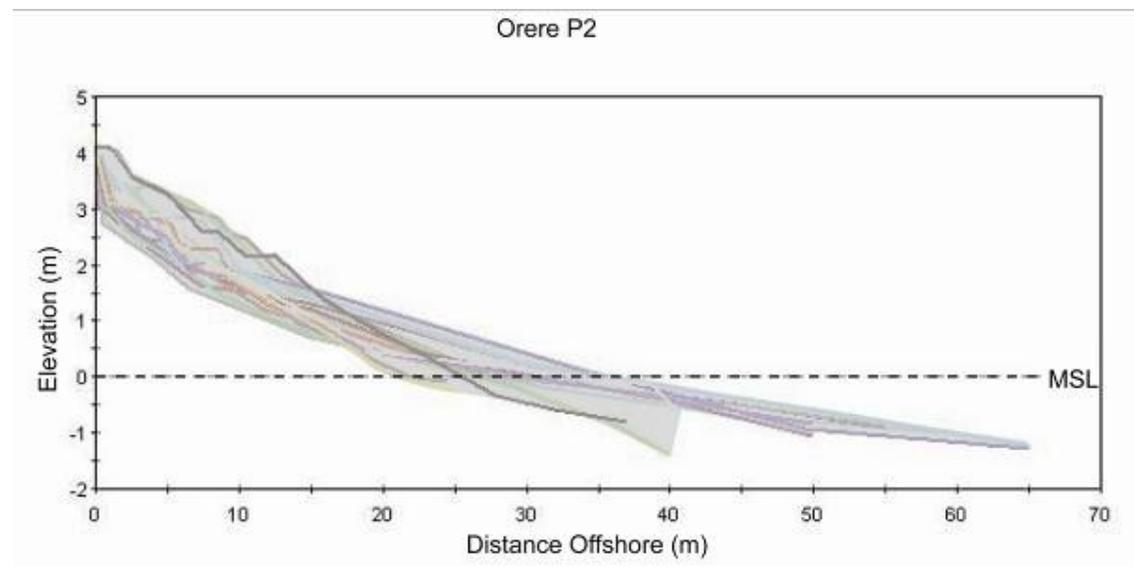


4.4.7 Orere Point

4.4.7.1 Envelope of Change

A total of two profiles were analysed at Orere Point. However, Profile 1 appears to be an abandoned profile, with surveys ceasing in June 2001. Whereas Profile 2 extends until September 2006. The envelopes of change at both sites show similar characteristics in the variability of beach level through time. The envelope of change is relatively uniform in thickness along the entire beach profile and is typically > 1 m (**Figure 22**, Appendix 1). This tends to indicate that variations in beach level are more likely a function of a shift in the entire beach system, rather than an exchange of sediment between the upper and lower sections of the beach as was observed particularly at Browns Bay and Campbells Bay.

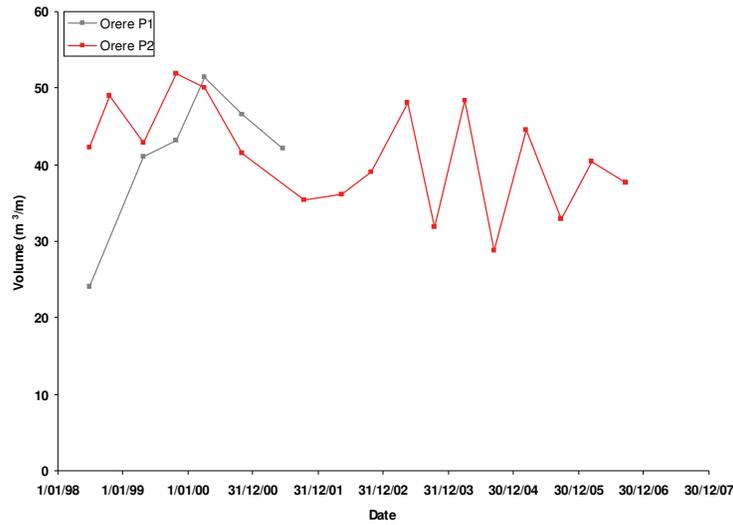
Figure 22 Orere Point profiles showing envelope of change, calculated along Profile 1. Grey shaded area captures zone within which all profiles are contained.



4.4.7.2 Changes in beach volume

During the short period of monitoring of Profile 1 there appears to be a trend of increasing beach volume, it is however difficult to comment as to whether this is a long term trend or a seasonal fluctuation (**Figure 23**) due to the short length of record. The volume of sediment contained within Profile 2 appears devoid of a long term trend within the short dataset. However, there is a noticeable fluctuation in the volume in the short term. Beach volume changes by as much as $20\text{m}^3/\text{m}$ between successive surveys (**Figure 23**). This readjustment shows a degree of seasonality, particularly in post 2002 surveys. The volume is highest after the summer season (March-May surveys), whereas after winter (Sept-Oct surveys) the volume is generally lower.

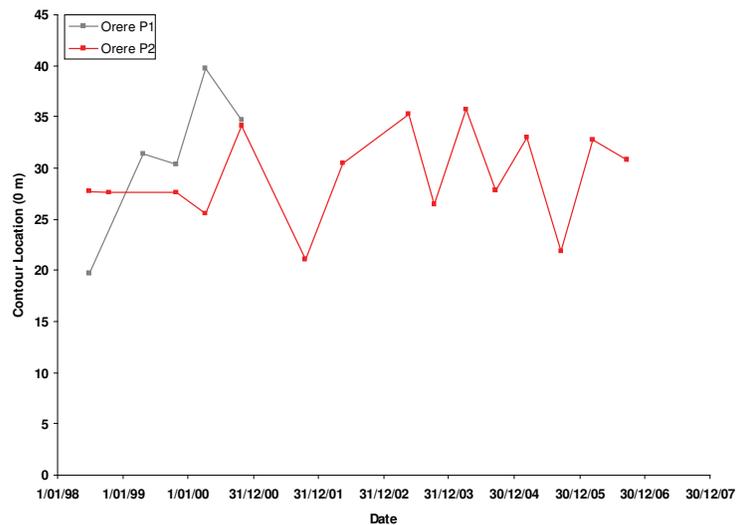
Figure 23 Time series of beach volume for sites P1-P3 at Orere Point.



4.4.7.3 Changes in beach width

The width of the beach shows the same apparent seasonality as the beach volume time series (**Figure 24**). In general, this is characterised by a wider beach present at the conclusion of summer and a narrow beach post-winter. While the time series is of insufficient length to determine the exact nature of this seasonality it would appear that during lower energy conditions of the summer period the beach experiences a marked increase in deposition of sediment. In contrast, higher energy conditions associated with the winter period act to strip the beach of this sediment and it is during this time the beach is in an erosional state. The available data for Orere Point suggests there is no long term trend with regards to the accretion or erosion of the beach. However, there does appear to be a noticeable fluctuation of the beach state as a result of seasonal oscillation.

Figure 24 History of beach width change at Orere Point.

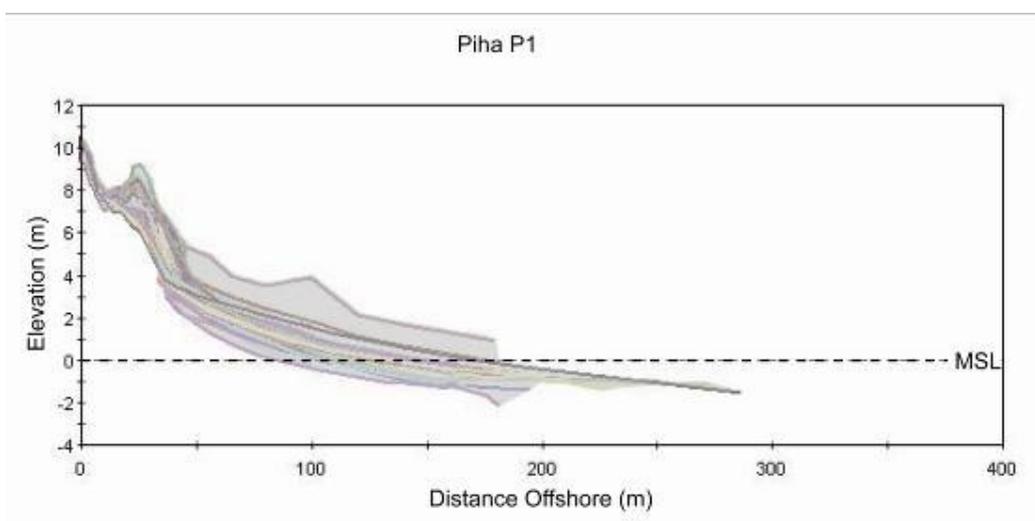


4.4.8 Piha

4.4.8.1 Envelope of Change

A total of five profiles were analysed from Piha Beach. One of these profiles (Profile 4) was first monitored in 1981, which represents the longest dataset analysed. The remaining four profiles have been surveyed consistently since 1993, with one starting in 1990. The extent of the profiles at Piha is variable, with several surveys failing to extend as far as the MSL point. All profiles show considerably variability in beach morphology through time (**Figure 25**, Appendix 1). The entire beach system is highly dynamic, with all profiles exhibiting vertical fluctuations between 2.0 – 4.5 m at a single point. In general, the most dynamic section of the beach is the foredune, however Profiles 1 and 5 have the largest variation in the upper foreshore.

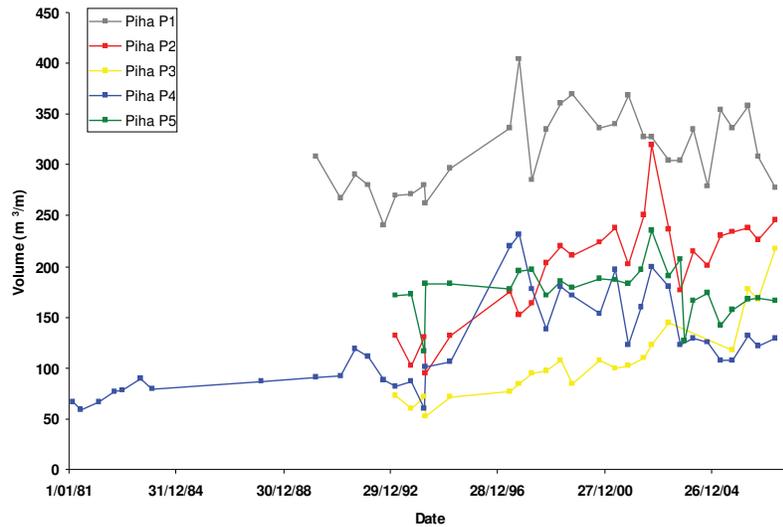
Figure 25 Piha profiles showing envelope of change, calculated along Profile 1. Grey shaded area captures zone within which all profiles are contained.



4.4.8.2 Changes in beach volume

The time series of beach volume contained under each profile (**Figure 26**) indicates a high degree of variability across the monitoring period. Three of the five sites show an underlying trend of increasing volume (Profiles 2, 3 and 4). These three profiles have increased in volume by a considerable amount, between 1994 and 2007. Profile 3 increased in volume from 52.2 m³/m to 217.7 m³/m while Profiles 2 and 4 have more than doubled in volume in this period. In contrast Profiles 1 and 5 show no such gradual increase in volume. Along with Muriwai, Piha is the highest energy setting in the ARC monitoring programme. The frequency of large swell events increases the dynamic nature of the beach surface, explaining observed changes in beach volume by as much as 119 m³/m (29%) between successive surveys.

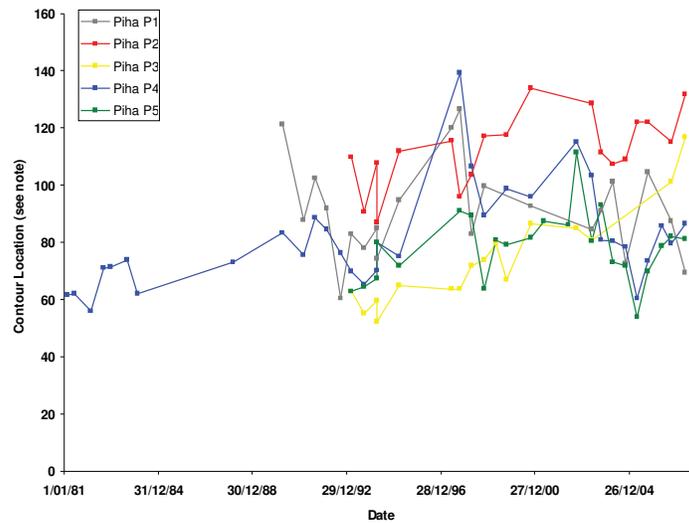
Figure 26 Time series of beach volume for sites P1-P5 at Piha.



4.4.8.3 Changes in beach width

The time series of beach width shares similar trends with beach volume in that it shows considerable fluctuation. Some of these fluctuations can be substantial, for example Profile 4 increased in beach width from 74.9 m to 139.0 m between March 1995 and October 1997 (Figure 27). This increase in width also corresponds with the highest volume contained by Profile 4 during the monitoring period. Beneath the high level of beach width variability is an underlying trend of long term change. Profiles 2, 3 and 4 show a distinct increase in beach width. This is particularly evident in Profile 3 on which width increases from 52.1 m to 116.8 m between April 1994 and May 2007. While three of the profiles exhibit a clear increase in beach width Profile 1 shows a decrease in width from 121.2 m and 69.3 m between April 1990 and May 2007. The remaining profile (Profile 5) appears stable with respect to beach width throughout the monitoring programme. The analysis of beach width and volume for Piha illustrates the high degree of variability within a high energy beach setting. Not only are there massive fluctuations between surveys there are also considerable oscillations within the beach system itself, with some profiles showing increases in width and volume, and others showing decreases at the corresponding interval. On balance, the data is suggestive of an increase in sediment volume, which is consistent with the findings of King et al. (2006).

Figure 27 History of beach width change at Piha Beach.

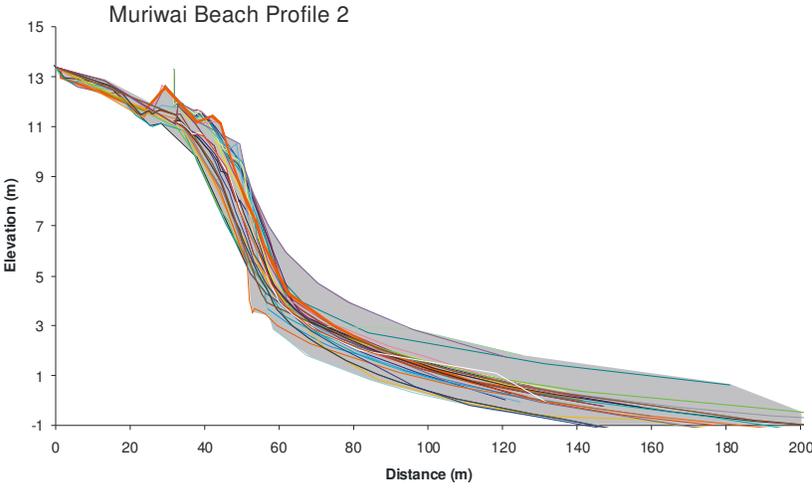
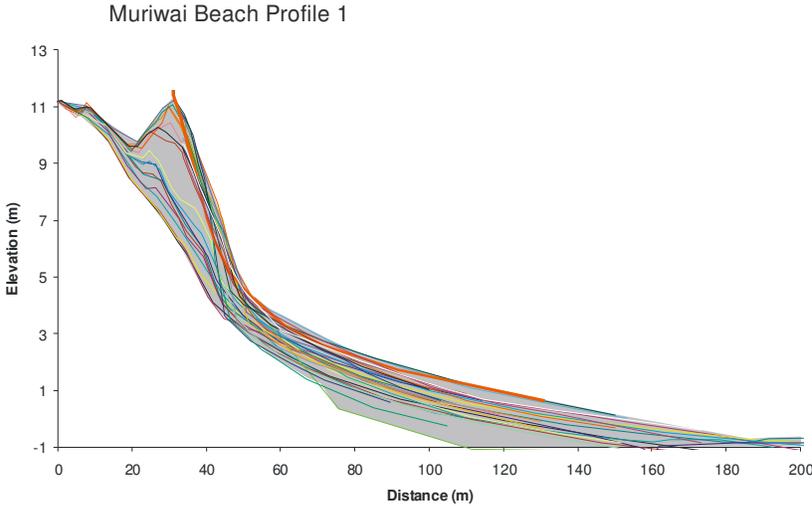


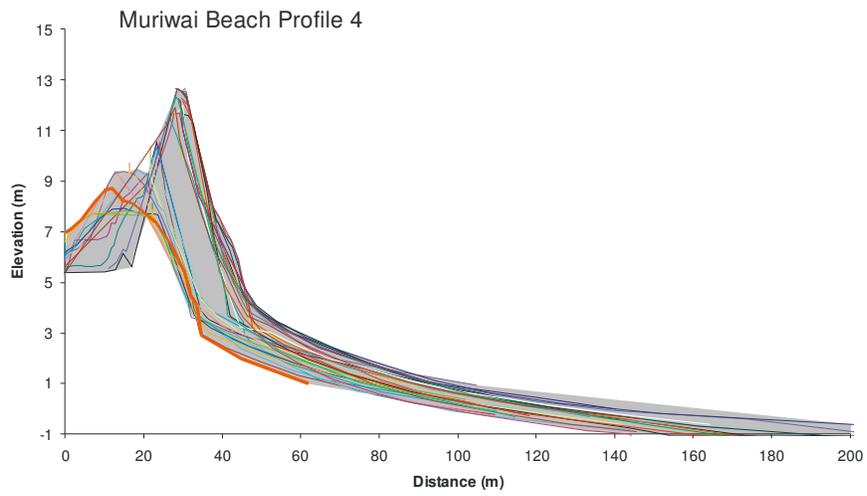
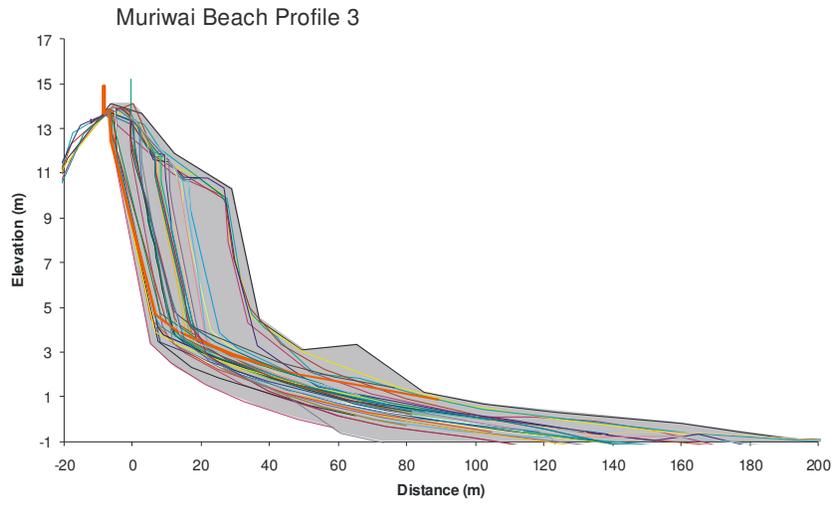
4.4.9 Muriwai Beach

4.4.9.1 Envelope of Beach Change

A total of four profiles were analysed from Muriwai Beach. One of these profiles (Profile 4) was first monitored in 1981, which represents the longest dataset analysed. The remaining three profiles have been surveyed consistently since 1990. All profiles show considerable variability in beach morphology through time (**Figure 28, Table 1**). The entire beach system is highly dynamic, with all profiles exhibiting vertical fluctuations between 2.0 – 4.5 m at a single point. In general, the most dynamic sections of the beach are the foredune and upper foreshore. Of note, Profiles 1 and 2 appear to have undergone net accretion through the monitoring period with the toe of dune approximately 10 m seaward, whereas Profiles 4 and 5 show net erosion in excess of 20 m. In particular, Profile 4 shows loss of the frontal dune during the survey period (**Figure 28**).

Figure 28 Muriwai Beach profiles showing envelope of change. Grey shaded area captures zone within which all profiles are contained. Bold orange line represents the most recent survey.

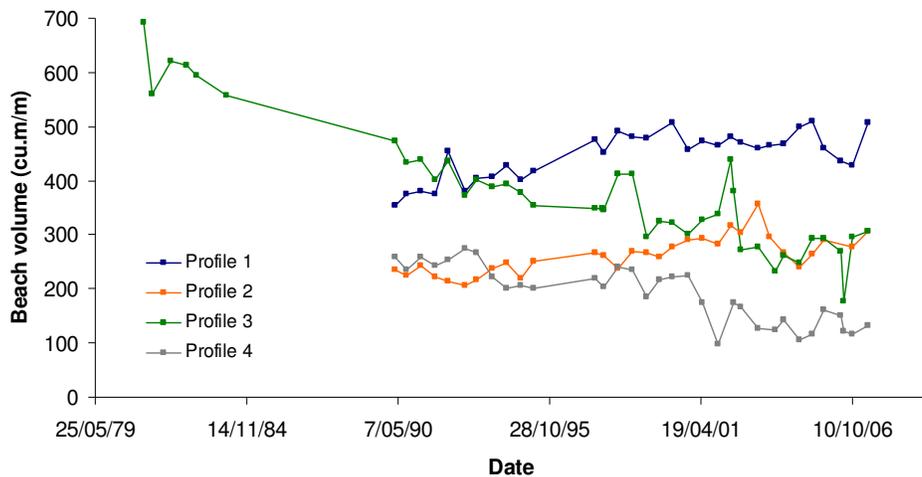




4.4.9.2 Changes in beach volume

The time series of beach volume contained under each profile (**Figure 29**) indicates that profiles display great temporal variability. Results in **Table 1** show that Muriwai profiles exhibit the greatest variability of all beaches monitored in the Auckland region, with the largest standard deviation values of 112 and 53 m³/m respectively for Profiles 3 and 4. It is also clear (as observed above) that Profiles 1 and 2 have behaved differently to Profiles 3 and 4. Profiles 1 and 2 indicate a net increase in beach volume since 1990 by approximately 90 and 70 m³ respectively for Profiles 1 and 2 (equating to 5 and 4.1 m³/m/yr). In contrast profiles 3 and 4 both show a reduction in beach volume over the monitoring period. Profile 3 reduced in volume from 693 m³/m to 507 m³/m between 1981 and 2007 (7.2 m³/m/yr) while Profile 4 reduced from 260 to 133 m³/m (from 1990 to 2007) at a rate of 7.4 m³/m/yr. Along with Piha, Muriwai is the highest energy setting in the ARC monitoring programme. The frequency of large swell events increases the dynamic nature of the beach surface, explaining observed changes in beach volume by as much as 161 m³/m (62 %) between successive surveys.

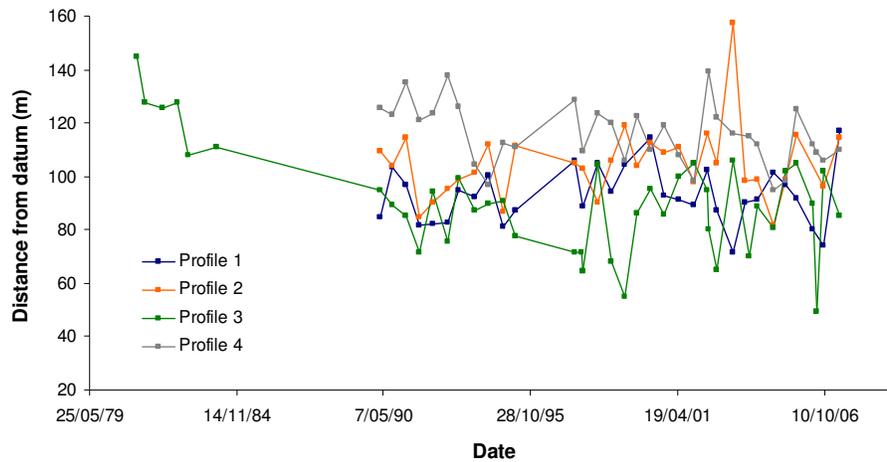
Figure 29 Changes in beach volume at Muriwai Beach. Beach volume calculated as the sand volume contained above the 1 m contour.



4.4.9.3 Changes in beach width

The time series of beach width shares similar trends to beach volume in that it shows considerable fluctuation (**Figure 30**). For example, beach width can change by up to 50 m within a 12 month period. Despite this high variability, and as demonstrated with the beach volume calculations, Profiles 3 and 4 indicate a trend of net reduction in beach width. Profile 4 beach width values changed from a maximum of 144 m in the initial survey in 1981 to 85 m in the latest survey. However, the narrowest beach width values on this profile are 49 and 54 m measured in 1999 and 2006 respectively. Profiles 1 and 2 suggest there has been a small increase in beach width. However, the large short-term variability makes any assertion regarding longer-term trends ambiguous.

Figure 30 Beach width change at Muriwai Beach. Beach width is measured as the distance from the datum to the 1 m contour.

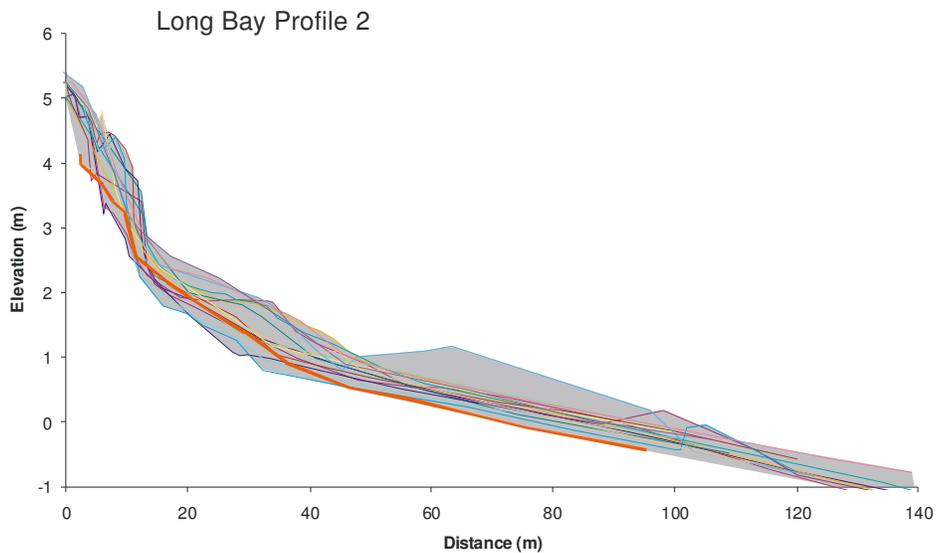
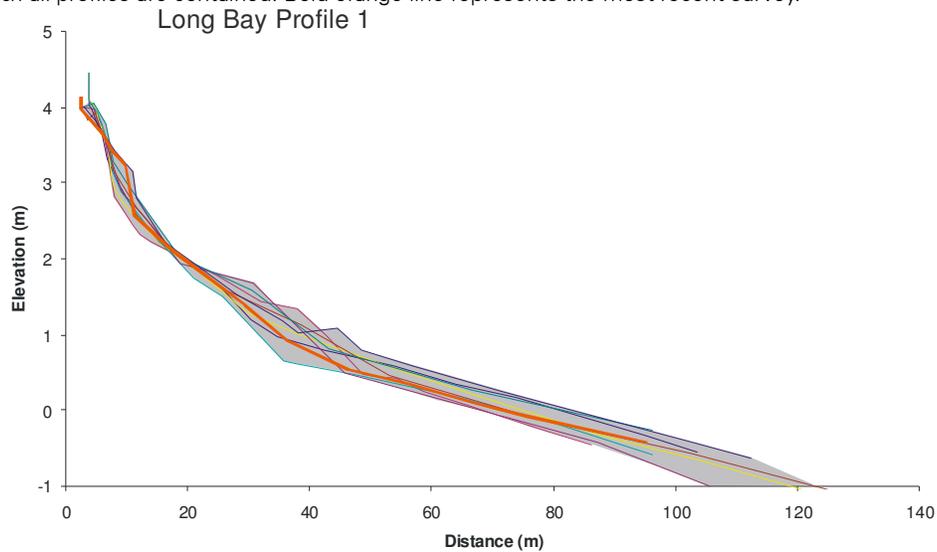


4.4.10 Long Bay

4.4.10.1 Envelope of Beach Change

The two profiles from Long Bay exhibit similar patterns with regards to the variability of beach levels (Table 1, Figure 31). Common throughout both profiles is a low level of dynamism in the upper foreshore (~1 m MSL). The maximum vertical fluctuations in beach levels at a single location are in the order of 1.5 m. The lower foreshore shows a degree of variability, which is noticeably less than the upper foreshore (typically ~0.5 m). Of note, the most recent surveys are positioned within the envelope of change.

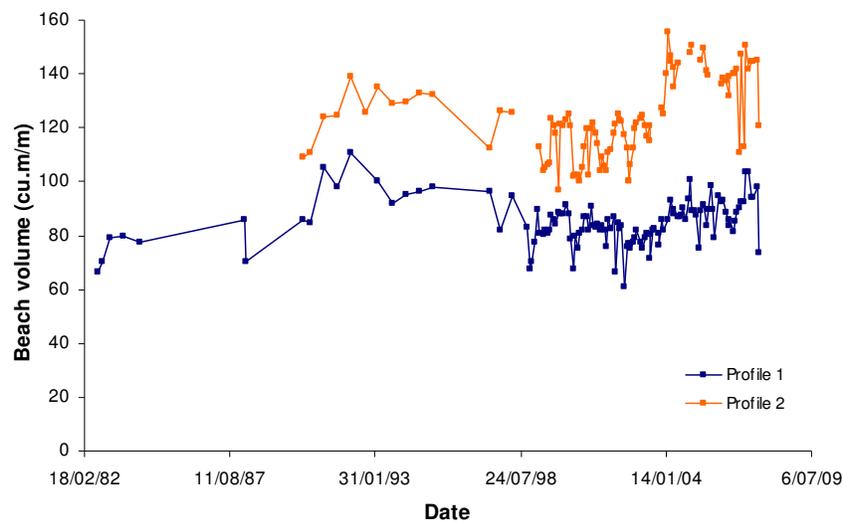
Figure 31 Long Bay beach profiles showing envelope of change. Grey shaded area captures zone within which all profiles are contained. Bold orange line represents the most recent survey.



4.4.10.2 Change in Beach Volume

The time series of beach volume contained under each profile shows considerable variability throughout the monitoring period. This is particularly noticeable on Profile 2 around December 2006, at which time beach volume changed by up to 38 m³/m between successive surveys (Figure 32). While the volume of beach sediment increases slightly across the survey period (from 109 to 120 m³/m on Profile 2) there is a longer-term oscillation in beach volume. This is observable as a reduction of approximately 10 m³/m from 1993 to 1999/2000 with subsequent increase by approximately 15 m³/m to 2007. The storm of July 2007 clearly impacted the beach reducing volume to levels comparable to those of the initial surveys. Consequently, this data suggest the beach volume is stable and susceptible to longer period oscillations.

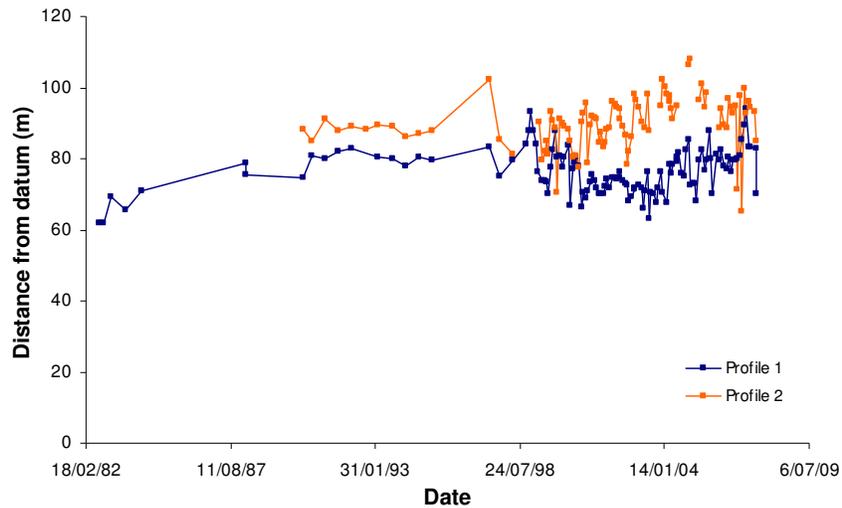
Figure 32 Changes in beach volume at Long Bay. Beach volume calculated as the sand volume contained above the 0 m contour.



4.4.10.3 Change in Beach Width

As with beach volume, the beach width time series at Long Bay shows variability between surveys with maximum change of up to 20 m. Also similar to beach volume results there appears a 6-10 year oscillation in changes in beach width. However, there is no strong long-term change in beach width (Figure 33). The variability appears consistent between sites, a particular example is the period between 1993 and 2004 where beach width appeared to reduce by 10-15 m at both profiles but has subsequently returned to slightly above the 1993 levels in the latest surveys. This data also suggests the beach width has at least remained stable across the monitoring period with significant short- to medium-term variability.

Figure 33 Beach width change at Long Bay. Beach width is measured as the distance from the datum to the 0 m contour.

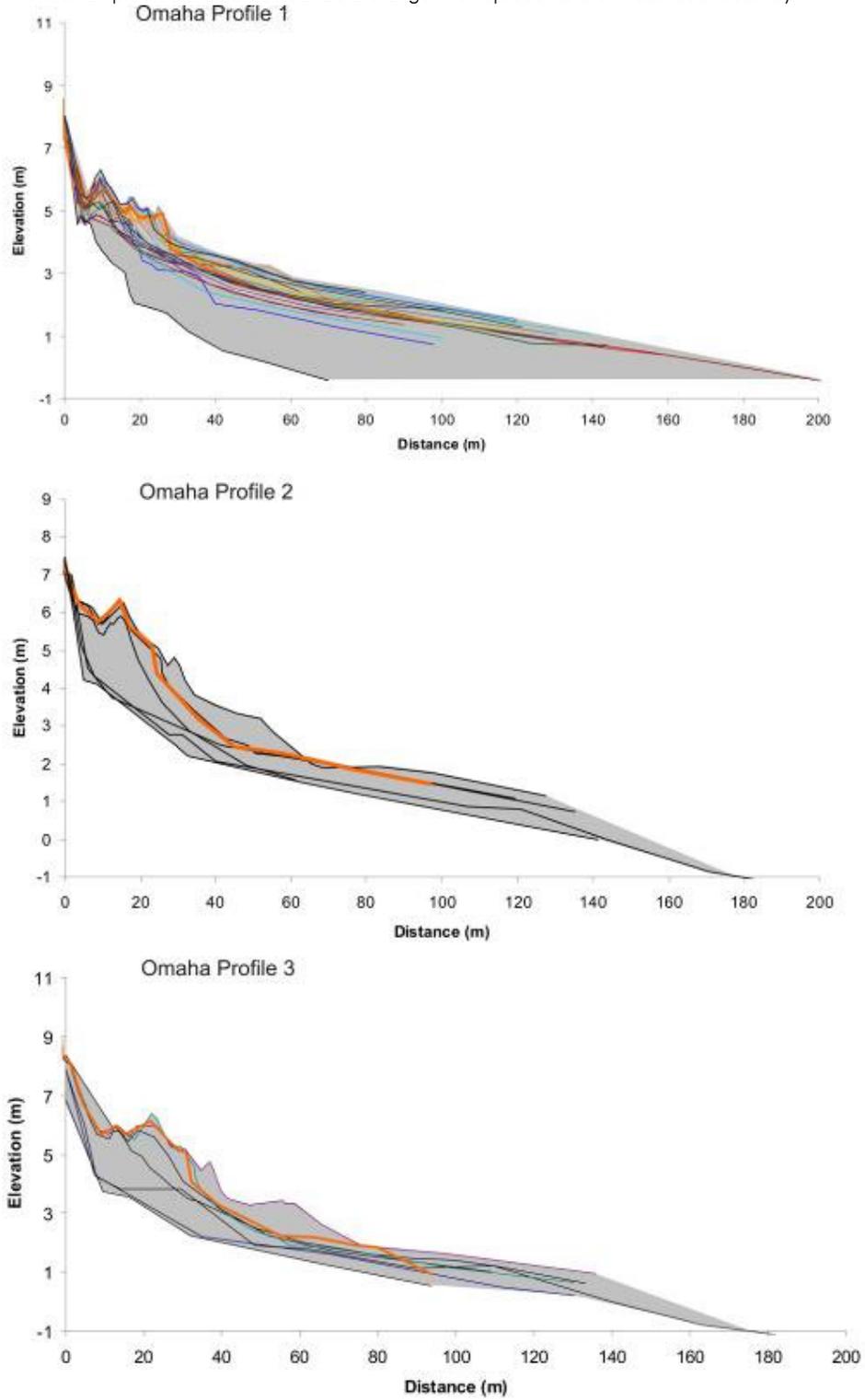


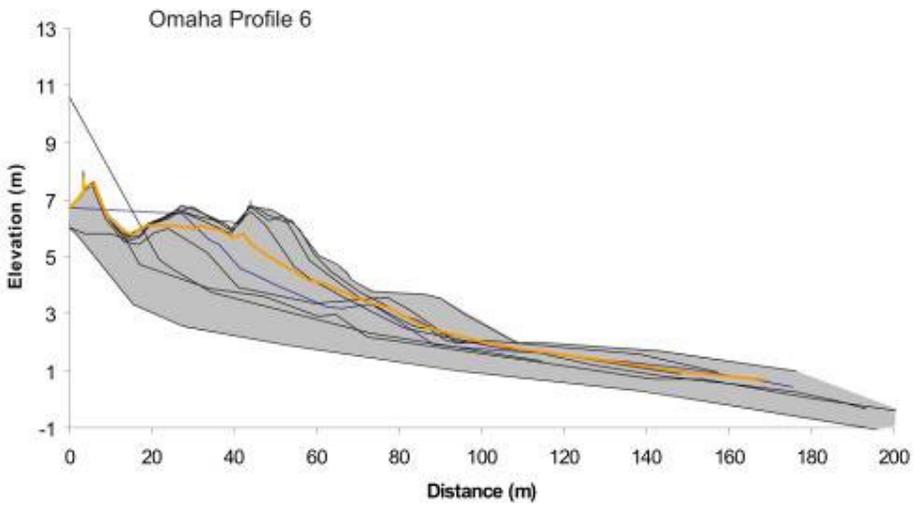
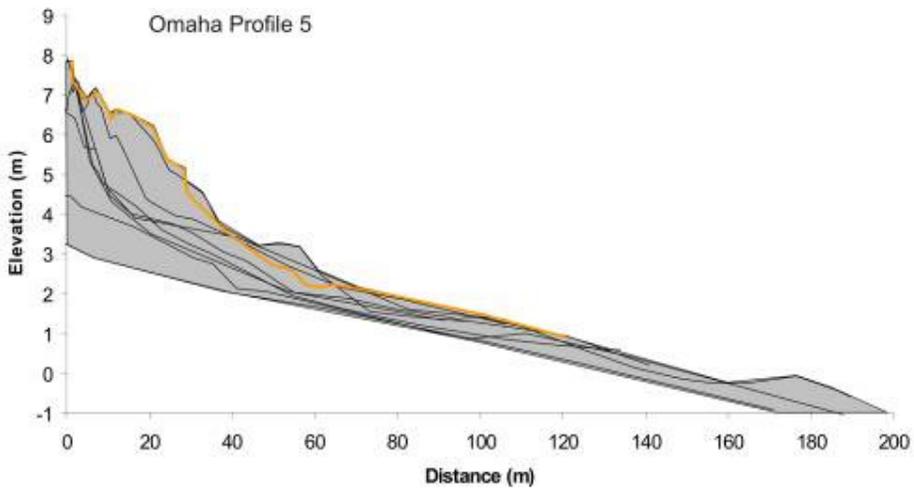
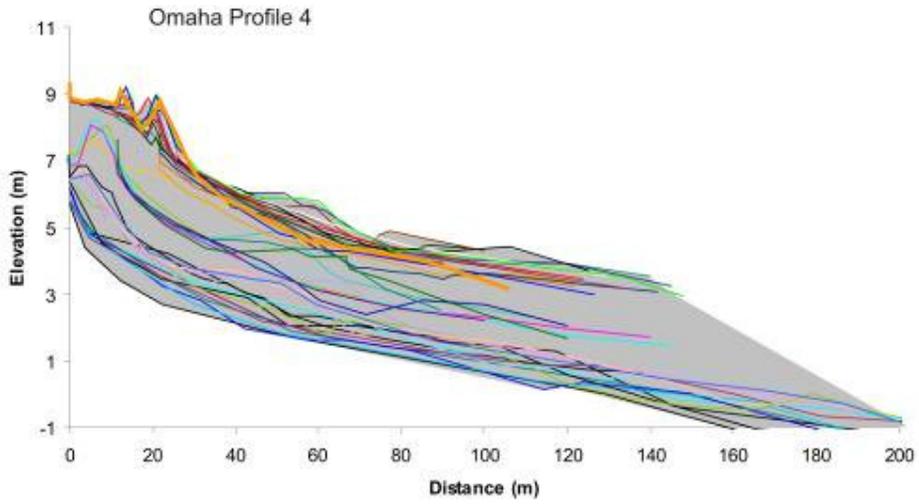
4.4.11 Omaha Beach

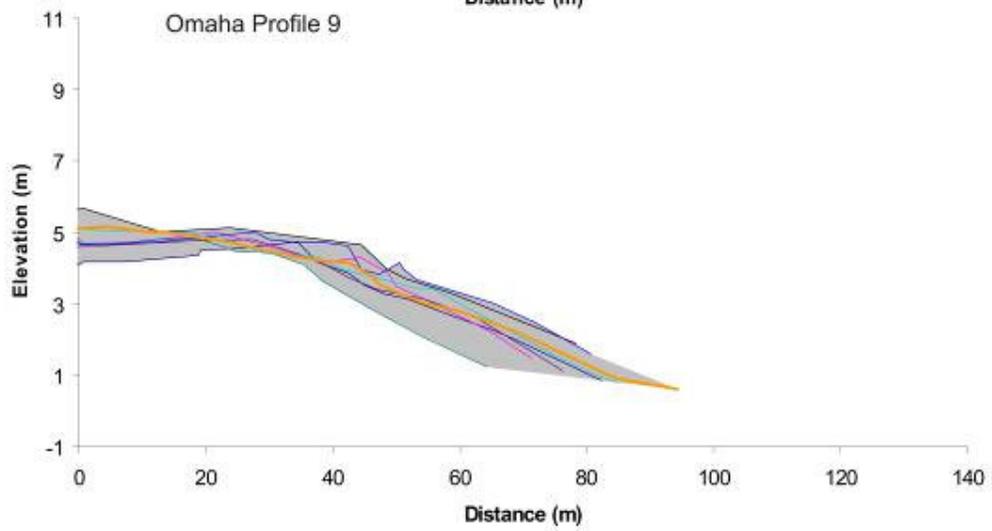
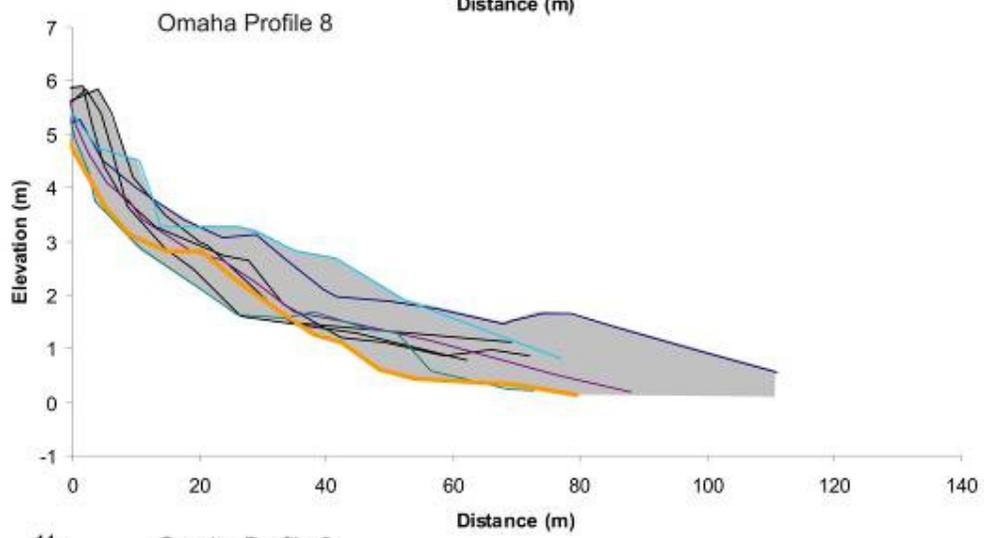
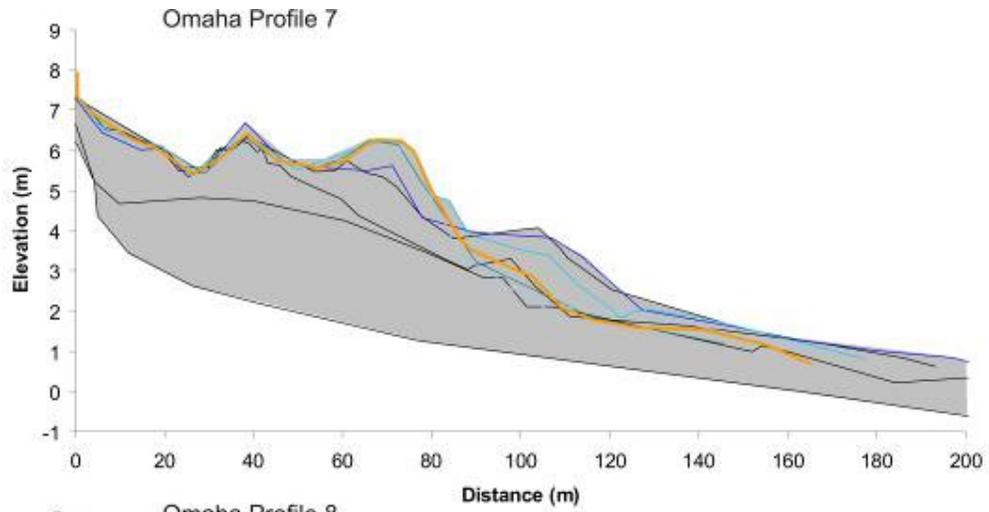
4.4.11.1 Envelope of Beach Change

A total of nine profiles were analysed from Omaha Beach (**Figure 34**). Of note, four of these profiles were initially surveyed in 1965 (P 2, 3, 5 and 6). The envelopes established for each profile generally show broad zones that encompass significant vertical (3-4 m) and horizontal variability in beach volume. Most profiles exhibit vertical fluctuations in bed level ranging from 2-3 m in the intertidal zone. Of note, the landward and lowest boundary of each envelope on Profiles 1-7 are surveys from 1978 when the beach experienced significant storm erosion. Since that time the beach has recovered with the most recent surveys positioned toward the seaward limit of this envelope on most profile lines (**Figure 34**). Of note, Profiles 8 and 9 exhibit much narrower beach envelopes and latest surveys are positioned at the centre or landward position of these envelopes. This is a result of the shorter monitoring record on these profiles (established in 1993) which has yet to develop a broad envelope of change.

Figure 34 Omaha Beach survey profiles showing envelope of change. Grey shaded area captures zone within which all profiles are contained. Bold orange line represents the most recent survey.





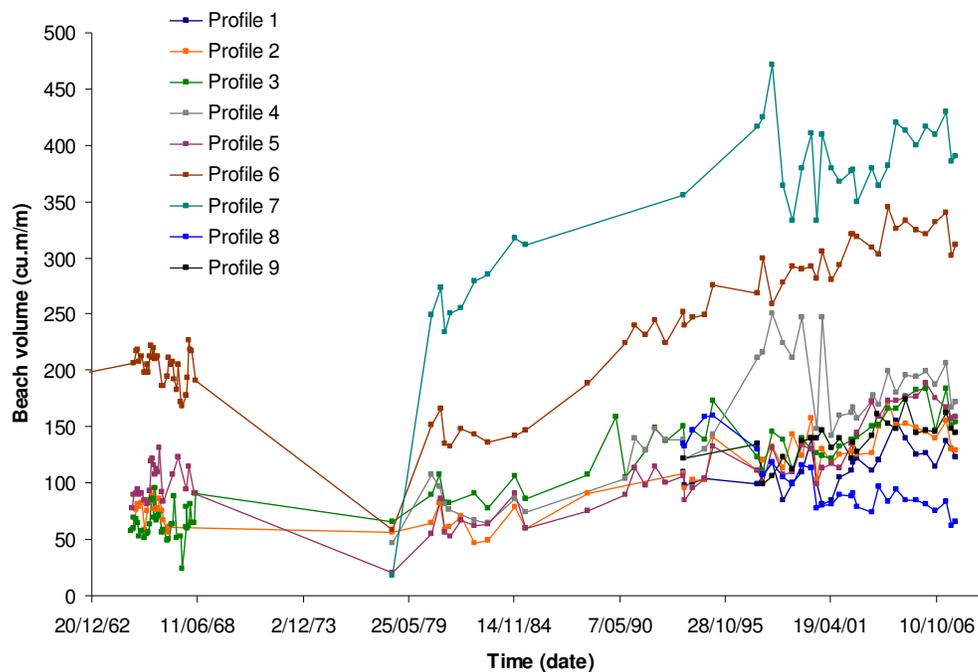


4.4.11.2 Changes in beach volume

Changes in beach volume under each profile (**Figure 35**) show significant change throughout the monitoring period. In particular data show:

- i. A substantial reduction in beach volume as a consequence of the storms in 1978 (volumes fell to 25 – 75 m³/m).
- ii. Rapid recovery to pre-1978 levels within five years.
- iii. Continued increase in beach volume on most profiles. For example, Profiles 6 and 7 show increases in beach volume of more than 100 m³/m from 1980 to the present (**Figure 35**).
- iv. The impact of a storm in July 2000 that reduced beach volume.
- v. Short-term change of +/- 50 m³/m and up to 100 m³/m in response to storms.

Figure 35 Changes in beach volume at Omaha Beach. Beach volume calculated as the sand volume contained above the 1 m contour.

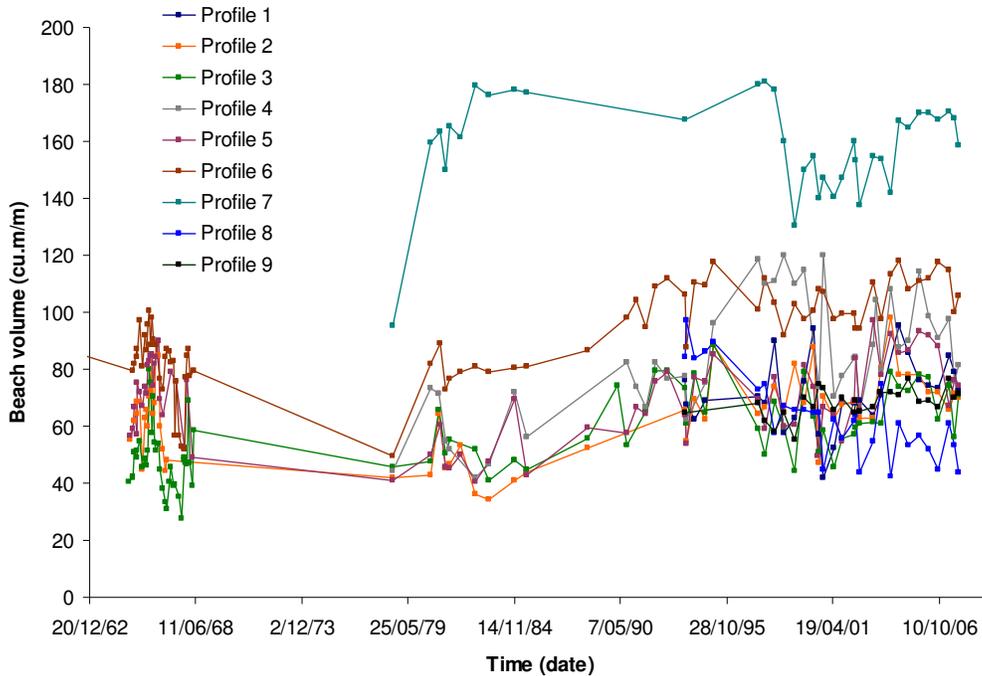


4.4.11.3 Change in Beach Width

Beach width also exhibits significant temporal variations at Omaha (**Figure 36**) that are consistent with changes in beach volume. Beach width is also shown to have contracted as a consequence of the 1978 storms followed by subsequent expansion. Maximum change in beach width is approximately 70 m on Profile 3 (between 1978 and 1980). In general, the period 1979 – 1992 is characterized by steady increase in beach width which has been followed by greater short-term variability with fluctuations in width of up to 20 m between surveys (on most profiles). Overall data indicate a net increase in width on Profiles 3, 4, 6 and 7 of the order

of 15-20 m (**Figure 36**). Other profiles do not exhibit such marked changes and have similar width to that measured in the mid-1960s change in beach width (**Figure 36**).

Figure 36 Beach width change at Omaha Beach. Beach width is measured as the distance from the datum to the 1 m contour.

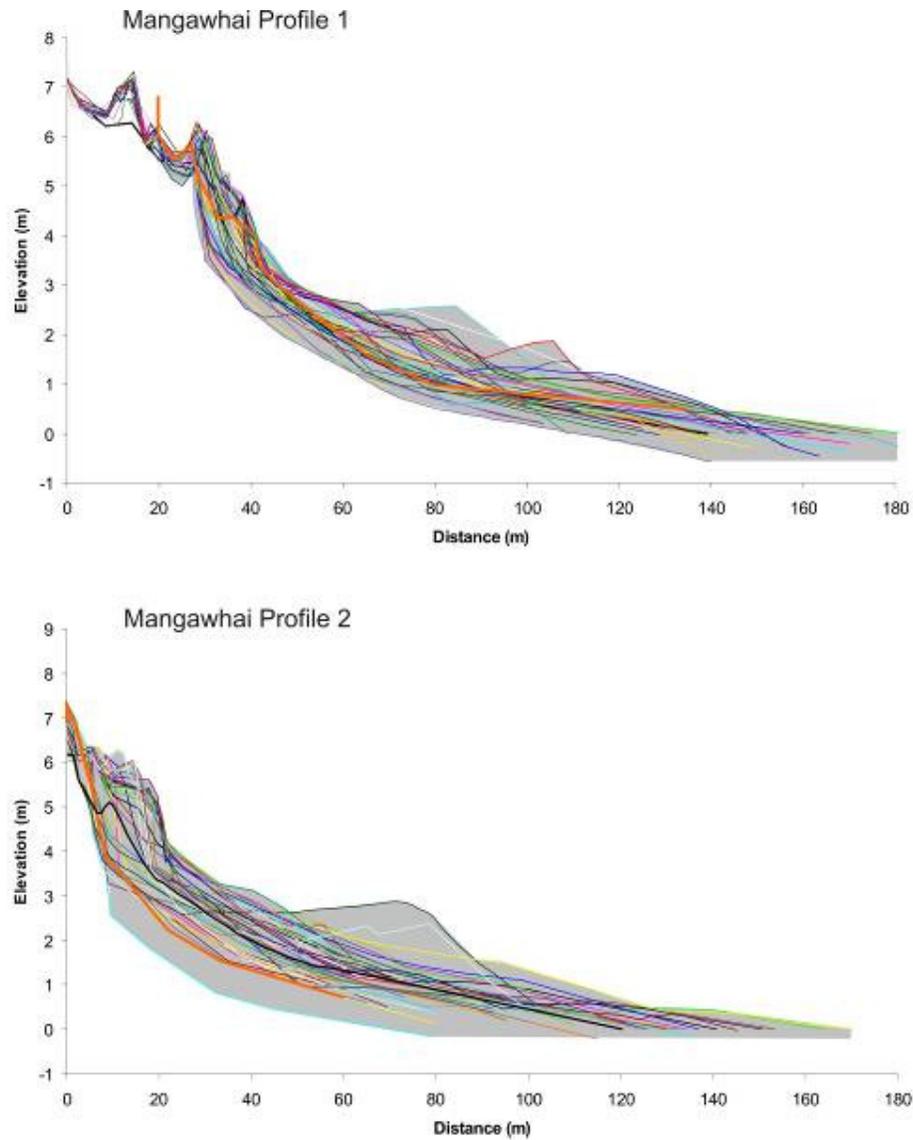


4.4.12 Mangawhai Beach

4.4.12.1 Envelope of Beach Change

Two profiles were analysed at Mangawhai on the moderate energy northeast coast of the Auckland Region (**Figure 37**). These profiles were initiated in 1989 and show considerable short-term variability in beach position. In particular, Profile 2 shows 2.5-3.0 m vertical fluctuations in beach level and 60 m variations in beach width (**Figure 37**). The envelopes established for each profile generally show broad zones that encompass significant vertical and horizontal variability in beach volume. The most recent surveys are located within the defined beach envelopes. However, the dune scarp is close to the landward limit of the envelop of beach change on Profile 2. This is likely the result of the storm event in July 2007.

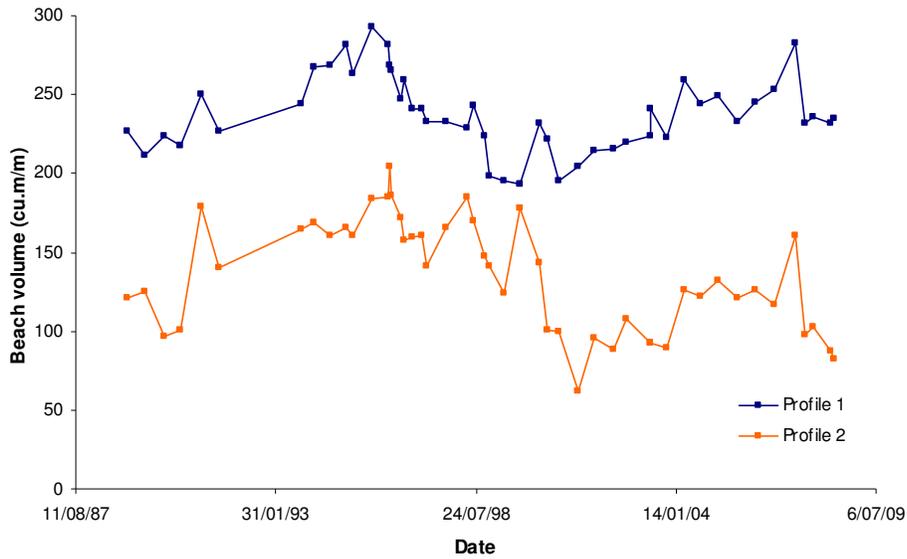
Figure 37 Mangawhai Beach survey profiles showing envelope of change. Grey shaded area captures zone within which all profiles are contained. Bold orange line represents the most recent survey.



4.4.12.2 Changes in beach volume

Unlike many other profiles analysed changes in beach volume do not exhibit large short-term variations (**Figure 38**). Changes occur of up to 50 m³/m but are temporally segregated. However, the data do indicate medium-term cyclic behaviour in beach volume at 8-10 year periods. Consequently, peak volumes were identified in 1995 and 2007 (at 292 and 283 m³/m on Profile 1 and 204 and 160 m³/m on Profile 2) and minimum values in 1989/90 and 2000/2001 (at 211 and 195 m³/m on Profile 1 and 96 and 62 m³/m on Profile 2). Net differences between the beginning and end of the monitoring record are much smaller than the variability within the record and consequently, a net trend can not be determined at this time.

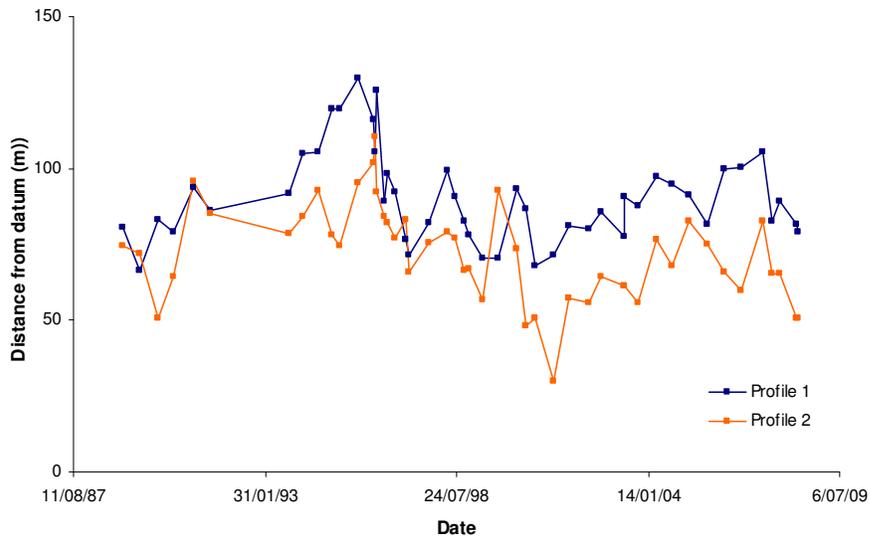
Figure 38 Changes in beach volume at Mangawhai Beach. Beach volume calculated as the sand volume contained above the 1 m contour.



4.4.12.3 Changes in beach width

The pattern of change in beach width (**Figure 39**) mirrors that of beach volume. The 8 to 10 year cyclic behaviour is evident with beach width varying by up to 50 m over this timeframe. There is a suggestion that beach width on Profile 2 has contracted over the monitoring period. However, such a trend is difficult to confirm due to data gaps early in the record and the variability in the record, which is much larger than any net difference.

Figure 39 Beach width change at Mangawhai Beach. Beach width is measured as the distance from the datum to the 1 m contour.

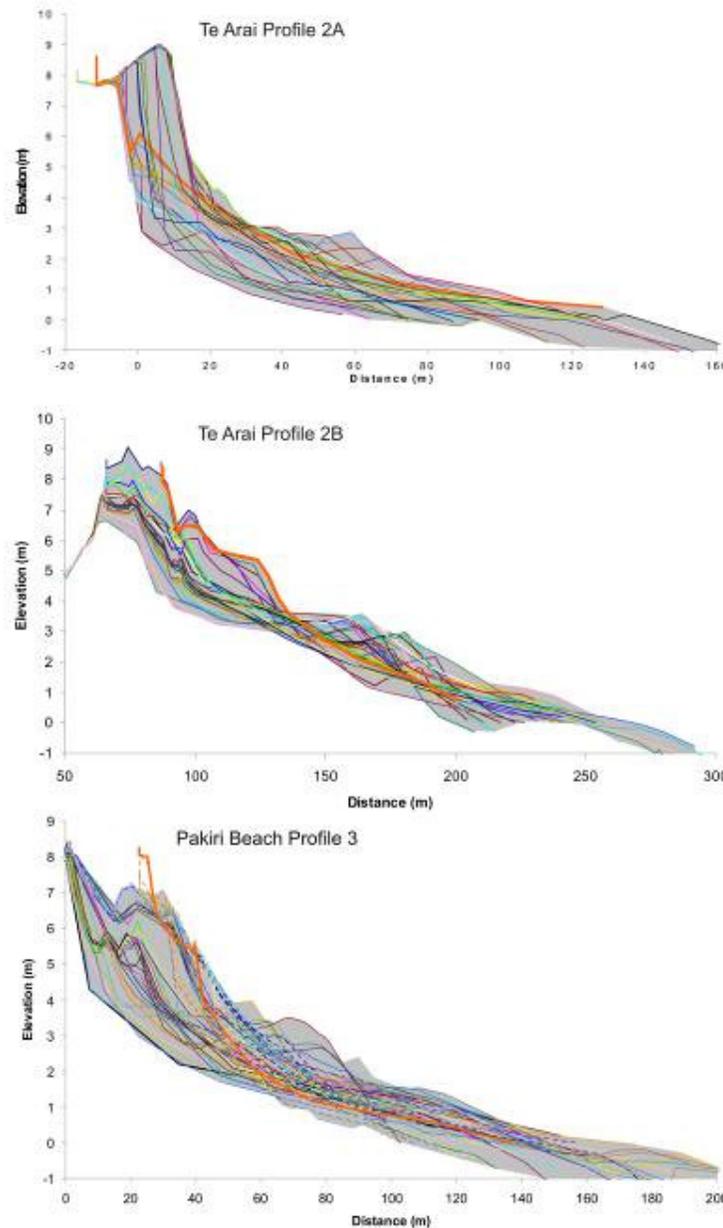


4.4.13 Te Arai

4.4.13.1 Envelope of Beach Change

Figure 40 presents the beach profile data (and envelopes of beach change) for three profiles in close proximity to Te Arai Point. Profile 3 at Pakiri is included in this analysis due to its close proximity to Te Arai Profile 2A. The profiles all exhibit considerable variation in beach morphology over the monitoring record with vertical and horizontal fluctuations in beach position of up to 3 m and 50 m respectively (**Figure 40**). In general, the most recent surveys are positioned within the envelope of beach change (**Figure 40**). However, the dune scarp on Profile 2A is located toward the landward limit of the beach change envelop.

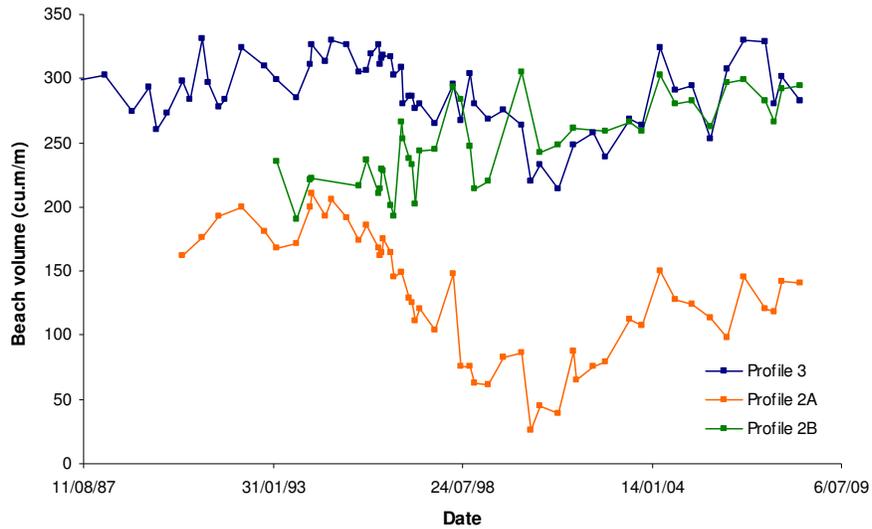
Figure 40 Te Arai Point survey profiles showing envelope of change. Grey shaded area captures zone within which all profiles are contained. Bold orange line represents the most recent survey.



4.4.13.2 Changes in beach volume

Changes in beach volume on Profiles 2A and 2B exhibit consistent trends across the monitoring period (**Figure 41**). In particular, beach volume fell from highest values in 1994/95 (of 330 and 210 m^3/m for Profiles 1 and 2 respectively) to low values in 2000 (220 and 26 m^3/m for Profiles 1 and 2) before increasing to values of around 290 and 145 m^3/m (for Profiles 1 and 2) in the most recent surveys (**Figure 41**). These large variations in beach volume make detection of long-term trends too ambiguous given the length of the record. Of note, the beach volume behaviour of Profile 3 does not show a consistent pattern with Profiles 2A and 2B. This profile appears to have increased in volume consistently since the initial monitoring began in 1993.

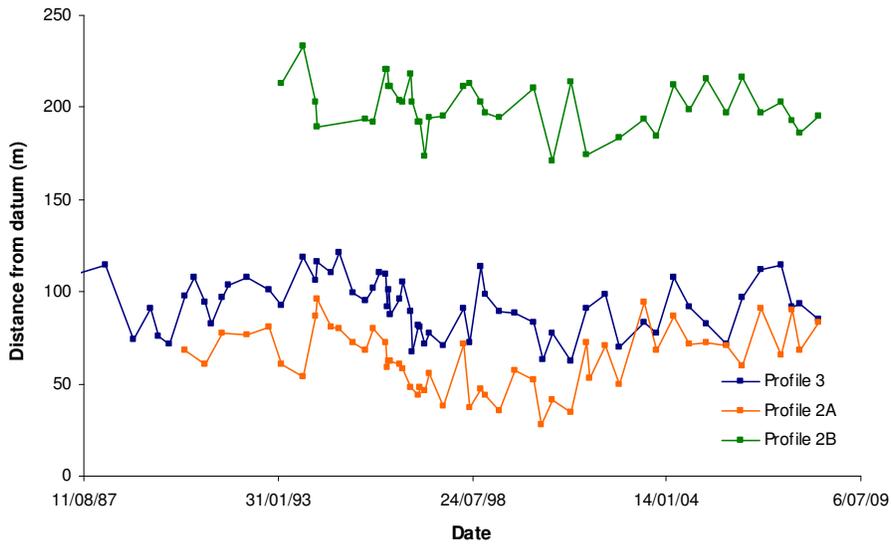
Figure 41 Changes in beach volume at Te Arai Point. Beach volume calculated as the sand volume contained above the 1 m contour.



4.4.13.3 Changes in beach width

The net pattern of change in beach width indicates relative stability across the monitoring record with short- and medium-term variability (**Figure 42**). Short-term variations in beach width range up to 40 m, whereas the multi-year oscillation in beach width is of the order of 30 m. Such variations mask any long-term trend.

Figure 42 Beach width change at Te Arai Point. Beach width is measured as the distance from the datum to the 1 m contour.

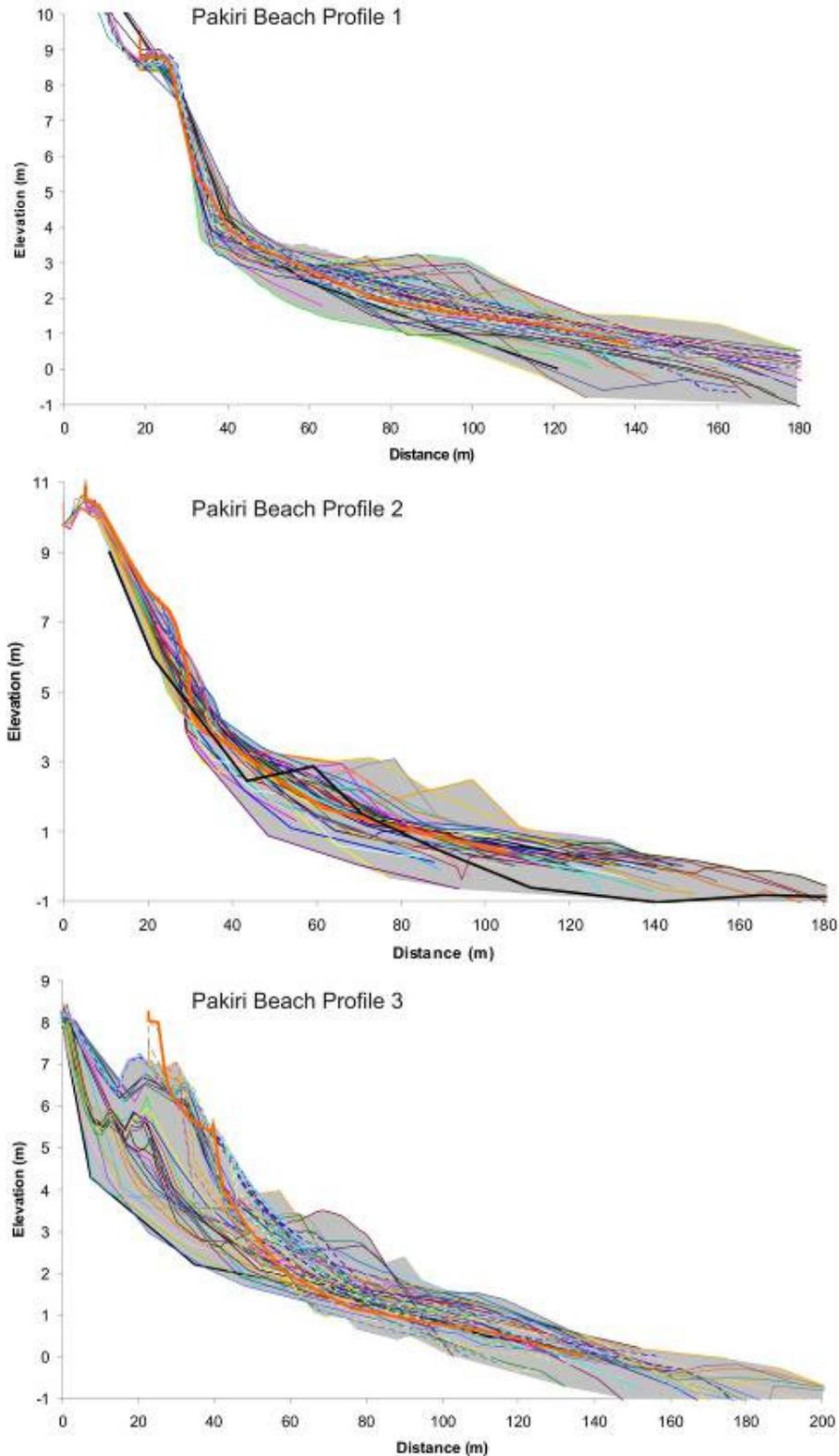


4.4.14 Pakiri Beach

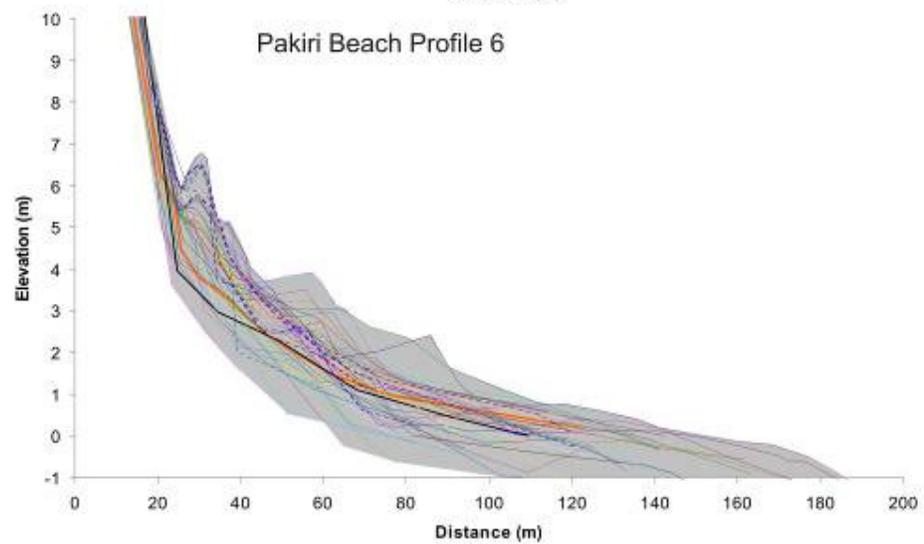
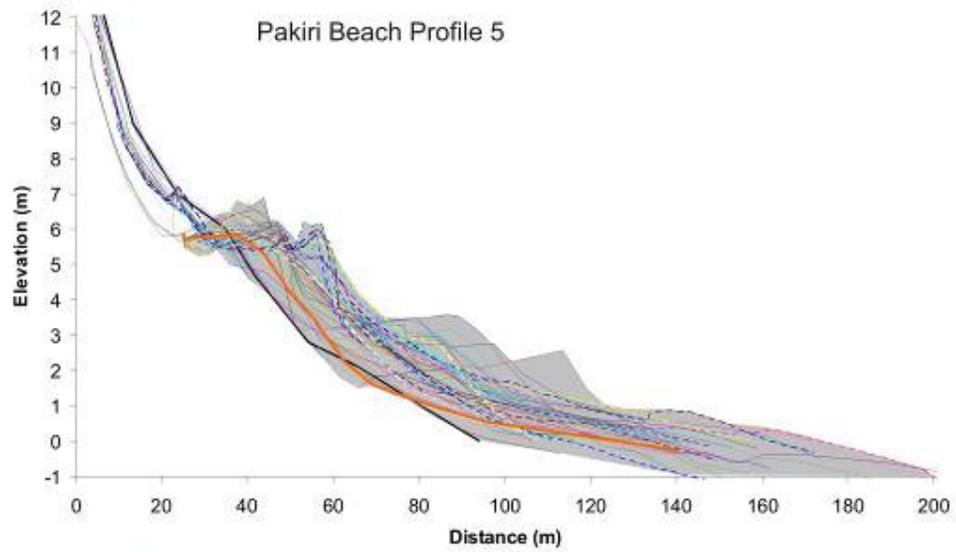
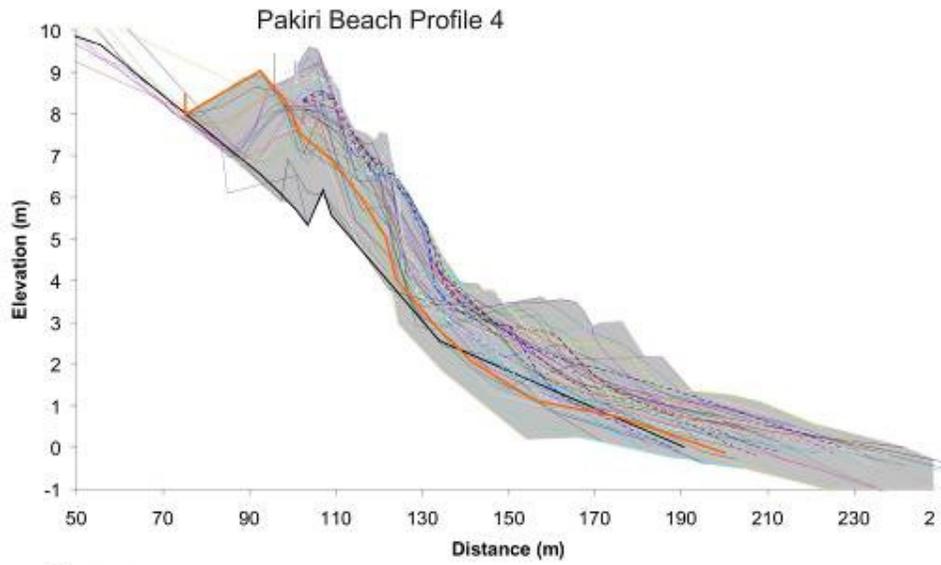
4.4.14.1 Envelope of Beach Change

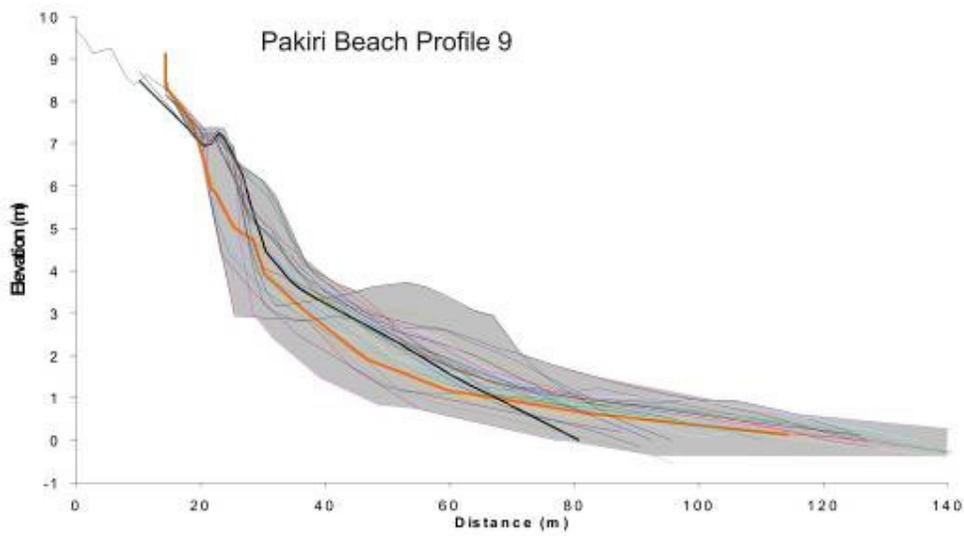
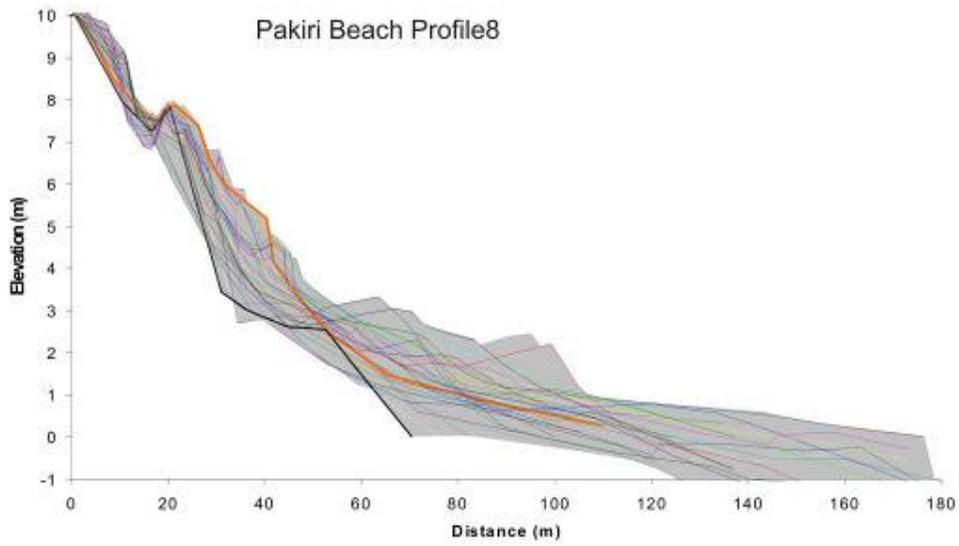
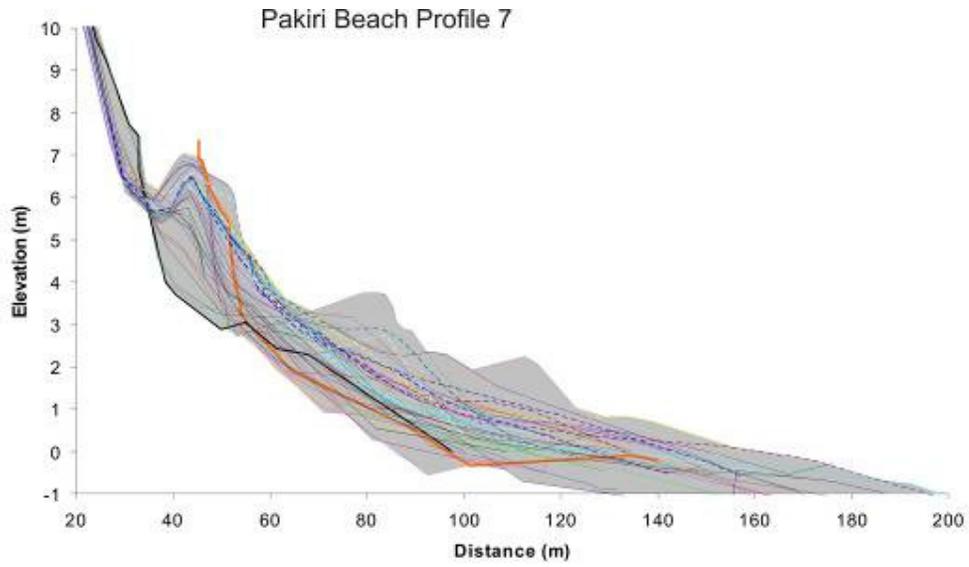
Nine profiles were analysed from Pakiri Beach (**Figure 43**). Six of these profiles have been monitored since 1978 (following the major storm events that impacted the northeast coast and which are observed in the Omaha beach profile records, Section 3.4.11). Profiles 1 and 2 are located north of Te Arai Point with the remaining profiles are located south of Te Arai Point. All profiles exhibit significant variations in beach morphology with vertical fluctuations in bed level in excess of 3.5 m and changes in horizontal position of up to 60 m on the lower foreshore (**Figure 43**). In general, recent surveys indicate the current beach position sits within the historic envelop of beach change. However, three profiles (1, 6, 9) do indicate that the upper dune scarp position is close to the landward boundary of this envelop.

Figure 43 Pakiri Beach survey profiles showing envelope of beach change. Grey shaded area captures zone within which all profiles are contained. Bold orange line represents the most recent survey. Black line depicts earliest survey.



depicts earliest survey.





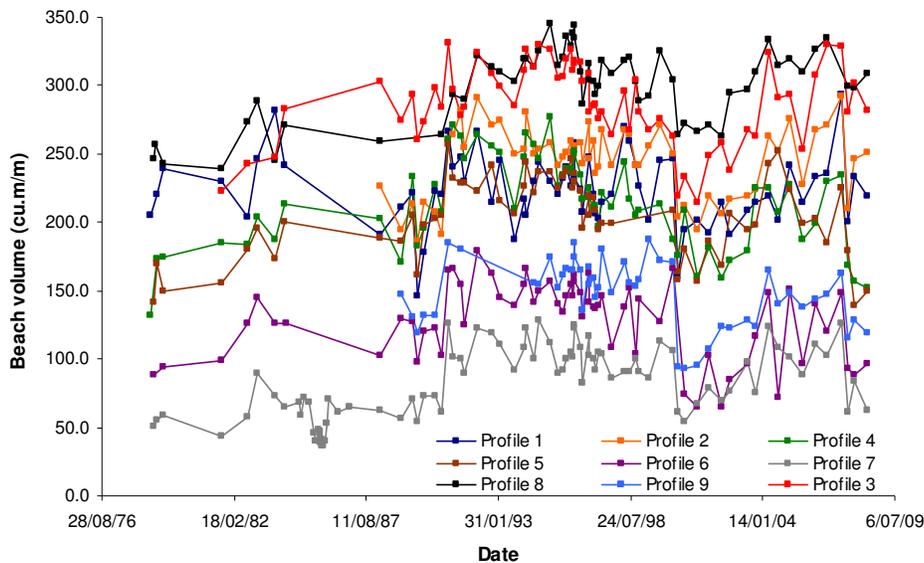
4.4.14.2 Changes in beach volume

Changes in the sand volume contained within beach profiles show consistent patterns between profiles (**Figure 44**). These are:

- i. The six longest profile records all show a net increase in sand volume over the monitoring record. However, these net changes are small (ranging from 8 m³/m on Profile 5 to 20 m³/m on Profile 4).
- ii. There are medium-term (8-10 year) cycles in beach volume. Beach volumes reached a peak on each profile between 1992 and 2000 with the addition of up to 100 m³/m to the profiles.
- iii. A marked reduction in volume occurred in July 2000, presumably associated with a storm event that stripped up to 100 m³/m from some beach profiles.
- iv. A further increase in beach volume occurred from July 2000 to July 2007. A storm in July 2007 promoted a second marked reduction in beach volume.
- v. There is considerable short-term variability in beach volume of up to 75 m³/m.

In general, the beach appears to be highly dynamic and susceptible to significant storm events that strip sediment from beaches. However, the record shows the beach sediment volume has been able to recover from the events and has not eroded below the levels contained in the beach at the initiation of the monitoring programme.

Figure 44 Changes in beach volume at Pakiri Beach. Beach volume calculated as the sand volume contained above the 1 m contour.

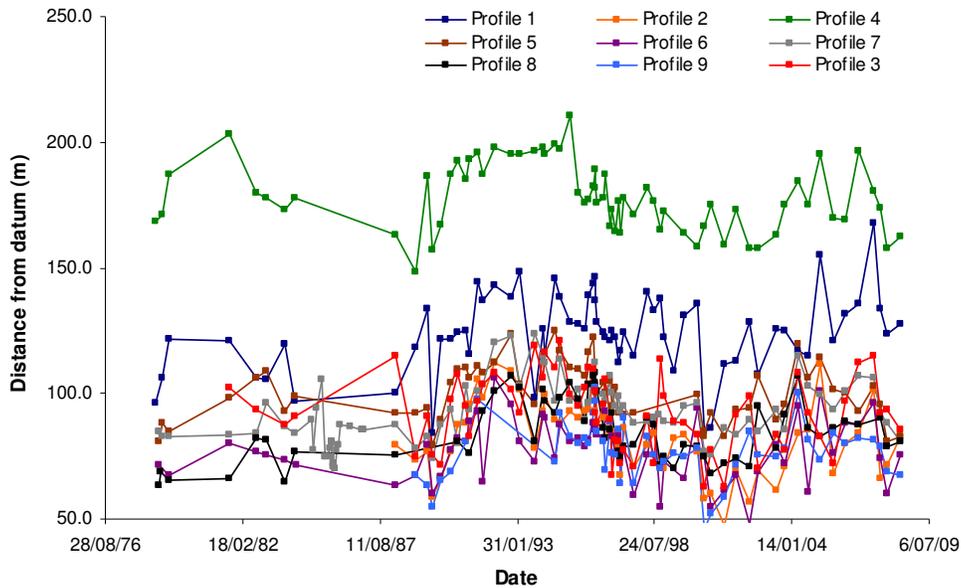


4.4.14.3 Changes in beach width

Five of the six profiles with the longest monitoring records exhibit a small increase in beach width between the start and end of the monitoring period (up to 20 m). However, Profile 4 indicates an 8 m reduction in beach width across the monitoring record. However, these changes are small compared with the large short- and medium-term beach width changes experienced on each profile. For example the storm episodes of July 2000 and 2007 promoted rapid contraction of beach width by up to 60 m, whereas the medium-term changes in beach

width range up to 40 m (**Figure 45**). These oscillations appear to be storm driven at 8 to 10 year cycles. The beach profile data indicate that the beach is relatively stable over the medium to long-term but subject to high temporal variation in beach width.

Figure 45 Beach width change at Pakiri Beach. Beach width is measured as the distance from the datum to the 1 m contour.



4.5 Summary of Beach Change

Results of profile analysis of the fourteen study sites show that all the beaches exhibit morphological variability. It is also apparent that the magnitude of this variability varies both between beaches and within beaches. Between beach variations broadly correspond to the different coastal settings as discriminated by wave energy.

Piha and Muriwai are the only West Coast beaches in the monitoring programme. These beaches have a high wave energy setting and exhibit the largest fluxes of sediment and substantial changes in beach width (**Table 1**, Figures 25-30). Beaches on the moderate energy exposed north east coast (Mangawhai, Te Arai, Pakiri and Omaha) possess the second largest degree of morphological variability in the monitoring programme (**Table 1**, Figures 34-45). In contrast, sites at Kawakawa Bay, Maraetai and Orere Point, which have the most sheltered energy regime, exhibit the smallest variations in sediment flux and changes in beach width (see standard deviation values in **Table 1**, and Figures 16-24). Beaches in the East Coast Bays sit between the end members of wave energy identified in this analysis. They clearly have greater morphological variability than the lower energy beaches and less than the high energy west coast sites (Muriwai and Piha) and more exposed northeast beaches from Mangawahi to Omaha (**Table 1**, Figures 4-15). These findings indicate that beaches within similar energy settings have similar morphodynamic characteristics. This suggests that monitoring multiple sites in each sub-environment may not be warranted and that effort may be better directed at identifying sentinel sites among a broader spectrum of coastal settings.

Monitoring records highlight that beach morphology varies at a range of spatial scales. Acknowledging the limited length of most of the datasets (10 years) it is clear that beach morphology varies at seasonal, inter-annual and sub-decadal timescales. Extension of these

monitoring records would likely establish longer-term variations in morphology at the decadal to multi-decadal timescale (e.g. McLean and Shen, 2006).

Few beaches exhibited significant long-term trends across the length of the monitoring records. This in part may reflect the relatively short length of some records (approximately 10 years). At these beaches existing monitoring has defined the envelope of beach change. This is useful from a monitoring perspective as it provides an excellent baseline against which future changes can be evaluated. There is some evidence for a small increase in sediment volume at Browns Bay between 2001 and 2007. However, there has been a more recent reduction in this sediment volume as a consequence of the major storm of July 2007.

The beaches with longer (>20 year) records reveal some long-term trends in beach behaviour:

- At Muriwai two profiles indicated net long-term shoreline erosion whereas other profiles indicated net beach accretion.
- There is evidence of an increase in sediment volume contained within a number of profiles at Piha. However, increases in sediment volume are only noticeable on individual profiles and are not consistent across the beach.
- At Omaha there has been a net increase in sediment volume on profiles since the 1978 storm events.
- At Pakiri long-term trends are difficult to determine due to significant short and medium-term variability. However, the beach profiles do not appear to be undergoing active erosion and are considered stable through the monitoring record.
- At Mangawhai, Pakiri, and Omaha there is clear evidence of decadal scale oscillations in beach behaviour (Figures 35, 36, 38, 39, 44, 45). However, the precise mechanisms causing beach change at these timescales is unclear.

Interpretation of long-term trends must be made with caution. First, given the length of monitoring records it is possible that such observations are indicative of inter-decadal oscillations in beach volume and width as opposed to a net longer-term (centennial scale) addition of sediment to the coastal system. Second, it is also possible that the small inputs of sediment reflect the onshore movement of sediment stored in the subtidal environment. Current profile surveys do not capture this much larger sediment component of the beach systems. Third, most profiles show the magnitude of short and medium-term variability is much greater than any observed net change. This is not unexpected but makes detection of unambiguous long-term trends problematic. Therefore, both the length of shorter records, truncated nature of the profiles and high levels of variability in beach morphology prevent firm conclusions on the budgetary or erosional status of the beaches. However, it is important to note that in all the beaches analysed there were no examples where the most recent survey of beach position was landward of the historic envelope of beach change.

4.6 Value of Monitoring Records to Support Hazard Evaluation

The existing monitoring records have defined the short-term variability in the upper beach compartments of all beaches analysed. Consequently, the envelope of beach change is able to be defined. Such information is important in hazard evaluation as it allows determination of the magnitude of 'storm cut' that may be expected in severe storm events.

Of equal importance in hazard management is establishing the inter-decadal variation in position of the entire envelope of beach change (medium-term change). It is morphological change at

this timescale that is perhaps most relevant for identifying areas of coast subject to hazards and informing the planning and management process. A number of New Zealand case studies have shown that movements of the envelope of beach change can be an order of magnitude larger than short-term changes in beach status, which are a consequence of storms (Bryan et al., in press). For example, at Ohiwa spit in the Bay of Plenty, the multi-decadal change in the beach envelope is approximately 150 m, whereas short-term oscillations in beach position (within the envelope) are on the order of 50 m.

The ARC monitoring programme currently has a number of beaches that span more than 10 years. These records are able to better detect decadal variations in position of the beach system. However, beach monitoring records that span a decade are currently only able to provide information on the short-term variability. They are now maturing to a point where ongoing monitoring commitment will greatly increase their value in hazard management by evaluating decadal scale changes.

4.7 Causes of Beach Change

As outlined in Section 3.5 current monitoring records do not indicate that monitored sites are experiencing chronic shoreline erosion. Perhaps one exception being two profiles at Muriwai (Figures 28-30). The records have highlighted varying levels of variability which is expected given differences in wave climatology in the Auckland region and differences in susceptibility to storms (exposure). For example, a number of records show marked reduction in beach sediment volume and beach width that are likely to correspond to storm impacts on beaches. In particular, storms in July 2000 and 2007 promoted significant reduction in sediment volume and beach width at Pakiri (Figure 44) and Omaha (Figure 35).

On a more generic basis it is important to note that it is extremely difficult to identify causes of erosion or accretion on coastal systems from monitoring data alone. There are a raft of causes of coastal change that are natural (change in wave climate, sediment supply and sea-level rise) and human-induced (e.g. sand extraction, shoreline modification). Accurate detection of the causes of shoreline change require complementary monitoring of key environmental variables (wave climate being of highest priority) and field investigation of human activities and modifications at the coast. Issues surrounding the causes of coastal erosion and identification of causes are outlined in detail in the ARC Coastal Hazard Strategy and Coastal Erosion Management Manual Erosion Manual.

4.8 Monitoring of Relevant Environmental Variables

No systematic measurement of environmental variables has occurred to support interpretation of coastal monitoring records. Wave climate is the most important parameter to measure. Wave energy and changes in both the direction and height of waves have been identified as a major contributor to short and medium-term coastal change (Ranasinghe et al., 2004; Short and Trembanis, 2004). The ARC supported collection of deep ocean wave data beyond Mokohinau Island for a finite period in the late 1990's and early 2000's. This dataset is the only multi-year record of wave energy input and is at the boundary of the Hauraki Gulf.

Of relevance to beach monitoring are wave records in close proximity to beaches of interest. Currently, wave records from such sites have not been collected in a systematic manner. A number of short duration records have been collected as part of university research theses and

consulting projects. However, these are generally of insufficient length for interpretation of beach monitoring datasets.

Sea level and changes in sea level are also an important control on beach behaviour. Important aspects of sea level of interest to the beach monitoring programme are: i) periods of extreme sea level associated with storms; ii) interannual and decadal variations in sea level driven by broad climatic oscillations (Bell and Goring, 1998; de Lange, 2000); and, long-term changes in sea level.

Although not part of the ARC monitoring programme a sea level recorder has been in operation in the Port of Auckland for more than a century. Analysis of the Auckland sea level record indicates significant decadal scale variation and a long-term increase over the past century of approximately 1.3 mm/y (Hannah, 2004). Such variations require careful and detailed interpretation in the context of beach monitoring records. Currently, there are few beach monitoring sites of sufficient length to allow such analysis to occur. This places a premium on development of multi-decadal coastal monitoring datasets to evaluate cause and effect relationships between wave climate, sea level and observed coastal change.

5 Summary of the Beach Monitoring Programme

5.1 Summary of Existing Programme

The existing monitoring programme is characterized by:

- Profiles on 16 beaches that represent 4 contrasting wave energy settings in the Auckland region.
- Six monthly or monthly surveys (at East Coast Bays beaches).
- Monitoring records that range in length from 10 years to 30 years.
- 2-dimensional beach profiles.
- Extension of beach profiles across the subaerial and upper intertidal zone only, which constrains the value of monitoring records to furnish information on sediment budgets and entire beach system responses.
- Use of outdated survey methodologies.
- At Muriwai two profiles indicated net long-term shoreline erosion whereas other profiles indicated net beach accretion.
- There is evidence of an increase in sediment volume contained within a number of profiles at Piha. However, increases in sediment volume are only noticeable on individual profiles and are not consistent across the beach.
- At Omaha there has been a net increase in sediment volume on profiles since the 1978 storm events.
- At Pakiri long-term trends are difficult to determine due to significant short and medium-term variability. However, the beach profiles do not appear to be undergoing active erosion and are considered stable through the monitoring record.
- At Mangawhai, Pakiri, and Omaha there is clear evidence of decadal scale oscillations in beach behaviour (Figures 35, 36, 38, 39, 44, 45). However, the precise mechanisms causing beach change at these timescales is unclear.

The ARC beach monitoring programme has generated valuable information on the short-term, seasonal and inter-annual scale variability in beach morphology.

The shorter datasets (10 years) are currently of insufficient length to determine net medium or long-term erosion or accretion trends. However, there is little sign of chronic erosion or accelerated accretion in the beach systems analysed (Section 3.0). In contrast, it is likely that longer (30 year) datasets can provide definitive indications of decadal scale variations in beach morphology.

Importantly, the existing monitoring data has defined the envelope of beach change. These envelopes provide the necessary baseline information to detect future coastal change. Continued commitment to maintaining a longitudinal monitoring programme is of critical importance for expanding the value of the data to support hazard management and medium-term coastal change analysis.

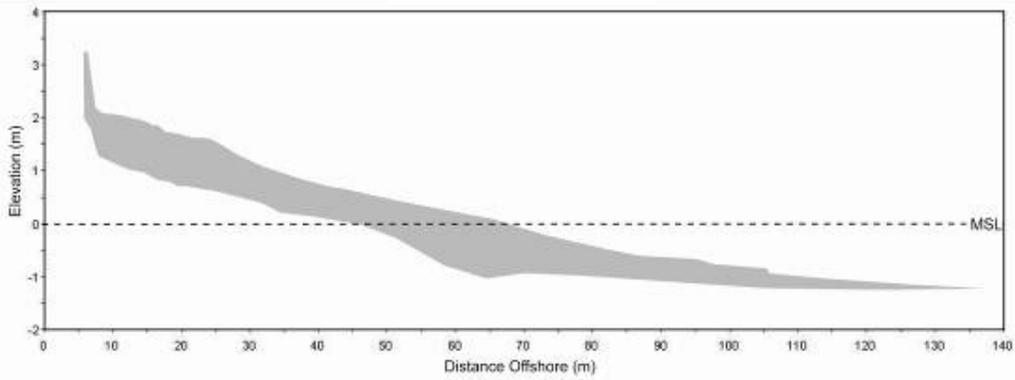
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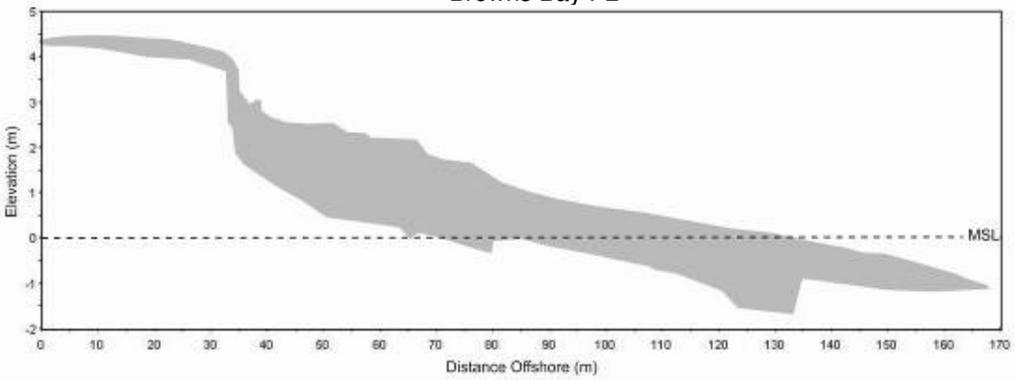
Appendix 1

Summary of Envelope of Beach Change

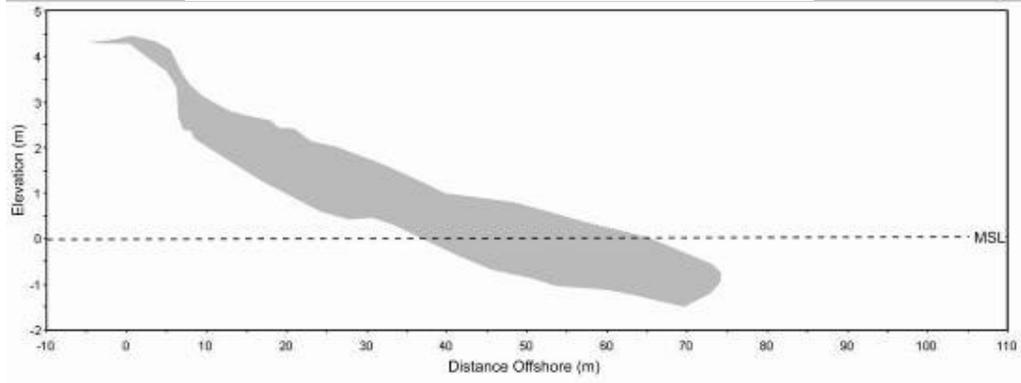
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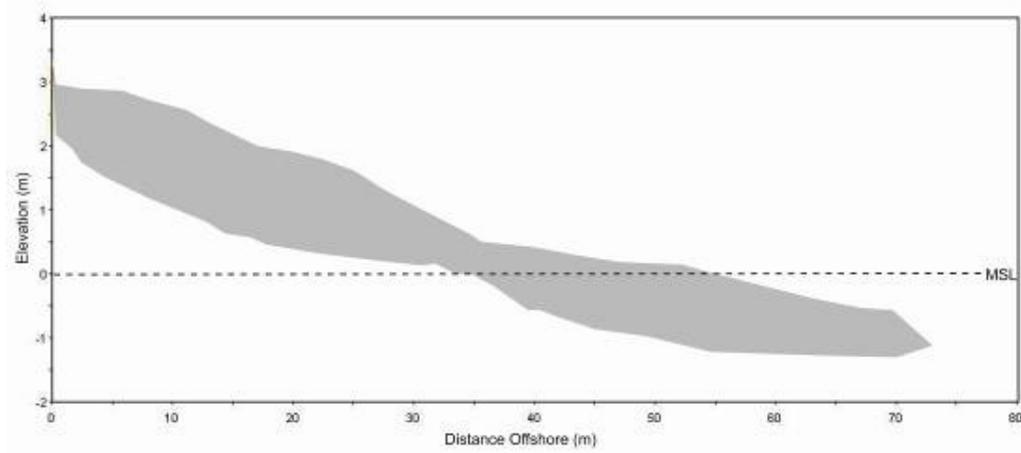
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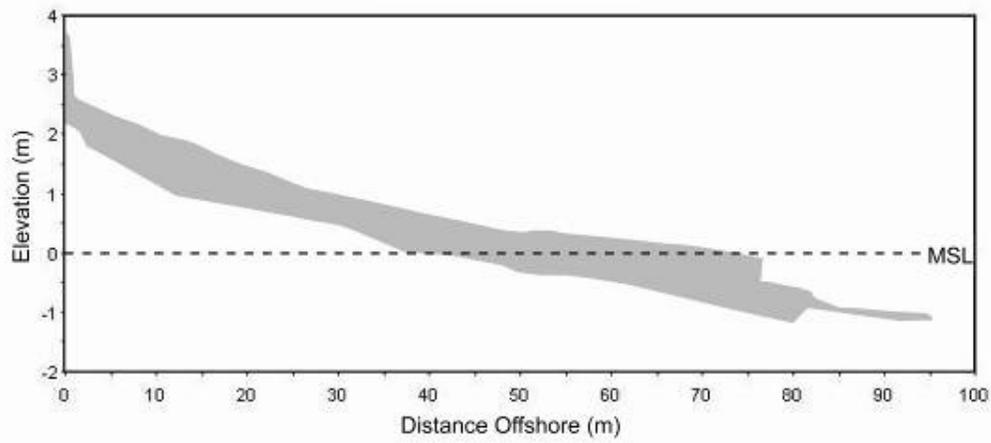
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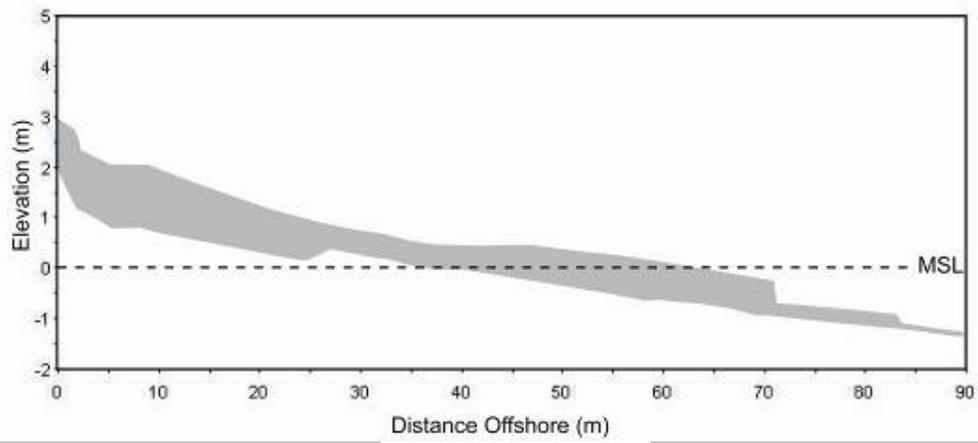
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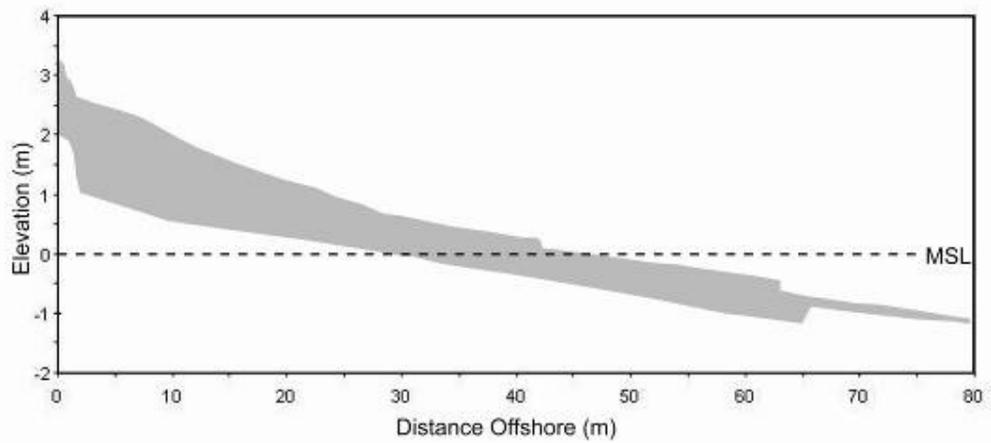
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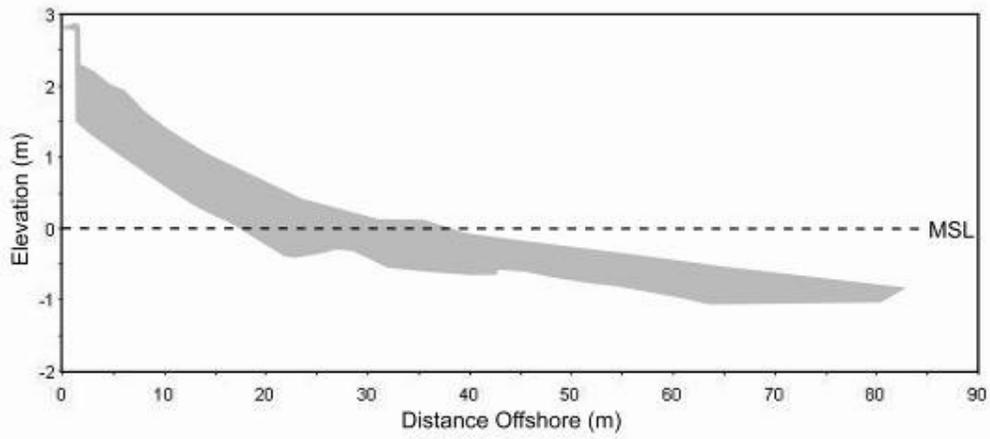
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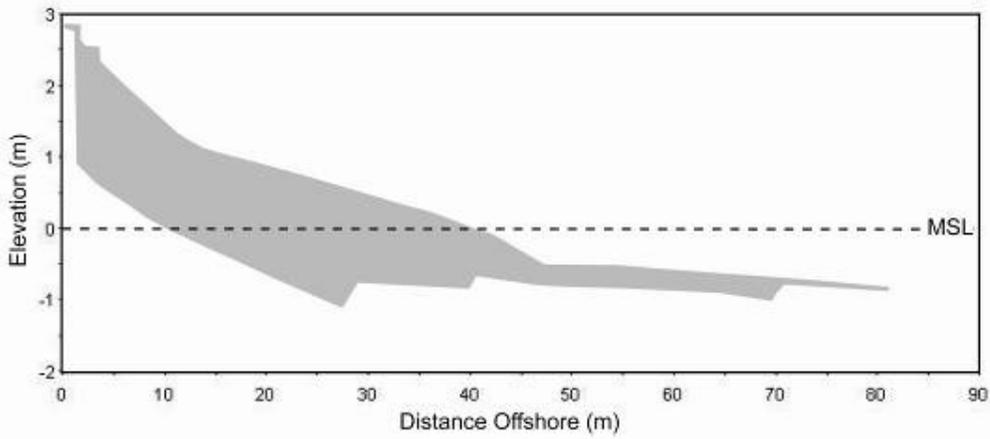
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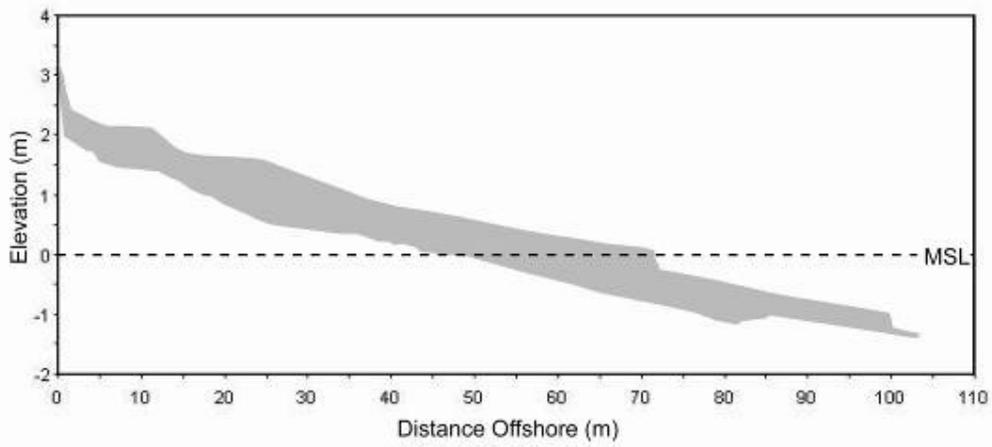
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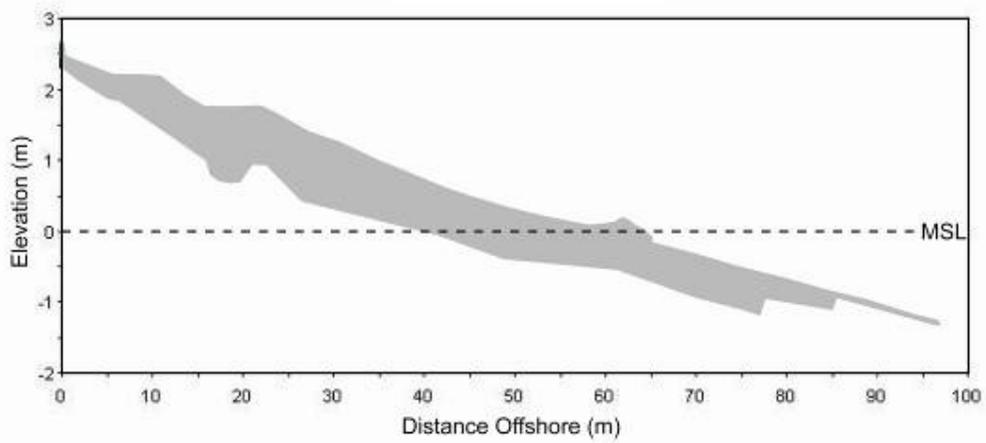
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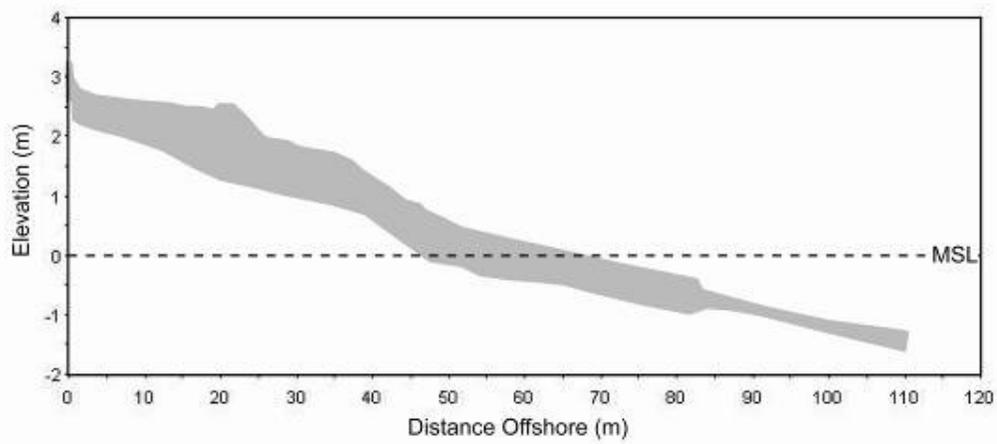
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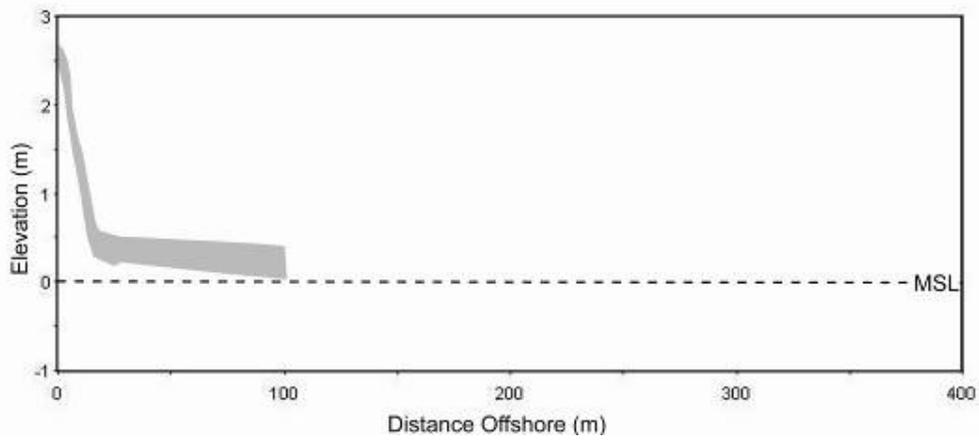
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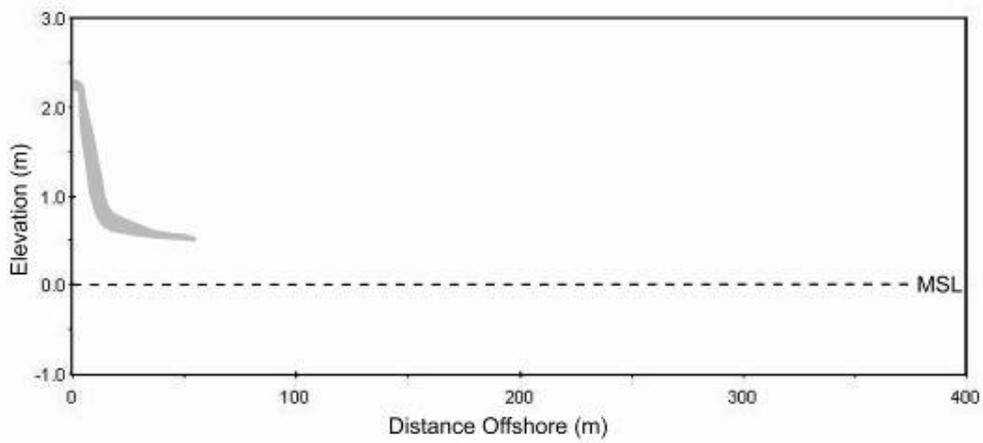
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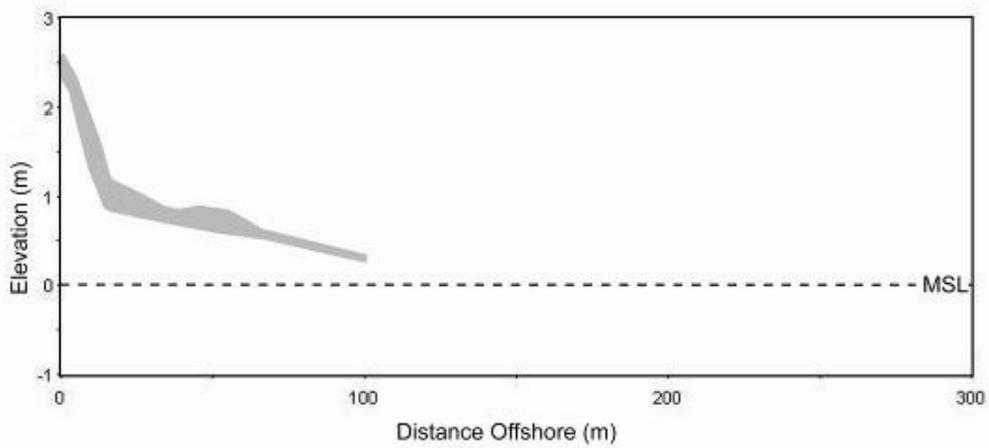
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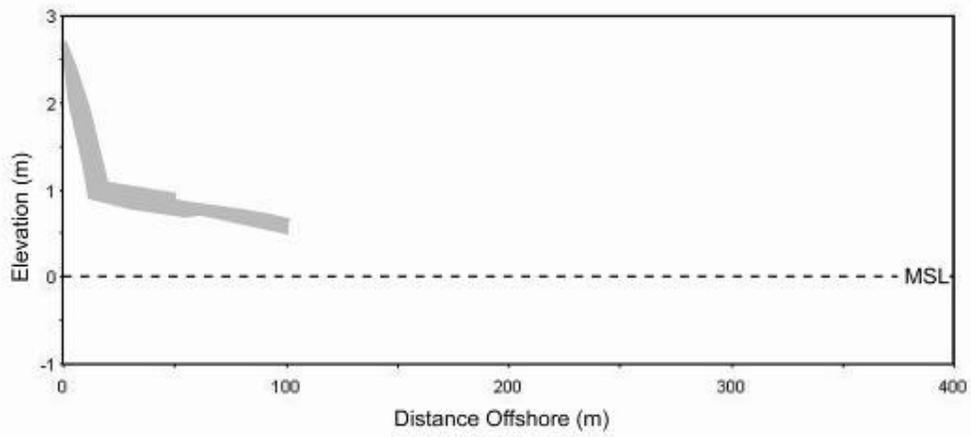
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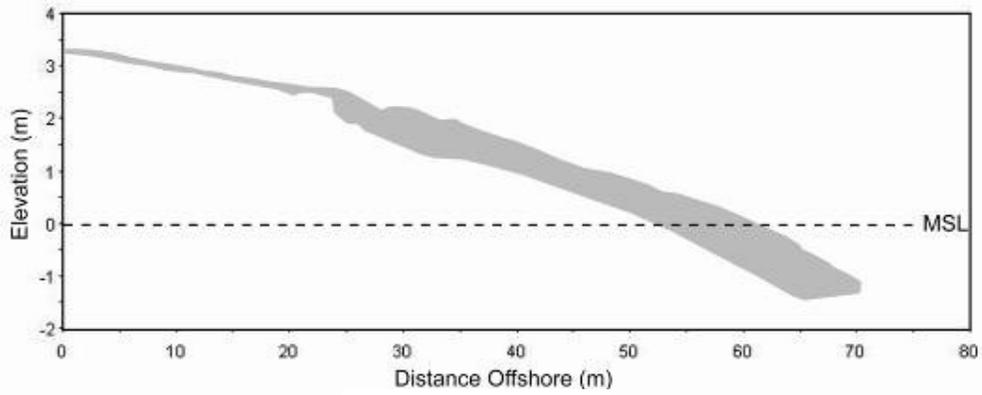
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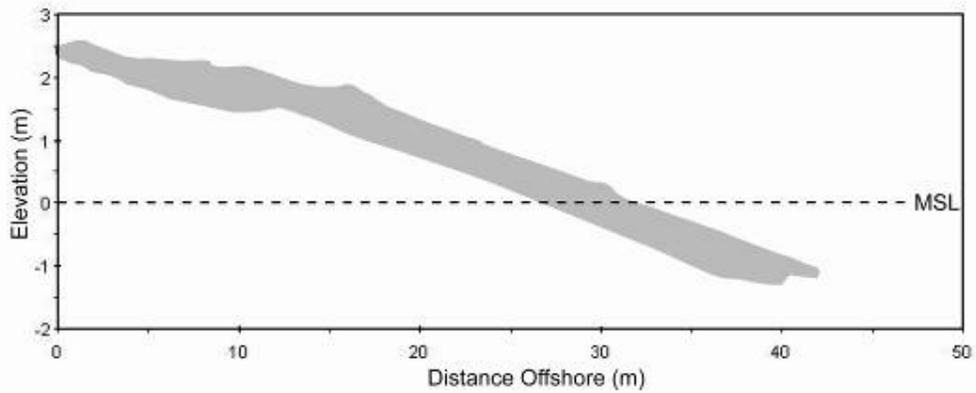
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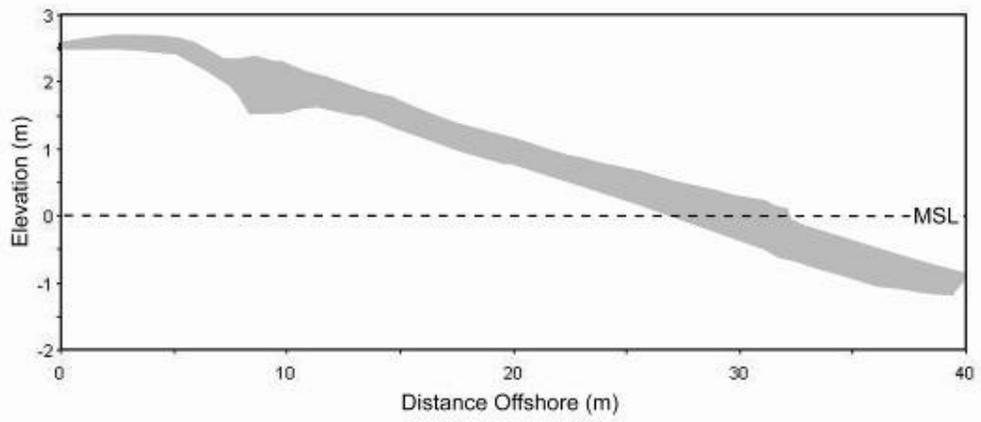
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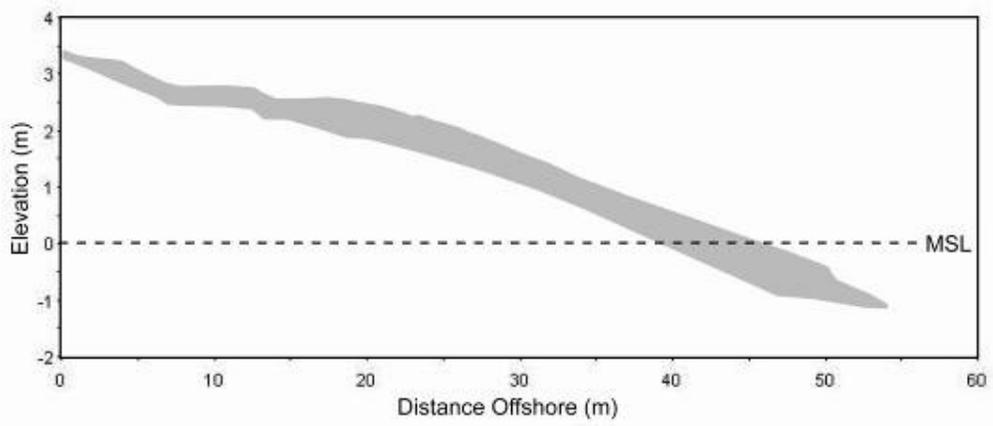
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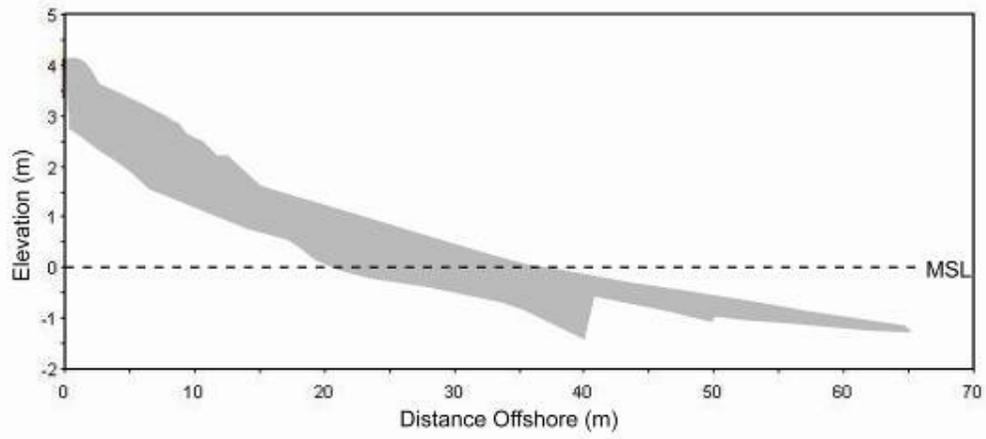
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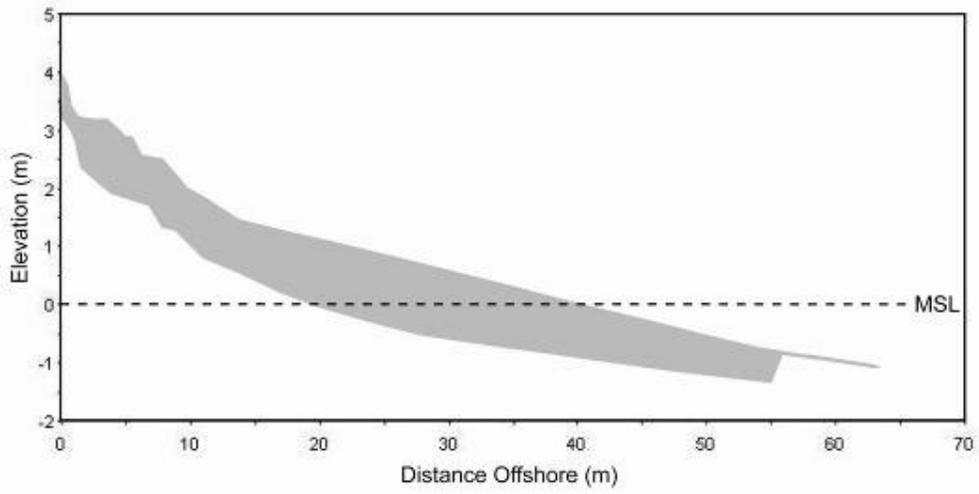
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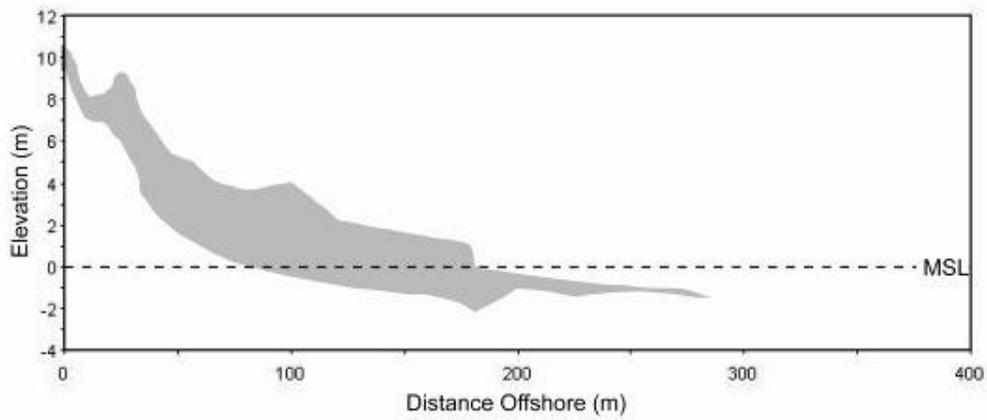
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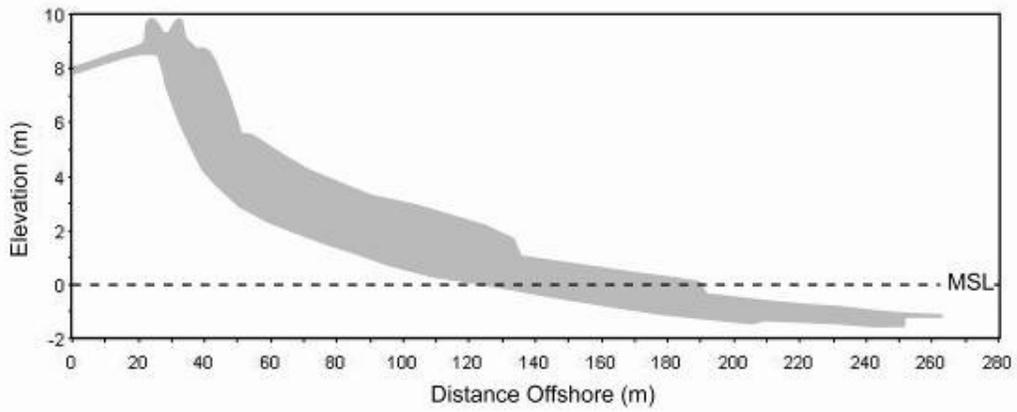
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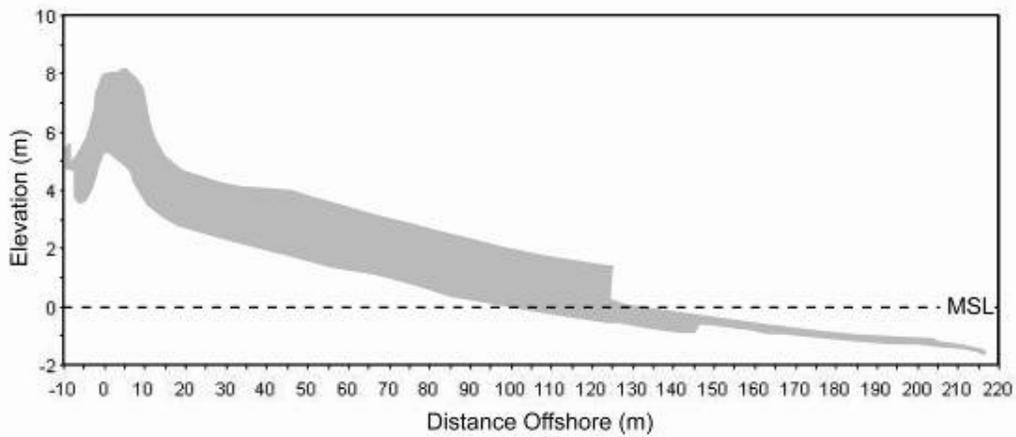
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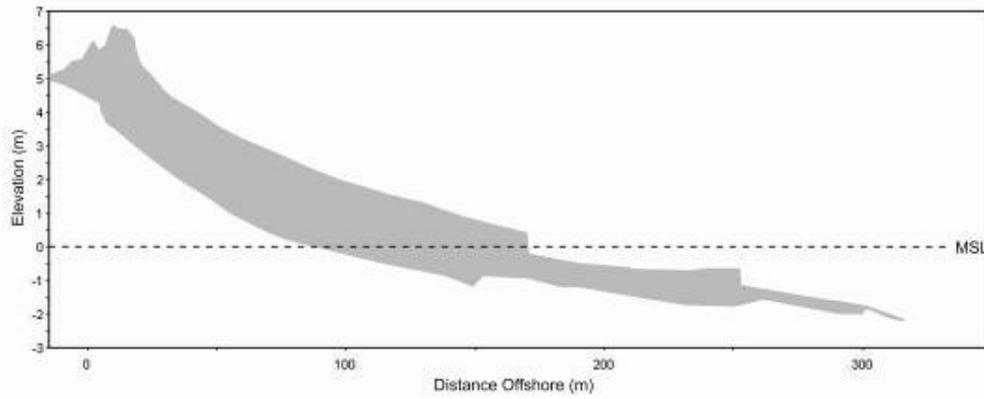
Piha P2



Piha P3



Piha P4



Piha P5

