Shoreline Monitoring in Tory Channel and Queen Charlotte Sound

FINAL REPORT

November 2009 – April (May) 2012

Report prepared for the Marlborough District Council

by

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1. Introduction

In an agreement between Marlborough District Council and Auckland UniServices Limited, dated 25 January 1997, Auckland UniServices Ltd, was engaged to establish and report on a shoreline monitoring programme in Tory Channel and Queen Charlotte Sound. Initially, the programme was for three years, involving six sets of surveys. Progress reports were provided every six months (following a survey of shoreline profiles), concluding with a final report in December 1999. The programme was then extended through to April 2002 with a further five surveys, concluding with a final report following the April 2002 survey. A contract for a further two surveys (November 2002 and April 2003) was negotiated in late 2002. In November 2003 a new contract was negotiated with James Cook University, Australia for the analysis of surveys in November 2003, April 2004, November 2004, April 2005, November 2005 and April 2006, concluding with a summary report, following Dr Kevin Parnell's move to that University. In February 2007, an extension to the contract provided for the analysis of surveys undertaken in November 2006, April 2007, November 2007, April 2008, November 2008 and April 2009, followed by a summary report. A further extension for the analysis of surveys in November 2009, April 2010, November 2010, April 2011, November 2011 and April 2012 was agreed in November 2009. Marlborough District Council decided not to undertake the survey in April 2010. This report therefore covers five surveys.

Marlborough District Council entered into an agreement with Ayson and Partners, Surveyors, of Blenheim, to maintain the shoreline profiles and to undertake the required surveys, under the direction of Dr Kevin Parnell.

2. Profile locations and methods

Details of the selection of survey sites, establishment of profiles, benchmarks and datums, and survey methodology are in the final report of the first contract period. Profile descriptions are also in that report. The location of the 21 profiles is shown in Figure 1, and their positions are detailed in Table 1. Positions are with respect to the WGS84 ellipsoid. A list of currently used benchmarks and their levels is in Appendix 1. A visual impression of the profiles can be obtained from the photographs in Section 4 and in Appendix 2.

Table 1: Profile positions

Pr	Name	Lat °	Lat '	Lat "	Long°	Long '	Long "
1	Picton Foreshore	41	17	17.6	174	0	25.1
2	The Snout at Picton Point	41	15	46.5	174	2	10.9
3	Double Bay	41	13	10.3	174	11	36.7
4	Ngaionui Bay (C Thomas)	41	14	16.5	174	11	8.5
5	Blackmore's at Waikawa	41	15	50.0	174	2	58.2
6	Moioio Island 2	41	14	39.4	174	12	56.9
7	Moioio Island 1	41	14	39.6	174	12	56.3
8	Bob's Bay	41	16	31.3	174	1	1.0
9	Te Awaiti	41	12	28.8	174	17	16
10	Tipi Bay	41	13	40.2	174	17	12.8
11	Long Island	41	7	22.3	174	16	12.6
12	Clark Point	41	8	12.6	174	17	30.7
13	Slip Beach	41	15	0.0	174	9	8.3
14	Ngaionui Point	41	14	27.6	174	10	46.2
15	Te Weka Bay	41	14	58.3	174	11	34.0
16	McMillan's Bay	41	14	45.5	174	12	11.4
17	McMillan's Side	41	14	43.5	174	12	9.6
18	Dieffenbach West	41	14	13.4	174	8	9.4
19	Curious Monkey	41	14	28.8	174	6	14.4
20	Patten's Passage	41	10	56.9	174	15	47.4
21	Blumine Island	41	9	37.0	174	14	4.4

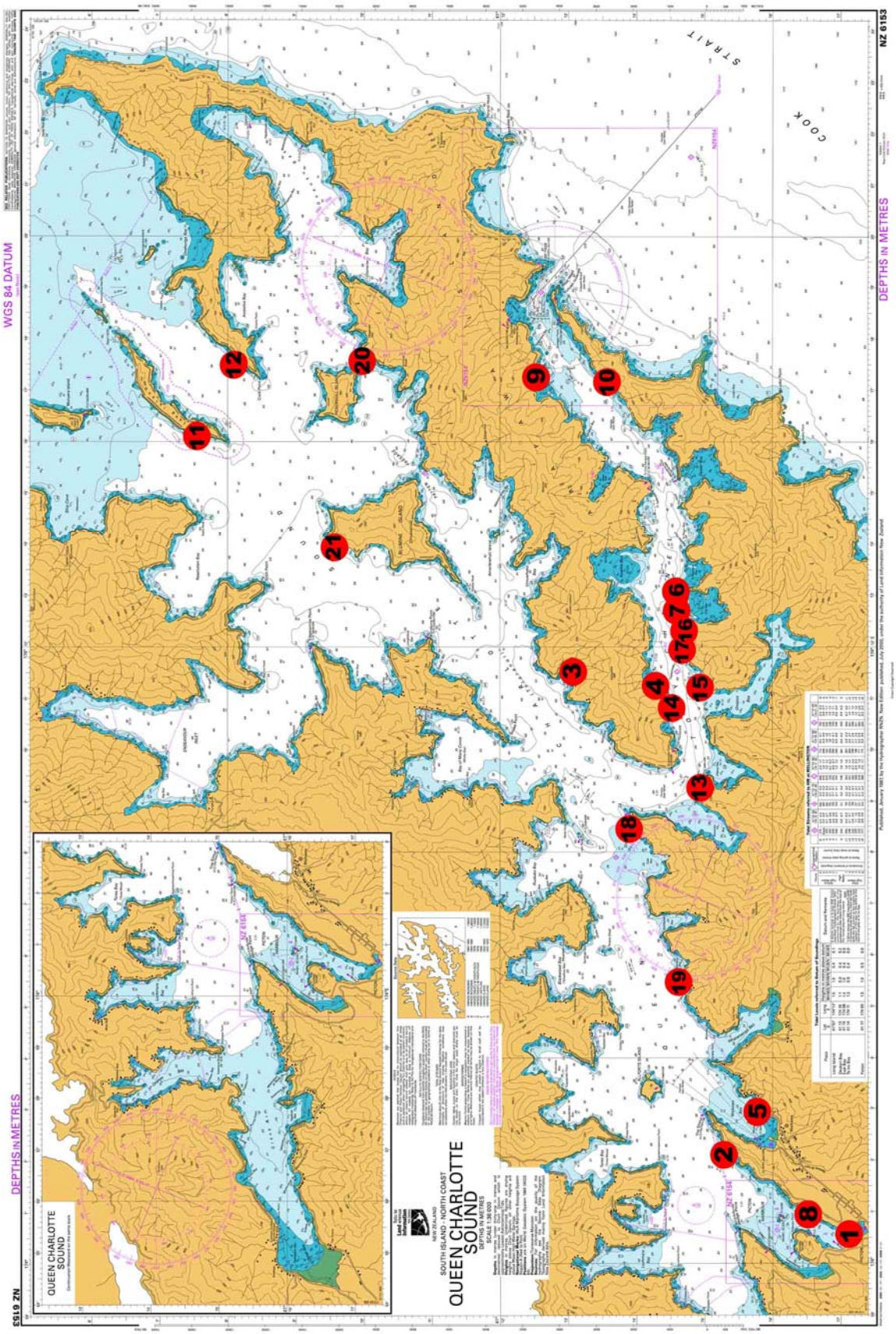


Figure 1: Profile locations

3. Vessel operations affecting the profile sites

Vessels carrying passengers and freight between Wellington and Picton, have operated the Tory Channel/Queen Charlotte Sound route for many years. In late 1994, fast vessel operations started using the route alongside the conventional ferries. Until 2000, various fast ferries operated over the summer months, after which an almost continuous service using fast vessels ran until April 2005. However, in December 2000 the Marlborough District Council enacted a bylaw that had the effect of slowing fast ferries to 18 knots while in the Sounds, so after that time the fast ferries operated at their normal service speed only outside the Marlborough Sounds. The Bylaw did not apply to conventional vessels. Fast ferries have not operated on the Wellington – Picton route since early 2005. Figure 2 shows the time periods over which various vessels have operated. Other vessels, both large and small, also use the route.

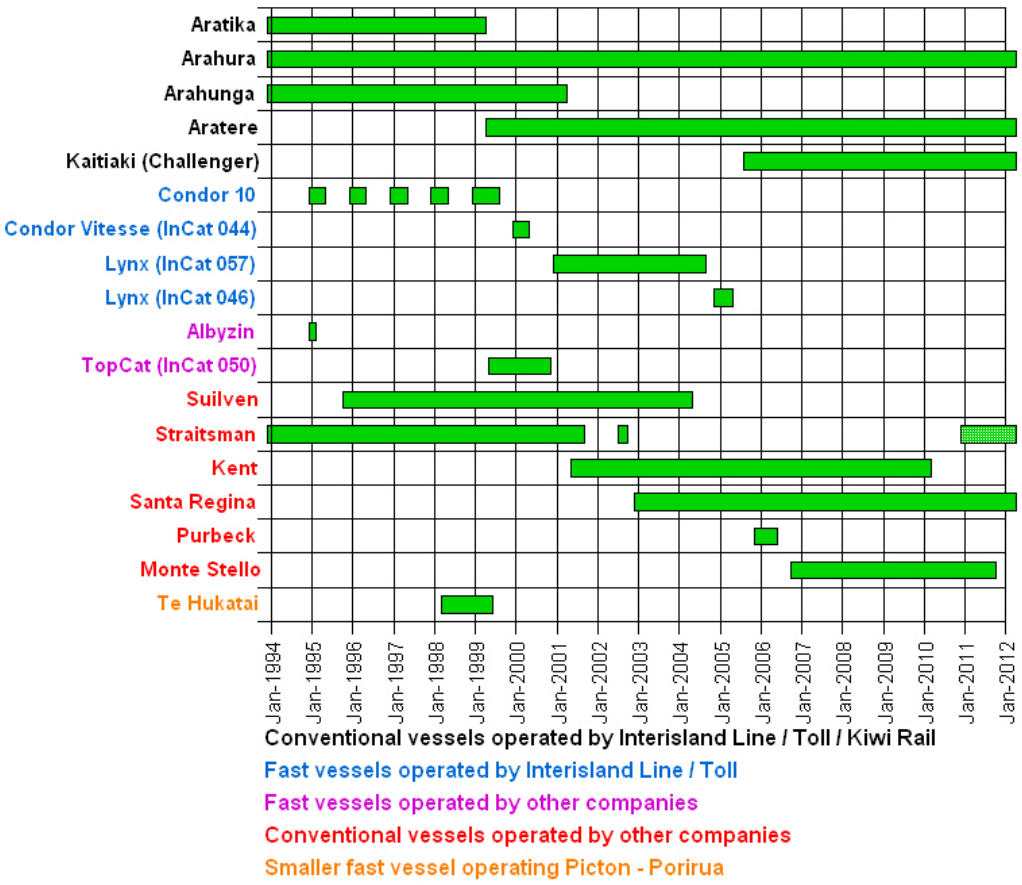


Figure 2: Vessels using the Tory Channel/Queen Charlotte Sound route on regular inter-island services. Note: The 'Straitsman' that commenced operation in December 2010 is a different vessel operating under the same name.

4. Profile analyses

In this section, data are presented for each profile and along with an interpretation of the changes that have occurred. Each profile analysis is accompanied by three pages of figures. The first page has photographs of the profile site taken from about 20 meters each side looking back towards the profile line at the top. At the bottom of the first page is a diagram of profile lines at the start of the monitoring programme in April 1997, the end of the first contract (November 1999), the end of the second contract period (April 2002), the end of the third contract (May 2006), the end of the fourth contract (April 2009) and at the end of the current contract (May 2012) . The second page comprises a 'spaghetti' diagram showing the 25 surveys of the profiles (April 1997, November 1997, April 1998, November 1998, April 1999, November 1999, April/May 2000, November 2000, June 2001, November 2001 and April 2002, November 2002, April 2003, November 2003, April 2004, November 2004, April 2005, November 2005, May 2006, November 2006, April 2007, November 2007, April 2008, November 2008, April 2009, November 2009, November 2010, April 2011, November 2011 and May 2012) in the upper section, and in the lower section, a different view of the same data commonly known as an 'Excursion Distance Analysis'. The final page shows beach volume data (m^3 per linear meter of beach) presented as a graph and a table. The limits for the calculations are determined as shown in Figure 3 and Table 2. The upper beach limit was a point on the upper beach landward of any profile change (if possible) or at the upper limit of the profile measurement. Because changes at the lower beach can indicate erosion, a measurement based on elevation is appropriate. This was taken at profile closure depth if this was evident, or at a point which was reached on most surveys. Where a profile did not reach the chosen lower limit, a value was estimated based on linear extrapolation or on values measured before and after a missing data point.

Table 2: Volume calculation limits

Prof.	Name	Upper beach limit (m)	Lower beach limit (m)
1	Picton Foreshore	6.87	-0.50
2	The Snout at Picton Point	0.00	-1.00
3	Double Bay	-1.50	-1.00
4	Ngaionui Bay (C Thomas)	-2.00	-0.25
5	Blackmore's at Waikawa	2.30	-0.75
6	Moioio Island 2	-2.00	-1.50
7	Moioio Island 1	0.00	-1.50
8	Bob's Bay	0.00	-1.00
9	Te Awaiti	0.30	-1.50
10	Tipi Bay	0.00	-1.25
11	Long Island	0.00	-0.75
12	Clark Point	0.00	-0.25
13	Slip Beach	-1.00	-1.25
14	Ngaionui Point	-2.00	-0.75
15	Te Weka Bay	2.00	-1.50
16	McMillan's Bay	0.00	-0.75
17	McMillan's Side	-2.00	-0.75
18	Dieffenbach West	0.00	-0.50
19	Curious Monkey	0.00	-0.50
20	Patten's Passage	0.00	-0.50
21	Blumine Island	0.00	-0.50

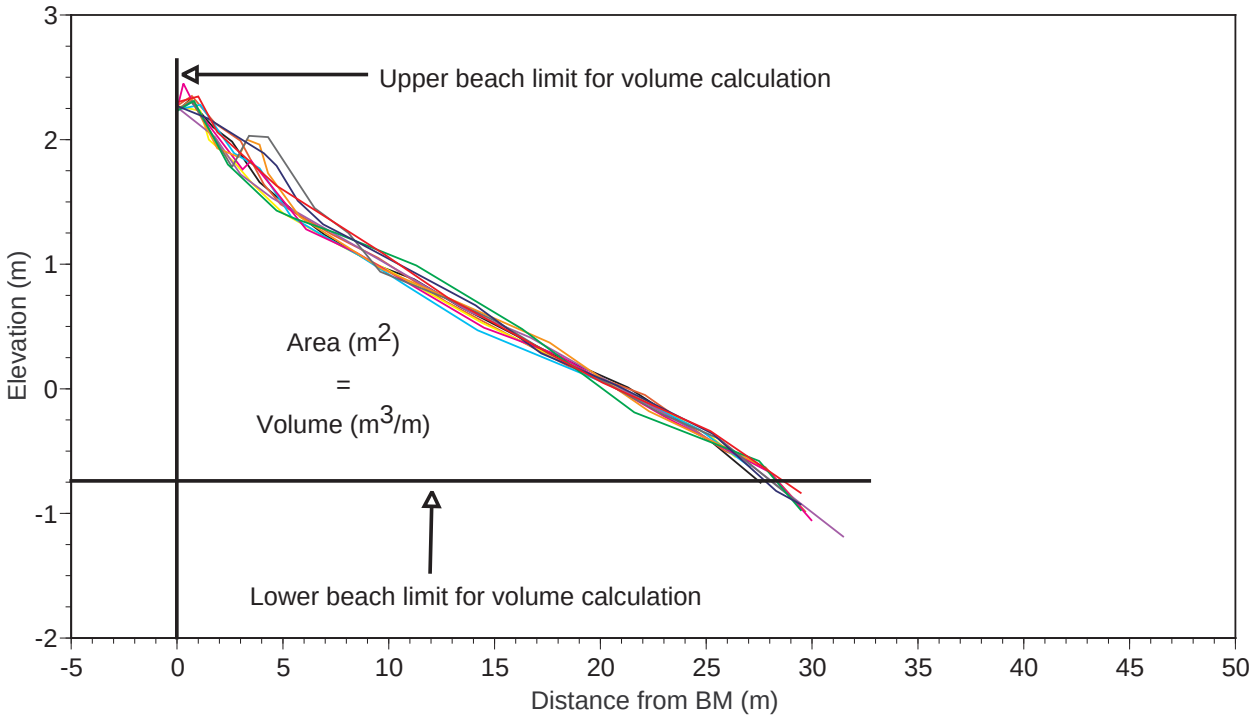


Figure 3: Volume calculation methodology

The ‘spaghetti’ plots of profiles are useful for establishing envelopes of change of the beach shape, but interpretations of changes that have occurred are difficult, due to the clutter of lines that are present. As the data set grows, any useful interpretation based on these plots becomes almost impossible. Excursion distance plots use exactly the same data plotted as a time series, and makes interpretation of beach changes easier. Excursion distance analysis is a method by which three dimensional data sets (distance, height and time) can be illustrated as plots with time on the independent axis. It can be undertaken with either distance or height on the vertical axis, although having distance on the vertical axis is more useful for most purposes. Excursion distances are calculated by determining a set of height values for which calculations will be made. These values are normally equally spaced and in the following figures, are shown in the box on the right hand side of the graph. These numbers are in units of metres above or below the datum (in this case approximate MSL). Using linear interpolation, the horizontal distance from the datum is calculated for each of the height values, and these are plotted as a time series with time on the horizontal axis. For each survey this provides a “point contour map” of the profile, and when plotted as a time series, an indication of how levels change through time. The graphs provide a lot of information. If two lines converge, the beach is getting steeper at those contour heights. If two lines diverge, the beach is getting flatter. If the lines trend seaward (increasing values on the distance axis), the beach is accreting. If the lines trend landward, the beach is eroding. Figure 4 attempts to show the methodology of Excursion Distance Analysis.

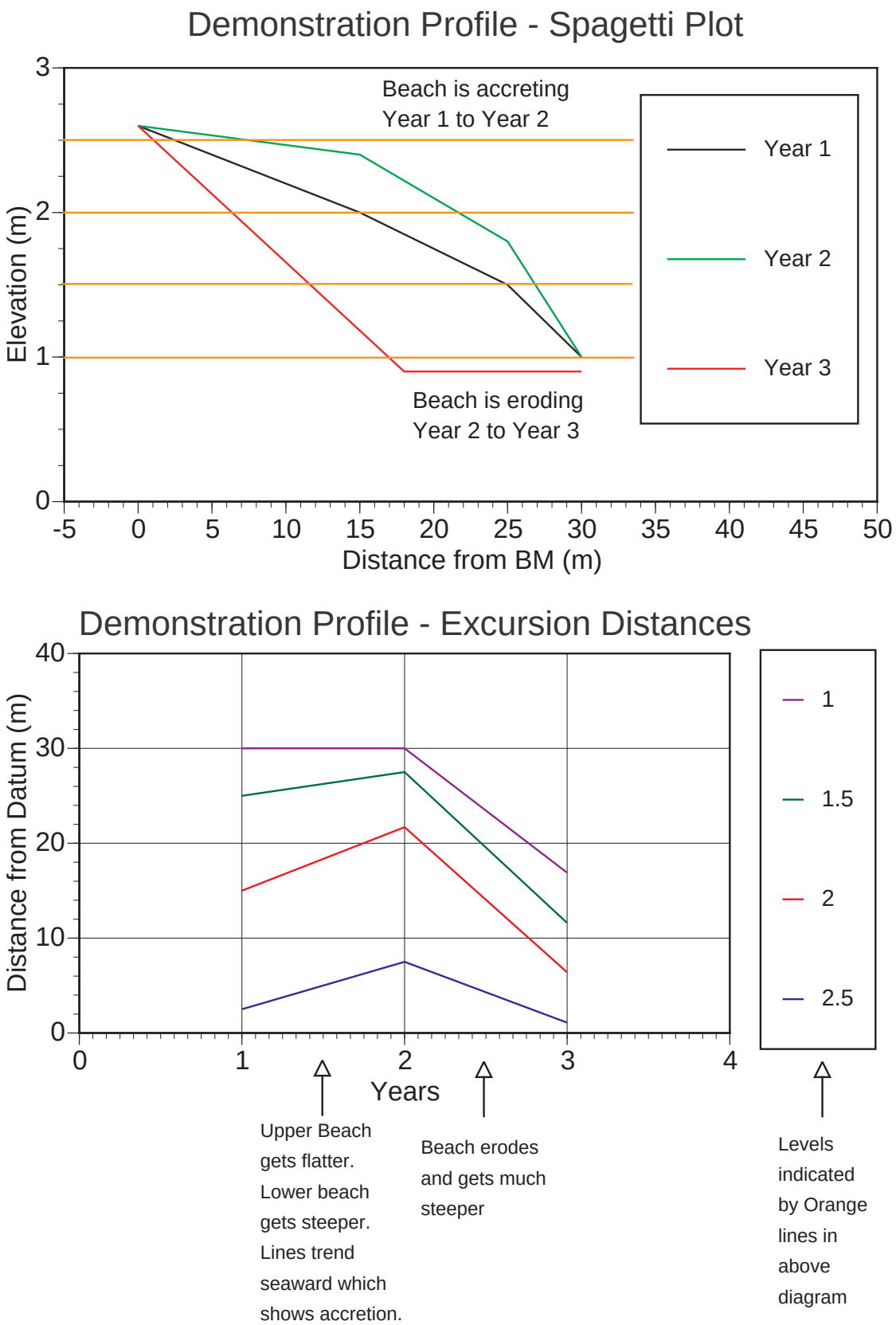
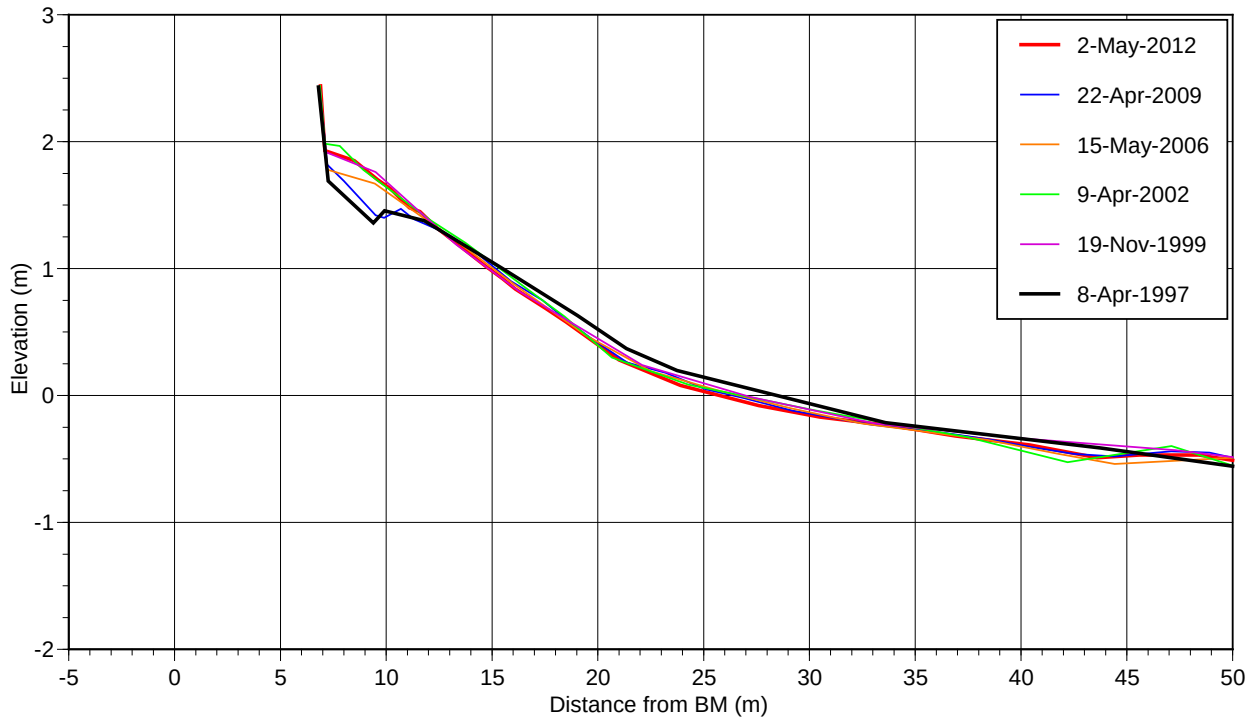


Figure 4 : Excursion Distance Analysis Demonstration

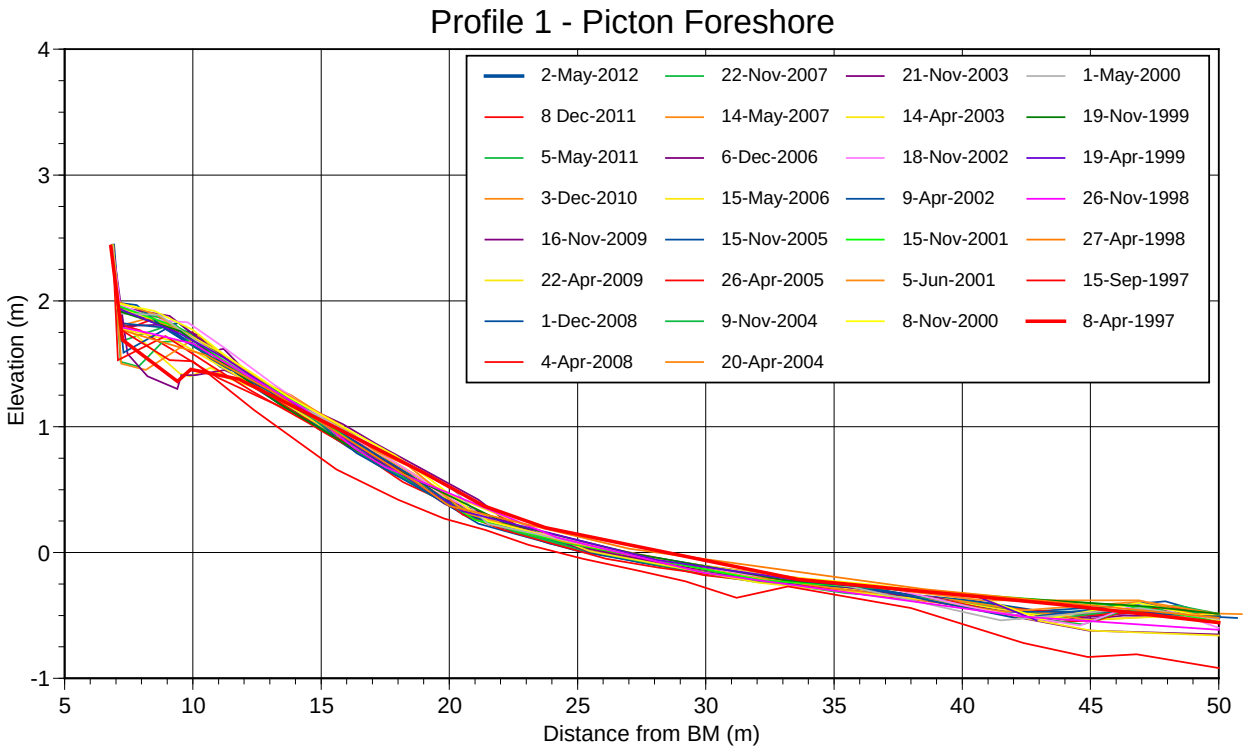
Profile 1 – Picton Foreshore

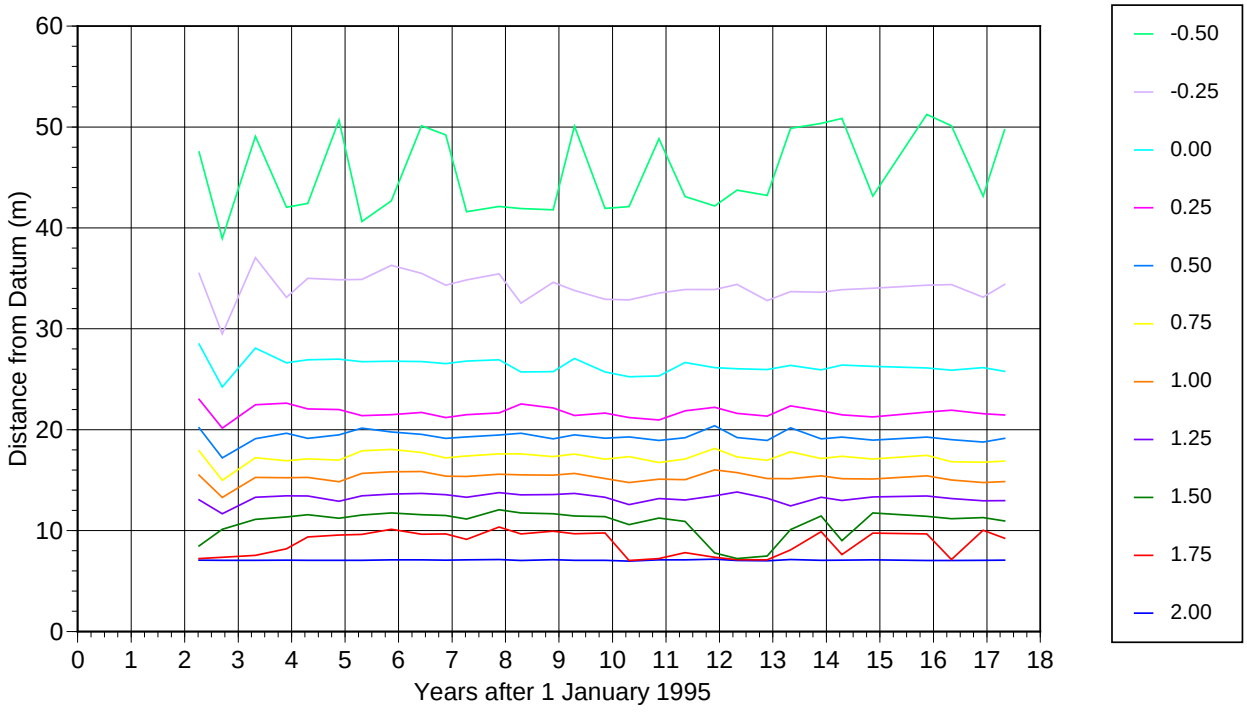
The Picton Foreshore underwent extensive modification with the improvement of the landward side of the retaining wall in late 1997. Sediments on the beach comprise both natural marine sediments and river sand deposited in a beach nourishment programme.

I do not know if further nourishment has taken place since late 1997 or early 1998. If further nourishment has taken place, then the rate of nourishment is clearly appropriate. If there has been no renourishment, then the beach has been very stable since that time. Beach volume has maintained a relatively narrow range since April 1998, between 29.1m^3/m and 32.9m^3/m. There has been no apparent change in sediment characteristics. There is no indication that the seawall has had an adverse effect on beach stability. There is no indication that waves caused by vessel wash in the inner harbour are having an adverse effect on the Picton foreshore beach.



Profile 1: Picton Foreshore





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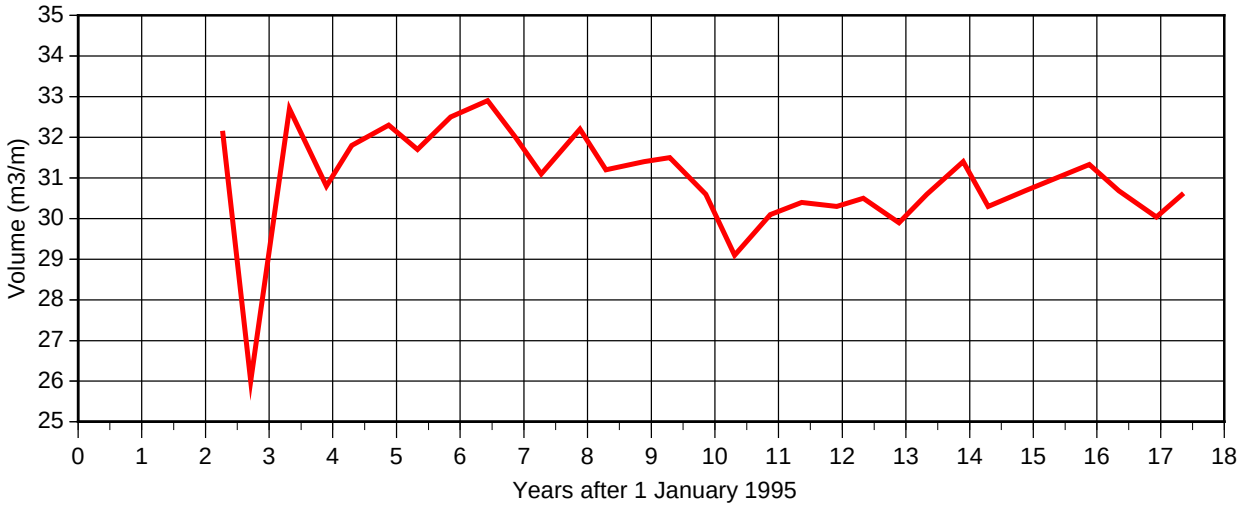
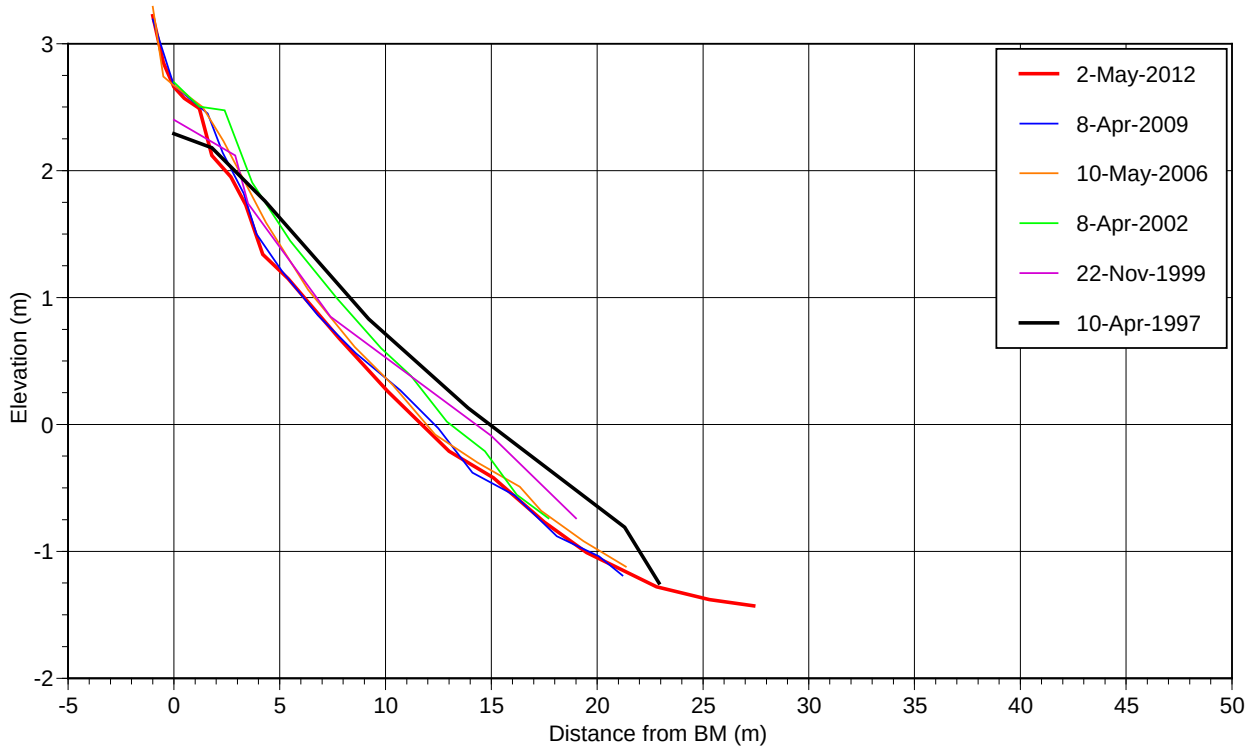


Date	Years after 1/1/95	Volume (m^3/m)
8-Apr-97	2.27	32.1
15-Sep-97	2.71	26.0
27-Apr-98	3.32	32.7
26-Nov-98	3.90	30.8
19-Apr-99	4.30	31.8
19-Nov-99	4.88	32.3
1-May-00	5.33	31.7
8-Nov-00	5.85	32.5
5-Jun-01	6.43	32.9
15-Nov-01	6.87	32.0
9-Apr-02	7.27	31.1
18-Nov-02	7.88	32.2
14-Apr-03	8.29	31.2
21-Nov-03	8.89	31.4
20-Apr-04	9.29	31.5
9-Nov-04	9.86	30.6
26-Apr-05	10.31	29.1
15-Nov-05	10.87	30.1
15-May-06	11.36	30.4
06-Dec-06	11.91	30.3
14-May-07	12.33	30.5
22-Nov-07	12.89	29.9
04-Apr-08	13.33	30.6
01-Dec-08	13.90	31.4
22-Apr-09	14.29	30.3
16-Nov-09	14.87	30.7
03-Dec-10	15.88	31.3
05-May-11	16.34	30.7
08-Dec-11	16.93	30.0
02-May-12	17.33	30.6

Profile 1: Picton Foreshore

Profile 2 – The Snout at Picton Point

Since April 1997, the profile has retreated and significantly steeped, seen particularly by the convergence of lines on the EDA plots. The major cause is probably the slow migration of the deepwater channel in a shoreward direction. Beach volumes have followed an almost linear trend of loss over the same period, with the loss of over $7m^3/m$. There have been no apparent changes to sediment composition. The reason for the channel migration is not clear, although the site does receive considerable wake energy.



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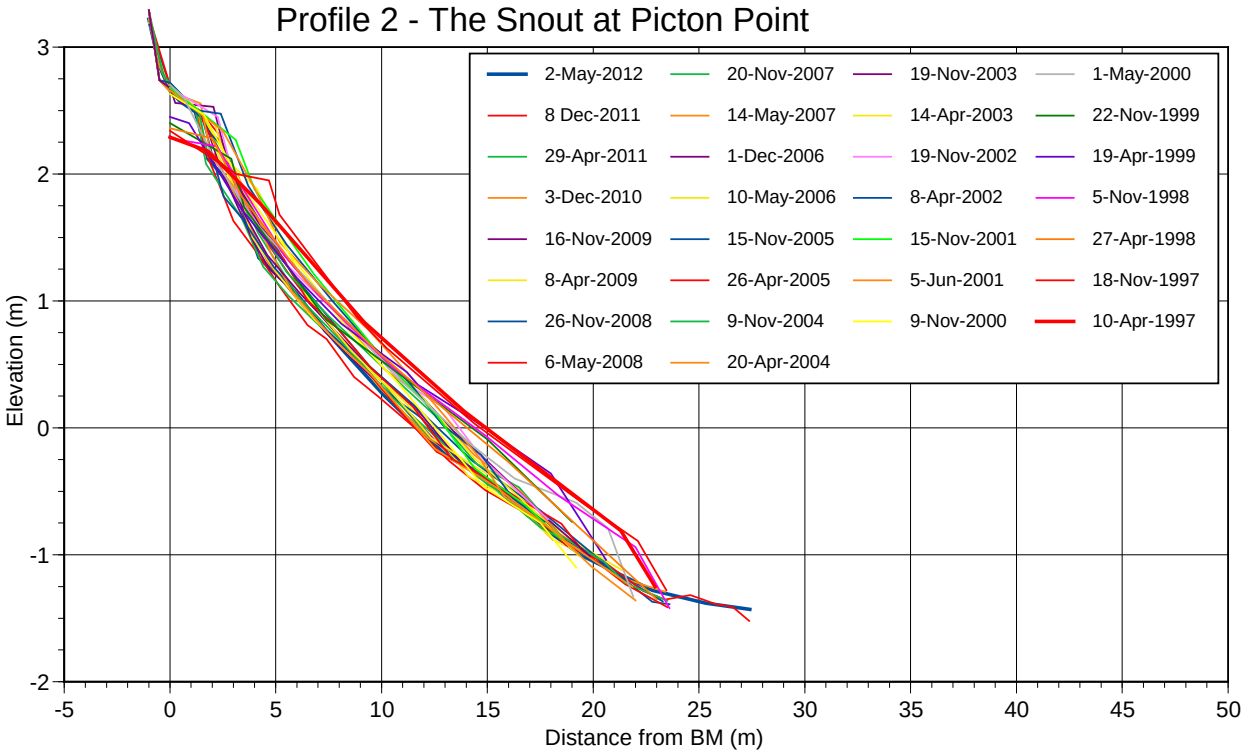
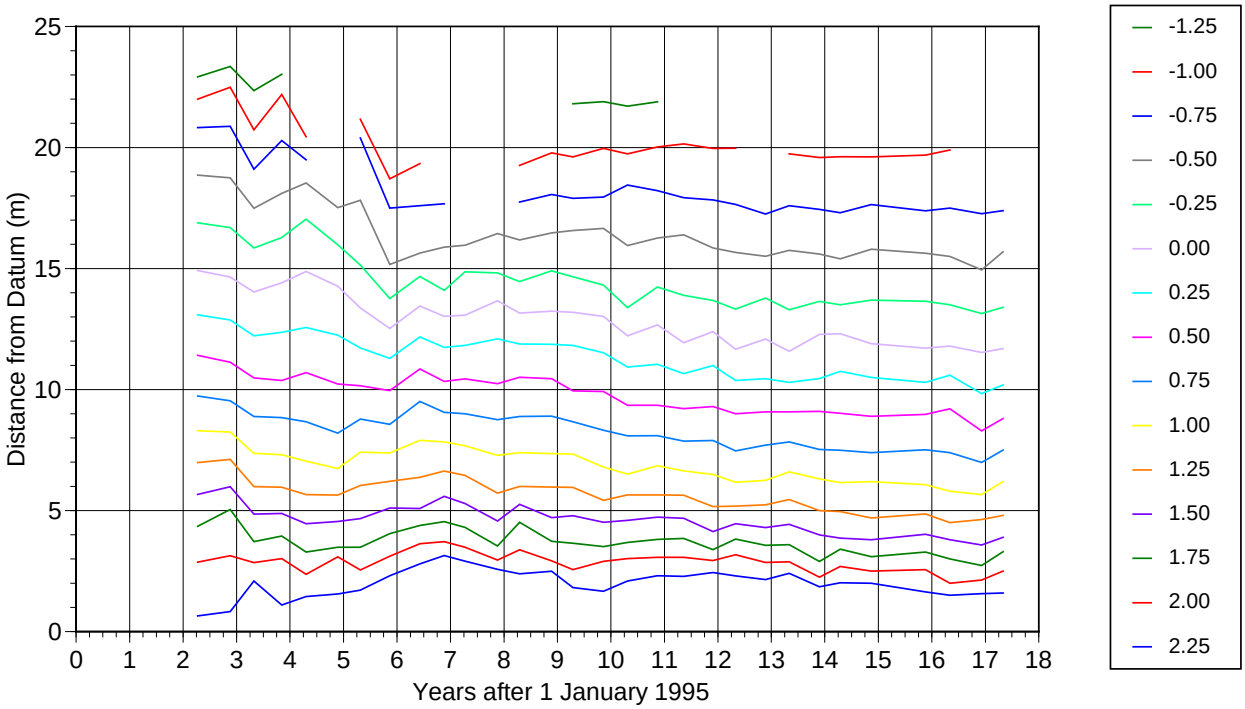
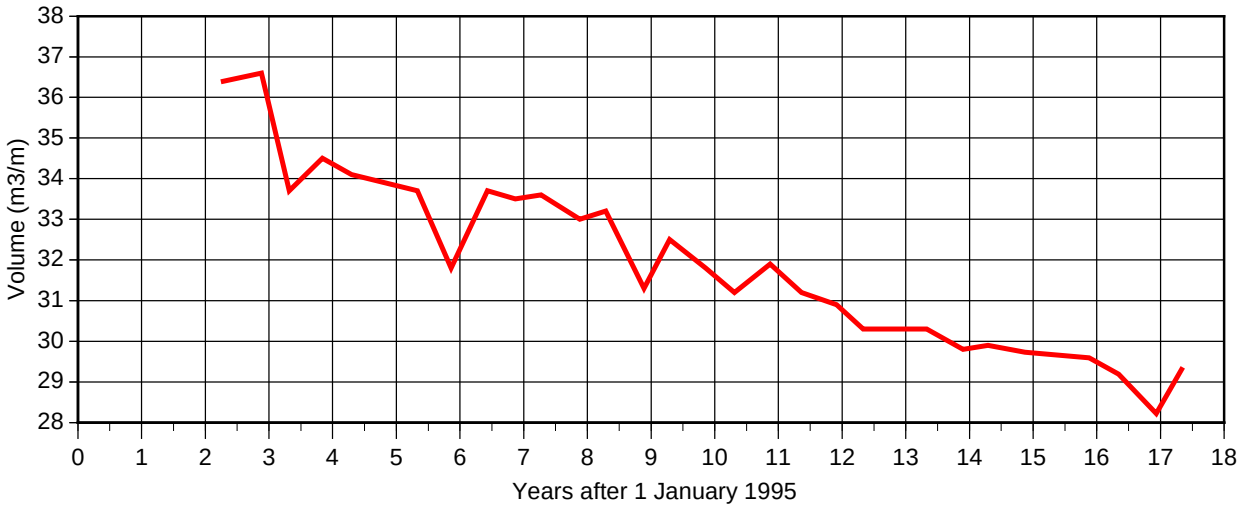




Profile 2: The Snout at Picton Point

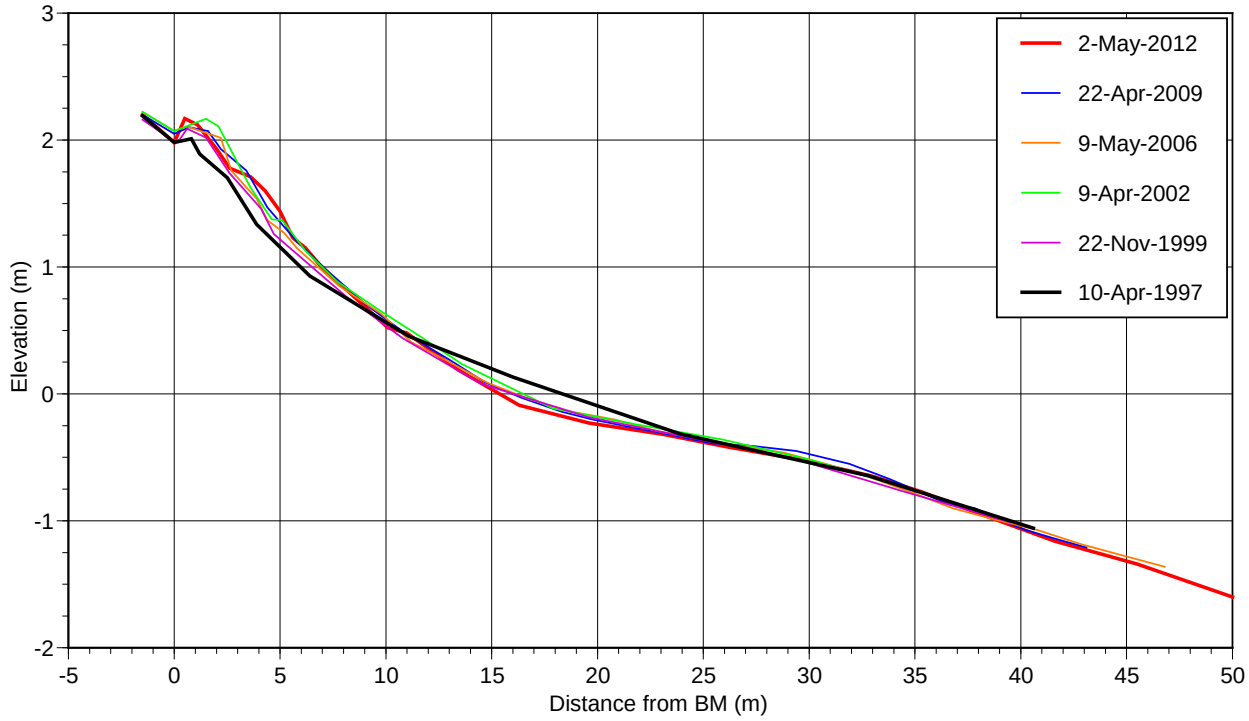


Date	Years after 1/1/95	Volume (m^3/m)
10-Apr-97	2.28	36.4
18-Nov-97	2.88	36.6
27-Apr-98	3.32	33.7
5-Nov-98	3.84	34.5
19-Apr-99	4.30	34.1
1-May-00	5.33	33.7
1-May-00	5.33	33.7
9-Nov-00	5.86	31.8
5-Jun-01	6.43	33.7
15-Nov-01	6.87	33.5
8-Apr-02	7.27	33.6
19-Nov-02	7.88	33.0
14-Apr-03	8.29	33.2
19-Nov-03	8.89	31.3
20-Apr-04	9.29	32.5
9-Nov-04	9.86	31.8
26-Apr-05	10.31	31.2
15-Nov-05	10.87	31.9
01-Dec-06	11.91	30.9
14-May-07	12.33	30.3
20-Nov-07	12.89	30.3
06-May-08	13.33	30.3
26-Nov-08	13.90	29.8
08-Apr-09	14.29	29.9
16-Nov-09	14.87	29.7
03-Dec-10	15.88	29.6
29-Apr-11	16.34	29.2
08-Dec-11	16.93	28.2
02-May-12	17.33	29.3

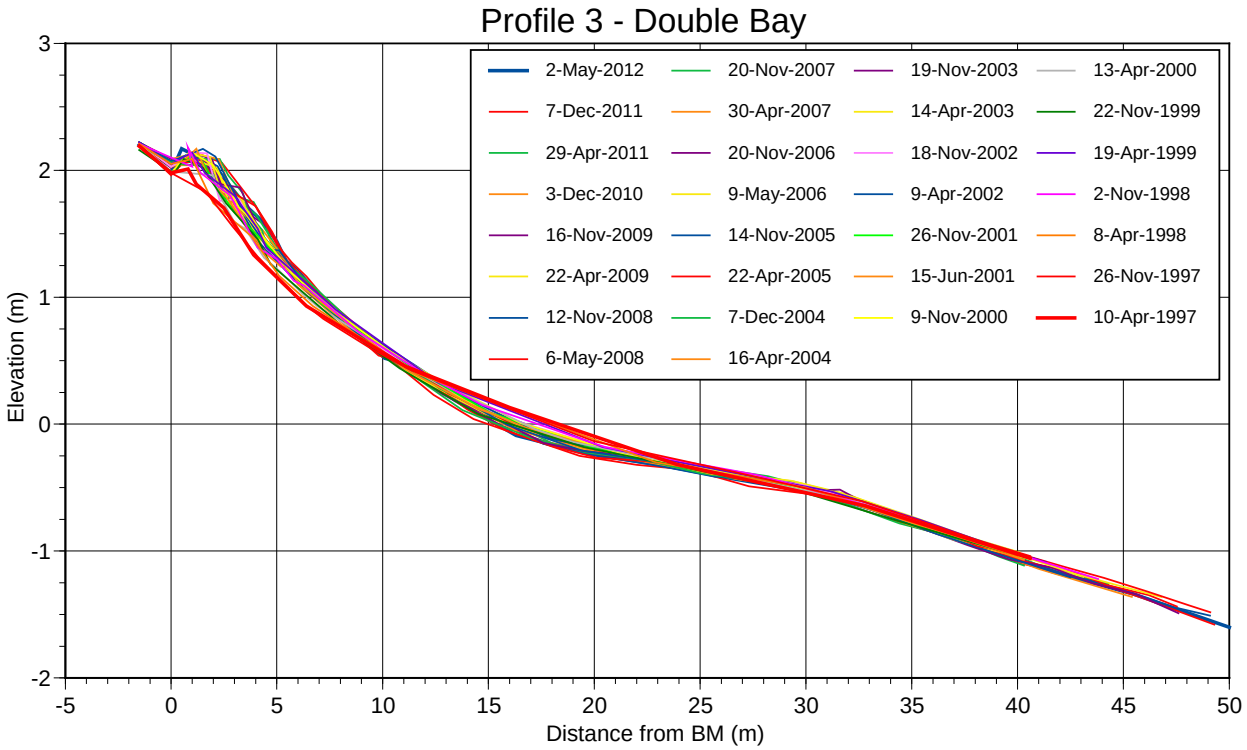
Profile 2: The Snout at Picton Point

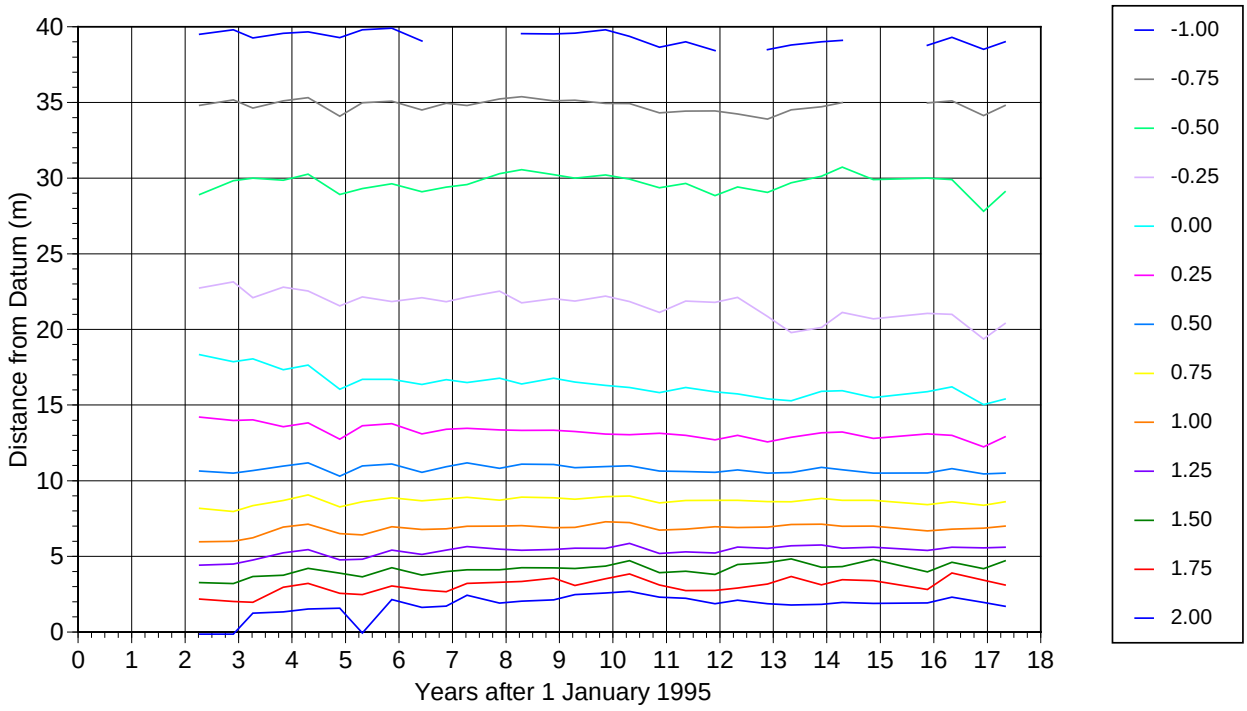
Profile 3 – Double Bay

The Double Bay beach profile has changed within a very narrow range over the period April 1997 to April 2012. The most recent profile data sits close to the centre of the long-term sweep, with beach volume in 2012 being only 0.2m^3/m different to April 1997. There has been a minor steeping of the beach with the construction of a berm over the earlier years of the survey and a minor lowering of the mid-beach surface. The profiles clearly reach closure depth at about -0.5m. Sediment characteristics have not changed significantly.

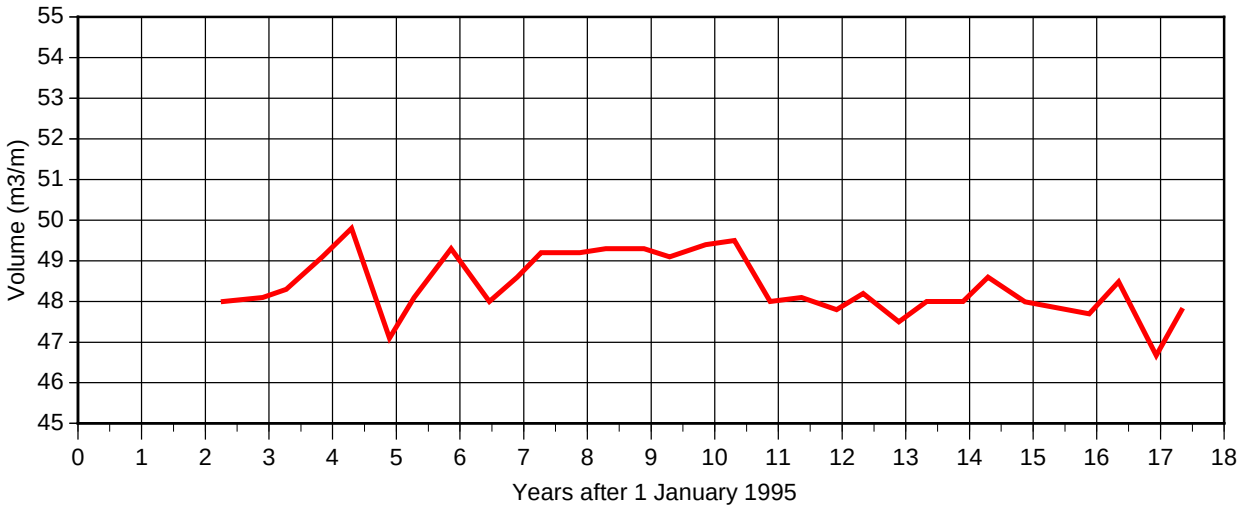


Profile 3: Double Bay





Profile 3: Double Bay

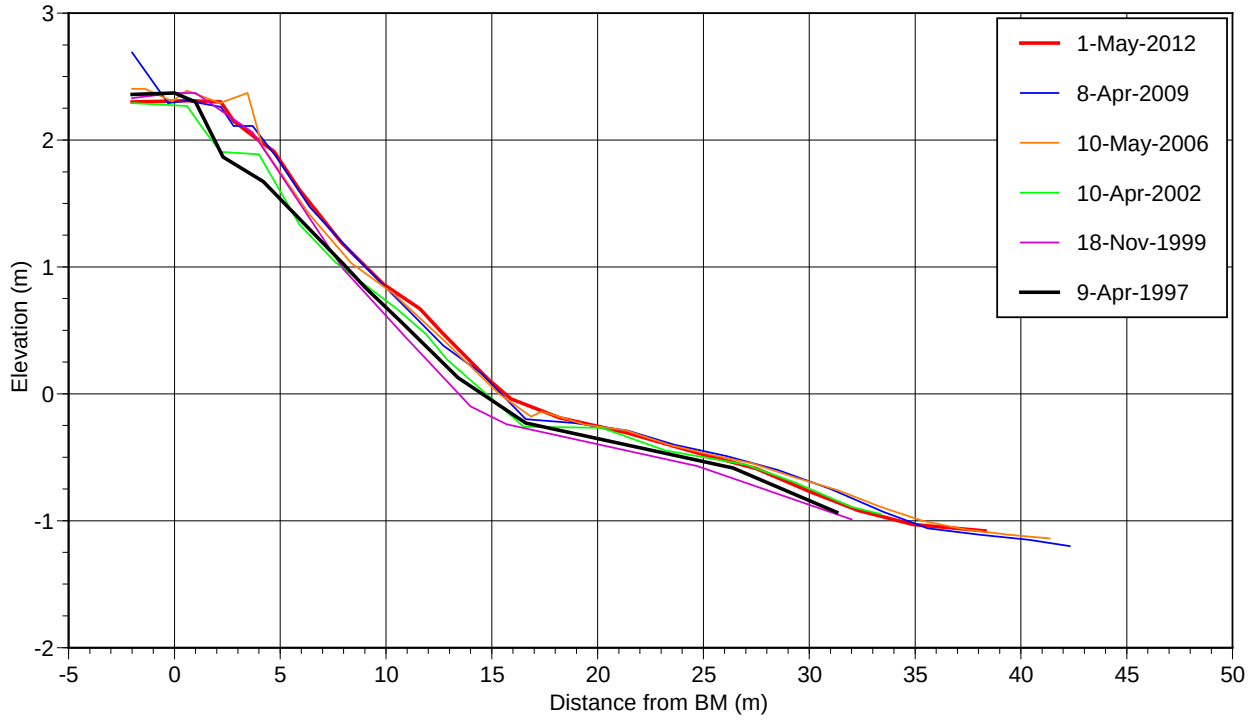


Date	Years after 1/1/95	Volume (m^3/m)
10-Apr-97	2.28	48.0
26-Nov-97	2.90	48.1
8-Apr-98	3.27	48.3
2-Nov-98	3.84	49.1
19-Apr-99	4.30	49.8
22-Nov-99	4.89	47.1
13-Apr-00	5.28	48.1
9-Nov-00	5.86	49.3
15-Jun-01	6.46	48.0
26-Nov-01	6.90	48.6
9-Apr-02	7.27	49.2
18-Nov-02	7.88	49.2
14-Apr-03	8.29	49.3
19-Nov-03	8.89	49.3
16-Apr-04	9.29	49.1
7-Dec-04	9.86	49.4
22-Apr-05	10.31	49.5
14-Nov-05	10.87	48.0
9-May-06	11.36	48.1
20-Nov-06	11.91	47.8
30-Apr-07	12.33	48.2
20-Nov-07	12.89	47.5
06-May-08	13.33	48.0
12-Nov-08	13.90	48.0
22-Apr-09	14.29	48.6
16-Nov-09	14.87	48.0
03-Dec-10	15.88	47.7
29-Apr-11	16.34	48.5
07-Dec-11	16.93	46.7
02-May-12	17.33	47.8

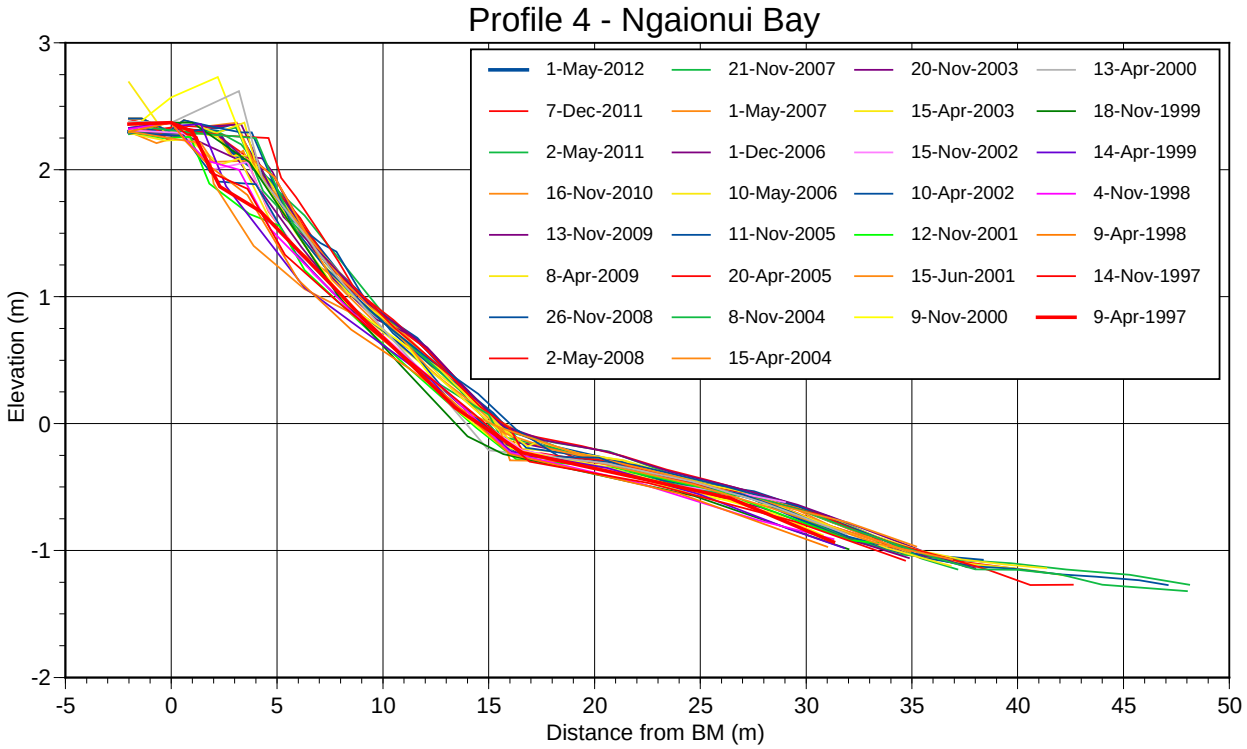
Profile 3: Double Bay

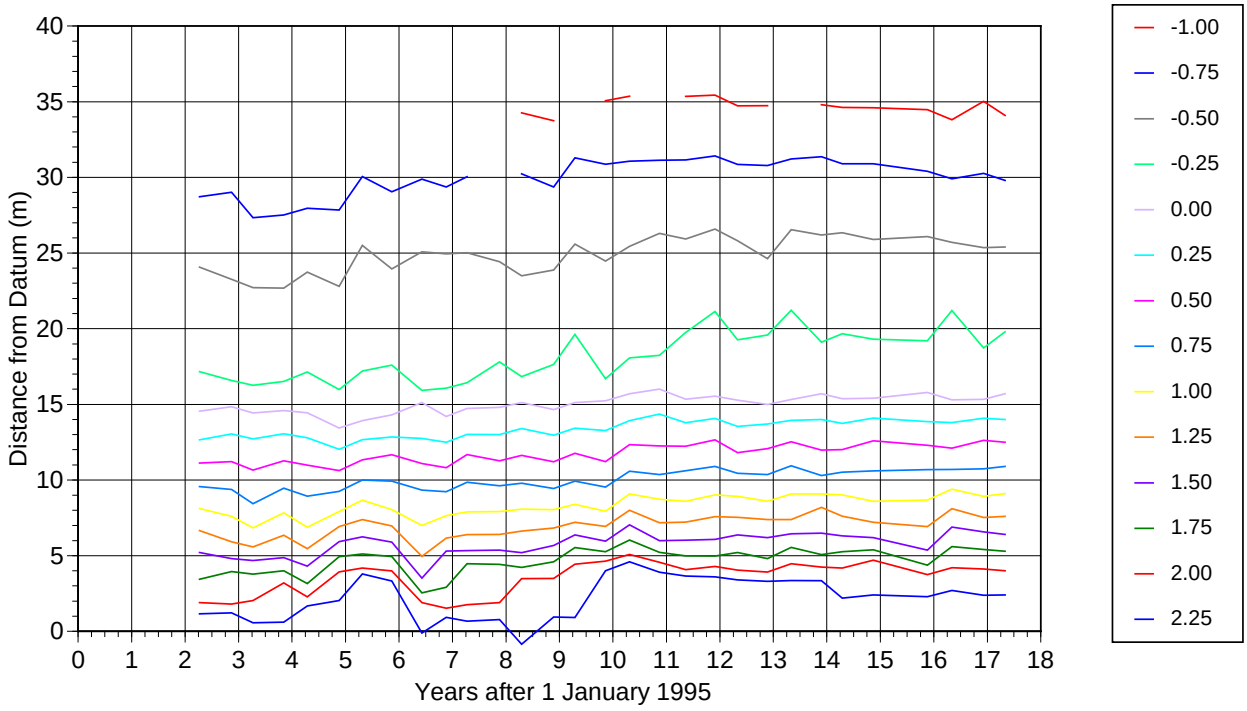
Profile 4 – Ngaionui Bay

The long-term history of this site has been discussed in previous reports. The site is complicated by relatively frequent human modifications (although the nature of any works and their frequency in recent times is not known). It is also complicated by the presence of a landslide at the western end of the beach, with sediment redistribution within the compartment. It was very clear that fast ferry operation contributed to significant beach accretion, and that all wakes and natural processes, coinciding with a sediment supply from the slip, have all contributed to slow beach building. However, since 2006, the beach has been relatively stable, with minor adjustments to the beach berm. Since 2006, beach volume has varied little within a $1m^3/m$ range.

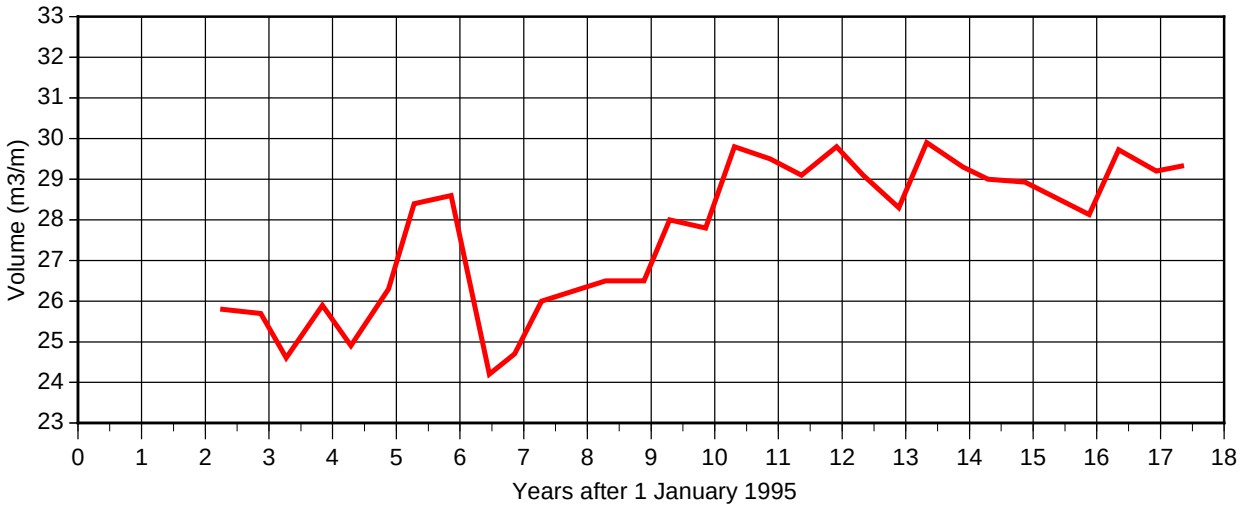


Profile 4: Ngaionui Bay





Profile 4: Ngaionui Bay



Date	Years after 1/1/95	Volume (m^3/m)
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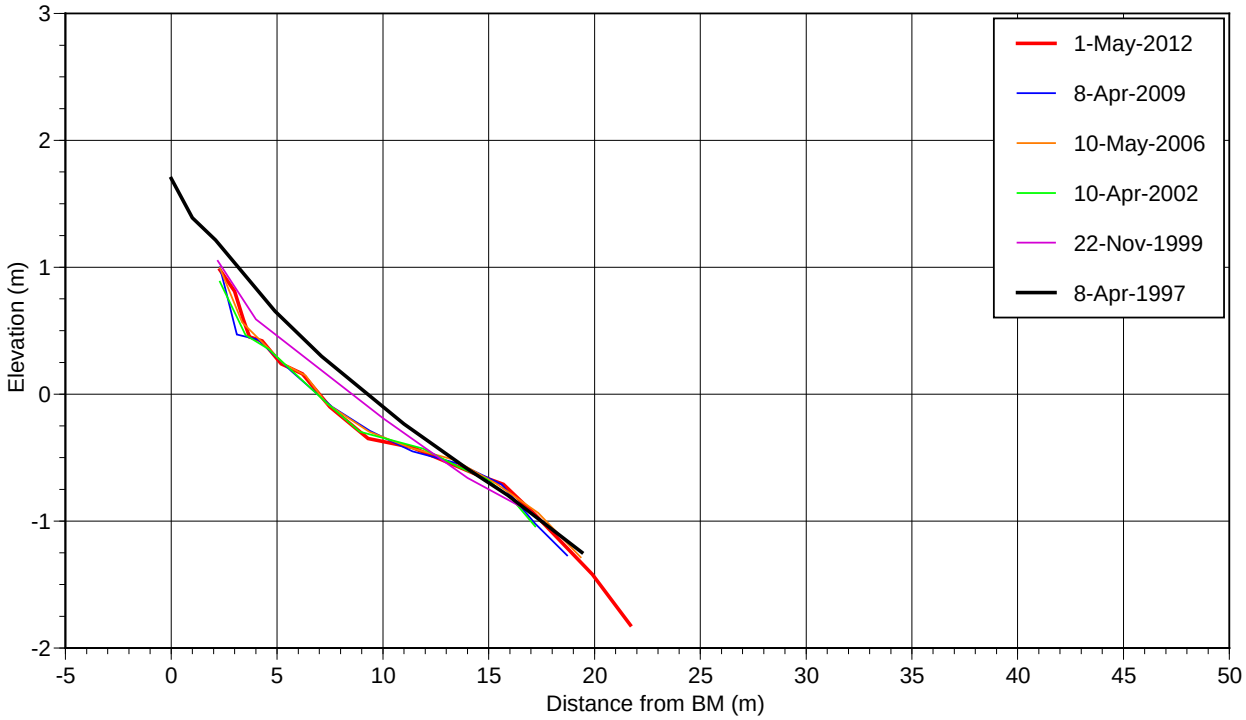
4-Nov-98	3.84	25.9
14-Apr-99	4.29	24.9
18-Nov-99	4.88	26.3
13-Apr-00	5.28	28.4
9-Nov-00	5.86	28.6
15-Jun-01	6.46	24.2
12-Nov-01	6.86	24.7
10-Apr-02	7.28	26.0
15-Nov-02	7.88	26.3
15-Apr-03	8.29	26.5
20-Nov-03	8.89	26.5
15-Apr-04	9.29	28.0
8-Nov-04	9.86	27.8
20-Apr-05	10.31	29.8
11-Nov-05	10.87	29.5
10-May-06	11.36	29.1
01-Dec-06	11.91	29.8
01-May-07	12.33	29.1
21-Nov-07	12.89	28.3
02-May-08	13.33	29.9
26-Nov-08	13.90	29.3
08-Apr-09	14.29	29.0
13-Nov-09	14.87	28.9
16-Nov-10	15.88	28.1
02-May-11	16.34	29.7
07-Dec-11	16.93	29.2
01-May-12	17.33	29.3

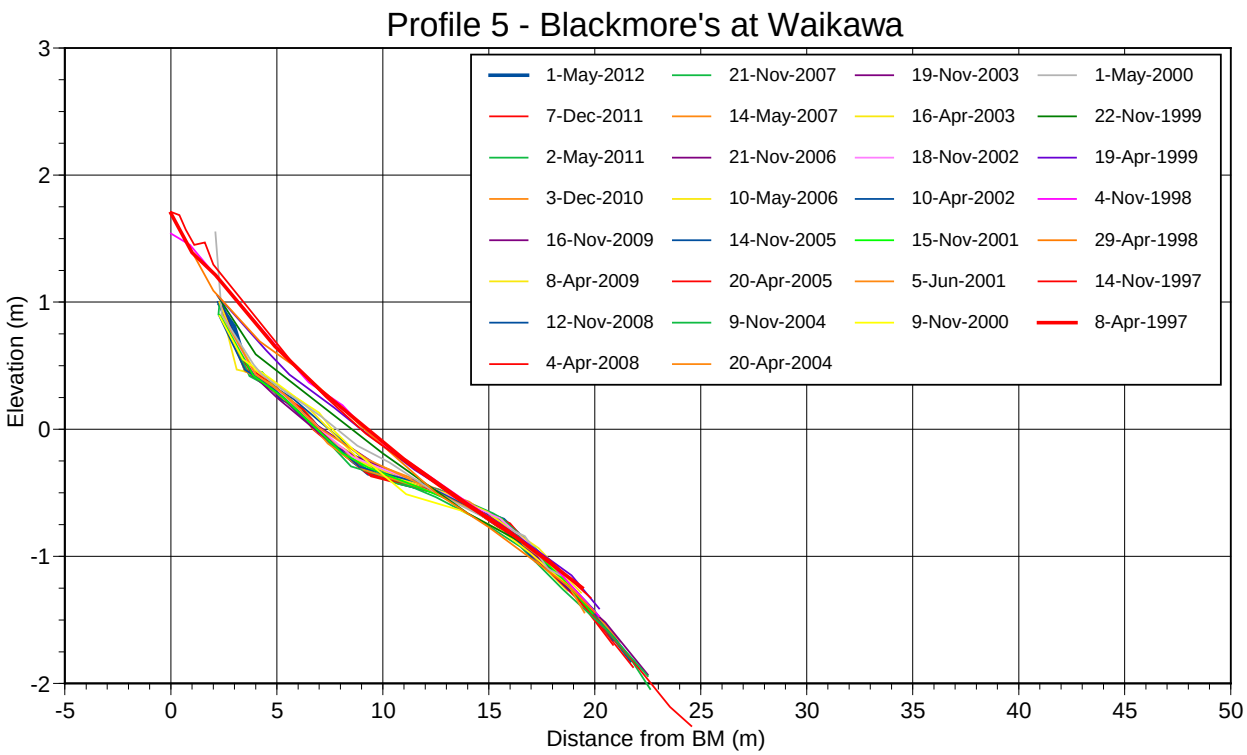
Profile 4: Ngaionui Bay

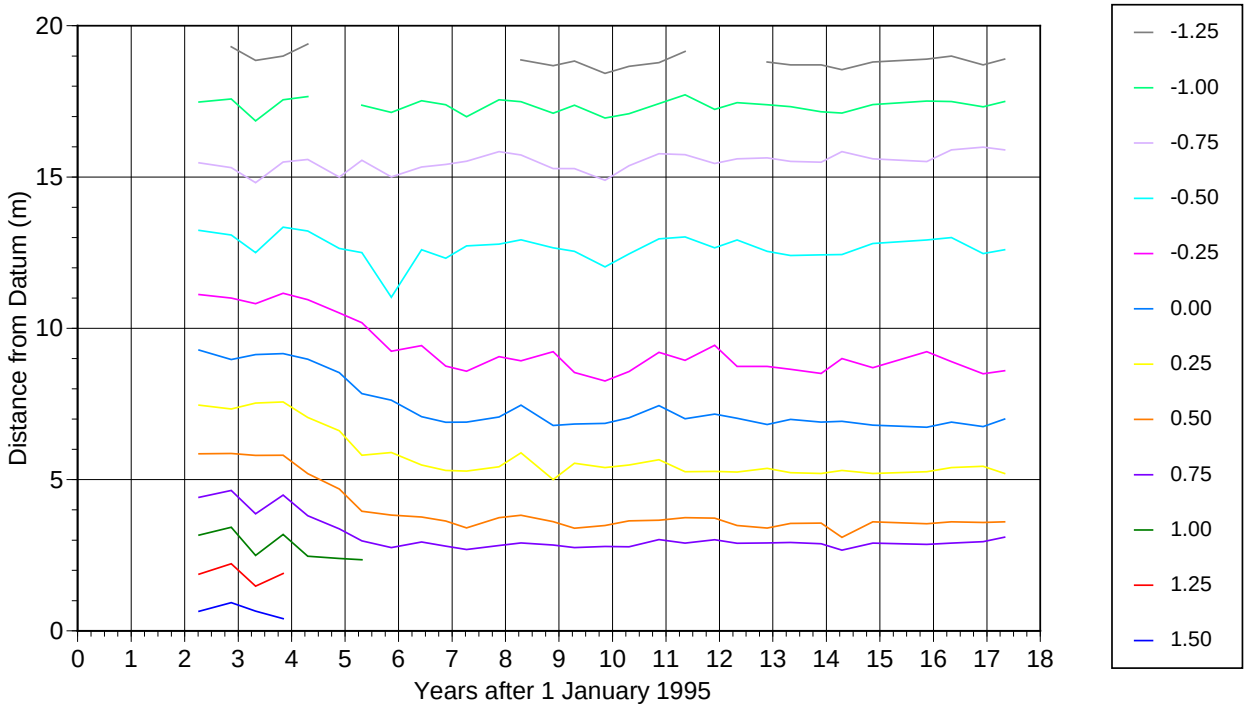
Profile 5 – Blackmore's at Waikawa

Between April 1999 and November 1999, sand on the small beach started to disappear. By November 2001, the beach had been stripped to bedrock, and it has remained essentially devoid of sediment since that time. Further loss of sediment is therefore not possible. There has been no recovery since the fast ferries slowed down in December 2000. Minor changes in profiles and volumes recorded since that time are likely to be the result of slightly different survey alignments, and possibly minor changes in sediments on the lower profile.

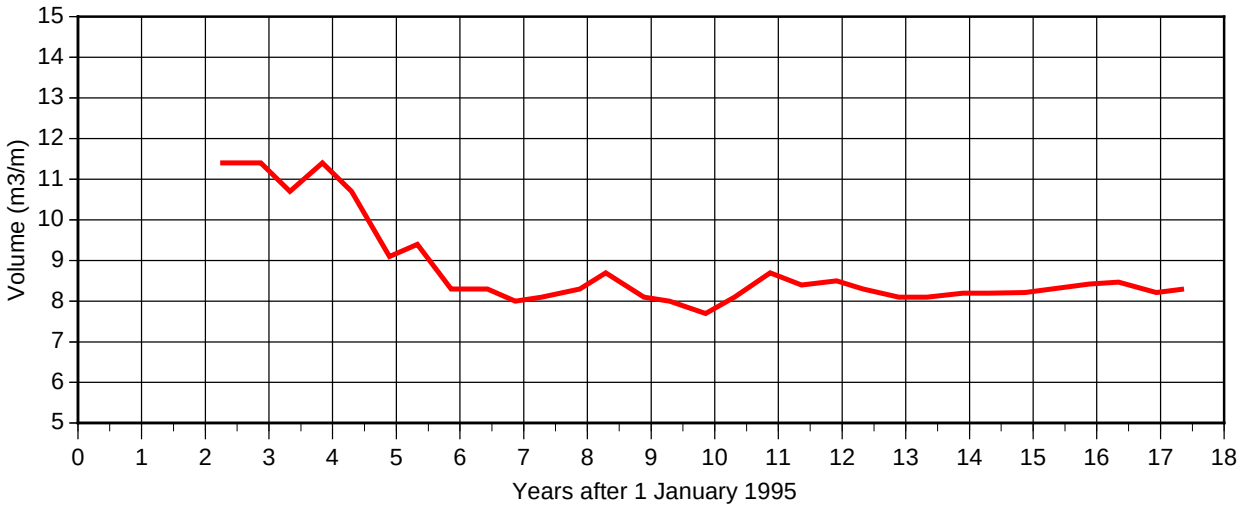


Profile 5: Blackmore's at Waikawa





Profile 5: Blackmore's at Waikawa



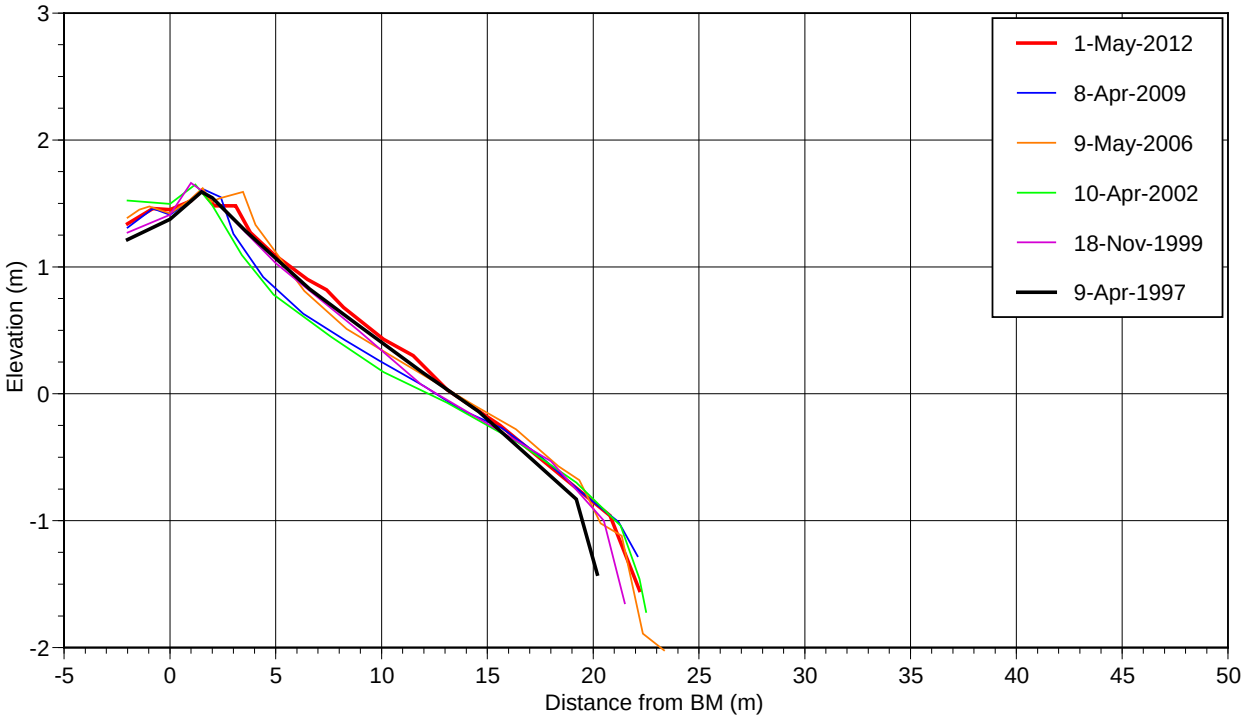
Date	Years after 1/1/95	Volume (m^3/m)
8-Apr-97	2.27	11.4
14-Nov-97	2.87	11.4
29-Apr-98	3.33	10.7
4-Nov-98	3.84	11.4
19-Apr-99	4.30	10.7
22-Nov-99	4.89	9.1
1-May-00	5.33	9.4
9-Nov-00	5.86	8.3
5-Jun-01	6.43	8.3
15-Nov-01	6.87	8.0
10-Apr-02	7.28	8.1
18-Nov-02	7.88	8.3
16-Apr-03	8.29	8.7
19-Nov-03	8.89	8.1
20-Apr-04	9.29	8.0
9-Nov-04	9.86	7.7
20-Apr-05	10.31	8.1
14-Nov-05	10.87	8.7
10-May-06	11.36	8.4
21-Nov-06	11.91	8.5
14-May-07	12.33	8.3
21-Nov-07	12.89	8.1
04-Apr-08	13.33	8.1
12-Nov-08	13.90	8.2
08-Apr-09	14.29	8.2
16-Nov-09	14.87	8.2
03-Dec-10	15.88	8.4
02-May-11	16.34	8.5
07-Dec-11	16.93	8.2
01-May-12	17.33	8.3

Profile 5: Blackmore's at Waikawa

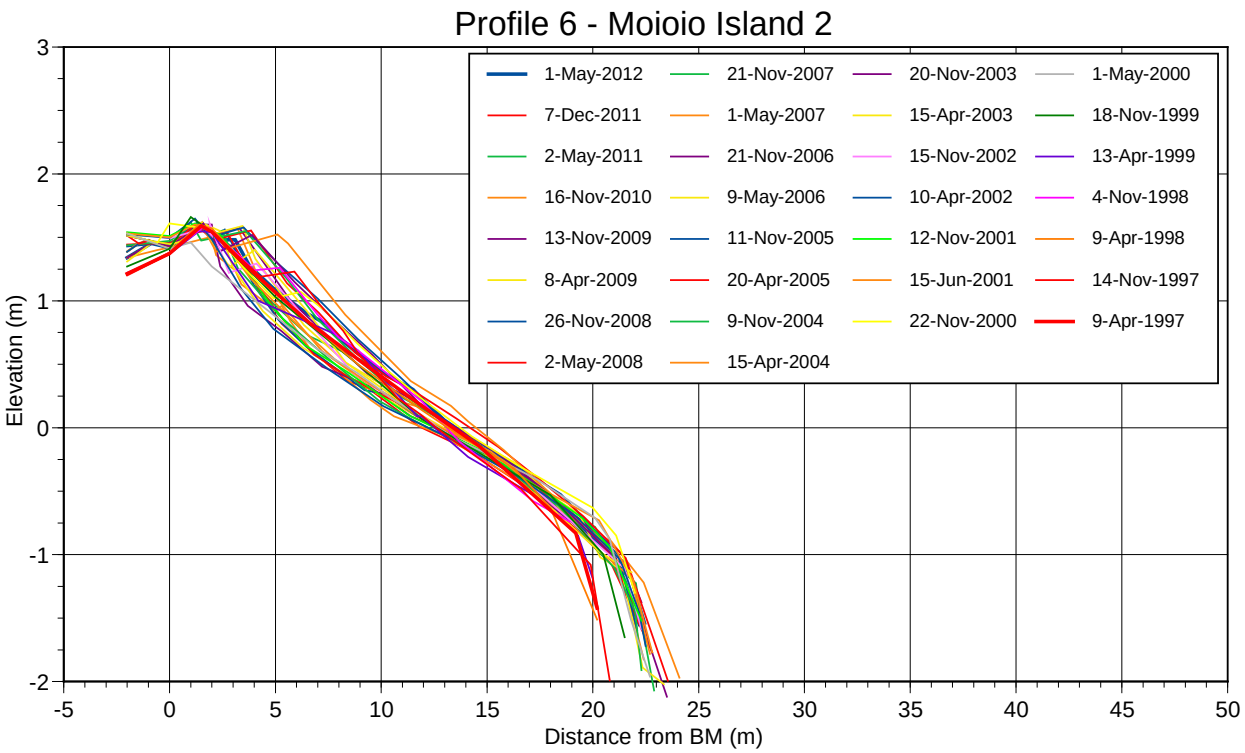
Profile 6 – Moioio Island 2

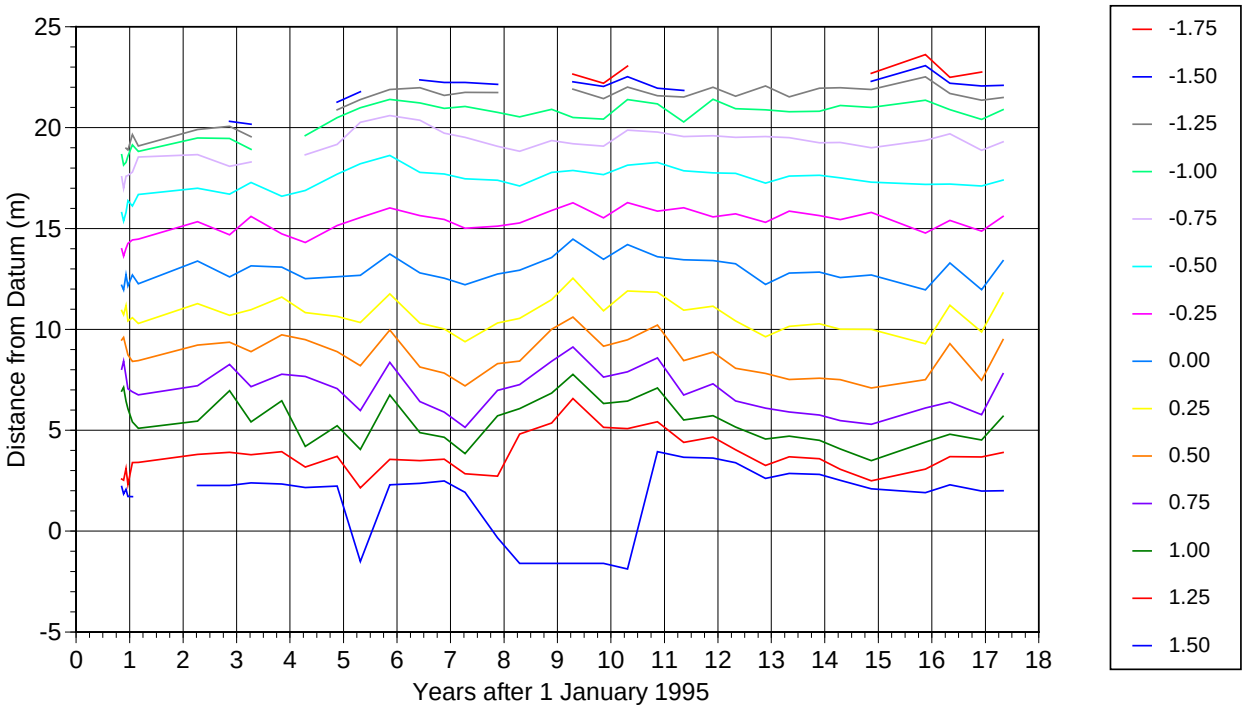
Moioio Island 2 is at the eastern end of the beach on the island, near the slip that was of considerable concern to Te Ati Awa at the time the fast ferries were operating. This profile has a record going back to November 1995 and until 1999 the beach profile demonstrated seasonality, with a build up of a berm on the upper beach over the winter months, and its removal over the summer months, after which time, seasonal patterns have not been evident. The beach experienced significant accretion up to 2005, with a significant reversal for a period between November 2000 and April 2002 (coinciding with the slowing of the fast ferries possible affecting sediment mobility from the slip source). Between 2005 and 2009 the beach eroded, particularly on the upper and middle sections. Over the last 3 years, the upper beach has again accreted, probably due to an input of sediment from the slip. A significant berm remains at the top of the profile, and the lower beach continues to extend slowly into the deep water channel.

The most significant effect on this profile has almost certainly been the adjacent slip. Major fluctuations in beach shape and volume, and indeed the general accretion, are almost certainly related to sediment supply from periods of activity and inactivity of the slip.

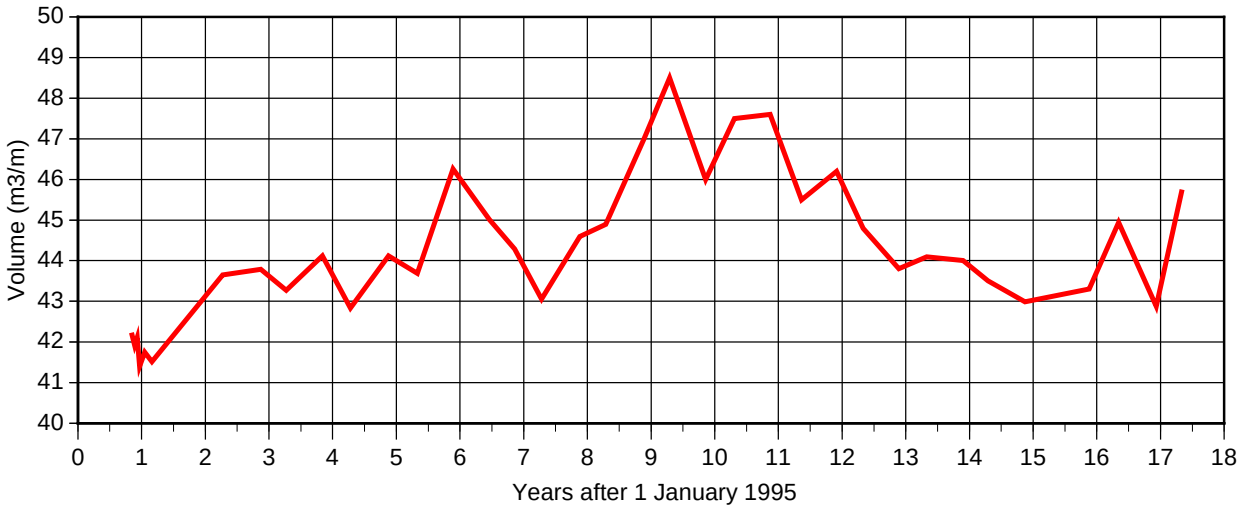


Profile 6: Moioio Island 2





Profile 6: Moioio Island 2



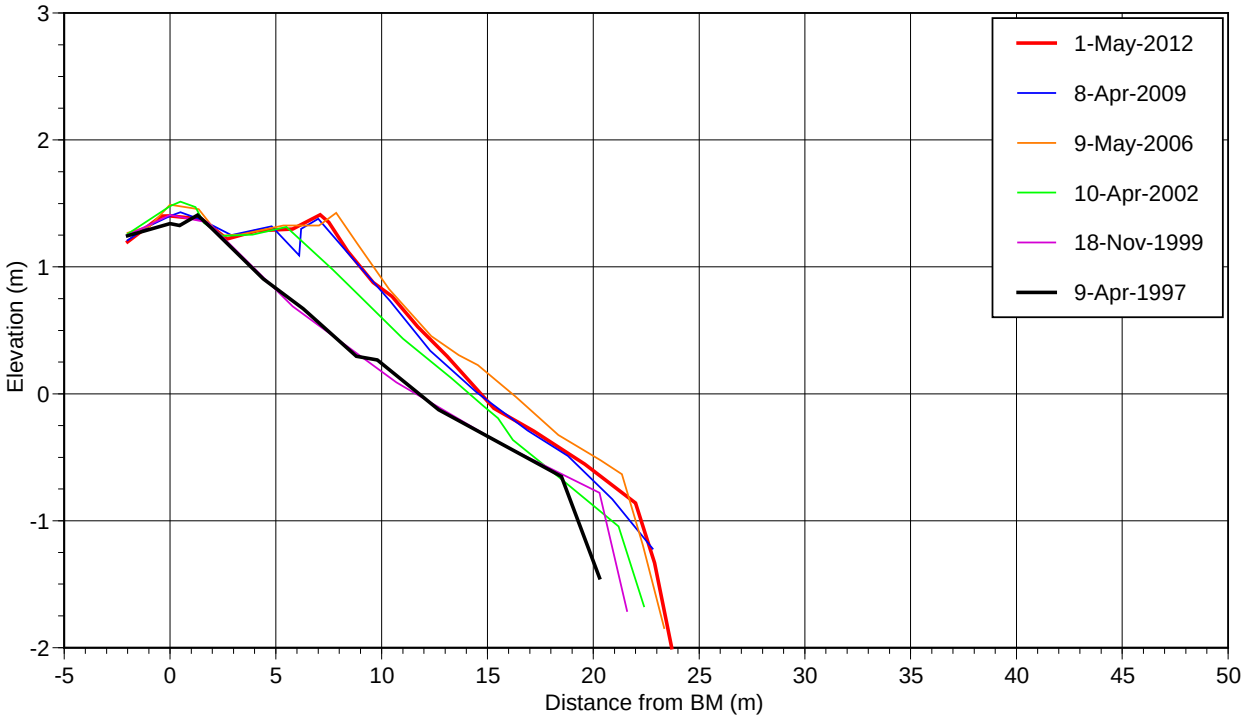
Date	Years after 1/1/95	Volume (m^3/m)
8-Nov-95	0.85	42.17
21-Nov-95	0.89	41.92
6-Dec-95	0.93	42.11
20-Dec-95	0.97	41.40
19-Jan-96	1.05	41.75
29-Feb-96	1.16	41.52
9-Apr-97	2.27	43.65
14-Nov-97	2.87	43.79
9-Apr-98	3.27	43.27
4-Nov-98	3.84	44.12
13-Apr-99	4.28	42.83
18-Nov-99	4.88	44.12
1-May-00	5.33	43.69
22-Nov-00	5.89	46.26
15-Jun-01	6.46	45.01
12-Nov-01	6.86	44.29
10-Apr-02	7.28	43.06
15-Nov-02	7.88	44.6
15-Apr-03	8.29	44.9
20-Nov-03	8.89	47.0
15-Apr-04	9.29	48.5
9-Nov-04	9.86	46.0
20-Apr-05	10.31	47.5
11-Nov-05	10.87	47.6
9-May-06	11.36	45.5
21-Nov-06	11.91	46.2
01-May-07	12.33	44.8
21-Nov-07	12.89	43.8
02-May-08	13.33	44.1
26-Nov-08	13.90	44.0
08-Apr-09	14.29	43.5
13-Nov-09	14.87	43.0
16-Nov-10	15.88	43.3
02-May-11	16.34	44.9
07-Dec-11	16.93	42.9
01-May-12	17.33	45.7

Profile 6: Moioio Island 2

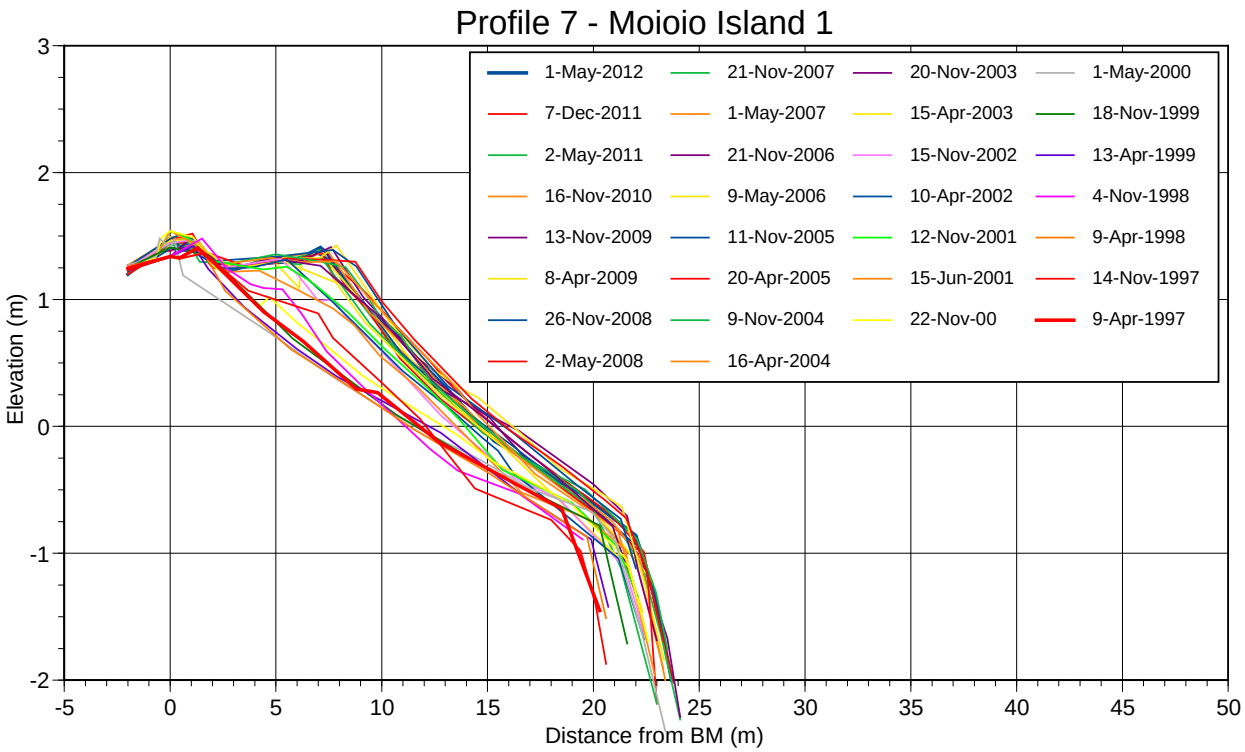
Profile 7 – Moioio Island 1

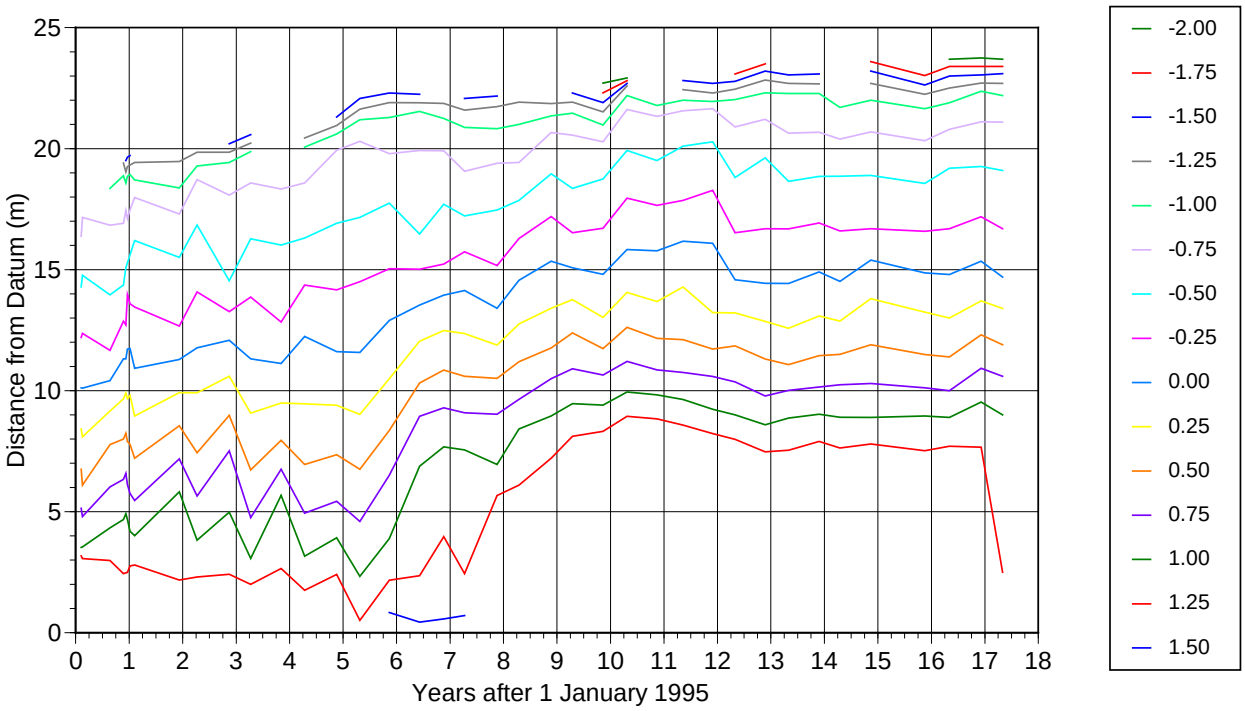
The Moioio Island 1 profile is to the west of Profile 6. There was remarkable seasonality up to the winter of 1999, with the growth of a berm over winter and its loss over summer. Up until the end of 2000, the upper beach was generally stable, with seasonality, and with the lower beach accreting into the channel. Up to 2006, like Profile 6, the whole profile accreted rapidly with very substantial volume increases. There was substantial accretion of the upper beach between May 2000 and May 2006, with a major increase in volume, particularly between May 2000 and April 2001. Like Profile 6, there was a reversal in 2006, with a year of significant erosion, although the substantial berm remained. Since 2007 the profile has been relatively stable. This profile is almost certainly reacting principally to sediment supply.

There is little doubt that the beach changes taking place on this profile are related in part to ferry operation (evidenced by the very strong seasonal signal when fast ferries were operating seasonally), but they are affected significantly by changes to sediment supply. For example, the accretion event observed on Profile 6 between April 2003 and April 2004 is reflected on Profile 7 between November 2004 and April 2005.

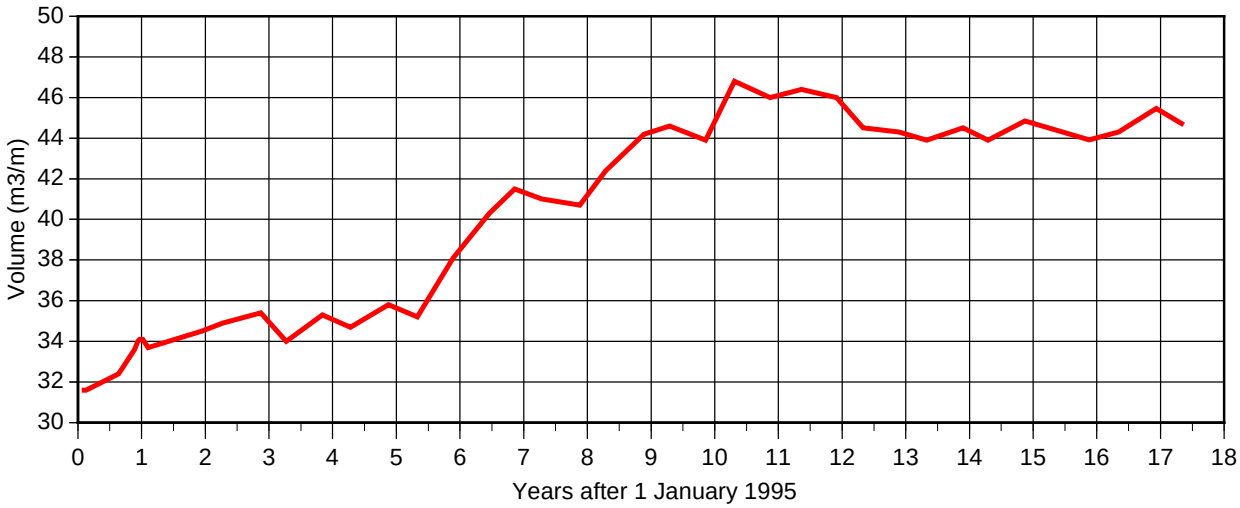


Profile 7: Moioio Island 1





Profile 7: Moioio Island 1



Date	Years after 1/1/95	Volume (m^3/m)
1977		38.3
8-Feb-95	0.10	31.6
17-Feb-95	0.13	31.6
22-Aug-95	0.64	32.4
22-Nov-95	0.89	33.6
8-Dec-95	0.94	34.0
20-Dec-95	0.97	34.1
7-Jan-96	1.02	34.1
8-Feb-96	1.10	33.7
9-Dec-96	1.94	34.5
9-Apr-97	2.27	34.9
14-Nov-97	2.87	35.4
9-Apr-98	3.27	34.0
4-Nov-98	3.84	35.3
13-Apr-99	4.28	34.7
18-Nov-99	4.88	35.8
1-May-00	5.33	35.2
22-Nov-00	5.89	38.1
15-Jun-01	6.46	40.3
12-Nov-01	6.86	41.5
10-Apr-02	7.28	41.0
15-Nov-02	7.88	40.7
15-Apr-03	8.29	42.4
20-Nov-03	8.89	44.2
16-Apr-04	9.29	44.6
9-Nov-04	9.86	43.9
20-Apr-05	10.31	46.8
11-Nov-05	10.87	46.0
9-May-06	11.36	46.4
21-Nov-06	11.91	46.0
01-May-07	12.33	44.5
21-Nov-07	12.89	44.3
02-May-08	13.33	43.9
26-Nov-08	13.90	44.5
08-Apr-09	14.29	43.9
13-Nov-09	14.87	44.8
16-Nov-10	15.88	43.9
02-May-11	16.34	44.3
07-Dec-11	16.93	45.5
01-May-12	17.33	44.7

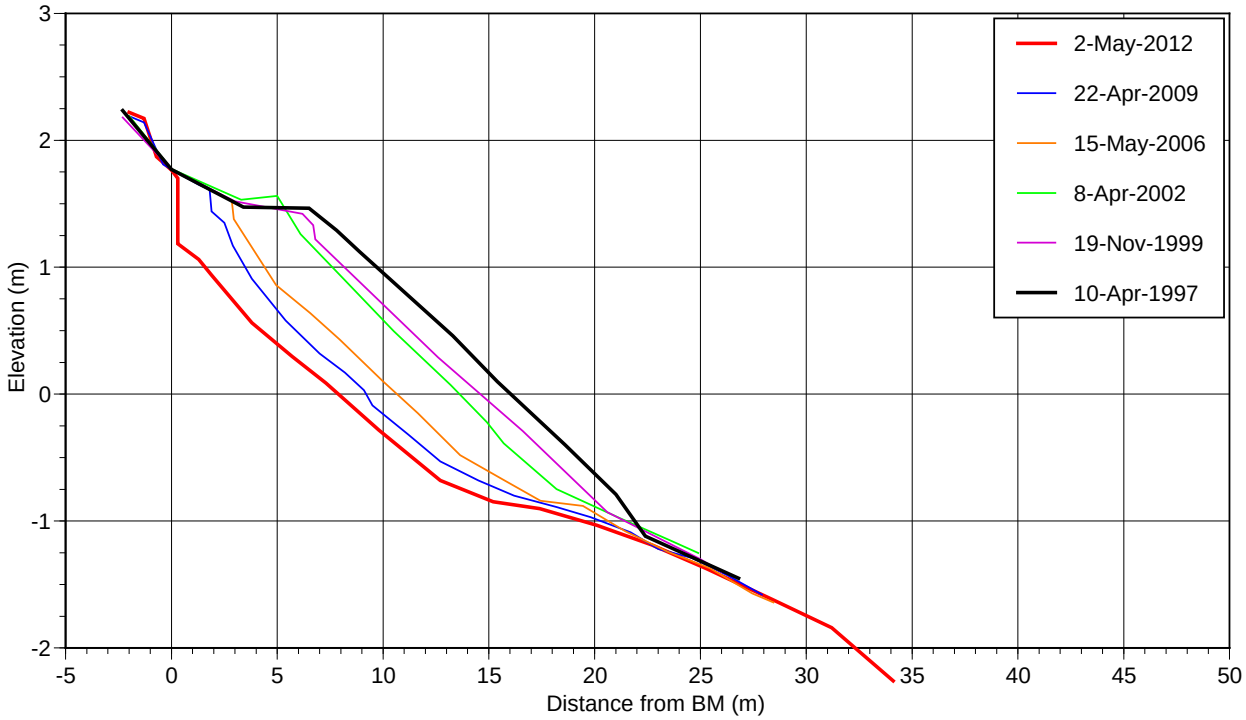
Profile 7: Moioio Island 1

Profile 8 – Bob's Bay

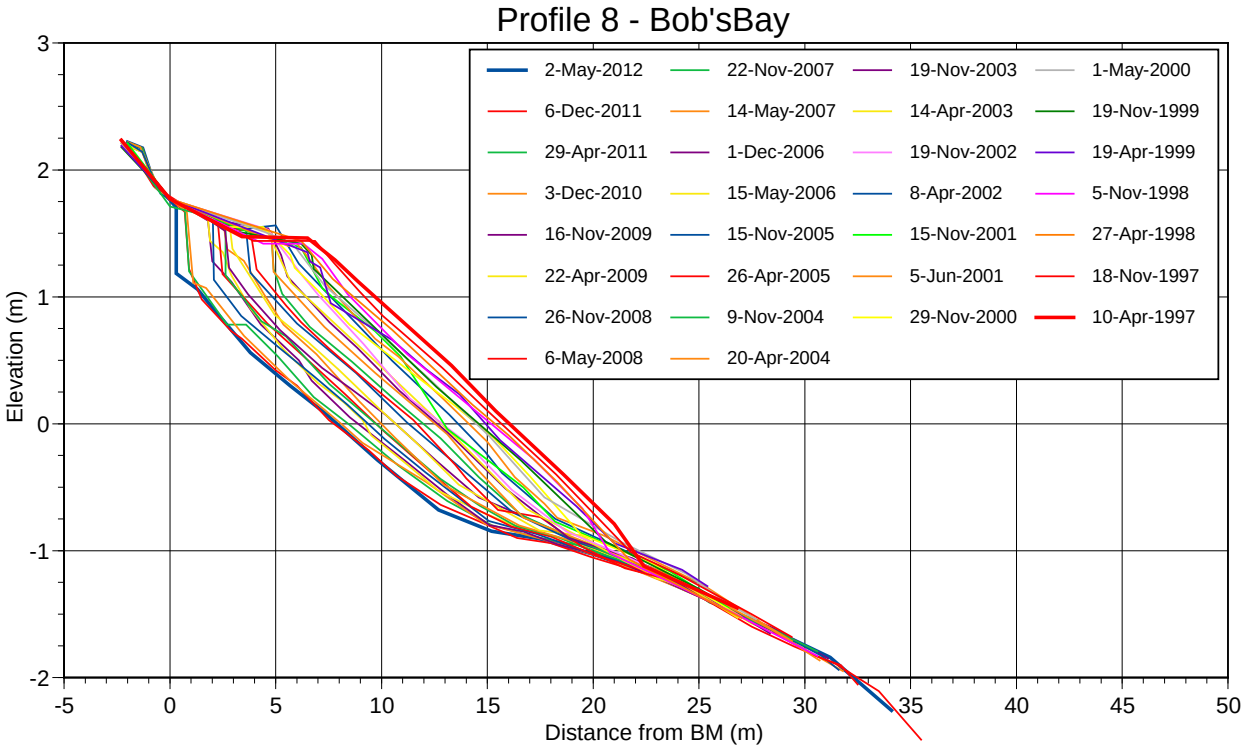
Bob's Bay has demonstrated an almost linear erosion trend since 1995 across the whole beach profile down to the change in slope (and probable closure depth) at about –1m. Most of the beach has lowered in level by about 1.2m. Volume data shows a volume change of the monitored area from 38.2m^3/m in 1995 to 16.9m^3/m since 1995. Because the profile line clearly encompasses the sweep zone, the 55% volume loss accurately reflects the total loss of sand. This erosion is very significant within the context of beaches in this study. The beach slope has stayed relatively constant.

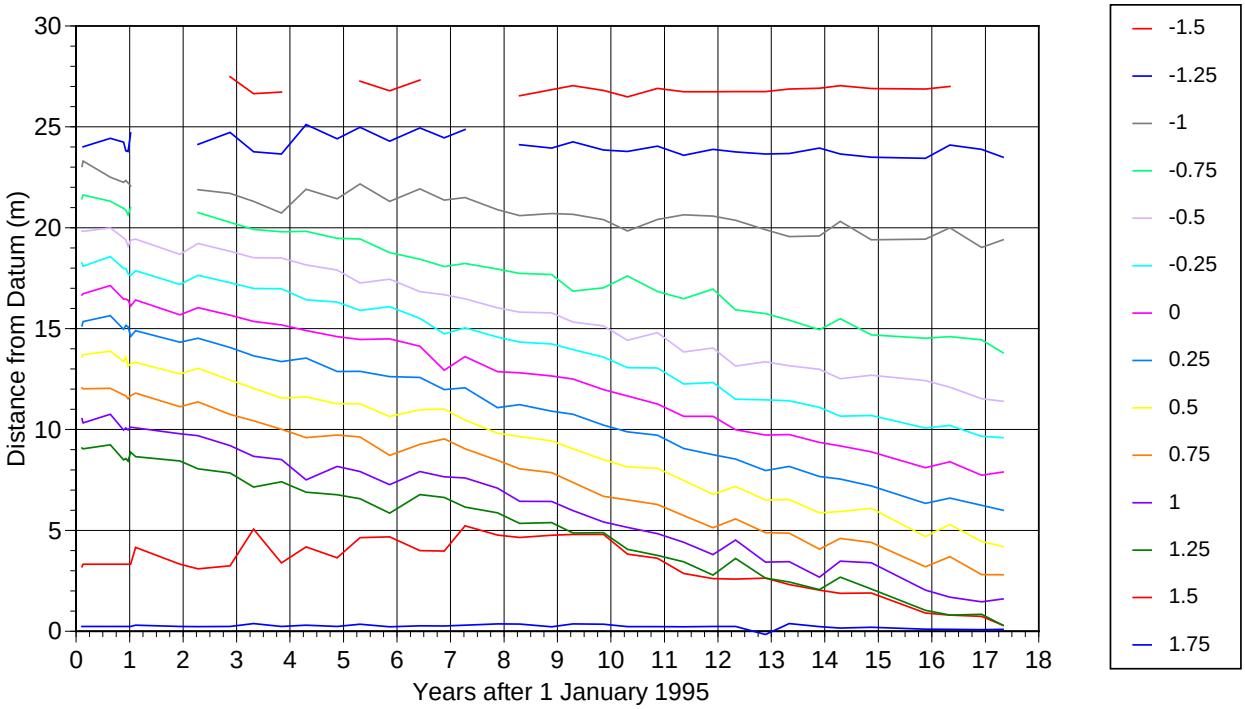
The location of this profile is at the northern end of the beach, adjacent to a headland of significance to Te Ati Awa. It may be that the erosion is accompanied by accretion elsewhere in the embayment.

The cause of the erosion is not known. The site is well inside Mabel Island, and all major shipping movements should be at low speed with small wakes. There is also limited fetch, so natural waves should also be small. The mechanism of sediment transport away from the profile line, and where the sediment goes could be investigated if erosion at this particular point becomes more of concern.

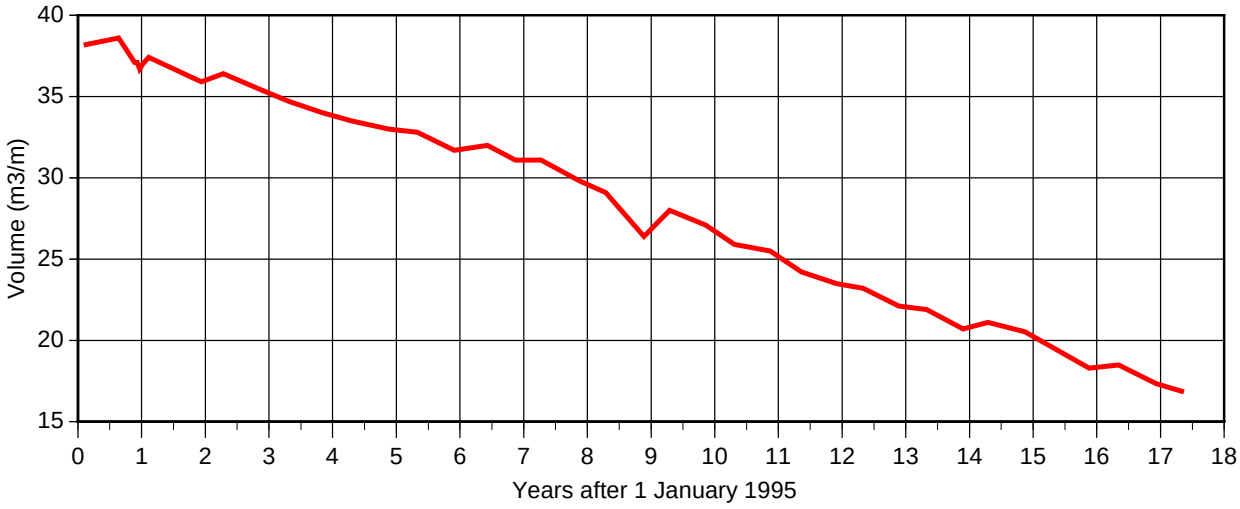


Profile 8: Bobs Bay





Profile 8: Bobs Bay

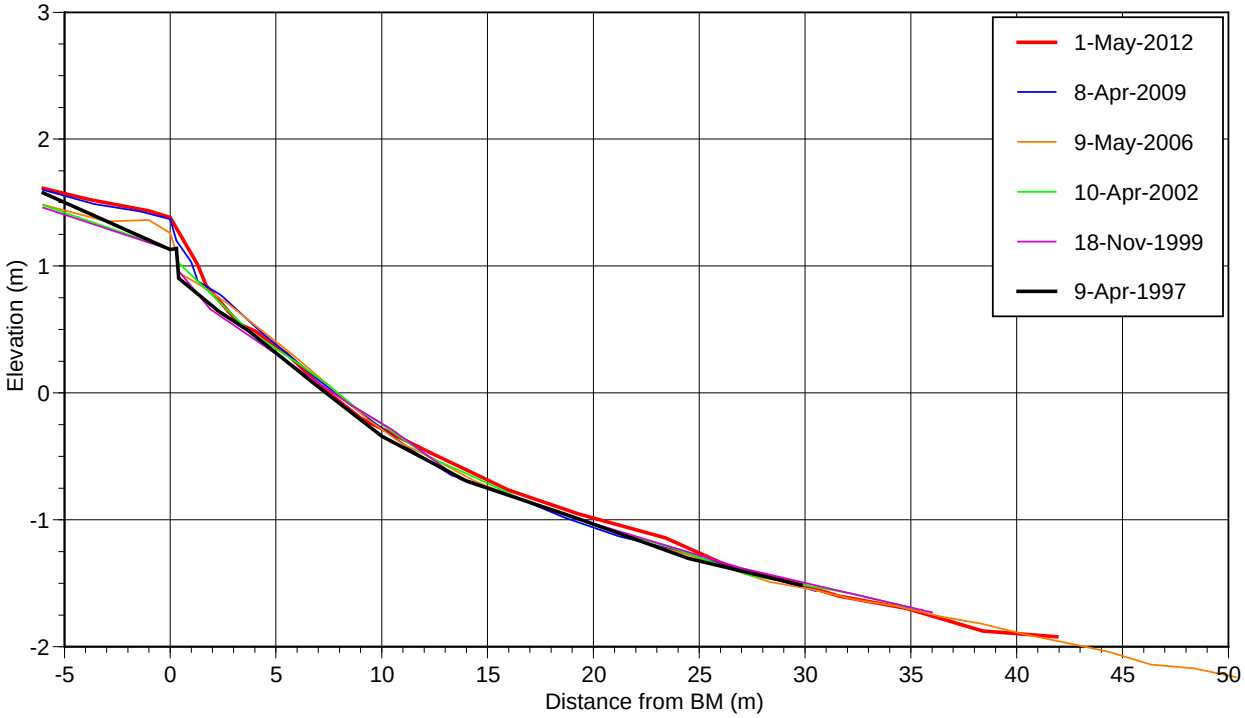


Date	Years after 1/1/95	Volume (m^3/m)
17-Feb-95	0.13	38.2
22-Aug-95	0.64	38.6
21-Nov-95	0.89	37.1
7-Dec-95	0.93	37.1
20-Dec-95	0.97	36.7
7-Jan-96	1.02	37.0
10-Feb-96	1.11	37.4
10-Dec-96	1.94	35.9
10-Apr-97	2.28	36.4
18-Nov-97	2.88	35.4
27-Apr-98	3.32	34.7
5-Nov-98	3.84	34.0
19-Apr-99	4.30	33.5
19-Nov-99	4.88	33.0
1-May-00	5.33	32.8
29-Nov-00	5.91	31.7
5-Jun-01	6.43	32.0
15-Nov-01	6.87	31.1
8-Apr-02	7.27	31.1
19-Nov-02	7.88	29.8
14-Apr-03	8.29	29.1
19-Nov-03	8.89	26.4
20-Apr-04	9.29	28.0
9-Nov-04	9.86	27.1
26-Apr-05	10.31	25.9
15-Nov-05	10.87	25.5
15-May-06	11.36	24.2
01-Dec-06	11.91	23.5
14-May-07	12.33	23.2
22-Nov-07	12.89	22.1
06-May-08	13.33	21.9
26-Nov-08	13.90	20.7
22-Apr-09	14.29	21.1
16-Nov-09	14.87	20.5
03-Dec-10	15.88	18.3
29-Apr-11	16.34	18.5
06-Dec-11	16.93	17.3
02-May-12	17.33	16.9

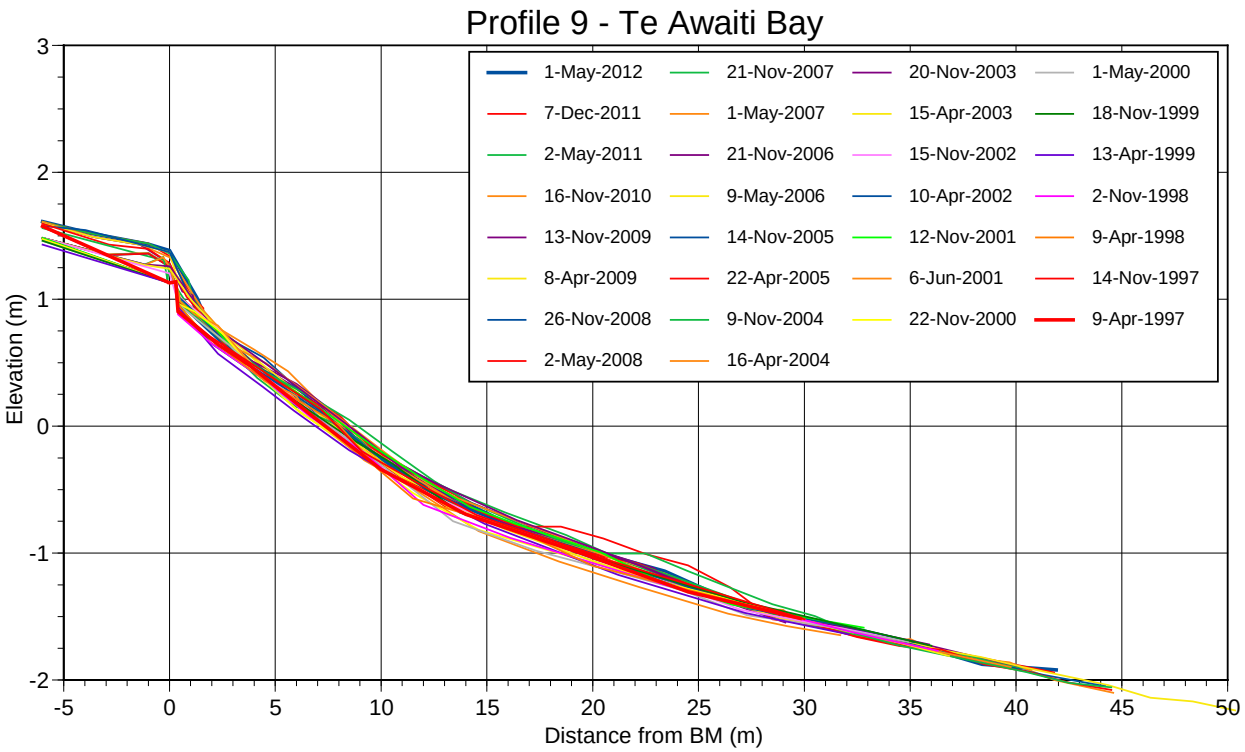
Profile 8: Bobs Bay

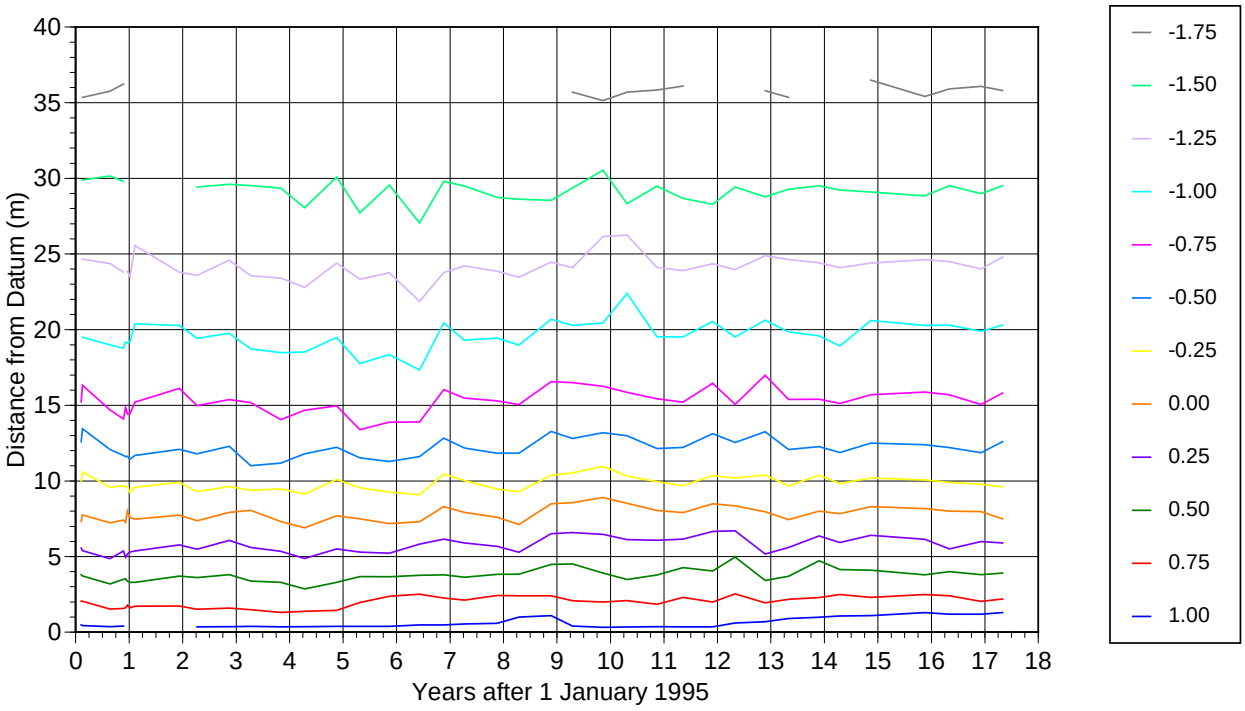
Profile 9 – Te Awaiti Bay

Despite frequent changes in surficial sediments (more common up to 2003), with the deposition and removal of a small quantity of fine sediment, the beach profile has changed little. Beach volumes were relatively stable up until 2001, but then increased significantly, coinciding with the slowing of the fast ferries. Volumes reduced slightly by 2006 after peaking in 2004, and have remained constant since. Some redistribution of sediment has occurred with deposition at the top of the beach. Photographs indicate that the sediment deposited at the top of the beach may have an aeolian origin.

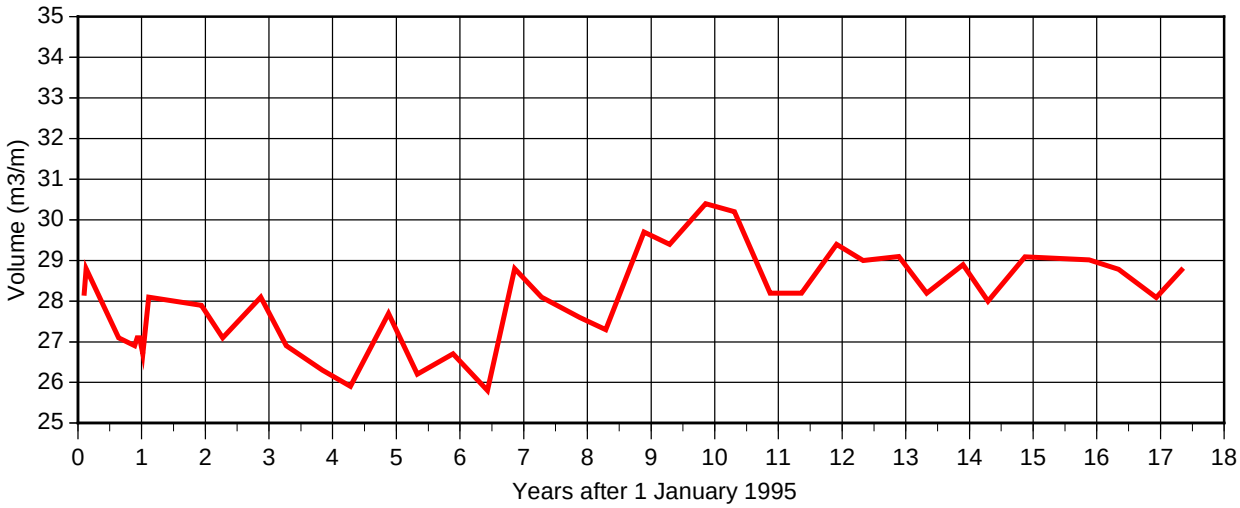


Profile 9: Te Awaiti Bay





Profile 9: Te Awaiti Bay

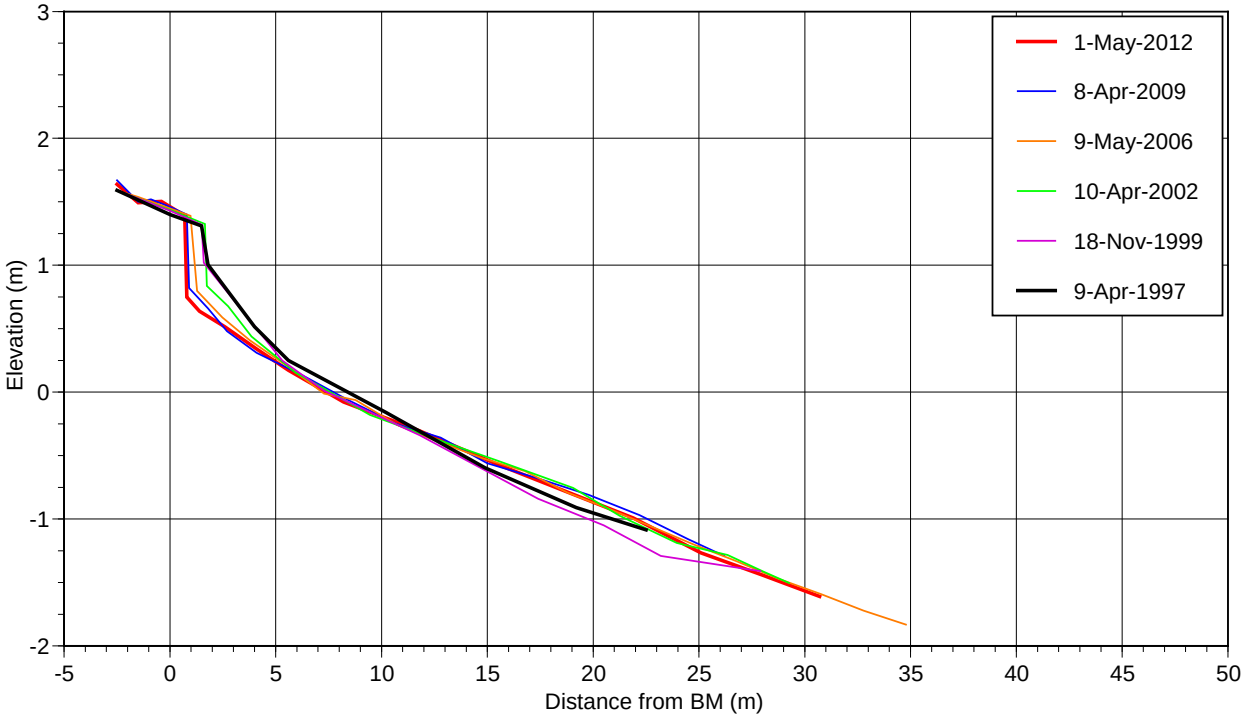


Date	Years after 1/1/95	Volume (m^3/m)
8-Feb-95	0.10	28.2
17-Feb-95	0.13	28.8
23-Aug-95	0.64	27.1
22-Nov-95	0.89	26.9
7-Dec-95	0.93	27.1
20-Dec-95	0.97	27.1
7-Jan-96	1.02	26.7
9-Feb-96	1.11	28.1
9-Dec-96	1.94	27.9
9-Apr-97	2.27	27.1
14-Nov-97	2.87	28.1
9-Apr-98	3.27	26.9
2-Nov-98	3.84	26.3
13-Apr-99	4.28	25.9
18-Nov-99	4.88	27.7
1-May-00	5.33	26.2
22-Nov-00	5.89	26.7
6-Jun-01	6.43	25.8
12-Nov-01	6.86	28.8
10-Apr-02	7.28	28.1
15-Nov-02	7.88	27.6
15-Apr-03	8.29	27.3
20-Nov-03	8.89	29.7
16-Apr-04	9.29	29.4
9-Nov-04	9.86	30.4
22-Apr-05	10.31	30.2
14-Nov-05	10.87	28.2
9-May-06	11.36	28.2
9-May-06	11.36	28.2
21-Nov-06	11.91	29.4
01-May-07	12.33	29.0
21-Nov-07	12.89	29.1
02-May-08	13.33	28.2
26-Nov-08	13.90	28.9
13-Nov-09	14.87	29.1
16-Nov-10	15.88	29.0
02-May-11	16.34	28.8
07-Dec-11	16.93	28.1
01-May-12	17.33	28.8

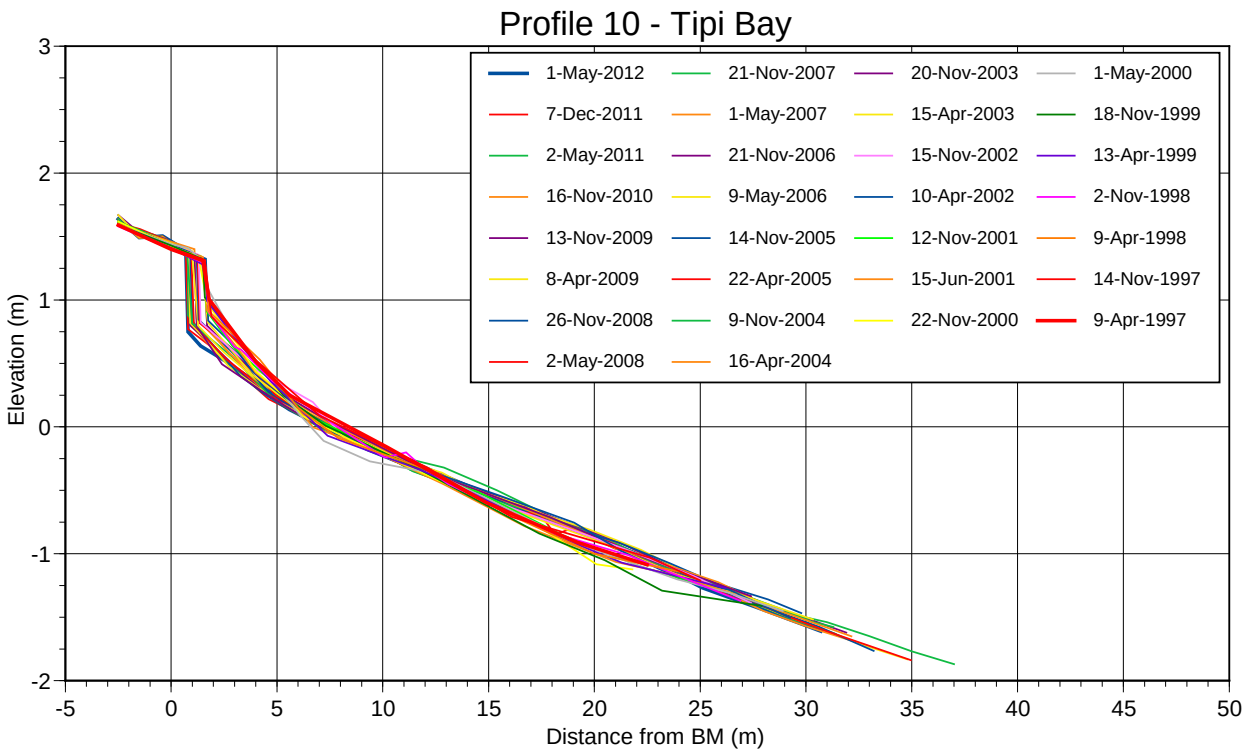
Profile 9: Te Awaiti Bay

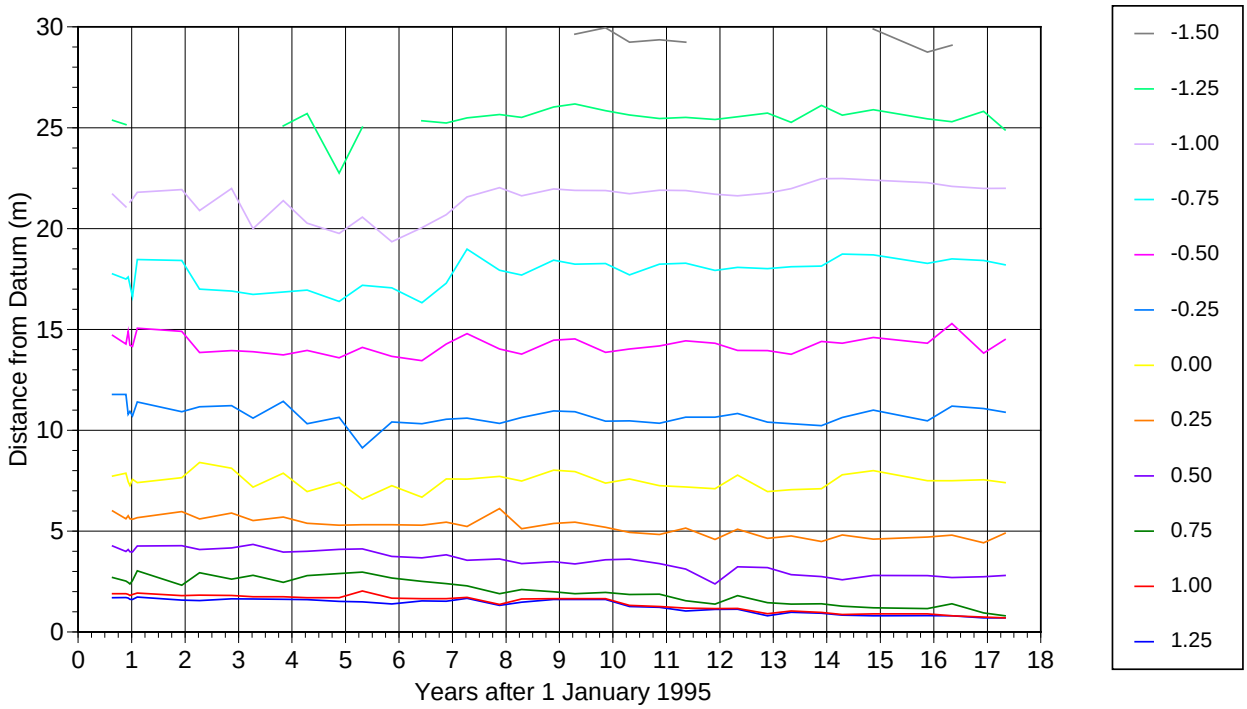
Profile 10 – Tipi Bay

There has been some retreat of the upper beach scarp (approximately 1m) and a corresponding increase in the level of the middle to lower beach, but the changes have generally been minor. Because of the relatively coarse nature of the sediments, the placement of the survey staff can have significant impact on the apparent appearance of the profile line. Overall, beach volumes have reduced only a little.

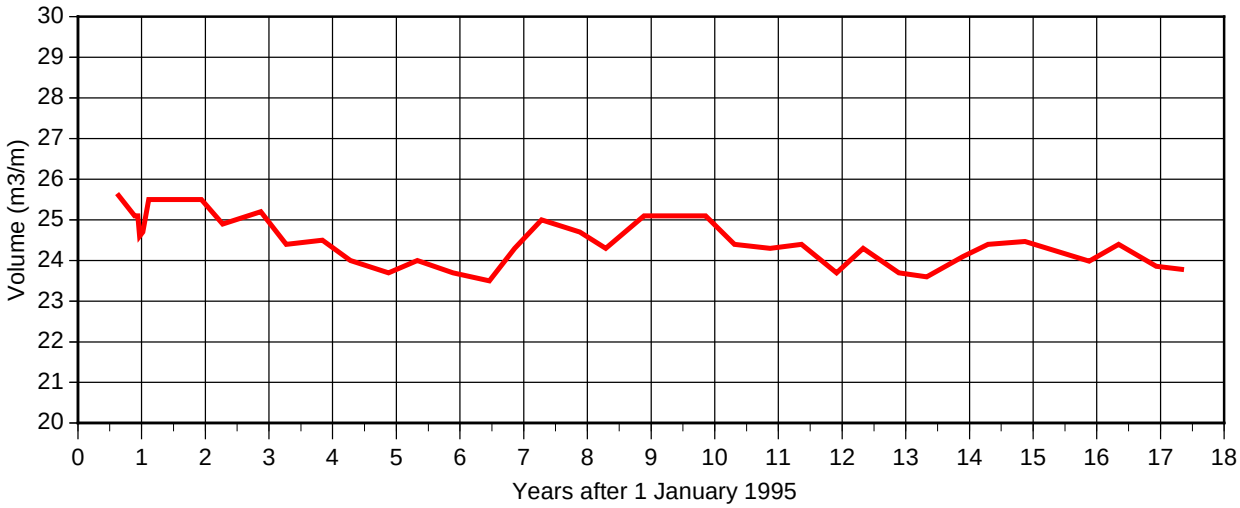


Profile 10: Tipi Bay





Profile 10: Tipi Bay

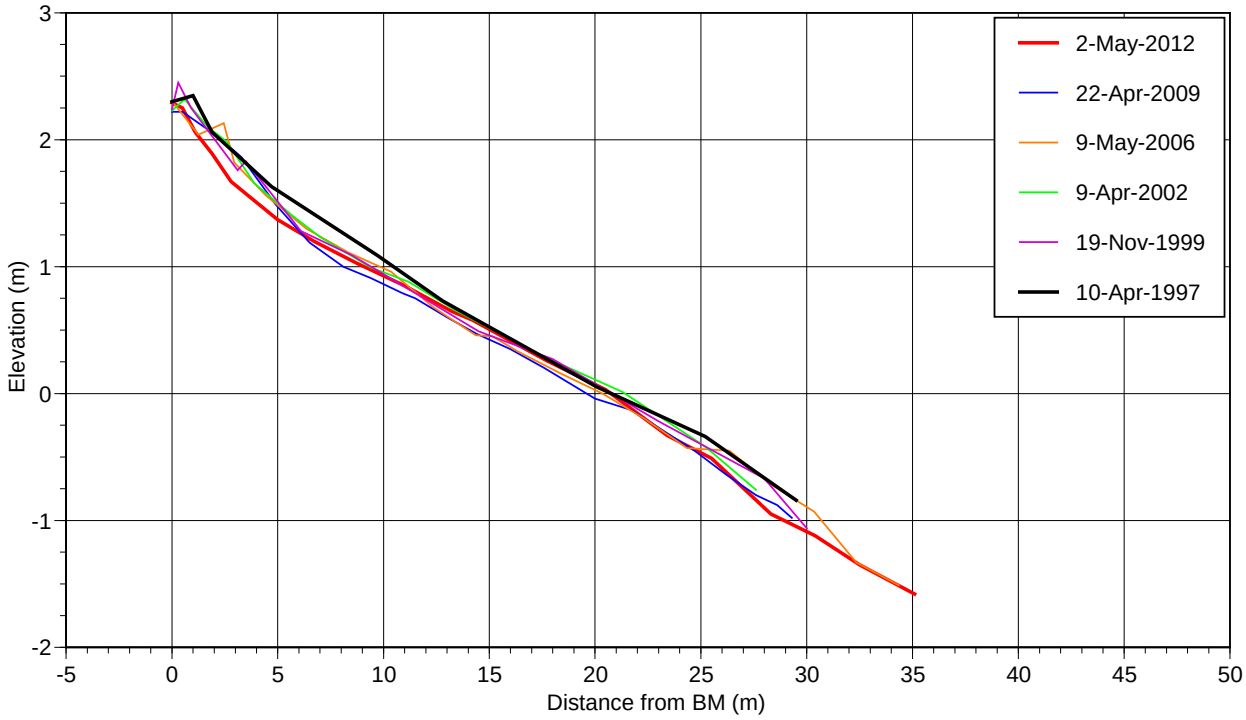


Date	Years after 1/1/95	Volume (m^3/m)
23-Aug-95	0.64	25.6
22-Nov-95	0.89	25.1
8-Dec-95	0.94	25.1
20-Dec-95	0.97	24.6
7-Jan-96	1.02	24.7
9-Feb-96	1.11	25.5
9-Dec-96	1.94	25.5
9-Apr-97	2.27	24.9
14-Nov-97	2.87	25.2
9-Apr-98	3.27	24.4
2-Nov-98	3.84	24.5
13-Apr-99	4.28	24.0
18-Nov-99	4.88	23.7
1-May-00	5.33	24.0
22-Nov-00	5.89	23.7
15-Jun-01	6.46	23.5
12-Nov-01	6.86	24.3
10-Apr-02	7.28	25.0
15-Nov-02	7.88	24.7
15-Apr-03	8.29	24.3
20-Nov-03	8.89	25.1
16-Apr-04	9.29	25.1
9-Nov-04	9.86	25.1
22-Apr-05	10.31	24.4
14-Nov-05	10.87	24.3
9-May-06	11.36	24.4
21-Nov-06	11.91	23.7
01-May-07	12.33	24.3
21-Nov-07	12.89	23.7
02-May-08	13.33	23.6
26-Nov-08	13.90	24.1
08-Apr-09	14.29	24.4
13-Nov-09	14.87	24.5
16-Nov-10	15.88	24.0
02-May-11	16.34	24.4
07-Dec-11	16.93	23.9
01-May-12	17.33	23.8

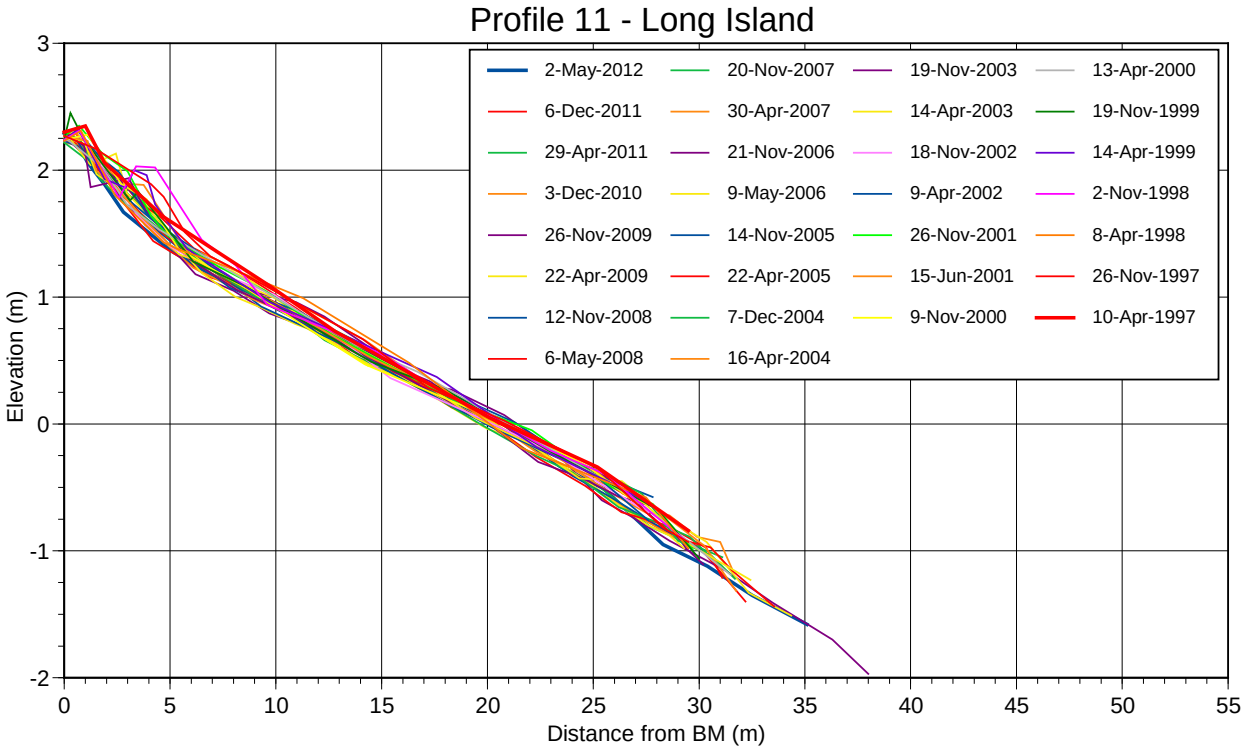
Profile 10: Tipi Bay

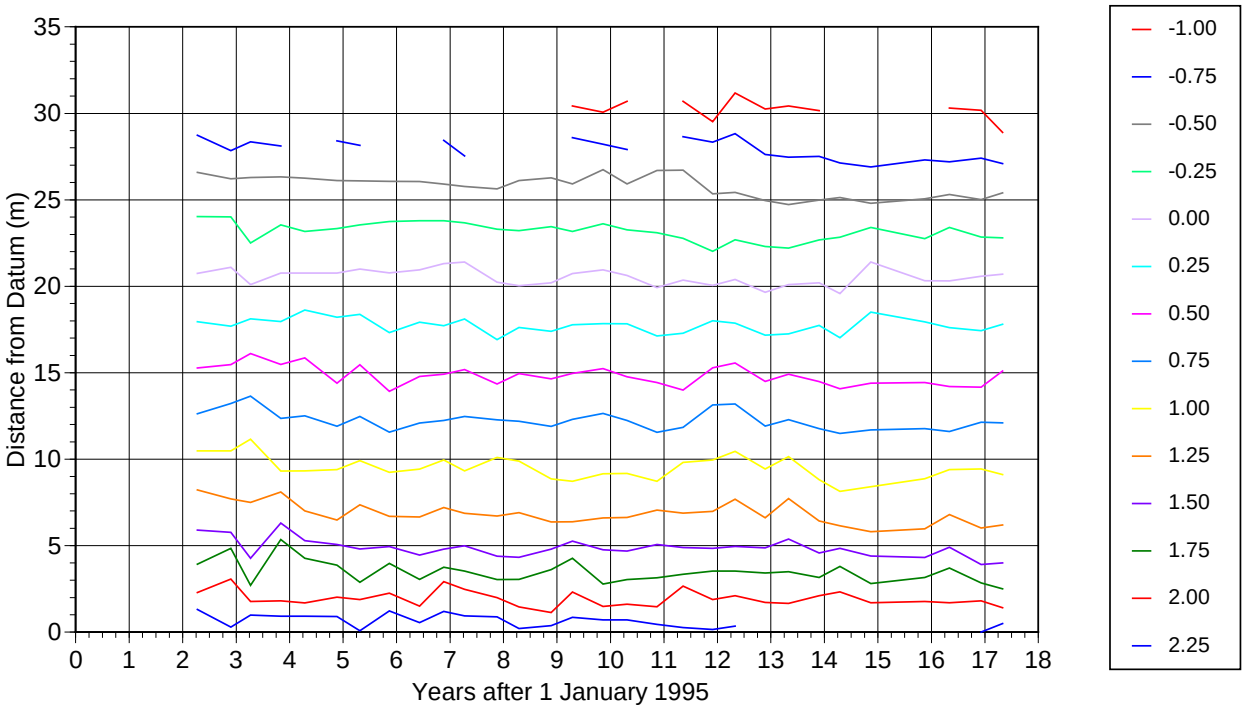
Profile 11 – Long Island

The Long Island profile is relatively exposed to storm events that cause waves to propagate through the northern entrance to Queen Charlotte Sound. There is considerable variability in the level of the upper beach, with the build up and removal of a berm, although this has been less evident since about 2000. The level of the middle and lower beach also shows some variability, but with no obvious seasonal trends. There has been an overall decrease in sediment volume since 1997, with considerable variability... There are no significant sedimentary trends.

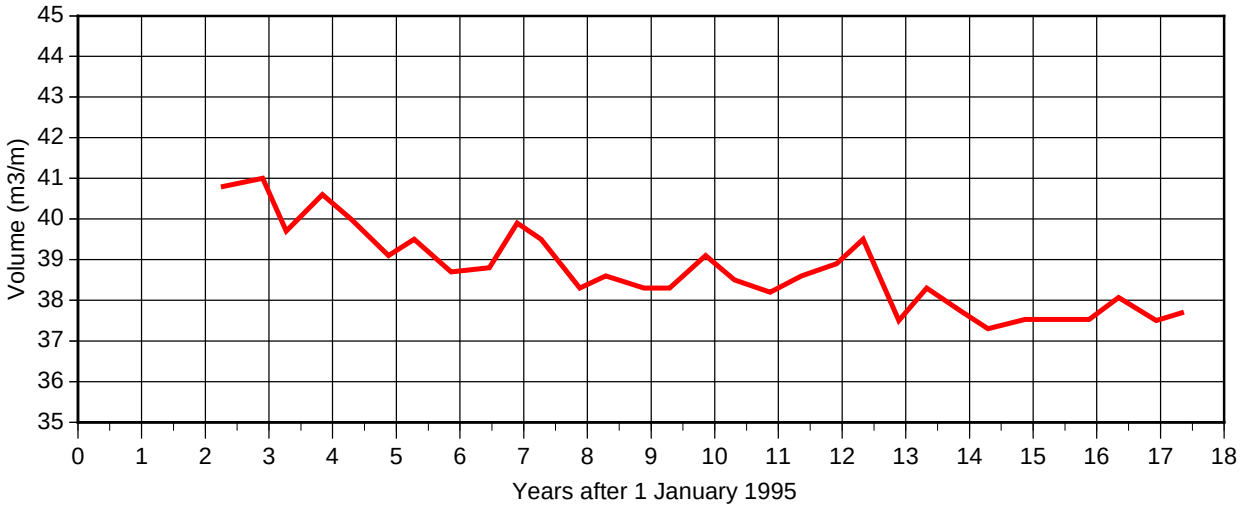


Profile 11: Long Island





Profile 11: Long Island

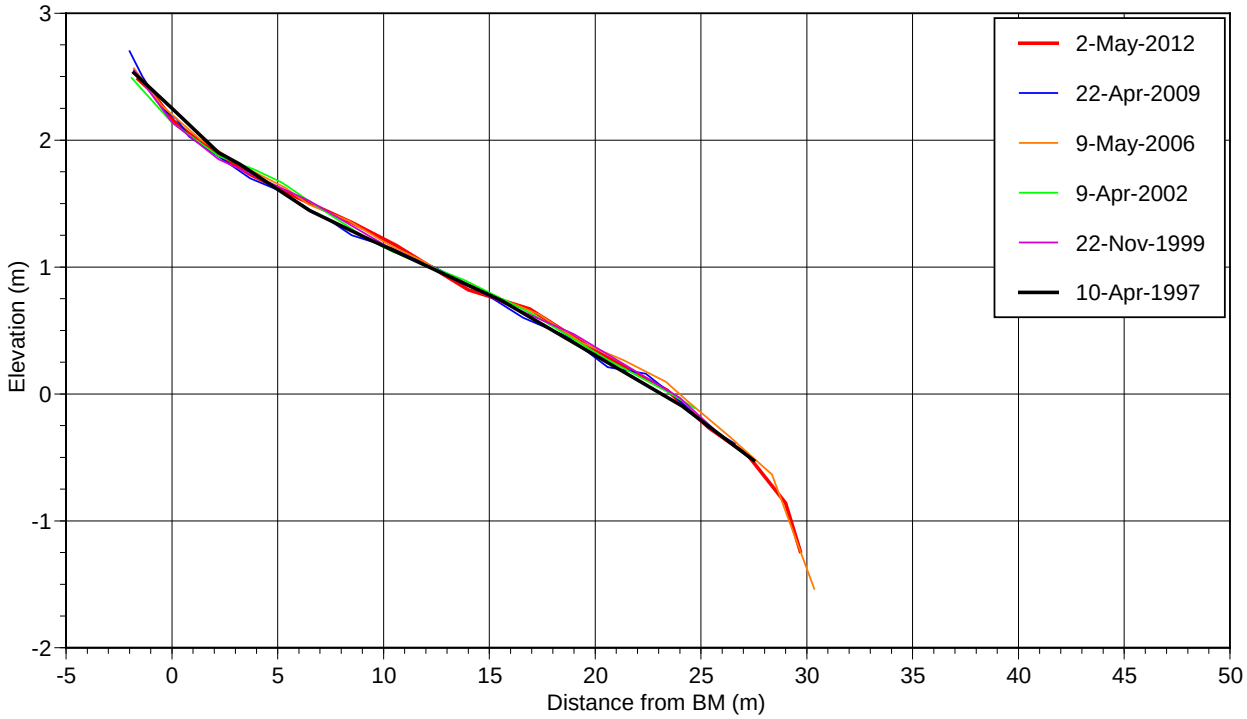


Date	Years after 1/1/95	Volume (m^3/m)
10-Apr-97	2.28	40.8
26-Nov-97	2.90	41.0
8-Apr-98	3.27	39.7
2-Nov-98	3.84	40.6
14-Apr-99	4.29	40.0
19-Nov-99	4.88	39.1
13-Apr-00	5.28	39.5
9-Nov-00	5.86	38.7
15-Jun-01	6.46	38.8
26-Nov-01	6.90	39.9
9-Apr-02	7.27	39.5
18-Nov-02	7.88	38.3
14-Apr-03	8.29	38.6
19-Nov-03	8.89	38.3
16-Apr-04	9.29	38.3
7-Dec-04	9.86	39.1
22-Apr-05	10.31	38.5
14-Nov-05	10.87	38.2
9-May-06	11.36	38.6
21-Nov-06	11.91	38.9
30-Apr-07	12.33	39.5
20-Nov-07	12.89	37.5
06-May-08	13.33	38.3
12-Nov-08	13.90	37.7
22-Apr-09	14.29	37.3
26-Nov-09	14.87	37.5
03-Dec-10	15.88	37.5
29-Apr-11	16.34	38.1
06-Dec-11	16.93	37.5
02-May-12	17.33	37.7

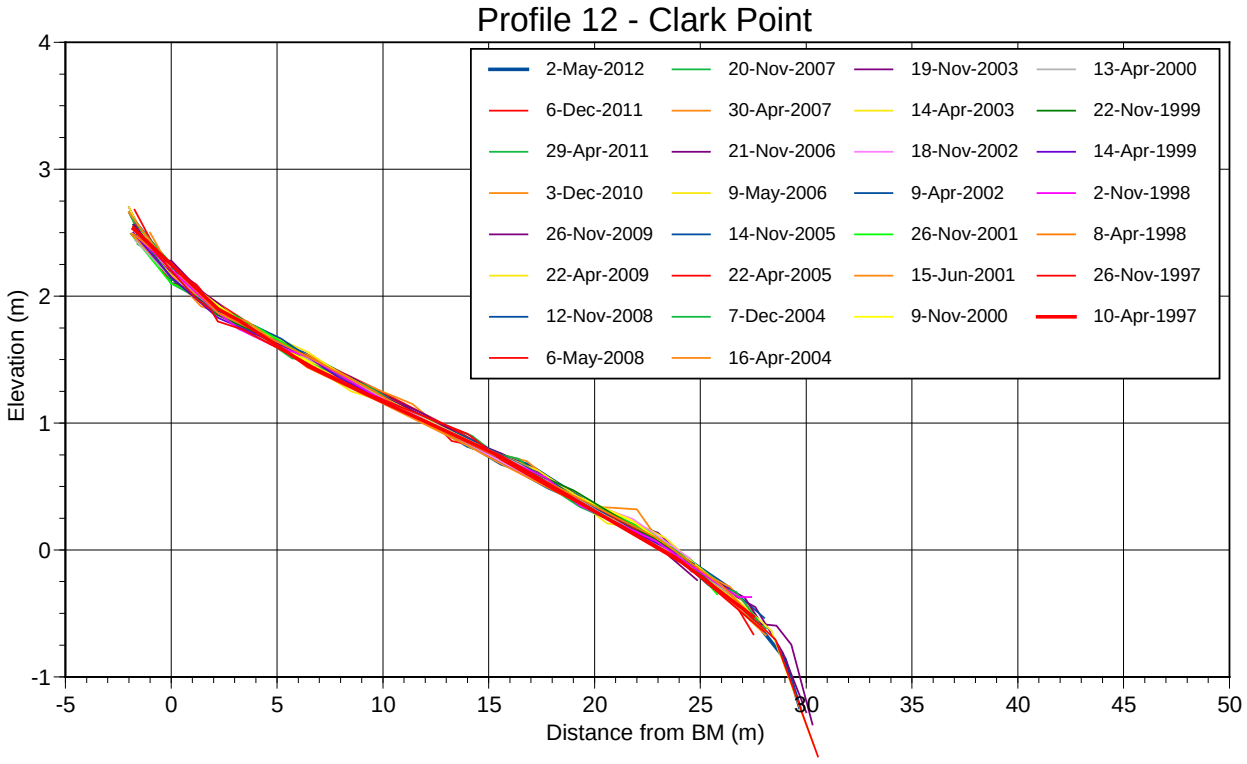
Profile 11: Long Island

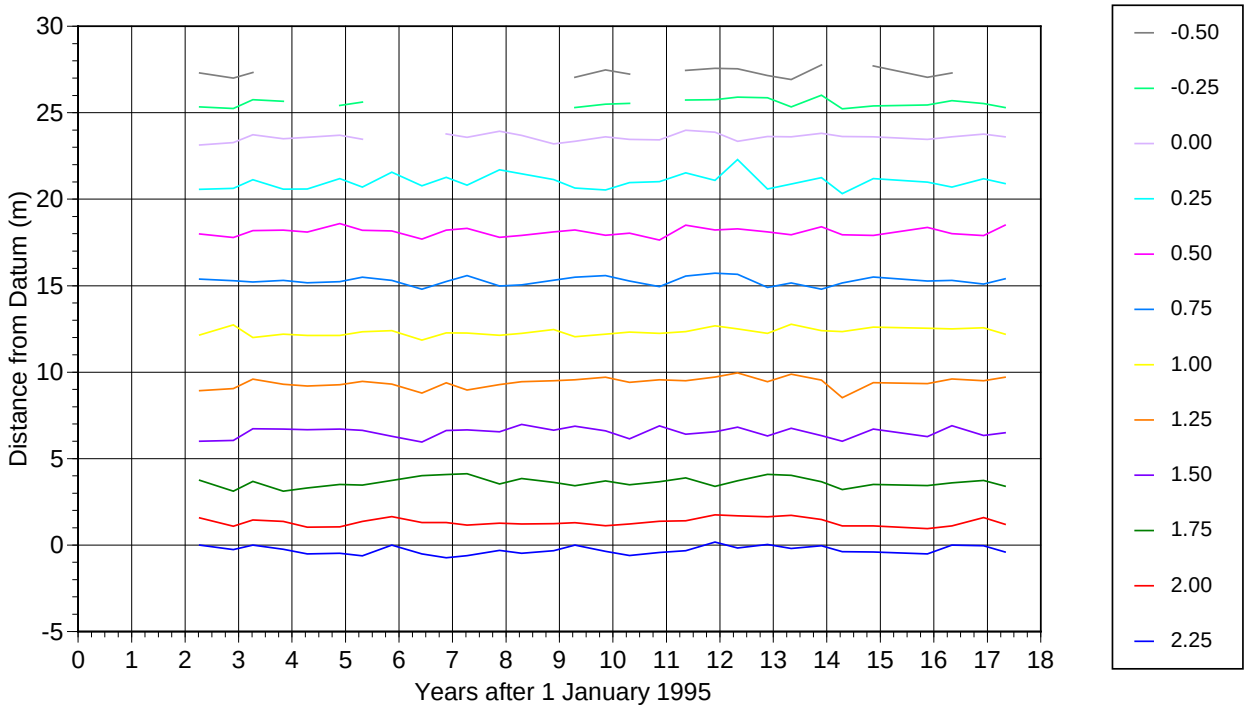
Profile 12 – Clark Point

This profile, with a similar aspect to Profile 11 (Long Island), has shown no significant change in level, volume or sedimentary characteristics since 1997.

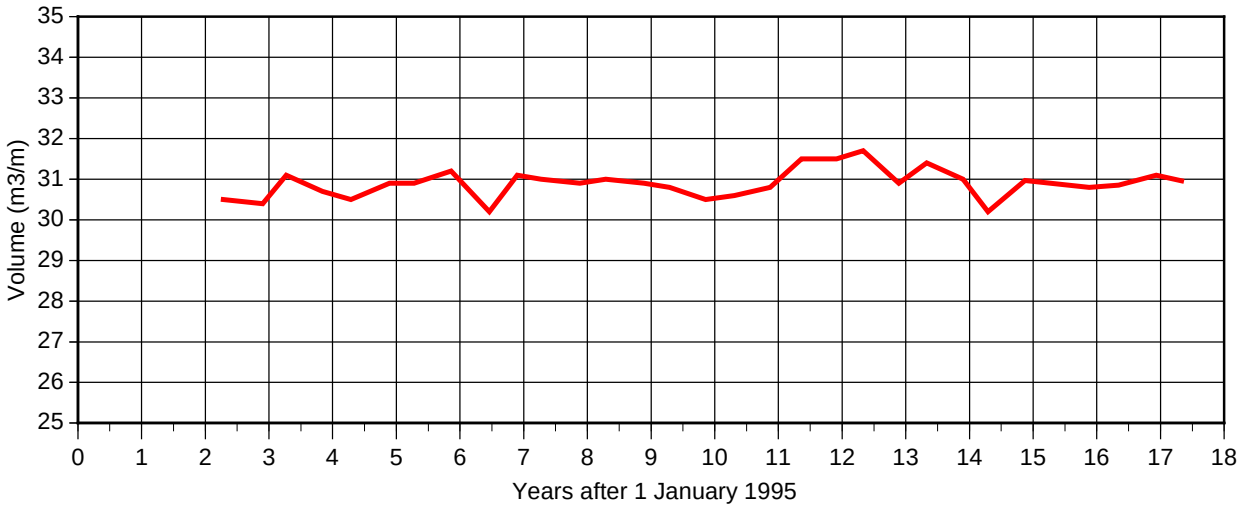


Profile 12: Clark Point





Profile 12: Clark Point



Date	Years after 1/1/95	Volume (m^3/m)
10-Apr-97	2.28	30.5
26-Nov-97	2.90	30.4
8-Apr-98	3.27	31.1
2-Nov-98	3.84	30.7
14-Apr-99	4.29	30.5
22-Nov-99	4.89	30.9
13-Apr-00	5.28	30.9
9-Nov-00	5.86	31.2
15-Jun-01	6.46	30.2
26-Nov-01	6.90	31.1
9-Apr-02	7.27	31.0
18-Nov-02	7.88	30.9
14-Apr-03	8.29	31.0
19-Nov-03	8.89	30.9
16-Apr-04	9.29	30.8
7-Dec-04	9.86	30.5
22-Apr-05	10.31	30.6
14-Nov-05	10.87	30.8
9-May-06	11.36	31.5
21-Nov-06	11.91	31.5
30-Apr-07	12.33	31.7
20-Nov-07	12.89	30.9
06-May-08	13.33	31.4
12-Nov-08	13.90	31.0
22-Apr-09	14.29	30.2
26-Nov-09	14.87	31.0
03-Dec-10	15.88	30.8
29-Apr-11	16.34	30.8
06-Dec-11	16.93	31.1
02-May-12	17.33	31.0

Profile 12: Clark Point

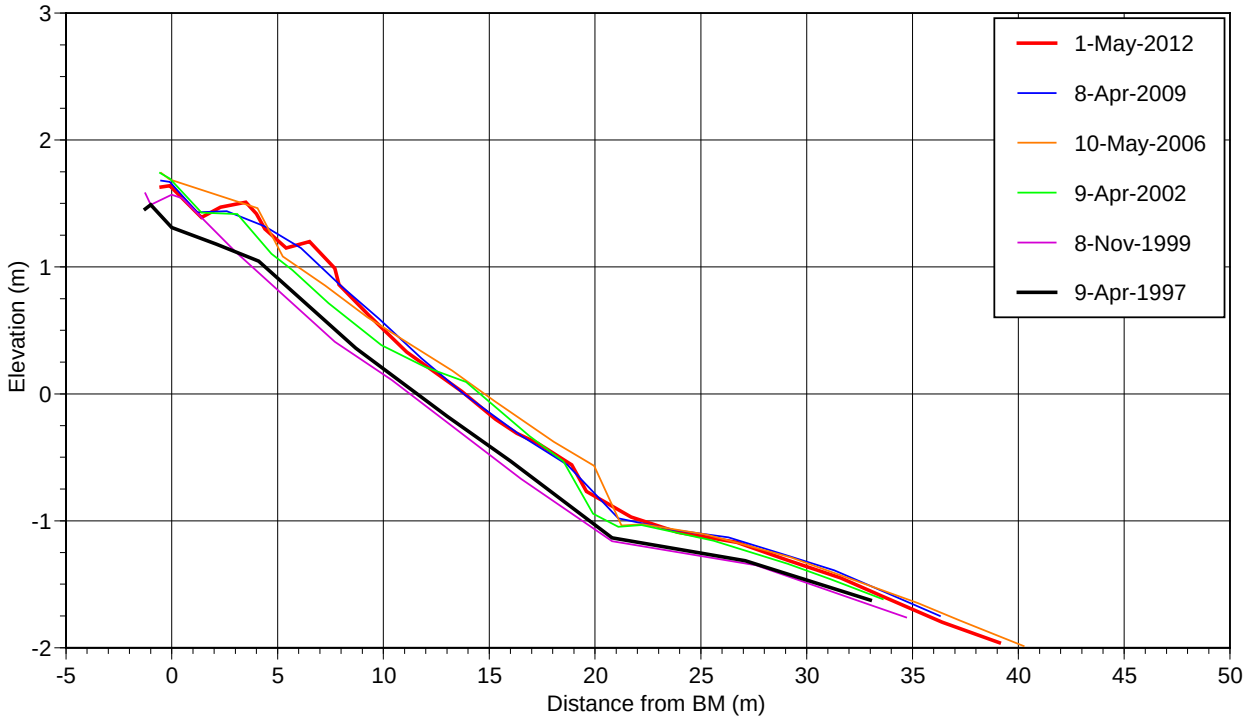
Profile 13 – Slip Beach

Slip Beach demonstrated considerable variability between 1995 and April 1998 when it reached its lowest level. Up until the end of 2000, there was variability but in the context of accretion. Between 2000 and 2006 there was less variability, but with continued accretion. Since 2006 the beach has been relatively stable from year to year, but with very significant seasonality, with accretion over the summer, and sediment loss over the winter (with occasional years when seasonality is less evident). Overall, however, the beach is in a considerably accreted state compared to the 1997.

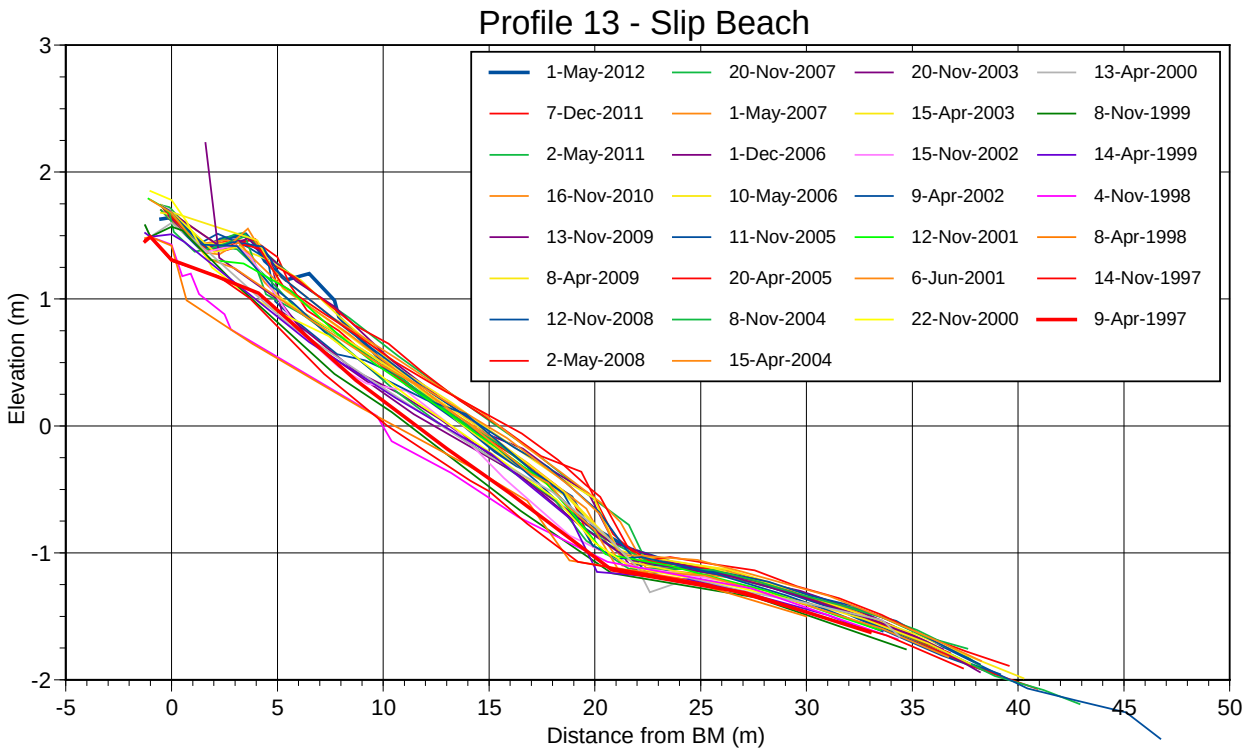
The photographs indicate that the dominant sediment type is sand with some small cobbles and pebbles.

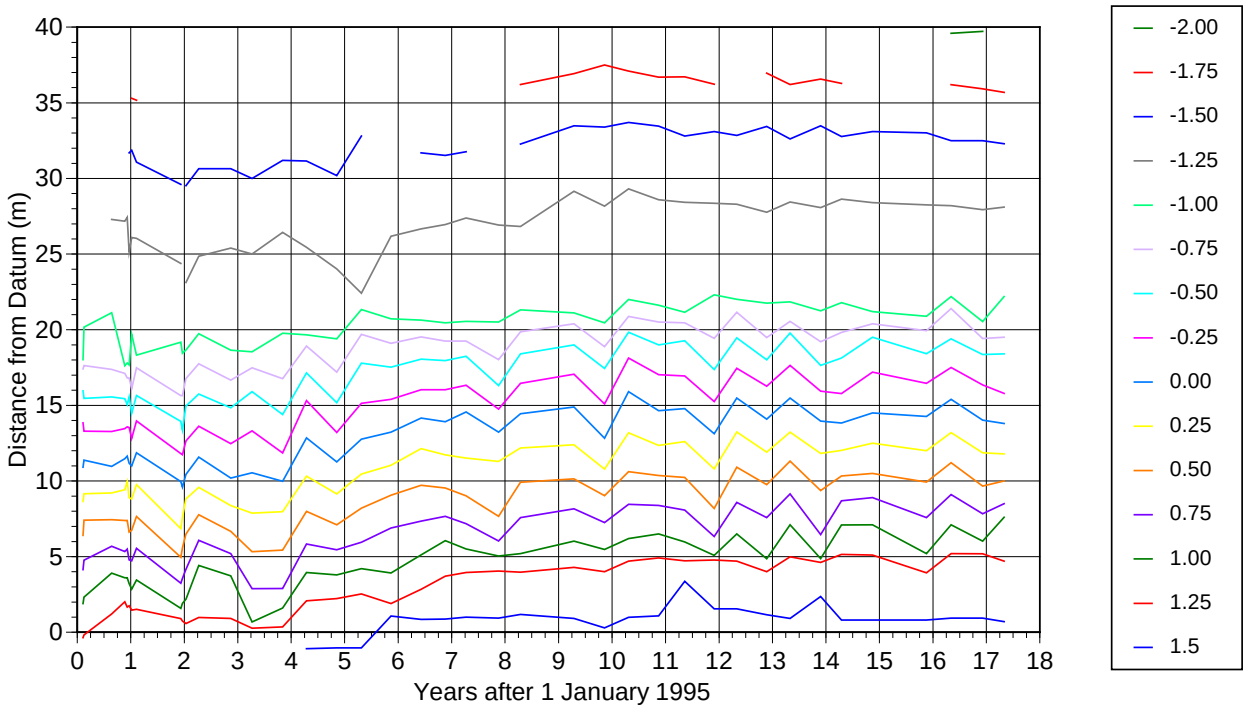
Although no obvious relationships between ferry operations and beach change were able to be determined, it is apparent that the considerable variability in the profile ceased about the same time as fast ferry operations ceased. Slip beach has a long fetch into Queen Charlotte Sound to the north, and natural waves may be substantial. However, wave measurements at this site have indicated substantial wake events that continue for unusually long periods of time.

Because of its unusual exposure, extreme seasonality, unusual wakes and, for the area, fine sediments, this location continues to be of particular interest, although apart from seasonality there is no obvious explanation for the changes observed.

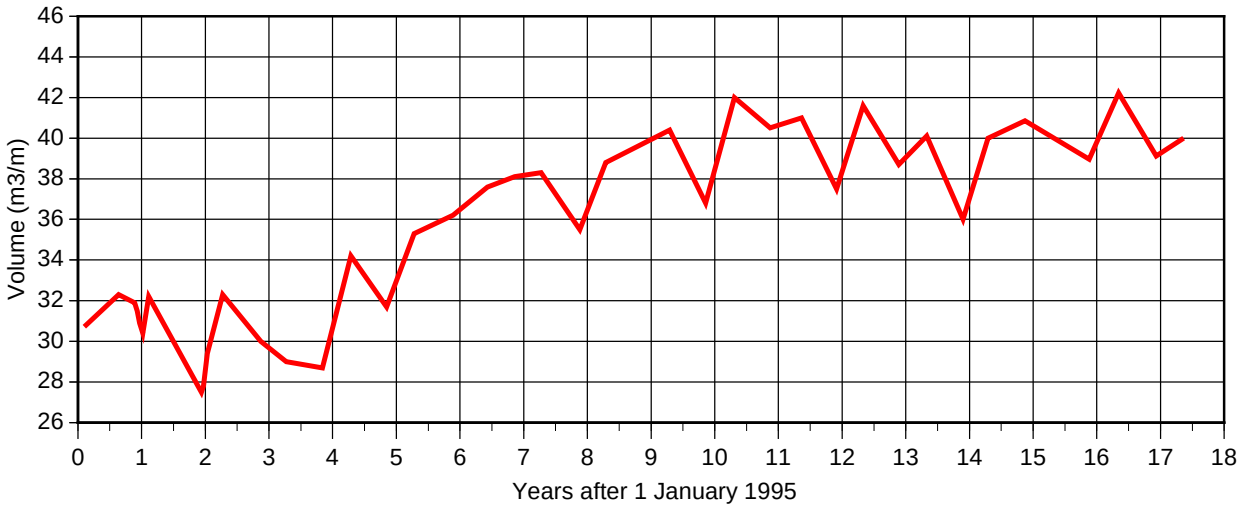


Profile 13: Slip Beach





Profile 13: Slip Beach



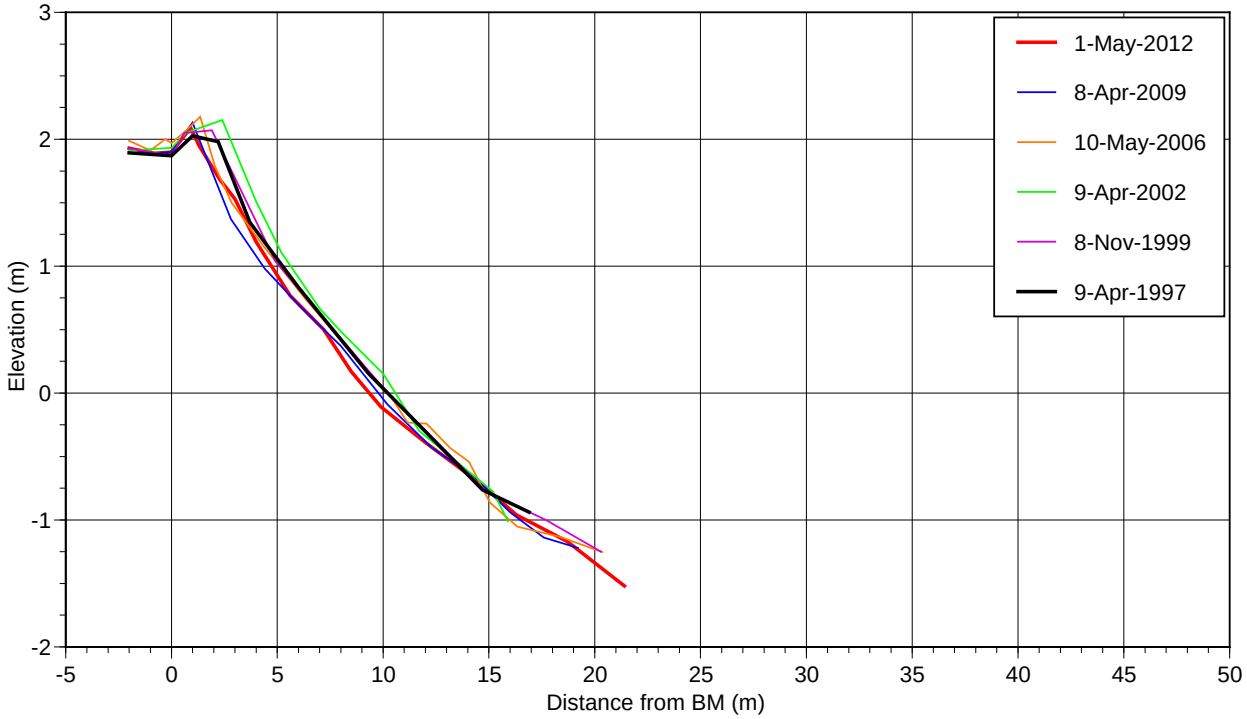
Date	Years after 1/1/95	Volume (m^3/m)
17-Feb-95	0.13	30.8
22-Aug-95	0.64	32.3
21-Nov-95	0.89	31.9
7-Dec-95	0.93	31.5
20-Dec-95	0.97	30.9
7-Jan-96	1.02	30.4
9-Feb-96	1.11	32.2
9-Dec-96	1.94	27.5
19-Dec-96	1.97	27.8
13-Jan-97	2.03	29.4
9-Apr-97	2.27	32.3
14-Nov-97	2.87	30.0
8-Apr-98	3.27	29.0
4-Nov-98	3.84	28.7
14-Apr-99	4.29	34.2
8-Nov-99	4.85	31.7
13-Apr-00	5.28	35.3
22-Nov-00	5.89	36.2
6-Jun-01	6.43	37.6
12-Nov-01	6.86	38.1
9-Apr-02	7.27	38.3
15-Nov-02	7.88	35.5
15-Apr-03	8.29	38.8
20-Nov-03	8.89	No data
15-Apr-04	9.29	40.4
8-Nov-04	9.86	36.8
20-Apr-05	10.31	42.0
11-Nov-05	10.87	40.5
10-May-06	11.36	41.0
01-Dec-06	11.91	37.5
01-May-07	12.33	41.6
20-Nov-07	12.89	38.7
02-May-08	13.33	40.1
12-Nov-08	13.90	36.0
08-Apr-09	14.29	40.0
13-Nov-09	14.87	40.9
16-Nov-10	15.88	39.0
02-May-11	16.34	42.2
07-Dec-11	16.93	39.1
01-May-12	17.33	39.9

Profile 13: Slip Beach

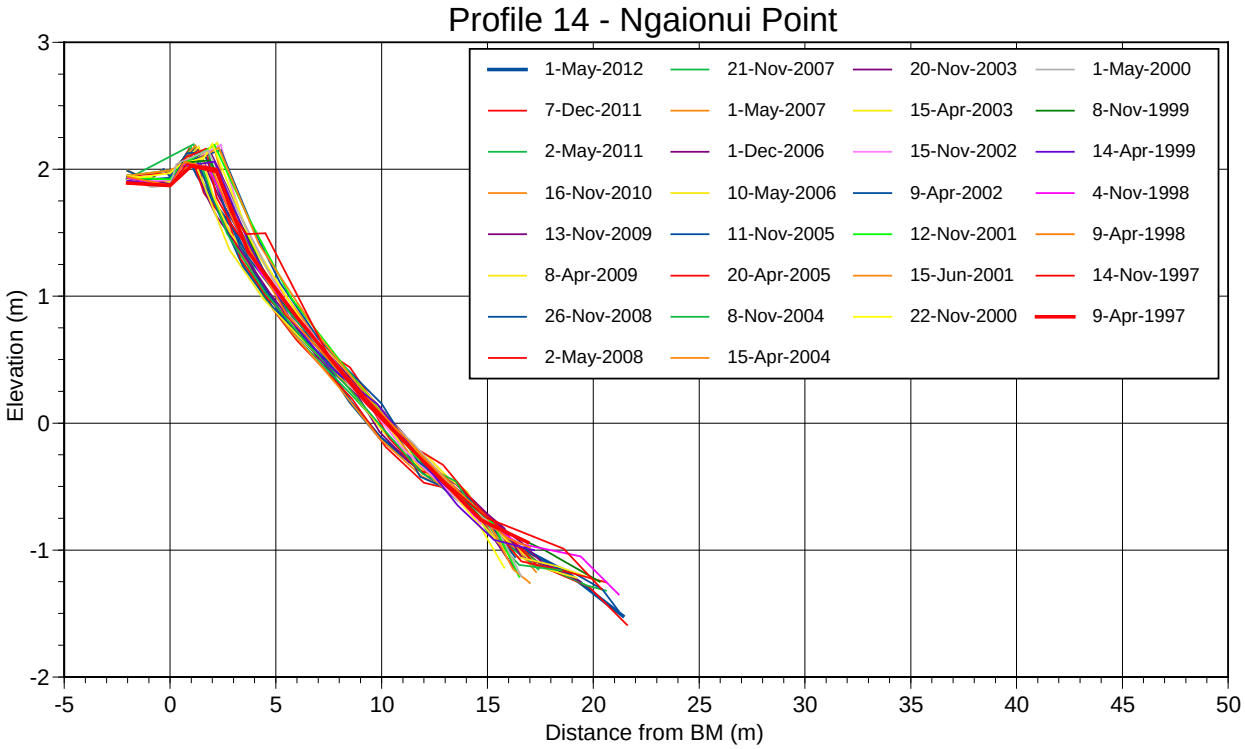
Profile 14 – Ngaionui Point

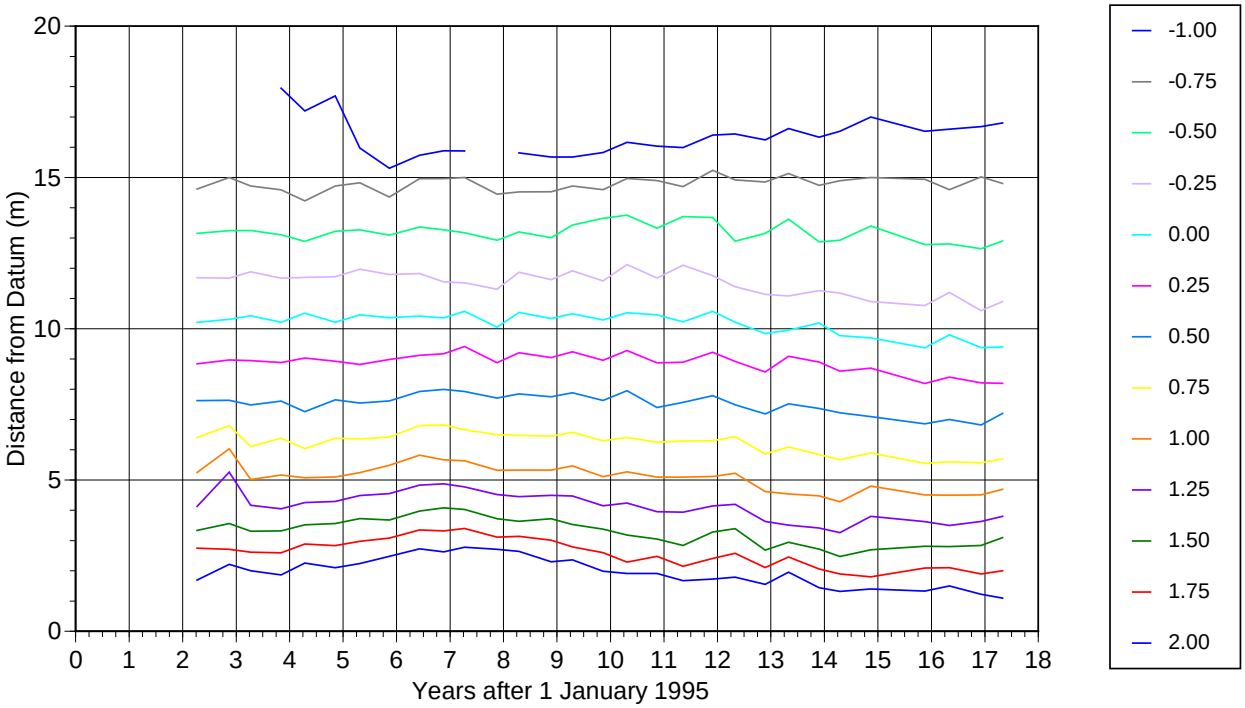
Given its proximity to the sailing line of vessels in Tory Channel, the beach at Ngaionui Point probably changed significantly when the fast ferry first started operation, and that the beach form has generally held since that time. There was a slow trend towards accretion up until about April 2002, and a trend of erosion since that time (although this has slowed in the last 3 years), reflecting the return to pre-fast ferry conditions. The beach is now lower than at the start of surveys. However, it is unknown what its status is compared to the situation prior to fast ferry operation.

Apparent changes at the very lower beach are probably the result of different survey placement. There have been no significant changes in sediments.

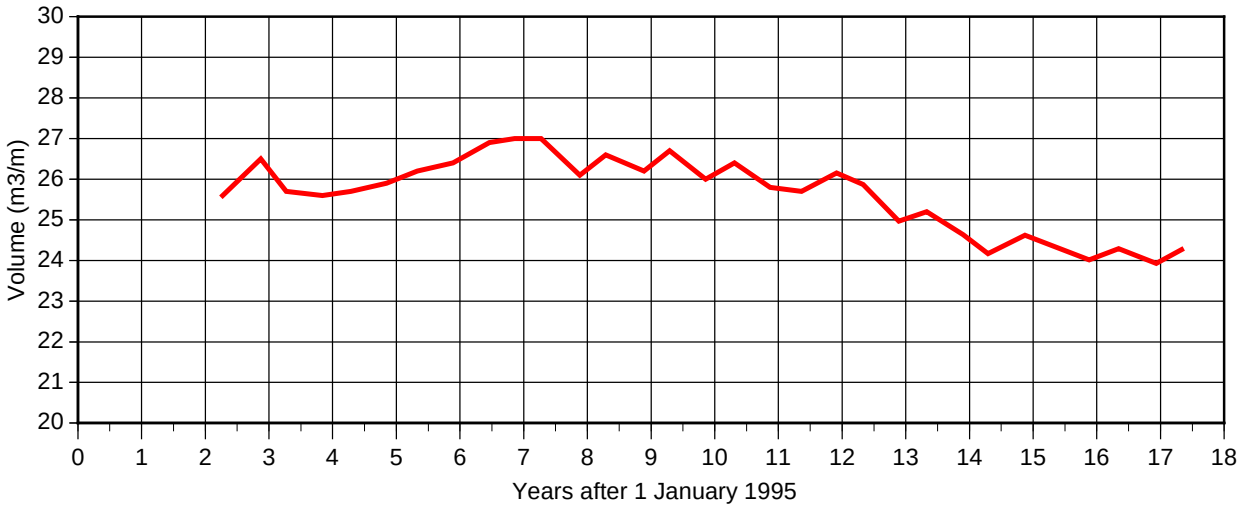


Profile 14: Ngaionui Point





Profile 14: Ngaionui Point



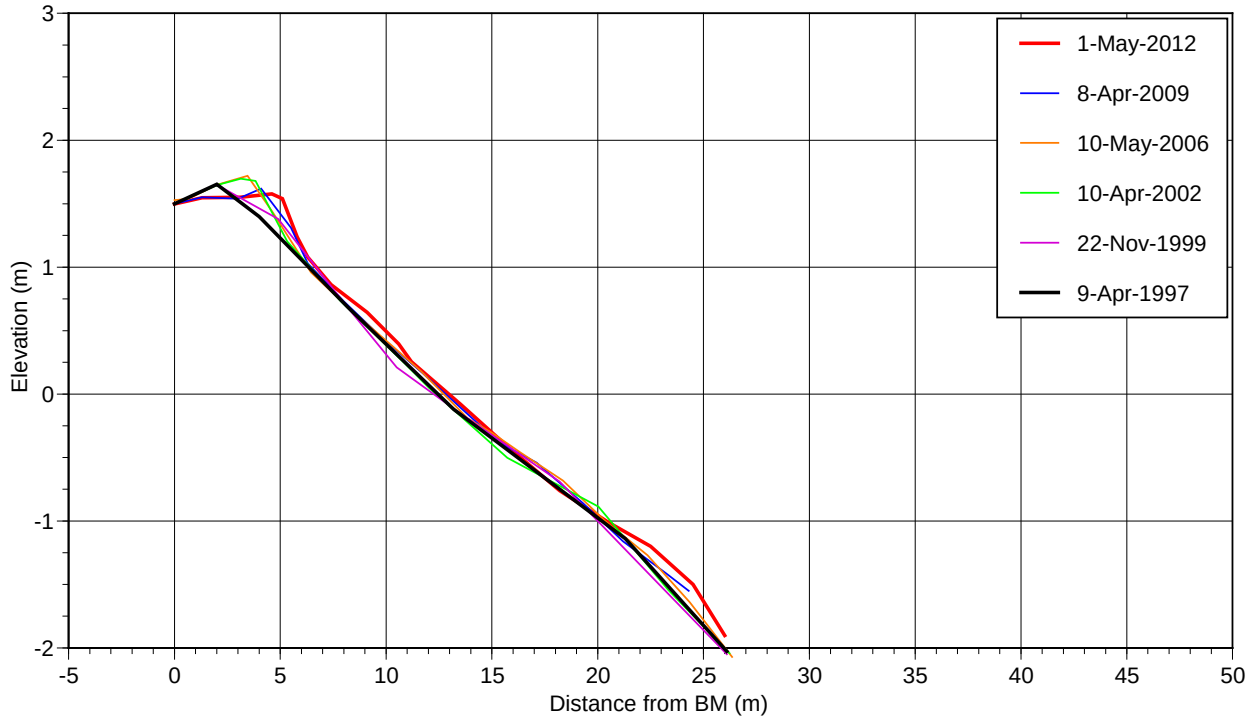
Date	Years after 1/1/95	Volume (m^3/m)
9-Apr-97	2.27	25.6
14-Nov-97	2.87	26.5
9-Apr-98	3.27	25.7
4-Nov-98	3.84	25.6
14-Apr-99	4.29	25.7
8-Nov-99	4.85	25.9
1-May-00	5.33	26.2
22-Nov-00	5.89	26.4
15-Jun-01	6.46	26.9
12-Nov-01	6.86	27.0
9-Apr-02	7.27	27.0
15-Nov-02	7.88	26.1
15-Apr-03	8.29	26.6
20-Nov-03	8.89	26.2
15-Apr-04	9.29	26.7
8-Nov-04	9.86	26.0
20-Apr-05	10.31	26.4
11-Nov-05	10.87	25.8
10-May-06	11.36	25.7
01-Dec-06	11.91	26.1
01-May-07	12.33	25.8
21-Nov-07	12.89	24.9
02-May-08	13.33	25.2
26-Nov-08	13.90	24.6
08-Apr-09	14.29	24.1
13-Nov-09	14.87	24.6
16-Nov-10	15.88	24.0
02-May-11	16.34	24.3
07-Dec-11	16.93	23.9
01-May-12	17.33	24.3

Profile 14: Ngaionui Point

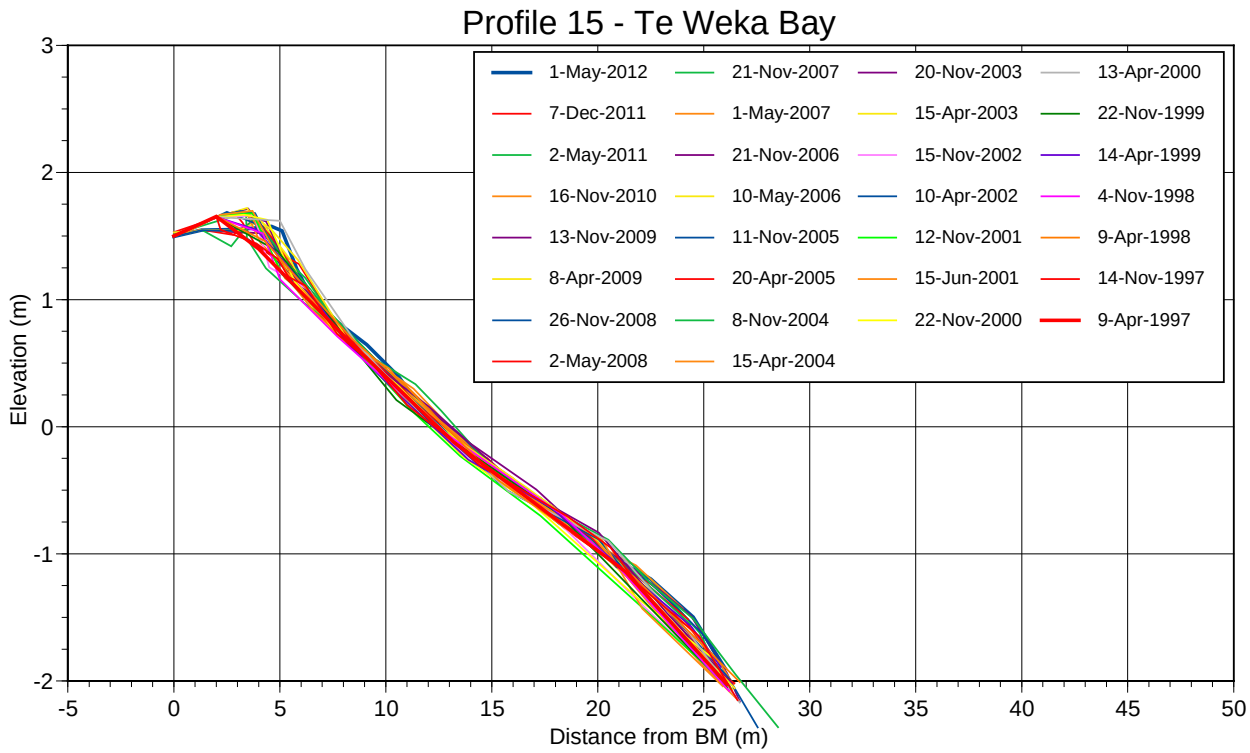
Profile 15 – Te Weka Bay

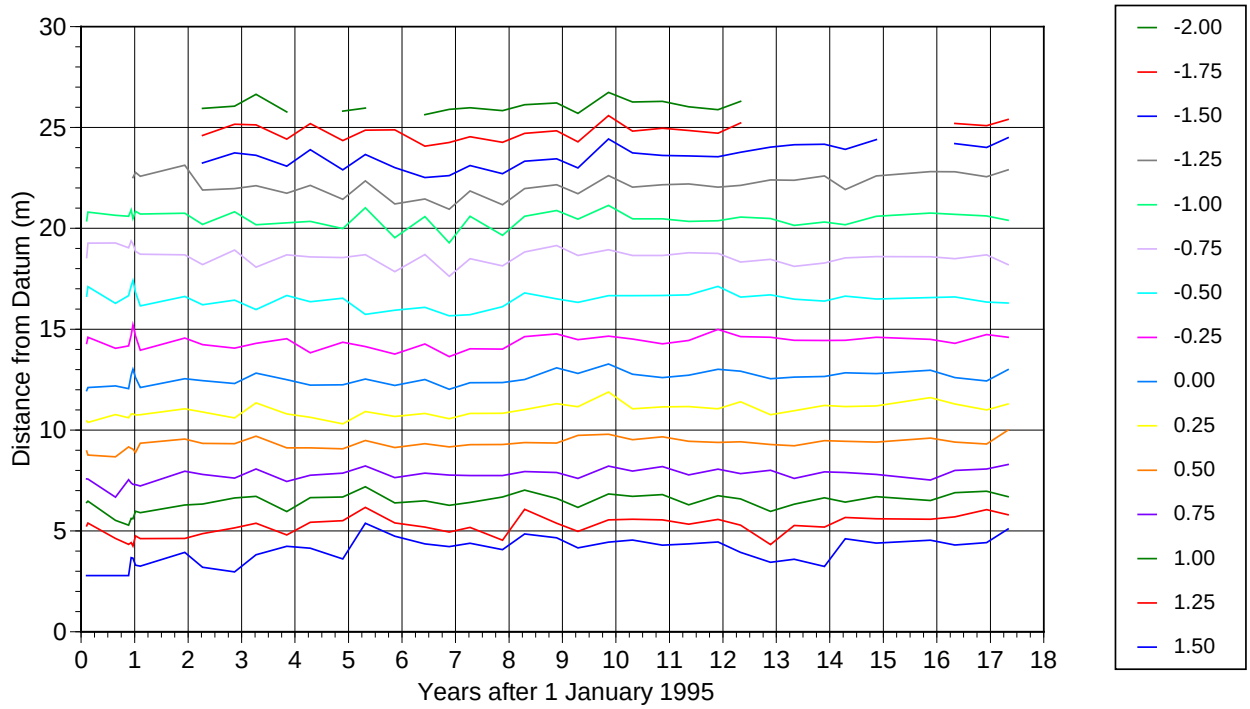
The Te Weka Bay profile has changed little since surveys began in 1995. The development of an upper beach berm and the reduction in level of the middle beach during the period of fast ferry operation is evident (reaching a peak in April 2000). The berm has remained generally intact, even building a little, since that time. Beach volumes now equal the 2000 peak.

There have been no significant changes in sediment characteristics.

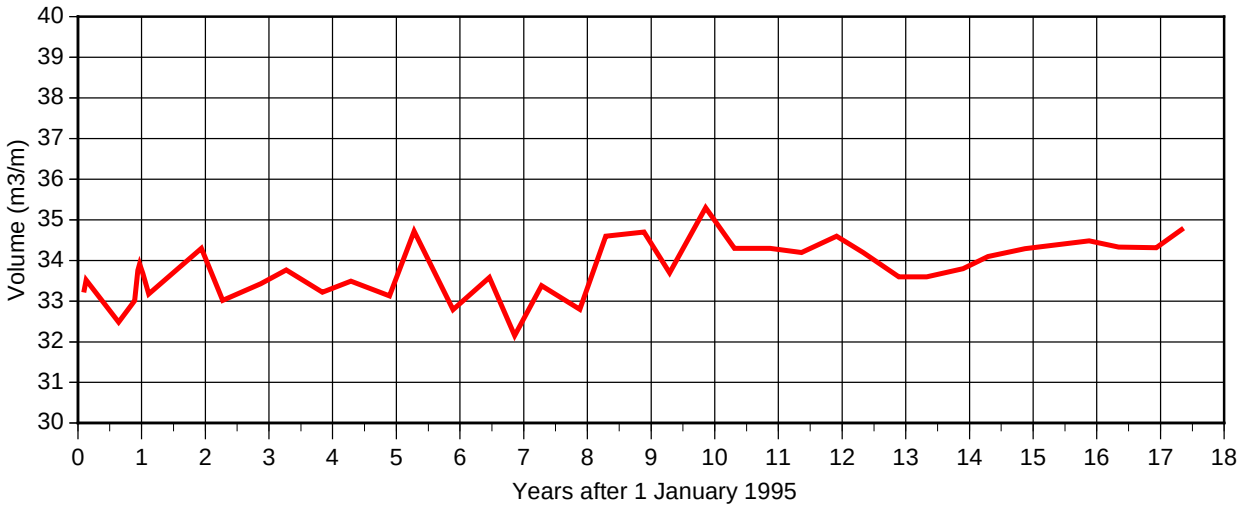


Profile 15: Te Weka Bay





Profile 15: Te Weka Bay



Date	Years after 1/1/95	Volume (m^3/m)
8-Feb-95	0.10	33.3
17-Feb-95	0.13	33.5
22-Aug-95	0.64	32.5
21-Nov-95	0.89	33.0
8-Dec-95	0.94	33.8
20-Dec-95	0.97	33.9
7-Jan-96	1.02	33.7
9-Feb-96	1.11	33.2
9-Dec-96	1.94	34.3
9-Apr-97	2.27	33.0
14-Nov-97	2.87	33.4
9-Apr-98	3.27	33.8
4-Nov-98	3.84	33.2
14-Apr-99	4.29	33.5
22-Nov-99	4.89	33.1
13-Apr-00	5.28	34.7
22-Nov-00	5.89	32.8
15-Jun-01	6.46	33.6
12-Nov-01	6.86	32.2
10-Apr-02	7.28	33.4
15-Nov-02	7.88	32.8
15-Apr-03	8.29	34.6
20-Nov-03	8.89	34.7
15-Apr-04	9.29	33.7
8-Nov-04	9.86	35.3
20-Apr-05	10.31	34.3
11-Nov-05	10.87	34.3
10-May-06	11.36	34.2
21-Nov-06	11.91	34.6
01-May-07	12.33	34.2
21-Nov-07	12.89	33.6
02-May-08	13.33	33.6
26-Nov-08	13.90	33.8
08-Apr-09	14.29	34.1
13-Nov-09	14.87	34.3
16-Nov-10	15.88	34.5
02-May-11	16.34	34.3
07-Dec-11	16.93	34.3
01-May-12	17.33	34.8

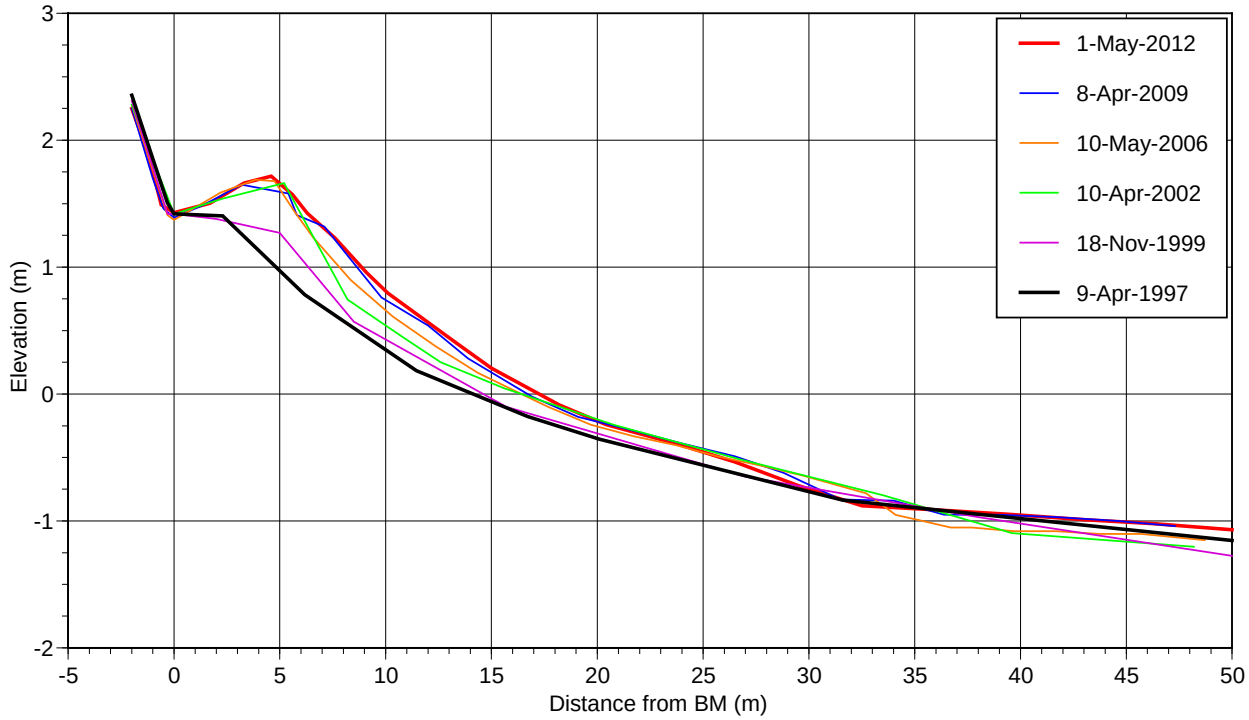
Profile 15: Te Weka Bay

Profile 16 – McMillan's Bay

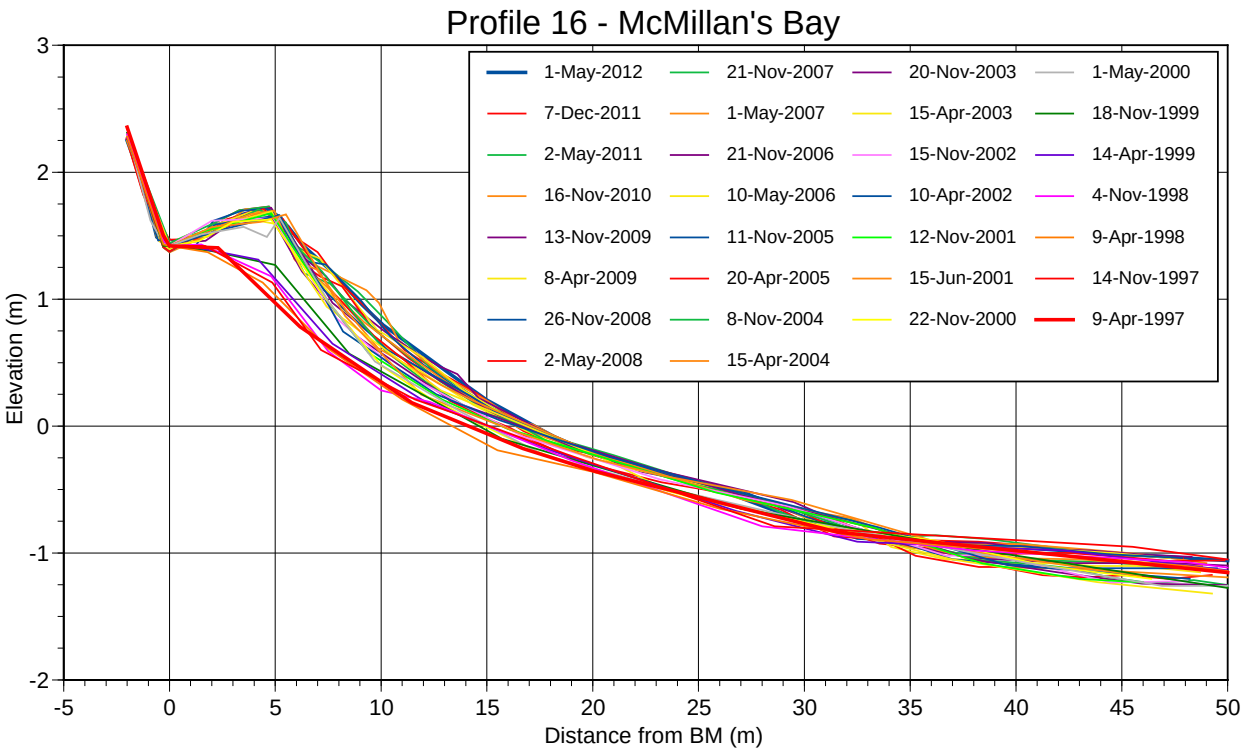
Up until November 1999 there had been a gradual accretion of the upper McMillan's Bay profile. The accretion was mainly comprised of gravels that were moving along the beach from the direction of Arrowsmith Point, although there had been some rise in the middle beach level, due to deposition of sand. Between November 1999 and May 2000 a major increase in the height of the upper beach berm occurred, with a very large deposit of gravel, again coming from the direction of Arrowsmith Point. This deposit has remained almost unchanged since that time. The upper to middle beach has continued to build with the deposition of sand. The lower beach has been relatively stable, apparent changes probably being the result of minor differences in survey line. The volume has been stable at the survey maximum over the period 2010-2012.

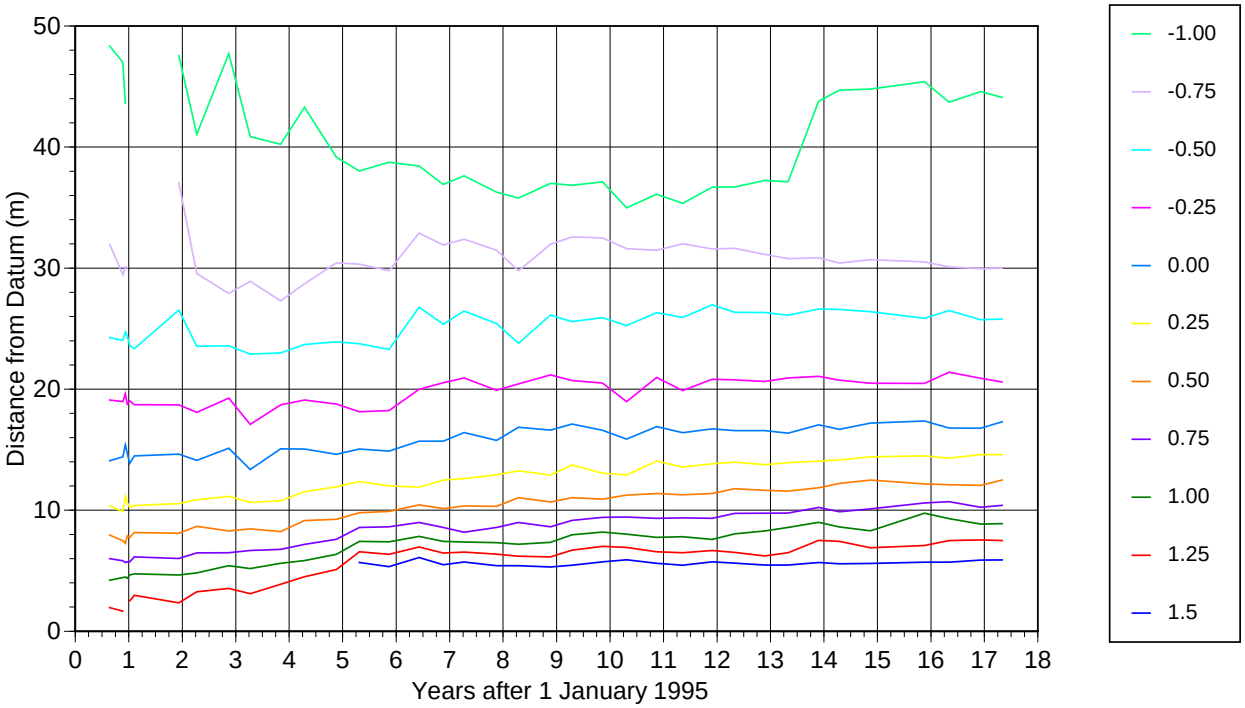
This profile line is clearly being influenced by longshore transport of gravels from west to east. It may also be that there is transport of sand either onshore or alongshore. It is most likely that the mechanism of accretion is the result of ferry generated wake waves. The rate of accretion dropped markedly about the time the fast ferry operation ceased, probably the result of a reduced ability of the waves to transport sediment.

McMillan's Bay is quite unusual in the context of the Tory Channel, being wide and with a relatively small slope. It has a wide 'surf' zone, unlike almost all other shorelines in the area.

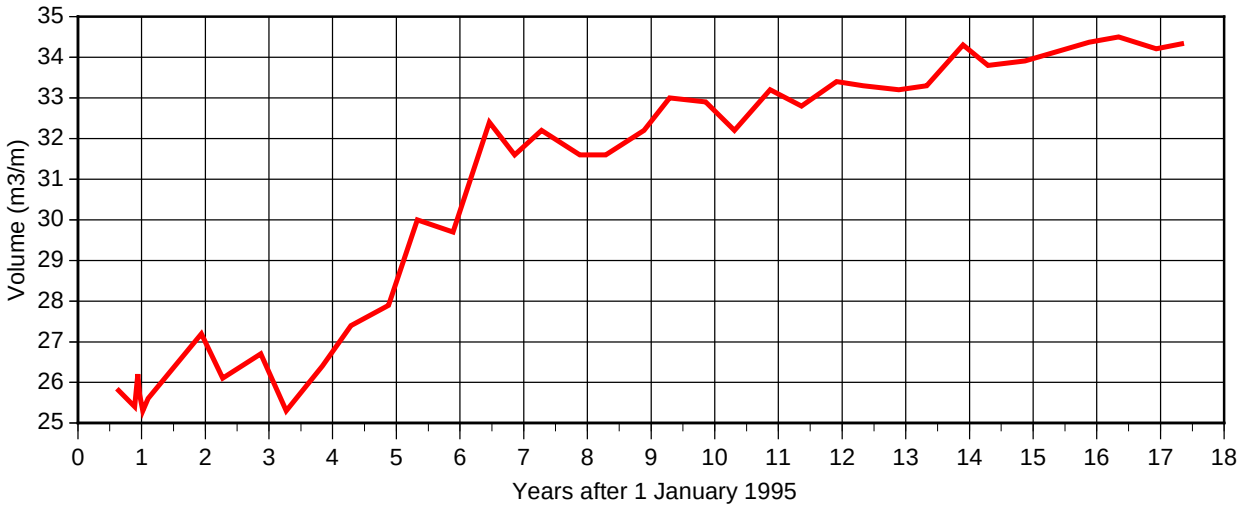


Profile 16: McMillan's Bay





Profile 16: McMillan's Bay



Date	Years after 1/1/95	Volume (m^3/m)
22-Aug-95	0.64	25.8
21-Nov-95	0.89	25.4
8-Dec-95	0.94	26.2
21-Dec-95	0.97	25.7
7-Jan-96	1.02	25.3
8-Feb-96	1.10	25.6
9-Dec-96	1.94	27.2
9-Apr-97	2.27	26.1
14-Nov-97	2.87	26.7
9-Apr-98	3.27	25.3
4-Nov-98	3.84	26.4
14-Apr-99	4.29	27.4
18-Nov-99	4.88	27.9
1-May-00	5.33	30.0
22-Nov-00	5.89	29.7
15-Jun-01	6.46	32.4
12-Nov-01	6.86	31.6
10-Apr-02	7.28	32.2
15-Nov-02	7.88	31.6
15-Apr-03	8.29	31.6
20-Nov-03	8.89	32.2
15-Apr-04	9.29	33.0
8-Nov-04	9.86	32.9
20-Apr-05	10.31	32.2
11-Nov-05	10.87	33.2
10-May-06	11.36	32.8
21-Nov-06	11.91	33.4
01-May-07	12.33	33.3
21-Nov-07	12.89	33.2
02-May-08	13.33	33.3
26-Nov-08	13.90	34.3
08-Apr-09	14.29	33.8
13-Nov-09	14.87	33.9
16-Nov-10	15.88	34.4
02-May-11	16.34	34.5
07-Dec-11	16.93	34.2
01-May-12	17.33	34.3

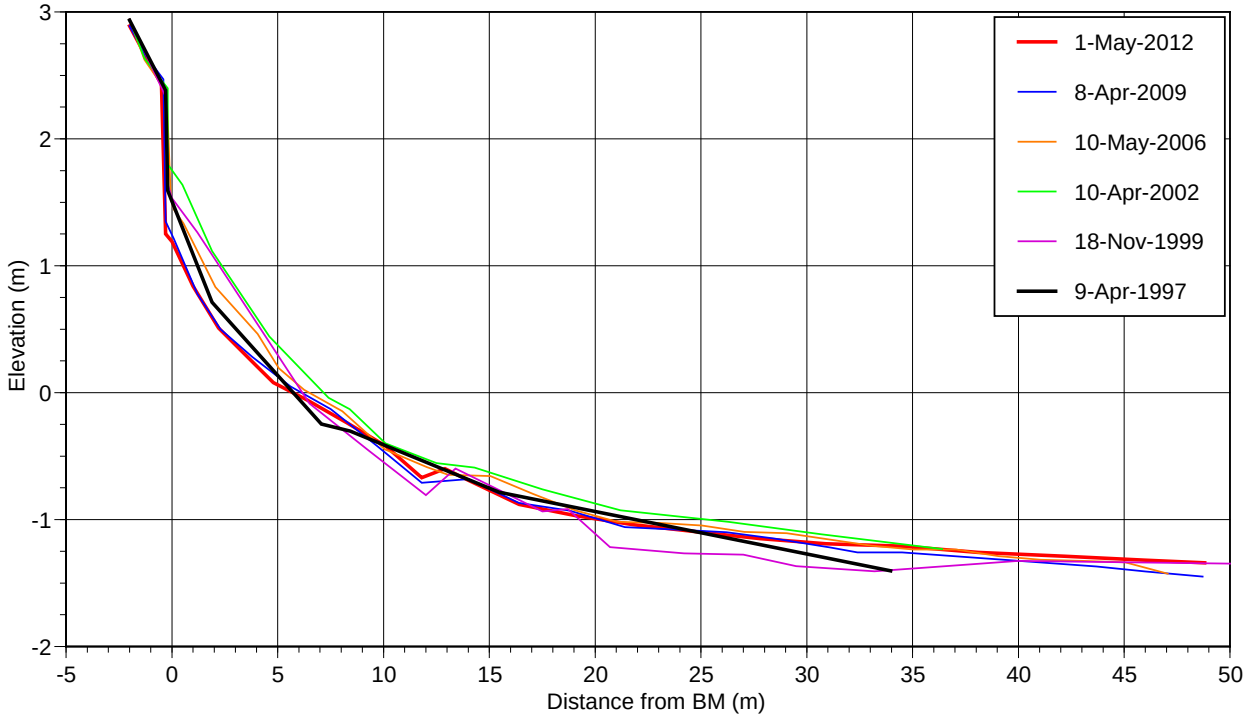
Profile 16: McMillan's Bay

Profile 17 – McMillan's Side

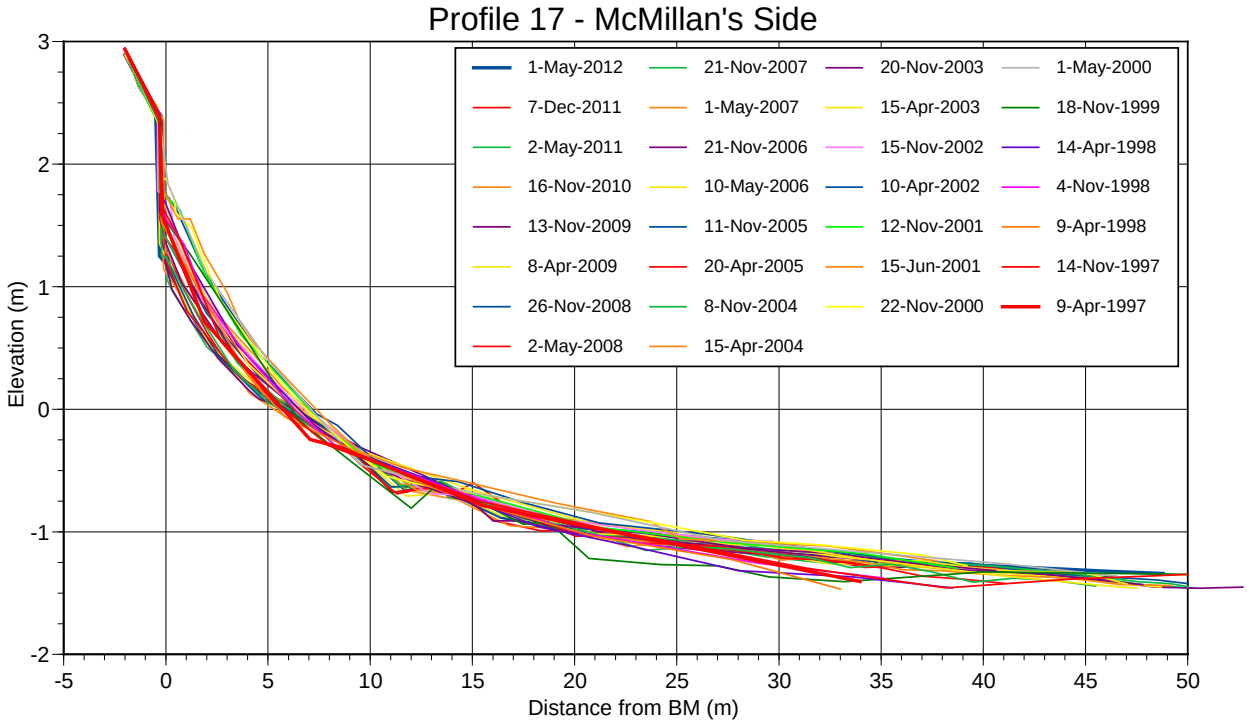
Between November 1999 and May 2000, at the same time as there was a major increase in the volume of the berm on Profile 16, there was a very significant deposition of sediment on the lower profile on Profile 17. Up until this time, the profile had been generally stable, with some accumulation on the upper beach, and perhaps some minor adjustments elsewhere on the profile line.

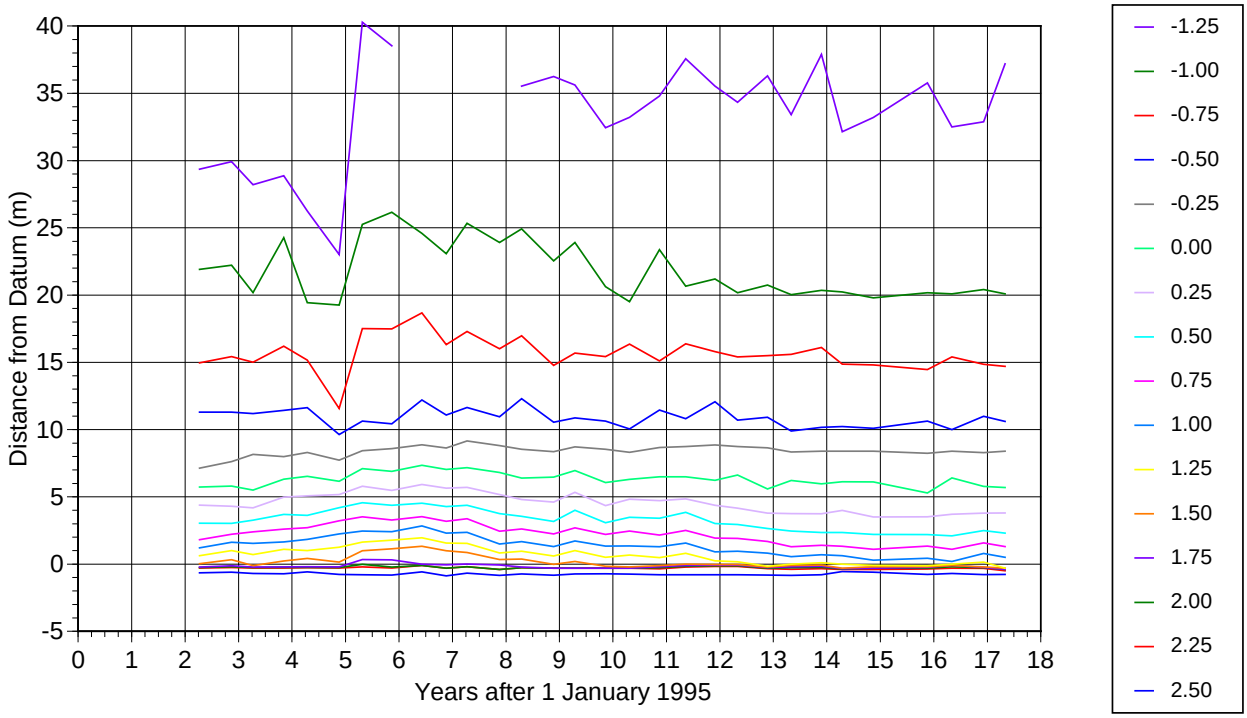
Beach volumes increased until 2001, with most of the accumulation on the lower profile. Since that time volumes have decreased, with most loss coming from the mid to upper beach. There is no indication of erosion at the upper beach scarp.

The reason for the major deposition between November 1999 and May 2000, reflected also on Profile 16, is unknown. However, there must have been a significant increase in sediment supply, perhaps a slip in the vicinity of Arrowsmith Point. After fast ferry operation ceased in 2000, there was a change from sediment accumulation to sediment loss, which continued through to 2009. This occurred at the same time as a change from sediment accumulation to stability on Profile 16. Since 2009 the profile and sediment volumes have changed little. Changes in this profile reflect changes in vessel operations, but there also appears to be a sediment supply control.

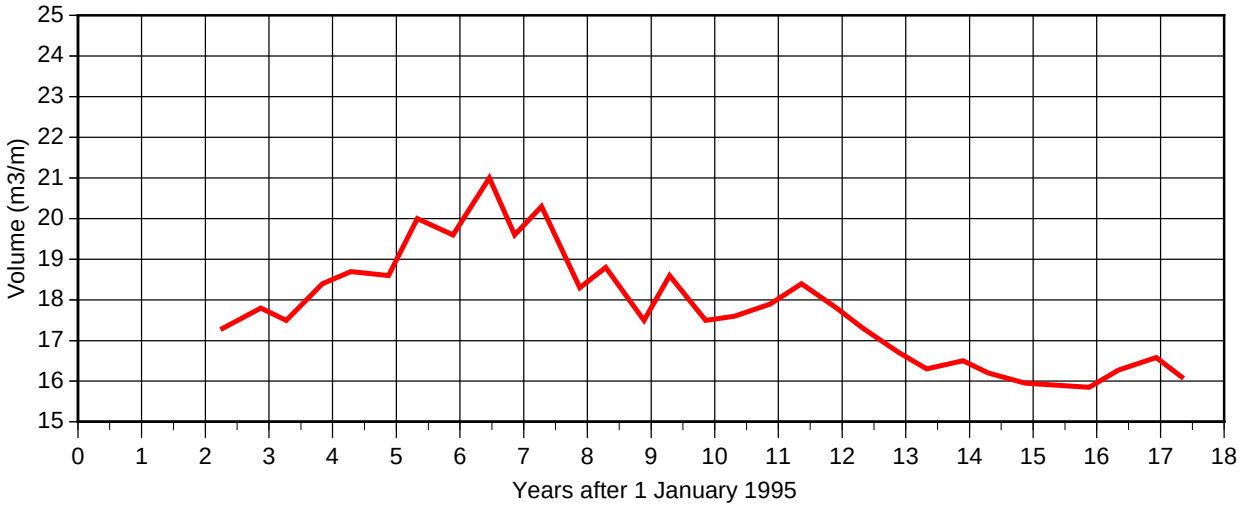


Profile 17: McMillan's Side





Profile 17: McMillan's Side



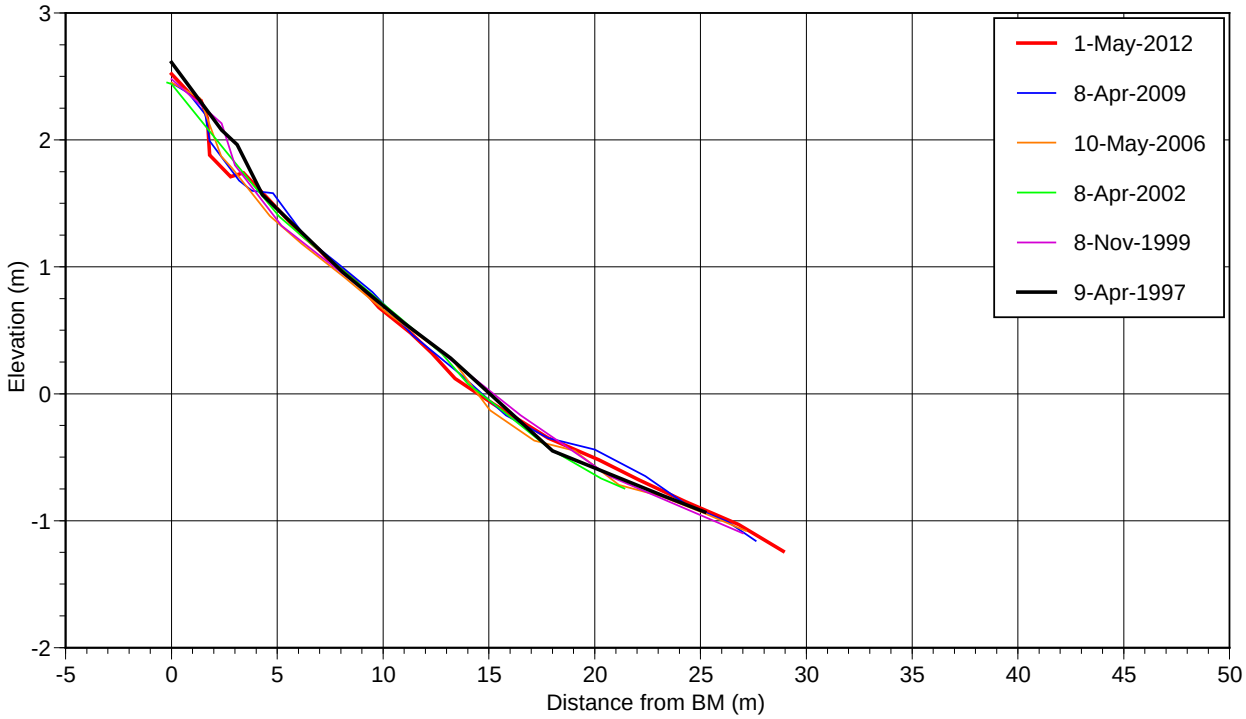
Date	Years after 1/1/95	Volume (m^3/m)
9-Apr-97	2.27	17.3
14-Nov-97	2.87	17.8
9-Apr-98	3.27	17.5
4-Nov-98	3.84	18.4
14-Apr-99	4.29	18.7
18-Nov-99	4.88	18.6
1-May-00	5.33	20.0
22-Nov-00	5.89	19.6
15-Jun-01	6.46	21.0
12-Nov-01	6.86	19.6
10-Apr-02	7.28	20.3
15-Nov-02	7.88	18.3
15-Apr-03	8.29	18.8
20-Nov-03	8.89	17.5
15-Apr-04	9.29	18.6
8-Nov-04	9.86	17.5
20-Apr-05	10.31	17.6
11-Nov-05	10.87	17.9
10-May-06	11.36	18.4
21-Nov-06	11.91	17.8
01-May-07	12.33	17.3
21-Nov-07	12.89	16.7
02-May-08	13.33	16.3
26-Nov-08	13.90	16.5
08-Apr-09	14.29	16.2
13-Nov-09	14.87	15.9
16-Nov-10	15.88	15.9
02-May-11	16.34	16.3
07-Dec-11	16.93	16.6
01-May-12	17.33	16.1

Profile 17: McMillan's Side

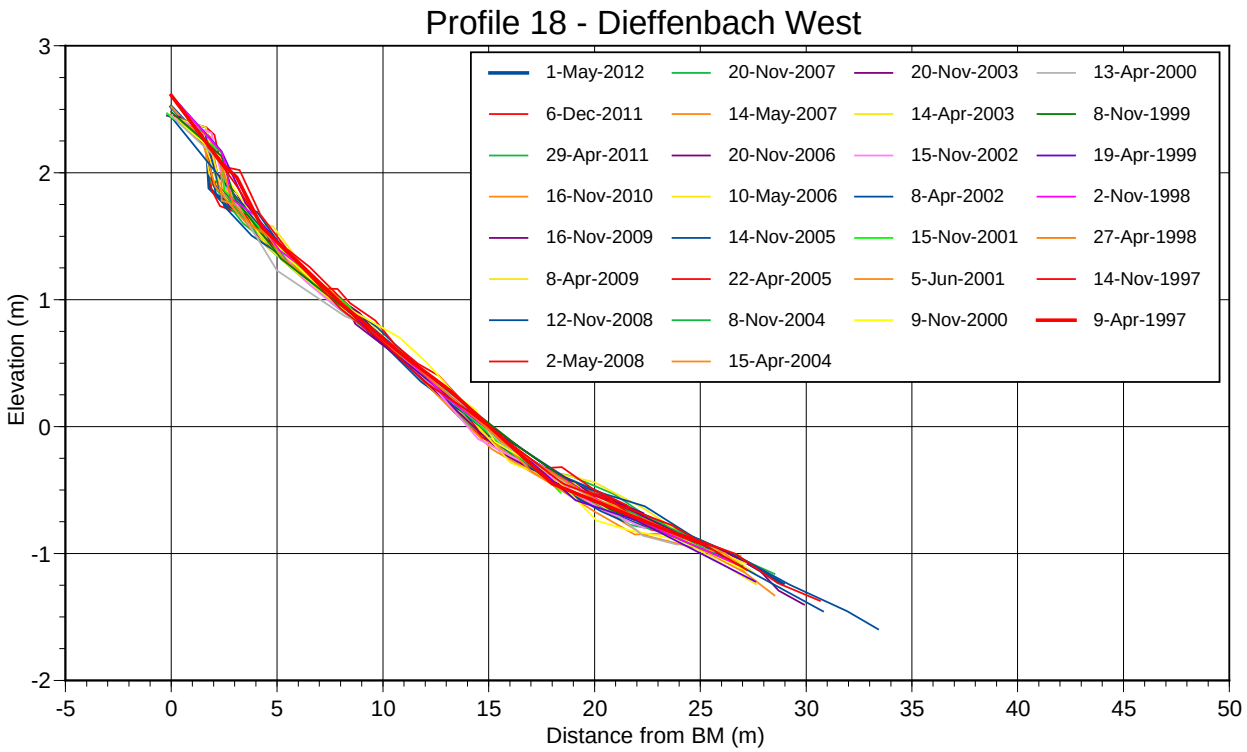
Profile 18 – Dieffenbach West

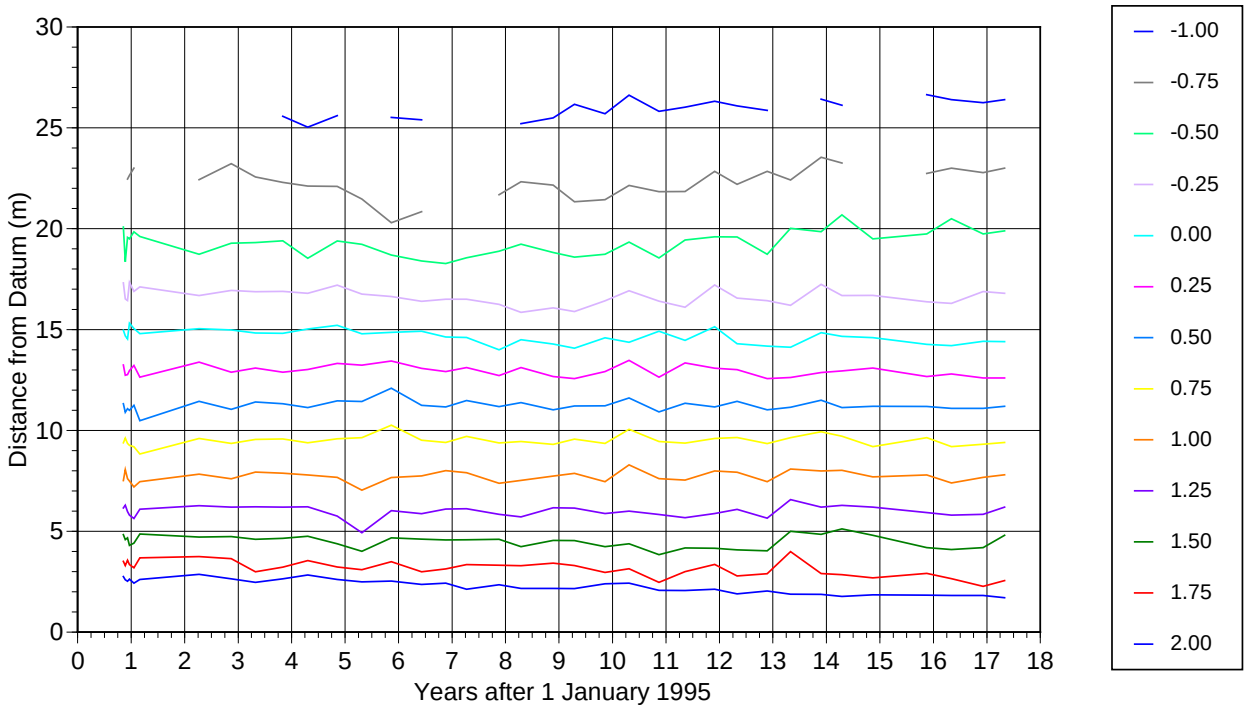
There has been no significant change in the profile shape or in sediment volume since 1997. The upper beach scarp has retreated by about 50cm. Levels on the lower beach have increased a little. A thin covering of sand is sometimes present over the coarser beach sediment.

During 2000 a small cottage was built at the northern end of this beach, and in 2003 a boatshed was built and a minimal wooden seawall constructed adjacent to the profile line. The seawall (which has slowly been destroyed) does not appear to be affecting beach processes, but it is also not providing any protection to the land. It has now virtually gone.

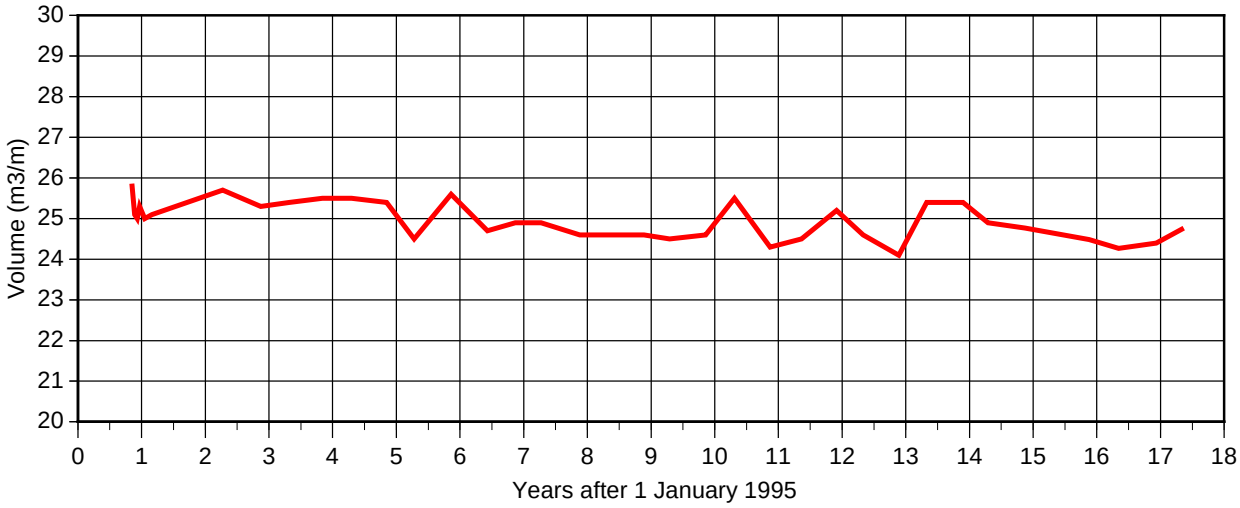


Profile 18: Dieffenbach West





Profile 18: Dieffenbach West



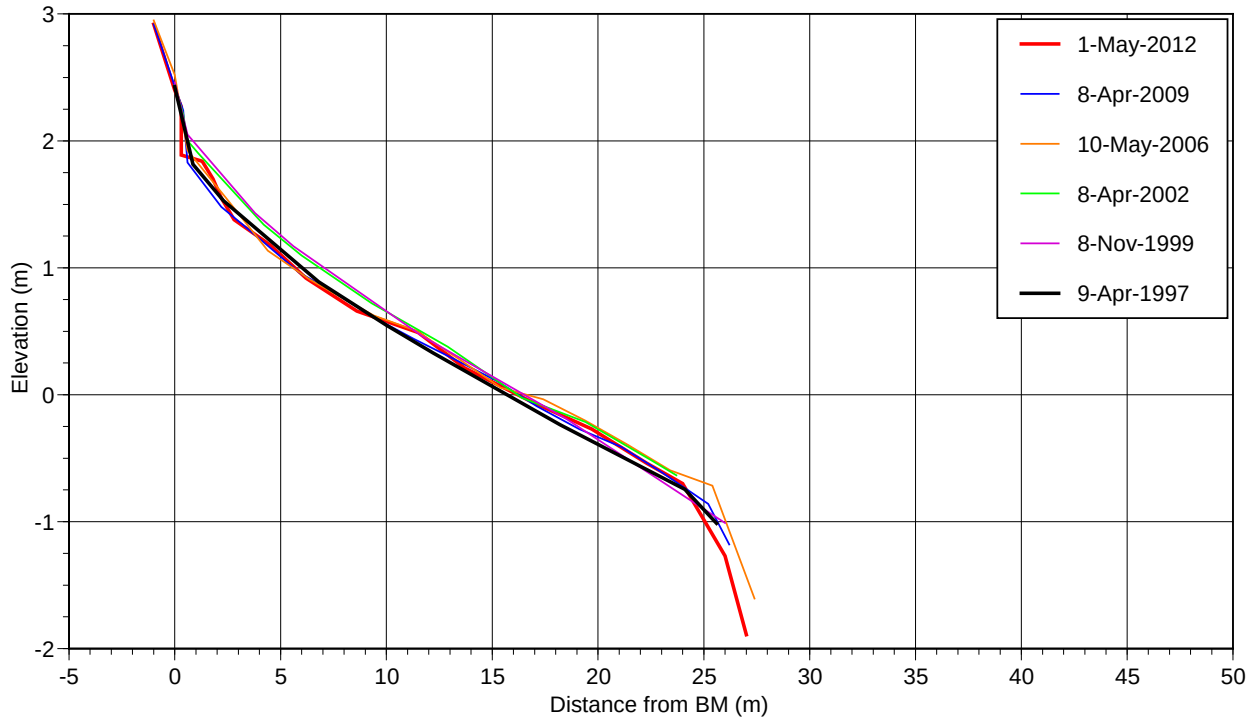
Date	Years after 1/1/95	Volume (m^3/m)
8-Nov-95	0.85	25.8
21-Nov-95	0.89	25.1
7-Dec-95	0.93	25.0
20-Dec-95	0.97	25.3
19-Jan-96	1.05	25.0
29-Feb-96	1.16	25.1
9-Apr-97	2.27	25.7
14-Nov-97	2.87	25.3
27-Apr-98	3.32	25.4
2-Nov-98	3.84	25.5
19-Apr-99	4.30	25.5
8-Nov-99	4.85	25.4
13-Apr-00	5.28	24.5
9-Nov-00	5.86	25.6
5-Jun-01	6.43	24.7
15-Nov-01	6.87	24.9
8-Apr-02	7.27	24.9
15-Nov-02	7.88	24.6
14-Apr-03	8.29	24.6
20-Nov-03	8.89	24.6
15-Apr-04	9.29	24.5
8-Nov-04	9.86	24.6
22-Apr-05	10.31	25.5
14-Nov-05	10.87	24.3
10-May-06	11.36	24.5
20-Nov-06	11.91	25.2
14-May-07	12.33	24.6
20-Nov-07	12.89	24.1
02-May-08	13.33	25.4
12-Nov-08	13.90	25.4
08-Apr-09	14.29	24.9
16-Nov-09	14.87	24.8
16-Nov-10	15.88	24.5
29-Apr-11	16.34	24.3
06-Dec-11	16.93	24.4
01-May-12	17.33	24.7

Profile 18: Dieffenbach West

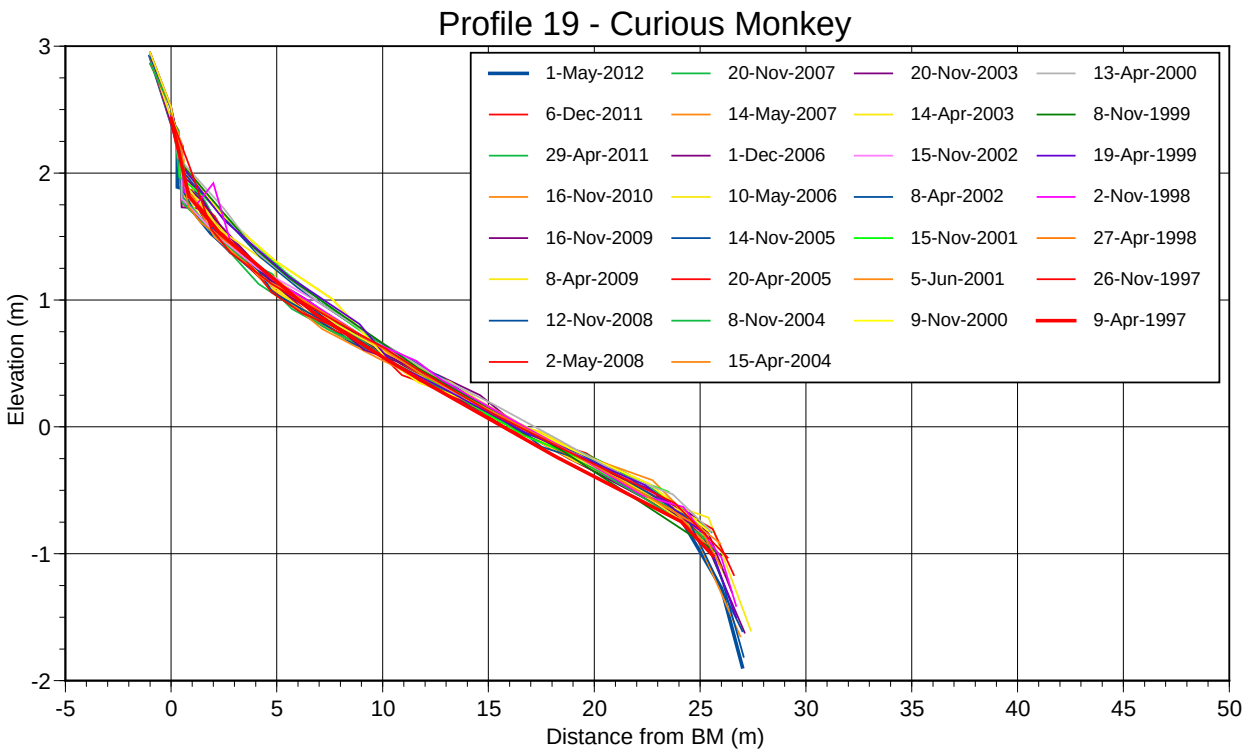
Profile 19 – Curious Monkey

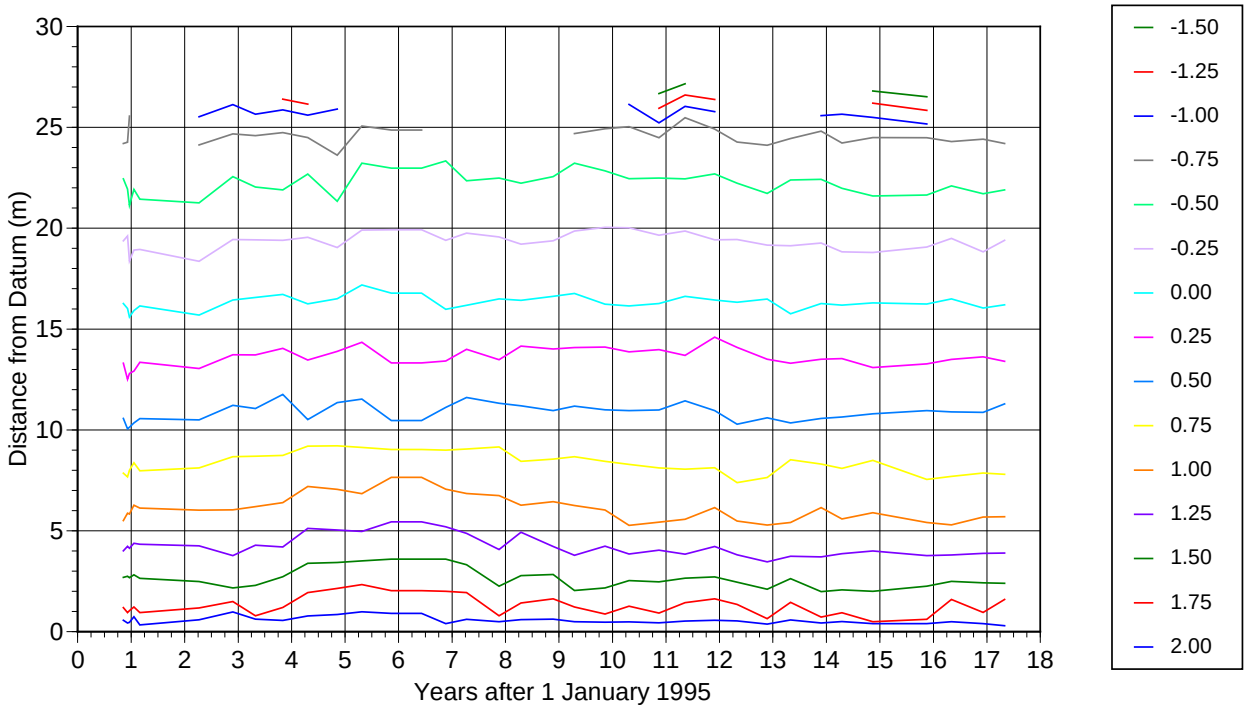
There was slow accretion over the period of fast ferry operation through to the end of 2000, and slow erosion following the end of fast-ferry operations through to 2007. Since 2007 the beach has been very stable. ,

There have been no notable changes in sediment characteristics.

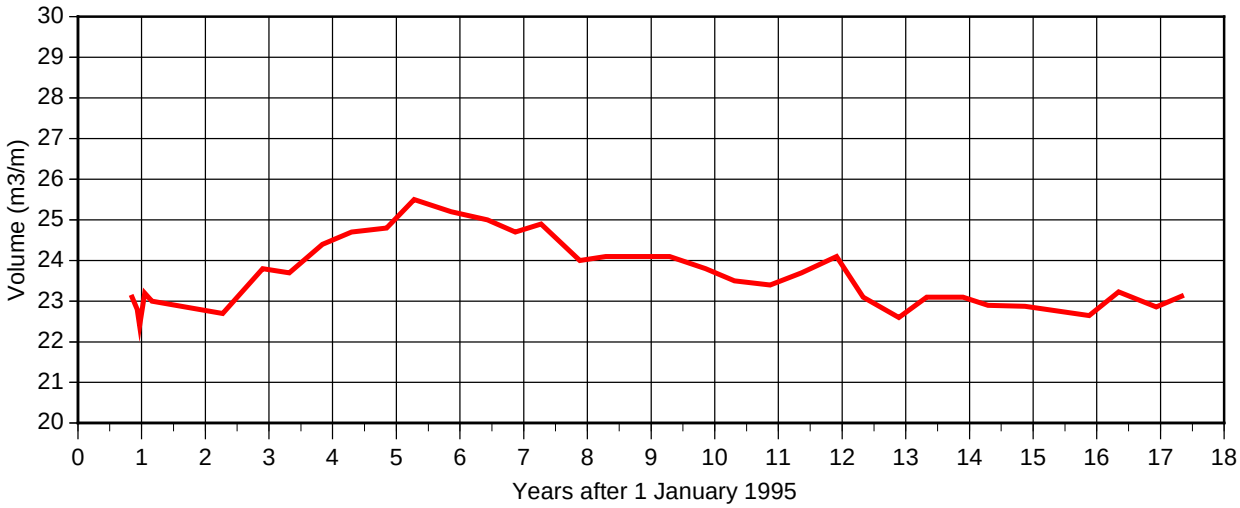


Profile 19: Curious Monkey





Profile 19: Curious Monkey

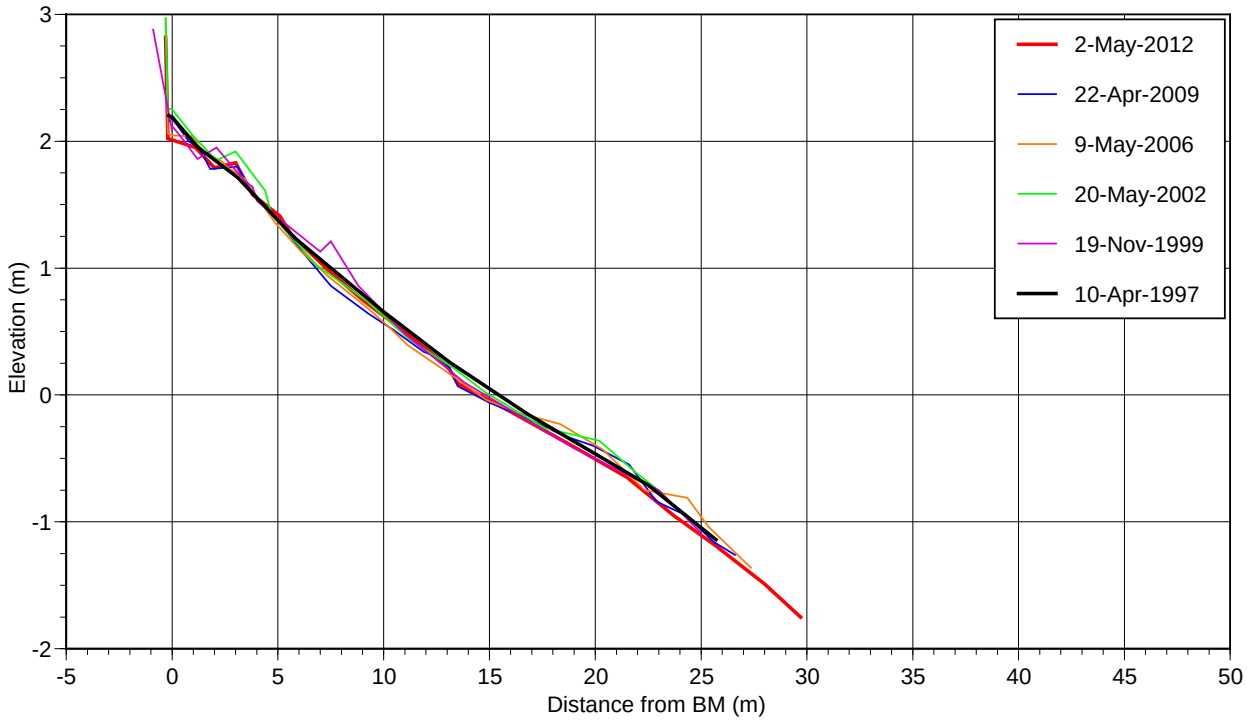


Date	Years after 1/1/95	Volume (m^3/m)
8-Nov-95	0.85	23.1
7-Dec-95	0.93	22.8
20-Dec-95	0.97	22.4
19-Jan-96	1.05	23.2
29-Feb-96	1.16	23.0
9-Apr-97	2.27	22.7
26-Nov-97	2.90	23.8
27-Apr-98	3.32	23.7
2-Nov-98	3.84	24.4
19-Apr-99	4.30	24.7
8-Nov-99	4.85	24.8
13-Apr-00	5.28	25.5
9-Nov-00	5.86	25.2
5-Jun-01	6.43	25.0
15-Nov-01	6.87	24.7
8-Apr-02	7.27	24.9
15-Nov-02	7.88	24.0
14-Apr-03	8.29	24.1
20-Nov-03	8.89	24.1
15-Apr-04	9.29	24.1
8-Nov-04	9.86	23.8
20-Apr-05	10.31	23.5
14-Nov-05	10.87	23.4
10-May-06	11.36	23.7
01-Dec-06	11.91	24.1
14-May-07	12.33	23.1
20-Nov-07	12.89	22.6
02-May-08	13.33	23.1
12-Nov-08	13.90	23.1
08-Apr-09	14.29	22.9
16-Nov-09	14.87	22.9
16-Nov-10	15.88	22.6
29-Apr-11	16.34	23.2
06-Dec-11	16.93	22.9
01-May-12	17.33	23.1

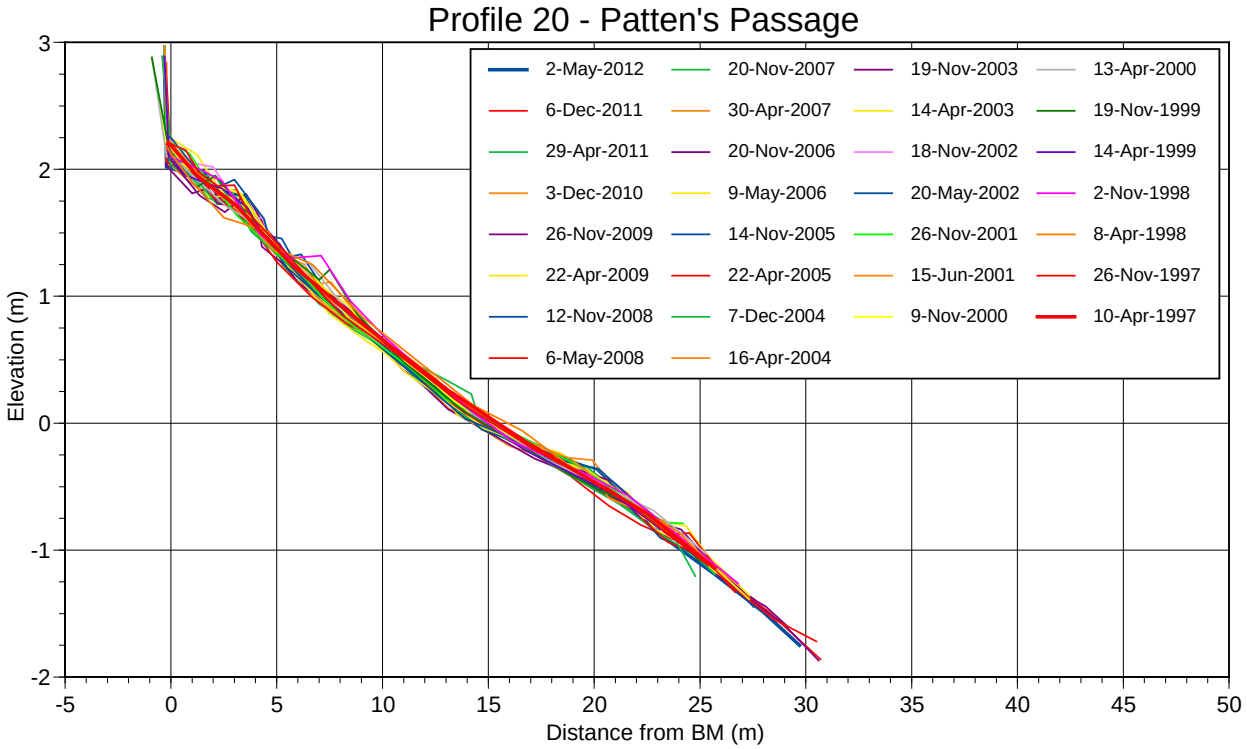
Profile 19: Curious Monkey

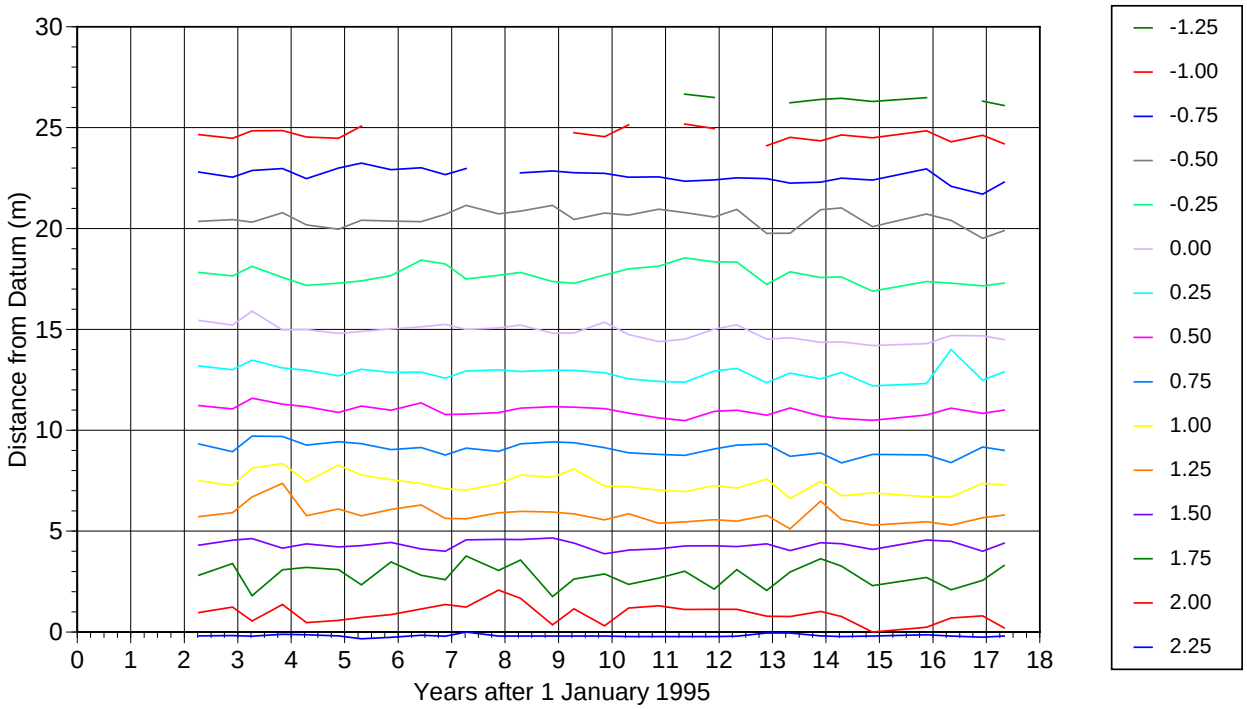
Profile 20 – Patten's Passage

There is considerable variability on the upper and middle beach, but overall stability, with perhaps an erosion trend in from 2003 to 2009 and an accretion trend since.. Small berms build and are removed on the upper beach, with no particular seasonal pattern. Sediments are gravels and sands, and there is frequent banding, but no significant trends in sediment cover are obvious.

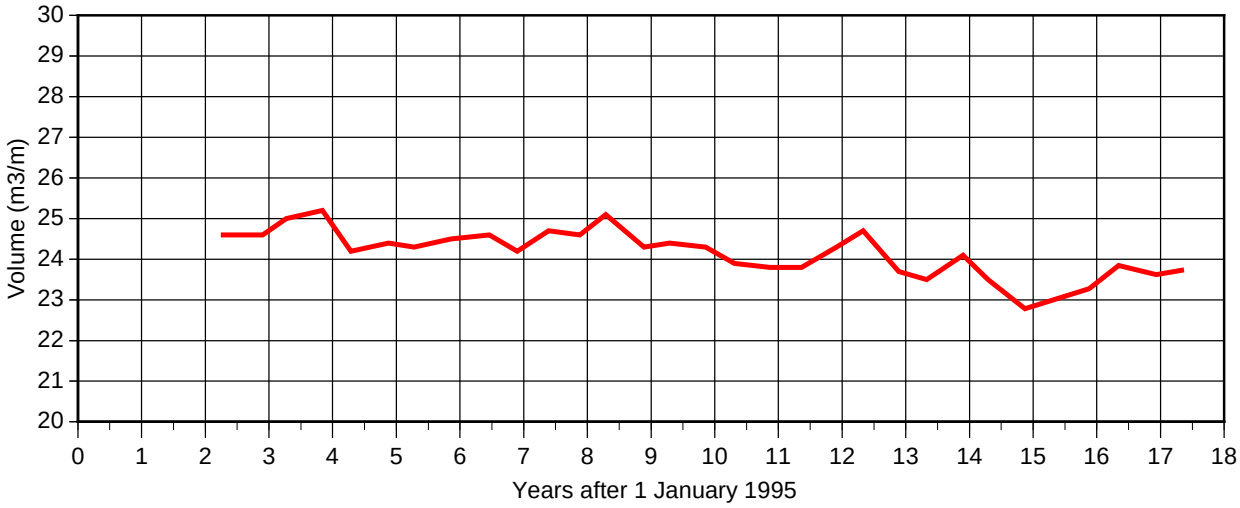


Profile 20: Patten's Passage





Profile 20: Patten's Passage

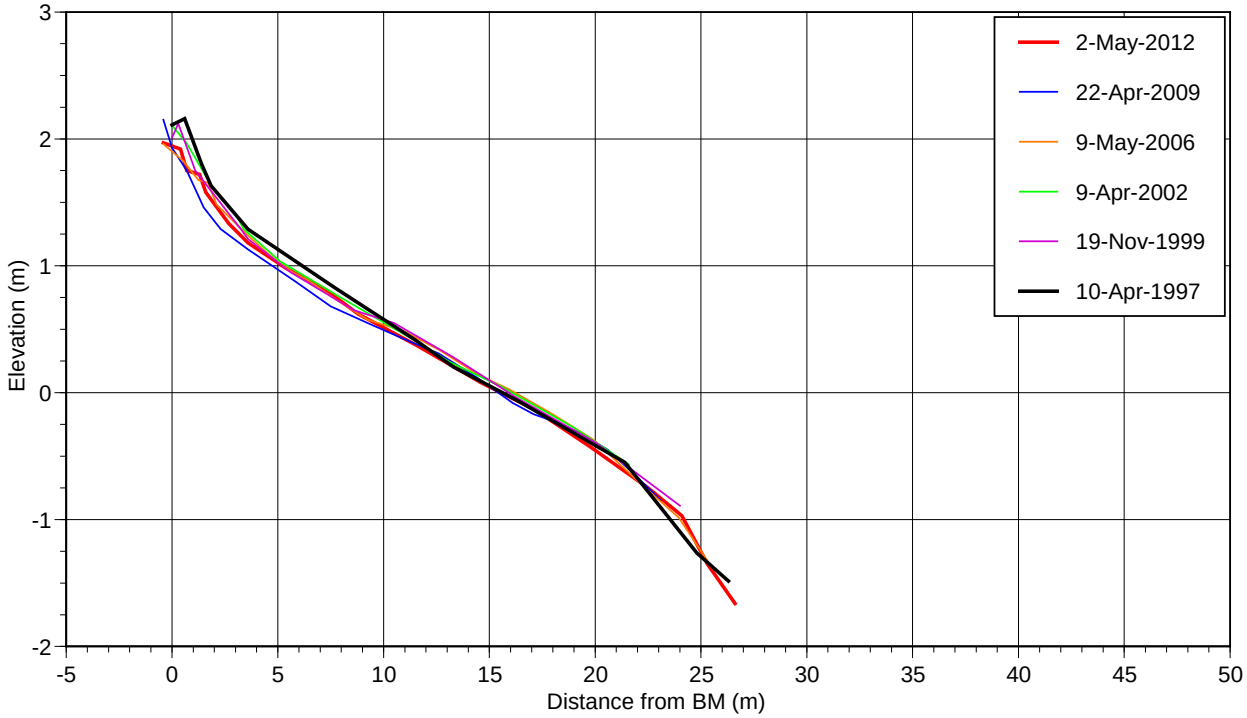


Date	Years after 1/1/95	Volume (m^3/m)
10-Apr-97	2.28	24.6
26-Nov-97	2.90	24.6
8-Apr-98	3.27	25.0
2-Nov-98	3.84	25.2
14-Apr-99	4.29	24.2
19-Nov-99	4.88	24.4
13-Apr-00	5.28	24.3
9-Nov-00	5.86	24.5
15-Jun-01	6.46	24.6
26-Nov-01	6.90	24.2
20-May-02	7.39	24.7
18-Nov-02	7.88	24.6
14-Apr-03	8.29	25.1
19-Nov-03	8.89	24.3
16-Apr-04	9.29	24.4
7-Dec-04	9.86	24.3
22-Apr-05	10.31	23.9
14-Nov-05	10.87	23.8
9-May-06	11.36	23.8
20-Nov-06	11.91	24.3
30-Apr-07	12.33	24.7
20-Nov-07	12.89	23.7
06-May-08	13.33	23.5
12-Nov-08	13.90	24.1
22-Apr-09	14.29	23.5
26-Nov-09	14.87	22.8
03-Dec-10	15.88	23.3
29-Apr-11	16.34	23.8
06-Dec-11	16.93	23.6
02-May-12	17.33	23.7

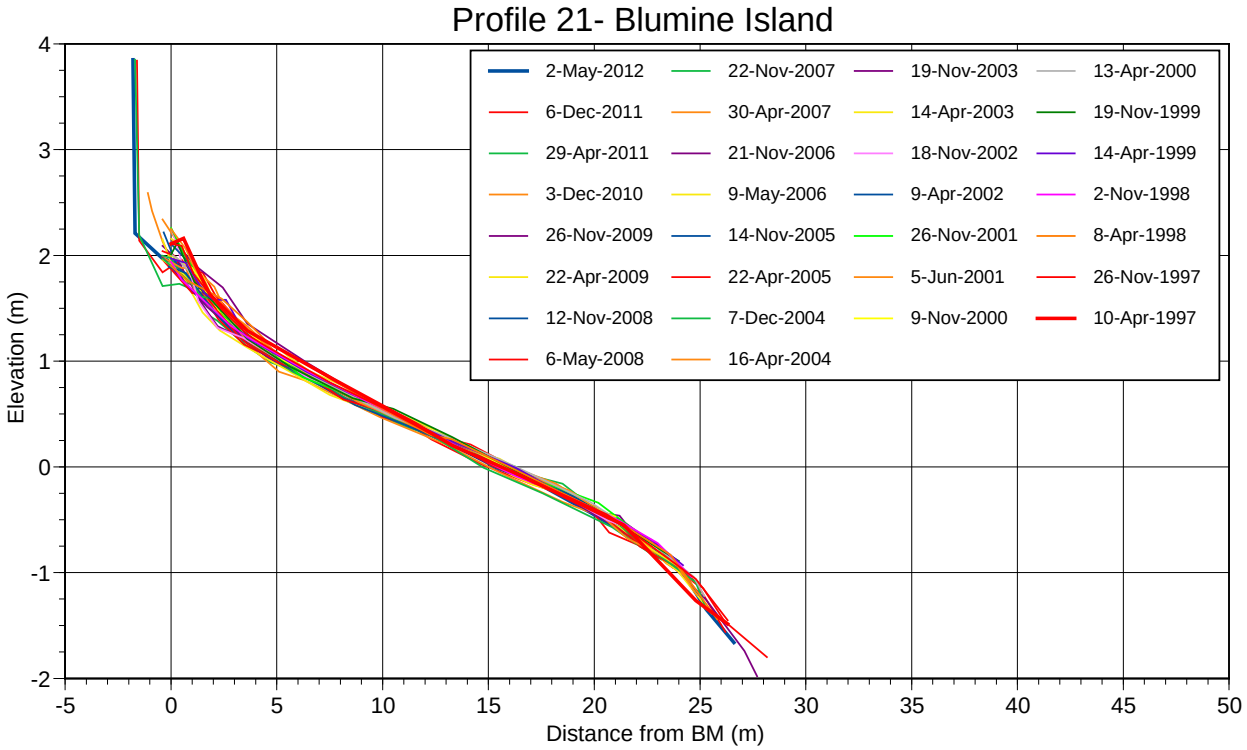
Profile 20: Patten's Passage

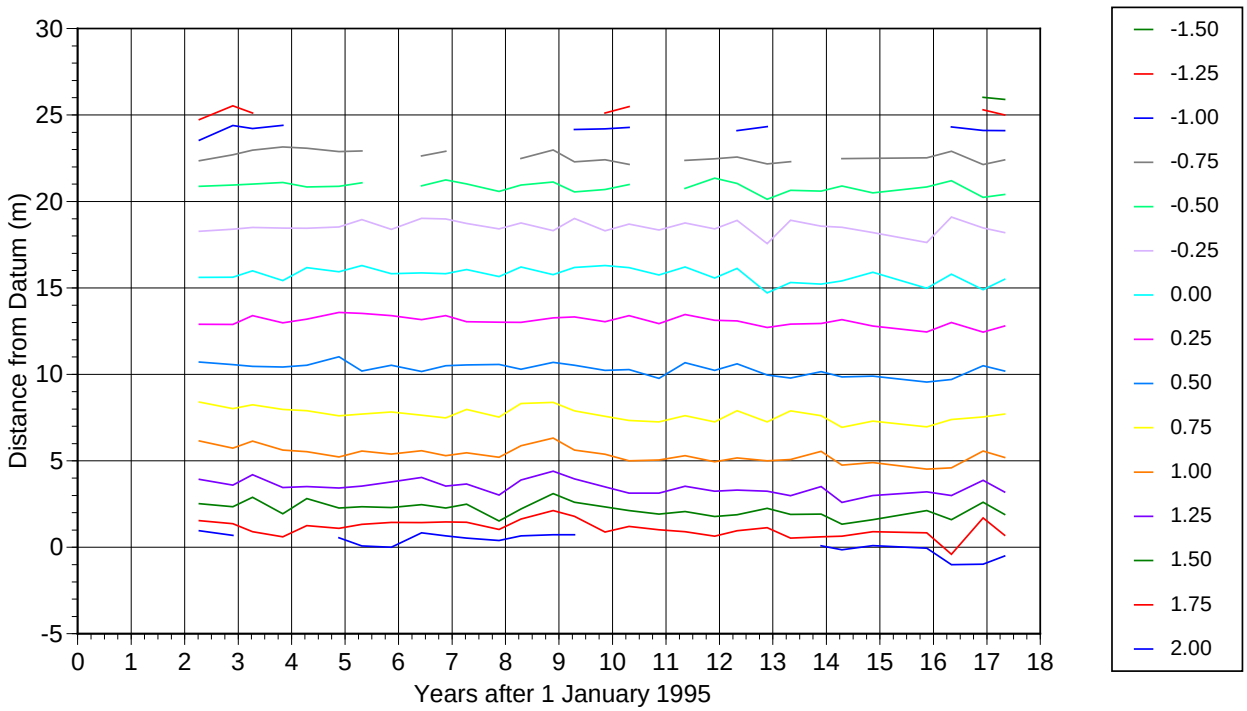
Profile 21 – Blumine Island

Blumine Island has a similar aspect to the Patten's Passage profile. Up until 2003 changes were generally minor, with no seasonality shown. Since 2003, there has been a slow erosion trend, with some seasonality (and perhaps reversing in the last year). Significant erosion at the beach scarp at the top of the beach was reported by the surveyors in 2009, and the profile line was extended landward to cope with this. There does not appear top have been further significant change at the beach scarp.

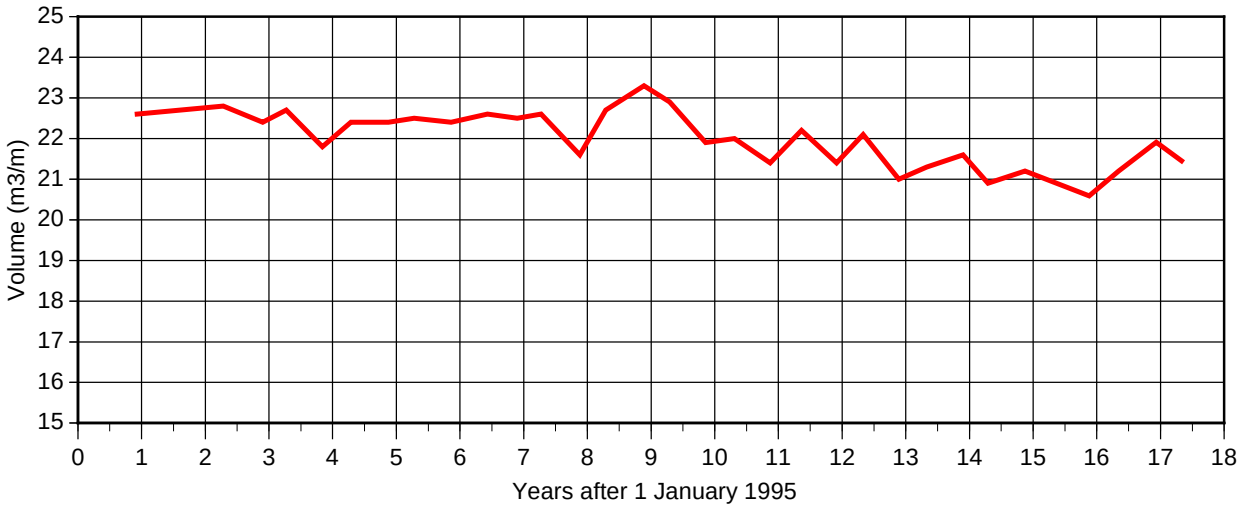


Profile 21: Blumine Island





Profile 21: Blumine Island



Date	Years after 1/1/95	Volume (m^3/m)
7-Dec-95	0.93	22.6
10-Apr-97	2.28	22.8
26-Nov-97	2.90	22.4
8-Apr-98	3.27	22.7
2-Nov-98	3.84	21.8
14-Apr-99	4.29	22.4
19-Nov-99	4.88	22.4
13-Apr-00	5.28	22.5
9-Nov-00	5.86	22.4
5-Jun-01	6.43	22.6
26-Nov-01	6.90	22.5
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7-Dec-04	9.86	21.9
22-Apr-05	10.31	22.0
14-Nov-05	10.87	21.4
9-May-06	11.36	22.2
21-Nov-06	11.91	21.4
30-Apr-07	12.33	22.1
22-Nov-07	12.89	21.0
06-May-08	13.33	21.3
12-Nov-08	13.90	21.6
22-Apr-09	14.29	20.9
26-Nov-09	14.87	21.2
03-Dec-10	15.88	20.6
29-Apr-11	16.34	21.2
06-Dec-11	16.93	21.9
02-May-12	17.33	21.4

Profile 21: Blumine Island

5. Summary of beach changes and the effects of vessel wakes

This summary is divided into three sections, comprising those sites that are conceivably influenced by vessels travelling in Tory Channel and Inner Queen Charlotte Sound (on the ferry sailing route), those sites in the outer Queen Charlotte Sound, and the Picton foreshore site, which is possibly influenced by vessels moving within the port area.

a) Picton foreshore

There is no indication that this site is currently affected by vessel operation, with the beach being relatively stable despite being highly modified. However, I do not have data on the timing and extent of any renourishment programmes.

b) Sites in outer Queen Charlotte Sound

There are five profiles located at sites in the outer Queen Charlotte Sound: Double Bay, Long Island, Clark Point, Patten's Passage and Blumine Island. The sites in outer Queen Charlotte Sound are not influenced by ferry traffic, although some are on the sailing line of larger vessels using Shakespeare Bay. All five sites have remained generally stable over the survey period since April 1997. Long Island has demonstrated a trend of slow erosion since surveys began, but in recent years this has reduced. Clark Point has been very stable. Double Bay has had periods of accretion and erosion, but the current volume is nearly identical to 1997. There has been very minor erosion at Blumine Island and at Patten's Passage.

c) Sites in Tory Channel and inner Queen Charlotte Sound

Many of the sites on the ferry route have exhibited change. However, trends or seasonality consistency between sites is not generally apparent. It is possible to make tentative links between the changing beach shape and vessel operational regimes at individual sites. Sites seem to be primarily influenced by local factors, particularly with respect to sediment supply.

Two sites have demonstrated consistent erosion. Blackmore's at Waikawa has been stripped to bedrock, and therefore no further erosion is likely. Bob's Bay is located on

the ferry route, but at a position where ferries are likely to be operating relatively slowly as they arrive in, or leave, Picton. There has been a consistent erosion trend across the whole profile. The particular circumstances that lead to erosion at this site are not understood, although the high number of boats of all types passing this point may be a factor.

Four profiles exhibit no significant change or trend. These are Te Awaiti, Te Weka Bay and Tipi Bay in Tory Channel, and Dieffenbach West on the inner Queen Charlotte Sound.

The Curious Monkey site showed a change from minor accretion to minor erosion coinciding with fast ferry operation ceasing, although overall changes are small, and there has been very little change since 2007. Ngaionui Point, a site very close to the vessel travel line, particularly on the Wellington to Picton journey, shows a change from accretion to erosion in 2002. The erosion trend eased in 2009, perhaps indicating a return to pre-fast ferry conditions.

The Snout at Picton Point, shows accretion at the top of the profile and significant erosion at the bottom, and therefore a steepening of the beach profile. Overall, a significant amount of sediment has been lost. The deep water channel is clearly cutting into the shoreline at this point. The reason may be related to vessel traffic, or may be entirely natural.

Ngaionui Bay and Slip Beach show a trend of beach building, although in both cases, the rate of accumulation has slowed since about 2003 and perhaps reversed since 2009. In the case of Ngaionui Bay, issues of sediment supply and human interventions complicate the interpretation. Slip Beach demonstrates the most variability of any of the profiles where there appears to be a distinct seasonal pattern.

McMillan's Bay and McMillan's Side, were relatively stable with a small amount of accretion until an event in 1999/2000 when a large amount of sediment accumulated on both profiles. Significant rates of accretion continued until the beginning of 2001, after which time the rate has reduced on the McMillan's Bay profile and erosion has been evident on the McMillan's Side profile (with the rate reducing in recent years). It is probable that the patterns relate to a mass movement event towards Arrowsmith Point,

and significant sediment transport capability due primarily to fast ferry operation, although I have no direct evidence for this.

Moioio Island is an unusual case, being a beach adjacent to a major landslide, and being towards the back of the island, not directly facing the vessel track. Seasonality was evident when the fast ferries were operating seasonally. Both profiles show that the beach is extending into the deep water channel over time (a process that takes a lot of sediment), and generally accreting. Both profiles reached their maximum accreted extent in 2006, and have cut back a little since that time (although there has been accretion on both profiles in the last year). These profiles are almost certainly influenced by changes in ferry operations, being almost completely sheltered from natural wind generated waves. However, the sediment supply from the landslide (which may be affected by vessel wakes) is likely to dominate the beach behaviour.

At the time of the summary report in 2002 it was concluded that with the exception of Bob's Bay near Picton, the beaches on the ferry route were accreting (or are stable) as opposed to eroding, although it was equally clear that local circumstances (particularly sediment supply) play a very significant role. It is now clear that on some profiles a change from accretion to relative stability (McMillan's Bay, Slip Beach, Ngaionui Bay), or accretion to erosion (Ngaionui Point, McMillan's Side, Curious Monkey) occurred at about, or soon after, the time fast ferry operation was restricted to 18 knots in December 2000. Over the last three years, the erosion has slowed or ceased, perhaps indicating a return to pre-fast ferry morphologies. Although a definitive conclusion may never be possible, the results support the understanding that the fast ferry wakes resulted in rapid sediment buildup at the top of the beach on most beaches along the ferry route. However, it is now becoming clear that under the current vessel operational regimes, either stability (with the newly inherited morphology remaining) or a return to pre fast ferry morphology is occurring or has occurred.

6. Recommendations

The beach monitoring programme has been underway for over 15 years, and has been through a range of vessel operation changes, the most significant being the commencement and subsequent abandonment of fast ferry services. Beach monitoring requires a long term commitment to provide value. The value of the monitoring programme comes in understanding how beaches of the region function, both in response to vessel wakes and in response to natural events.

Although changes caused by the introduction of the fast ferries were never captured (although it is assumed that they caused rapid accretion particularly on gravel beaches), it is now possible to conclude that their removal has resulted in a slow reversal of this trend, and possibly a return, in many cases, to pre-fast ferry conditions.

Profiles in the outer Queen Charlotte Sound, off the ferry route, were established to provide an element of control, and in response to the possibility of significant boat traffic using port facilities in Shakespeare Bay, using the northern entrance to Queen Charlotte Sound. These profiles have been generally stable, and prior to 2009 it was concluded that that they were likely to remain stable unless driving forces change (such as a significant change is vessel traffic, or significant sea level change). However, at the time of the last report in 2009 there was a suggestion that a slow erosion trend may have been emerging. However, it is now difficult to support this tentative conclusion. If the monitoring programme were to continue, I suggest continued monitoring but at a reduced frequency.

Profile 5 (Blackmore's at Waikawa) was established at the request of Council. This site demonstrated erosion, but has now been stripped to bedrock for a number of years, but it is unlikely that the reason for the loss of sand is ever going to be known. As previously noted, I see no good reason for maintaining this site.

Profile 1 (Picton Foreshore) does not seem to be changing, and certainly not with respect to vessel traffic. In terms of the purposes of this monitoring programme, continued monitoring is probably unnecessary, although there may be other reasons to continue. If this site is continued, provision of other data, such as the dates and

amounts of maintenance nourishment or other construction or maintenance activity, are required.

Other sites in Tory Channel and inner Queen Charlotte Sound continue to provide good data. The possible return to pre fast ferry conditions on some profiles is of significant interest. The Bob's Bay profile has been continuously eroding. Erosion may be caused by all vessel wakes in the high traffic area near Picton (including the many small boats that pass quite close to the shore at this point), but may be entirely natural. Should erosion at this site be of particular concern, another profile towards the southern end of the bay should be established, to determine if the whole beach is eroding or if sediment is being redistributed within the embayment. In the longer term, some process studies could be considered.

In summary, the following changes to the monitoring programme could be considered:

1. *Reduce the frequency of survey of the profiles in outer Queen Charlotte Sound, and perhaps inner Queen Charlotte Sound and Tory Channel.* The disadvantage of reducing the frequency is that if profile markers are lost, they will be harder to reinstate in the future.
2. *Abandon the Blackmore's at Waikawa site*.
3. *Reconsider the purpose and value of the Picton Foreshore site*.
3. *Establish a second profile towards the other end of the beach at Bob's Bay*, should the continued erosion be of particular concern.
4. *Establish quality vertical control for profile benchmarks*. The survey lines have never had very good vertical control. The zero datum level used has been established independently for each profile, sometimes from water level measurements and assumed tidal curves, and sometimes for consistency with data sets collected by other groups (such as Kirk and Single). It would be very useful if the profiles were able to be tied together. RTK-GPS technology is now available to enable this to be done, although the topography of the area will make the task difficult. Undertaking such a survey would have the additional benefit of enabling survey lines to be accurately reconstructed should permanent marks be lost.

I am happy to discuss these recommendations with Council staff.

Appendix 1

Survey Benchmarks
as at April 2012

Levels used in this report are in BOLD

Pr	Name	Peg	Dist	Ayson RL	KP RL	Kirk RL	SL RL	Notes
1	Picton Foreshore	Seawall	6.87				**2.440**	Top of wall
1	Picton Foreshore	C	0.00				**2.550**	C" hole in grey stone
2	The Snout at Picton Point	IT	-1.00	10.34			**3.293**	
2	The Snout at Picton Point	W	0.00	10.00			**2.950**	
3	Double Bay	W	-1.50	10.74			**2.720**	
3	Double Bay	IT	0.00	10.00			**1.980**	
4	Ngaionui Bay (C Thomas)	W	-2.00	10.31			**2.680**	
4	Ngaionui Bay (C Thomas)	IT	-2.5	10.02			**2.39**	
5	Blackmore's at Waikawa	Nail	0.00	10.00			**1.900**	In round post
6	Moioio Island 2	W	-2.00		0.33		**1.740**	Based on Kirk and SL Difference
6	Moioio Island 2	0IS A	0.00		0.00		**1.410**	KP Peg
7	Moioio Island 1	W	-2.00	10.36		1.70	**1.700**	
7	Moioio Island 1	IT	0.00	10.00		1.34	**1.340**	
8	Bob's Bay	W	-2.00	11.19		2.96	**2.959**	
8	Bob's Bay	IT	0.00	10.00		1.77	**1.769**	
9	Te Awaiti	W	-6.00	10.87		2.01	**2.006**	
9	Te Awaiti	IT	0.00	10.00		1.13	**1.133**	
10	Tipi Bay	W	-2.50	10.65		2.19	**2.188**	
10	Tipi Bay	IT	-1.5	10.02		1.56	**1.56**	
11	Long Island	W	0.00	10.00			**2.840**	
11	Long Island	IT	-2.50	9.30			**2.140**	
12	Clark Point	IT	0.00	10.00			**1.620**	
12	Clark Point	OISA	2.20	9.77			**1.393**	Biol peg
12	Clark Point	W	6.50					Biol peg ???
13	Slip Beach	IT	-0.55	10.25		1.74	**1.740**	
13	Slip Beach	W	-0.10	10.51		2.00	**2.000**	

Pr	Name	Peg	Dist	Ayson RL	KP RL	Kirk RL	SL RL	Notes
14	Ngaionui Point	W	-2.00	10.52			**2.386**	
14	Ngaionui Point	IT	0.00	10.00			**1.870**	
15	Te Weka Bay	IT	0.00	10.00		1.50	**1.498**	
16	McMillan's Bay	W	-2.00	11.49		2.91	**2.908**	
16	McMillan's Bay	IT	0.00	10.00		1.42	**1.418**	
17	McMillan's Side	IT	-2.00	11.15			**2.938**	Based on Kirk and SL Difference
17	McMillan's Side	W	-1.3	11.48			**3.263**	
18	Dieffenbach West	OIS A	0.00	-0.09			**2.520**	Reestablished after disturbance
18	Dieffenbach West	W	-0.2	-0.04			**2.570**	Reestablished after disturbance
19	Curious Monkey	W	-1.00		1.18		**3.700**	
19	Curious Monkey	OIS A	0.00		0.00		**2.520**	KP peg
20	Patten's Passage	IT	-1.10	10.85			**3.488**	KP peg
20	Patten's Passage	W	0.00	10.00			**2.640**	KP peg
21	Blumine Island	W	-0.40	0.45			**2.66**	KP peg
21	Blumine Island	Railway iron	3.60		0.23		**2.440**	KP peg
21	Blumine Island	IS(new)	-5.5	2.60			**4.81**	

Appendix 2

Profile Photographs

Photographs are taken looking alongshore from both sides of the profile line, looking back towards the profile line. The profile line is approximately 20m from the camera, and appears in all photographs.