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Quinns Beach - Survey Review & Evaluation of Groyne Field

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1. Introduction

1.1 Background

Quinns Beach has been affected by coastal erosion for many decades. At various times throughout the decades this erosion has threatened public infrastructure in the vicinity of the beach. Such was the threat from this erosion that in 1970 the City of Wanneroo constructed a roughly placed rubble seawall to provide protection to a car park and toilet block located near Quinns Road. Additional protection works were completed in 1977 when a rubble headland was constructed to the north of this area to encourage accretion along the southern beach.

More recently, between 1997 and 2002 sand nourishment and removal of public infrastructure in effected areas was used in an attempt to manage the problems associated with the erosion, however after significant erosion was experienced along sections of the beach in 2001 further works were undertaken. Three rubble groynes were constructed with extensive sand nourishment also completed in stages between 2002 and 2006. The location of these structures is shown in Figure 1.1.

1.2 The Groyne & Sand Nourishment Scheme

The groyne construction and sand nourishment was completed in an attempt to provide a longer term solution to the problem. The design of this scheme was completed by MRA with details provided in MRA report R110 Rev 1 (August 2002). The proposed program of these works involved:

- Year 1 – construction of groynes 1 and 2 and 60,000 m^3 of beach nourishment between the groynes.
- Year 2 – construction of groyne 3 and 60,000 m^3 of beach nourishment.
- Year 3 – 72,000 m^3 of beach nourishment.
- Additionally, it was noted that episodic beach nourishment of about 40,000 m^3 should be allowed for each decade or so to rectify deficiencies caused by abnormal weather conditions.

To date the three groynes have been constructed, however the full amount of sand nourishment has not been placed. The progression of the works has been as follows:

- October 2002 – construction of groynes 1 and 2 and 60,000 m^3 of sand nourishment.
- October 2003 – construction of groyne 3 and 60,000 m^3 of sand nourishment.
- October 2004 – 36,000 m^3 of sand nourishment.
- October 2006 – 16,000 m^3 of sand nourishment.

Based on the above figures a total of 20,000 m^3 of sand nourishment is yet to be placed. The effect of this will be considered further later in this report.

1.3 Review & Evaluation of Scheme

During the period between August 2007 and February 2008 localised erosion occurred immediately north and south of groyne 1. This erosion was of concern to the City and as the groyne field has been in place for approximately 5 to 6 years it is prudent to investigate the cause of this erosion as well as the overall response of the beach to the implementation of this scheme. A key element of this review is examination of the observed weather conditions during this period.

A brief review of the metocean conditions will be included in this report along with an examination of the change in the beach that has occurred between February 2002 (prior to the construction of the groynes and sand nourishment) and May 2008. This review will enable recommendations to be made regarding items for further investigation, further action, or a combination of both.

Figure 1.1 - Locations of Coastal Structures on Quinns Beach

2. Metocean Conditions

The metocean conditions have a significant effect on the formation and dynamics of sandy beaches. Simplistically, the directionality and severity of the various metocean events dictate the direction and magnitude of sand transport along the coast. This is particularly significant at Quinns Beach, where previous investigations and modelling suggests that gross movements of sediment along the coast are typically in the order of 80,000 to 100,000 m^3 per year but the net transport is typically more in the order of 5,000 m^3 per year.

As a general rule, the occurrence of winter storms results in a net southerly transport of sediment along the beach, with sea breeze events resulting in a net northerly transport of sediment. The balance of these events is therefore critical when it comes to beach stability, as a proportional change in the number or severity of each event can upset the balance of the system and lead to erosion of some areas and corresponding accretion in others.

It is believed that such an imbalance occurred in 2001 during which a significantly decreased number of winter storms were experienced compared to a typical year. This resulted in an erosion of approximately 42,000 m^3 from the southern beach. This occurrence was also a significant factor in the development and construction of the groyne field option to provide some protection to Quinns Beach.

Table 2.1 provides an annual breakdown of the number of sea breeze, storm and severe storm events experienced along the metropolitan coastline since 1995. It is obvious from this data that during 2001 the number of storms experienced was exceedingly low insofar as the actual number of storms experienced was only 13, which is half of the longer term average of 26. The number of sea breeze events experienced was also approximately 20% above average during 2001 which would have exacerbated the net northerly transport of sand away from the southern beach.

Conversely to 2001, the data shows that 2007 was a particularly stormy year with a total of 71 storms and 6 severe storms experienced. These are well above the longer term averages of 26 and 2 respectively. Further, the number of sea breeze events was around 20% below average. The combination of these two factors would result in an increased transport of sediment to the south during 2007. This is the opposite of what was observed during 2001.

It is also significant to note that during the period between 1st June and 24th August 2007 data from DPI's tide gauge at Fremantle Fishing Boat Harbours indicates that a total of seven significant water level events were experienced (per comm. Reena Lowry, Oceanographic Officer Tides and Waves, DPI). Using MRA's data on extreme water level events for Fremantle it is estimated that of these seven events, five were around the 1 year return period event, while the other events were around the 2 and 10 year events. As a result of this it can be inferred that the winter period of 2007 contained a significant amount of high water level events.

Another significant feature of the data presented in Table 2.1 is the fact that the data between 1995 and 2001 shows that the number of sea breeze events were on or above the average, while the number of storm events were no or below the average. For the period between 2002 and 2007 the opposite was observed, with the number of sea breeze events below average and the number of storm events above average. Essentially, this would mean that prior to 2002 there would have been an increased

propensity for northerly transport of sediment along Quinns Beach, whereas from 2002 onwards there would have been an increased propensity for southerly transport of sediment.

Table 2.1 - Annual Summary of Sea Breeze & Storm Events 1995 - 2007

SEA BREEZE – NUMBER OF DAYS													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
1995	26	20	16	18	7	1	0	5	8	2	16	20	139
1996	26	27	17	13	7	4	1	1	4	17	17	27	161
1997	19	16	22	9	7	2	4	9	6	12	14	25	145
1998	22	26	20	19	0	0	0	0	4	18	18	25	152
1999	29	21	22	14	0	0	0	0	0	17	21	25	149
2000													148
2001													171
2002	25	22	19	8	6	2	0	0	6	8	13	17	126
2003	20	18	14	8	4	2	0	2	4	14	19	21	126
2004	23	21	20	13	4	1	2	4	7	8	11	19	133
2005	25	20	17	6	3	0	2	5	4	7	15	6	110
2006	17	14	17	12	10	0	0	0	1	9	15	20	115
2007	18	13	20	9	3	4	0	0	1	12	20	21	121
												AVG:	**140**
STORMS – NUMBER OF EVENTS													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
1995	0	0	0	1	3	3	4	6	0	3	1	0	21
1996	0	0	0	2	2	4	5	3	7	1	1	1	26
1997	0	0	0	0	3	2	3	5	4	2	1	1	21
1998	0	0	0	0	4	4	3	3	5	0	0	0	19
1999	0	0	1	0	2	3	3	5	3	1	0	0	18
2000													23
2001					3	0.5	2.5	2.5	3.5	1			13
2002	0	0	0	2	2	4	8	7	5	3	1	0	32
2003	0	2	0	2	3	5	6	5	5	2	3	1	34
2004	1	0	1	1	4	5	5	7	1	3	1	0	29
2005	0	0	0	1	2	7	4	7	6	3	2	3	35
2006	3	1	2	0	3	4	9	8	6	3	2	1	42
2007	3	2	6	8	6	6	10	8	8	8	2	4	71
												AVG:	**26**
SEVERE STORMS – NUMBER OF EVENTS													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
1995	0	0	0	0	1	2	1	0	0	0	0	0	4
1996	0	0	0	0	0	1	2	0	1	0	0	0	4
1997	0	0	0	0	0	1	0	1	1	0	0	0	3
1998	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	1	0	0	0	1	0	0	2
2000	0	0	0	0	0	0	0	1	0	0	0	0	1
2001	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	1	1	0	0	1	0	0	3
2003	0	0	0	0	1	0	0	1	0	0	0	0	2
2004	0	0	0	0	1	0	0	1	0	0	0	0	2
2005	0	0	0	0	0	0	0	0	1	0	0	0	1
2006	0	0	0	0	0	0	0	1	0	0	0	0	1
2007	0	0	0	0	0	0	4	1	1	0	0	0	6
												AVG:	**2**

Note: Monthly breakdowns of event numbers were not available for all years.

3. Visual Assessment of Performance

The modelling completed by MRA during the development of the groyne and sand nourishment regime indicated that under the influence of the full scheme an additional buffer of around 5 to 10 m would be created for the area between the existing headland and the northern groyne (groyne 3). Visual inspection by MRA indicates the following:

- The beach to the south of the headland appears to have experienced significant accretion. This is considered a good result as the relocation of the surf club to this beach along with the development of district beach facilities is likely to increase the demand for beach space in this area. The wider beach would help to accommodate this.

Figure 3.1 - Southern Beach

- The southern compartment (between the existing headland and groyne 1) appears to have experienced accretion in the longer term, particularly at the south of the compartment where a fore dune has established. However, the north of the compartment adjacent to groyne 1 did experience erosion during the 2007 winter period. This is believed to have been a result of the increased number of winter storms, which grossly increased the amount of southerly sand transport and therefore resulted in erosion on the southern side of groyne 1 since insufficient sand was bypassing from the north of the groyne. Furthermore, it should be noted that the occurrence of several higher water level events during 2007 lead to erosion higher up on the beach profile which has more of an impact visually.

Figure 3.2 - Headland to Groyne 1

- The central compartment (between groynes 1 and 2) has not experienced the same recent accretion as the northern compartment as there is no fore dune present. However, over time a dune has formed along this compartment and now provides a buffer to help protect the car park. This buffer is believed to generally be in the order of around 5 m and is shown in the photographs below. Nevertheless, in the summer of 2007/2008 erosion was experienced immediately to the north of groyne 1. This is believed to have occurred as a result of the switch from the winter regime (where sand is transported to the south) to the summer regime (where sand is transported to the north). Given the abnormally high number of storms during the winter of 2007 that resulted in erosion to the south of Groyne 1, when the season switched back to the summer regime there was insufficient sand on the southern side of the groyne to feed around to the north. Consequently, the erosion occurred to the north of groyne 1 until such time as the sediment built up on the southern side of the groyne to such an extent that it began to bypass the head of the groyne.

Figure 3.3 - Groyne 1 to Groyne 2

- The northern compartment (between groynes 2 and 3) appears to have experienced noticeable accretion and has developed a buffer in the order of around 10 to 15 m. This is indicated by the formation of a small fore dune as seen in the photographs below.

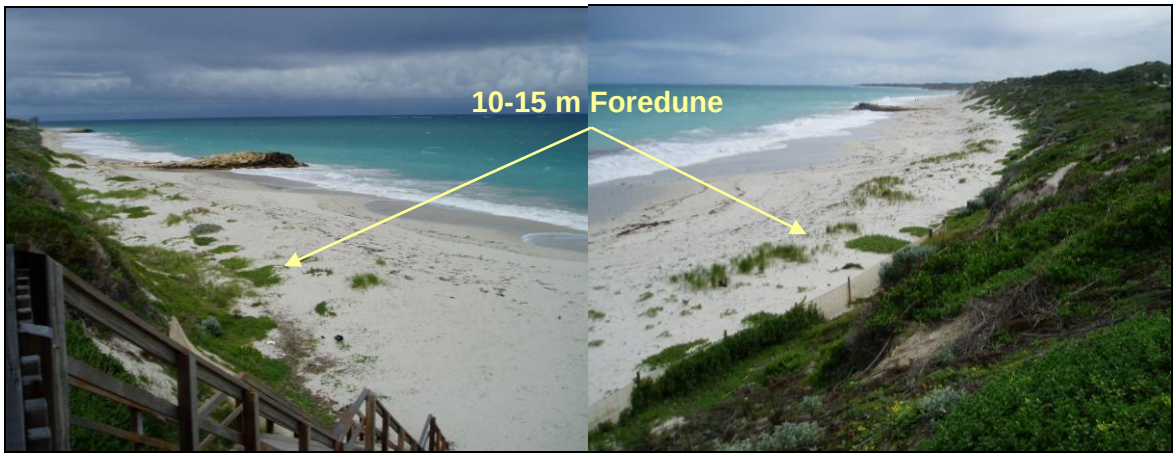

Figure 3.4 - Groyne 2 to Groyne 3

- The beach to the north of groyne 3 appears to have stabilised as there does not appear to be any recent signs of erosion of the dune face which is better than the predicted outcome. This beach was predicted to erode at about 1 m/year. The better than anticipated performance may have resulted from the magnitude of southerly sediment transport in recent years.

Figure 3.5 - North of Groyne 3

Based on the above it would appear that since the implementation of the scheme the chronic erosion that was experienced along Quinns Beach has largely been halted and buffers to allow for the action of storm erosion have been established. This is in line with predictions made in the MRA report that the scheme would *"halt the erosion trend and provide an additional 5 to 10 m buffer to the northern car park. This buffer should be sufficient to accommodate possible errors in the modelling and provide a buffer for some storm erosion"*.

The fluctuation experienced along most of the approximately 2.4 km of shoreline seems to be acceptable. The 0.2 km of shoreline either side of the southern groyne has experienced some periods of erosion that create undesirable outcomes in respect to beach access and security of the car park.

4. Survey Information

Prior to the implementation of the groyne field and sand nourishment regime a near shore survey of the Quinns Beach area was completed by DPI. This survey was completed in February 2002. Most recently, a comparable survey was completed by DPI in May 2008.

To establish the changes in the shoreline that have occurred in the period between these two surveys, or since the commencement of the scheme, DPI provided a series of plots that show the changes in near shore elevation that occurred between February 2002 and May 2008. These plots have been amalgamated and are provided in Figure 4.1. Cross sections of the beach profiles in February 2002 and May 2008 are also provided in Figure 4.2 to identity areas of erosion and accretion on the beach profiles.

As shown in Figure 4.1, the beach was broken up into sections so the change in sand volume within each section could be determined. The volumes provided show that there has been a net accumulation of sediment in each of the sections. It is particularly noticeable however that the majority of the sediment has accumulated in the southern areas - to the south of groyne 1. The two northern sections (north of groyne 1) have experienced quite modest accumulations of sediment.

Unfortunately, the survey from 2002 did not extend north of where groyne 3 is now located, so it is impossible to draw comparisons for this region.

In total, the difference plots suggest that around 225,000 m^3 of sediment has accumulated within the survey area. This is around 50,000 m^3 more than the actual volume of sand nourishment (172,000 m^3) placed in this area. Nevertheless, it should be acknowledged that due to the accuracy of the surveys the total volume of sediment that has accumulated would be around ±18,000 m^3 although could be up to ±36,000 m^3 in the worst case. Despite this, the survey suggests that all of the sand nourishment placed as part of the scheme appears to have remained within the system. Further, if as the surveys suggest, more sediment has accumulated in this area the majority of any extra sediment is likely to have come from the north of groyne 3. This is especially likely due to the increased propensity for southerly sand transport as a result of the metocean conditions experienced since the groynes were constructed. Nevertheless, some of this additional sand may have been the result of onshore feed from shallow near shore areas.

Other significant points to note from the difference plot and cross sections are:

- There has been significant accretion of the dunes and beach berm in Area 1 (south of the headland) in the period between 2002 and 2008. This has resulted in a wider area of useable beach in front of the newly developed surf club and associated facilities.

- Significant accretion has occurred on the fore dune and beach berm in Area 2 (between groyne 1 and the headland). Despite this accretion, erosion has occurred higher up the beach profile in the northern half of this area. It is likely that this erosion is a result of the events of 2007 where the high water levels and seasonal variations in beach alignment resulted in erosion of the dune face on the southern side of groyne 1.

- There has been a net accretion in Area 3 (between groynes 1 and 2) however there has also been erosion higher up the profile adjacent to groyne 1. Similarly to Area 2 this erosion is likely to have been the result of high water level events experienced in 2007 and seasonal variations in beach alignments.

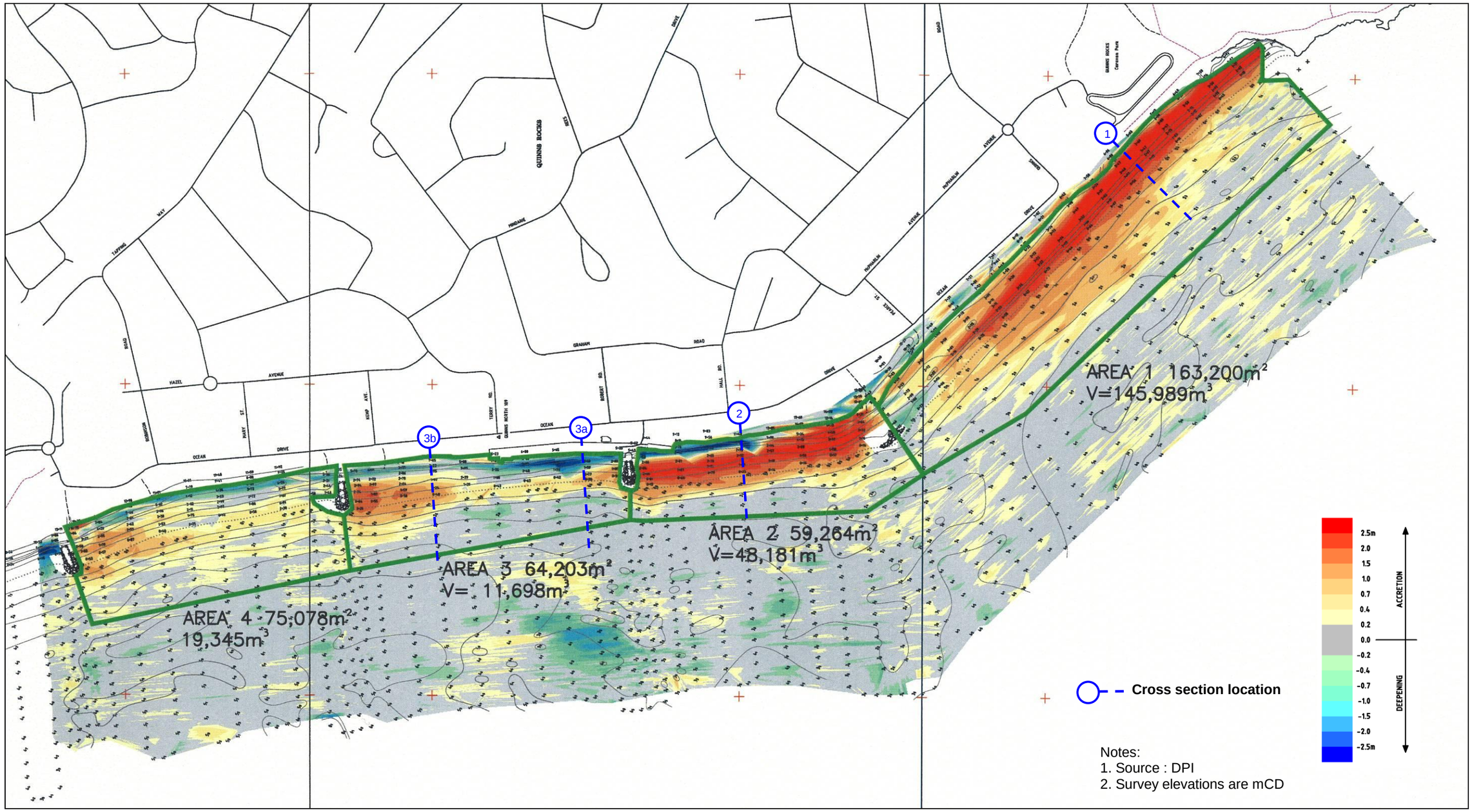

Figure 4.1 - Difference plot May 2008 - February 2002

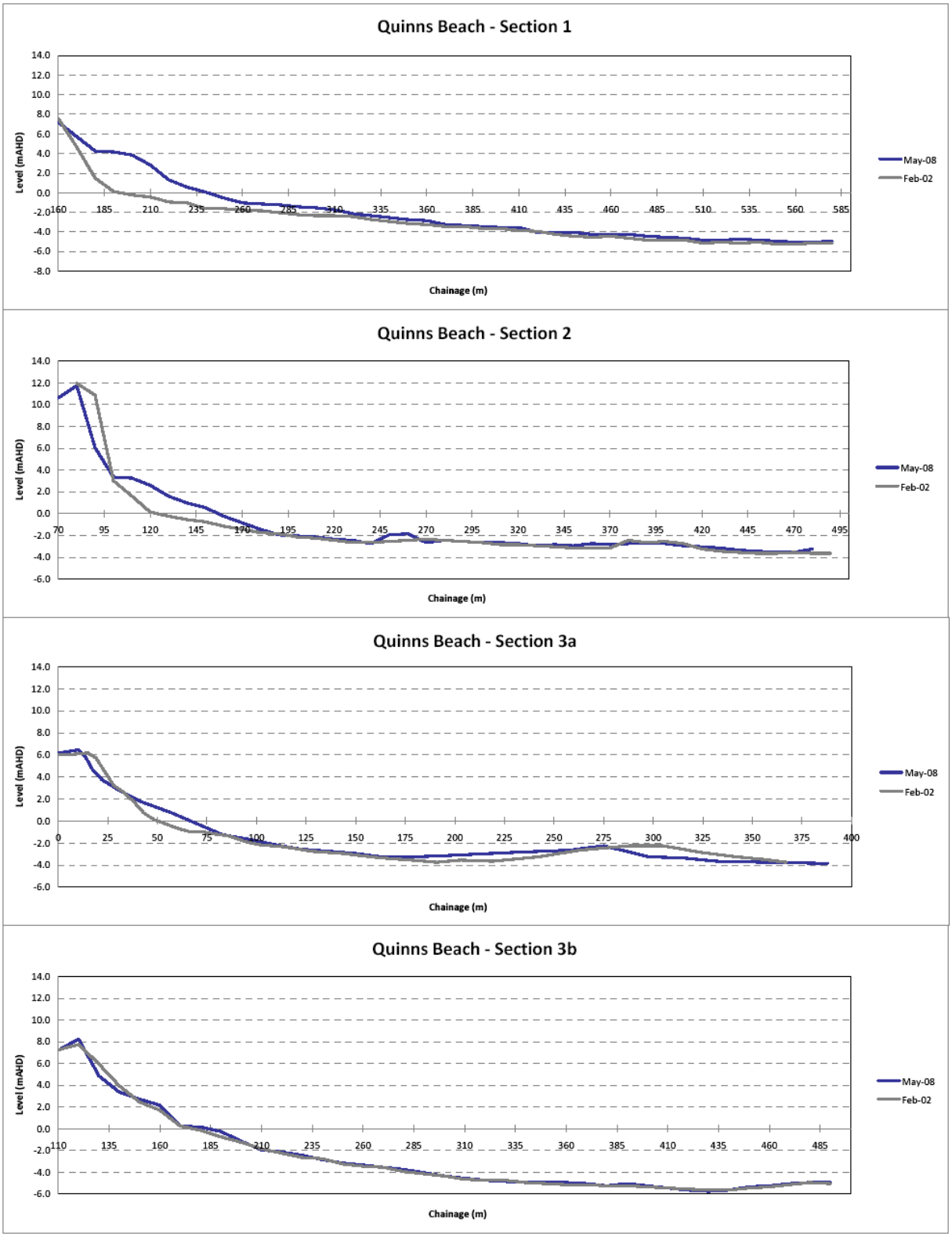

Figure 4.2 - Beach Profile Cross-sections

5. Summary & Conclusions

The following points contain a summary of what are considered to be the main points to note from the above investigations as well as conclusions that have been drawn from this information.

- The net annual sediment transport rates at Quinns have previously been shown to be highly dependent on the annual metocean conditions. A summary of the annual metocean conditions suggests that the balance of sea breeze and storm events has changed since 2002, with below average numbers of storms and above average numbers of sea breeze events prior to 2002. The opposite has been observed since 2002, with above average numbers of storms and below average numbers of sea breeze events.

- The change in relative proportions of storm and sea breeze events before and after 2002 appears to have resulted in a shift in the net sediment movement from net northerly prior to 2002 to net southerly since 2002.

- Contra to 2001, when half the average number of storms were experienced and there was an accelerated net northerly transport of sediment resulting in erosion of southern areas, in 2007 there was over twice the average number of storms resulting in an accelerated net southerly transport of sediment.

- The accelerated net southerly transport of sediment in 2007 resulted in erosion on the southern side of groyne 1 towards the end of the winter period. It is expected that this erosion occurred as a result of insufficient sand bypassing from the north of the groyne. Furthermore, it should be noted that the occurrence of several higher water level events during 2007 lead to erosion higher up on the beach profile which has more of an impact visually.

- Subsequent to the erosion on the southern side of groyne 1, during the change from the winter weather regime (where sand is transported to the south) to the summer weather regime (where sand is transported to the north) there was insufficient sand on the southern side of the groyne to feed around to the north. Consequently, the erosion occurred to the north of groyne 1 until such time as the sediment built up on the southern side of the groyne to such an extent that it began to bypass the head of the groyne.

- A comparison between surveys taken in February 2002 (prior to the construction of the groynes and placement of any sand nourishment) and May 2008 suggests that a total of around 225,000 m^3 of sediment has accumulated within the area. This is around 50,000 m^3 more than the actual volume of sand nourishment placed. This additional sand is believed to have mainly come from the north of groyne 3, however some may have also been the result of onshore feed.

- Analysis of the surveys and visual inspection of the area shows that there has been an overall accretion along all sections of beach within the scheme. This is particularly obvious along the southern beach where a wide section of useable beach has formed in front of the new surf club and associated infrastructure. The only areas that did show erosion were high up on the beach profile 200 m to the north and south of groyne 1. It is believed that the reason for erosion in these areas is largely due to the anomalous weather conditions experienced in 2007.

- It is considered that the implementation of the groyne and sand nourishment scheme has generally had the desired effect insofar as the entire coastline to the south of groyne 3 has experienced accretion. The erosion that has occurred high up on the profile 200 m north and south of groyne 1 is the only area that could be considered to have not completely delivered the desired outcome, however this may be a consequence of the anomalous conditions experienced during 2007. Erosion in this area is also highlighted since there is no significant buffer or dune in this area. This erosion could also be a shortcoming of the groyne field.

6. Options & Recommendations

Given that overall the scheme has generally achieved its desired outcomes the only reason that minor changes may need to be made would be to achieve a greater level of protection to the area adjacent to groyne 1. There are a few options that could be considered by the City. These options are outlined simplistically below and would be subject to further investigation and design.

6.1 Option 1 – Extend Groynes & Sand Nourishment

One option to address the erosion surrounding groyne 1 would be to increase the length of this groyne. However, if this extension was completed in isolation it is highly likely that this would only exacerbate the seasonal erosion either side of the groyne as it would take longer for the sediment to accumulate on one side of the groyne to such an extent that it begins to bypass the head. During this extended period before bypassing of the head occurs, sediment would be eroded from the other side of the groyne; therefore leading to larger erosion prior to when the sand begins to bypass.

To eliminate this problem all of the groynes would have to be extended and adequate sand nourishment would have to be placed to achieve the desired increase in beach width. Therefore, if an increased buffer of 5 m was required, all of the groynes should be extended by 5 m and enough sand nourishment would need to be placed to advance the beach profile along the entire length by 5 m. This would require approximately 100,000 m^3 of sand nourishment. The cost of this scheme would therefore be in the order of around $3.5 million.

6.2 Option 2 – Sand Nourishment

The sand nourishment shortfall of 20,000 m^3 could be placed. Further, it was acknowledged in the original design that additional quantities of up to about 40,000 m^3 could be required due to abnormal weather conditions. The placement of this additional sand nourishment could assist in building out the beach berm along the coast. This would mean that it would take less time for sediment to bypass the groynes and would therefore limit the seasonal erosion that would occur on the down drift side of the groynes. This could help to solve the problem that occurs either side of groyne 1.

Additionally, the placement of the additional 40,000 m^3 of sediment, or part thereof, could help given that the overall weather regime since the construction of the groynes has resulted in an overall southerly transport of sediment.

The cost of this option would obviously be determined by how much sand was to be placed on the beach. Placement of the 20,000 m^3 shortfall would cost around $0.7 million.

6.3 Option 3 - Retreat

Given that the only area that has not achieved the desired outcome as a result of this implementation of the scheme is immediately adjacent to groyne 1, it follows that a solution that deals with this area only would be ideal. One way to assist in solving this problem would be to retreat locally in this location. This could involve removing the car parking bays on one side of the car park. As car bays are typically in the order of 5 m in length, removing the car bays from one side of the car parking area would provide an additional 5 m buffer at relatively low cost. This increased buffer may allow space

for the formation of a small fore dune that would provide a greater buffer against the seasonal variations that occur.

6.4 Option 4 – Do Nothing

It is believed that the cause of the erosion high on the beach profile either side of groyne 1 could have been the combined effect of a series of high water levels that were experienced during 2007, as well as the increased southerly transport of sediment that resulted due to the relative number of sea breeze and storm events. Given that the events of 2007 are a relative anomaly, it follows that one option is to accept that from time to time erosion will occur and it will be obvious in locations such as to the north and south of groyne 1 where there is no significant buffer present. Temporary works may be required at such times to ensure public safety is maintained, however this may only occur every few years (based on what has been observed). The option to complete no further works should therefore be considered and the situation monitored for a further few years.

6.5 Recommendations

Options 3 and 4, the retreat and do nothing options, seem to offer good solutions at modest costs and are recommended for consideration by the City.