City of Wanneroo
October 1999

Quinns Beach Coastal Protection Works

Stage 2 Report

M P ROGERS & ASSOCIATES PTY LTD
Coastal and Port Engineers
Report R060 Rev 0

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Executive Summary

The Shire of Wanneroo has been involved in combating coastal erosion at Quinns Rocks since 1970. Presently, coastal erosion is threatening to undermine the car park located to the north of Quinns Cusp, and there are also concerns regarding the ongoing stability of the beach to the south and adjacent Ocean Drive. The aim of this study is to provide a comprehensive evaluation of suitable coastal protection options for Quinns. The study is defined by the following three stages:

- **Stage 1**
  The review of existing data and technical reports, the calculation of appropriate design criteria for coastal protection options, and the preliminary review of coastal protection options.
- **Stage 2**
  A comprehensive review of suitable coastal protection options.
- **Stage 3**
  The final design and cost estimate of the coastal management option nominated by Wanneroo.

This report documents the findings of Stage 2 of the Study.

For the purposes of evaluating suitable coastal management options, the Quinns foreshore was divided into the Southern and Northern Beaches.

Southern Beach

Since the construction of the artificial headland in 1977, the Southern Beach has remained relatively stable. Survey results indicate that the region accreted by about 80,000 m^3 during the twenty years between December 1977 and December 1997. However, a localised loss of about 12,000 m^3 has occurred from the primary dune seawards of Ocean Drive. This amount is relatively small in the overall system. However, it does suggest that without appropriate coastal management, a succession of severe storm events may reduce the buffer protecting Ocean Drive and threaten to undermine it.

Suitable management options have been reviewed and the recommended option is to increase the present buffer (ie width of dune) protecting Ocean Drive and undertake sand renourishment following severe storm events which cause significant erosion of the primary dune. An alternative option is to construct a seawall; however, this option is likely to be more costly and may increase the amount of erosion which occurs to the north of the cusp.

Allowing the dune to continue to erode is not recommended as storm erosion may produce a recession of the primary dune which may threaten to undermine a section of Ocean Drive. The value of the assets which may be lost through erosion is considered to be significantly greater than the cost of protecting them.

Northern Beach

Since the construction of the artificial headland in 1977, the Northern Beach has progressively eroded, receding at a rate of about 1 m/year. The total net loss of sediment from the Northern Beach was about 170,000 m^3 during the twenty year period between December 1977 and December 1997 (ie about 8,500 m^3/year). The future rate of erosion has been estimated to be about 7,000 m^3/year.

The present buffer protecting the Northern Car Park and Stubbs Park is minimal, and without the appropriate coastal management these amenities are likely to be undermined. If the present trend of erosion continues in the longer term, a section of Ocean Drive may also be threatened.

Suitable management options have been reviewed and seawall construction combined with renourishment was found to be the most appropriate management option**.** This option was found to be more cost effective than straight renourishment because the construction of the seawall was less costly than an appropriate increase of the dune buffer using sand from an external source. However, it should be noted that the construction of the seawall is not expected to significantly reduce the losses of sediment from the area, and an average annual renourishment requirement of 7,000 m^3/year is expected.

The construction of groynes or headlands is not recommended because they are not the most cost effective option as they will be visually and physically obstructive to the users of the beach. In addition, they are likely to have an adverse effect on the surrounding coastline, and may be less effective in the longer term. In essence this solution would transfer the erosion problem to the coast to the north.

Seawall construction without renourishment is not recommended. Although the seawall would preserve the Car Park, it is likely that the beach would be lost through continued erosion seawards and longshore of the seawall.

Allowing the erosion to continue (ie do nothing) is also not recommended. Although the upper foreshore would continue to supply sand to the eroding beach, access and other amenities would be lost, and in the longer term, a section of Ocean Drive may be threatened.

Contents

1. Introduction

1.1 General

The Shire of Wanneroo (previously the City of Wanneroo) has been involved in combating coastal erosion at Quinns Rocks since 1970 when a seawall was constructed to protect the parking lot and toilet block located at the end of Quinns Road. Additional protection works were completed in 1977, with a rubble headland built to the immediate south of Quinns Cusp to encourage accretion along the Southern Beach. Presently, coastal erosion is threatening to undermine the car park located to the north of the cusp, and there are also concerns regarding the ongoing stability of the Southern Beach and adjacent Ocean Drive (refer to Figure 1.1).

In 1997, a study of the coastal processes at Quinns was prepared by Tremarfon (1997) which recommended a combination of sand renourishment and retreat in the short term, with the construction of seawalls at defined locations in the longer term if renourishment proved ineffective and the foreshore continued to recede. The option of seawalls was reviewed by the Department of Transport (Transport*)* and concerns were raised regarding the potentially adverse effects and likely costs.

The present study was commissioned by the Shire of Wanneroo (Wanneroo) to provide a comprehensive evaluation of the coastal protection options available. These options include renourishment, seawall construction, groynes / headlands and breakwaters. The study is defined by the following three stages:

- **Stage 1**
  The review of existing data and technical reports, the calculation of appropriate design criteria for coastal protection options, and the preliminary review of coastal protection options.
- **Stage 2**
  A comprehensive review of suitable coastal protection options.
- **Stage 3**
  The final design and cost estimate of the coastal management option nominated by Wanneroo.

The results of the Stage 1 investigations were presented in Rogers & Associates (1999), and the results and recommendations of Stage 2 are presented in this report.

1.2 Study Area

Quinns Beach is located approximately 35 km north of Perth, Western

Australia. Thousands of years ago sand accreted in the sheltered coastal region north-east of Quinns Rocks, forming what is referred to as Quinns Cusp (Smith, 1985). However, in more recent times, sections of this cusp have eroded, with the recession of the foreshore threatening to undermine public assets and reduce the recreational amenity of the beaches.

The focus of this study is the protection of amenities which are located along the section of coastline between Caldera Close in the south and Tapping Way in the north. For the purpose of the study Quinns Cusp will be referred to as the *Cusp*, the foreshore located to the south of the Cusp will be referred to as the *Southern Beach*, and the foreshore located to the north of the Cusp will be referred to as the *Northern Beach* (refer to Figure 1.1).

1.3 Results of Stage 1

Coastal Processes

Existing data and technical reports were reviewed. This information was supplemented through further investigation and analysis described in the Stage 1 Report (Rogers & Associates, 1999). The results of the study indicated that the artificial headland constructed to the south of the Cusp in 1977 greatly influenced the stability of the Quinns coast. Since its construction, the Southern Beach has remained relatively stable while the Northern Beach has progressively eroded. This finding was the principal difference between the Stage 1 Study and Tremarfon (1997). The latter indicated that the erosion of the Northern Beach may be the result of severe storms experienced between 1994 and 1996 rather than a progressive trend.

Sediment budgets based on shoreline movements and a comparison of surveys recorded between 1977 and 1997 indicated that the volume of sand along the Quinns beaches varied significantly with both seasonal and annual fluctuations. However, on average, about 4,000 m^3/year accreted on the Southern Beach and about 8,500 m^3/year was lost from the Northern Beach.

Design Criteria

Design still water levels were determined from the results of Steedman (1988) and analysis completed as part of the present study (refer to Table 1.1).

The computer model 2GWave was used to analyse the wave climate at Quinns and determine appropriate nearshore significant wave heights for a range of storm events (refer also to Table 1.1). However, in most cases the height of incident waves will be depth limited with energy losses occurring as the waves approach the foreshore entering shallower water.

Table 1.1 - Nearshore Design Criteria

ARI Event	Design Still Water Level	Significant Wave Height (at -4 m CD)
10 year	+1.75 m CD ($\approx$ 1.0 m AHD)	2.5 m
20 to 30 year	+1.8 m CD ($\approx$ 1.1 m AHD)	2.6 m
50 to 100 year	+1.9 m CD ($\approx$ 1.2 m AHD)	2.8 m

Preliminary Analysis of Management Options

Southern Beach

The evaluation of coastal processes at Quinns indicated that since the construction of the artificial headland in 1977, the Southern Beach remained relatively stable, with survey results indicating that the beach accreted by about 80,000 m^3 between 1977 and 1997. The present beach berm provides effective protection to the primary dune. However, during very severe storm events the dune may erode.

To protect Ocean Drive from being undermined by the gradual erosion of the primary dune, it was recommended that the following management options be considered in Stage 2:

1. Do nothing.
2. Sand renourishment on an as needed basis in response to severe storm erosion.
3. Seawall construction.

Northern Beach

The evaluation of coastal processes at Quinns indicated that since the construction of the artificial headland in 1977, the Northern Beach has progressively eroded. Survey results indicated that the beach eroded by about 170,000 m^3 between 1977 and 1997. The preliminary evaluation of management options recommended investigation of the following options in Stage 2:

1. Do nothing.
2. Regular sand renourishment.

3 Seawall construction.

4 Combined lower strength seawall construction and regular renourishment.

5 Groyne / Headland construction.

2. Management Options

2.1 Do Nothing

The Do Nothing Option is essentially that, to implement **no** coastal protection measures and allow the foreshore to be reshaped in response to natural coastal processes. On eroding coastlines this option can be referred to as retreat, and is often considered appropriate in cases where interference with coastal processes is undesirable or where the cost of protection works exceeds the value of amenities threatened by erosion.

The suitability of the Do Nothing Option is dependent on the cost and impacts of the alternative management options in comparison to the value (financial, recreational, environmental etc) of the amenities which are likely to be lost if the Do Nothing Option is adopted.

2.2 Sand Renourishment

The Renourishment Option involves artificially replacing the sand which is eroded from Quinns Beach. Sand renourishment is generally viewed throughout the world as an environmentally friendly or soft coastal management option. It allows the natural coastal processes to continue to remove sand from the eroding section of coast without causing a recession of the foreshore. The sand feeds into the system preventing deficiencies in sediment supply to downcoast beaches, thus avoiding the relocation of the erosion problem further along the coast. In appropriate locations, long stretches of shore can be maintained through a relatively small input of sand.

Provided appropriate quantities of suitable sand are used, the Renourishment Option can maintain existing facilities, beach widths and dune locations with limited adverse effects on the surrounding environment. The suitability of this option is dependent of the volume of sand required, and the availability and cost of suitable sand.

Source and Cost of Suitable Renourishment Sand

A number of sand pit operators were contacted and queried on the availability of sand suitable for renourishment at Quinns. Rocla Quarries identified a number of sources of sand which may be suitable, and estimated that supply costs were likely to be between $7/t to $10/t. It is likely that if a long term renourishment programme is established, or large volumes are required to saturate groynes or headlands, then more competitive prices could be obtained. Therefore, the supply cost of $7/t is considered appropriate for the cost evaluation of options involving sand renourishment.

The Overfill Factors of the sand offered by Rocla Quarries were calculated in accordance with the Shore Protection Manual (1984) and ranged between 1.00 and 1.11. Therefore, assuming an Overfill Factor of 1.1 and an average compacted density of about 1.75 t/m^3, the cost to replace sand lost due to erosion sand is estimated at \$13.50/m^3. It is important to note that this figure is different to the cost of supplied uncompacted or loose sand (ie in the truck), which is estimated to cost about \$10.50/m^3.

Additional costs will include management, administration and the spreading and general stabilising of the sand (assume total cost of \$1.50/m^3). Therefore, for the purposes of the investigation a cost of \$15/m^3 in situ has been used for the replacement of sand lost through erosion or introduced to saturate groynes or headlands.

The Shire of Wanneroo is presently seeking tenders for renourishment works to be conducted over the next 3 years. The tender submissions are likely to identify a number of suitable sand supplies, and the award of this contract will provide a more accurate estimate of the cost of future sand renourishment.

Additional sources of sand include the sand trap at Ocean Reef and possibly offshore dredging if it proved cost effective. A number of areas to the north of Quinns are likely to be developed in the near future and suitable sand from these works may also become available.

2.3 Seawall Construction

The purpose of a seawall is to create a barrier which prevents erosion landwards of the seawall. However, it should be noted that erosion can continue seawards and longshore of the seawall, and in many cases, erosion in these areas can be increased by the construction of a seawall.

Coastal defence using seawalls is most appropriate in cases where the foreshore is generally stable or accreting under normal conditions, but suffers significant erosion during severe storm events. If the seawall is constructed to the rear of the beach, beyond the reach of the ocean during normal conditions, the beach is able to respond naturally during these conditions with a general onshore movement of sand occurring. While during periods of severe storms, when storm surges can produce increased water levels and large waves attack the shore, the seawall is able to restrict the limit of the erosion. This is the situation at the Southern Beach.

If a seawall is constructed on a beach which is eroding during normal conditions, the erosion of the beaches seawards and longshore of the seawall can be increased by wave reflection from the seawall, and a reduction in sediment supply from the region landwards of the seawall. This is the situation at the Northern Beach.

2.4 Seawall Construction Combined with Renourishment

As discussed in Section 2.3, if a seawall is constructed on a beach which is eroding during normal conditions, the erosion of the beaches seawards and longshore of the seawall can be increased by wave reflection from the seawall, and a reduction in sediment supply from the region landwards of the seawall. However, this process can be avoided through renourishment which can be used to maintain the beaches during normal conditions.

The benefit of this option over straight seawall construction is that the beach amenity is maintained for beach users, and the size and capacity of the seawall can be reduced due to the increased protection offered by the beach.

This option may be preferable over straight renourishment if the cost of the seawall is less than the cost of renourishment required to form an adequate buffer to protect the amenities. Although the seawall will reduce temporary losses during severe storm events, it is not likely that the long term net losses from the area will be reduced. In the case of the Northern Beach, the net losses are primarily caused by a net northwards longshore drift. These losses will not be prevented by the construction of a seawall.

2.5 Groyne / Headland Protection

Groynes and headlands can be used to trap littoral drift, reducing net losses in sediment and changing the angle and width of the beach. However, the influence of these structures should be carefully evaluated as the construction of groynes or headlands generally transfers the erosion problem further along the beach.

Following a period of erosion which threatened to undermine the southern flank of Ocean Drive, an artificial headland was constructed immediately south of the Cusp in 1977. Since this time the Southern Beach has remained relatively stable with a net accretion of 80,000 m^3 recorded between December 1977 and December 1997. However, it is likely that the headland transferred the erosion problem to the Northern Beach which was previously accreting and is now eroding.

If groynes or headlands are used to protect the Northern Beach, it is likely that the beach to the north of the most northern structure will erode.

3. Management of the Southern Beach

3.1 Coastal Processes

Since the construction of the artificial headland in 1977, the Southern Beach has remained relatively stable. Survey results indicate that the region accreted by about 80,000 m^3 between December 1977 and December 1997. However, localised erosion produced some recession of the primary dune. Observations by Wanneroo personnel, and SBEACH modelling undertaken in Stage 1, indicates that severe storm events are capable of eroding the beach berm and producing a minor recession in the primary dune.

Sediment volume change analysis of the survey results indicated that the localised loss from the primary dune was about 6,000 m^3. This, combined with the 6,000 m^3 of sand renourishment undertaken by Wanneroo in November 1997, indicates that although the Southern Beach has accreted over the past 20 years, localised erosion has produced a loss of about 12,000 m^3 from the primary dune. This amount is relatively small in the overall system. However, it does suggest that a succession of severe storm events may reduce the buffer protecting Ocean Drive and threaten to undermine it. At present, the buffer between Ocean Drive and the primary dune is as small as 15 metres in some places.

3.2 Do Nothing

If the Do Nothing Option is adopted, a succession of severe storm events may reduce the buffer protecting Ocean Drive and threaten to undermine it. The threatened section of Ocean Drive is:

1. the sole access road to 15 private residences,
2. the main route of access to other private residences, and
3. a traffic route utilised by the wider community accessing various amenities at Quinns.

A very conservative approach would be to suggest that Ocean Drive is worth at least the value of the residences which rely on the road for sole access.

The average value of properties sold along Ocean Drive was obtained from the Department of Land Administration. These records indicated that between 1996 and 1998 the average value of properties sold was $294,000 (18 sales). In 1998 the average value of properties sold was $348,000 (5 sales). Based on this information $300,000 per lot is considered to be a conservative estimate. 15 private residences at $300,000 per lot equates to $4,500,000.

Additional costs include the removal of Ocean Drive between Mary Street and Terry Road at a cost of about $50,000, plus removal costs of structures on the 15 private lots at about $75,000 (ie $5,000 per lot), and legal costs of at least $150,000 ($10,000 per lot).

Cost Analysis

The cost analysis of the Do Nothing Option is detailed in Table A.1 of Appendix A. In this analysis it has been assumed that Quinns Drive would be undermined and access to the 15 residences lost in year 35. Table 3.1 below is a summary of Table A.1.

Table 3.1 - Summary Cost Analysis of the Do Nothing Option

Discount Rate	Net Present Value of Costs
0%	$4,775,000
2%	$2,435,384
4%	$1,258,461
6%	$658,528
8%	$348,791
10%	$186,905

This analysis is based on the concept of discounted cash flow which considers that money has a real time value, ie money spent or gained now has more value than that paid or received later (refer to de Neufville *et al*, 1971). The rate at a which the value of money changes is referred to as the discount rate. This rate is dependent on the economic climate, and the objectives of the organisation intending to raise or expend revenue. For government bodies which must plan a long way into the future, long term bonds rates are often considered to be appropriate indicators of the discount rate. The current long term bonds rates are about 4% pa, and this value has been used in the final cost comparison of the management options (refer to Sections 5.1 and 5.2).

3.3 Sand Renourishment

An important factor in the management of the Southern Beach is the seasonal and interannual fluctuations in beach width. Stage 1 identified that seasonal weather conditions can produce significant rotation of the shore, with Transport surveys recording seasonal longshore movements of sediment in the order of 80,000 m^3. Inter annual fluctuations were also noted in Section 5.4 of Stage 1. Therefore, the degree of protection provided by the beach berm can vary significantly and caution should be exercised when evaluating appropriate buffers between the active shore and valuable amenities such as Ocean Drive.

In Stage 1, SBEACH modelling of a range of Southern Beach profiles was undertaken. 50 to 100 year ARI events were applied and the results indicated that the recession of the primary dune would be small (<5 metres). SBEACH modelling described in Section 4.2 (Stage 2) indicated that storm induced recession of the primary dune north of the cusp was unlikely to exceed 15 metres (at 4 metres AHD). Assuming that on occasion the berm protecting the southern primary dune may become eroded to form a beach similar the Northern Beach, recession of the primary dune during an extreme event may exceed 5 metres, but is unlikely to be greater than 15 metres. With the addition of 5 metres of buffer width to maintain a stable slope of 1V:2H between the eroded face of the dune and the edge of Quinns Drive, the minimum recommended buffer width between Ocean Drive and the 4 metre AHD contour is 20 metres.

At present, most of the Southern Beach has a buffer of 20 metres or greater. However, additional sand is recommended along the dune from Quinns Road to about 150 metres to the north (estimated volume 5,000 m^3). The 20 metre buffer is the minimum recommended by the study, and any increase in this buffer seawards of Ocean Drive will offer increased protection and will allow the Shire of Wanneroo more time to conduct emergency protection works should the need arise. An increase in the buffer to 30 metres will require about 12,000 m^3 of additional sand and is strongly recommended.

It should be noted that extending the primary dune seawards may make the dune more susceptible to erosion during severe storm events, thus increasing the renourishment required to maintain the dune. Using SBEACH, a 50 to 100 year ARI event was modelled for a Southern Beach profile with the inclusion of an additional 10 metre buffer. The results suggested an additional loss of about 1.25 m^3/m, which equates to about 500 m^3 per extreme event. This volume is not substantial considering erosion of the primary dune is not expected more frequently than once every five years. However, the cost for the additional material has been included in the cost evaluation detailed in Table A.2 of Appendix A.

Additional costs include the revegetation of the face of the dune. This may cost in the order of $15,000 (400 m x 12.5 m x $3/m^2) following the increase in the buffer protecting Ocean Drive, and about $5,000 following severe storm events which cause significant erosion requiring renourishment.

Cost Analysis

The cost analysis of the Renourishment Option is detailed in Table A.2 of Appendix A. Table 3.2 below is a summary of Table A.2.

Table 3.2 - Summary Cost Analysis of the Renourishment Option

Discount Rate	Net Present Value of Costs
0%	$681,000
2%	$559,187
4%	$482,862
6%	$433,123
8%	$399,440
10%	$375,784

3.4 Seawall Construction

Section 4.5 contains a detailed evaluation of the management of the Northern Beach through a combination of sand renourishment and seawall construction. The severe wave heights at the Southern Beach are similar to those at the Northern Beach, and provided the Southern Beach continues to remain stable during normal conditions, it is comparable with the Northern Beach maintained through renourishment. Therefore, the seawall recommended for the Northern Beach in Section 4.5 (refer to Figure 4.10B) is considered appropriate for the Southern Beach.

The seawall would be constructed along the primary dune, and should not be exposed to wave action under normal conditions due to the protection offered by the foredune. Under severe storm conditions when the foredune may be eroded through the offshore movement of sand, the seawall will halt the recession of the shore and prevent losses from the primary dune. Following the storm event, natural coastal processes are likely to return the sediment from the offshore and renourishment of the Southern Beach should not be required.

The length of shore south of the Cusp requiring protection is about 400 metres long. Therefore, seawall protection is likely to cost in the order of $400,000, with maintenance estimated at $40,000 per 10 year period.

A negative impact of the construction of a seawall is that it reduces the amount of sand which would have previously entered the system from erosion during severe storm events. This volume has been estimated to be about 600 m^3/year (ie about 3,000 m^3 every 5 years). If it is assumed that this material reduced losses from the Northern Beach by moving northwards during sea-breeze conditions, or by reducing the amount of sand moving south past the Cusp, then an additional 3,000 m^3 of sand renourishment will be required at the Northern Beach every five years. The cost of this renourishment has been included in the cost analysis for the Southern Beach detailed in Table A.3 of Appendix A, because the works are required as a direct result of constructing a seawall to protect the Southern Beach.

Cost Analysis

The cost analysis of the Seawall Option is detailed in Table A.3 of Appendix A. Table 3.3 below is a summary of Table A.3.

Table 3.3 - Summary Cost Analysis of the Seawall Option

Discount Rate	Net Present Value of Costs
0%	$790,000
2%	$677,117
4%	$603,581
6%	$554,161
8%	$519,925
10%	$495,511

3.5 Seawall Construction Combined with Renourishment

The Southern Beach accreted by about 80,000 m^3 between December 1977 and 1997. Although some of the primary dune eroded during this period, it is likely that this localised erosion can be managed through either renourishment or the construction of a seawall. Unless the Southern Beach enters an erosion trend, the combination of seawall construction and regular renourishment is not considered warranted. One or the other should be adequate to manage the Southern Beach.

3.6 Groyne / Headland Construction

Since the construction of the headland in 1977, the Southern Beach has remained relatively stable. Modelling of storm erosion indicates that the present beach width offers adequate protection to the primary dune, with recession of the dune only expected during very severe storm events. This is supported by survey monitoring undertaken by Transport which indicates that losses from the primary dune have been relatively minor (ie about 12,000 m^3) over the past 20 years. Therefore, increases in the beach width through the construction of further headlands or groynes is not considered warranted at present.

However, it should be noted that the Southern Beach is quite dynamic and experiences significant rotation due to seasonal variations in dominant wave climates. The present regime of stability is dependent on a fine balance of large sediment fluxes, and minor changes in weather patterns may produce significant changes in the coastal processes and upset this balance. If the Southern Beach enters a trend of long term erosion, the management of the Southern Beach should be re-evaluated. Reducing the beach rotation through the construction of a second headland may be appropriate.

4. Management of the Northern Beach

4.1 Coastal Processes

Since the construction of the artificial headland in 1977, the Northern Beach has progressively eroded, receding at a rate of about 1 m/year. The total net loss of sediment from the Northern Beach was about 170,000 m^3 during the twenty year period between December 1977 and December 1997 (ie about 8,500 m^3/year).

Survey analysis, and wave modelling and analysis indicates that this loss of sediment is the result of small net differences in much larger seasonal fluctuations of longshore sediment transport. On average, there is a net movement of sand northwards along the coast. This sand is not replaced with sufficient quantities of sand entering the system from the south, and hence there is a net loss of sand from the Northern Beach.

Waves produced by summer sea-breezes are believed to be the principal cause of the northwards longshore transport of sediment. Although severe storms can produce offshore movements of sediment and recession of the primary dune, they are not believed to be the cause of the progressive erosion at the Northern Beach. In fact, storms from the north-west can produce significant southwards transport and reduce the net losses from the area.

Due to the complexity of the system, it is not possible to accurately determine how far the foreshore would recede before a stable realignment would be achieved, or even whether a stable realignment would be achieved at all.

4.2 Do Nothing

The present buffer between the active shore and the Northern Car Park and Stubbs Park is minimal. The Car Park itself facilitates access to the Northern Beach and supports a toilet block and surf club. Without appropriate coastal management these facilities will be undermined if the present rate of erosion continues.

The present buffer protecting the northern flank of Ocean Drive is considered barely adequate. The height of Ocean Drive varies between 10 metres and 16 metres AHD. Assuming an average height of about 11 metres AHD and a stable slope of 1V:2H, Ocean Drive may become unstable if the 4 metres AHD contour recedes to within 14 metres of the road.

The buffer between the road and the 4 metres AHD contour is less than 30 metres in places and the section of Ocean Drive between Mary Street and

Terry Road may be undermined within 15 to 20 years, if the buffer continues to recede at the present rate of 1 m/year. The full length of Ocean Drive between Robinson Road and Robert Road may be undermined within 35 years.

Figure 4.1 shows the approximate location of the present 4 metres AHD contour location and the estimated location of this contour in 15, 25 and 35 years, assuming an average recession rate of 1 m/year. Also shown is the 14 metre buffer from Ocean Drive required to insure slope stability.

The combination of a gradual erosion trend with episodic recession of the foreshore during severe storm events may threaten to undermine Ocean Drive sooner than the noted 15 to 20 year period. SBEACH modelling was used to evaluate the possible storm induced erosion which may threaten Ocean Drive. A profile extending seawards of a location approximately 50 metres south of Mary Street was used. This profile was obtained from Transport's October 1996 survey. A series of 50 to 100 year ARI events were applied, with the storm induced sand bar removed between storm events. This conservative approach was adopted to simulate the combination of storm erosion and possible losses due to longshore movements.

The SBEACH modelling indicated that a single 50 to 100 year ARI event would produce a relatively minor recession in the 4 metres AHD contour of about 3 metres. However, with the offshore bar removed and the event repeated, the 4 metres AHD contour retreated about 10 metres landwards of its initial location. This process was repeated a further 2 times with the final position of the 4 metres AHD contour located about 13 metres from its initial location. The results of the SBEACH modelling are supported by the coastline movement analysis conducted in Stage 1, which indicated that between 1970 to 1998 a maximum recession of 12 metres occurred between December 1980 and October 1983. Therefore, although the average recession rate is about 1 m/year, it is possible that a series of severe storm events may produce a recession of the primary dune by as much as 15 metres.

Threatened Amenities

Assuming a 1 m/year rate of foreshore erosion, the following amenities are likely to be threatened by coastal erosion within a 35 year period:

1. Northern Car Park,
2. Stubbs Park,
3. Surf Club,

4. Toilet Block,

5. Northern Beach, and

6. Quinns Drive between Robinson Road and Robert Road.

The Northern Beach is listed among the threatened amenities because the desirability of the location to beach users will be greatly reduced by the loss of the vehicle access provided by the Northern Car Park, the loss of amenities provided by the public toilets, and the loss of the safety and recreation opportunities provided by the surf club.

Threatened Amenities 1 to 5

Methods for Determining Economic Value

The present and future economic value of the amenities associated with the Northern Beach (ie amenities 1 to 5 listed above) is difficult to determine accurately. Evaluating the construction costs of the human made facilities is not an appropriate method of determining the overall value, as this excludes the value of the benefit they provide to the community. After all, the facilities would not have been constructed if the benefits did not outweigh the costs.

South Australian Coastal Protection Board (1993) lists the following four methods for determining the value of beaches:

1. Shadow Prices - Use related market prices as an indication of the value of the likely benefit or willingness-to-pay (eg the cost to enter a public swimming pool).
2. Travel Cost Method - Estimate the travel costs to and from the beach, and other associated costs, to estimate the minimum amount that people are prepared to pay to use the beach.
3. Contingent Valuation Method - Asking people directly what they are prepared to pay to receive the benefit of the beach, or alternatively be compensated for the loss of the beach.
4. Hedonic Price Method - Infers values for particular resources based on related markets (eg the influence of beach frontage on property prices).

Evans *et al* (1993) used methods 1, 2, and 4 listed above when evaluating the economic value of Adelaide metropolitan beaches. The study included the effect on property values, day users of the beaches, and public finance (rates only). Evans *et al* estimated that the Adelaide metropolitan beaches were worth an average of between \$550,000/km/year and \$750,000/km/year.

Beach Value Specifically Related to Vehicle Access and Facilities

Various studies conducted in Western Australia and elsewhere (Elliott, 1986, Hassell *et al*, 1986 and Houghton, 1988) have identified that access and facilities are key factors in beach usage. Houghton (1988) stated that, *"40% of the* (Perth) *metropolitan coastline attracts relatively little use. For the most part, this situation appears to reflect difficulty of access and a general lack of parking and other facilities."*

Hassell *et al* (1986) estimated that about 84% of Adelaide's beach users arrived by car, and $250,000/km/year to $450,000/km/year of the Evans *et al* (1993) beach value estimation related to the day users of the beaches. Therefore, adequate vehicle access to the Adelaide beaches can be considered to be worth between $210,000/km/year and $380,000/km/year (ie 84% of the above).

Houghton (1988) concluded that the travel habits of beach users at Perth and Adelaide were broadly similar. Houghton (1988) also found that of the Perth metropolitan beach users which travelled by car, over half travelled a distance greater than 10 km to the beach. This suggests that as the North-West Corridor develops there will be an increasing demand for parking and other amenities at Quinns Beach. In the five years between 1991 and 1995, Wanneroo North-West was the fastest growing statistical division in Western Australia. The population increased from 5,855 to 17,880 at an average annual rate of 25% per year. Wanneroo Central Coastal was the third fastest growing statistical division in Western Australia, and the second fastest within the Perth metropolitan statistical division. Its population increased from 25,263 to 38,889 at an average annual rate of 9% per year.

Woods (1989) described the beach north of the Northern Car Park as "*a good sandy beach"*, which would "*obviously attract user pressure"*, and estimated that the beach could attract in the order of 400 users at any one time. The Northern Car Park has a capacity of about 140 vehicles, which would facilitate 350 people, assuming an average of 2.5 people per vehicle.

The construction of a second car park on the northern flank of Quinns (north of Tapping Way) was not recommended by Woods (1989). The preferred option was to direct users further to the north through the provision of appropriate facilities where the landforms were more stable. Clearly, the sacrifice of the existing Northern Car Park and associated amenities would further increase pressure on the surrounding beaches.

Assuming the Northern Car Park can facilitate about 350 people at any one time, it is not difficult to believe that as the North-West Corridor develops this Car Park will be regularly at, or just below, capacity during peak periods such as summer weekends. 350 people is only a little above 84% (ie the approximate % of dependence on vehicle access) of the 400 beach users estimated in Woods (1989).

The number of people using Perth metropolitan beaches was evaluated by Houghton (1988). Houghton (1988) used an aerial survey to quantify the number of people using the beaches between 11:30 AM and 12:00 PM on Sunday 7 February 1988. Houghton (1988) found that there was over 1 person/metre of beach at Hillarys Boat Harbour, Sorrento, Trigg, Scarborough, North Swanbourne, North Cottesloe, Cottesloe and Port Beach (note: the survey area did not extend to Quinns). If adequate facilities are available, beach usage at Quinns in excess of 1 person/metre, or in excess of 500 people within a 500 metre section of beach in the vicinity of the Northern Car Park, is considered reasonable in the longer term.

Also, it is likely that most people will not stay at the beach for the entire day. Therefore, a majority of parking spaces will be utilised by multiple vehicles over the course of a single day.

Peak usage of the beach is expected to be during summer weekends and public holidays, with an expected reduction in usage during the other seasons and on weekdays.

Shadow Prices Method Evaluation of the Northern Car Park

Based on the above information, and assuming that the recreational amenity of a beach can be loosely compared with the recreational amenity provided by a public pool (cost $\approx$ \$3/person), the Shadow Prices method can be used to determine the economical value of the beach amenity provided by the Northern Car Park.

- Summer Peak Usage = 350 people
- Summer Peak Daily Usage = 2 x (Summer Peak Usage)

  = 700 people/day
- Summer Weekly Usage = 2 x (Summer Peak Daily Usage)

  + 5 x (Summer Peak Daily Usage) x (20%)

  = 2100 people/week

- Other Seasons Weekly Usage = (Summer Weekly Usage) x (15%)

  = 315 people/week

- Yearly Usage = 13 x (Summer Weekly Usage)

  + 39 (Other Seasons Weekly Usage)

  = 39,585 people/year

- **Economic Value = (39,585 people/year) x ($3/person)**

  = $119,000/year

The above assessment used best guess approximation to determine the beach usage. Insufficient information was available to determine more accurate figures, and the scope of the Study did not include or warrant a more comprehensive investigation into beach usage.

The 20% of beach users which do not depend on vehicle access to beaches are unlikely to be deterred by the loss of the Car Park. However, the loss of the surf club and toilet facilities would make the Northern Beach less desirable. If it is assumed that about half of these beach users were deterred by the loss of facilities, then the total economical value of the Northern Beach amenities would be about **$131,000/year** (ie 110% of $119,000/year).

The approach used to determine the economical value of the Northern Beach is considered to be very conservative. This is supported by Evans *et al* (1993) which estimates that a similar length of Adelaide's beaches is worth 2 to 3 times the above value.

Additional costs of sacrificing Amenities 1-5 include the cost to remove the Car Park pavement, the Toilet Block and Surf Club. These demolition and removal costs are estimated at $45,000.

Threatened Amenity 6

Quinns Drive between Robinson Road and Robert Road is the sole access road to 35 private residences. It is also the main route of access to other private residences, and is a traffic route utilised by the wider community accessing various amenities at Quinns. A very conservative approach would be to suggest that Ocean Drive is worth at least the value of the residences which rely on the road for sole access.

The average value of properties sold along Ocean Drive was obtained from the Department of Land Administration. These records indicated that between 1996 and 1998 the average value of properties sold was $294,000 (18 sales). In 1998 the average value of properties sold was $348,000 (5 sales). Based on this information $300,000 per lot is considered to be a conservative estimate.

Additional costs include the removal of Ocean Drive between Mary Street and Terry Road at a cost of about $100,000, plus removal costs of structures on the 35 private lots at about $5,000 per lot, and legal costs of $10,000 per lot.

Cost Analysis

The cost analysis of the Do Nothing Option is detailed in Table A.4 of Appendix A. Table 4.1 below is a summary of Table A.4.

Table 4.1 - Summary Cost Analysis of the Do Nothing Option

Discount Rate	Net Present Value of Costs
0%	$14,903,500
2%	$9,297,448
4%	$6,046,391
6%	$4,084,995
8%	$2,854,998
10%	$2,055,000

4.3 Sand Renourishment

Since the construction of the artificial headland in 1977, the Northern Beach has progressively eroded, receding at a rate of about 1 m/year. The total net loss of sediment from the Northern Beach was about 170,000 m^3 during the twenty year period between December 1977 and December 1997 (ie about 8,500 m^3/year). However, it is not clear how much of this quantity is associated with changes which occurred immediately following the construction of the artificial headland which may have now stabilised, how much is associated with changes resulting from the severe winter storms of 1995 and 1996, and how much is associated with other fluctuations in weather patterns.

Figure 5.1 of the Stage 1 report shows a possible future sediment budget based on the assumption that the beach to the south of the Cusp had become saturated and the Southern Beach was no longer accreting at a rate of 4,000 m^3/year. This suggests that 5,000 m^3/year may be sufficient to protect the Northern Beach, with an additional 2,000 m^3/year needed to protect the beach to the north of the Study area.

For evaluation and planning purposes it is recommended that an average annual renourishment requirement of 7,000 m^3/year (in situ) is used for the Northern Beach. This should allow for losses which may occur as a result of seasonal sediment transport spreading the renourishment sand through the system. However, it is noted that fluctuations in weather conditions and longer term changes in erosion trends may influence the volume of sand required.

As discussed in Section 4.2, SBEACH modelling indicates that the recession of the upper foreshore (ie the 4 metres AHD contour) is unlikely to exceed 15 metres during a series of severe storm events. Therefore, a minimum buffer of 15 metres is recommended between the 4 metres AHD contour and the edge of the Northern Car Park, and 30 metres is recommended between the 4 metres AHD contour and the edge of Ocean Drive (note: additional distance is required for a stable slope between the 4 metres AHD contour and the edge of the road located at about 11 metres AHD).

These buffers are viewed as reasonable minimum distances which should be maintained. If progressive erosion or a severe storm event produces a recession in the primary dune beyond these distances, immediate action should be undertaken to increase the degree of protection, particularly if Ocean Drive is threatened.

The January 1999 survey completed by Transport indicates that in most locations along the beach the buffers protecting the Car Park and Ocean Drive are about equal to or slightly greater than minimum buffers recommended above. However, at the northern end of the Car Park an additional 1,000 m^3 of sand may be required to supplement the present buffer.

By increasing the present buffers, greater protection can be offered to the Northern Car Park and Ocean Drive, and the dependence on emergency protection works can be reduced. This would allow Wanneroo greater time to respond to a phase of foreshore recession, possibly allowing the gradual replacement of lost material through scheduled (budgeted) renourishment sessions. To increase the buffer by 10 metres along 600 metres of the most vulnerable section of foreshore, approximately 48,000 m^3 of sand would be

required (assuming an active zone from
-3 metres CD to +5 metres CD). This increase in the buffer is recommended if renourishment is adopted as the long term management option.

Cost Analysis

The cost analysis of the Renourishment Option is detailed in Table A.5 of Appendix A. Table 4.2 below is a summary of Table A.5.

Table 4.2 - Summary Cost Analysis of the Renourishment Option

Discount Rate	Net Present Value of Costs
0%	$4,395,000
2%	$3,376,265
4%	$2,700,617
6%	$2,250,953
8%	$1,935,863
10%	$1,706,933

4.4 Seawall Construction

The results of Tremarfon (1997) indicated that the Northern Beach had historically been relatively stable, with trends of both accretion and erosion. It was stated that the more recent foreshore erosion recorded by the vegetation line plots of 1985 and 1995 were possibly the result of severe storm events between 1993 and 1995. Based on these findings, the construction of a seawall was recommended if the erosion trend persisted.

Stage 1 of the present study reviewed the findings of Tremarfon (1997), and obtained additional information from subsequent surveys and evaluation of aerial photography. The results indicated that although the severe storms between 1993 and 1995 may have contributed to the erosion, the erosion of the Northern Beach appeared progressive since the construction of the artificial headland in 1977, with the principal cause of the erosion likely to be a reduced sediment supply from the south due to the headland. This finding greatly alters the criteria used to determine the most appropriate coastal management options for the Northern Beach, and the criteria used in their design.

In general, seawalls are not recommended for locations which exhibit the trends identified at the Northern Beach by Stage 1 of the present study. Waves produced by the summer afternoon sea-breeze, and west to south-west winter seas will continue to produce a northwards longshore movement of sand, and although swell and north of west winter storms may return some of this sand to the Northern Beach, a continuation of the past net losses is expected. These losses will denude the beaches seawards and longshore of the seawall, increasing the water depth at the toe of the seawall and allowing larger waves to attack the seawall.

The erosion rate over the last 20 years has averaged about 1 m/year. If this trend continues, a foreshore recession of 25 metres is predicted over the next 25 years. This foreshore recession was applied to a beach profile obtained from the December 1997 survey results, and the resulting profile was modelled using SBEACH for 20-30 year ARI and 50-100 year ARI storm events. The results are displayed in Figures 4.2 and 4.3.

The SBEACH modelling was repeated for the 20-30 year ARI event assuming 35 years of erosion at a rate of 1 m/year (refer to Figure 4.4). Allowing for the additional 10 years of erosion did not increase the maximum significant wave height at the seawall or the maximum eroded depth at the seawall. However, seabed depths further seawards of the seawall were greater and increased protection at the toe may be required in the longer term if the foreshore continues to erode at the present rate.

The seawall would remain accessible for maintenance should the need arise, and the degree of protection required for public assets such as car parks is generally viewed as less critical than the protection required for private residences and essential roadways. Therefore, for the purposes of the preliminary design of the seawall, the 20-30 year ARI event is considered appropriate. The profile which assumed 25 metres of erosion produced the greatest depth immediately seawards of the seawall and was therefore used (refer to Table 4.3). However, as noted above, the profile which assumed 35 metres of erosion produced the larger depths further seawards. Therefore, additional works to reinforce the toe may be required in the longer term.

Table 4.3 - Seawall Design Criteria

Significant wave height (H_s)	2.5 metres
Eroded depth at toe	-3.1 metres AHD
Estimated eroded depth at toe with adequate toe protection	-2.0 metres AHD

Seawall Construction Methods

Revetment Mattresses

Research conducted by the University of New South Wales Water Research Laboratory (1997) on behalf of Foreshore Protection Pty Ltd indicated that the collapsible block revetment mattress system installed at a slope of 1V:2H was not suitable in wave climates of 1.1 metres or greater (water depth = 4 metres, wave period = 10 seconds). Given that this system was the most robust and appropriate system recommended to Transport (Transport, 1998) by Foreshore Protection Pty Ltd, and assuming that other revetment mattress suppliers do not have cost effective systems which are able to withstand significant wave heights of 2.5 metres, the use of a revetment mattress to construct a seawall is not recommended.

Geofabric Tubes

Geofabric tubes are not recommended because the seawall is likely to be regularly if not constantly exposed, and the tubes would be vulnerable to damage and vandalism.

Interconnected Concrete Blocks

Transport (1998) reviewed a system of interconnected concrete blocks referred to as "Seabees". The design capacity and cost of Seabee seawalls constructed at Wamberal Beach (NSW) and Beacon Cove (VIC) were detailed. The seawall at Wamberal Beach appears to be similar to the seawall which would be required at the Northern Beach (refer to Table 4.4).

The seawall at Wamberal Beach is slightly higher (toe to crest) and can withstand slightly larger waves. However, the expected trend of progressive erosion at the Northern Beach will necessitate more extensive toe protection and support. Therefore, given that the Seabee seawall at Wamberal Beach cost about $4,800 per lineal metre, it is estimated that a seawall of similar configuration at the Northern Beach will cost about the same.

Table 4.4 - Seabee Seawall Comparison

Location	Wamberal Beach	Northern Beach Quinns
Significant wave height	2.8 metres	2.5 metres
Wave period	14.4 seconds	8 seconds
Crest RL	8.0 metres	6 metres (AHD)
Toe RL	-0.6 metres	-2 metres (AHD)

Rubble Seawall

Throughout Western Australia rubble (ie rock) is generally the preferred material for the construction of coastal protection structures in locations exposed to large wave action. This is primarily due to the availability and low cost of suitable rubble, coupled with its ability to progressively rather than suddenly fail when overloaded.

A preliminary design was prepared (refer of Figure 4.5) using the ACES design package (developed by the US Army Corps of Engineers) to determine the appropriate armour size and filter layer. It is estimated that the rubble seawall will cost in the order of $3,770 per lineal metre (refer to Table 4.5).

Maintenance of the seawall should be minimal during the first 10 years. However, as the beach seawards of the seawall erodes, the wave forces on the seawall will increase. The seawall has been designed to withstand severe storm wave attack (20 to 30 year ARI storm event) without the protection currently provided by the beach. However, over time the rubble at the toe of the structure may settle within the seabed, and additional armour at the toe may be required. An allocation of $330/m for maintenance in the 20th year (ie 10 m^3/m of armour stone at $33/$m^3$) is considered appropriate.

Table 4.5 - Option 3 Rubble Seawall Cost Estimates

Item	Rate	Amount	Cost
Armour	$33/m^3	72 m^3/m	$2,376.00/m
Filter	$33/m^3	21 m^3/m	$693.00/m
Excavation			
Dozer	$0.50/m^3	50 m^3/m	$25.00/m
Excavator	$5.50/m^3	33.5 m^3/m	$184.25/m
Subtotal			**$3,278.25/m**
Management	5%		$163.91/m
Contingencies	10%		$327.83/m
Total			**$3,769.99/m**

Schedule of Works

Option 3 would initially involve the construction of a seawall to protect the Northern Car Park at a cost of about $1,320,000 (ie 350 metres at $3,770/m).

If the present trend of erosion to the immediate north of the Car Park continued, then an extension of the seawall to protect Ocean Drive would be required in approximately 15 years, at a cost of about $2,451,000 (ie 650 metres at $3,770/m).

After the foreshore seawards of the seawall has eroded and the wall is exposed to larger wave action, it is likely to require maintenance works following severe storm events. Also, as noted in the beginning of this section, additional toe protection may be required in the longer term. An allowance for $400,000 of maintenance and reinforcement works is recommended, and has been applied in the 35th year of the cost analysis.

Impacts

Wave reflection from the seawall and a reduction in the amount of sediment entering the system from the protected area, may increase the erosion of the beaches longshore and seawards of the wall. It is likely that the beach seawards of the seawall would be lost within 5 years of the construction of the seawall. If the present trend of erosion to the immediate north of the Car Park continued, then the beach would erode back to the primary dune within 10 years, and would be completely lost within 20 years.

Cost Analysis

The cost analysis of the Seawall Option is detailed in Table A.6 of Appendix A. Table 4.6 below is a summary of Table A.6.

Table 4.6 - Summary Cost Analysis of the Seawall Option

Discount Rate	Net Present Value of Costs
0%	$7,092,000
2%	$5,279,487
4%	$4,116,066
6%	$3,344,544
8%	$2,817,720
10%	$2,448,595

4.5 Seawall Construction Combined with Renourishment

Renourishment Requirements

It is likely that the principal cause of the erosion of the Northern Beach is a gradient in longshore drift, with an insufficient supply of sediment to replace lost material. Smith Corporation (1985) indicated that there is minimal sediment exchange between Quinns and the rocky headlands to the south, or between Quinns and the offshore. Therefore, it is likely any net losses from the Quinns area result from northerly sediment movements which are produced by summer sea-breeze conditions and west to south west winter seas.

As the construction of a seawall will not prevent the losses of beach sand due to the above processes, it is predicted that the volume of material needed to maintain the beach seawards of the seawall would be equivalent to the annual renourishment requirements detailed in Section 3.3 (ie 7,000 m^3/year).

Seawall Design Criteria

SBEACH was used to model the effect of 20 to 30 year ARI and 50 to 100 year ARI storm events on the Northern Beach, with the inclusion of a seawall at Chainage 30 metres (refer to Table 4.7 and Figures 4.6 and 4.7).

Table 4.7 - Seawall Design Criteria (with renourishment)

Event	20 to 30 year ARI	50 to 100 year ARI
Significant wave height	0.8 metre	1.0 metre
Eroded depth at toe	-0.3 metre AHD	-0.9 metre AHD
Estimated eroded depth at toe with adequate toe protection	-0.1 metres AHD	-0.3 metre AHD

Although the design of the seawall proposed in Section 4.4 used the 20 to 30 year design criteria, it was decided that the design of the seawall for the present option would use the 50 to 100 year design criteria. This was because the present option's seawall is dependent on the protection provided by the beach which is to be maintained through renourishment. This introduces a process which requires regular monitoring and management activities which may be delayed due to unforeseen circumstances. Therefore, a more conservative approach was adopted.

Seawall Construction Methods

Revetment Mattresses

Research conducted by the University of New South Wales Water Research Laboratory (1997) on behalf of Foreshore Protection Pty Ltd indicated that the collapsible block revetment mattress system installed at a slope of 1V:2H was not suitable in wave climates of 1.1 metres or greater (water depth = 4 metres, wave period = 10 seconds). This suggests that the revetment mattress would be at the limit of its capacity in the event of the conditions predicted for a 50 to 100 year ARI storm, and an insufficient safety factor would exist for possible faults in the mattress or for wave forces in excess of those predicted. Unlike a rubble seawall which would continue to offer substantial protection following partial failure, significant losses could be expected if the revetment mattress system failed during a severe storm event.

Although the use of the above revetment system is not recommended due to its limited capacity, a preliminary design was prepared to enable a cost estimate (refer to Figure 4.8) of the system. Based on the approximate cost of $46.75/m^2 for the revetment mattress as detailed in Transport (1998), it is estimated that the system would cost in the order of $1,550 per lineal metre to install (refer to Table 4.8). This cost is in excess of other seawall options detailed below, and it is considered unlikely that other revetment mattress manufactures would be able to supply alternative revetment mattress systems which have greater design capacity, at a significantly reduced cost. Therefore, the use of revetment mattress systems to protect the Northern Car Park and Ocean Drive is not recommended.

Table 4.8 Option 4 Revetment Mattress Cost Estimates

Item	Rate	Amount	Cost
Revetment Mattress	$46.75/m^2	17.6 m^2/m	$822.80/m
Filter Layer	$33.00/m^3	12.5 m^3/m	$412.50/m
Excavation			
Dozer	$0.50/m^3	135 m^3/m	$67.50/m
Excavator	$5.50/m^3	7.5 m^3/m	$41.25/m
Subtotal			**$1,344.05/m**
Management	5%		$67.20/m
Contingencies	10%		$134.41/m
Total			**$1,550/m**

Geofabric Tubes

For the purposes of evaluating sand filled geofabric tubes as seawall protection for the Northern Beach, products supplied by Maccaferri Pty Ltd were evaluated. A preliminary design of a geotube configuration was prepared (refer to Figure 4.9), and approximate installation costs determined (refer to Table 4.9). It is estimated that the use of Geotubes to protect the Northern Car Park and Ocean Drive would cost in the order of $1,060 per lineal metre, plus $11,500 for mobilisation and demobilisation of plant.

Table 4.9 - Option 4 Sand Filled Geotube Cost Estimates

Item	Rate	Amount	Cost
Geotubes	\$240.00/m	2	\$480.00/m
Scour protection	\$100.00/m	1	\$100.00/m
Excavation			
Dozer	\$0.50/m^3	135 m^3/m	\$67.50/m
Excavator	\$5.50/m^3	7.5 m^3/m	\$41.25/m
Sand Emulsifier			
Mobilisation	\$10,000	1	\$10,000.00
Pumping	\$3.00/m^3	15 m^3/m	\$45.00/m
Extra Sand	\$15/m^3	12.5m^3/m	\$187.50/m
Subtotal			**\$921.25/m plus \$10,000**
Management	5%		\$46.06/m plus \$500.00
Contingencies	10%		\$92.13/m plus \$1000.00
Total			**\$1,060/m plus \$11,500**

Interconnected Concrete Blocks

Transport (1998) reviewed a system of interconnected concrete blocks referred to as "Seabees". The design capacity and cost of Seabee seawalls constructed at Wamberal Beach (NSW) and Beacon Cove (VIC) were detailed. The seawall at Beacon Cove appears to be similar to the seawall which would be required at the Northern Beach if the present option was adopted (refer to Table 4.10).

Table 4.10 - Seabee Seawall Comparison

Location	Beacon Cove	Northern Beach Quinns
Significant wave height	1.3 metres	1 metre
Wave period	4.0 seconds	8 seconds
Crest RL	+2.5 metres	+3.5 metres (AHD)
Toe RL	-3.2 metres	-1 metres (AHD)

The seawall at Beacon Cove is higher (toe to crest) and can withstand a slightly larger wave. Therefore, given that the Seabee seawall at Beacon Cove cost about $2,750 per lineal metre, it is estimated that a seawall of similar configuration at the Northern Beach will cost about $2,200 per lineal metre.

If the seawall is constructed satisfactorily, maintenance should be minimal during the 25 year period. However, this will be dependent on the maintenance of the beach seawards of the seawall.

Rubble Seawall

Throughout Western Australia rubble (ie rock) is generally the preferred material for the construction of coastal protection structures in locations exposed to large wave action. This is primarily due to the availability and low cost of suitable rubble.

A preliminary design was prepared (refer of Figure 4.10A) using the ACES design package to determine the appropriate armour size and filter layer. It is estimated that the rubble seawall will cost in the order of $1,120 per lineal metre (refer to Table 4.11).

Table 4.11 - Option 4 Rubble Seawall Cost

Item	Rate	Amount	Cost
Armour	$27/m^3	20 m^3/m	$540.00/m
Filter Layer	$33/m^3	4.9 m^3/m	$161.70/m
Excavation			
Dozer	$0.50/m^3	154 m^3/m	$77.00/m
Excavator	$5.50/m^3	27 m^3/m	$148.50/m
Extra Sand	$15/m^3	3.2 m^3/m	$48.00/m
Subtotal			**$975.20/m**
Management	5%		$48.76/m
Contingencies	10%		$97.52/m
Total			**$1,120/m**

Cost savings can be achieved by reducing the depth of the seawall (refer to Table 4.12). However, additional armour protection would be required at the toe of the seawall, as shown in Figure 4.10B. If the beach seawards of the seawall becomes eroded during a severe storm event, it is expected that some of the armour stone at the toe will settle into the seabed, preventing the seawall from being undermined. The alternative rubble seawall is likely to cost in the order of $1,020 per lineal metre.

The maintenance requirements for the rubble seawall would be dependent on the performance of the regular renourishment undertaken to maintain the beach seawards of the seawall. However, it may be in the order of 10% of the capital cost (ie $102/m), per 10 year period.

Table 4.12 - Option 4 Rubble Seawall with Armoured Toe

Item	Rate	Amount	Cost
Armour	$27/m^3	22 m^3/m	$594.00/m
Filter Layer	$33/m^3	4 m^3/m	$132/m
Excavation			
Dozer	$0.50/m^3	135 m^3/m	$67.50/m
Excavator	$5.50/m^3	12.5 m^3/m	$68.75/m
Subtotal			**$862.25/m**
Management	5%		$43.11/m
Contingencies	10%		$86.23/m
Total			**$1,020/m**

Recommendations

Of the seawall construction methods evaluated for the present option, the rubble seawall with an armoured toe is recommended. This seawall would initially be about 350 metres long and would extend around the seawards perimeter of the Northern Car Park, at a cost of about $350,000. Maintenance requirements include regular renourishment of about 7,000 m^3 of sand per year at a cost of about $105,000 per year, and structural maintenance of about $35,000 per 10 year period.

The principal protection will be provided by the renourishment programme. The purpose of the seawall is to provide increased protection during severe storm events and reduce the extent of erosion during these periods. Sections of the seawall may fail if the beach is not adequately maintained or if the storm event is significantly more severe than the design storm event. However, the seawall should continue to provide a significant degree of protection after partial failure.

A larger more durable seawall could be used to provide greater protection; however, it would be more costly as shown in Section 4.4. Alternatively, a smaller but less expensive seawall could be used; however, it would offer less protection during very severe events. The recommended seawall is considered to be an appropriate design for the conditions which are likely to occur during the next 35 years.

Provided the renourishment programme is successful in abating the long term erosion trend, an extension of the seawall to protect Ocean Drive should not be required. However, an increase in the renourishment programme or an extension of the seawall should be considered in the longer term, if changes in coastal processes increase the net losses due to erosion.

Cost Analysis

The cost analysis of the Seawall and Renourishment Option is detailed in Table A.7 of Appendix A. Table 4.13 below is a summary of Table A.7.

Table 4.13 - Summary Cost Analysis of the Seawall and Renourishment Option

Discount Rate	Net Present Value of Costs
0%	$4,235,000
2%	$3,205,373
4%	$2,545,602
6%	$2,107,399
8%	$1,806,003
10%	$1,591,673

4.6 Groyne / Headland Protection

The results of the 2GWave modelling conducted for Stage 1 together with the Shore Protection Manual energy flux method (CERC, 1984) were used to determine the volume of longshore sediment transport produced by the following conditions, for a range of beach angles:

- Swell,
- Sea-Breeze generated waves,
- 10 year ARI storm event,
- 20 to 30 year ARI storm event, and
- 50 to 100 year ARI storm event.

The longshore sediment transport produced by an average storm event and a 1 year ARI storm event were approximated using relative wave heights obtained from Steedman (1988). The combination of an appropriate number of each of the events was then used to obtain a net annual sediment transport for the Northern and Southern Beaches. The results indicated that a very small change in the angle of the beach was likely to significantly change the net annual movements. A rotation of the mean beach angle by 1 degree altered the net annual sediment transport at the Northern and Southern Beaches by about 12,000 m^3/year and 7,000 m^3/year respectively.

This result is supported by the response of the Southern Beach to the installation of the headland in 1977. A comparison of the November 1974 and December 1997 surveys indicates that the mean beach angle rotated by about 1 degree after the construction of the headland, and sediment budgets prepared in Stage 1 indicate that this change altered the net annual sediment transport of the Southern Beach by about 7,000 m^3 (ie -3,000 m^3 to +4,000 m^3). It should be noted, however, that the predicted changes in sediment transport are based on a number of assumptions and the results are only considered to be representative of the order of magnitude of longshore sediment movement which is likely to occur.

Based on the predicted changes in sediment transport for the Northern Beach, it is likely that only a small change in the mean beach angle (ie about 1 degree) will be required to stop the present net annual sediment loss of 7,000 m^3. However, if groynes or headlands are constructed to produce this change, seasonal changes in the direction of sediment transport are likely to produce a seasonal rotation of the beach. This rotation may be in the order of 3 degrees which is currently observed to the south of the Cusp.

To create a mean beach angle change of 1 degree, while allowing for a maximum seasonal rotation of 3 to 4 degrees, it is recommended that three structures be used (refer to Figures 4.11 and 4.12). These structures would need to be capable of extending the width of the adjacent beach by about 20 metres to allow for the combination of the mean beach angle change and the seasonal rotation of the beach (refer to Figure 4.11). It is estimated that about 70,000 m^3 of sand would be required to initially saturate these structures.

Using less structures to stabilise the beach was considered. However, this would require larger structures and more sand, and the associated costs would significantly exceed the possible savings which could be made by reducing the number of structures.

Using more structures to stabilise the beach was also considered. However, to make this scheme more cost effective than the recommended option would require a reduction in the distance that the beach is extended seawards. This was not considered feasible due to uncertainties in the saturated beach angle which would be produced by the structures. Also, it was believed that it would be preferable to beach users that the number of structures be minimised.

Design Criteria

SBEACH was used to model the effect of a 20 to 30 year ARI storm event on the Northern Beach, using the wave modelling results obtained in Stage 1. Figure 4.13 shows the predicted beach profile change and maximum significant wave heights.

After the structures have become saturated with sand, it is unlikely that the bed depth immediately seawards of the groyne or headland will exceed -1.8 metres AHD (ie 1 metre below low water). Therefore, based on the SBEACH wave height predictions, the maximum significant wave height at the structure is unlikely to exceed 2.1 metres during a 20 to 30 year ARI storm event. Based on breakwater modelling using ACES, two layers of 5 tonne limestone armour is appropriate for this wave climate.

Groyne Design and Cost Estimates

If a groyne is used to stabilise the Northern Beach, the structure will need to extend back to the primary dune to prevent wave action from eroding behind the landward end of the structure during severe storm events. The section of the structure between the dune and the present low water line is unlikely to be attacked by large wave action as it is in shallow water, and is perpendicular to the shore and in the lee of the head of the groyne. Assuming a pre-storm beach height of 1 metre AHD adjacent to this section of the structure, the significant wave height is unlikely to exceed 0.8 metres during a 20 to 30 year ARI storm event. Breakwater modelling using ACES indicates that two layers of 0.4 tonne limestone armour is appropriate for this wave climate.

Figure 4.14 illustrates the preliminary design of the a groyne suitable for the extension of the beach width immediately to the south of the structure by about 20 metres. It is estimated that this groyne would cost in the order of $130,000. Table 4.14 provides a breakdown of this preliminary cost estimate.

Table 4.14 - Groyne Cost Estimate

Item	Rate	Amount	Cost
Armour			
5 tonne	$33/m^3	1,600 m^3	$52,800.00
0.4 tonne	$30/m^3	580 m^3	$17,400.00
Core	$27/m^3	1230 m^3	$33,210.00
Excavation			
Dry Material	$1.00/m^3	1200 m^3	$1,200.00
Wet Material	$5.50/m^3	290 m^3	$1,595.00
Plant Mobilisation			$5,000.00
Subtotal			**$111,205.00**
Management	5%		$5,560.25
Contingencies	10%		$11,120.50
Total			**$128,000**

Headland Design and Cost Estimates

Figure 4.15 illustrates the preliminary design of a headland suitable for the extension of the beach width immediately to the south of the structure by about 20 metres. It is estimated that this headland would cost in the order of $140,000. Table 4.15 provides a breakdown of this preliminary cost estimate.

Table 4.15 - Headland Cost Estimate

Item	Rate	Amount	Cost
5 tonne Armour	$33/m^3	2,650 m^3	$87,450.00
Core	$27/m^3	1,000 m^3	$27,000.00
Plant Mobilisation			$5,000.00
Subtotal			**$119,450.00**
Management	5%		$5,972.50
Contingencies	10%		$11,945.00
Total			**$137,367.50**

Maintenance

The maintenance of the groynes and headlands is estimated at about $42,000 per 10 year period.

Contingencies

The recommended configuration of these structures was based on the best estimate of the likely beach change. As the estimate of the likely beach change was obtained from computer analysis and the evaluation of the effects of the existing headland on the Southern Beach, it is only considered accurate to ± 2 degrees.

Also, the present regime is dependent on a fine balance of large sediment fluxes. Fluctuations in seasonal and interannual weather conditions and minor changes in longer term weather patterns may alter this balance and change the beach angle required for stabilisation. Stage 1 indicated that the net seasonal movement of sediment at the Southern Beach may be in the order of 60,000 m^3. If fluctuations in weather conditions produce a 50% difference between the volume of sand moving south in one winter and the volume of sand moving north in the following summer, then the additional beach rotation would be in the order of 2 degrees.

If the maximum beach angle rotation is only 1 degree, then an additional 96,000 m^3 of sand would be required to saturate the structures, at a cost of about $1,440,000. Alternatively, if groynes were used then these structures could be shortened by 12 metres at a cost of about $70,000, or if headlands were used these structures could be moved 12 metres at a cost of about \$150,000.

If the maximum beach angle rotation is 5 degrees (ie 2 degrees greater than the estimated 3 degrees), then each structure would need to be extended by 12 metres and resaturated with sand. Extending the groynes would cost about \$170,000, while moving the headlands would cost about \$240,000. The additional sand is likely to cost in the order of \$300,000 (ie 20,000 m^3 at \$15/m^3).

Given the significant cost implications of small differences between the estimated mean beach angle and rotations and the possible post construction mean beach angle and rotations, it is recommended that \$300,000 is allowed as contingencies for possible remedial works.

Impacts

As noted in Section 2.5, the protection of an eroding coast using groynes or headlands often moves the erosion trend further along the coast. In the case of the protection of the Northern Beach it is likely that the erosion trend will be moved to the north of the most northern structure.

The Shire of Wanneroo has advised that to the north of the Study area the minimum development setback from the coast is about 80 metres. This coastline eroded by about 15 metres during the 18 year period between 1978 and 1995. The reduction in sediment supply caused by the construction of groynes or headlands is likely to increase this rate of erosion, and the present buffer between the shore and the intended development may be depleted and require protection within 30 years.

Assuming coastal protection costs relative to the Northern Beach, with about 1.5 km of shore to protect, the cost to protect the coast is estimated at \$2,235,000. This includes \$40,000 for investigations, \$650,000 for the construction of Groynes or Headlands and \$1,575,000 for sand renourishment.

As well as reducing the flow of sediment northwards during summer, the use of groynes or headlands to stabilise the Northern Beach may produce a reduction in the southwards flow of sediment during winter. Initially this reduction should be relatively minor. However, as the beach to the north erodes, greater quantities of sand will be required to saturate then flow around the most northern structure. Over time this may significantly reduce the flow of sediment southwards during winter, which could reduce the performance of the structures and may destabilise the Southern Beach.

Cost Analysis

The initial cost analysis of the Groyne / Headland Option is detailed in Table A.8 of Appendix A. Table 4.16 below is a summary of Table A.8.

Table 4.16 - Summary Cost Analysis of the Groyne / Headland Option

Discount Rate	Net Present Value of Costs
0%	$4,459,000
2%	$3,339,635
4%	$2,700,948
6%	$2,328,649
8%	$2,106,222
10%	$1,969,457

Following the public meeting held on the 7 September 1999, the City of Wanneroo requested that consideration be given to the cost implications of constructing the structures over a number of years.

The cost analysis of constructing 3 headlands over a period of 3 years is detailed in Table A.9 of Appendix A. Table 4.17 below is a summary of Table A.9, and Table 4.18 provides the estimated yearly expenditure for the first 10 years.

Table 4.17 - Summary Cost Analysis of the Headland Option with the Structures Constructed over 3 Years

Discount Rate	Net Present Value of Costs
0%	$4,513,000
2%	$3,329,158
4%	$2,640,487
6%	$2,227,132
8%	$1,969,483
10%	$1,801,556

Table 4.18 – Estimated Expenditure for the First 10 Years

Year	Yearly Expenditure
1st	$513,000
2nd	$513,000
3rd	$438,000
4th	$0
5th	$300,000
6th	$53,000
7th	$0
8th	$0
9th	$0
10th	$42,000

5. Public Meeting 7/9/99

The results of the study were presented at a public meeting held on the 7 September 1999 at the Gumblossom Community Centre, Quinns Rocks. In total, 51 members of the local community attended the meeting. In general the findings of the study were well received by the community. A copy of the minutes is attached in Appendix B.

During question time, discussion on the Southern Beach was relatively limited. Indications were that the community generally supported the recommendation to increase the existing dune buffer, then conduct sand renourishment on an as needed basis.

There was rigorous discussion concerning the Northern Beach. Support for the long term management of the Northern Beach was generally divided between seawall construction with ongoing renourishment, and the construction of groynes or headlands. When the preference for each of these options was put to a vote, seawall construction with ongoing renourishment received a slightly higher number of votes (14 to 11).

The Communities concerns regarding the management of the Northern Beach included:

- Adequate beach access should continue to be provided (desire expressed for continued slipway access).
- Seawall construction with renourishment requires ongoing works (some expressed preference for capital works).
- Groynes and Headlands can provide fishing opportunities.
- Groynes and Headlands along the coast will be physically and visually obtrusive.

6. Summary and Recommendations

6.1 Southern Beach Summary

Since the construction of the artificial headland in 1977, the Southern Beach has remained relatively stable. A seawall protects the Southern Car Park and Toilet Block, while natural limestone appears to protect the region to the south. Survey results indicate that the region accreted by about 80,000 m^3 during the twenty years between December 1977 and December 1997. However, analysis of Transport surveys indicates a localised loss of about 12,000 m^3 occurred from the primary dune seawards of Ocean Drive. This amount is relatively small in the overall system. However, it does suggest that without appropriate coastal management a succession of severe storm events may reduce the buffer protecting Ocean Drive and threaten to undermine it.

Suitable management options were reviewed and the results have been summarised in Table 6.1. Tables A.1 to A.3 of Appendix A provide a breakdown of the net present value of the costs of each option. These costs are also displayed in Figure 6.1, which shows the net present value of the costs for a range of discount rates.

The recommended option is to increase the present buffer (ie width of dune) protecting Ocean Drive and undertake sand renourishment following severe storm events which cause significant erosion of the primary dune. An alternative option is to construct a seawall; however, this option is assessed to be more costly and may increase the amount of erosion which occurs to the north of the cusp.

The Do Nothing Option is not recommended as storm erosion may produce a recession of the primary dune which may threaten to undermine a section of Ocean Drive which is the sole vehicle access route for 15 private residential lots. The net present value of the assets which may be lost through erosion is considered to be significantly greater than the cost of protecting them.

Table 6.1 - Summary Evaluation of Management Options for the Southern Beach

	Do Nothing	Sand Renourishment	Seawall Construction
Capital Works	None	Increase in the existing buffer protecting Ocean Drive	Seawall Construction
Ongoing / Maintenance Works	None	(2) Occasional Sand Renourishment (3,500m^3/5 years)	Minor maintenance after very severe storm events
Local Impacts	Possible loss of Ocean Drive and access to 15 private residences	Minimal	Some degree of visual impact
Environmental Impacts	Minimal	Minimal	Minimal if renourishment to the north is increased (included in cost estimate)
Net Present Value for 35 year Period[1]	$1,260,000	$480,000	$600,000
Ranking	**3**	**1**	**2**

Notes:
1. The discounted costs for the 35 year period are based on a discount rate of 4% pa. An analysis of long term bonds, inflation rates and Capital Index Bonds has indicated that this discount factor is appropriate for the current economic climate.
2. Renourishment of 3,500 m^3 in situ equates to about 4,500 m^3 uncompacted from external source.

6.2 Northern Beach Summary

Since the construction of the artificial headland in 1977, the Northern Beach has progressively eroded, receding at a rate of about 1 m/year. The total net loss of sediment from the Northern Beach was about 170,000 m^3 during the twenty year period between December 1977 and December 1997 (ie about 8,500 m^3/year). Assessment of the likely future losses suggest that the area may erode at a rate of 7,000 m^3/year.

Survey analysis, and wave modelling and analysis indicates that this loss of sediment is the result of small net differences in much larger seasonal fluctuations of longshore sediment transport. On average, there is a net movement of sand northwards along the coast. This sand is not replaced with sufficient quantities of sand entering the system from the south, and hence there is a net loss of sand from the Northern Beach.

Waves produced by summer sea-breezes are believed to be the principal cause of the northwards longshore transport of sediment. Although severe storms can produce offshore movements of sediment and recession of the primary dune, they are not believed to be the cause of the progressive erosion at the Northern Beach. In fact, storms from the north-west can produce significant southwards transport and reduce the net losses from the area.

Due to the complexity of the system, it is not possible to accurately determine how far the foreshore would recede before a stable realignment would be achieved, or even whether a stable realignment would be achieved at all. However, it is clear that the buffer protecting the Northern Car Park and Stubbs Park is minimal, and without the appropriate coastal management these amenities will be undermined. If the present trend of erosion continues in the longer term, a section of Ocean Drive may also be threatened.

A range of management options were reviewed and the results are summarised in Table 6.2 and outlined below. Tables A.4 to A.10 of Appendix A provide a breakdown of the net present value of the costs of each option. These costs are also displayed in Figures 6.2 and 6.3, which show the net present value of the costs for a range of discount rates.

Seawall Construction Combined with Renourishment

The construction of a seawall can provide increased protection during storm events. However, the seawall will not significantly reduce the long term losses of sediment from the area. Therefore, to maintain the beach seawards of the wall about 7,000 m^3/year (9,000 m^3/year uncompacted truck volume) of sand will be required. This volume of renourishment will generally maintain the Northern Beach in its present state and may also reduce erosion further to the north.

Seawall construction combined with renourishment was found to be more cost effective than straight renourishment because the construction of the seawall was less costly than an appropriate increase of the dune buffer at a cost of \$15/m^3 (in situ) of sand.

Construction of Groynes or Headlands

The construction of groynes or headlands will alter the dynamics of the beach, thus allowing the beach to respond to the seasonal processes without a significant loss of sand. However, this option entails rubble structures along the coast, and will move the erosion problem to the north. In time, development to the north is likely to be threatened by coastal erosion and may also require protection. The cost of this protection has been incorporated in the cost analysis.

Although the effect of the structures on the Northern Beach has been calculated as accurately as possible with the resources available, small differences from the predicted changes could be costly to manage. Some contingencies have been allowed for within the cost analysis for minor differences.

The gradual erosion of the beaches to the north of Quinns and the associated protection works may reduce the flow of sediment returning from the north during winter. In the longer term, this may reduce the performance of the structures protecting the Northern Beach and possibly affect the Southern Beach.

The construction of groynes or headlands is not recommended because they are not the most cost effective option, they will be visually and physically obstructive to the users of the beach, they are likely to have an adverse effect on the surrounding coastline, and may be less effective in the longer term.

Other Options

Sand renourishment will maintain the present beach and dunes with minimal impact on beach users or the environment. However, the present buffer between the active shore and valuable assets is not considered adequate for long term management. If long term renourishment is adopted, the present buffer would need to be increased through renourishment at a cost of about $\$15/m^3$(in situ). However, the study indicated that the construction of the seawall shown in Figure 4.10B was found to be more cost effective than an increase in the buffer by 10 metres.

The Seawall Protection (ie without renourishment) and Do Nothing Options are not recommended. Both of these options would involve sacrificing a large portion of the Northern Beach amenity. Although the seawall would preserve the Car Park, it is likely that the beach would be lost through erosion. The Do Nothing Option may preserve some of the beach but access and other amenities would be lost and a section of Ocean Drive may be threatened.

Table 6.2 - Summary Evaluation of Management Options for the Northern Beach

	Do Nothing	Sand Renourishment	Seawall Construction	Renourishment and Seawall Construction	Groyne / Headland Construction
Capital Works	None	Increase in the existing buffer	Seawall Construction	Seawall Construction	Groyne / Headland Construction
Ongoing / Maintenance Works	None	(2) Sand Renourishment (7,000m^3/year)	Maintenance after very severe storm events	(2)Renourishment (7,000m^3/year) and seawall maintenance after severe storms	Occasional Renourishment
Local Impacts	Loss of beach access and amenities, and possible loss of Ocean Drive	Minimal	Visual impact and loss of the adjacent beaches	Minor visual impact	Significant visual and beach user impact
Environmental Impacts	Minimal	Minimal	Likely increase in erosion of adjacent beaches	Minimal	Erosion problem moved to the north
Net Present Value for 35 year Period[1]	>$6,050,000 (Conservative Estimate)	$2,700,000	$4,120,000	$2,550,000	$2,640,000
Cost Based Ranking	**5**	**3**	**4**	**1**	**2**

Notes:
1. The discounted costs for the 35 year period are based on a discount rate of 4% pa. An analysis of long term bonds, inflation rates and Capital Index Bonds has indicated that this discount factor is appropriate for the current economic climate.
2. Renourishment of 7,000 m^3 in situ equates to about 9,000 m^3 uncompacted from external source.

6.3 Recommendations

Southern Beach

It is recommended that the present buffer (ie width of dune) protecting Ocean Drive be increased through 17,000 m^3 (in situ) of sand renourishment and the dune be revegetated.

Following severe storm events which cause significant erosion of the primary dune, sand renourishment should be undertaken on an as needed basis.

Northern Beach

It is recommended that about 7,000 m^3/year (in situ, ie. about 9,000 m^3/year uncompacted truck volume) of sand renourishment is placed seawards of the car park to maintain the beach.

It is also recommended that a seawall as shown in Figure 4.10B be constructed to provide increased storm protection to the northern car park and associated amenities.

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Figures

Figure 1.1 - Location Diagram

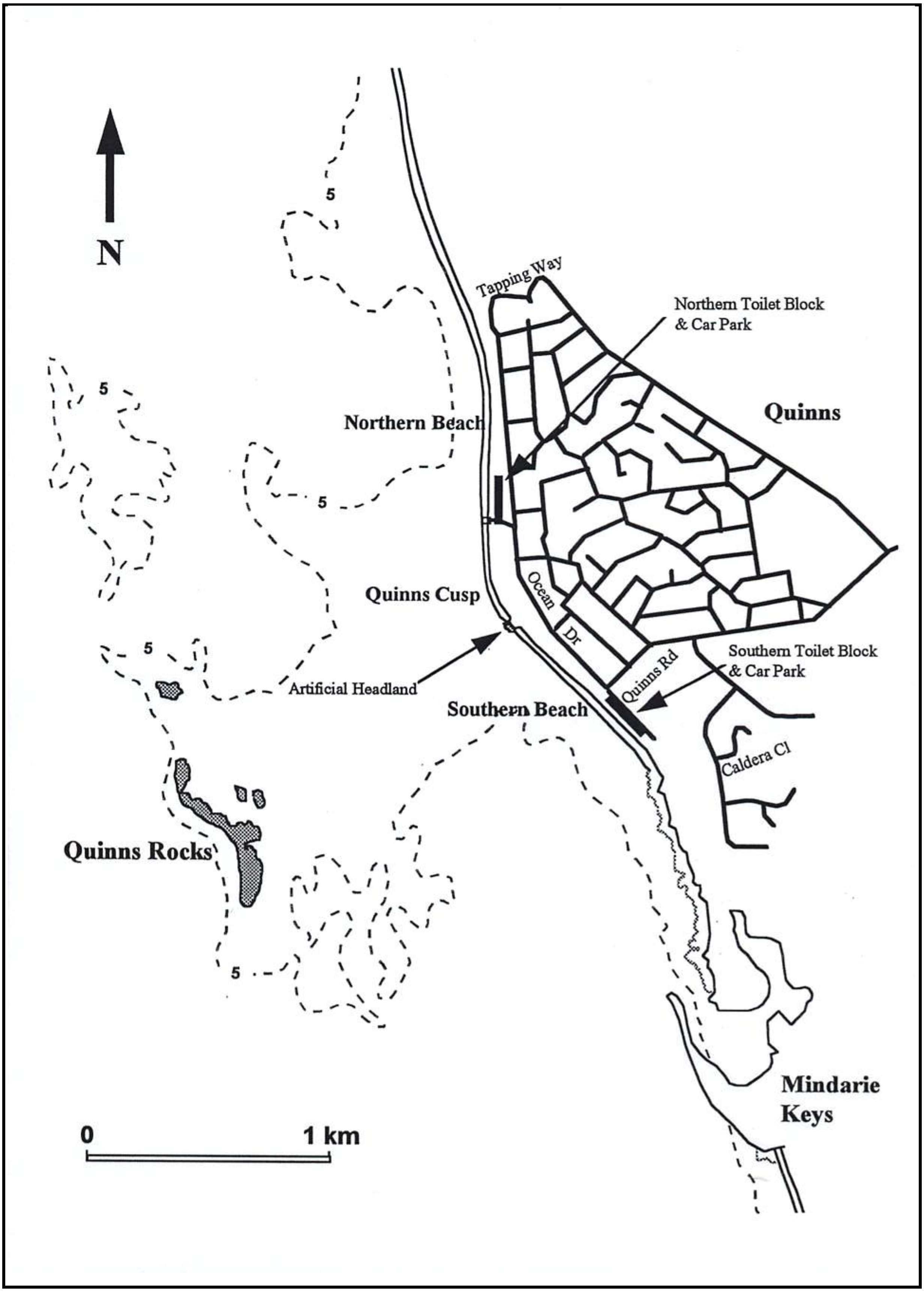


Figure 4.1 - Possible Future Erosion Contours for the Northern Beach

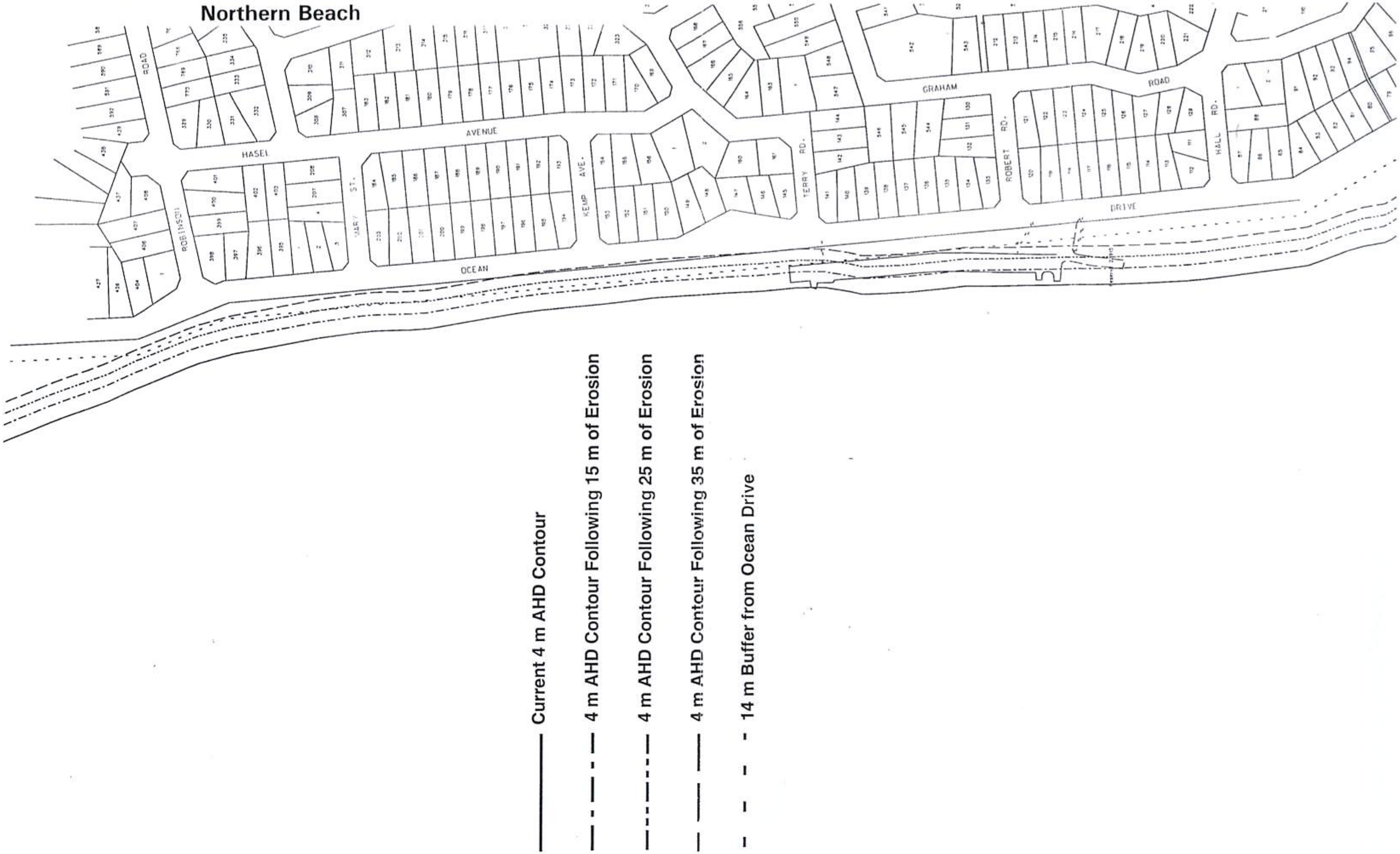


Figure 4.2 - SBEACH Results - Northern Beach with Seawall & 25m Erosion (20 to 30 yr ARI)

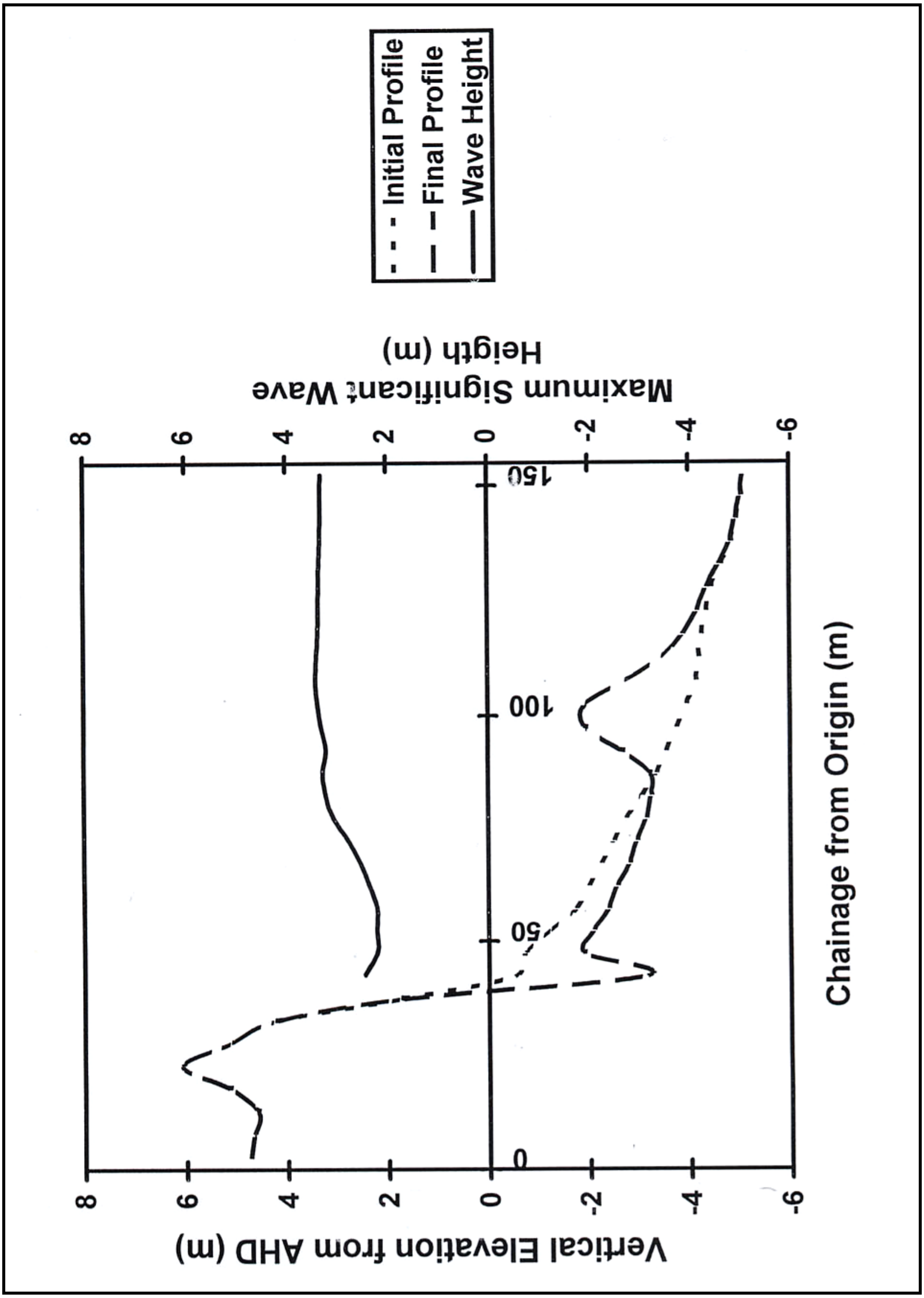


Figure 4.3 - SBEACH Results - Northern Beach with Seawall & 25m Erosion (50 to 100 yr ARI)

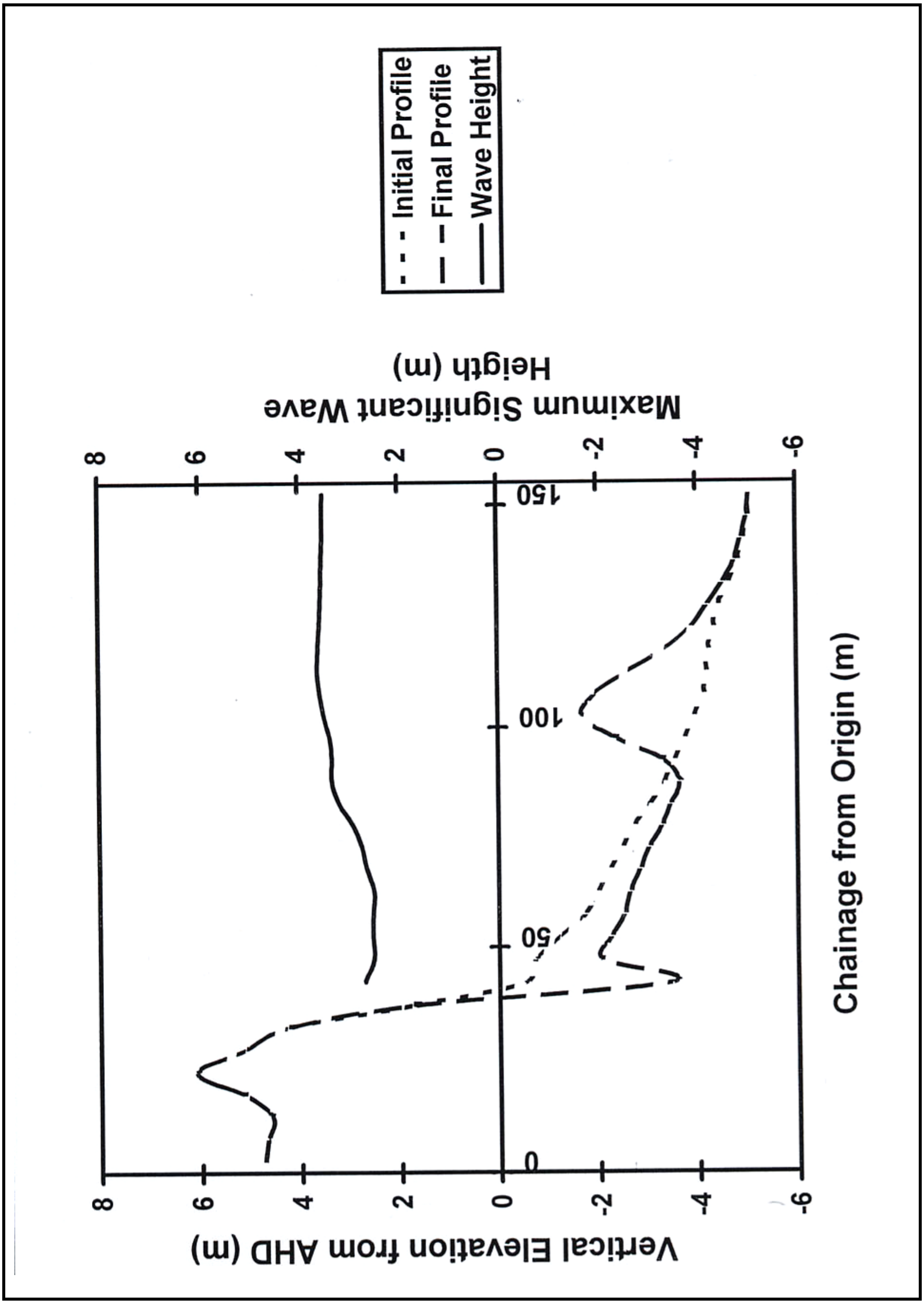


Figure 4.4 - SBEACH Results - Northern Beach with Seawall & 35m Erosion (20 to 30 yr ARI)

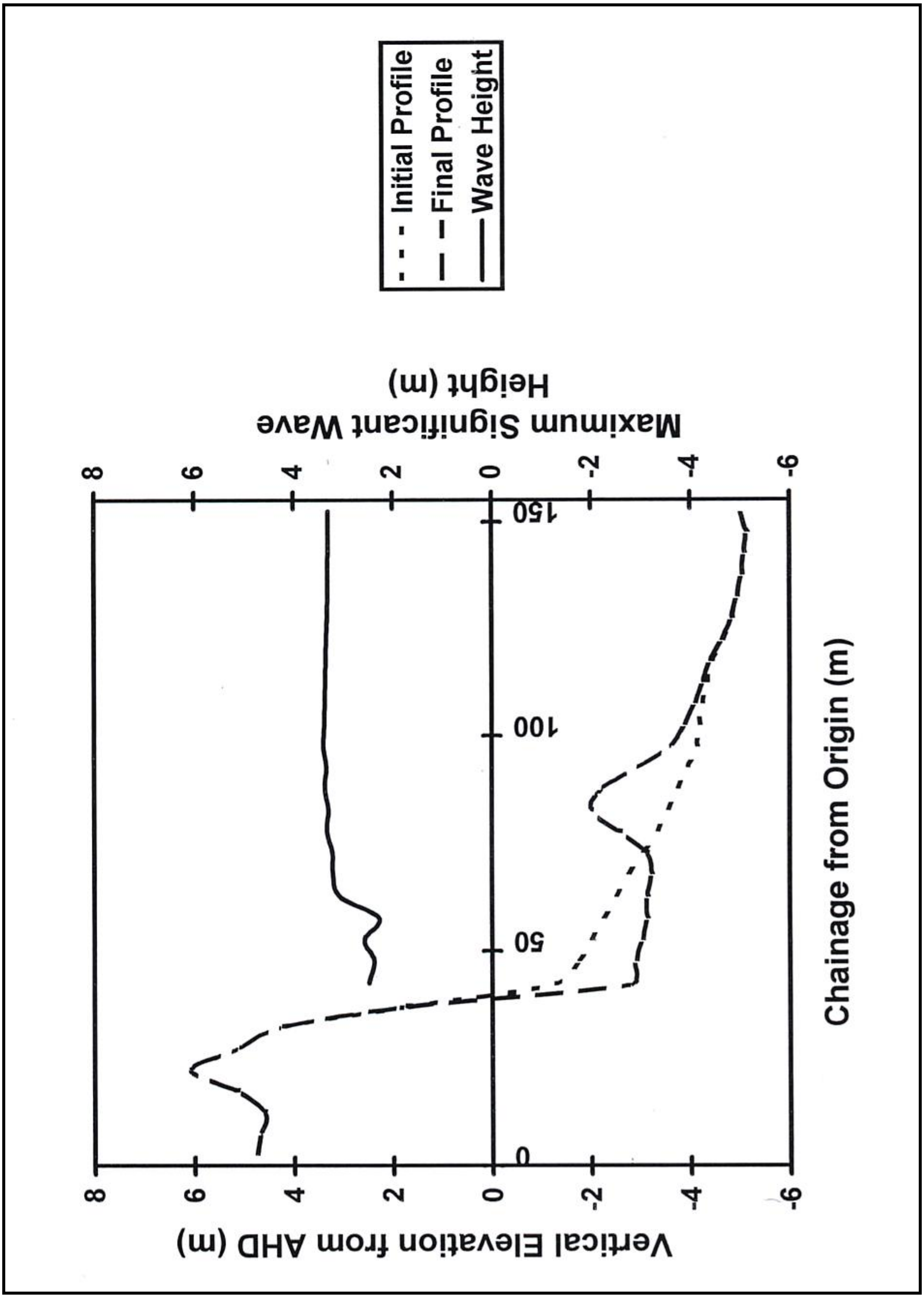


Figure 4.5 - Seawall Preliminary Design

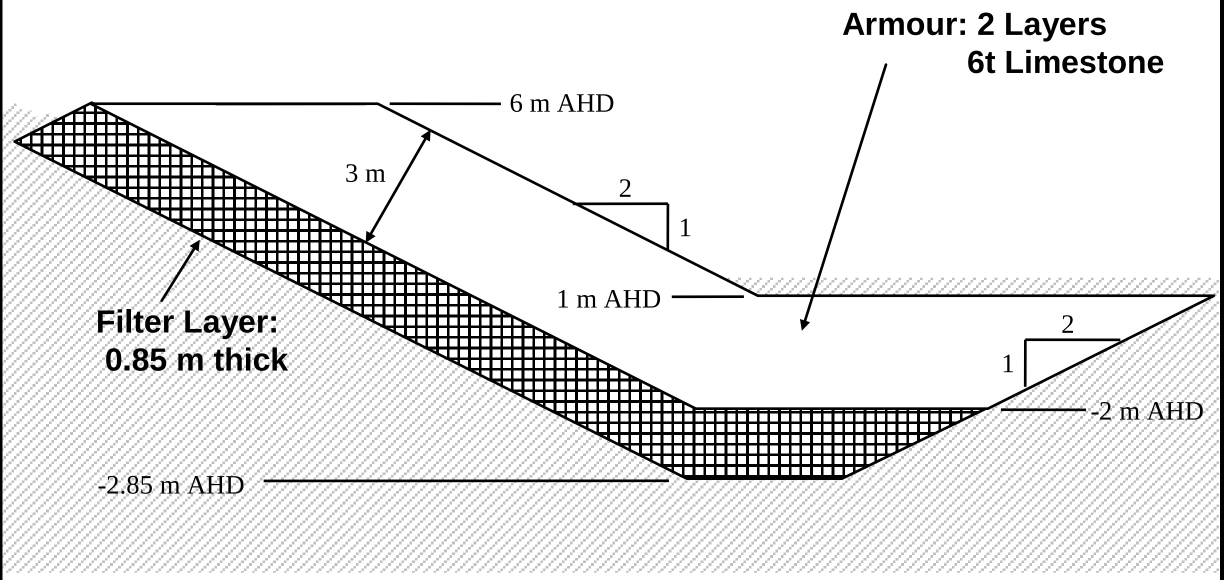


Figure 4.6 - SBEACH Results - Northern Beach with Seawall & Renourishment (20 to 30 yr ARI)

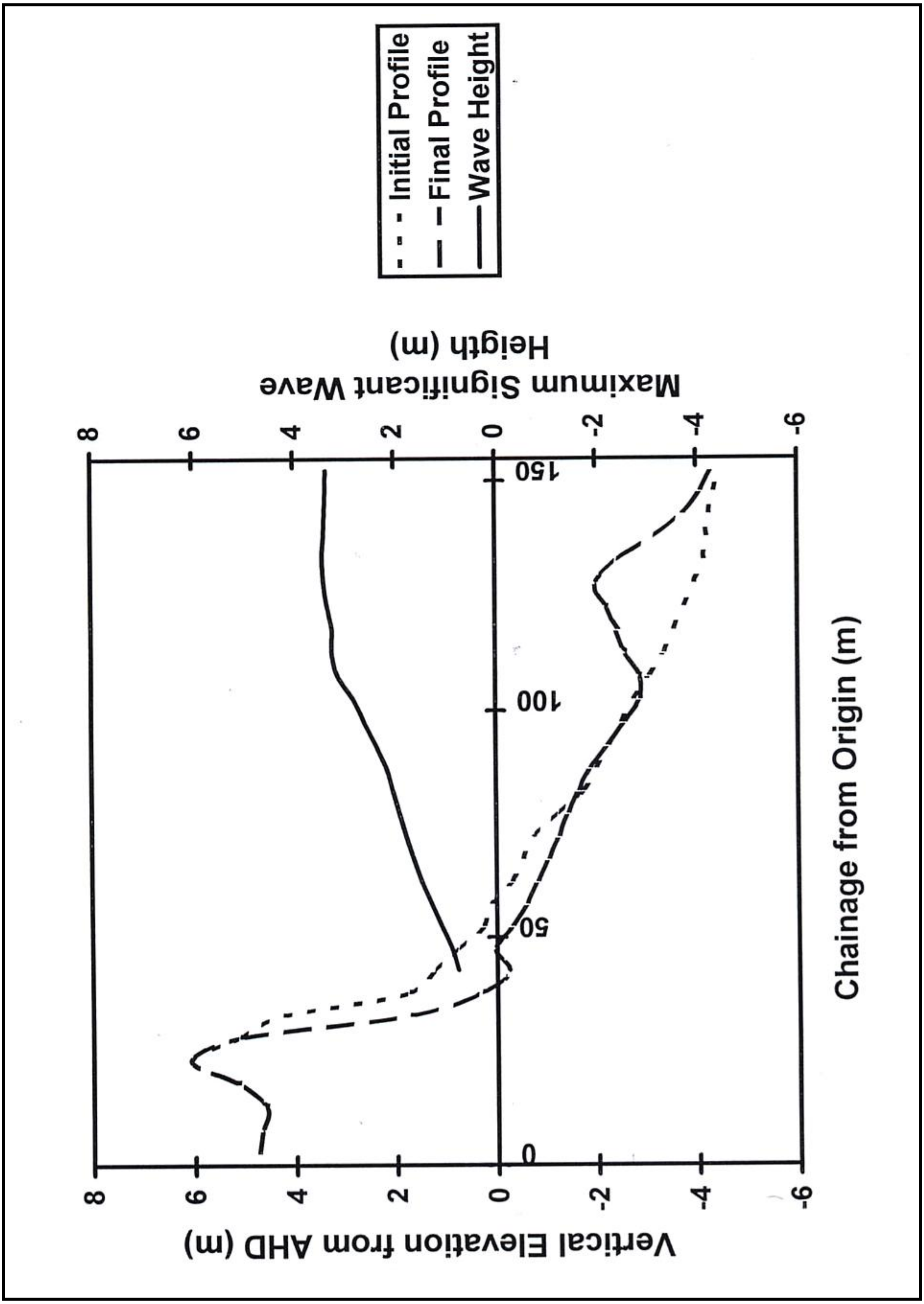


Figure 4.7 - SBEACH Results - Northern Beach with Seawall & Renourishment (50 - 100 yr ARI)

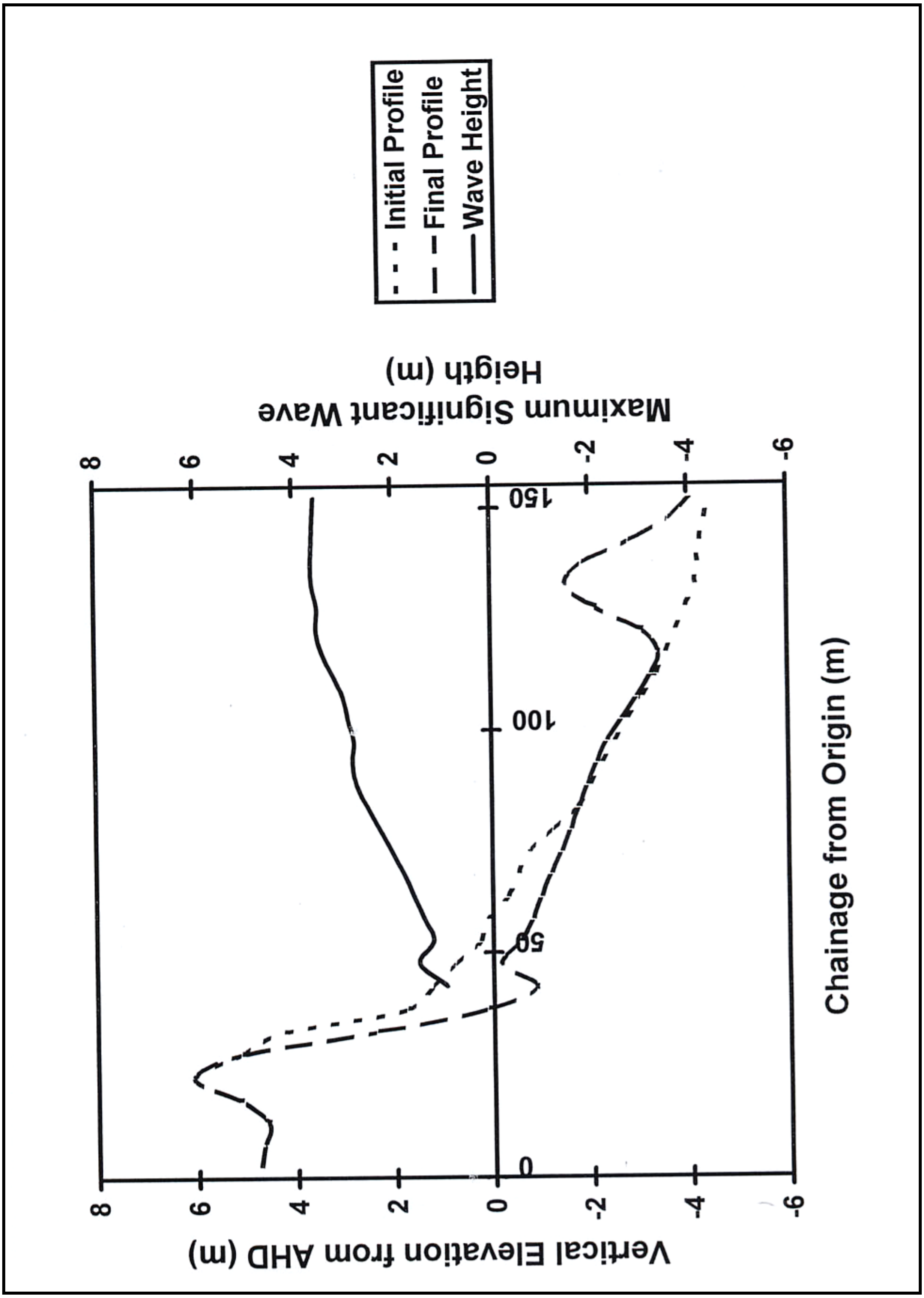


Figure 4.8 - Revetment Mattress Preliminary Design

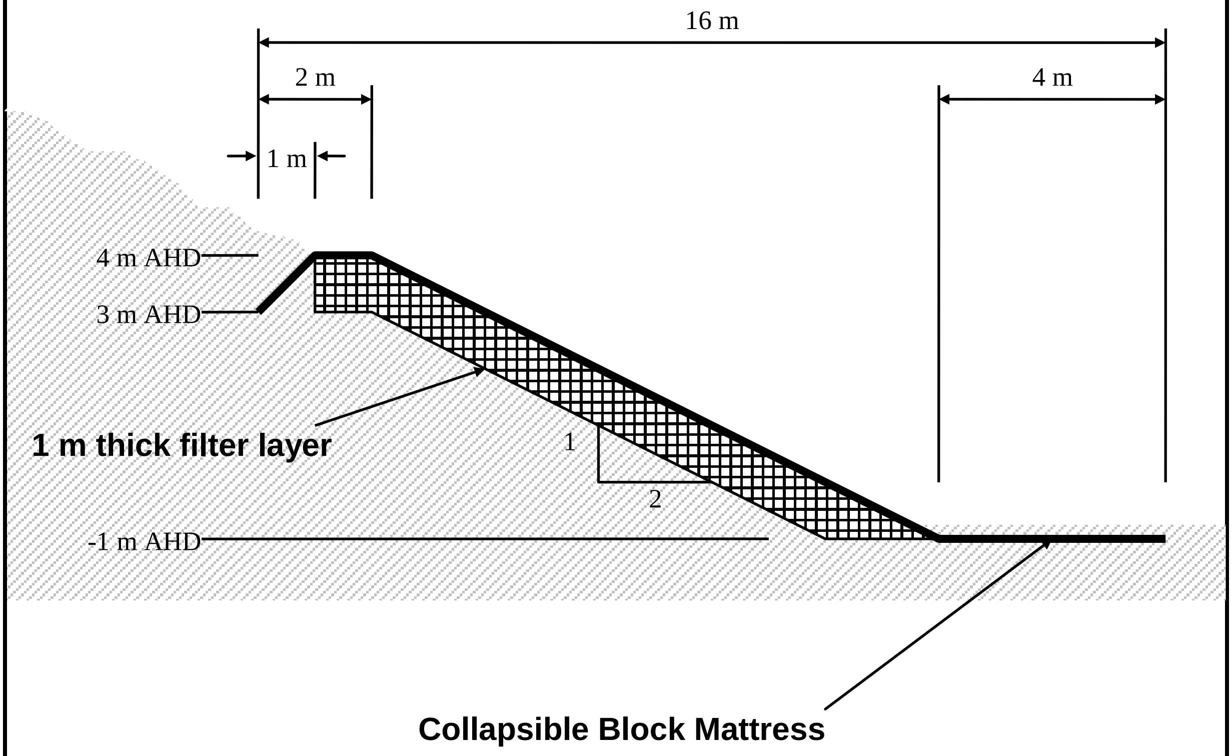


Figure 4.9 - Geotube Seawall Preliminary Design

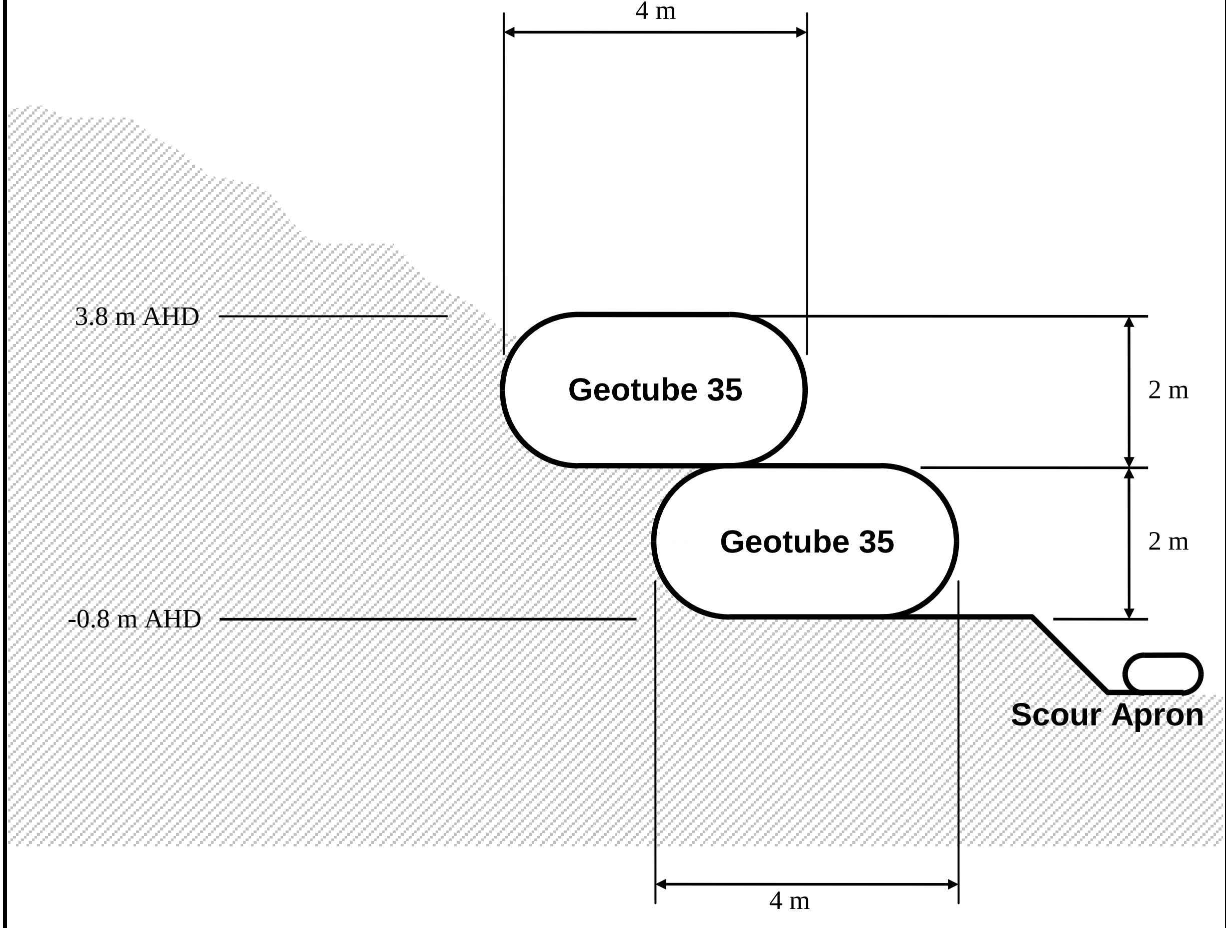


Figure 4.10 - Rubble Seawall Preliminary Designs

Figure 5.5A - Standard Seawall

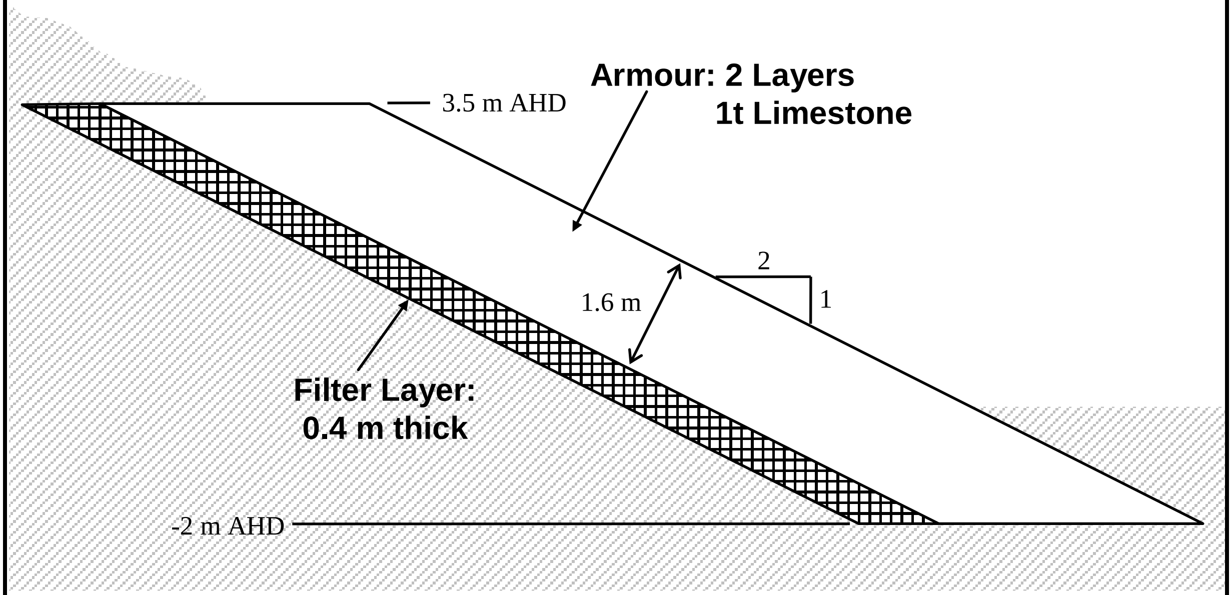


Figure 5.5B - Seawall with Reduced Depth and Armoured Toe

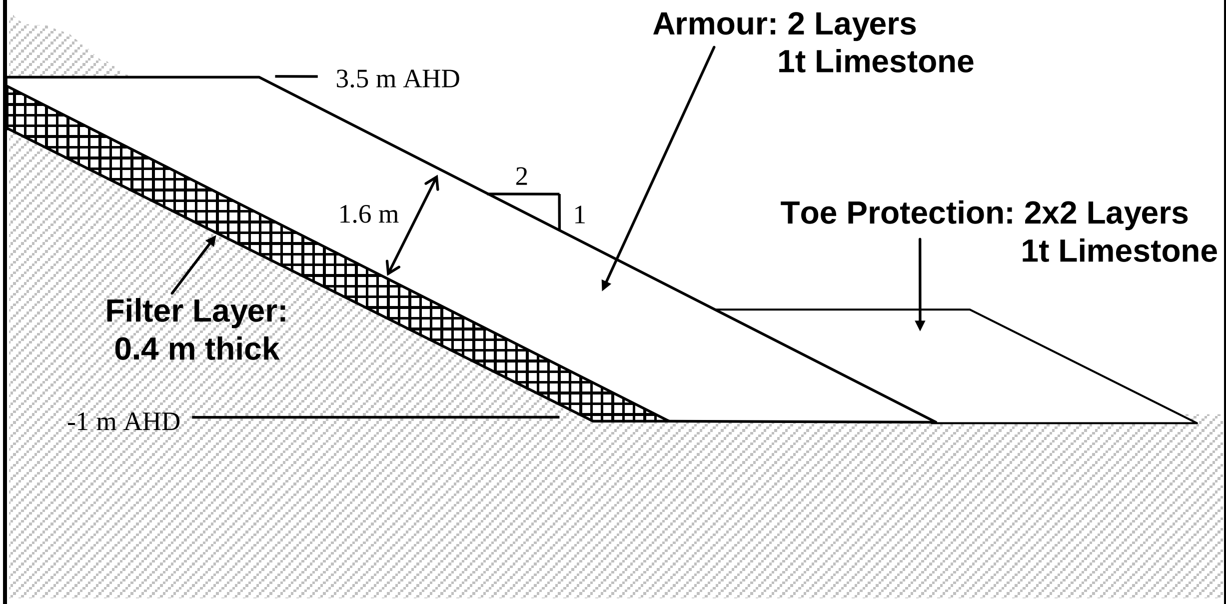


Figure 4.11 - Groyne / Headland Beach Angle Diagram

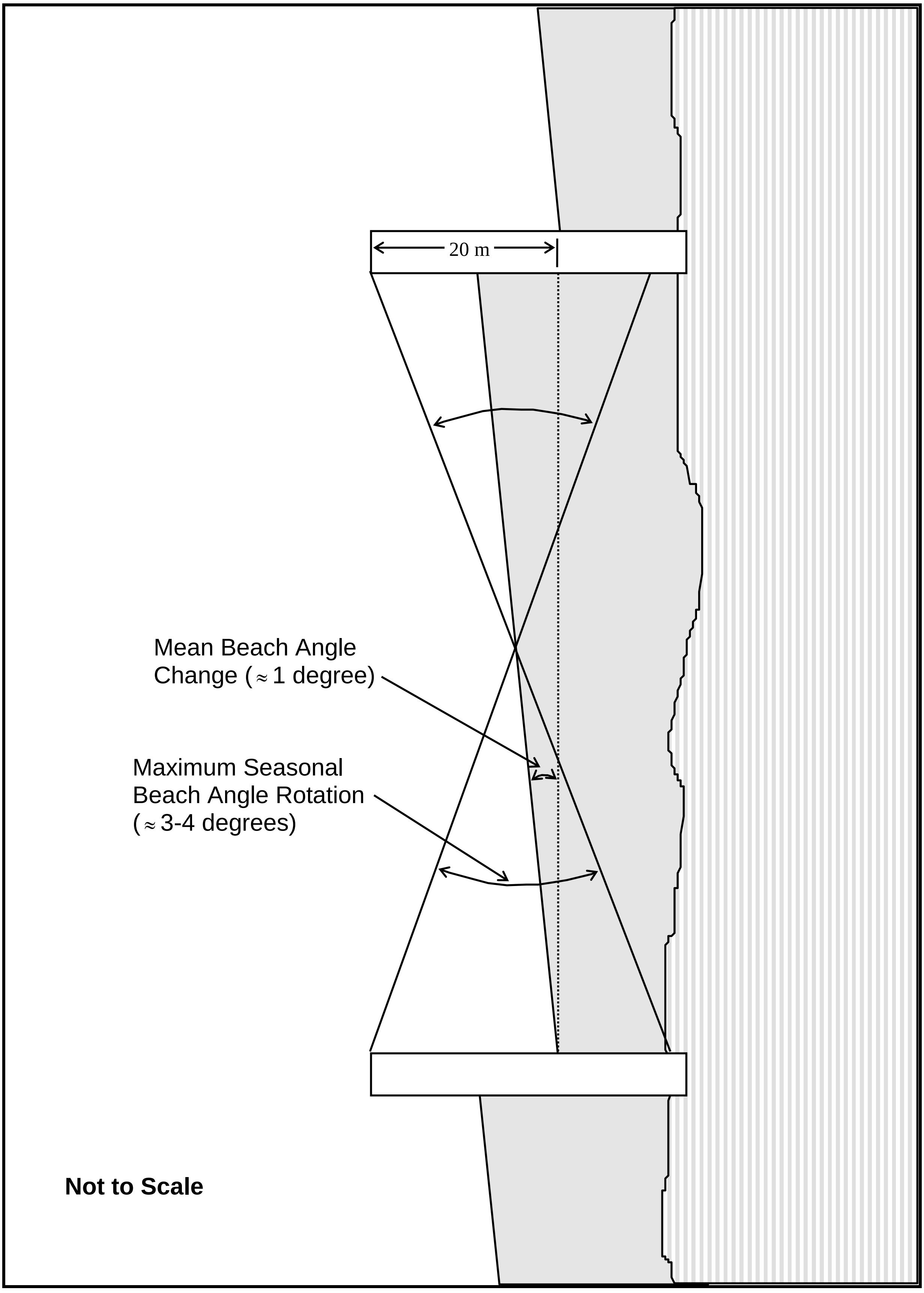


Figure 4.12 - Groyne / Headland Configuration Diagram

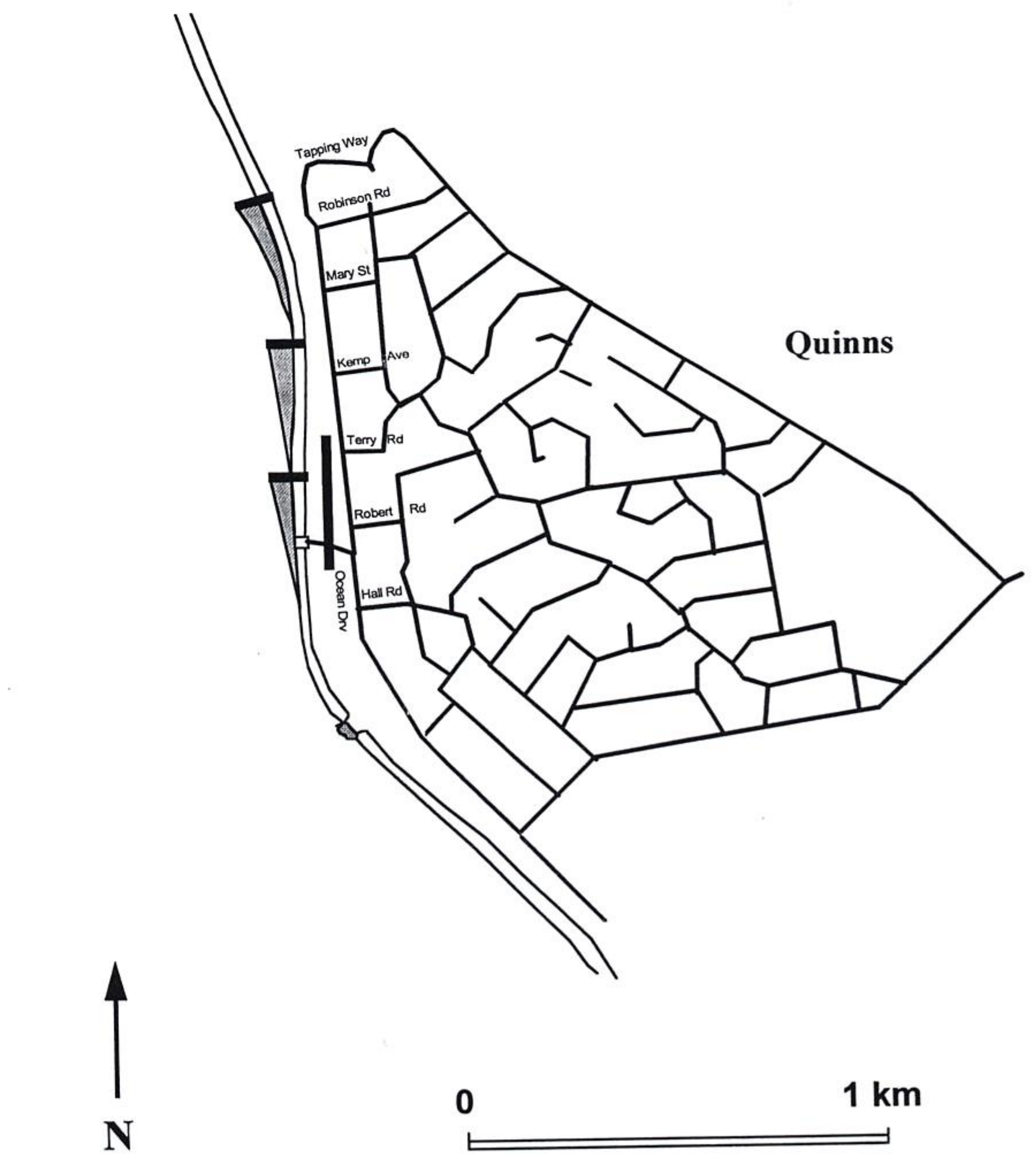


Figure 4.13 - SBEACH Results - Northern Beach with Groynes / Headlands (20 to 30 year ARI)

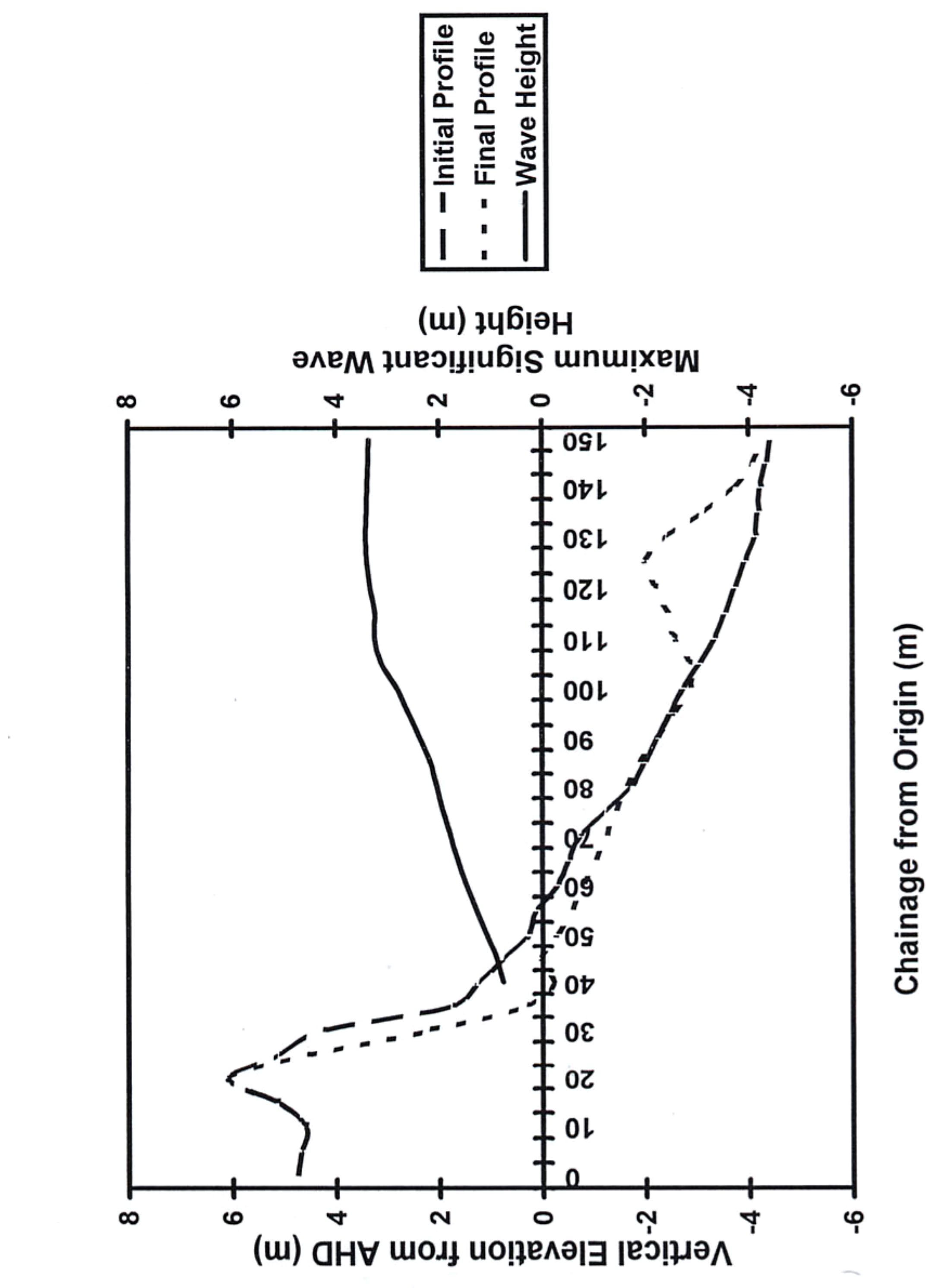
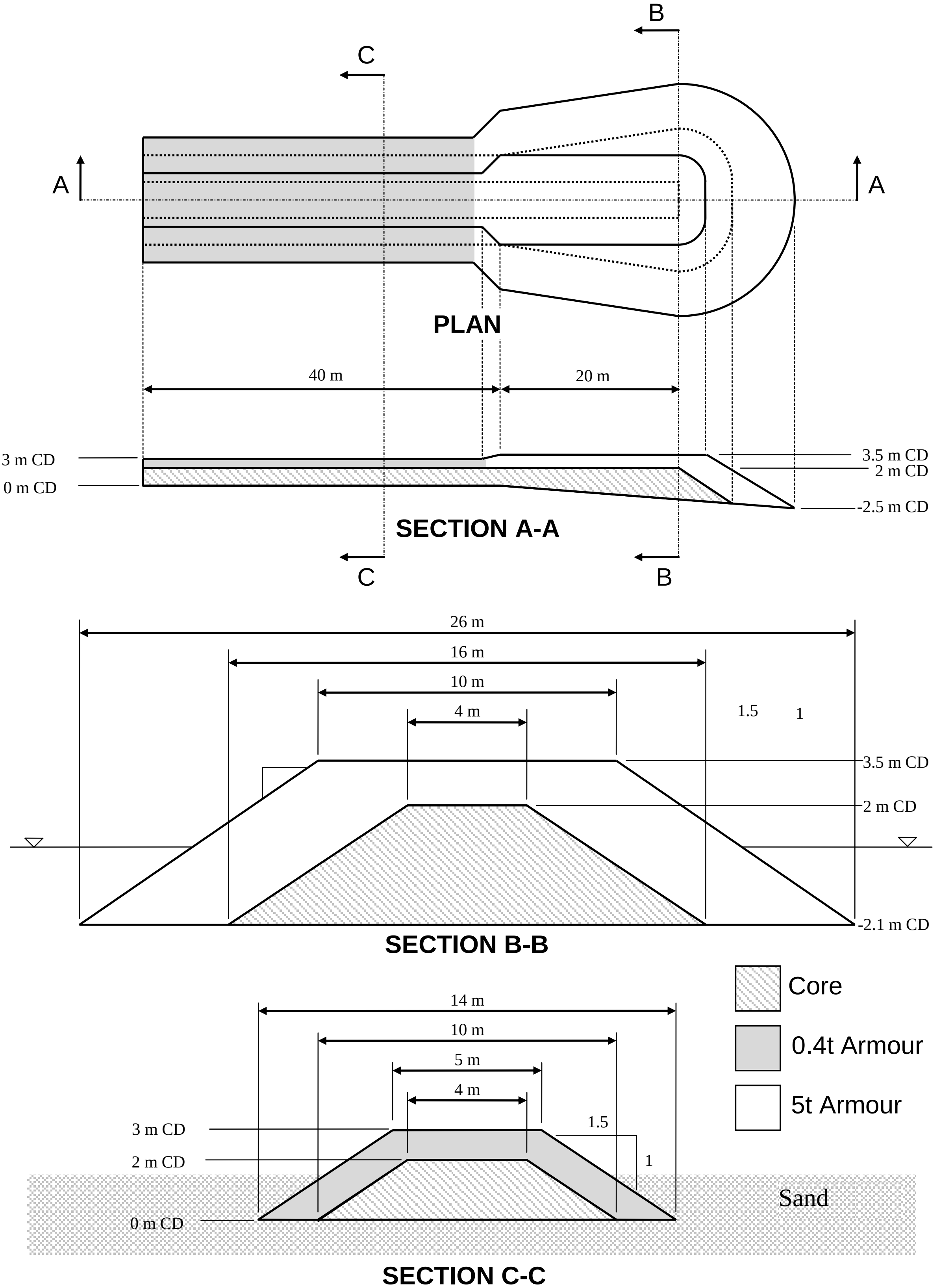
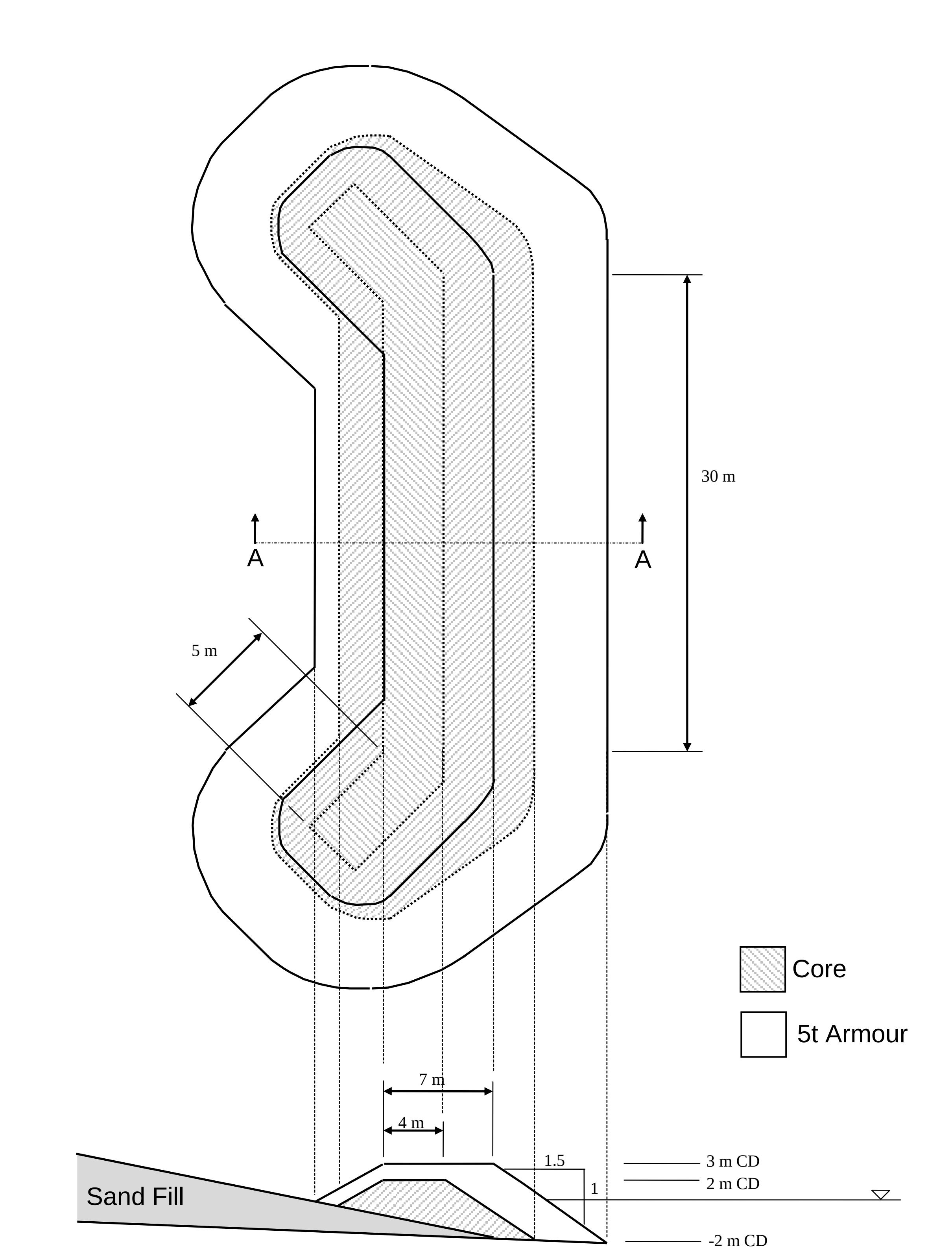


Figure 4.14 - Groyne Preliminary Design



Note: 2 Layers of Armour on the sides, 1 Layer of Armour on the top.

Figure 4.15 - Headland Preliminary Design



Note: 2 Layers of Armour on the front and ends, 1 Layer of Armour on the top and rear.

Figure 6.1 - Net Present Value of the Costs of the Management of the Southern Beach

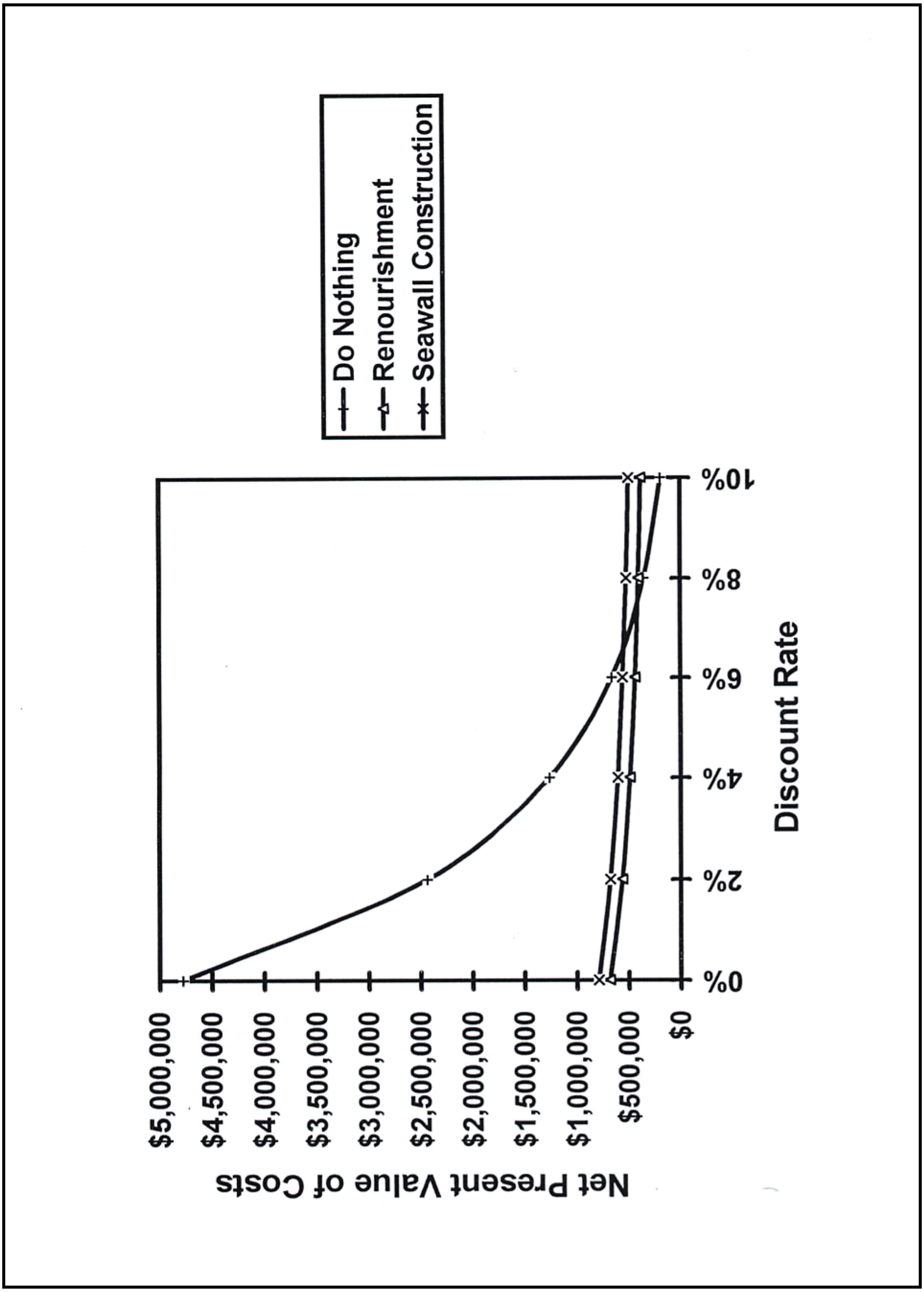


Figure 6.2 - Net Present Value of the Costs of the Management of the Northern Beach No.1

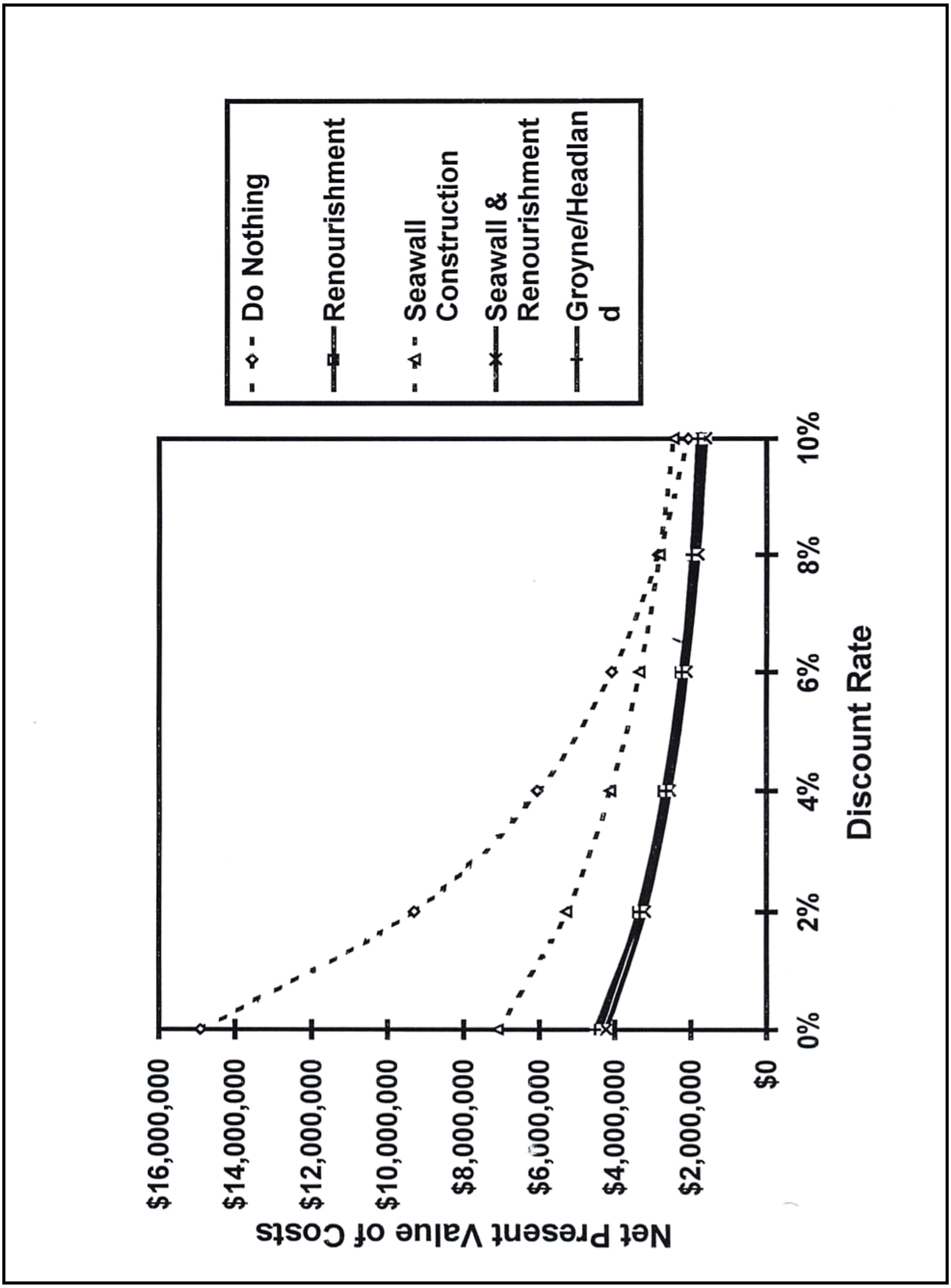
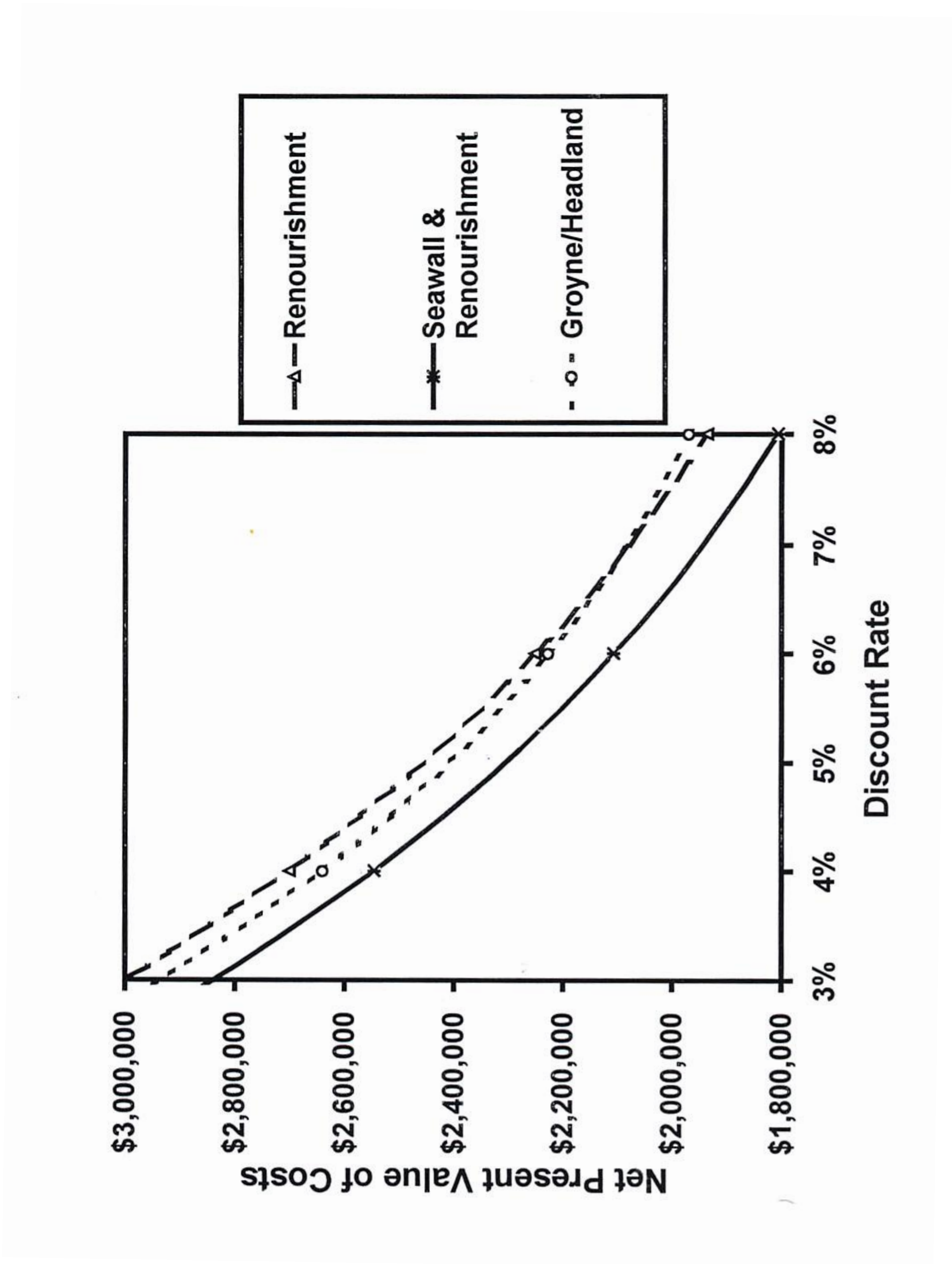


Figure 6.3 - Net Present Value of the Costs of the Management of the Northern Beach No.2



Appendix A - Discounted Cost Analysis of Options

Year	Item	Cost in 1999	Net Present Value of Cost for a Range of Discount Rates				
			0.02	0.04	0.06	0.08	0.10
	Totals	$4,775,000	$2,435,384	$1,258,461	$658,528	$348,791	$186,905
1	Nil	$0	$0	$0	$0	$0	$0
2	Nil	$0	$0	$0	$0	$0	$0
3	Nil	$0	$0	$0	$0	$0	$0
4	Nil	$0	$0	$0	$0	$0	$0
5	Nil	$0	$0	$0	$0	$0	$0
6	Nil	$0	$0	$0	$0	$0	$0
7	Nil	$0	$0	$0	$0	$0	$0
8	Nil	$0	$0	$0	$0	$0	$0
9	Nil	$0	$0	$0	$0	$0	$0
10	Nil	$0	$0	$0	$0	$0	$0
11	Nil	$0	$0	$0	$0	$0	$0
12	Nil	$0	$0	$0	$0	$0	$0
13	Nil	$0	$0	$0	$0	$0	$0
14	Nil	$0	$0	$0	$0	$0	$0
15	Nil	$0	$0	$0	$0	$0	$0
16	Nil	$0	$0	$0	$0	$0	$0
17	Nil	$0	$0	$0	$0	$0	$0
18	Nil	$0	$0	$0	$0	$0	$0
19	Nil	$0	$0	$0	$0	$0	$0
20	Nil	$0	$0	$0	$0	$0	$0
21	Nil	$0	$0	$0	$0	$0	$0
22	Nil	$0	$0	$0	$0	$0	$0
23	Nil	$0	$0	$0	$0	$0	$0
24	Nil	$0	$0	$0	$0	$0	$0
25	Nil	$0	$0	$0	$0	$0	$0
26	Nil	$0	$0	$0	$0	$0	$0
27	Nil	$0	$0	$0	$0	$0	$0
28	Nil	$0	$0	$0	$0	$0	$0
29	Nil	$0	$0	$0	$0	$0	$0
30	Nil	$0	$0	$0	$0	$0	$0
31	Nil	$0	$0	$0	$0	$0	$0
32	Nil	$0	$0	$0	$0	$0	$0
33	Nil	$0	$0	$0	$0	$0	$0
34	Nil	$0	$0	$0	$0	$0	$0
35	Loss of Ocean Drive and Lots	$4,775,000	$2,435,384	$1,258,461	$658,528	$348,791	$186,905

Table A.1 - Southern Beach - Option 1 "Do Nothing"

Year	Item	Cost in 1999	Net Present Value of Cost for a Range of Discount Rates				
			0.02	0.04	0.06	0.08	0.10
	Totals	**$681,000**	**$559,187**	**$482,862**	**$433,123**	**$399,440**	**$375,784**
1	Renourishment (17,000 m^3)	$260,000	$260,000	$260,000	$260,000	$260,000	$260,000
1	Revegetation	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000
2	Nil	$0	$0	$0	$0	$0	$0
3	Nil	$0	$0	$0	$0	$0	$0
4	Nil	$0	$0	$0	$0	$0	$0
5	Renourishment (3,500 m^3)	$53,000	$48,964	$45,305	$41,981	$38,957	$36,200
5	Revegetation	$5,000	$4,619	$4,274	$3,960	$3,675	$3,415
6	Nil	$0	$0	$0	$0	$0	$0
7	Nil	$0	$0	$0	$0	$0	$0
8	Nil	$0	$0	$0	$0	$0	$0
9	Nil	$0	$0	$0	$0	$0	$0
10	Renourishment (3,500 m^3)	$53,000	$44,348	$37,237	$31,371	$26,513	$22,477
10	Revegetation	$5,000	$4,184	$3,513	$2,959	$2,501	$2,120
11	Nil	$0	$0	$0	$0	$0	$0
12	Nil	$0	$0	$0	$0	$0	$0
13	Nil	$0	$0	$0	$0	$0	$0
14	Nil	$0	$0	$0	$0	$0	$0
15	Renourishment (3,500 m^3)	$53,000	$40,167	$30,606	$23,442	$18,044	$13,957
15	Revegetation	$5,000	$3,789	$2,887	$2,212	$1,702	$1,317
16	Nil	$0	$0	$0	$0	$0	$0
17	Nil	$0	$0	$0	$0	$0	$0
18	Nil	$0	$0	$0	$0	$0	$0
19	Nil	$0	$0	$0	$0	$0	$0
20	Renourishment (3,500 m^3)	$53,000	$36,381	$25,156	$17,517	$12,281	$8,666
20	Revegetation	$5,000	$3,432	$2,373	$1,653	$1,159	$818
21	Nil	$0	$0	$0	$0	$0	$0
22	Nil	$0	$0	$0	$0	$0	$0
23	Nil	$0	$0	$0	$0	$0	$0
24	Nil	$0	$0	$0	$0	$0	$0
25	Renourishment (3,500 m^3)	$53,000	$32,951	$20,676	$13,090	$8,358	$5,381
25	Revegetation	$5,000	$3,109	$1,951	$1,235	$788	$508
26	Nil	$0	$0	$0	$0	$0	$0
27	Nil	$0	$0	$0	$0	$0	$0
28	Nil	$0	$0	$0	$0	$0	$0
29	Nil	$0	$0	$0	$0	$0	$0
30	Renourishment (3,500 m^3)	$53,000	$29,845	$16,995	$9,782	$5,688	$3,341
30	Revegetation	$5,000	$2,816	$1,603	$923	$537	$315
31	Nil	$0	$0	$0	$0	$0	$0
32	Nil	$0	$0	$0	$0	$0	$0
33	Nil	$0	$0	$0	$0	$0	$0
34	Nil	$0	$0	$0	$0	$0	$0
35	Renourishment (3,500 m^3)	$53,000	$27,031	$13,968	$7,309	$3,871	$2,075
35	Revegetation	$5,000	$2,550	$1,318	$690	$365	$196

Table A.2 - Southern Beach - Option 2 "Renourishment"

Year	Item	Cost in 1999	Net Present Value of Cost for a Range of Discount Rates				
			0.02	0.04	0.06	0.08	0.10
	Totals	$790,000	$677,117	$603,581	$554,161	$519,925	$495,511
1	Seawall Construction	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000
2	Nil	$0	$0	$0	$0	$0	$0
3	Nil	$0	$0	$0	$0	$0	$0
4	Nil	$0	$0	$0	$0	$0	$0
5	Nil	$0	$0	$0	$0	$0	$0
6	Renourishment (3,000 m^3)	$45,000	$40,758	$36,987	$33,627	$30,626	$27,941
7	Nil	$0	$0	$0	$0	$0	$0
8	Nil	$0	$0	$0	$0	$0	$0
9	Nil	$0	$0	$0	$0	$0	$0
10	Seawall Maintenance	$40,000	$33,470	$28,103	$23,676	$20,010	$16,964
11	Renourishment (3,000 m^3)	$45,000	$36,916	$30,400	$25,128	$20,844	$17,349
12	Nil	$0	$0	$0	$0	$0	$0
13	Nil	$0	$0	$0	$0	$0	$0
14	Nil	$0	$0	$0	$0	$0	$0
15	Nil	$0	$0	$0	$0	$0	$0
16	Renourishment (3,000 m^3)	$45,000	$33,436	$24,987	$18,777	$14,186	$10,773
17	Nil	$0	$0	$0	$0	$0	$0
18	Nil	$0	$0	$0	$0	$0	$0
19	Nil	$0	$0	$0	$0	$0	$0
20	Seawall Maintenance	$40,000	$27,457	$18,986	$13,221	$9,268	$6,540
21	Renourishment (3,000 m^3)	$45,000	$30,284	$20,537	$14,031	$9,655	$6,689
22	Nil	$0	$0	$0	$0	$0	$0
23	Nil	$0	$0	$0	$0	$0	$0
24	Nil	$0	$0	$0	$0	$0	$0
25	Nil	$0	$0	$0	$0	$0	$0
26	Renourishment (3,000 m^3)	$45,000	$27,429	$16,880	$10,485	$6,571	$4,153
27	Nil	$0	$0	$0	$0	$0	$0
28	Nil	$0	$0	$0	$0	$0	$0
29	Nil	$0	$0	$0	$0	$0	$0
30	Seawall Maintenance	$40,000	$22,524	$12,826	$7,382	$4,293	$2,522
31	Renourishment (3,000 m^3)	$45,000	$24,843	$13,874	$7,835	$4,472	$2,579
32	Nil	$0	$0	$0	$0	$0	$0
33	Nil	$0	$0	$0	$0	$0	$0
34	Nil	$0	$0	$0	$0	$0	$0
35	Nil	$0	$0	$0	$0	$0	$0

Table A.3 - Southern Beach - Option 3 "Seawall"

Year	Item	Cost in 1999	Net Present Value of Cost for a Range of Discount Rates				
			0.02	0.04	0.06	0.08	0.10
	Totals	$14,903,500	$9,297,448	$6,046,391	$4,084,995	$2,854,998	$2,055,000
1	Nil	$0	$0	$0	$0	$0	$0
2	Nil	$0	$0	$0	$0	$0	$0
3	Nil	$0	$0	$0	$0	$0	$0
4	Nil	$0	$0	$0	$0	$0	$0
5	Loss of 50% of Beach Amenities	$65,500	$60,512	$55,990	$51,882	$48,144	$44,737
6	Loss of 50% of Beach Amenities	$65,500	$59,325	$53,836	$48,945	$44,578	$40,670
7	Loss of 50% of Beach Amenities	$65,500	$58,162	$51,766	$46,175	$41,276	$36,973
8	Loss of 50% of Beach Amenities	$65,500	$57,022	$49,775	$43,561	$38,219	$33,612
9	Loss of 50% of Beach Amenities	$65,500	$55,904	$47,860	$41,096	$35,388	$30,556
10	Removal of Beach Amenities	$45,000	$37,654	$31,616	$26,635	$22,511	$19,084
10	Loss of 100% of Beach Amenities	$131,000	$109,615	$92,039	$77,539	$65,533	$55,557
11	Loss of 100% of Beach Amenities	$131,000	$107,466	$88,499	$73,150	$60,678	$50,506
12	Loss of 100% of Beach Amenities	$131,000	$105,358	$85,095	$69,009	$56,184	$45,915
13	Loss of 100% of Beach Amenities	$131,000	$103,293	$81,822	$65,103	$52,022	$41,741
14	Loss of 100% of Beach Amenities	$131,000	$101,267	$78,675	$61,418	$48,168	$37,946
15	Loss of 100% of Beach Amenities	$131,000	$99,282	$75,649	$57,941	$44,600	$34,496
16	Loss of 100% of Beach Amenities	$131,000	$97,335	$72,740	$54,662	$41,297	$31,360
17	Loss of Ocean Drive, Mary to Terry	$4,785,000	$3,485,613	$2,554,751	$1,883,597	$1,396,696	$1,041,355
17	Loss of 100% of Beach Amenities	$131,000	$95,426	$69,942	$51,568	$38,238	$28,509
18	Loss of 100% of Beach Amenities	$131,000	$93,555	$67,252	$48,649	$35,405	$25,918
19	Loss of 100% of Beach Amenities	$131,000	$91,721	$64,665	$45,895	$32,783	$23,562
20	Loss of 100% of Beach Amenities	$131,000	$89,922	$62,178	$43,297	$30,354	$21,420
21	Loss of 100% of Beach Amenities	$131,000	$88,159	$59,787	$40,846	$28,106	$19,472
22	Loss of 100% of Beach Amenities	$131,000	$86,431	$57,487	$38,534	$26,024	$17,702
23	Loss of 100% of Beach Amenities	$131,000	$84,736	$55,276	$36,353	$24,096	$16,093
24	Loss of 100% of Beach Amenities	$131,000	$83,074	$53,150	$34,295	$22,311	$14,630
25	Loss of 100% of Beach Amenities	$131,000	$81,446	$51,106	$32,354	$20,659	$13,300
26	Loss of 100% of Beach Amenities	$131,000	$79,849	$49,140	$30,523	$19,128	$12,091
27	Loss of 100% of Beach Amenities	$131,000	$78,283	$47,250	$28,795	$17,711	$10,992
28	Loss of 100% of Beach Amenities	$131,000	$76,748	$45,433	$27,165	$16,399	$9,992
29	Loss of 100% of Beach Amenities	$131,000	$75,243	$43,686	$25,628	$15,185	$9,084
30	Loss of 100% of Beach Amenities	$131,000	$73,768	$42,005	$24,177	$14,060	$8,258
31	Loss of 100% of Beach Amenities	$131,000	$72,321	$40,390	$22,808	$13,018	$7,507
32	Loss of 100% of Beach Amenities	$131,000	$70,903	$38,836	$21,517	$12,054	$6,825
33	Loss of 100% of Beach Amenities	$131,000	$69,513	$37,343	$20,299	$11,161	$6,204
34	Loss of 100% of Beach Amenities	$131,000	$68,150	$35,906	$19,150	$10,334	$5,640
35	Loss of 100% of Beach Amenities	$131,000	$66,814	$34,525	$18,066	$9,569	$5,128
35	Loss of Ocean Drive, Rob. to Robert	$6,340,000	$3,233,579	$1,670,920	$874,359	$463,107	$248,164

Table A.4 - Northern Beach - Option 1 "Do Nothing"

Year	Item	Cost in 1999	Net Present Value of Cost for a Range of Discount Rates				
			0.02	0.04	0.06	0.08	0.10
	Totals	$4,395,000	$3,367,265	$2,700,617	$2,250,953	$1,935,863	$1,706,933
1	Renourishment (20,000 m^3)	$300,000	$300,000	$300,000	$300,000	$300,000	$300,000
2	Renourishment (14,000 m^3)	$210,000	$205,882	$201,923	$198,113	$194,444	$190,909
3	Renourishment (14,000 m^3)	$210,000	$201,845	$194,157	$186,899	$180,041	$173,554
4	Renourishment (14,000 m^3)	$210,000	$197,888	$186,689	$176,320	$166,705	$157,776
5	Renourishment (14,000 m^3)	$210,000	$194,008	$179,509	$166,340	$154,356	$143,433
6	Renourishment (14,000 m^3)	$210,000	$190,203	$172,605	$156,924	$142,922	$130,393
7	Renourishment (7,000 m^3)	$105,000	$93,237	$82,983	$74,021	$66,168	$59,270
8	Renourishment (7,000 m^3)	$105,000	$91,409	$79,791	$69,831	$61,266	$53,882
9	Renourishment (7,000 m^3)	$105,000	$89,616	$76,722	$65,878	$56,728	$48,983
10	Renourishment (7,000 m^3)	$105,000	$87,859	$73,772	$62,149	$52,526	$44,530
11	Renourishment (7,000 m^3)	$105,000	$86,137	$70,934	$58,631	$48,635	$40,482
12	Renourishment (7,000 m^3)	$105,000	$84,448	$68,206	$55,313	$45,033	$36,802
13	Renourishment (7,000 m^3)	$105,000	$82,792	$65,583	$52,182	$41,697	$33,456
14	Renourishment (7,000 m^3)	$105,000	$81,168	$63,060	$49,228	$38,608	$30,415
15	Renourishment (7,000 m^3)	$105,000	$79,577	$60,635	$46,442	$35,748	$27,650
16	Renourishment (7,000 m^3)	$105,000	$78,017	$58,303	$43,813	$33,100	$25,136
17	Renourishment (7,000 m^3)	$105,000	$76,487	$56,060	$41,333	$30,648	$22,851
18	Renourishment (7,000 m^3)	$105,000	$74,987	$53,904	$38,993	$28,378	$20,774
19	Renourishment (7,000 m^3)	$105,000	$73,517	$51,831	$36,786	$26,276	$18,885
20	Renourishment (7,000 m^3)	$105,000	$72,075	$49,837	$34,704	$24,330	$17,168
21	Renourishment (7,000 m^3)	$105,000	$70,662	$47,921	$32,739	$22,528	$15,608
22	Renourishment (7,000 m^3)	$105,000	$69,276	$46,078	$30,886	$20,859	$14,189
23	Renourishment (7,000 m^3)	$105,000	$67,918	$44,305	$29,138	$19,314	$12,899
24	Renourishment (7,000 m^3)	$105,000	$66,586	$42,601	$27,489	$17,883	$11,726
25	Renourishment (7,000 m^3)	$105,000	$65,281	$40,963	$25,933	$16,558	$10,660
26	Renourishment (7,000 m^3)	$105,000	$64,001	$39,387	$24,465	$15,332	$9,691
27	Renourishment (7,000 m^3)	$105,000	$62,746	$37,872	$23,080	$14,196	$8,810
28	Renourishment (7,000 m^3)	$105,000	$61,516	$36,416	$21,774	$13,145	$8,009
29	Renourishment (7,000 m^3)	$105,000	$60,309	$35,015	$20,541	$12,171	$7,281
30	Renourishment (7,000 m^3)	$105,000	$59,127	$33,668	$19,378	$11,269	$6,619
31	Renourishment (7,000 m^3)	$105,000	$57,967	$32,373	$18,282	$10,435	$6,017
32	Renourishment (7,000 m^3)	$105,000	$56,831	$31,128	$17,247	$9,662	$5,470
33	Renourishment (7,000 m^3)	$105,000	$55,716	$29,931	$16,271	$8,946	$4,973
34	Renourishment (7,000 m^3)	$105,000	$54,624	$28,780	$15,350	$8,283	$4,521
35	Renourishment (7,000 m^3)	$105,000	$53,553	$27,673	$14,481	$7,670	$4,110

Table A.5 - Northern Beach - Option 2 "Renourishment"

Year	Item	Cost in 1999	Net Present Value of Cost for a Range of Discount Rates				
			0.02	0.04	0.06	0.08	0.10
	Totals	$7,092,000	$5,279,487	$4,116,066	$3,344,544	$2,817,720	$2,448,595
1	Car Park Seawall Construction	$1,320,000	$1,320,000	$1,320,000	$1,320,000	$1,320,000	$1,320,000
2	Nil	$0	$0	$0	$0	$0	$0
3	Nil	$0	$0	$0	$0	$0	$0
4	Nil	$0	$0	$0	$0	$0	$0
5	Loss of 25% of Beach Amenities	$33,000	$30,487	$28,209	$26,139	$24,256	$22,539
6	Loss of 25% of Beach Amenities	$33,000	$29,889	$27,124	$24,660	$22,459	$20,490
7	Loss of 25% of Beach Amenities	$33,000	$29,303	$26,080	$23,264	$20,796	$18,628
8	Loss of 25% of Beach Amenities	$33,000	$28,728	$25,077	$21,947	$19,255	$16,934
9	Loss of 25% of Beach Amenities	$33,000	$28,165	$24,113	$20,705	$17,829	$15,395
10	Loss of 50% of Beach Amenities	$66,000	$55,226	$46,371	$39,065	$33,016	$27,990
11	Loss of 50% of Beach Amenities	$66,000	$54,143	$44,587	$36,854	$30,571	$25,446
12	Loss of 50% of Beach Amenities	$66,000	$53,081	$42,872	$34,768	$28,306	$23,133
13	Loss of 50% of Beach Amenities	$66,000	$52,041	$41,223	$32,800	$26,210	$21,030
14	Loss of 50% of Beach Amenities	$66,000	$51,020	$39,638	$30,943	$24,268	$19,118
15	Ocean Drive Seawall Construction	$2,451,000	$1,857,552	$1,415,391	$1,084,080	$834,470	$645,425
15	Loss of 50% of Beach Amenities	$66,000	$50,020	$38,113	$29,192	$22,470	$17,380
16	Loss of 50% of Beach Amenities	$66,000	$49,039	$36,647	$27,539	$20,806	$15,800
17	Loss of 50% of Beach Amenities	$66,000	$48,077	$35,238	$25,981	$19,265	$14,364
18	Loss of 50% of Beach Amenities	$66,000	$47,135	$33,883	$24,510	$17,838	$13,058
19	Loss of 50% of Beach Amenities	$66,000	$46,211	$32,579	$23,123	$16,516	$11,871
20	Loss of 100% of Beach Amenities	$131,000	$89,922	$62,178	$43,297	$30,354	$21,420
21	Loss of 100% of Beach Amenities	$131,000	$88,159	$59,787	$40,846	$28,106	$19,472
22	Loss of 100% of Beach Amenities	$131,000	$86,431	$57,487	$38,534	$26,024	$17,702
23	Loss of 100% of Beach Amenities	$131,000	$84,736	$55,276	$36,353	$24,096	$16,093
24	Loss of 100% of Beach Amenities	$131,000	$83,074	$53,150	$34,295	$22,311	$14,630
25	Loss of 100% of Beach Amenities	$131,000	$81,446	$51,106	$32,354	$20,659	$13,300
26	Loss of 100% of Beach Amenities	$131,000	$79,849	$49,140	$30,523	$19,128	$12,091
27	Loss of 100% of Beach Amenities	$131,000	$78,283	$47,250	$28,795	$17,711	$10,992
28	Loss of 100% of Beach Amenities	$131,000	$76,748	$45,433	$27,165	$16,399	$9,992
29	Loss of 100% of Beach Amenities	$131,000	$75,243	$43,686	$25,628	$15,185	$9,084
30	Loss of 100% of Beach Amenities	$131,000	$73,768	$42,005	$24,177	$14,060	$8,258
31	Loss of 100% of Beach Amenities	$131,000	$72,321	$40,390	$22,808	$13,018	$7,507
32	Loss of 100% of Beach Amenities	$131,000	$70,903	$38,836	$21,517	$12,054	$6,825
33	Loss of 100% of Beach Amenities	$131,000	$69,513	$37,343	$20,299	$11,161	$6,204
34	Loss of 100% of Beach Amenities	$131,000	$68,150	$35,906	$19,150	$10,334	$5,640
35	Maintenance & Renforcement	$400,000	$204,011	$105,421	$55,165	$29,218	$15,657
35	Loss of 100% of Beach Amenities	$131,000	$66,814	$34,525	$18,066	$9,569	$5,128

Table A.6 - Northern Beach - Option 3 "Seawall"

Year	Item	Cost in 1999	Net Present Value of Cost for a Range of Discount Rates				
			0.02	0.04	0.06	0.08	0.10
	Totals	$4,235,000	$3,205,373	$2,545,602	$2,107,399	$1,806,003	$1,591,673
1	Seawall Construction	$350,000	$350,000	$350,000	$350,000	$350,000	$350,000
1	Renourishment (14,000 m^3)	$210,000	$210,000	$210,000	$210,000	$210,000	$210,000
2	Renourishment (7,000 m^3)	$105,000	$102,941	$100,962	$99,057	$97,222	$95,455
3	Renourishment (7,000 m^3)	$105,000	$100,923	$97,078	$93,450	$90,021	$86,777
4	Renourishment (7,000 m^3)	$105,000	$98,944	$93,345	$88,160	$83,352	$78,888
5	Renourishment (7,000 m^3)	$105,000	$97,004	$89,754	$83,170	$77,178	$71,716
6	Renourishment (7,000 m^3)	$105,000	$95,102	$86,302	$78,462	$71,461	$65,197
7	Renourishment (7,000 m^3)	$105,000	$93,237	$82,983	$74,021	$66,168	$59,270
8	Renourishment (7,000 m^3)	$105,000	$91,409	$79,791	$69,831	$61,266	$53,882
9	Renourishment (7,000 m^3)	$105,000	$89,616	$76,722	$65,878	$56,728	$48,983
10	Renourishment (7,000 m^3)	$105,000	$87,859	$73,772	$62,149	$52,526	$44,530
10	Seawall Maintenance	$35,000	$29,286	$24,591	$20,716	$17,509	$14,843
11	Renourishment (7,000 m^3)	$105,000	$86,137	$70,934	$58,631	$48,635	$40,482
12	Renourishment (7,000 m^3)	$105,000	$84,448	$68,206	$55,313	$45,033	$36,802
13	Renourishment (7,000 m^3)	$105,000	$82,792	$65,583	$52,182	$41,697	$33,456
14	Renourishment (7,000 m^3)	$105,000	$81,168	$63,060	$49,228	$38,608	$30,415
15	Renourishment (7,000 m^3)	$105,000	$79,577	$60,635	$46,442	$35,748	$27,650
16	Renourishment (7,000 m^3)	$105,000	$78,017	$58,303	$43,813	$33,100	$25,136
17	Renourishment (7,000 m^3)	$105,000	$76,487	$56,060	$41,333	$30,648	$22,851
18	Renourishment (7,000 m^3)	$105,000	$74,987	$53,904	$38,993	$28,378	$20,774
19	Renourishment (7,000 m^3)	$105,000	$73,517	$51,831	$36,786	$26,276	$18,885
20	Seawall Maintenance	$35,000	$24,025	$16,612	$11,568	$8,110	$5,723
20	Renourishment (7,000 m^3)	$105,000	$72,075	$49,837	$34,704	$24,330	$17,168
21	Renourishment (7,000 m^3)	$105,000	$70,662	$47,921	$32,739	$22,528	$15,608
22	Renourishment (7,000 m^3)	$105,000	$69,276	$46,078	$30,886	$20,859	$14,189
23	Renourishment (7,000 m^3)	$105,000	$67,918	$44,305	$29,138	$19,314	$12,899
24	Renourishment (7,000 m^3)	$105,000	$66,586	$42,601	$27,489	$17,883	$11,726
25	Renourishment (7,000 m^3)	$105,000	$65,281	$40,963	$25,933	$16,558	$10,660
26	Renourishment (7,000 m^3)	$105,000	$64,001	$39,387	$24,465	$15,332	$9,691
27	Renourishment (7,000 m^3)	$105,000	$62,746	$37,872	$23,080	$14,196	$8,810
28	Renourishment (7,000 m^3)	$105,000	$61,516	$36,416	$21,774	$13,145	$8,009
29	Renourishment (7,000 m^3)	$105,000	$60,309	$35,015	$20,541	$12,171	$7,281
30	Seawall Maintenance	$35,000	$19,709	$11,223	$6,459	$3,756	$2,206
30	Renourishment (7,000 m^3)	$105,000	$59,127	$33,668	$19,378	$11,269	$6,619
31	Renourishment (7,000 m^3)	$105,000	$57,967	$32,373	$18,282	$10,435	$6,017
32	Renourishment (7,000 m^3)	$105,000	$56,831	$31,128	$17,247	$9,662	$5,470
33	Renourishment (7,000 m^3)	$105,000	$55,716	$29,931	$16,271	$8,946	$4,973
34	Renourishment (7,000 m^3)	$105,000	$54,624	$28,780	$15,350	$8,283	$4,521
35	Renourishment (7,000 m^3)	$105,000	$53,553	$27,673	$14,481	$7,670	$4,110

Table A.7 - Northern Beach - Option 4 "Seawall + Renourishment"

Year	Item	Cost in 1999	Net Present Value of Cost for a Range of Discount Rates				
			0.02	0.04	0.06	0.08	0.10
	Totals	$4,459,000	$3,339,635	$2,700,948	$2,328,649	$2,106,222	$1,969,457
1	3 Groynes/Headlands	$420,000	$420,000	$420,000	$420,000	$420,000	$420,000
1	Renourishment (70,000 m^3)	$1,050,000	$1,050,000	$1,050,000	$1,050,000	$1,050,000	$1,050,000
2	Nil	$0	$0	$0	$0	$0	$0
3	Contingencies	$300,000	$288,351	$277,367	$266,999	$257,202	$247,934
4	Nil	$0	$0	$0	$0	$0	$0
5	Nil	$0	$0	$0	$0	$0	$0
6	Renourishment (3,000 m^3)	$53,000	$48,004	$43,562	$39,605	$36,071	$32,909
7	Nil	$0	$0	$0	$0	$0	$0
8	Nil	$0	$0	$0	$0	$0	$0
9	Nil	$0					
10	Maintenance	$42,000	$35,144	$29,509	$24,860	$21,010	$17,812
11	Renourishment (3,000 m^3)	$53,000	$43,478	$35,805	$29,595	$24,549	$20,434
12	Nil	$0	$0	$0	$0	$0	$0
13	Nil	$0	$0	$0	$0	$0	$0
14	Nil	$0	$0	$0	$0	$0	$0
15	Nil	$0	$0	$0	$0	$0	$0
16	Renourishment (3,000 m^3)	$53,000	$39,380	$29,429	$22,115	$16,708	$12,688
17	Nil	$0	$0	$0	$0	$0	$0
18	Nil	$0	$0	$0	$0	$0	$0
19	Nil	$0	$0	$0	$0	$0	$0
20	Maintenance	$42,000	$28,830	$19,935	$13,882	$9,732	$6,867
21	Renourishment (3,000 m3)	$53,000	$35,667	$24,189	$16,526	$11,371	$7,878
22	Nil	$0	$0	$0	$0	$0	$0
23	Nil	$0	$0	$0	$0	$0	$0
24	Nil	$0	$0	$0	$0	$0	$0
25	Nil	$0	$0	$0	$0	$0	$0
26	Renourishment (3,000 m^3)	$53,000	$32,305	$19,881	$12,349	$7,739	$4,892
27	Investigations	$40,000	$23,903	$14,428	$8,792	$5,408	$3,356
28	Nil	$0	$0	$0	$0	$0	$0
29	Nil	$0	$0	$0	$0	$0	$0
30	Maintenance (Existing Structures)	$42,000	$23,651	$13,467	$7,751	$4,508	$2,648
30	Construction of Groynes/Headlands	$630,000	$354,761	$202,010	$116,271	$67,616	$39,715
30	Renourishment (70,000 m^3)	$1,575,000	$886,902	$505,026	$290,677	$169,041	$99,287
31	Renourishment (3,000 m^3)	$53,000	$29,260	$16,341	$9,228	$5,267	$3,037
32	Nil	$0	$0	$0	$0	$0	$0
33	Nil	$0	$0	$0	$0	$0	$0
34	Nil	$0	$0	$0	$0	$0	$0
35	Nil	$0	$0	$0	$0	$0	$0

Table A.8 - Northern Beach - Option 5 "Groyne/Headland"

Year	Item	Cost in 1999	Net Present Value of Cost for a Range of Discount Rates				
			0.02	0.04	0.06	0.08	0.10
	Totals	$4,513,000	$3,329,158	$2,640,487	$2,227,132	$1,969,483	$1,801,556
1	1st Groyne/Headland	$138,000	$138,000	$138,000	$138,000	$138,000	$138,000
1	Saturation of Structure (18,000 m3)	$270,000	$270,000	$270,000	$270,000	$270,000	$270,000
1	Renourishment (7,000 m^3)	$105,000	$105,000	$105,000	$105,000	$105,000	$105,000
2	2nd Groyne/Headland	$138,000	$135,294	$132,692	$130,189	$127,778	$125,455
2	Saturation of Structure (18,000 m3)	$270,000	$264,706	$259,615	$254,717	$250,000	$245,455
2	Renourishment (7,000 m3)	$105,000	$102,941	$100,962	$99,057	$97,222	$95,455
3	3rd Groyne/Headland	$138,000	$132,641	$127,589	$122,820	$118,313	$114,050
3	Saturation of Structure (20,000 m3)	$300,000	$288,351	$277,367	$266,999	$257,202	$247,934
4	Nil	$0	$0	$0	$0	$0	$0
5	Contingencies	$300,000	$277,154	$256,441	$237,628	$220,509	$204,904
6	Renourishment (3,000 m^3)	$53,000	$48,004	$43,562	$39,605	$36,071	$32,909
7	Nil	$0	$0	$0	$0	$0	$0
8	Nil	$0	$0	$0	$0	$0	$0
9	Nil	$0	$0	$0	$0	$0	$0
10	Maintenance	$42,000	$35,144	$29,509	$24,860	$21,010	$17,812
11	Renourishment (3,000 m^3)	$53,000	$43,478	$35,805	$29,595	$24,549	$20,434
12	Nil	$0	$0	$0	$0	$0	$0
13	Nil	$0	$0	$0	$0	$0	$0
14	Nil	$0	$0	$0	$0	$0	$0
15	Nil	$0	$0	$0	$0	$0	$0
16	Renourishment (3,000 m^3)	$53,000	$39,380	$29,429	$22,115	$16,708	$12,688
17	Nil	$0	$0	$0	$0	$0	$0
18	Nil	$0	$0	$0	$0	$0	$0
19	Nil	$0	$0	$0	$0	$0	$0
20	Maintenance	$42,000	$28,830	$19,935	$13,882	$9,732	$6,867
21	Renourishment (3,000 m3)	$53,000	$35,667	$24,189	$16,526	$11,371	$7,878
22	Nil	$0	$0	$0	$0	$0	$0
23	Nil	$0	$0	$0	$0	$0	$0
24	Nil	$0	$0	$0	$0	$0	$0
25	Nil	$0	$0	$0	$0	$0	$0
26	Renourishment (3,000 m^3)	$53,000	$32,305	$19,881	$12,349	$7,739	$4,892
27	Investigations	$40,000	$23,903	$14,428	$8,792	$5,408	$3,356
28	Nil	$0	$0	$0	$0	$0	$0
29	Nil	$0	$0	$0	$0	$0	$0
30	Maintenance (Existing Structures)	$42,000	$23,651	$13,467	$7,751	$4,508	$2,648
30	Construction of 5 Groynes/Headlands	$690,000	$388,547	$221,249	$127,344	$74,056	$43,497
30	Renourishment (70,000 m^3)	$1,575,000	$886,902	$505,026	$290,677	$169,041	$99,287
31	Renourishment (3,000 m^3)	$53,000	$29,260	$16,341	$9,228	$5,267	$3,037
32	Nil	$0	$0	$0	$0	$0	$0
33	Nil	$0	$0	$0	$0	$0	$0
34	Nil	$0	$0	$0	$0	$0	$0
35	Nil	$0	$0	$0	$0	$0	$0

Table A.9 - Northern Beach - Option 5 "Groynes/Headlands Constructed over 3 years"

Appendix B – Public Meeting 7/9/99 Minutes

QUINNS COASTAL PROTECTION WORKS - PUBLIC MEETING

TIME: 7:30 TO 9:30 PM ON TUESDAY, 7 SEPTEMBER 1999

VENUE: GUMBLOSSOM COMMUNITY CENTRE, QUINNS ROCKS

ATTENDEES:

Harry Morgan	Commissioner of Wanneroo
Mick Rogers	M P Rogers and Associates
Ben Moloney	Department of Transport
Harminder Singh	City of Wanneroo
Dennis Blair	City of Wanneroo
Danney Lenfemana	City of Wanneroo
Phil Calley	City of Wanneroo
Brett Spencer	City of Wanneroo
Patrick Heely	Resident
Bill Jeffrey	Mindarie CoastCare
Yvette Thomson	Quinns Mindarie SLSC
Ben Tomson	Quinns Mindarie SLSC
Tony Moloney	Quinns Mindarie SLSC
Miguel Castillo	Quinns Rocks Civic Association
Lorna Mikhaiel	Quinns Mindarie SLSC
Muriey Lee	Quinns Mindarie SLSC
Nev Hogan	Quinns Mindarie SLSC
Alan Lee	Quinns Mindarie SLSC
Arthur Tarbox	Resident
Murray Hamilton	Resident
Vicki Jenkins	Resident
Sue Martin	Resident
Les Martin	Resident
Andrew Scotford	Resident
Eric Covrens	Quinns Rocks Fishing Club
Des Blackwell	Quinns Rocks Fishing Club
Judy Sylva	Resident
Fianees Couch	Resident
Bryan Couch	Resident
Jan Syla	Resident
Anne Hodgson	Resident
Fred Jacobi	Resident
Perry	Resident
Rick Simpson	Resident
Chris Mailly	Quinns Mindarie SLSC
Steve Gale	Quinns Mindarie SLSC
Ryan Brown	Quinns Mindarie SLSC
Sandra Payne	Quinns Mindarie SLSC
Karen Gale	Quinns Mindarie SLSC

Mick Bray	Quinns Mindarie SLSC
Charlene Gale	Quinns Mindarie SLSC
Samantha Gale	Quinns Mindarie SLSC
Jack Gale	Quinns Mindarie SLSC
Geoff Appelbee	Resident
Sue Pertile	Resident
Joan Gumby	Resident
Bob Gumby	Resident
Fred Naylen	Resident
Greg Grundy	Resident
Sue Grundy	Resident
Tony Cormack	Resident
Ben Bridge	Resident
A Pericic	Resident
Iain MacLean	Resident
Barry Higgins	Resident
Tony Carlsen	Resident
Kristen Dans	Quinns Mindarie SLSC
Patsy Appelbee	Resident
Mark Nelli	Resident

INTRODUCTION:

Commissioner Harry Morgan

OUTLINE:

Dennis Blair

- Foreshore erosion at Quinns has been a problem since the 1970's.
- Tremarfon conducted the initial review of the current erosion problem in 1996.
- Current study by M P Rogers to expand on this investigation.
- Meeting arranged to present the findings of Stage 2 of the current study which is approaching completion.

PRESENTATION:

Mick Rogers

- Erosion Problem Outline
- Outline of Previous Works
- Outline of Previous Study
- Outline of Present Study

STAGE 1

- Shoreline Movement Plots were analysed and indicated that over the past twenty years the Southern Beach remained relatively stable while the Northern Beach eroded.
- Survey Analysis indicated that over the past twenty years the Southern Beach had accreted by about 80,000 m^3, while the Northern Beach eroded by about 170,000 m^3.

- Sediment Budgets were calculated and it was estimated that there would be limited future change in the sediment volume of the Southern Beach. However, the Northern Beach was expected to erode at a rate of about 7,000 m^3/year.
- Wave and Storm Modelling were undertaken to determine the extent of possible erosion during storm events.

STAGE 2

Management of the Southern Beach

Coastal Processes

- No erosion trend
- Subject to erosion in severe storms

Options

- Do Nothing
- Sand Renourishment
- Seawall

Do Nothing

- In periods of very severe storms the Primary Dune will erode and Ocean Drive may be undermined.
- This would sever road access to 15 properties
- Net Present Value of Costs $\approx$\$1.3 Million

Sand Nourishment

- In severe storms sand will erode and the dune will recede.
- Action: Improve the dune buffer and replace/renourish after storm erosion.
- About 17,000 m^3 is recommended to improve the dune buffer.
- It was estimated that 3,500 m^3 / 5 years would be required to replace sand lost during severe storms.
- Net Present Value of Costs $\approx$\$0.5 Million

Seawall

- In periods of storms the beach will erode back to the seawall.
- May need some sand renourishment to replenish the beach (about 3,000 m^3 / 5 years)
- Net Present Value of Costs $\approx$\$0.6 Million.

Recommended Management Option for Southern Beach: Sand Renourishment

Management of the Northern Beach

Coastal Processes

- Erosion trend due to longshore movement of sediment.
- Erosion rate of about 7,000 m^3/year.
- Subject to storm erosion.

Options

- Do Nothing
- Sand Renourishment
- Seawall
- Seawall & Renourishment
- Groynes or Headlands

Do Nothing

- Will lose car park, facilities, beach amenity ($130,000/year), Ocean Drive and access to 35 properties.
- Net Present Value of Costs $\approx$$6.0 Million

Sand Renourishment

- On going erosion of beach in normal and storm conditions.
- Action: Replace eroded sand on a regular basis.
- It was estimated that 7,000 m^3/year insitu ($\approx$9,000 m^3 in the truck) would be required.
- About 48,000 m^3 is recommended to improve the dune buffer.
- Does not stop erosion.
- Net Present Value of Costs $\approx$$2.7 Million

Seawall

- Erosion of the car park and facilities prevented by seawall.
- Beach seawards of the seawall will continue to erode and will be lost.
- Several types of seawalls were examined and rock revetment was found to be the best.
- Net Present Value of Costs $\approx$$4.1 Million.

Seawall and Sand Renourishment

- On going erosion of beach in normal and storm conditions.
- Seawall to limit storm erosion.
- Regular sand renourishment required to replace sand taken by erosion trend.
- It was estimated that 7,000 m^3/year insitu ($\approx$9,000 m^3 in the truck) would be required.
- Net Present Value of Costs $\approx$$2.5 Million

Groynes or Headlands

- Involves changing the coastal processes and realigning the coast to make seasonal rate of longshore drift more balanced.
- It was found that 3 structures were optimum.
- A large volume of sand (70,000 m^3) is required to saturate the groyne/headland field.
- Will create erosion problem to the north.
- Net Present Value of Costs $\approx$$2.7 Million

Recommended Management Option for Northern Beach: Seawall & Sand Renourishment

QUESTION TIME:

Question/Statement/Suggestion	Response
An alternative protection system was proposed for the Northern Beach which involved the dissipation of wave energy using rows of tractor tyres chained together. The tyres could be installed during winter and removed during summer.	Alternative forms of seawalls were considered such as mortar filled revetment mattresses and interconnected concrete blocks (Seabees). The rubble revetment was found to be the most cost effective. Although protection against storm erosion during winter is important, much of the sand losses from the Northern Beach are caused by summer sea-breezes.
Concern was raised regarding rock from the proposed seawall being scattered along the beach during severe storm events.	The recommended seawall was designed to withstand an appropriate wave climate and includes an armoured toe to prevent undermining. However, ongoing sand renourishment is essential to maintain the beach and limit the wave action at the seawall.
A query was made regarding the expected width of the beach if the seawall was constructed.	If a seawall was constructed without sand renourishment the beach would be lost. The recommended option involves the combination of a seawall to provide protection against storm erosion and renourishment to maintain the beach. If this option was implemented the expected beach width would be similar to the present beach width.
A query was raised regarding access to the beach if a seawall were constructed.	Access could be provided at locations along the seawall.
Support for groynes was stated and examples of successful groyne systems were identified.	Groynes were considered, but the Study indicated that they were not the most cost effective option. Adverse impacts include moving the erosion problem to the north.
It was stated to systems could be put in place to move sand past the groynes to prevent erosion to the north.	The purpose of the groynes is to trap sand and the proposed would reduce the effectiveness of the groynes and would allow the present erosion problem to continue.
Support was made for a series of groynes to be constructed, with the groyne field continuing northwards until natural rock provides adequate protection.	This option had been evaluated but was found not to be cost effective. The costing of the Groyne/Headland option included the construction of a second series of structures north of Quinns 30 years after the first series of structures have been completed.

QUESTION TIME:

Question/Statement/Suggestion	Response
An alternative protection system was proposed for the Northern Beach which involved the dissipation of wave energy using rows of tractor tyres chained together. The tyres could be installed during winter and removed during summer.	Alternative forms of seawalls were considered such as mortar filled revetment mattresses and interconnected concrete blocks (Seabees). The rubble revetment was found to be the most cost effective. Although protection against storm erosion during winter is important, much of the sand losses from the Northern Beach are caused by summer sea-breezes.
Concern was raised regarding rock from the proposed seawall being scattered along the beach during severe storm events.	The recommended seawall was designed to withstand an appropriate wave climate and includes an armoured toe to prevent undermining. However, ongoing sand renourishment is essential to maintain the beach and limit the wave action at the seawall.
A query was made regarding the expected width of the beach if the seawall was constructed.	If a seawall was constructed without sand renourishment the beach would be lost. The recommended option involves the combination of a seawall to provide protection against storm erosion and renourishment to maintain the beach. If this option was implemented the expected beach width would be similar to the present beach width.
A query was raised regarding access to the beach if a seawall were constructed.	Access could be provided at locations along the seawall.
Support for groynes was stated and examples of successful groyne systems were identified.	Groynes were considered, but the Study indicated that they were not the most cost effective option. Adverse impacts include moving the erosion problem to the north.
It was stated to systems could be put in place to move sand past the groynes to prevent erosion to the north.	The purpose of the groynes is to trap sand and the proposed would reduce the effectiveness of the groynes and would allow the present erosion problem to continue.
Support was made for a series of groynes to be constructed, with the groyne field continuing northwards until natural rock provides adequate protection.	This option had been evaluated but was found not to be cost effective. The costing of the Groyne/Headland option included the construction of a second series of structures north of Quinns 30 years after the first series of structures have been completed.

Question/Statement/Suggestion	Response
Concern was raised that the views of the public would be ignored when the final decision was made on the protection strategy to be implemented.	The Study was set up to include public consultation at the present meeting. A report on the discussions and views expressed at this meeting would be prepared, and the findings considered when commissioning the final design stage (Stage 3). Written submissions should be directed to the City of Wanneroo and would also be considered.
Queries were made regarding the influence of the changes on the beach slope.	It was acknowledged that the erosion trend may have increased the slope of the beach. Another influencing factors could be the seasonal flows of sand along the foreshore.
It was asked whether removing the artificial headland would be beneficial since the study indicated that it had caused the erosion problem at the Northern Beach.	Prior to the headland the Southern Beach was eroding. The construction of the headland reduced this problem but moved the problem to the north. Removing the headland would reduce the erosion of the Northern Beach but would return the erosion problem to the Southern Beach.
Concern was raised regarding the possible impacts that the beach changes may have had on seagrasses.	This problem was beyond the scope of the study; however, the magnitude and location of sediment level changes were available for evaluation. Most of the changes were limited to the near shore region with accretion on the southern flank and erosion on the northern flank.
Concern was raised regarding human development along the coast contributing to the erosion problem.	It was stated that beaches are very dynamic and natural beaches unaffected by human development are often in states of erosion or accretion.
A preference for capital works to solve the problem rather than ongoing maintenance was voiced.	The study had indicated that ongoing maintenance works were more cost effective based on a net present value of estimated costs over a 35 year period.
The use of offshore breakwaters was suggested.	This option had been considered but was not found to be cost effective.
The use of tyres to construct submerged breakwaters was suggested.	This option has been considered elsewhere. It has been found that they are not appropriate in shallow water (i.e. <5m).

Question/Statement/Suggestion	Response
An inquiry was made regarding the City of Wanneroo's preferred option.	Dennis Blair advised that the submissions made by the public would assist in the decision process. The City would also consider the recommendations of the Coastal Engineering Consultant and comments from the Department of Transport.
It was moved by Ben Bridge and seconded by Geoff Blackwell that a vote be taken for support of the construction of groynes to protect the Northern Beach.	11 people were in favour.
It was moved by Vicky Jenkins and seconded by Sue Martin that a vote be taken for support of the construction of a seawall and ongoing sand renourishment to protect the Northern Beach.	14 people were in favour.

CONCLUDING REMARKS:

Dennis Blair

- It appears that two options require detailed consideration
    1) Seawall construction with ongoing renourishment; and
    2) construction of Groynes or Headlands.
- A report on the meeting would be prepared and public submissions evaluated.
- A decision on the preferred option will be made by Council in October with the final design to be completed at the beginning of 2000.
- Funding for the implementation of the preferred option would be sought in the 2000/2001 budget.