4 COASTLINE MANAGEMENT CONSIDERATIONS

4.1 Beach Erosion Problem

The Redcliffe shoreline is subject to a threat of erosion associated with:

- Cliff degradation as a result of relentless weathering by wind, rain and wave action;
- Short term storm events;
- Medium to long term shortfall of natural sand supply; and
- Long term recession as a result of impacts of climate change (mean sea level rise)

Assessment of historical shoreline behaviour provides evidence of persistent sediment volume losses from the coastal system and resulting progressive erosion. To mitigate these persistent losses of sediment, the Redcliffe shoreline has an extensive history of active shoreline management. Most of today's beaches along the east coast of the Redcliffe Peninsula consist of imported sand. The native beaches prior to importation of sand were quite narrow and believed to have predominantly consisted of calcareous material (ie. shell gritt). Imported sand has been sourced from Southern Pacific Sands at Ningi, Moreton Bay (Bribie Island) and the Pine River. In recent years on average about 2,500m^3 of sand is imported from these sources and placed onto the Redcliffe beaches each year. In addition, sand is relocated/recycled within the Redcliffe Peninsula coastal system.

The average net longshore sand transport along the Eastern Beaches is northward, but is not constant along the Eastern Beaches and varies considerably from year to year. On average the net longshore sand transport potential along the Eastern Beaches is in the order of 5,000 m^3 to 10,000 m^3 per year.

The regional sediment transport is strongly influenced by the various coastal features (natural headlands, revetments, groynes and reclamations) that are present along the Redcliffe shoreline. Several groynes have been built to intercept the northerly sand transport. The most significant of these groynes being at Redcliffe Point, Shields Street, Osbourne Point, Queens Beach North, Drury Point and Scarborough Point. Furthermore, the breakwaters of the Scarborough Boat Harbour and the land reclamations at Bramble Bay intercept the longshore sediment transport.

The effect of these structures has been accumulation of sand on their updrift side (on the south at the Eastern Beaches) and the initiation of erosion on their downdrift side (on the north). It appears that at most groynes sand has accumulated to such an extent that sand bypassing occurs around the groynes during most of the year. Nevertheless, the longshore transport rate tends to be greater on the northern side of these groynes and smaller at the southern side. The southern ends of the beaches therefore experience continued erosion, necessitating seawall construction and beach nourishment at these locations.

The land reclamations at Bramble Bay, the Redcliffe Point groyne and the breakwater of the Scarborough Boat Harbour seem to intercept the longshore transport completely and the sediment transport around these structures is expected to be negligible.

Coastal issues requiring management action in the SEMP may be classified as:

- Coastal erosion (eg. beach loss, threat to adjacent development).
- Coastal land management and planning (eg. provision of access and transport links, preservation of dune ecology, visual landscape management).

For the SEMP, key requirements are to preserve the beach as a recreational asset, with appropriate access and land management provisions, and to protect existing development.

At Redcliffe, the foreshore has substantial development, comprising private residential property and public infrastructure. Previous erosion threats have prompted the construction of a number of revetment walls and several groynes. Some of the revetment walls provide the houses behind the structure adequate protection against erosion. However, the structural integrity of many revetment sections is uncertain.

In many areas the available dune buffer width is less than the calculated short term erosion buffer width requirement of ~16m. Solutions to problems where the beach and dune buffer width is inadequate and property is threatened by erosion generally involve engineering works and are almost invariably expensive.

Based on the evaluation of the existing shoreline and the assessment of the coastal processes, it was possible to identify erosion problem areas along the Redcliffe shoreline. Specific areas of concern, which are to be addressed in this SEMP, and their primary cause, are listed in Table 3-1.

Table 4-1 Specific areas of concern for Redcliffe SEMP

Location	Problem	Primary causes
Shoreline at Princes Terrace, Clontarf	Slow but persistent shoreline erosion	Reduced sediment supply from Bramble Bay
Shoreline around the “Gayundah” wreck	Ongoing erosion / illegal dumping of armouring material on foreshore	Differentials in longshore sediment transport rate
Shoreline around Picnic Point	Structural integrity of existing seawall inadequate	Geotechnical distress due to wave overtopping
Scott’s Point Beach/ Margate Beach	Ongoing beach erosion/insufficient dune buffer width	Lack of sand supply / longshore sediment transport to the north
Suttons Beach	Sand drift (sediment transport by wind) transports sand into park causing siltation of recreation areas and pathways	Accumulation of sand behind Redcliffe Point groyne
Queens Beach South (between Shields Street and Redcliffe Point)	Shoreline erosion threatens significant Norfolk Pines, a foreshore bikeway and other foreshore assets	Shoreline realignment in response to implementation of Redcliffe Jetty offshore breakwater
Queens Beach	Ongoing beach erosion/insufficient dune buffer width	Lack of sand supply / longshore sediment transport to the north
Northern end of Shield Street groyne, Osbourne Point groyne, Drury Point groyne and Scarborough Point groyne	Ongoing erosion at downdrift end of structure	Differentials in longshore sediment transport rate
Shoreline along Oyster Point Esplanade, Scarborough	Slow but persistent shoreline erosion	Reduced sediment supply from around North Reef Point
Most sandy beaches	Loss of dune vegetation Slumping of dune front	Ongoing shoreline erosion; Uncontrolled public access

4.2 Generic Option Considerations

A range of generic management options are available for consideration, which may be classified in terms of their consistency with natural coastal and environmental processes and the natural character and values of the coastline as follows:

“Soft” Options: Options which restore and/or preserve the natural character, behaviour and values of the coastal system. These will ensure the sustainable existence and natural character of the sandy beaches and dunes such that future erosion, both during short term storms and over the longer term, can be accommodated in a coastal buffer zone without threat to development requiring protective works.

Soft options may include works such as beach nourishment with sand or planning solutions that require development to be outside the zone of potential erosion (buffer zone), including:

- regulatory controls on building in undeveloped areas;
- removal of existing development from erosion prone land, and/or
- works aimed at restoration of the beach/dune system seaward of the development to provide an adequate buffer width to accommodate erosion.

"Hard" Options: Options that involve construction of works either to form a barrier to natural coastal erosion to protect development (seawalls) or to alter the natural processes to change the way in which the beach behaves (groynes and breakwaters).

Combinations of options or "hybrid" management approaches are often the most suitable where existing development lies within the erosion prone area. For example, works options such as terminal protection (seawalls) are sometimes combined with partial set-back of development, or may be augmented with ongoing beach nourishment to offset associated deleterious environmental and recreational amenity impacts. In addition, most options need to be supplemented with relevant amendments to local planning controls.

Thus, engineering works options for the Redcliffe shoreline may include 'soft' or 'hard' solutions, or a combination of both. The most common feasible works options for overcoming beach erosion problems include the following and are discussed in more detail below:

- beach nourishment with sand to restore the beach and dune system;
- seawalls to protect property;
- groynes to control the longshore movements of sand; and
- offshore breakwaters or submerged reefs to modify wave processes which erode the beach.

Such works options are generally expensive, typically in the range $2,000 to $5,000 per metre length of beach to construct for adequate protection, and the 'hard' structural options typically may have adverse side effects on the beach system. Ongoing maintenance requirements must be considered in both the design and financing. Experience indicates that careful design in full cognisance of the prevailing coastal and ocean processes and the short and longer term effects is essential for success and cost-effectiveness of such works.

For example, it is known that seawalls constructed on retreating shorelines may give protection to property, but will eventually cause loss of the adjacent beach. There is a need to ensure that the foundations of the seawall are sufficiently deep for stability to cater for the loss of the beach, typically requiring deeper foundations the more seaward the seawall is located. Similarly, beach nourishment must be designed and implemented to provide for the cross-shore and longshore movements of sand affecting the area for long term effectiveness in providing property protection while maintaining the recreational amenity of sandy beach systems.

4.3 Decision Matrix

It is convenient to consider beach protection options in the broad terms of the matrix illustrated in Table 4-2. This matrix, in effect, represents a decision tool based on criteria relating to:

- 'natural' versus 'altered' character; and

- ‘non-works’ (planning) versus ‘works’ options.

Table 4-2 Matrix of Beach System Management Options

	Preserve Natural Beach System Character	**Accept Change to Natural Beach System Character**
Non-Works Options **(planning, management and regulation)**	Development free buffer zones via planning or land use regulation; Resumptions of erosion prone development; Set-back of buildings; Building guidelines and controls; Land use guidelines and controls; Management including dune care activities.	Accept development on vulnerable erosion prone land, but prevent any protection works (allow loss of buildings and facilities as erosion occurs).
Works Options	Beach nourishment with sand to restore the beach and dune system; Submerged reefs for shore protection and/or surfing.	Seawalls to protect property; Groynes to control the longshore movements of sand; Offshore breakwaters to modify beach shape and sand transport.

To be consistent with coastal management policy guidelines and the priorities generally adopted by the community in areas where beach amenity is important, the options in the column headed ‘Preserve Natural Beach System Character’ would normally have highest ranking in any assessment criteria. Consideration may also be given to other low cost temporary works options and hybrid options that combine the beneficial characteristics and offset deleterious characteristics of specific individual options.

The likelihood of success (or the risk of failure) is a key consideration in the selection of possible solution options. The options adopted involving expenditure of public funds should preferably be tried and proven techniques for dealing with beach erosion problems. There are a number of other (generally lower cost) options that are commonly put forward, covering a wide range of operational modes and with various claims of success. Most of these options typically have limited theoretical backing, have limited potential for providing significant long term benefits and/or have generally not been proven as an effective means of beach stabilisation. Such options would be ranked as low feasibility of success and would not be recommended for the Redcliffe shoreline. Options for Redcliffe

4.4 General Considerations

The need for and nature of solution options to deal with the coastal erosion problem along the Redcliffe Peninsula depends on the nature and level of the threat and consequences if it is left unchecked. The erosion problem to be addressed is jointly one of threat to property and loss of the beach, with a varying degree of magnitude along the beach. The most appropriate management options may vary along the Redcliffe peninsula.

It must be recognised that most of the existing beaches along the Redcliffe Peninsula are artificial and without engineering works the beaches would be non-existent or have a different appearance. The existing beaches and cliffs form important features of the Redcliffe Peninsula landscape.

There are two basic strategic approaches for dealing with the joint problems of erosion threat to the development and loss of the beach, namely:

- Do nothing and allow the natural erosion processes to occur; or
- Hold or improve the present coastal alignment by protection in one of many ways.

Do nothing

Where development has limited value and the cost of necessary protection works are relatively high, the most appropriate solution to the erosion threat is generally to take no action and allow the beach and dune to behave in the natural manner.

However, at the Redcliffe shoreline, the Do Nothing option is likely to be socially unacceptable and economically inappropriate because:

- There is substantial development that would become under threat by erosion if the beach was allowed to behave in its natural manner;
- The beaches would become substantially narrower than the existing beach and lose landscape and aesthetic value;
- The composition of the beach material on the beaches would gradually change and may eventually become predominantly shell grit which is less comfortable for beach users.

Protection Options

The protection options can generally be considered in two sub-categories based on the principle nature of the works such as:

- beach nourishment options (with or without structures); or
- structural protection options.

An overview of the characteristics and general considerations associated with these options is provided below.

4.4.1 Beach Nourishment Options

Beach nourishment refers to the direct placement of additional sand onto the beach by pumping or by conventional earthmoving techniques, with the primary intent to offset sand volumes that have been lost from the coastal system. The main driver for beach nourishment can be restoring an adequate buffer zone width to accommodate natural beach fluctuations or ensure existence of a recreational beach.

Beach nourishment is in particular an effective measure to control erosion at shorelines that suffer from a progressive loss of beach material. In these situations, the nourished sand effectively replaces the deficit of sand that is causing the erosion.

The quantity of sand required will be dependent on the design philosophy with respect to the level of initial and ongoing protection and the use of structures to enhance the longevity of the works. Sufficient sand should ideally be provided to be able to accommodate short term (storm) erosion and a period of long term recession associated with longshore sediment transport differentials and sea level rise.

Beach nourishment without accompanying control structures is beneficial to the beach system, with no adverse erosion effects. However, beach nourishment alone (without accompanying control structures) is subject to the significant dispersion of sand to adjacent beaches and river deltas. Such losses can be minimised with the use of control structures such as groynes or offshore breakwaters to help hold the sand where it is most needed.

The design of any nourishment program must be undertaken carefully, recognizing that re-nourishment may be required from time to time to provide ongoing protection. Provision should be made for the placed sand to extend across the full beach profile to nourish depleted nearshore areas as well as the upper beach, the total quantity of sand being determined accordingly. If the sand is placed only on the upper visible portion of the beach, redistribution will quickly occur to establish an equilibrium beach profile giving the impression that the sand is ‘lost’ and the project is a failure. In such a case, the sand is, in fact, not ‘lost’ but remains in the active system providing an overall net gain commensurate with the quantity placed after cross-shore distribution.

Dune construction and stabilisation works to prevent sand loss due to wind erosion usually needs to form part of any substantial beach nourishment scheme aimed at restoring the beach and dune system. In that case, it would incorporate design provisions to prevent dune overtopping and oceanic inundation as well as to accommodate the effects of climate change including sea level rise. Where the aim of the nourishment is to re-establish a beach in front of an existing seawall without provision of a dune, the need for stabilisation works such as establishment of native dune vegetation would depend on the potential for wind erosion resulting from the works.

While beach nourishment may affect the ecological values of the beach and nearshore areas, it needs to be recognised that the nourishment sand would be placed in the active zone where the natural environment is one of substantial fluctuations and disturbances to which the ecological communities adapt naturally. The nourishment would effectively rebuild the beach. As such, while there may be some short term ecological impacts, in the longer term the environment will generally adapt and recolonise to behave as a natural beach system.

One of the inherent advantages of beach nourishment is that it maintains the natural character and recreational amenity of the beach while also providing property protection. As such, where the beach is severely depleted, it provides many intangible benefits to the general community, as well as a direct economic benefit to those businesses that rely on tourism and the presence of a usable beach.

However, identification and access to sources of suitable nourishment sand is usually a key issue, as is the cost (dependent on the applied volume, the sand source and method of placement). Transport of the sand to the beach is most cost-effectively achieved by dredging procedures. The use of trucks is typically slow and costly, with adverse impacts on the local community and road infrastructure.

There will be an ongoing cost to maintain this protection and amenity through future maintenance re-nourishment works in areas where the shoreline recession is progressive and/or future sea level rise will exacerbate the present problem. This needs to be assessed and provisions made in the initial design.

When considering the effectiveness of previous beach nourishment operations as an indicator for future nourishment it will be necessary to consider the extra rate at which sand must be added to offset the erosion due to future sea level rise.

4.4.1.1 Nourishment Alone

Beach nourishment alone (ie. without accompanying control structures) is beneficial to the beach system, with no adverse erosion effects, as it introduces additional sand into the active beach system. The sand will gradually disperse to the adjacent beaches under the influence of the prevailing wave conditions. This process will provide a net benefit to those adjacent beaches but will gradually reduce the volume of sand and the available buffer in the zone initially nourished.

Accordingly, the design of any nourishment program must be undertaken carefully, recognizing that re-nourishment may be required from time to time to provide ongoing protection, particularly in areas experiencing long term recession. The quantity and frequency of such re-nourishment will be dependent on the initial design philosophy with respect to ongoing protection as well as the prevailing conditions that will be subject to natural variability.

For Redcliffe's Eastern Beaches, there is evidence that the sand moves northwards over time and there is a potential to recycle or back-pass this sand to reduce the need to continually introduce sand into the system. Potential locations to capture the longshore sediment transport at the Eastern beaches include the northern end of Suttons Beach and the northern section of the Eastern Beaches (Scarborough Beach or Reef Point).

The long term success of beach nourishment as a coastal protection option is therefore dependent on the nature of the shoreline processes (ongoing recession or dynamically stable) and, potentially, ongoing availability of suitable sand and an ongoing commitment (including available funds) for re-nourishment or recycling as necessary.

Monitoring should be carried out following nourishment to determine its longer term trend of behaviour, allowing for short term fluctuations associated with storm erosion and subsequent natural beach accretion. This would provide essential information for any future decisions on coastal management at the site.

4.4.1.2 Nourishment with Control Structures

As discussed above, beach nourishment alone is subject to the gradual dispersion of sand to adjacent beaches and ongoing losses as part of long term recession trends. Such losses can be minimised with the use of control structures such as groynes or offshore breakwaters to help hold the sand where it is most needed. The structures will act to hold the sand and change the coastal alignment thereby stabilising the shoreline to a degree and potentially reducing long term recession rates.

While such structures will increase the longevity of the beach nourishment and the protection it provides in some parts of the beach, they can introduce adverse impacts to adjacent beaches, depending on the initial nourishment and re-nourishment strategy. Potential exacerbation of erosion on the downdrift (northern) side of control structures can be minimised by ensuring the initial nourishment essentially 'fills' them and re-nourishment essentially provides for the ongoing losses.

Due to the stabilizing effect of the structures, the ongoing overall losses in the nourishment area would be less. As such, the design life of a particular quantity of beach nourishment is may be increased compared to that without control structures. However, there would be the added cost and impacts of the structures.

On a beach with progressive sand loss and associated shoreline recession, erosion of the nourished beach with control structures will commence and be greatest at the updrift (southern) end of each compartment and immediately downdrift of the structures. The rate of long term recession will reduce southwards towards the control structures and be effectively zero immediately updrift of the control structures. As such there will be variations in the rate of recession and associated erosion threat along the shoreline, to be considered in the design of the works. If the desired beach improvement is to be maintained along the whole beach length, re-nourishment would be required from time to time.

Even if the structures are fully nourished initially and ongoing re-nourishment is carried out to replace the eroded sand, some exacerbation of the downdrift erosion would be likely due to the stabilising influences of the control structures locking up sand and transferring long term losses. Consideration could be given to either accepting this erosion in undeveloped areas or carrying out other mitigation works such as other control structures and/or the placement of additional nourishment sand to compensate. The quantity and frequency of re-nourishment in this case would therefore be dependent on the need to minimise adverse impacts to the south.

4.4.1.3 Nourishment with Terminal Protection (Seawalls)

Appropriate planning, monitoring and management of a beach nourishment scheme would aim for timely re-nourishment to occur if and as needed to ensure that a suitable buffer is retained to accommodate storm erosion. However, there are often uncertainties associated with incomplete understanding of the likely future beach behaviour or feasibility of future re-nourishment such that there would be a risk that property behind could be threatened by erosion at some stage.

An option for dealing with this risk is to incorporate terminal protection in the form of a seawall together with the nourishment. This seawall would provide protection against further erosion until re-nourishment is carried out. It should be constructed as far landward as possible and would remain buried for the majority of time and would only become exposed if timely re-nourishment is not carried out.

If the intent of the scheme includes a commitment to ongoing maintenance of a beach in front of the seawall to provide protection and amenity, then the design standard for the seawall could be relaxed in the knowledge that its function is to provide interim protection for a short duration when the beach sand is depleted during storms. In such a case, the wall would not need to be designed to withstand substantial scour in front, as would be the case for a seawall only scenario on a receding shoreline.

4.4.2 Structural Protection Options

Structural options provide protection of property against ongoing erosion either directly through the construction of a seawall or by rebuilding of the beach through the construction of groynes. They are options that could be considered in the event that sufficient beach nourishment sand is not available and/or retreat options are not viable. However, there are always some adverse impacts of such an approach where no additional sand is provided, as outlined below.

Such structures would typically be of flexible rubble mound design with rock being sourced and trucked to the site from quarries in the region. While they may be effective in protecting property or providing a localized wider beach, they are generally accompanied by associated costs related to adverse impacts on the adjacent beaches. This cost is typically made up of direct costs associated with lost income from the tourist industry and other intangible costs associated with the natural coastal amenity, beach access, loss of recreational beach area and degradation of ecological values.

4.4.2.1 Seawalls

Seawall or rock walls such as those constructed at Redcliffe are commonly built with the intent of providing terminal protection against shoreline retreat. Seawalls are robust structures constructed along the shoreline which provide a physical barrier separating the erodible material immediately behind the structure from wave and current forces acting on the beach itself. They are typically constructed of loosely placed rock to allow for some flexible movement or concrete retaining structures. Sea walls need to be designed to withstand severe wave attack.

Where possible, seawalls should be continuous to prevent end effects and/or discontinuities that could threaten the overall integrity of the wall. They also have to be suitably founded for stability against scour at the toe of the structure, particularly on a receding shoreline.

While a properly designed and constructed seawall can protect the landward property from erosion, it effectively isolates the sand located behind the wall from the active beach system and may lead to other adverse consequences.

On a receding shoreline, the seawall becomes progressively further seaward on the beach profile over time. This leads to a gradual increase in the quantity of sand effectively lost from the beach system, with:

- lowering and eventual loss of the beach in front of the wall; and
- exacerbation of the erosion on the downdrift end of the wall where the losses are transferred and concentrated.

Both consequences have been experienced at Redcliffe and will continue until the overall shoreline alignment has moved seaward from the structure.

Scour and lowering of the beach in front of the wall ultimately exposes it to higher wave attack and can lead to slumping and the need for ongoing maintenance. Such maintenance is typically in the form of topping up of the wall with additional rock. However, where the seawall is not adequately designed or constructed, complete reconstruction may be needed.

Seawalls in isolation can thus be effective in protecting the property behind, but at a cost of the loss of the beach in front and exacerbated erosion on the downdrift side.

4.4.2.2 Groynes and Artificial Headlands

Groynes and artificial headlands are impermeable structures constructed at right angles to the shoreline and extend across the beach and the nearshore surf zone. Their function is to trap sand moving along the shoreline under longshore transport processes to build up and stabilise the alignment of the beach on the updrift side. By necessity they starve the beach of sand supply on the downdrift side causing erosion as shown in Figure 4-1.

The sand trapped on the updrift side provides a buffer of sand to accommodate short term storm erosion. The shoreline alignment will also change providing greater stability and reduced long term erosion immediately updrift of the structure. The extent of accretion and length of shoreline affected is dependent on the length of the structure as well as the characteristics of the longshore transport processes. Generally, the longer the groyne, the more sand it will trap over a longer distance with decreasing influence away from the structure.

However, there is a physical limit to the length of shoreline affected and therefore a number of structures may be needed if substantial benefit or protection is required over a long stretch of shoreline. In such a case, there is a balance between the length and spacing of groynes that needs to be optimised as part of a detailed design process.

An artificial headland is a substantial groyne type structure that has a physical width at its head in comparison to a conventional narrow groyne. It is believed that this width alters the mechanisms of sand transport past the end of the structure and may allow a wider/longer beach to be retained on the updrift side for the same protrusion offshore. This could have the benefit of minimising the need for, or maximising the spacing of, additional structures to provide protection for a long stretch of coastline. However, such headland type structures would be larger and more expensive to construct.

Groynes or artificial headlands can thus be used to rebuild a beach and stabilise the shoreline against ongoing recession on the updrift side. However, in the absence of other works such as beach nourishment, this comes at the cost of exacerbated erosion on the downdrift side to where the erosion trend is transferred.

Another significant consideration associated with groynes is their potential visual intrusion to the vista of a long sweeping beach and interruption to direct access along the beach. There are various design options with respect to the style and crest height of the structures that could be considered to minimise such adverse effects.

Figure 4-1 Beach at Osbourne Point groyne showing impact of a groyne

4.5 Material Sources and Costing Considerations

The implementation of coastal protection works is dependent on suitable material being available and placed in a practical, economical and environmentally acceptable manner. General considerations associated with sourcing, cost and applicability of different material types are discussed below, including preliminary estimates in terms of unit costs for capital and ongoing maintenance works provided on the basis of available information.

Cost estimates for the various options are based on these unit rates for comparison purposes. Specific recommended works would be subject to detailed design, impact assessment and tendering processes that may influence the final cost. There will also be on costs associated with the design, impact assessment and approval processes for the recommended options.

4.5.1 Beach Nourishment

The feasibility of beach nourishment is dependent on the practical and cost-effective availability of a suitable source of sand. Sand should be of suitable quality (grain size and colour) and would ideally match the existing beach sand. When nourishment sand is imported from outside the beach system, sufficient quantities of sand should be available for both initial and ongoing nourishment and should be able to be obtained and placed without adverse environmental impacts. Most of existing sand on the Eastern Beaches is off-white to light brown, with a typical grain size of approximately 0.5mm.

4.5.1.1 Offshore Marine Sand Sources

General considerations with respect to use of offshore sand sourcing sites include:

- identification of sand source(s);
- suitability of the sand;
- transport of the sand to the site;
- rezoning and approval for sand extraction; and
- potential environmental impacts.

Possible offshore sources of sand for beach nourishment purposes have not been investigated in detail to date, but it is possible that sand could be available from navigation channel dredging maintenance in Moreton Bay through the Port of Brisbane Corporation (PBC). Although it is expected that Moreton Bay sand is finer than the beach material that is currently present on the Redcliffe beaches, cooperative sourcing of nourishment sand in conjunction with PBC channel dredging potentially offers a cheap sand source for nourishment. Taking advantage of dredge establishment and sand extraction by PBC, the cost for this sand source, if viable, could potentially only cover the placement cost and incremental transport cost.

Alternatively Moreton Bay sand can be sourced from commercial borrow sites at Middle, Yule and Spitfire Banks. There are five authorized extraction suppliers at these borrow sites, all represented by Bowen Barge and Tug. The costs of these sources would however be significantly more expensive as they are commercial ventures.

The sand in Moreton Bay has a median grain size of 0.2 to 0.3mm, which is smaller than the median grain size that is currently present on the Eastern Beaches (0.5mm). Although Moreton Bay sand could potentially be used, it should be noted that finer sand is mobilised in greater quantities under the influence of waves, currents and wind, leading to greater sediment transport rates and consequently a requirement of larger volumes of maintenance beach nourishment. Furthermore, finer sand would naturally form a flatter beach profile, which may affect the beach width and shoreline alignment around existing groynes and headlands at Redcliffe. This affect should be investigated if Moreton Bay sand is considered as a sand source for beach nourishment at the Redcliffe beaches. Also, this sand is likely to be “whiter” than the current sand from Ningi.

Sand from offshore areas is typically dredged with a trailing arm suction hopper dredge that also transports the material to the deposition site where it would be pumped ashore or discharged to a nearshore area. The precise logistics for delivery depend on the location and how close the dredge can approach the shore. Ideally, the dredge would pump sand onto the beach, where it would be moved directly into design profiles by earthmoving machinery. Alternatively, it could be delivered elsewhere and trucked to the site.

If the transport distance is less than about 1.0-1.5 km (eg. beach recycling or sand relocation operations), small suction dredges may be used. Costs of such sources, if viable, are typically around \$10 - \$20/m^3.

4.5.1.2 Land-based Sand Sources

Considerations with respect to use of such sites include:

- identification of sand source(s);
- suitability of the sand – grading and colour;
- transport of the sand to the site;
- possible need to purchase the property involved;
- rezoning and approval for sand extraction;
- potential environmental impacts including acid sulfate soil considerations; and
- site rehabilitation.

Possible onshore sources of sand for beach nourishment purposes have not been investigated to date. In recent years, beach nourishment sand has been sourced from an onshore sand pit at Ningi. Sand from the Ningi sand pit is similar to that which currently exists on most Eastern Beaches (i.e. similar colour and grain size). The sand pit is operated by Southern Pacific Sands and is located approximately 40km by road from the Redcliffe Beaches.

Previous sand deliveries from Ningi have been delivered to site by truck and distributed by earthwork machinery. This is a proven method, but transportation of the sand by truck may be an issue, particularly if large quantities are involved. Trucks would cause disruption and damage along access roads. For beach nourishment operations where larger quantities are involved, a specific management plan is required to avoid/manage environmental and traffic concerns. Based on recent beach nourishment operations by Council, the cost to supply, deliver and place sand imported from Ningi is about \$35 - \$40 per m^3.

An alternative to delivery by road is to deliver the sand by barges. For Ningi sand, sand would be trucked from Ningi to Sandstone Point and then barged to the Redcliffe beaches. Cost and most appropriate equipment will depend on the quantities and the accessibility to possible loading and unloading locations.

4.5.2 Coastal Structures

Coastal protection structures are typically of a flexible mound construction type to allow for some movement and to absorb some of the wave energy. Rock is the dominant material used in such structures and is dependant on suitable local sources being available. Alternative construction materials such as concrete armour units and sand filled geotextile bags could also be considered for such structures but have limitations such as high cost and poor visual amenity of concrete units and short practical life due to decay, failure and vandalism of geotextile units.

Rock armour units would need to be obtained from local hard rock quarries. While the specific extent and limitations of the available resource is not known, it is evident that sufficient rock would be available but would need to be sourced by truck from quarries at substantial distance and cost. A significant constraint associated with rock armour is the need to truck the material to the site over local roads. For large projects, this can mean frequent truck movements over an extended time frame.

Indicative cost estimates for the supply and transport to site of rock based on typical experience are as follows:

- Armour rock supply to site: $30 - $40 / tonne
- Quarry run rock supply to site: $15 - $25 / tonne

On this basis, typical coastal structure costs including materials, and on-site placement are estimated as follows:

- Seawall (toe level -0.5m AHD, crest +3.1m AHD) ~ $3,000 / m
- Groyne (toe level 2m below seabed, crest +3.0m AHD) ~ $5,000 / m

For the assessment of the erosion management options, a nominal contingency allowance of 25% has been applied to the above coastal structure cost estimates.

Rock structures by their nature are subject to movement and settlement over time. They are also subject to damage during storm events although they are designed to withstand major wave attack. A typical design criterion is for less than 5% damage during a 50 year storm. As such, ongoing maintenance will be required to ensure the structural stability is not compromised.

This will necessitate maintaining access to the top of any seawall to allow 'top up' works to be carried out. Minor slumping of groyne and offshore breakwater structures after initial construction is generally not such an issue provided that the function and structural stability are retained. An ongoing maintenance cost of 1% per year is typically adopted for rock structures subject to storm wave attack.