TECHNICAL REPORT

SALTER POINT FORESHORE RESTORATION PLAN REVIEW

SEPTEMBER 2015

FOR
CITY OF SOUTH PERTH

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PART 1: INTRODUCTION

1.0 PROJECT CONTEXT

Syrinx Environmental PL (Syrinx) was appointed by the City of South Perth (the City) in November 2010 to develop the Foreshore Restoration Plan for the Salter Point spit as several areas of western shoreline were showing signs of severe erosion and vegetation stress. The spit was identified as a Priority 1 management area in the Swan and Canning Rivers Foreshore Assessment and Management Strategy (SRT, 2008) based on the high biodiversity, amenity, recreational and cultural values. To manage these values, the Swan River Trust (the Trust) recommended weed management, infill planting and management of localised areas of high erosion.

The Foreshore Restoration Plan (FRP) was completed in March 2011 (Syrinx 2011) to address erosion of the western foreshore and the channel connecting the lagoon with the river in line with the Trust's management recommendations. The FRP outlined the restoration techniques required to reduce the rate of erosion and help the establishment of native vegetation.

The FRP and the associated technical specifications and drawings were used to guide restoration works in 2012. All of the erosion control works and the planting of lower foreshore were conducted between January and March 2012. The upper foreshore works which consisted of weed control and planting were conducted in June 2012 followed by supplementary planting in autumn of 2013.

Both the FRP and the Implementation of works in 2012 – 2013 were partly funded through the SRT Riverbank Grant program.

The restoration works were monitored and maintained by Syrinx during 2013 and continued until June 2015.

As early as June / October 2012 it was evident that the success of restoration works in terms of plant establishment was low and this did not improve after the supplementary planting in 2013. As a result of this, the City has commissioned Syrinx in January 2014 to undertake a review of the FRP and develop revised options for future restoration works taking into consideration changes in river conditions and the latest climate change information.

The overall aim of this review is to prioritise restoration options in terms of their importance to conserving overall integrity and values of the site and in line with budgetary constraints so the City can strategically implement the future restoration works.

1.1 THE SITE

Salter Point spit is located within the City of South Perth and refers to the triangle shaped promontory with a lagoon in the middle (Figure 1). The lagoon is hydraulically connected to Canning River via a narrow channel and is the last remaining natural lagoon of this type within the Swan - Canning River System (SRT, 2009). As such, the lagoon has been recognised on the Register of National Estate and the Directory of Important Wetlands having high conservation and heritage values.

Figure 1 Salter Point spit location (left) and extent of site works (right) (Imagery: Google, 2012)

The site has also been incorporated in Bush Forever (Site 333) due to its biodiversity values. In addition, the site has high cultural, amenity and recreational values that have been recognised in a number of City's strategic and technical reports (e.g. the State of the Environment Report (City of South Perth, 2002), Waterford Foreshore Management Plan (Siemon, 2000) and the City of South Perth Green Plan (Everall Consulting, 2002).

The soil type found at Salter Point consists of alluvial (water deposited) sands and silts at the foreshore and Bassendean sands on the elevated areas of the site. The Bassendean sands are prone to erosion, and subsequently to vegetation loss and soil degradation (e.g. loss of soil biota and or weed invasion). The waves (particularly during storm surges) and anthropological disturbances are the key factors causing erosion of soils on the spit and as such are addressed in this document.

1.2 SCOPE OF WORKS

The scope of work for the project included research and development of new options for the restoration of the western foreshore of the Salter Point spit.

In particular, the scope required:

- Desktop study and research into changing river conditions and the resulting erosion of the foreshore;
- Field assessments establishing areas of highest impact and identifying actions required to mitigate erosion risks based on previous restoration works;
- Development of restoration options and presentation of these options to the City;
- Prioritisation of areas for restoration; and
- Submission of the final report including cost estimate and timelines for implementation of the preferred option.

PART 2: METHODOLOGY

2.0 DESKTOP RESEARCH

The desktop research was conducted on literature published after the issue of the FRP (Syrinx, 2011). Particular attention was given to literature concerning climate change, changing river conditions and impacts of various activities on the shoreline stability. The literature included:

- URS (2013) – Assessment of Swan and Canning River Tidal and Storm Surge Water Levels; and
- McMullen (2012) - Coastal flooding of the Swan River and the effects of climate change induced mean sea level rise.

In addition, tide data for the 2009 – 2013 (DoT, 2013) period was reviewed, to determine the level of inundation and possible impacts of rising water levels on the stability of the western foreshore and the spit point.

3.0 FIELD RESEARCH

A field data collection was undertaken on 10th April 2014 at mid tide. The current condition of existing erosion protection structures was assessed and areas of highest erosion and vegetation loss noted. Together with the field records collected during the 2013 maintenance period, these notes were assessed, to understand the efficacy of the techniques used and help develop appropriate management strategies for the future.

A visual inspection of most of the intertidal region recorded following:

- Location of all foreshore areas that are undergoing erosion (both active and past) and the likely causes of erosion;
- The severity of the erosion and capacity of the erosion to contribute to ongoing environmental and recreational problems such as loss of lower and upper foreshore vegetation, compromise of the lagoon landform, foreshore amenity and access; and
- Vegetation health (qualitative, by observation of growing tissues such as branch tips, new leaf growth, etc.).

4.0 DATA ANALYSIS

All of the data gathered during the desktop study and field survey were analysed and compared with the data collected in 2010 - 2011 for the preparation of the FRP. Based on the findings, the following items were presented in the report:

- Relevance of each factor to the condition of the foreshore and the success of original restoration efforts in 2012;
- Suggested management actions to rehabilitate eroding areas and prioritise them; and
- Potential restoration options to manage erosion and improve vegetation establishment.

5.0 CONSULTATION AND OPTIONS DEVELOPMENT

The options developed on the basis of field findings and the literature review were presented to City of South Perth and the Swan River Trust to obtain their input and recommendations prior to describing the preferable option for restoration.

The preferred option was then described in more detail and the order of magnitude costs and timelines for implementation works provided.

PART 3: REVIEW – CAUSE, EFFECT AND MANAGEMENT

In order to best explain the success or otherwise of restoration works implemented in 2012, background information on causes of erosion and vegetation loss on the site are given prior to presenting the results of current investigations. For orientation, the site has been divided into five zones as presented in Figure 2 incorporating the type and extent of restoration works completed in 2012.

Figure 2 also shows the location of access tracks, the boardwalk and two Telstra service access pits. The pathways are constructed of compacted crushed limestone bordered by pine treated logs and metal edging. Due to frequent flooding in winter the northern section of the pathway (north of boardwalk) is overlain by sand. Similarly, the pathway to the spit (Zone 4 in Figure 2) is also sandy. The infrastructure elements such as the southernmost Telstra service access pit and the boardwalk are likely to influence erosion particularly the areas adjacent to these structures.

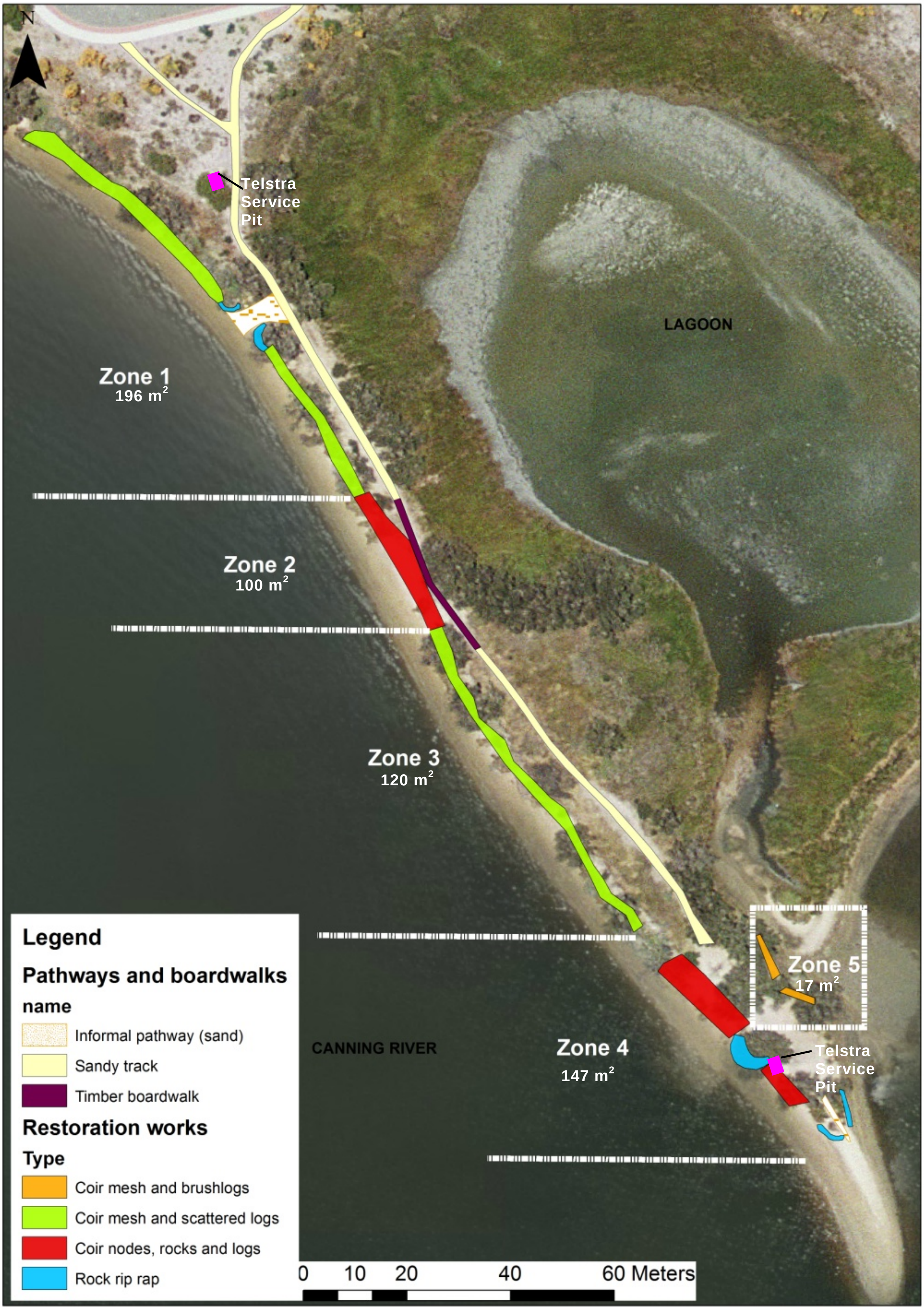

Figure 2 Restoration Zones at Salter Point Spit showing extent of previous (2012) restoration works (Imagery: Landgate, 2006)

6.0 FORESHORE EROSION

Erosion and sedimentation are natural processes occurring in all riverine and coastal environments. The amount of natural erosion and sedimentation or “accretion” depends on the shape of the shoreline, seasonal fluctuations in water levels or flows, wind strength, direction and wave behaviour. In addition, anthropogenic activities such as boating, fishing and infrastructure can also modify the erosion and sedimentation processes.

An observation of historical photographs between 1953 and 2013 has revealed that most of the erosion for the site has occurred along the eastern and western foreshores and the channel connecting the lagoon to the river (indicated by red arrows in Figure 3).

Figure 3 Changes in shoreline extent between 1953 and 2013 (Imagery: Landgate, 2013) showing approximate sites of significant erosion

Please note: the eastern shoreline is not discussed in this report as it was outside of scope of works.

Given the variation in river water levels (some images were taken at different times of the year and both high and low tides), the overall erosion of the western foreshore since 1953 would account for less than 5m of the shoreline loss, with the highest level of erosion being observed in the area currently adjacent to the boardwalk (Zone 2, see red arrow on Figure 3) and at the lagoon outlet. It appears that the shoreline deposition process is occurring to the north west of the site (indicated by yellow arrow).

6.1 FACTORS INFLUENCING EROSION ON SITE

The main factors that were identified in the past and are currently contributing to erosion are discussed in more detail in the following sections and include:

- Waves (wind waves and boat wash);
- Flooding;
- High tides;
- Severe storms / Storm surges;
- Loss of riparian vegetation;
- Informal public access and infrastructure;
- Climate change particularly the sea level changes;
- Sediment availability and
- Changes in river hydrodynamics.

6.1.1 Waves

Wave generated erosion was identified as the major eroding force on site (Syrinx, 2011). While the waves continue to influence the erosion and accretion processes on the spit, boat wash appears also to influence shoreline stability.

In the review of the effect of boat wash and wind waves on shoreline erosion (Gourlay, 2011) indicates that the measurement and comparison of the effect of these waves on shoreline is difficult to establish as it is site dependant and requires determination of a cumulative transmitted wave energy above a site specific erosion threshold – something that is very difficult to obtain in practice. The most efficient way to compare the effect of boat and wind waves is to record maximum wave height, the corresponding wave period and transmitted wave energy. This exercise requires long term investigation and modelling and was out of scope for the preparation of the FRP and for this review, and is best conducted by the qualified hydrologists in tandem with determining net sediment transport.

6.1.1.1 Wind waves

Wind waves are created when winds blow over an area of water, referred to as the fetch. The size of the waves created by the wind is determined by:

- the size of the fetch;
- the water depth;
- the speed of the wind; and
- the length of time or duration the wind blows over the fetch.

The size and the prevalent direction of the wind waves at Salter Point spit are influenced by a relatively small fetch and shallow water which generate small waves. Because the largest fetch is located to the north east and north west of the site, these waves are likely to be largest and influence the sediment movement conducive to erosion and sedimentation.

The analysis of wind roses for the Perth area suggests that the dominant wind directions are light to moderate north easterlies in the mornings and moderate to strong south westerlies in the afternoon for the majority of the year. The prevailing south westerly winds deposit sediment, whereas the north westerly winds that blow in winter, particularly during storms, erode it (Figure 4).

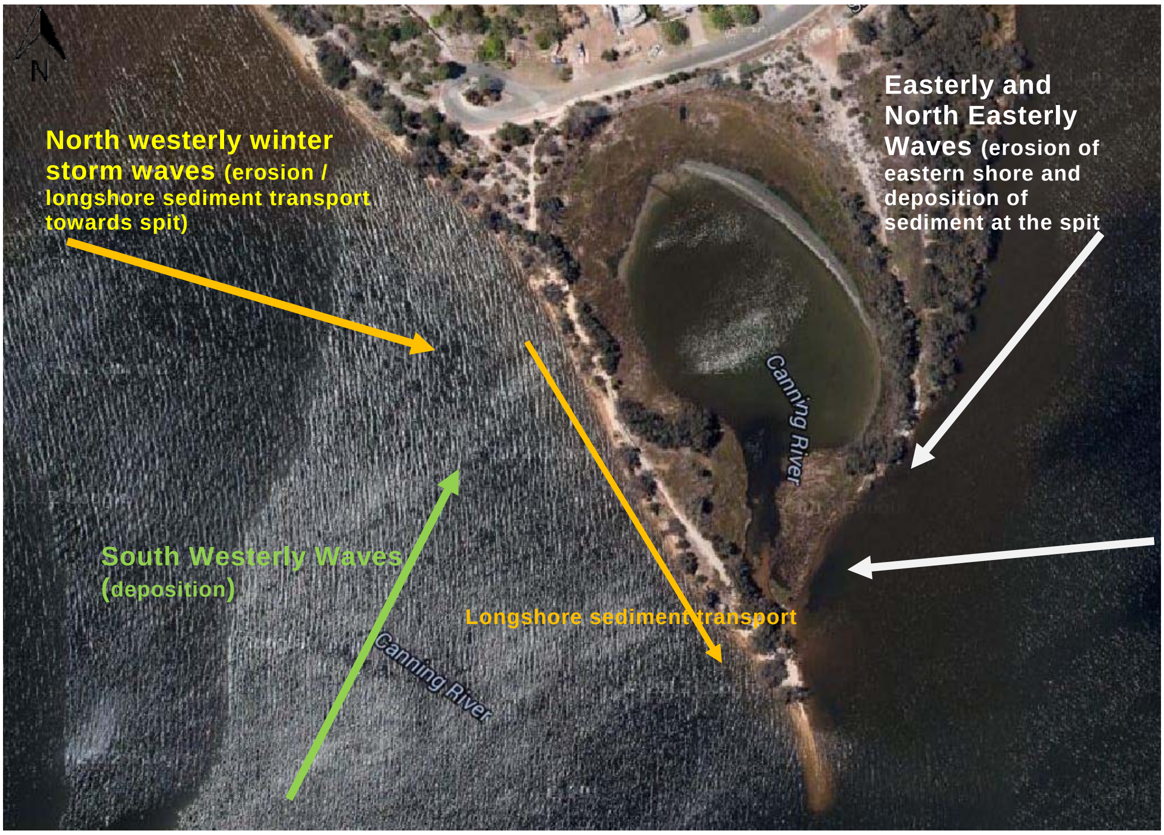

Figure 4 Aerial photograph of the site showing dominant wind / wave direction (Imagery: Google, 2012)

When the wind speed is high and water levels rise (due to tides and the storm surge events) the height and the period of waves increases causing them to reach areas of upper foreshore that are usually not subject to wave action. Unaccustomed to this change, the vegetation found in these areas is susceptible to damage by waves. Once the vegetation is damaged and the cover reduced, the soils erode further allowing waves to penetrate deeper into the foreshore profile. This is most evident in Zones 2 and 3 where waves reach higher elevations (~ 0.6 mAHD).

6.1.1.2 Waves generated by boat wash

Unlike wind waves that are usually of short height and period, waves generated by boat wash are higher and have a longer period. Because of this, waves generated by boats have a higher capacity to move the sediments and thus cause erosion (Gourlay, 2011, AMC, 2009).

The wave pattern generated by a boat is largely dependent on the boat shape, speed and the water depth in the area (AMC 2009). Given that the area is predominantly frequented by smaller vessels, the boat speeds are low (5 knots) and the ski area located downstream at Aquinas Bay, the waves generated by boats are likely to have lower impact on the shoreline and be short in duration. In addition, most of the boating activity occurs in summer when the water levels are generally lower, so it could be assumed that waves generated by boats do not have a significant impact on the shoreline stability compared to wind waves. Only a detailed study specific to the effects of boat wash on the erosion of Salter Point foreshore could confirm the validity of the above statement.

6.1.2 Flooding, Tides and Storm Surges

6.1.2.1 Flooding

Flooding along the Swan and Canning Rivers can occur after significantly heavy or prolonged rainfall which produces large amounts of runoff (WRC 2000, McMullen, 2012). Salter Point spit is located in the lower reaches of the Canning River so it is likely to be dominated by the ocean tides as well, which in addition to its low topography would increase the likelihood of flooding particularly during winter months.

Whilst flooding due to freshwater input has occurred in the past in both Swan and Canning River floodplains (McMullen, 2012, Middlemann *et al,* 2005) nowadays particularly with reference to the Salter Point spit and the drier climate, the flooding is caused most frequently by storm surges and high tides. The Department of Water (DoW) recently assessed the Swan and Canning River tidal and storm surge levels (URS, 2013) in order to incorporate the predicted sea level rise due to climate change and produce the new 100 year ARI flood levels. These new levels provide information necessary to evaluate current floodplain mapping and help build new guidelines for development near floodplain.

The list below shows 100 year ARI water levels for the Canning River (Site Can 3 located near Salter Point (URS, 2013)) based on modelling results provided by URS (2013) and those presented previously by PWDWA, (1982) and WAWA, (1987). These levels include the maximum water level for that site (Can 3) including the wind set up. The wind set up refers to the effect of the wind on tide levels during storm surges (i.e. elevation in the direction towards which the wind is blowing).

100 year ARI developed in the1980s and used until 2010	1.22 mAHD
100 year ARI “Present Day”	1.47 mAHD
100 year ARI Future (2110)	2.27 mAHD

The DoW has mapped the 100 year floodway and the flood fringe boundaries for the Swan Canning River System for the present day conditions. The section relevant to Salter Point spit is shown in Figure 5 and indicates that almost entire site is subject to flooding under current 100 year ARI (DoW, 2013).

Figure 5 100 year ARI Floodway and Flood Fringe Line (Source: Landgate, 2014 with dataset by DoW (2013)

6.1.2.2 Ocean tides

The water levels at Salter Point spit are influenced by tides, as the Canning River is hydraulically connected to the ocean via Swan - Canning estuary. These tidal influences are attenuated by the narrow areas of the estuary and the lower Canning River resulting in smaller water level fluctuations at the site compared to the Perth Waters (i.e. Barrack Street Jetty).

At Barrack Street Jetty, the daily tide range is typically about 0.3 – 0.5 m during spring tides depending on season (based on the predicted tides tables produced by BOM (2014)) and around 0.0 – 0.2 m during neap tides. It is expected that the Salter Point spit is likely to have a similar tidal range to Barrack Street Jetty under normal tidal conditions, with highest astronomical tide (HAT) being close to 0.5 mAHD (using HAT for Barrack Street Jetty of 0.55 mAHD, URS, 2013).

From the observations taken in the field during construction of works and the subsequent monitoring and excluding storm events, most tidal movements on site occur between 0.2 and 0.6 mAHD with storm surge event water levels between 0.6 and 1 mAHD.

6.1.2.3 Storm Surges

The regular rise and fall of tides (or the sea level) is continuously modified by the effects of the weather. High winds and a reduction in atmospheric pressure are the two main causes of changes in tide levels. These changes are called the storm surge levels or non-tidal residual.

The effect of the storm surge is most severe when high winds and low atmospheric pressure occur in conjunction with the high tide. Conversely, an increase in atmospheric pressure and a decrease in winds in conjunction with neep (low) tides results in a decreased tide level which is also known as the inverse barometer effect. The storm surge is also influenced by low bathymetry such as the shallow areas of the river at Salter Point spit.

Most recently recorded significant surge that is particularly relevant to the site restoration works occurred between 10th and 13th June 2012. The readings recorded at Barrack Street Jetty on all three days show tides in excess of 1.6 m Chart Datum (m CR) (equivalent to 0.85 mAHD) with the tide peak of 0.96 mAHD recorded on 10th and 11th June (BoM, 2012).

On 11th June 2012, the event persisted for several hours causing prolonged inundation of the site which was recorded by the Syrinx maintenance crew. On 12 and 13 June the Swan River water levels at Perth (Barrack Street) equalled or exceeded 0.85 mAHD for only a short period of time (less than an hour) with a peak of 0.86 mAHD, suggesting little local inundation (BoM, 2012).

The typical tidal movements for the site and those of the storm surge have been presented in Figure 6 using topographic contours of the area (Figure 6). Photographs of the site during winter high tide (Figure 6 c) and the storm surge on 11th June 2012 (Figure 6 d) are also presented.

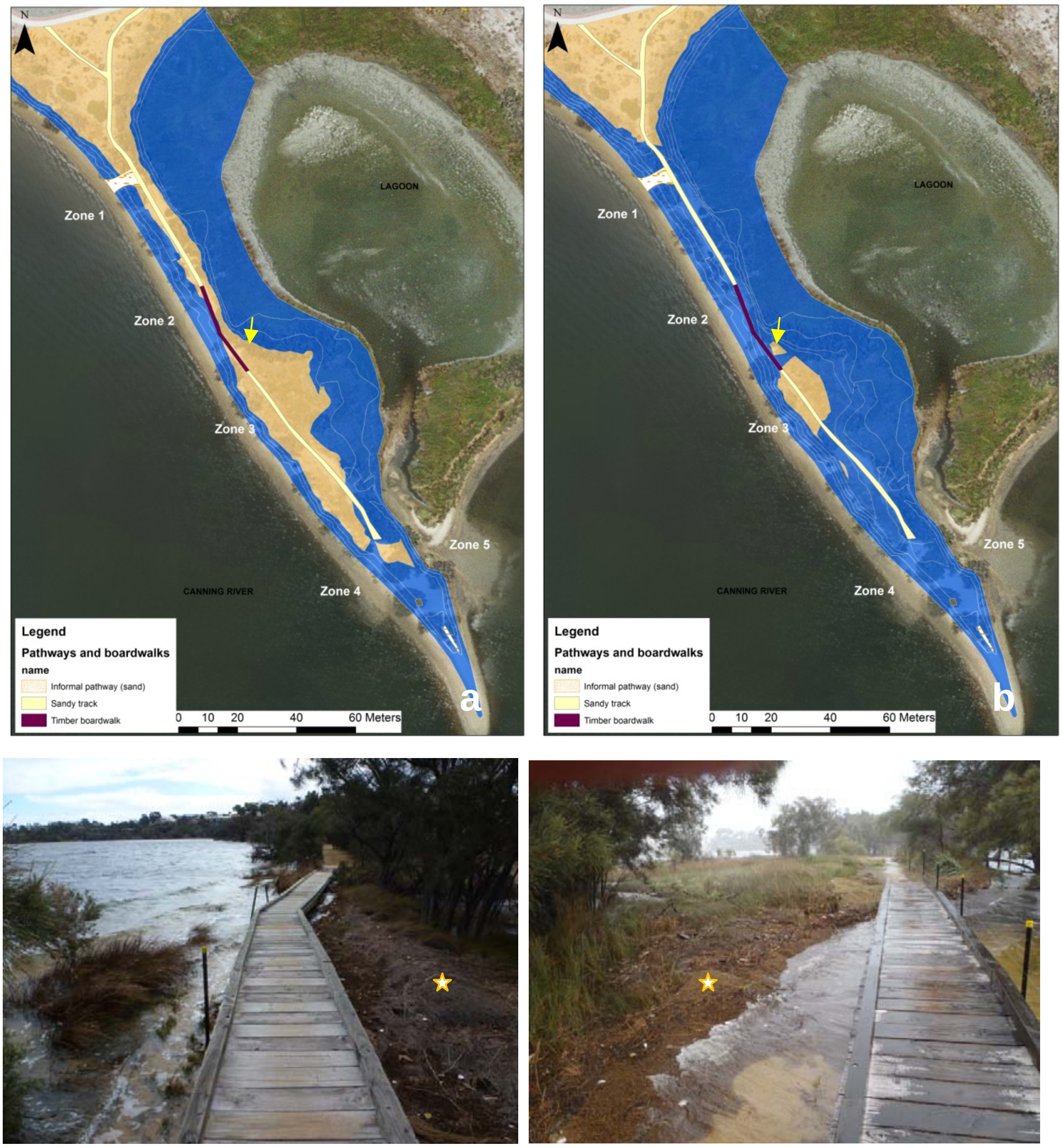

Figure 6 Current expected flood levels (in blue) due to winter storm tidal movements to 0.6 mAHD (a) and the storm surge to 1 mAHD (b). Photographs from site (location shown with yellow arrow) show the extent of flooding for 0.55mAHD* tide (c, facing north) and at 0.65mAHD* tide during 11th June 2012 storm surge (d, facing south).

* Figures taken from observed tides at Barack St. Jetty at the time the photographs were taken.

☆ .Indicate location of the elevated section of the bank indicated with yellow arrows in figures (a) and (b).

Please note that the tide heights presented in Figure 6 (b) and (d) show increased water level to 0.8m AHD on the site which was contributed by strong wind waves.

The review of the tide data for the 2009 – 2013 period collated by the Department of Transport (DoT) (Figure 7) for Barrack Street Jetty, shows that since June 2012 event another surge occurred on 28 – 29th November 2012 which reached 1.03 mAHD (1.78 m CD). During 2013 most significant tide was recorded on May 8 with a recording of 0.92 mAHD (1.67 mCD). Although short in duration, it is likely that these events also contributed to the poor establishment of vegetation, however February 2012 and June 2012 events are most significant as they occurred during and immediately after planting thus causing most damage.

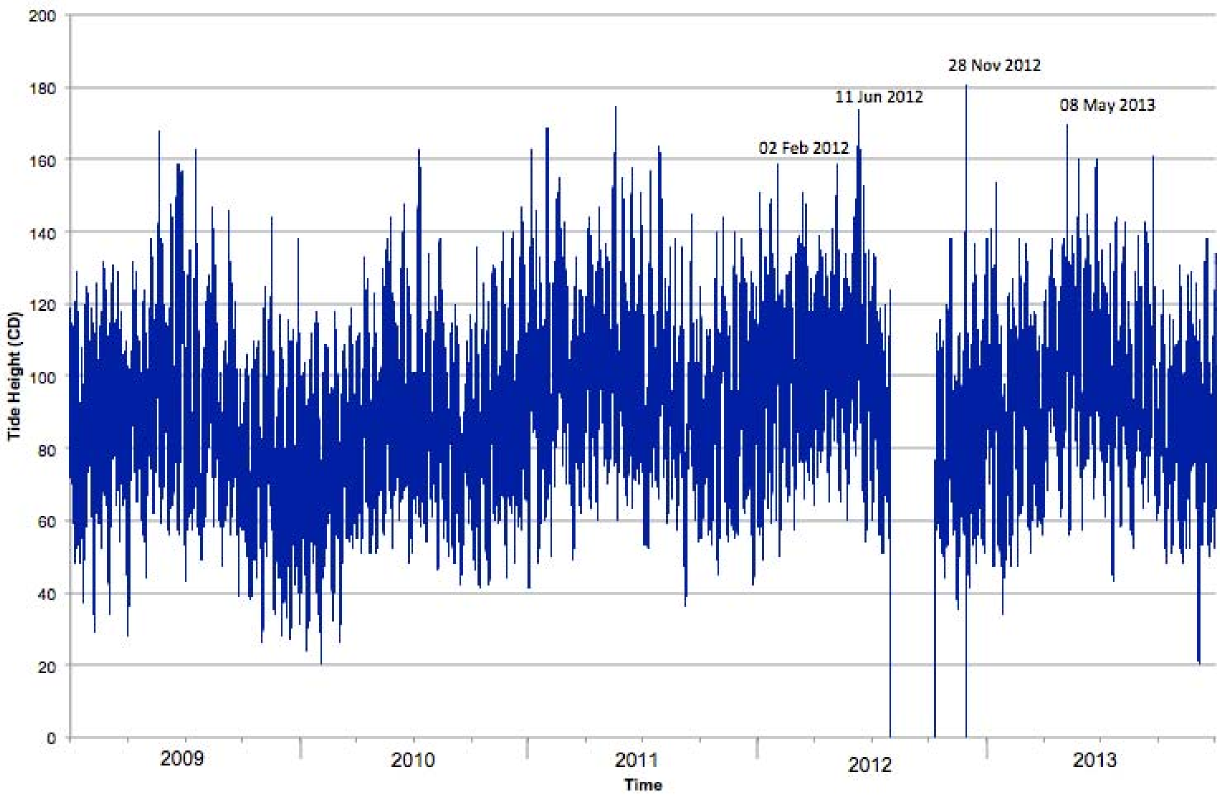

Figure 7 Tide records for Barrack Street Jetty 2009 – 2013 (Data from DoT, 2014)

Note: Datum recorded in the figure above is Chart Datum (CD) which is 2.234m below tidal benchmark BM MWB 1484.

No data records are available for August – October 2012.

6.1.3 Informal Public Access and Infrastructure

In addition to the factors described above, recreational (passive) use of the area either for fishing, kayaking or walking in addition to infrastructure such as boardwalk or utilities servicing pits (e.g. fibre optic cable) and changes to the local catchment contribute to soil erosion and vegetation loss.

Informal use of the spit area over a long period has resulted in trampling of vegetation which has affected the stability of the shoreline, particularly at the spit end. It is possible that loose sands promoted by high traffic at the spit point not only discourage plant establishment but may also promote loss of sediment to the river.

The temporary erosion control measures implemented along the shoreline often pose difficulty in beach access for recreational users prompting them to walk over newly restored (easy to access) areas or remove the temporary structures altogether. The limestone rocks used to protect the base of a large *Casuarina obesa* tree at the spit end have been moved by public to different areas of the site most frequently for crossing of the lagoon channel or to form seating areas. Some of the smaller rocks have been thrown into the river. These actions have inadvertently impacted on the success of the project.

Whilst temporary fencing has been installed to prevent access to rehabilitated areas, it is difficult to discourage visitors particularly fishermen from accessing them without significant policing or installation of more robust fencing which would reduce amenity of the area. Some fishermen and other visitors access the spit point almost every day of the year and particularly on the weekends during low tide as the access further into the river via spit point is possible.

The presence of infrastructure particularly the Telstra service access pit at the spit end has increased erosion surrounding the pit. The hard walling of the pit reflects the waves, increasing their amplitude which in turn increases scour and loss of sand at the base and sides of the pit. The erosion is made even more prominent by fishermen who frequently use the area for seating and storing of the fishing gear. Likewise, the installation of the boardwalk in the 1980s has caused localised erosion particularly at the base of the posts supporting the boardwalk structure.

In addition to increasing wave energy and erosion near the built structures, the buried optic cable also contributes to erosion by hindering the appropriate installation of erosion control measures and the subsequent revegetation. The pot holing was not attempted in 2012 to determine the exact location of the cable; however, a plant finder was used to estimate its location relatively accurately. This was done as the implementation of erosion control works requires installation of long jarrah stakes parallel to the telecommunications line. Even if the contractors pot holed the area to determine exact location of the cables, the Telstra Duty of

Care guidelines stipulate any boring of ground (such as installation of jarrah stakes) to be located at 2m distance from the cable.

This distance meant that the erosion control works were installed lower in the profile than would be considered optimal, with the height of the coir logs being at less than the highest astronomical tide (0.55 m AHD at Barrack Street, (URS, 2013), reducing its efficacy in protecting new plants from the wave impact.

6.1.4 Vegetation loss

Rather than being the cause of the erosion, vegetation loss in a riparian environment usually occurs as a result of eroding forces of water and wind. Nonetheless, in some instances loss of vegetation cover as a result of vegetation clearing, fire, trampling, drought, increased inundation times or increased / decreased salinity, disease and other anthropogenic disturbances can be a precursor to erosion.

The loss of vegetation at Salter Point has occurred as a result of combination of most of these processes, the clearing of the lagoon channel in 1985 – 1988 (City of South Perth *pers. comm*.) and the site's low topography and bathymetry. Notable losses of vegetation have occurred in the area of Zone 2 where clumps of *Juncus kraussii* used to occupy the shore, most likely as a result of the use of the area for fishing and beach access.

Vegetation losses between 1995 and 2013 are shown in Figure 8 below (red arrows).

Figure 8 Vegetation losses on site 1995 – 2014 (Source: Landgate, 2014)

It is likely that the prolonged inundation and increased salinity due to low rainfall have contributed to the decline of some of the fringing vegetation in the recent years in combination with waves generated by wind and boats. Given that the trees like *Melaleuca cuticularis* and *Casuarina obesa* have very shallow roots (an adaptation to avoid anoxic conditions deeper in the sediment), even small amount of erosion around the roots can de-stabilise the trees and cause them to be uprooted during strong winter storms. Roots of trees are rigid and dense and do not dissipate wave energy as well as the flexible stems of *Juncus kraussii* for example. *Juncus kraussii* while having good wave dissipation and sediment trapping properties are susceptible to undercutting. Therefore, shoreline re-profiling in areas of undercutting is important in preventing losses of this species and making the population sustainable for the future.

6.1.5 Long term causes of erosion

6.1.5.1 Sea level changes

One of the more significant effects of climate change is the change in the sea levels. The amount of heat stored in the global oceans has increased significantly particularly in the recent decades. As a result, the global mean sea level has risen by 225 mm from 1880 to 2012 (CSIRO, 2014) both due to thermal expansion and the melting of glaciers and ice sheets.

Rates of sea-level rise vary around the world as well as around the Australian coastlines, with higher sea-level rise observed in the north and rates similar to the global average observed in the south and east (CSIRO, 2014). Swan Rive Trust indicated an annual sea level rise of 1.54 mm a year between 1897 and 2007 (SRT, 2007) and this trend is expected to continue despite the recent fall in global sea levels between 2010 and 2011 which were attributed to the intense La Nina (event which was partly responsible for high rainfall and floods in Australia in 2011).

Under all scenarios (low, medium or high greenhouse gas emissions) sea level will continue to rise after 2100, with high emissions leading to a sea-level rise of 1 metre to more than 3 metres by 2300 (CSIRO, 2014). As a result, it is expected the increases in mean sea level and the frequency of storm surges will cause flooding along the Swan and Canning River catchment, particularly in low lying areas such as the Salter Point spit.

Whilst the sea level change would not be significant for 2012 – 2013 year period of restoration works it is possible that the prolonged inundation and increase in salinity over previous decade has affected some of the species which grew at a lower topography 0.2-0.4 mAHD such as *Melaleuca cuticularis*.

Sea level changes up to 0.5m will submerge the current extent of the lower shoreline vegetation up to the access path. Any storm surges would inundate the entire spit as previously shown in Figure 5 Section 6.1.2.1. Sea level rise of 0.9 m would inundate the spit area and the lagoon entirely leaving only small parts of the dryland adjacent to the end of Salter Parade (north end of the promontory).

Whilst the investment in restoration works appears to be futile when considering future sea level scenarios, the short term protection of the habitat will increase longevity of the lagoon landform, provide amenity and habitat for fauna and importantly provide valuable knowledge with regards to adaptive restoration techniques which can be utilised in other areas of the foreshore in the future. One aspect of future restoration may involve low level of translocation of vegetation material particularly sedges to the appropriate hydrological zones with respect to sea level changes. These studies could be done by the City in collaboration with local universities in addition to studies of other effects of the sea level change.

6.1.5.2 Sediment availability and changes in river hydrodynamics

Changes in river hydrodynamics due to low rainfall, changes to catchment (e.g. increase in non permeable surfaces or changes to structures protruding into or bordering the river such as jetties, groynes, sea walls and bridges) or groundwater levels can all affect the rate of erosion or deposition by increasing or decreasing the transport of sediments.

Estimations or calculation of the net sediment transport can help delineate the areas where sediments are lost and deposited and with that the best options for installation of the appropriate bioengineering or structures such as groynes, headlands and breakwaters.

The net sediment transport calculations require careful consideration and measurements as they are dependent on seasonal fluctuations and are usually performed by the qualified hydrologists. As such, sediment transport is not further discussed in this document suffice to say that the longshore transport is the prevalent mode of sediment transport along the western foreshore (sediment movement towards spit point causes erosion and movement towards north cause deposition).

6.2 REVIEW OF THE IMPLEMENTED EROSION CONTROL METHODS

Following section reviews the erosion control methods used in 2012 restoration works and outlines their performance.

All erosion control structures were implemented using best practice standards as outlined in the Swan River Trust Guidelines (SRT, 2009) and as per specifications outlined in the FRP (Syrinx, 2011).

The erosion techniques used were originally selected with regards to the intensity of erosion, flood levels (as available in 2011 using 1980’s data) and limitations due to the fibre optic cable and the public access to the spit.

6.2.1 Coir mesh and scattered wood debris

This technique was implemented in the low erosion environments where foreshore vegetation was relatively intact - predominantly in Zones 1 and 3.

The level of erosion in these zones after restoration works appears to be reduced based on the amount of sand accretion occurring surrounding the woody debris, with most logs being buried two years after installation (Figure 9). Only small areas of Zone 3 contain coir matting predominantly in the upper part of the foreshore where the influence of waves and tides is less frequent.

Figure 9 Coir mesh and scattered wood debris showing site in May 2014 – all logs buried in sand Zone 1 (left) and exposed logs in Zone 3 (right)

Coir mesh and scattered wood debris method of erosion protection was valuable and has prevented further erosion where installed, particularly in Zone 1. However, in the areas of Zone 3 where undercutting at 0.5 and 0.6 mAHD is present, this method does not appear to have been as effective, with little to no sand accretion particularly in areas that have sedges missing (Figure 9). The logs installed in Zone 3 were positioned slightly higher (~0.3 mAHD) than in Zone 1 (0.1 - 0.2 mAHD) which was likely to have been the reason for the difference in addition to increased water scour as a result of the undercut areas.

This technique requires modification either by using brush logs to help with wave energy dissipation and sediment accretion in front of the undercut or other techniques that would allow for the same process to occur. Installing brushlogs that are slightly higher than the top of the undercut would help minimise the impact of waves and promote vegetation establishment.

The banks were not re-profiled in the 2012 restoration works due to site access and costs associated with bringing in the sand. Although the exposed undercuts were covered with coir mesh, this was not sufficient to stop the erosion during storm events resulting in vegetation planted on and in front of the undercut to be lost.

Conclusions / recommendations

Slight re-profiling of the banks in the most affected areas (i.e. areas with undercuts over 25cm) should be done prior to erosion fabric installation and planting during future restoration works to minimise wave scour. This can be done by using river sand replenishment preferably in summer and from a suitable source.

6.2.2 Coir nodes

Coir nodes were installed in Zone 2 and Zone 4. This method was used previously at Cloisters Foreshore downstream from the site to capture sediment and establish vegetation with great success. The nodes were installed at 0.2 and 0.4 mAHD in Zone 2 to maximise sediment capture (Figure 10).

The upper level of the nodes located at approximately 0.4m AHD worked well to trap the sand and promote plant establishment for Marine Couch (*Sporobolus virginicus)* and few large *Juncus kraussii*. Both node levels were disintegrated by wave action after 16 months *in situ* with only small sections of the logs buried in sand remaining.

When wet, coir nodes can enhance wave reflection (SRT, 2010) since they have a low porosity which in turn causes undercutting at the base of the log and the loss of coir material. However, despite the loss of the coir logs, the erosion in this area was minimised, and sand accretion promoted.

Figure 10 Coir node restoration in Zone 2 (2012 -2014)

Coir node method was successful in terms of minimising erosion and encouraging sand accretion. However, this method was not the best choice for longer term protection of Zones 2 and 4 and general plant establishment. This is attributed to high wave impact in these zones, particularly in winter. The hard surfaces such as the boardwalk (Zone 2) and the Telstra service access pit (Zone 4), in addition to very little or no vegetation cover and the strong wind waves are the main causes of erosion in these areas. Installing coir nodes at 0.2mAHD did not appear to hold any benefits as they were submerged at all times during autumn and winter periods and this had no effect in breaking the wave impact except at very low tides.

The height of the coir logs was insufficient to help reduce wave impact on vegetation planted behind the wave front. Marine Couch benefited the most from installation of coir logs most probably due to its low height so the seedlings were always well protected from the wave action.

Conclusions / recommendations

Installation of brush logs, wave erosion fence or similar, with the height of 0.6m (i.e. higher than the HAT of 0.55 mAHD) would likely work better than coir logs in both Zone 2 and Zone 4.

Once the coir logs are eroded, the stake ends are unsightly and offer a tripping hazard. The stakes should be removed either by pulling them out (a difficult and likely disruptive procedure that may cause localised erosion) or cutting the top of the stake and driving it further into the ground using sledge hammer. Driving stakes into the ground or cutting them to be flush with the shore would be preferable as pulling stakes out may break them causing large splinters which would be hazardous to beach walkers.

6.2.3 Rock Rip Rap

Rock Rip Rap was the simplest method of restoration works implemented on site whereby soil erosion is minimised by dissipating the wave energy across a multitude of medium to small limestone rocks. The rock rip rap was used to protect bases of the large trees (Figure 11) at the spit end (Zone 4) and in areas of high traffic such as access points. This method was deemed appropriate due to high disturbance in the area (high foot traffic) and other methods such as coir logs, brushmattressing and coir matting were not possible due to the proximity of the Telstra cable and size of the tree root ball which would have also hindered planting in the area

Figure 11 Rock Rip Rap surrounding a large tree in Zone 4 in 2012 (a) and 2014 (b)

Beyond keeping the erosion at bay in the low wave impact zone such as Zone 1, Rock Rip Rap did not work well in Zone 4 with no additional sand accretion observed either at the large tree base or at the spit point.

Whilst it can be argued that the weight of the rocks and their wave energy dissipation have helped maintain the *status quo* in terms of preventing erosion and the loss of the tree, this method worked poorly particularly in an exposed and heavily used area such as the spit point. Use of rock rip rap may even increase the likelihood of erosion and changing of the wave patterns locally, a situation worsened by presence of the hard structure such as the Telstra service access pit. Because the area is frequented by fishermen, the rocks are often dislodged to gain access to tree trunk for shade in summer, or form a crossing at the lagoon outlet which further limits efficacy of this method.

Conclusions / recommendations

Given that the fibre optic cable will not be moved, the area will be used by fishermen regularly, and that the water levels will be higher in the future, restoration in Zone 4 may not be possible and the best outcome would be to allow natural erosion to occur and leave any fallen trees *in situ*. An alternative would be to consider low level sand nourishment at the start of summer.

6.2.4 Brush logs and coir matting

Installed along the western end of the lagoon outlet channel, this method has proven most efficacious in terms of sand accretion and building of the beach with no additional erosion occurring in the area (Figure 12). This is due to the ability of the brushlog to reduce wave and scour energy as well as trap the sediments.

Brush logs have had an excellent result in terms of sediment capture and beach stabilisation, helping establish a more stable shore and maintain the flows to and from the lagoon.

To maintain the efficacy of this erosion control structure, the brush logs should be monitored and maintained regularly and planting of *J. kraussii* conducted – once established, stems of the sedges can grow through the brush unlike the solid structures such as coir and timber logs.

Figure 12 Brush Log technique of erosion control (lagoon outlet)

6.3 EROSION: SUMMARY AND RECOMMENDATIONS

After examining the main causes of erosion at Salter Point, it can be concluded that wind waves coupled with storm surge events have the greatest effect on shoreline stability particularly in the areas without vegetation.

The installed erosion control structures on site varied in terms of their efficacy to prevent erosion, increase sediment capture and promote vegetation establishment.

The most successful method for erosion control was brush log installation in Zone 5 at the lagoon outlet channel, and the poorest was the rock rip rap in Zone 4. Coir log nodes and coir matting with scattered woody debris have both been successful to a large degree in preventing erosion in the short term.

Given the predicted increase in frequency of storm surge events and the expected sea level rise as a result of climate change, following erosion management actions integrated with foreshore planting are recommended to help maintain the integrity of the site as long as possible:

- Implement brush wall technique in Zone 2. The brush wall should be installed at 0.3 or 0.4 mAHD and be at a minimum of 0. 6m. This height is level with the top of the boardwalk and will allow for wave attenuation during high tides and storm surge events.

- Use combination of brush wall and coir matting to restore upper sections of the foreshore in Zone 3.

- Investigate possibility of using other temporary erosion protection methods such as ‘wave fence’ to help dissipate wave energy before it can act on upper parts of the bank. Wave fence is still under development and involves sandwiching fine thin layer of brush material between fine mesh (6.5 x 6.5mm grid (e.g. mouse and snake mesh) supported by star pickets or jarrah wooden stakes. The fence can be removed in summer if needed and installed again in winter and may be more economical and efficient in the long term, particularly considering the changes in sea levels and tidal influences.

- Maintain current restoration works particularly in the areas where there has been a success in erosion protection (e.g. Zone 1 and Zone 2).

- Perform potholing to determine exact location of the cable to investigate possibility of installing brush log groynes at the spit end to help capture some sediment particularly near Telstra service access pit which would help with retention of the large tree in the area. Should the large tree be uprooted it should be left *in situ* to help with accumulation of sand (i.e. the tree can act as a groyne) however, careful positioning would be required to achieve the best result.

7.0 VEGETATION ESTABLISHMENT

Vegetation establishment in any particular area is dependent on several environmental factors the main being soils (nutrients), water and sunlight. Any changes to these three factors can prevent or enhance vegetation growth. This is largely a simplistic view and there are many other variables to consider particularly with respect to each species requirements for establishment, growth and reproduction within each topographical setting.

In the previous sections a lot of emphasis has been placed on the stability of soils; both physical stability and chemical influences (e.g. increases in salinity and waterlogging through inundation) were mentioned as these appear to be some of the causes of poor health and loss of the remnant vegetation at Salter Point spit. However, continued decrease in rainfall and increase in temperatures (as a result of climate change), extraction of groundwater and increase in hard surfaces in the local and wider catchment can also affect plant growth along the foreshore particularly in the long term.

In this section climate effects such as temperature and rainfall are analysed as well as the plant propagation material characteristics which contribute to the establishment of species.

7.1 FACTORS INFLUENCING VEGETATION ESTABLISHMENT AT SALTER POINT

7.1.1 Climate

The latest report on the State of Climate – 2014 (CSIRO, 2014) indicates that Australia's climate has warmed by 0.9°C since 1910, and the frequency of extreme weather has changed, with more extreme heat and reduction in rainfall for the south west of Australia, particularly in the last 20 years. This trend is projected to continue in the future with more prominent increases in temperature, decrease in rainfall and an increase in sea level rise (CSIRO, 2014).

The combination of drying and increased evaporation results in decreased soil moisture which adversely affects establishment and persistence of vegetation cover particularly in the dryland or upper foreshore areas. This in turn has a direct impact on functioning of ecosystems at large. Similarly, prolonged inundation and increased salinity caused via entry of sea water into the water column also has a negative impact on the sustainability of the ecosystems which were once adapted to a milder climatic regime.

7.1.1.1 Local Climate

The site experiences typically warm Mediterranean climate characterised by wet, mild winters and dry, hot summers. The closest meteorological station to the site with reliable long term data that would likely be similar to site, is located at Jandakot Airport (Jandakot Aero (009172) weather station) located 7.9 km south of site (Perth Metro and Perth Airport weather stations are located 12.3 km north and 15.1km north-east respectively).

The mean minimum and maximum winter (July) temperatures are 6.7°C and 17.9°C whilst the mean minimum and maximum summer (February) temperatures are 17.1°C and 31.7°C. The average annual rainfall is 819.3 mm, with 56 % (410 mm) falling in the winter months (June to August) (BoM, 2014).

Historical climate data for Jandakot Aero (009172) weather station, showing annual rainfall and mean temperature maxima for the years 1989 to 2013 is summarised in Figure 13.

Mean annual rainfall for the years 2004 to 2014, represented by the pale blue line, is 720 mm, 99.3 mm below the 42-year (1972-2015) long-term average of 819.3 mm. Annual rainfalls well below the 10-year average (2004 – 2014) of 720 mm were recorded for 2010 (496 mm), 2006 (509 mm), and 2014 (566 mm).

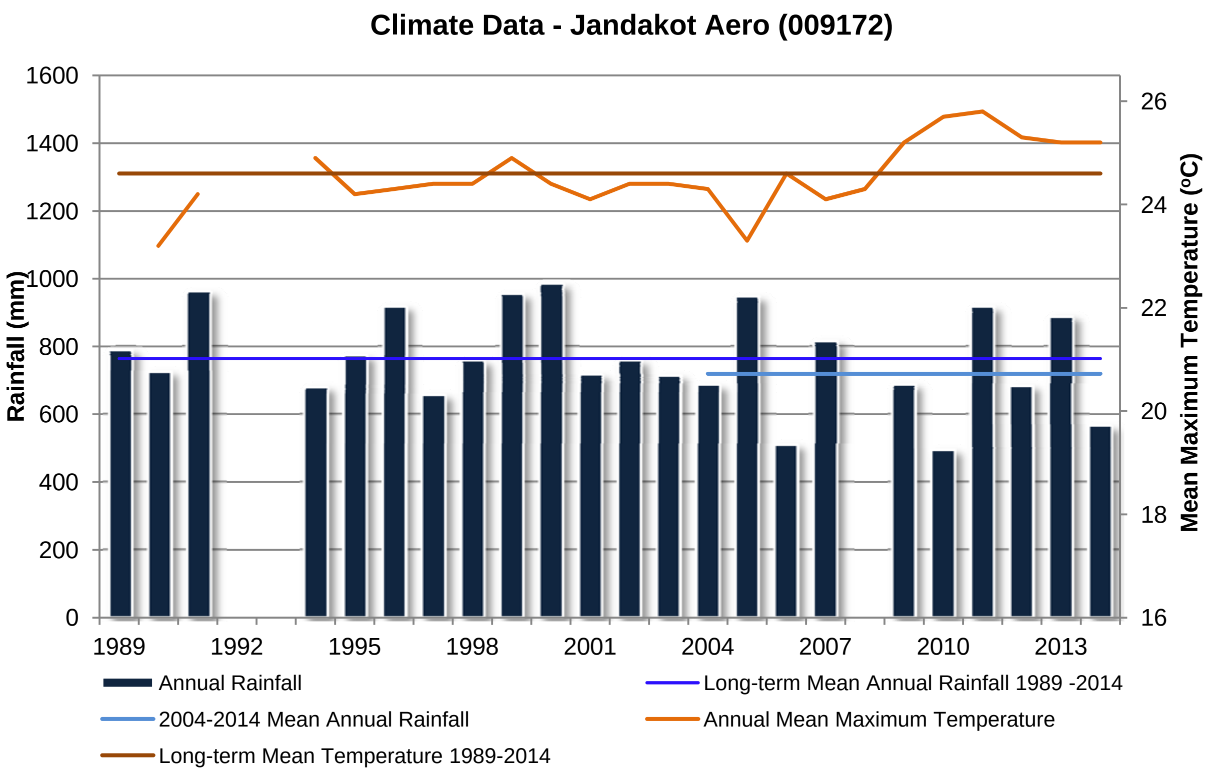

Figure 13 Annual rainfall and mean temperature maxima for Jandakot Aero (009172) weather station for years 1989 to 2014 including the long-term (42-year) mean annual rainfall (BoM 2015)

Since 2008 the mean annual temperature maxima have consistently exceeded the long-term average of 24.5°C with temperatures in 2010 and 2011 having temperatures of 1.2 and 1.3°C above mean long term average with slight drop in 2008 by 0.8°C. These increases in temperature are higher than the Australian estimate provided by CSIRO (CSIRO, 2014) which outlined average warming of 0.9°C.

When the monthly rainfall recorded between the 2010 and 2014 is compared with the long-term (42 year) mean, the data indicates that the winter/spring rainfall has been below average particularly for years 2010 and 2012. The highest monthly mean temperature is also higher for these years.

7.1.1.2 Effects of rainfall and temperature on Salter Point restoration

Most Salter Point foreshore planting works have occurred late January – March 2012 (Figure 14). Although no rainfall occurred in March 2012, the average summer rainfall and possibly the groundwater conditions on site would have been suitable for initial establishment of the foreshore species. However, the temperatures recorded during the planting period were much higher than average and combined with winds on site have contributed to high transpiration or water loss from the plants. Whilst the plants were watered during the establishment period, the watering frequency was low (limited by budget constraints) and amount was not adequate to counteract water losses.

Low winter rainfall also had an effect on the growth of dryland species which were planted in June 2012. The below average July rainfall, lack of manual irrigation and water repellent nature of existing soils has likely contributed to the poor establishment and death of the dryland species. Whilst the temperatures were slightly higher than the mean average maximum temperatures, this is unlikely to have been the cause of the poor dryland / upper foreshore vegetation establishment (Figure 14).

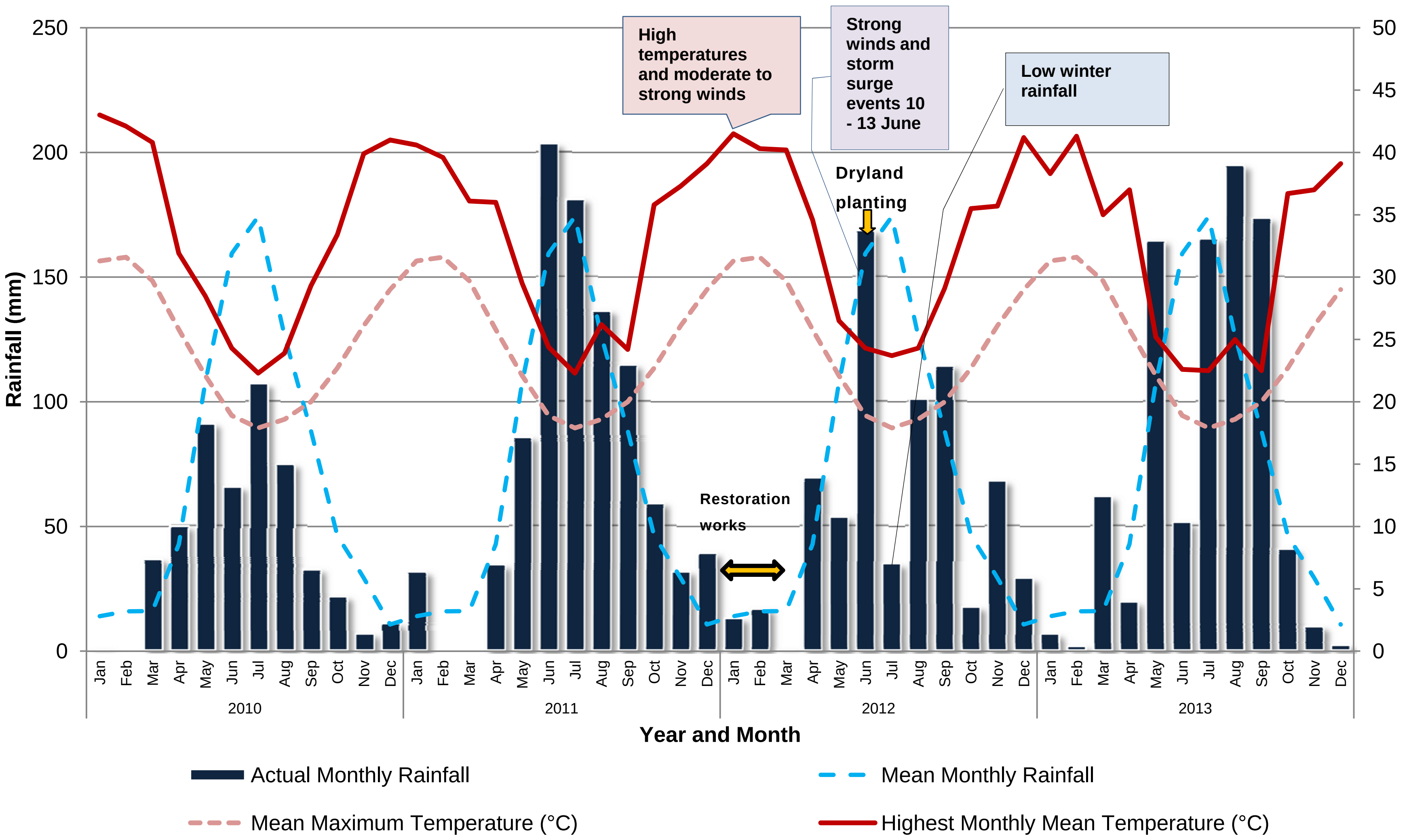

Figure 14 Monthly rainfall and the long-term average monthly rainfall for Jandakot Aero (009172) weather station for years 2010 to 2013 (BoM 2014) showing significant weather events during restoration works

7.1.2 Tubestock quality

In addition to appropriate species selection, the quality of the planting material obtained from the nursery largely dictates the success or failure of any restoration project.

Plant stock that shows good health and vigour, is free from pests and has no signs of disease is most likely to establish particularly if it has been hardened off to cope with local environmental conditions (i.e. low humidity or high salinity). In terms of foreshore plants, the plant height is also important as it allows the plant to cope with water inundation.

The stock used for planting on site consisted largely of immature plants that were not adequately hardened off to cope with the local conditions. In addition to this, some of the stock was in poor condition showing signs of stress even before being planted on site. These factors and in the case of the foreshore planting the height of the plants were some of the main contributors to poor plant establishment.

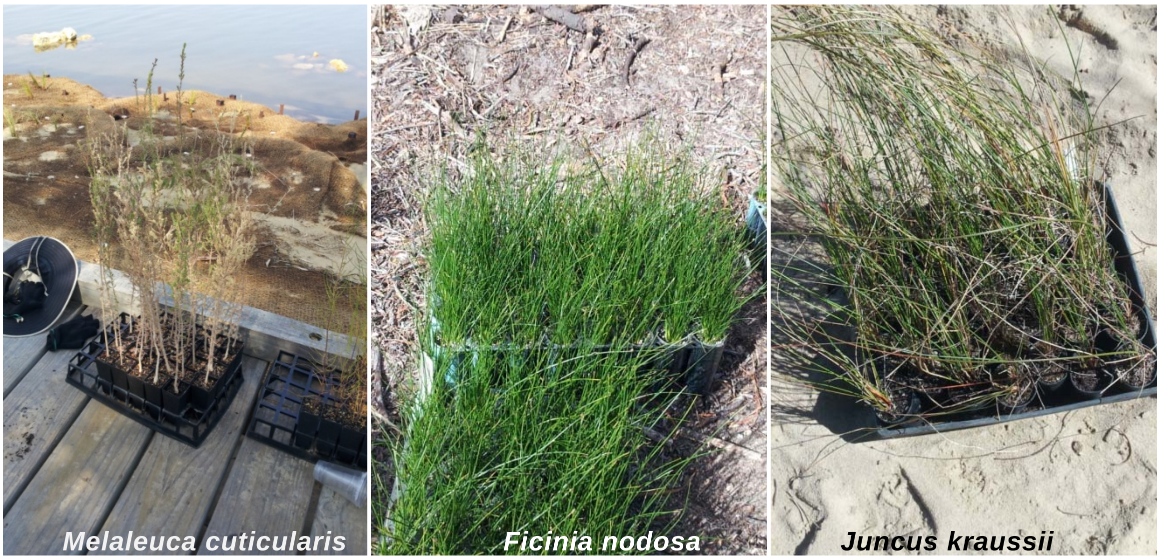

Figure 15 Condition of stock planted during restoration works in 2012.

While in most instances having a smaller tubestock or cell plugs works better in terms of long term plant establishment, having larger stock is often beneficial for foreshore restoration, particularly for species such as *Juncus kraussii*. The larger stock of *Juncus kraussii* (140mm pot) with hardened off plants had a much better rate of establishment. The reasons for this are: plant height (inundation is avoided), good vigour, acclimatisation (hardening off prior to planting), denser growth so plants are better able to cope with wave action and the larger above and underground biomass (storage of starches) to help maintain plants through the establishment period. Once installed properly, larger plants are more difficult to dislodge from the sediment by the wave action than smaller tubestock or plugs from the cell trays.

The disadvantage of large stock is that it is more expensive and unless hardened off it can be more difficult to establish in the field with root systems having been more accustomed to the potting mix that is rich in organic material, and has better water holding capacity than the soils on site (particularly upper foreshore and dryland areas).

7.1.3 Species selection and growth conditions

Correct species selection is at the core of any good restoration. Species that are indigenous to the area work best as they are best adapted to local conditions. Given that until more recently propagation of some species in the nurseries was not attempted or not possible, some of the key species that occur in the dryland areas at Salter Point are not easily available. In such cases, substitutions are made or numbers of particular species increased over other. This can result in either a good or poor success in restoration.

Given the conservation, cultural and aesthetic value of the site, use of indigenous plants is paramount. Careful planning delineating species suited to particular microclimate are necessary to ensure successful plant establishment. Such planning needs to take into consideration exposure to sun, topography, orientation of the slope, prevailing winds, salt spray and inundation among others. Climate change needs to be taken into consideration and the interface between the foreshore and dryland maintained to allow for gradual and natural migration of foreshore plant communities.

Whilst planting trees on in the foreshore strip provides diversity and soil stabilisation, the overall density should be kept low (approx. 1 tree per 20m^2) to allow establishment of the understory which is far better at attenuating wave velocity and retaining sediments. High level of shade and leaf litter can inhibit the growth of understory, increasing the susceptibility of soils to erosion. However, some shading and wind protection by trees is necessary as it provides a microclimate in which lower story plants are protected for some or most of the day from the harsh sunlight and high temperatures resulting in reduced transpiration and water loss.

The list prepared for the FRP (Syrinx, 2011) was based on the species listed in the Salter Point and Waterford Foreshore Management Plan (EMS, 2000). It incorporated species found in the areas to the west of Salter Point underlain by limestone such as those near Aquinas Bay, as well as the species previously planted at Salter Point by the City.

In general the species selection was appropriate for the foreshore areas, however, the upper foreshore or dryland areas particularly those adjacent to the Salter Parade to the north of the spit was less appropriate based on site conditions and the species composition which would have occupied the area naturally. Species such as *Spyridium globulosum, Acacia rostellifera, Banksia sessilis* and *Melaleuca systena* are more suited to higher topography and sands over limestone rather than low sand profile of the upper foreshore at Salter Point

(Bassendean Sands), particularly towards spit point where water levels during winter are high.

Control of weeds is also needed to enable optimum growth of planted species. While all efforts were taken in minimising and eliminating weeds on site few areas with weeds still persist and may have contributed to poor establishment of some of the planted stock through competition for water resources.

7.2 REVIEW OF VEGETATION ESTABLISHMENT POST RESTORATION WORKS

7.2.1 Lower foreshore vegetation

In general the establishment of lower foreshore vegetation was successful for the hardened off plants, plants installed above 0.4mAHD and plants which had sufficient height and size to cope with prolonged inundation. Marine couch (*Sporobolus virginicus*) showed the best rate of establishment with almost all plants surviving (Figure 16, April 2014).

Figure 16 Plant establishment over a two year period (2012 photos are to the left and 2014 photographs to the right)

Hardened off stock and correct planting position for Marine Couch have contributed to its establishment success. *Juncus kraussii* planting showed poor establishment throughout with the exception of the mature stock. Non compliant stock is the main reason for the poor establishment together with incorrect planting of some of the stock below 0.3m AHD which resulted in 'drowning' of new seedlings.

High tides and storm surges have also contributed to the poor establishment of vegetation and have also negatively affected the vegetation that is already established (signs of water stress and erosion of soils being the main factors).

7.2.2 Upper foreshore and dryland vegetation

Similar to lower foreshore vegetation, upper foreshore and dryland species did not establish to a satisfactory level. The main reason for the lack of success for the southern section of the site was the June 2012 storm surge which occurred within a first week of planting. The prolonged inundation over the course of three days and loss of plants through wave action were the main contributors to poor success in 2012.

The supplementary planting of dryland conducted in autumn 2013 has produced better results particularly for shrub species such as *Rhagodia baccata* and *Jacksonia furcellata;* however, only very low numbers of *Ficinia nodosa* and other ground species are surviving (Figure 17). It appears the lack of more consistent watering was the main contributor to poor supplementary plant establishment. Shrubs planted in the upper foreshore are still small in size and susceptible to high tides and storm surges.

Shading by the surrounding trees, leaf litter and weeds also affect the growth of newly planted tubestock, although the weed cover is relatively low.

Figure 17 Upper Foreshore planting in the southern section of the spit (Zone 3) in 2012 (looking west) and the same area (looking north) in 2014

7.3 VEGETATION ESTABLISHMENT: SUMMARY AND RECOMMENDATIONS

Vegetation establishment was poor in all zones on site with the exception of species such as Marine Couch (*Sporobolus virginicus*) on the lower foreshore and *Rhagodia baccata* on the upper foreshore. The main contributors to the lack of vegetation establishment along the lower foreshore was the persistence of high tides during the planting period and the poor quality of the planting stock (stock was small and not hardened off).

The upper foreshore was predominantly affected by storm surges immediately after planting and lack of adequate freshwater irrigation during hot summer months. Species selection and poorly hardened off stock in addition to tree shading has also had an effect on poor plant establishment on lower foreshore.

Vegetation establishment in the dryland area to the north of the spit was poor mainly due to lack of appropriate irrigation during establishment, shading and water competition from the large shrubs such as *Acacia saligna*.

To ensure vegetation establishment (note erosion will not be discussed here as it was already discussed in the earlier sections suffice to say some form of protection will be necessary for plant establishment) following actions must be undertaken:

Lower Foreshore

- Complete nursery orders at least 1 year ahead of the proposed planting date to avoid issues with immature stock or stock not being available. Growing stock in few nurseries versus single nursery is also beneficial to protect stock from disease and ensure adequate numbers for restoration particularly for difficult to propagate species.

- For the foreshore planting only plant stock that meets specifications as the environment may be too harsh for immature plants.

- Grow at least 1/3 of *Juncus kraussii* for Zones 2 and 4 in larger pots (140mm) to help with vegetation establishment in these zones. Plant larger stock lower on the profile as it would be able to cope with inundation better than the small stock.

- Start planting *Juncus kraussii* into Marine Couch areas to allow for widening of the ‘*Juncus* belt’ and to prevent future erosion.

- When planting use the extent of the adjacent patches of *J. kraussii* and the high tide mark to establish a guide as to how far this species can be planted. In general, this should be approximately between 0.3 mAHD and up to 0.6 mAHD.

- Provided erosion control structures such as brush walls are installed, sedges can be planted in bands in accordance with topography (e.g. plant densely between 0.3 and 0.5 m AHD first year followed by 0.5 – 0.8m AHD the second year etc if budget is limited or plant bands in one year).

- Plant trees sporadically (~ 1 per 20m^2) making sure the understory plants have enough light to grow and form thick strands.

Upper Foreshore

- Perform weed control two weeks prior to planting – hand remove any weeds that would affect planted stock from exposure to chemicals;

- Species to be planted in dryland areas on site are to have some 'plasticity' in terms of impeding sea level changes and increase in soil salinity.

- Planting density will depend on the type of plant (tree shrub or sedge, herb) and the existing cover – attempt to have a dense understory.

- Avoid planting large shrubs such as *Acacia saligna* and *Acacia rostellifera*. They can be weedy and suppress the growth of other species by exclusion, shading and litter production which could have negative impacts on the shoreline stability in the long term.

- Planting position should be considered in terms of shade tolerance and the species planted accordingly.

- Any damaged native sedges that are uprooted during storm events (and still green) can be subdivided for cultivation in the nursery particularly if they are rhizomatous and planted the following season. However, if nursery hygiene protocols do not allow for this practice alternative site can be used to raise this stock.

Dryland

The elevation of 1 mAHD and above appears to be suitable for planting of the dryland species in the short term (next 5 years). Most upper foreshore species would cope with growth to 1.2 mAHD and thus dryland planting should be focused towards the north end of the spit than the small area to the south of the spit.

- Regular and more frequent watering is to be conducted on site to help with the establishment of species after planting. Wetting agents can be added surrounding the plant to help with the initial establishment. Adding Terracottem® or similar during planting is also advisable.

- Species typical of the area should be trialled in the next planting particularly in areas with *Nuytsia floribunda* where there is a lack of understory. The lack of understory will eventually cause these trees to die as they rely on other species (including weed species such as grasses) to survive. Therefore, removal of weeds needs to be considered carefully when these plants are in question.

Signage

To help minimise damage to any implemented works and prevent further erosion, it is recommended that the City considers installation of a small number of signs.

- Install signage at the entrance and at the end of the spit to inform the public of restoration works and how damage to these works can be minimised through their participation.

- Install a small sign under the tree at the spit end indicating the value of the tree so visitors can protect it. The sign can be simple or have a more explanatory text about the tree species, how we can protect it and what values the tree provides (e.g. shade, amenity, carbon sequestration, soil stabilisation, habitat for fauna etc). A ‘message from the tree’ is often powerful (e.g. “*I give you shade in summer and protect you from storms in winter. I have been doing so for the past 60 years. Please help me do the same for you and your grandchildren. Protect my roots and don’t break my branches. Thank you. Kwelly*)

- Use Noongar names for any plants mentioned on signage panels (e.g. *Kwelly* (a Noongar name for Swamp Sheoak: nomenclature after Davis).

Fencing off the spit area from public is likely to create alternative routes for public access and may damage shoreline further. For this reason, the complete closure of any area on site is not advisable. Signage pointing to access points will provide the best mode of shoreline protection.

PART 4: OPTIONS FOR RESTORATION

Based on review of existing information and data, the success of previous restoration efforts and the latest climate change information, three options to manage erosion at Salter Point spit have been prepared. These management options have varying levels of environmental, social and economic implications on the overall environment at Salter Point and are further discussed in this section.

7.4 OPTION 1 – DO NOTHING

The 'Do Nothing' option to mitigate damage and sediment loss may be applicable in the short or long term if the value of adjacent land is too low, or in environments where there is a large buffer of stable riparian vegetation between the river and the infrastructure.

Given that the site and the lagoon have a high conservation, cultural and amenity value this option does not seem to be appropriate for the site. The western shoreline separating the lagoon from the river has been compromised in small sections of the site (mainly Zone 2) and the wave action is directly affecting the infrastructure (boardwalk) and fibre optic access port (manhole) (at the spit end).

Without a wide vegetation buffer or other measures to prevent erosion, the small section of the western foreshore in Zone 2 can be lost, re-connecting the lagoon and the river to the west. Whilst it is not known exactly how long this process may take, the recent observations have indicated that even a single high impact storm event may cause the sand spit to collapse in the already weak areas (e.g. Zone 2). What this would do to the ecology of the lagoon, the future integrity of the spit and the sediment transport up and downstream from the spit is not clear.

In the long term this option might be considered suitable given the predicted sea level rises; however, based on the precautionary principle and the managed retreat philosophy, at least in the short term the benefits of establishing a stable foreshore would outweigh the 'Do nothing" option. Therefore, Option 1 (Do Nothing) is not recommended at Salter Point.

7.5 OPTION 2 – WHOLE SITE RESTORATION

As outlined in the FRP, (Syrinx 2011) this option involves a combination of direct and indirect shore stabilisation approaches which helps minimise or stop foreshore erosion with the added benefit of increasing sedimentation and helping with plant establishment.

When viewing this section of the report, Figure 2 should be referred to as it presents an overview plan of the site and labels each erosion zone in a numerical order from north to south of the spit point. The whole site restoration will involve similar techniques as the FRP (Syrinx 2011), most notably brush logs and brush wall.

Brush logs and brush wall were used to stabilise erosion in Zone 5 (refer to Figure 12) with a great success as they helped prevent further erosion and facilitated accretion of sand. When singular brush logs are stacked upon each other vertically they form a brush wall. The brush wall used in Zone 5 was 1 - 2 logs high (0.2 – 0.4m) however, higher walls (up to 4 logs or approximately 0.7 m) can be built to accommodate attenuation of waves during high water levels such as high tides or storm surge events. A diagram showing the brush wall concept is shown in Figure 18 below.

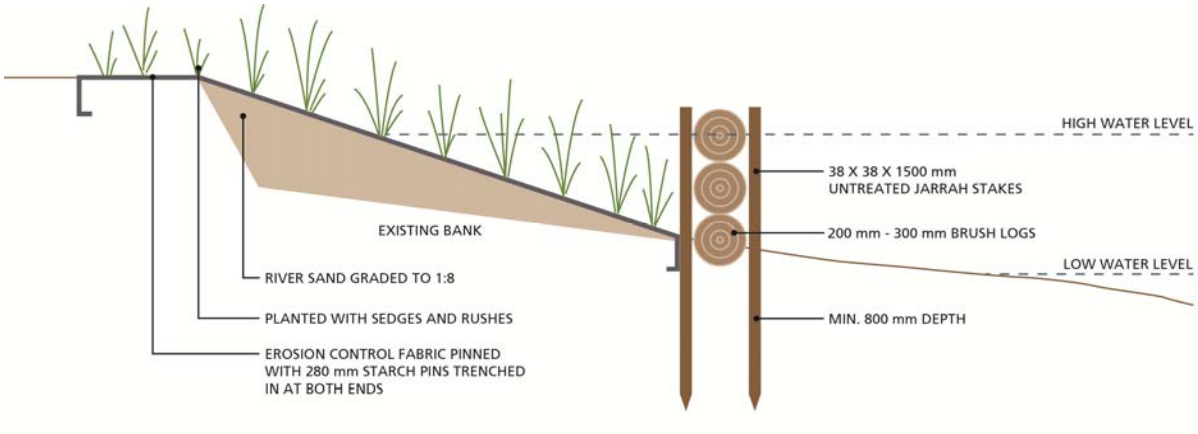

Figure 18 Example of brush wall in front of re-graded bank

Brush wall works best in exposed areas where there is lack of foreshore vegetation and to stabilise steep eroding banks where re-profiling is not possible. The brush material lasts up to 7 years provided it is regularly maintained thus affording a longer term protection for the plants than would be a case with the coir logs.

Installing brush logs and brush walls on site will involve following:

Zone 1 – As this is a zone of low impact, placement of brush logs in areas currently most affected by erosion is recommended - mostly between the access point and the Zone 2. The logs would be installed parallel to the shore at or just below 0.4 mAHD mark and the bare areas behind them densely planted with *Juncus kraussii*. to 0.6 mAHD. Areas which currently have a relatively dense cover of Marine Couch should also be planted at least sporadically with *Juncus kraussii* to enable better wave attenuation. For the same reason no additional trees should be planted below 0.6 m AHD. This will also help with light penetration necessary for the optimal growth of sedges.

Zone 2 – As indicated previously this is a zone of high wave impact where vegetation establishment is lowest. To prevent any losses of vegetation due to wave action and to help maintain sand levels, a brush wall approximately 0.6 m high (or 3 logs high) should be installed just below 0.4 mAHD mark and in line with the current distribution of sedges (*Juncus kraussii*). The height of the wall should allow dissipation of waves due to regular tidal movements and help with sediment retention during storm surge events. At the same time, the brush wall would maintain the natural process of longshore transport and avoiding interference with the fibre optic cable. For the observer standing on the boardwalk, the brush wall would be as high as the boardwalk and should not detract from the views to the river or decrease amenity of the area significantly. A representation of how the brush wall may look like in the vicinity of the boardwalk looking north is provided in Figure 19.

Figure 19 Conceptual perspective of brush wall in Zone 2 prior to installing plants

After three years of growth and establishment of the *Juncus kraussii* belt, top two brush logs could be removed to increase amenity value leaving the bottom log for sediment capture.

The brush wall requires regular maintenance usually monthly and after storm events to ensure its integrity for the long term.

Zone 3 – A combination of single brush logs as well as brush walls approximately 2 – 3 logs high will be used in the area depending on vegetation cover and the extent of erosion at the time of installation. As erosion is mostly prevalent at higher water levels and steeper portion of the foreshore profile (~ 0.6 – 0.8 m AHD), the positioning of brush logs and walls will need to be determined during installation.

Prior to installing logs any debris organic or otherwise should be cleared (i.e. large amounts of flotsam) and bank re-profiled particularly in highly eroded areas with steep banks. This can be done by adding sand and installing coir matting. Ideally brush walls would always be positioned at a distance of 0.5 m minimum from the undercut to allow for adequate plant establishment.

Juncus kraussii with very occasional *Melaleuca cuticularis* should be planted densely between 0.4 and 0.6 m AHD with the trees being planted at the higher end. *Schoenus subfascicularis* and *Gahnia trifida* should be planted between 0.6 and 1.2 m AHD with shrubs such as *Rhagodia baccata, Lechenaultia floribunda*, *Jacksonia furcellata* and herbs like *Conostylis aculeata* at 1.2 m AHD. *Schoenus subfascicularis* is already growing on site and large areas with this sedge can be found on the eastern side of the lagoon, where some of the material can be harvested for propagation in the nursery. Surviving *Ficinia nodosa* should be retained and form part of the new vegetation assemblage; however, if *Schoenus subfascicularis* becomes available *Ficinia nodosa* should not be planted on site.

Zone 4 – As indicated previously, despite the attempts to protect the shoreline in this area during 2012 restoration, erosion is still ongoing. Anthropogenic influences have exacerbated erosion particularly surrounding large trees at the spit point and the Telstra service access pit located at the spit point.

It is unlikely that the area would experience less traffic in the future and installing erosion protection structures or implementing planting would restrict access to the point and also compromise the fibre optic cable. Unless the cable is potholed to provide exact location and Telstra amend their 2 m exclusion rule, the only option at increasing sediment retention in this area is building of groynes, possibly made of geotextile bags filled with sand coupled with the initial groyne nourishment.

This method is likely to be very expensive and would require design by experienced hydrologists who would need to calculate the number and best position for the groynes so as to retain natural sediment transport processes and maintain clearance from the historical landing platform which is located in the area. Similarly, breakwaters or headlands can be implemented however, it is very unlikely that such structures would be appropriate to this setting or approved by the Swan River Trust

Given the predicted sea level rises it would appear unwise to invest a great deal of effort in this area. In the event of trees toppling over they might provide some protection to the shore. However, once this occurs the trees may also modify sand transport up the shore so careful consideration will need to be made prior to deciding if the tree should be removed, repositioned or retained.

Zone 5 – This zone would benefit from some additional planting and maintenance of the existing brush wall / logs. Similar to Zone 4 due to anthropogenic effects the likelihood of planting success in this area would be low and, therefore, the effort and investment in works in this area focused mostly on the maintenance of existing structures.

7.6 OPTION 3 – PRIORITY AREA CONCEPT

The Priority Area Concept is a management strategy that is limited to providing erosion mitigation measures in the foreshore areas labelled “Priority Areas”.

This option incorporates same techniques as described in Option 2 but it prioritises them based on the severity of the problem and the budgetary constraints. It also allows for changes in implementation methodology on the basis of new research, which would make any restoration works more economical. One such change would be implementation of erosion fence instead of brush wall to dissipate wave energy, or planting of sedges like *Juncus kraussii* sequentially in bands in accordance with topography (e.g. planting between 0.4 and 0.6 m AHD only in the first year followed by higher elevations in the following years.

The priority areas as at June 2015 based on the current level of erosion and plant cover are outlined in Figure 20 together with the proposed planting plan in Figure 21.

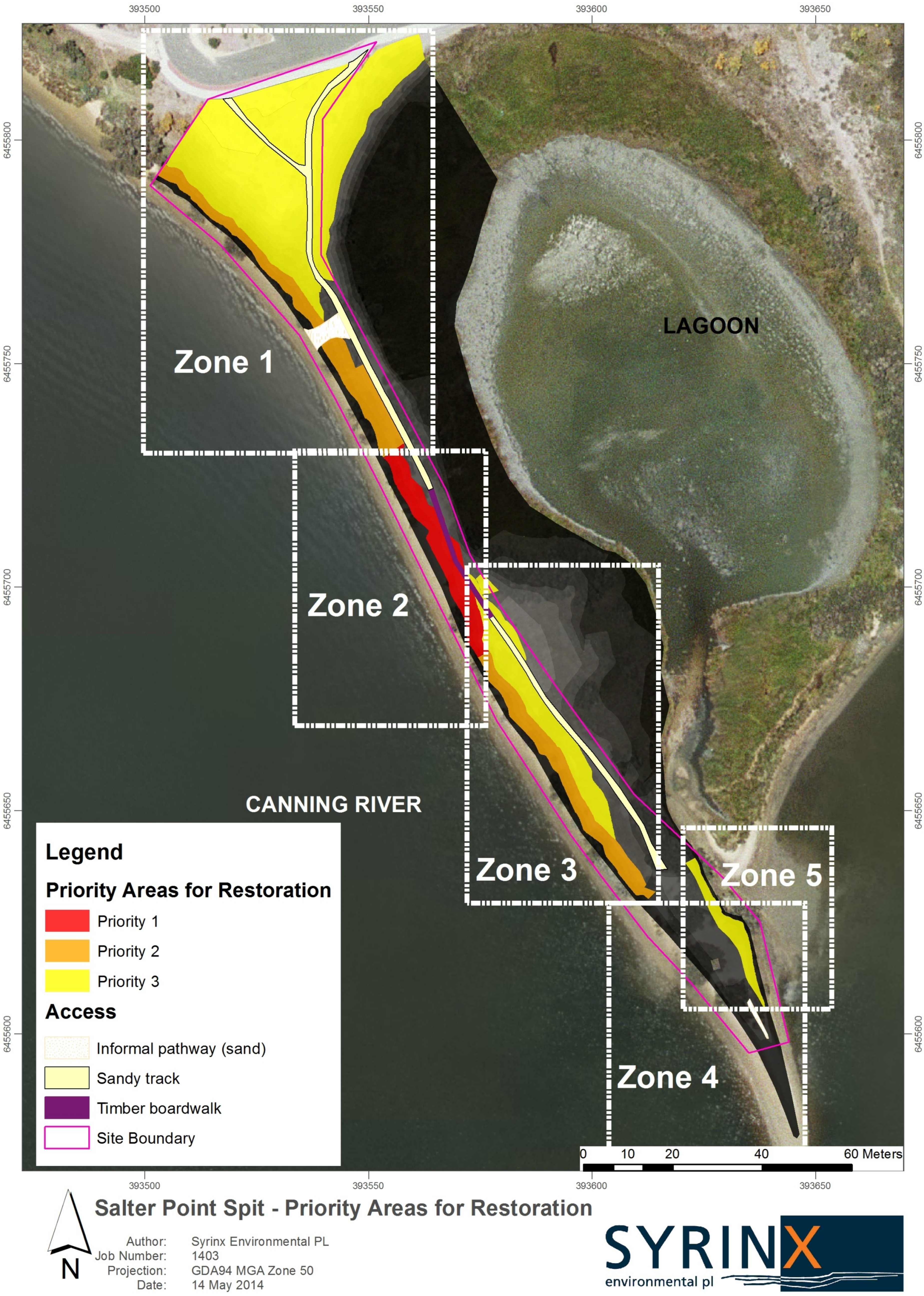

Figure 20 Prioritisation of areas for restoration at Salter Point spit

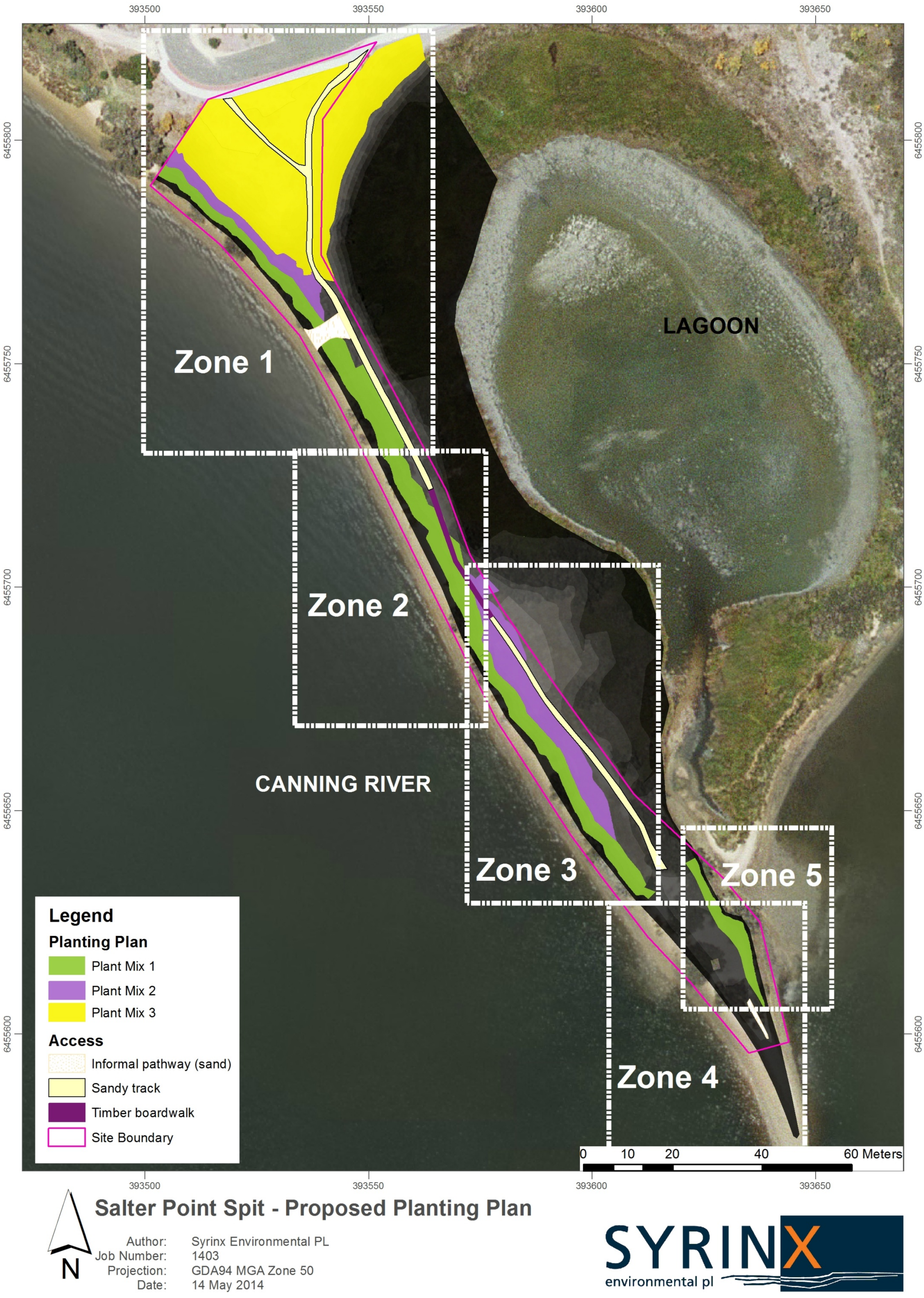

Figure 21 Proposed planting plan

8.0 PLANTING LIST

Three zones of vegetation planting are proposed for the site similar to the zones outlined in the FRP (Syrinx, 2011). Only species indigenous to the area are to be used for revegetation. The approximate number of plants required to provide a dense vegetation layer which would help with stabilisation of the shoreline in the long term and allow for a gradual succession of species is outlined in Table 1. This number includes a contingency of 15% plant loss after planting.

Table 1 Plant List for the restoration of Salter Point spit

Species name	Common name	Form	Planting Mix 1 Lower Foreshore 796 m²	Planting Mix 2 Upper Foreshore 390 m²	Planting Mix 3 Dryland 1326 m²
Acacia pulchella	Prickly Moses	Shrub			50
Acacia stenoptera	Narrow Winged Wattle	Shrub			40
Adenanthos cygnorum	Common Woollybush	Shrub			5
Alexgeorgea nitens		Rush			50
Allocasuarina humilis	Dwarf Sheoak	Tree			5
Astartea scoparia		Shrub			25
Baumea juncea	Bare Twigrush	Sedge		150	
Bossiaea eriocarpa	Common Brown Pea	Shrub			135
Conostylis aculeata	Prickly Conostylis	Herb			50
Dasypogon bromeliifolius	Pineapple Bush	Herb			50
Eremaea pauciflora	Common Brown Pea	Shrub			50
Gahnia trifida	Coast Saw Edge	Sedge		100	
Gastrolobium capitatum		Shrub			50
Gompholobium tomentosum	Hairy Yellow Pea	Shrub			50
Haemodorum spicatum	Mardja	Herb			20
Hibbertia hypericoides	Yellow Buttercups	Shrub			50
Hypocalymma angustifolium	White Myrtle	Shrub			60
Juncus kraussii	Sea Rush	Sedge	4000		
Lechenaultia floribunda		Shrub		40	100
Lyginia barbata		Rush			100
Melaleuca cuticularis	Saltwater Paperbark	Tree	20	10	
Patersonia occidentalis	Purple Flag	Herb			150
Phlebocarya ciliata		Herb			100
Rhagodia baccata	Berry Saltbush	Shrub		40	
Schoenus subfascicularis		Rush		1800	
Scholtzia involucrata	Spiked Scholtzia	Shrub			50
Sporobolus virginicus	Marine Couch	Grass	750	230	
Synaphea spinulosa		Shrub			20
Thysanotus patersonii		Herb			50
Tricoryne elatior	Yellow Autumn Lily	Herb			20
Xanthorrhoea preissii	Grass tree	Herb			50
		TOTAL	**4770**	**2370**	**1330**
		Overall planting density	**6 plant per m²**	**6 plant per m²**	**1 plant per m²**

Please note that the planting densities will vary along the shoreline depending on the extent of remnant vegetation. Whilst planting a lower number of plants is possible it is recommended that higher number is used to achieve faster vegetation cover and minimise areas that the weeds can invade.

9.0 IMPLEMENTATION TIMELINES AND COSTS

The most appropriate option for restoration of the Salter Point spit is to implement Option 2 (Whole Site Restoration). To facilitate best environmental outcome and to minimise costs, all restoration works should be conducted within one year. Staging the project over several years increases costs due to mobilisation, plant propagation and project administration.

9.1 RESTORATION SCHEDULE

Whilst the restoration works are best conducted in summer (December to February) due to favourable tide conditions, the project starts in early July - August with organising plant orders, weed control (both herbaceous and woody weed) and the general ordering of materials and planning of the implementation works.

The schedule outlined in Table 2 should be referred to for guiding project managers to conduct all works in the timely, efficient and cost effective manner.

Table 2 Implementation Schedule

Activity	Winter		Spring			Summer			Autumn			
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Award of Contract	■											
Preparation of plans / administration												
Order plants from the nursery	■	■										
Weed control – chemical	■		■		■		■					
Weed control – manual	■						■					
Order materials for works			■	■	■							
Site preparation					■	■						
Erosion control works							■	■				
Planting (Planting mix 1)										■		
Planting (Planting mix 2 and 3)												■
Watering									■	■	■	■
Practical completion												■
Maintenance start												■

All planting works should be scheduled to ensure success of planting as much as possible. Foreshore species are planted earlier so they have time to extend roots into the soil profile before the onset of rains and storms. The upland species would succumb to dehydration if planted early and are thus best planted in late May – June following good rainfalls. It is of upmost importance that the contractor observes weather patterns and selects the most appropriate time for planting to minimise dehydration of plant tissues.

9.2 COSTS

The approximate costs for the implementation of recommended Option 2 (i.e. all works completed within 1 year) are summarised in Table 3 below. The Bill of Quantities (BoQ) based on the costs presented in Table 7 is given in Appendix 1.

Table 3 Approximate overall costs for implementation of Option 2

Item	Indicative Costs (Ex GST)
Preliminaries including start-up and PC meetings	$2,900.00
Weed control	$4,000.00
Erosion control - Materials and installation	$32,720.00
Plant stock supply	$18,246.00
Plant stock installation	$18,540.00
1st year maintenance (12 monthly visits)	$10,800.00
2nd year maintenance (12 monthly visits)	$9,000.00
Project Management and administration	$1,440.00
Total	**$97,646.00**

Please note the costs presented are indicative only and it is likely that savings can be made if the City propagates own plant stock or implements regular weed control prior to works commencing at the spit. A detailed list for pricing of plant stock is outlined in Table 4.

Because some of the plants listed are more difficult to propagate the average pricing for the tubestock has been adjusted to $1.80. The pricing of advanced stock has been adjusted to $4.80 per 140mm pot to compensate for salt hardening process in the nursery.

Table 4 Indicative plant stock supply schedule and costs

Botanical name	Common name	Growth Form	Size	Price	Quantity	Cost
Acacia pulchella	Prickly Moses	Shrub	50mm	$ 1.80	50	$ 90.00
Acacia stenoptera	Narrow Winged Wattle	Shrub	50mm	$ 1.80	40	$ 72.00
Adenanthos cygnorum	Common Woollybush	Herb	50mm	$ 1.80	5	$ 9.00
Alexgeorgea nitens		Herb	50mm	$ 1.80	50	$ 90.00
Allocasuarina humilis	Dwarf Sheoak	Shrub	50mm	$ 1.80	5	$ 9.00
Astartea scoparia		Rush	50mm	$ 1.80	25	$ 45.00
Baumea juncea	Bare Twigrush	Shrub	50mm	$ 1.80	150	$ 270.00
Bossiaea eriocarpa	Common Brown Pea	Shrub	50mm	$ 1.80	135	$ 243.00
Conostylis aculeata	Prickly Conostylis	Herb	50mm	$ 1.80	50	$ 90.00
Dasypogon bromeliifolius	Pineapple Bush	Herb	50mm	$ 1.80	50	$ 90.00
Eremaea pauciflora		Shrub	50mm	$ 1.80	50	$ 90.00
Gahnia trifida	Coast Saw-sedge	Sedge	50mm	$ 1.80	100	$ 180.00
Gastrolobium capitatum		Shrub	50mm	$ 1.80	50	$ 90.00
Gompholobium tomentosum	Hairy Yellow Pea	Shrub	50mm	$ 1.80	50	$ 90.00
Haemodorum spicatum	Mardja	Herb	50mm	$ 1.80	20	$ 36.00
Hibbertia hypericoides	Yellow Buttercups	Shrub	50mm	$ 1.80	50	$ 90.00
Hypocalymma angustifolium	White Myrtle	Shrub	50mm	$ 1.80	60	$ 108.00
Juncus kraussii	Sea Rush	Rush	140mm	$ 4.80	1000	$ 4,800.00
Juncus kraussii	Sea Rush	Rush	50mm	$ 1.80	3000	$ 5,400.00
Lechenaultia floribunda	Free-flowering Leschenaultia	Shrub	50mm	$ 1.80	140	$ 252.00
Lyginia barbata		Rush	50mm	$ 1.80	100	$ 180.00
Melaleuca cuticularis	Saltwater Paperbark	Tree	70mm	$ 1.80	30	$ 54.00
Patersonia occidentalis	Purple Flag	Herb	50mm	$ 1.80	150	$ 270.00
Phlebocarya ciliata		Herb	50mm	$ 1.80	100	$ 180.00
Rhagodia baccata	Berry Saltbush	Shrub	50mm	$ 1.80	40	$ 72.00
Schoenus subfascicularis		Sedge	50mm	$ 1.80	1800	$ 3,240.00
Scholtzia involucrata	Spiked Scholtzia	Shrub	50mm	$ 1.80	50	$ 90.00
Sporobolus virginicus	Marine Couch	Shrub	50mm	$ 1.80	980	$ 1,764.00
Synaphea spinulosa		Shrub	50mm	$ 1.80	20	$ 36.00
Thysanotus patersonii		Herb	50mm	$ 1.80	50	$ 90.00
Tricoryne elatior	Yellow Autumn Lily	Herb	50mm	$ 1.80	20	$ 36.00
Xanthorrhoea preissii	Grass trees	Herb	50mm	$ 1.80	50	$ 90.00
				Total Cost	**8470**	**$18,246.00**

9.3 CONCLUDING REMARKS

The restoration of Salter Point spit and the surrounding foreshore areas will be an ongoing process and no permanent / long term solution is possible given the natural significance of the area, the current impacts and the current available technology. Installation of hard wall structures is possible; however, this form of shoreline protection is offset by the interruption of sediment transport to areas up or downstream of site, reduction in amenity and habitat value for fauna and is not appropriate for Salter Point at least not in the short term (5 - 10 years).

The increase in recreational use of the site, which is likely to continue in the future, will have an influence on the success of the currently proposed restoration (use of brush logs and brush walls). Therefore, future works need to carefully consider the use of the area by public and how the impacts public causes can be minimised. Renourishment of the spit end (Zone 4) is one alternative and it is advisable the City consults a hydrologist to investigate if this method is a viable option for the City.

The City and the Swan River Trust should investigate opportunities for collaborative work with universities to do a range of studies that would inform the future works at the spit end. The funds invested in these studies can be used to inform restoration of other sites along the Swan-Canning River System and improve current foreshore stabilisation techniques.

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APPENDICES

Appendix 1 Bill of Quantities

Item	Task	Unit	Quantity	Total quantity	Rate ($)	Total
1.1	**Preliminaries**					
1.1.1	Mobilisation/demobilisation	**item**	1	1	$ 2,000.00	$ 1,500.00
1.1.2	Preparation and meetings including start up and PC meetings	**item**	2	2	$ 600.00	$ 600.00
1.1.4	Construction Management Plan	**item**	1	1	$ 800.00	$ 800.00
1.2	**Chemical and manual weed control: 4 treatments in all areas**	**item**	1	4	$ 1,000.00	$ 4,000.00
1.3	**Erosion control**					
1.3.1	Site preparation including minor earthworks (import of river sand to regrade undercut banks)	**item**	1	1	$ 5,000.00	$ 5,000.00
1.3.2	Supply and installation of coir mesh and starch pins (5/m²)	**m²**	1	120	$ 21.00	$ 2,520.00
1.3.3	Supply and installation of brushwall	**lm**	1	120	$ 210.00	$ 25,200.00
1.4	**Planting**					
1.4.1	Supply of foreshore plants (advanced stock)	**item**	1	1000	$ 4.80	$ 4,800.00
1.4.2	Installation of foreshore plants (advanced stock)	**item**	1	1000	$ 3.60	$ 3,600.00
1.4.3	Supply of foreshore plants (tubestock)	**item**	1	7470	$ 1.80	$ 13,446.00
1.4.4	Installation of foreshore plants (tubestock)	**item**	1	7470	$ 2.00	$ 14,940.00
1.5	**1st year monthly maintenance inc. all consumables and reporting**	**month**	1	12	$ 900.00	$ 10,800.00
1.6	**2nd year monthly maintenance inc. all consumables and reporting**	**month**	1	12	$ 750.00	$ 9,000.00
1.7	**Additional project costs inc. project management and administration**	**year**	1	2	$ 720.00	$ 1,440.00
TOTAL						**$ 97,646.00**