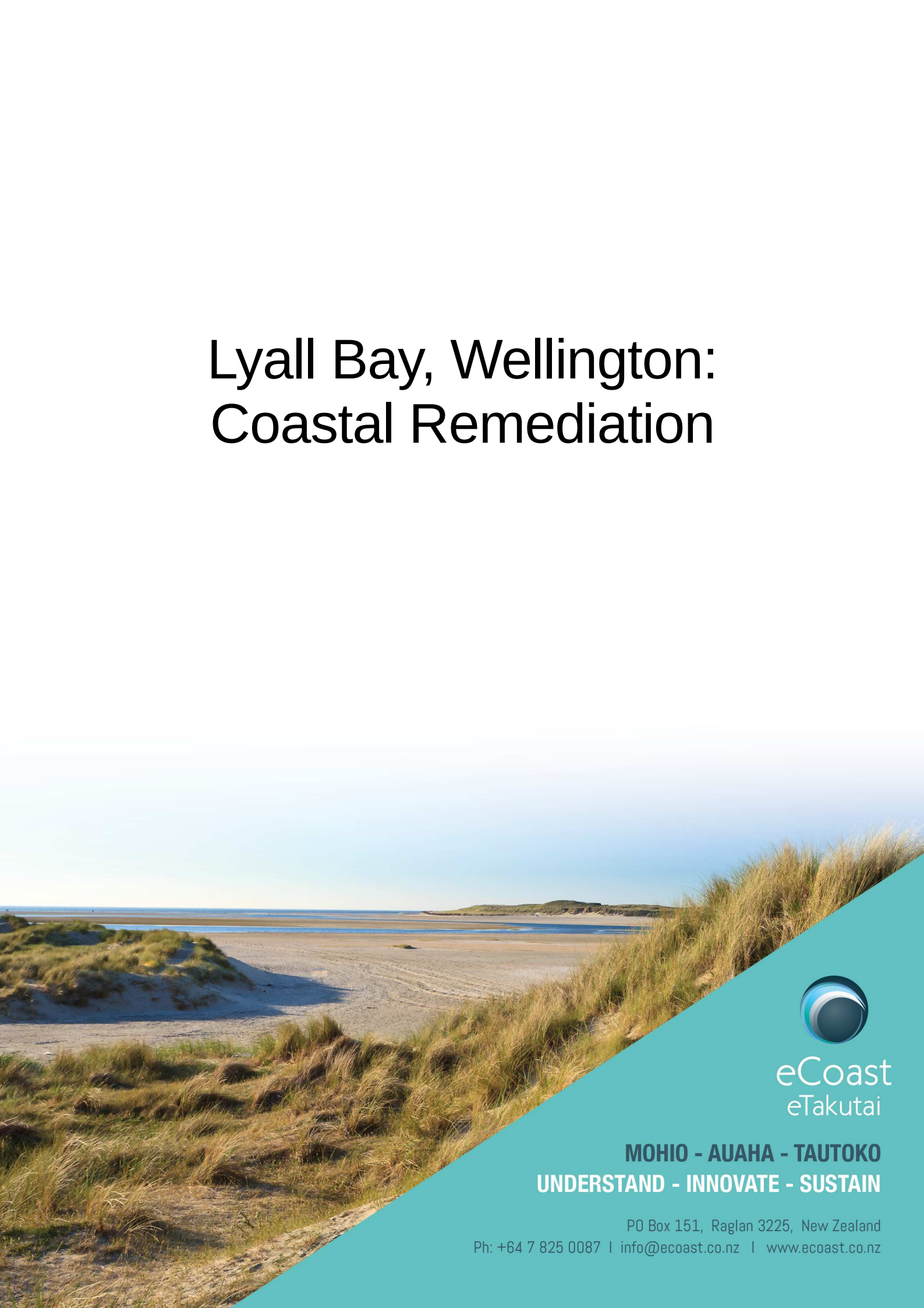
# Lyall Bay, Wellington: Coastal Remediation



eCoast
eTakutai

MOHIO - AUAHA - TAUTOKO
UNDERSTAND - INNOVATE - SUSTAIN

PO Box 151, Raglan 3225, New Zealand
Ph: +64 7 825 0087 | info@ecoast.co.nz | www.ecoast.co.nz

# Lyall Bay, Wellington: Coastal Remediation

**Report Status**

| Version | Date | Status | Approved by |
|---|---|---|---|
| V 1 | 16 May 2016 | Final Draft | DJP |
| | | | |
| | | | |
| | | | |
| | | | |

It is the responsibility of the reader to verify the version number of this report.


Authors

Shaw Mead *BSc, MSc (Hons), PhD*

David Phillips *CPEng, FIPENZ, IntPE, PhD*



The information contained in this document, including the intellectual property, is confidential and propriety to Ecological and Physical Consultants Limited (T/A eCoast). It may be used by the persons to whom it is provided for the stated purpose for which it is provided, and must not be imparted to any third person without prior written approval from eCoast. eCoast reserves all legal rights and remedies in relation to any infringement of its right in respects of its confidential information. © eCoast 2016.

# Executive Summary

The purpose of this project is to propose options for Lyall Bay with regard to protecting the natural and built coastal infrastructure and reinstating a functioning dune. The aim is to retain as much beach and dune amenity, access and parking, provide defence for the road, footpath, structures and other buried and above ground utilities (predominantly stormwater outlets), and resolve the undermining of Surfer's Corner. The preliminary options assessment has been developed with consideration of the assets at risk, as well as the assumptions and constraints with respect to what options can be applied.

Lyall Bay was divided into 4 areas of interest to address:

1. Section A: Surfers Corner carpark
2. Section B: Surfers Corner to playground
3. Section C: Playground to 249 Queens Drive
4. Section D: Dorrie Leslie Park

While there are 4 areas of concern, it is important that a holistic approach is taken that incorporates the bay-wide processes. A 'working with nature' approach has led to a hybrid solution that will incorporate hard and soft interventions. In addition, it is important to recognise that Lyall Bay is a modified built environment, rather than a natural beach, and as such will require management and maintenance much the same as terrestrial parks do.

In addition to site visits and review of existing information and data relevant to Lyall Bay and the beach, the options were developed through the scope provided and included meetings with key internal stakeholders (i.e. Council managers) and external stakeholders (e.g. residents', community associations, Tangata Whenua, businesses, sports clubs, environmental groups, and beach users), which included the development of power-point presentations and an information flyer describing the project and each option; these were used when consulting with the wider community. This was undertaken to determine a comprehensive understanding of all the issues, and importantly provided the opportunity for the local people and stakeholders to include their views and opinions.

When considering Lyall Bay it is important to be aware that it is a highly modified beach environment that has been developed since early last century. This leads to a number of constraints and changes when coastal processes are considered:

- The dune field has been replaced by people/houses/buildings;
- The bay has been contained/confined within walls, roads and parking;
- Stormwater discharges into the bay through over 20 different outfalls, and;

- The eastern third of the bay has been reclaimed for the airport, and a further 350 m of reclamation is proposed in the near future.

These constraints reduce the beaches ability to respond naturally to extreme events and mean the beach will always require on-going management and maintenance.

In terms of coastal processes, the main driver of beach change in Lyall Bay is wave-energy, often generated by wind. Lyall Bay is exposed to occasional large wave events from the southern quarter, although due to the shape of the bay (a beach located at the end of a long embayment), wave heights at the beach are significantly smaller than those offshore, and there is a wave height gradient with the largest waves in the middle of the bay and reducing wave height to either end (due to the process of refraction). One of the effects of this is the sorting of sand and gravel, with the centre of the beach having the coarsest sand and gravel, which gets finer and less gravelly towards the east and west.

The process of refraction also aligns the waves to the seabed contours, which means that by the time they break at the beach, they are breaking parallel to it. As a result, there is very little alongshore sediment transport along Lyall Bay beach. This has implications on the management of the beach. For example, stormwater structures that protrude across the intertidal beach do not result in a 'groyne-effect', i.e., the loss of sand on one side and build up on the other which would occur with alongshore sediment transport. Consequently, stormwater outlets discharging into the dune area that result in increased erosion due to liquefaction of the sand can be moved seaward without impacting on coastal processes.

The strong bi-modal winds at Lyall Bay also have a large impact on the beach. Wellington is known as New Zealand's "Windy City". When wind speeds exceed 5 knots, winds blow 60% of the time from the north and 38% from the south and 2% from the remaining directions. Northerly winds often lead to accretion at Lyall, with the combination of long-period waves and offshore winds (which blow the surface water offshore, bringing the bottom water shoreward), transporting sand shoreward. It is noted that there is only a very small supply of 'new' sand that can be transported into Lyall Bay (Carter and Lewis, 1995). The southerly onshore winds cause erosion of the beach, especially when strong (i.e. storm conditions).

Analysis of aerial photographs and satellite images from 1938 to 2015 to consider the beach width presents the impacts of human intervention at Lyall Bay. Between 1938 and 1984, the beach at Lyall Bay retreated/eroded up to 55 m, due to both wind-blown loss of sand and the loss of the dune system (i.e. the inability of the beach to respond to extreme events due to the loss of the dune system) – note the coastal road and other developments (flattening of the dune fields and building) had already occurred by 1938. By the mid-1980's there was

very little dune area remaining and the seawall was damaged along several parts of the beach during southerly storms.

This trend of erosion has reversed over the past 20 years following the establishment of dune plants in the mid-late 1990's; the beach then widened/accreted some 15-20 m, although recent storms have impacted heavily of the dune system. As the evidence of an accreting beach suggests, Lyall Bay is a sink for sand that is slowly transported into the bay from the Cook Strait; this provides a source of material to slowly widen the dune field and increase the robustness of Lyall Bay beach; i.e. the aim of the project.

Due to the coast, the nature of the geology along Dorris Leslie Park, a mixture of clay, sandstone and bedrock along with the nearshore fringing reefs, the erosion rates and trends are quite different from those that have occurred at Lyall Bay beach. Erosion is far slower and episodic, and there has been no recovery. The image analysis of the Dorris Leslie Park coast indicates slow/chronic erosion since 1938 with rates ranging from ~2 m to ~8 m during the past 80 years, an average of 6 cm/year.

Through the combination of site visits, review of existing information and data, meetings with key internal and external stakeholders, and professional experience, preliminary options to achieve the objective of the project were developed. The preliminary options to increase the robustness of the whole bay include:

1. Do nothing.
2. Lengthen the stormwater outlets so that they discharge into the intertidal zone.
3. The addition of spinifex and pingao, and the gradual removal of marram grass.
4. Angling beach access ways to reduce wind-blown sand loss and funnelling during extreme wave events.
5. Additional signage and ropes/bollards to encourage people to stay off of the dunes.
6. Regular management/maintenance.
7. Development of a simple beach monitoring programme to assist with beach management and developing an adaptive management plan to address sea level rise in the future.

Preliminary options for the each of the 4 areas of Lyall Bay include:

<u>Section A – Surfer's Corner:</u>

1. Removal of the western ~110 m of the carpark and replanting the upper-shore with spinifex and pingao.
2. Relocation of parking to the road reserve on the opposite side of the road (between Tirangi Road and Cochrane Street) and adjacent to the Loose as a Goose café.

3. Construction of a seawall (~100 m in length) adjacent to the footpath (similar to that which extends along much of Lyall Bay), along with 3 access points in order to keep foot-traffic off the dunes and further protect the dune plants.
4. Re-contouring of the existing rock riprap adjacent to the stormwater outfall to tie in with the reinstated dune area.

Section B – Surfer's Corner to the Playground

1. Restricting access by lengthening the wall towards Surfer's Corner (~210 m).
2. Replacing the seawall where it was removed in the 1990's to reduce the loss of wind-blown sand.
3. Introducing more spinifex into the dune system is recommended to develop wider dunes (rather than the high dunes developed by marram grass).
4. Restricting access to the dune next to the playground.
5. There is also the option of increasing the height of the wall to 1.5 m along the central part of this section (~350 m) to provide a higher backing to accommodate a wider and higher dune (i.e. a greater volume of sand and more resilience).

Section C – Playground to 249 Queens Drive:

1. Dune planting and fencing off in front of the playground and between the buildings except for access ways to limit access to the dunes.
2. Continued planting of spinifex and fencing of the dune area at the western end of the bay.
3. Regular management of sand around the buildings.

Section D – Dorris Leslie Park:

1. Re-grading northernmost area of the grassed part of the park (~100 m) where the scarp is <0.5 m high and planting with coastal plants.
2. Armouring with similar materials as have been applied to the southern part of the park (i.e. tipped rock on a geotextile filter) where the Pohutakawa trees are threatened by undermining and the high beach scarp is present (~180 m).
3. Armouring with similar materials as have been applied to the southern part of the park (i.e. tipped rock on a geotextile filter) around the small headland on which the stone statue, Moai, is located.

For the stormwater in particular, it is concluded that:

- There is a range of different types and sizes of outfalls on Lyall Bay beach, and there is a number of significant issues with stormwater discharge to the beach environment which are having negative impacts on: coastal processes leading to increased erosion, amenity (alongshore access), environmental (pollution and aesthetically) and effectiveness of the outlet to disperse stormwater.
- An assessment on their impacts on coastal processes and effectiveness has been undertaken which has ranked each outlet on a scale of 1 to 5 for Impact: (1) Very Low to (5) Very High and Effectiveness: (1) Very high to (5) Very Poor.
- In general, there are too many outlets both discharging to the beach and in locations in or near the dune field which increases scour and erosion through transport of liquefied sand, and a significant number are not environmentally or people-friendly (e.g. pollutants discharged to the beach and pipes blocking access).
- A list of work priorities and actions has been compiled, which should be assessed by council and stakeholders for budgeting and implementation. Some urgent works are required to prevent the ongoing impact of erosion.
- More detailed investigation will be required for specific outlets to confirm quantities of flow, ground levels, stormwater pipeline and outlet invert levels, and gradients to assess if the number of discharging outlets can be reduced by combining two or more together into one outlet through stormwater line diversion. In particular the smaller 225 mm dia. catchpit leads being connected into the larger outlets.
- Ideally the larger beach outfalls should be at a lower invert level under the beach or more sand on top so that they do not create a walking barrier or obstacle on the beach, and also discharge into the inter-tidal zone to increase the effectiveness of the outfall and remove debris and pollution from the upper beach where it is presently deposited, and reduce erosion of the upper beach and dune area.
- Consideration is also required of recharging the ground water through soakage of the lower quantity stormwater base flows (or all if low flow – dependant on size of contributing catchment) in submerged outlets under the beach (for the 150 to 225 mm dia. pipes, and larger pipes with low base-flows), with overflow outlets for rainfall events away from the dune field preventing erosion of the upper beach and dune. This would require geotechnical investigation of the sub-soils and groundwater table, to determine the permeability and potential for soakage.
- Environmental consideration should be assessed of potential preventative actions in the contributing catchment; including: regular cleaning schedule of sediment from catchpits (cheapest option), Enviropods fitted to catchpits, Storm-filters and

Downstream Defender/Up-flo Filter manhole systems to remove fine sediment, contaminants and debris from the stormwater discharge. For consideration: Are there any wastewater flows in the stormwater system that could be discharging at the beach – illegal or from pump station overflows)?

- Consideration could also be undertaken on the placement of Aqua cells or similar systems under parking or other suitable areas, to allow detention of peak flow quantities to reduce beach scour and erosion, allow sediment and contaminant settlement and potentially soakage of water into the ground.
- It has been proposed to assess the use of sandcrete (or attachment of rocks/stones), to naturalise outlets so that they blend into the beach environment as reef type structures, which also provide amenity on the beach (e.g. people can climb over them) as well as being robust structures to surround and support the pipe outlets for resilience to storm events.
- It appears a number of gates and flaps have been utilised in the past on the outfalls to prevent sand egress into the pipelines, but are no longer in place. Only one is still in existence, and appears to be preventing outflow of woody material and debris which is clogging the pipe. Hynds WaStops are a more recent product that is being utilised on coastal stormwater outlets, however a more robust assessment would be required on the effectiveness in high energy coastlines. Councils in Wellington is successfully using these devices in lower energy estuarine areas in the city.
- It is recommended for the stormwater outlets that actions be planned, budgeted, and undertaken as necessary, to address both the immediate significant problems through to longer-term projects which will have positive benefits for the community and beach users. Cost-Benefit Feasibility Analysis would be required on some of the options (such as soakage and use of Aqua cells) to determine the viability versus the amount of budget available, as well as practicality in the Lyall Bay environment.

Cost estimates for the preliminary options are included in Appendix C.

# Contents

Executive Summary ..... 3
Contents ..... 9
Figures ..... 11
Tables ..... 15
1 Introduction ..... 16
1.1 Project Scope ..... 17
2 Review of Existing Information ..... 21
2.1 Coastal Processes ..... 21
2.2 The Lyall Bay Integration Project (Parks & Open Spaces, 2004) ..... 23
2.3 Surfer's Corner Carpark (Spencer Holmes, 2010) ..... 28
2.4 Potential Impacts Due to the Airport Extension ..... 30
2.5 Aerial Photograph Analysis ..... 33
2.6 Impacts of Sea Level Rise (SLR) ..... 39
3 Stormwater Assessment ..... 59
3.1 Introduction ..... 59
3.2 Asset Investigation ..... 59
3.2.1 Stormwater Asset Investigation ..... 61
4 Preliminary Options Assessment and Recommendations ..... 41
4.1 Baywide Options ..... 41
4.2 Stormwater Options ..... 85
4.2.1 Stormwater Outlet Rankings ..... 87
4.2.2 Summary of Recommended Stormwater Outlet Options ..... 90
4.3 Section A – Surfer's Corner ..... 44
4.4 Section B – Surfer's Corner to Playground ..... 47
4.5 Section C – Playground to 249 Queens Drive ..... 51
4.6 Area D –Dorris Lesley Park ..... 54
4.7 Summary of Recommended Beach Options ..... 57
References ..... 59

Appendix A. Consultation Mail-Out ..... 96
Appendix B. Lyall Bay Coastal Processes ..... 97
Appendix C. Cost Estimates ..... 120

# Figures

Figure 1.1. Lyall Bay, Wellington with dog walker and surfer, two of the regular users at the beach. ..... 16
Figure 1.2. Lyall Bay, Wellington (Source: WCC, 2015). ..... 18
Figure 2.1. Output from a boussinesq model showing the refraction of wave crests and the loss of wave energy as waves propagate into Lyall Bay, and the alongshore wave height gradient (especially at the western end). ..... 22
Figure 2.2. Wind-rose for Lyall Bay (NZ MetService, 1981). ..... 23
Figure 2.3. Activities in and around Lyall Bay (Mitchell Partnerships, 2016). ..... 25
Figure 2.4. Current and proposed configurations of the eastern Lyall Bay foreshore (Mitchell Partnerships, 2016). ..... 26
Figure 2.5. Proposed configuration cross sections (Mitchell Partnerships, 2016). ..... 27
Figure 2.6. Proposed foreshore sketch of the eastern section of the bay (Mitchell Partnerships, 2016). ..... 27
Figure 2.7. Extent of damage to seawall – facing west ..... 29
Figure 2.8. Recent storm damage to the Surfer's Corner carpark (December 2015). ..... 29
Figure 2.9. The proposed extension does not directly impact on wave energy entering Lyall Bay, since it is to the east and south of the existing western breakwater spur; wave energy to the east of this (indicated by the black arrow to the right of the red arrow) does not propagate into the beach at Lyall Bay. Airport Rights is a big-wave surfing break located off the southern end of the airport, in the area of the proposed extension (Background image source, DHI, 2015a) ..... 30
Figure 2.10. Preliminary indication of the wave focussing structure proposed to mitigate the loss of surfing amenity in Lyall Bay. (Source, DHI, 2015a) ..... 31
Figure 2.11. Summary figure of DHI (2015b) preliminary beach response investigation. ..... 33
Figure 2.12. Historical shoreline change from 1938 to 2015 for Lyall Bay beach. ..... 35
Figure 2.13. Central Lyall Bay in January 1986; very little dune area remained and the seawall had failed (Source, John Lawson). ..... 36
Figure 2.14. The undermined seawall in May 1985 (Source, John Lawson). ..... 36
Figure 2.15. Machinery was used to push up beach sand and create a narrow dune in mid-1996 (Source, John Lawson). ..... 37
Figure 2.16. The narrow dune was planted in marram grass and fenced off (Source, John Lawson). ..... 37
Figure 2.17. Historical shoreline change from 1938 to 2015 at Dorris Leslie Park. ..... 38
Figure 2.18. The chronically eroding coast along much of Dorris Leslie Park (Phillips, 2015) ..... 39

Figure 3.1. An aerial perspective of Lyall Bay showing the straight access pathways and an example of the erosion cut caused by discharging stormwater above the high tide mark. Paths through the dunes can also be seen; foot-traffic damage dune plants and so reduce resilience of the dunes. Inset; signage to instruct people to stay off the dunes..... 43
Figure 3.2. An existing angled access way at Lyall Bay (Mead, 2015) ..... 44
Figure 3.3. Angled access ways and ropes/bollards have already been put in place at Lyall Bay during the repair works after the 2015 winter storms (Mead, 2015). ..... 44
Figure 3.6. The high tide mark is at the base of the wooden wall and rock revetment at the Surfer's Corner carpark and as a result is within the surfzone during extreme events which exacerbates erosion and results in structural damage (Mead, 2015)..... 45
Figure 3.7. Recommended modifications to the Surfer's Corner area. The existing carpark is currently too far seaward, which has negative impacts on the beach (causes loss of sand through reflection off the hard structure), and leads to repeated damage to the carpark. It is recommended that it is removed and the area is reinstated with sand/dune plants, and that the road reserve is converted to carparks. ..... 46
Figure 3.8. Section B from Surfer's Corner to the Playground. The red line in the middle of the area indicates the location of the approximately 60 m stretch where the seawall is currently missing ..... 47
Figure 3.9. Recommended options for Section B. ..... 49
Figure 3.10. Beach sand 'leaking' onto the footpath along the ~60 m of fencing where the wall was removed in the 1990's – it is recommended that this section of wall is replaced to reduce loss of sand due to the wind. ..... 49
Figure 3.11. The dune in Section B where there is a wall present is in many places higher than the wall, and also topped by a fence to restrict access. Increasing the height of the wall to 1.5 m would assist with continued dune development, although this should be weighed against visual impacts (i.e. loss of sea view). ..... 50
Figure 3.12. The dune adjacent to the playground is currently very impacted by foot-traffic, which is assumed to be accessed from the eastern end of the playground area. This access to the dune should be prevented. ..... 50
Figure 3.13. Section C – Playground to 249 Queens Drive. ..... 51
Figure 3.14. The beach in Section C has widened along with the rest of Lyall Bay beach following the reinstatement of the dune's in the 1990's, and today covers many of the original access ways. ..... 52
Figure 3.15. The stormwater outlet next to the Maranui SLSC is one of the most troublesome in Lyall Bay; it outfalls at the base of the seawall (i.e. is the more landward than others), is very close to the building and has a relatively high discharge rate compared to others.

Burying and lengthening to the intertidal zone will reduce the negative impacts on beach stability and amenity..... 53
Figure 3.16. The footpath area behind the existing buildings on the beach is wide enough to allow for relocation. ..... 53
Figure 3.17. Section D, Dorris Lesley Park is mostly typified by a gravel/soil substrate above a gravel beach which is perched on a fringing reef..... 54
Figure 3.18. The northern section of Dorris Lesley Park (Phillips, 2015). ..... 55
Figure 3.19. The retreat of the coast in the norther section of Dorris Lesley Park has resulted in a scarp of up to 2 m in height and now several Pohutakawa trees are at risk of being completely undermined and falling seaward (Phillips, 2015).. ..... 55
Figure 3.20. The fringing reef becomes wider and chronic erosion has cutback the foreshore up to 8 m in the past 80 years so that now some of the infrastructure is being impacted, and significant areas of the park are vulnerable to acute erosion during storms (Phillips, 2015). 56
Figure 3.21. The southernmost 300 m of the park has recently been protected by a tipped rock revetment to safeguard the coastal road and carpark (Phillips, 2015)..... 56
Figure 4.1. The beach at Lyall Bay with the pipelines in the distance (left) and the 3x1300mm dia. outlets that discharge the airport runway stormwater (right) (Source: Phillips, 2015). ... 61
Figure 4.2. GIS view of the pipes and outlets (left) (Wellington City Council GIS, accessed 17/11/15), and the 3 storm water outlets close to the airport (Source: Phillips, 2015)..... 61
Figure 4.3. Stormwater sump lead 225mm dia. concrete pipe (Wellington City Council GIS, accessed 17/11/15)..... 62
Figure 4.4. Stormwater outlet 0.225m dia. with concrete rectangular casing (left)(Source: Wellington City Council GIS, accessed 17/11/15). ..... 63
Figure 4.5. Stormwater outlet 0.6m dia. with concrete rectangular casing (left) (Source: Phillips, 2015), and the GIS view of the stormwater infrastructure (right) (Source: Wellington City Council GIS, accessed 17/11/15). ..... 64
Figure 4.6. The stormwater outlet with broken concrete visible (left) and the actual pipe with reinforcing steel visible (right)(Source: Phillips, 2015). ..... 64
Figure 4.7. Stormwater outlet 0.75m dia. with concrete rectangular casing (left) (Source: Wellington City Council GIS, accessed 17/11/15), and the pipe on the beach (right) (Source: Phillips, 2015). ..... 65
Figure 4.8. The stormwater outlet (left) and sand in the pipeline (right)(Source: Phillips, 2015). ..... 66
Figure 4.9. Stormwater outlet 0.225m dia. with concrete rectangular casing (left)(Source: Wellington City Council GIS, accessed 17/11/15). ..... 67
Figure 4.10. Stormwater outlet 0.225m dia. with concrete rectangular casing (left)(Source: Wellington City Council GIS, accessed 17/11/15). ..... 68

Figure 4.11. Stormwater outlet 0.75m dia. with concrete rectangular casing (left)(Source: Wellington City Council GIS, accessed 23/11/15). ..... 69
Figure 4.12. Stormwater outlet with manhole (left)(Source: Wellington City Council GIS, accessed 23/11/15) and erosion on beach (right)(Source: Phillips, 2015). ..... 70
Figure 4.13. Stormwater outlet on the beach (Source: Phillips, 2015). ..... 70
Figure 4.14. Stormwater outlet 0.225m diameter (Source: Wellington City Council GIS, accessed 23/11/15). ..... 71
Figure 4.15. Stormwater outlets with concrete rectangular casing (left) (Source: Wellington City Council GIS, accessed 17/11/15), and the outlets on the beach (right)(Source: Phillips, 2015). ..... 72
Figure 4.16. The stormwater outlet (left) and scour and erosion near the building (right) (Source: Phillips, 2015). ..... 73
Figure 4.17. Stormwater outlet 0.225m dia. pipe (Source: Wellington City Council GIS, accessed 17/11/15). ..... 74
Figure 4.18. Stormwater outlet 0.375m dia. with concrete rectangular casing (left) (Source: Wellington City Council GIS, accessed 17/11/15), and the pipe on the beach (right) (Source: Phillips, 2015). ..... 75
Figure 4.19. The stormwater outlet and sand/debris in the pipeline (left), and scour and erosion on the beach in the dune field (right) (Source: Phillips, 2015). ..... 75
Figure 4.20. Stormwater outlet 0.225m dia. pipe (Source: Wellington City Council GIS, accessed 17/11/15). ..... 76
Figure 4.21. Stormwater outlet 0.60m dia. with concrete square casing (left) (Source: Wellington City Council GIS, accessed 17/11/15), and the pipe on the beach (right) (Source: Phillips, 2015). ..... 77
Figure 4.22. The stormwater pipeline looking from the upper beach (left) and from along the beach (right) (Source: Phillips, 2015). ..... 77
Figure 4.23. Stormwater outlet 0.150m dia. with concrete rectangular casing (left)(Source: Wellington City Council GIS, accessed 17/11/15). ..... 78
Figure 4.24. Stormwater outlet 0.225m dia. pipe (Source: Wellington City Council GIS, accessed 23/11/15). ..... 79
Figure 4.25. Stormwater outlet 0.225m dia. concrete pipe (left)(Source: Wellington City Council GIS, accessed 17/11/15), and the pipe on the beach (right)(Source: Phillips, 2015). ..... 80
Figure 4.26. Stormwater outlet 0.225m dia. concrete pipe (left) (Source: Wellington City Council GIS, accessed 17/11/15), and the pipe on the beach (right) (Source: Phillips, 2015). ..... 81

Figure 4.27. Stormwater outlet 0.225m dia. pipe (left) (Source: Wellington City Council GIS, accessed 17/11/15), and the pipe on the beach (right)(Source: Phillips, 2015). ..... 82
Figure 4.28. Stormwater outlet 0.30m dia. pipe next to boast ramp (left) (Source: Phillips, 2015), and the pipe and outlet on the beach (right)(Source: Phillips, 2015)..... 83
Figure 4.29. Stormwater outlet 0.30m dia. with concrete square casing (Source: Wellington City Council GIS, accessed 17/11/15). ..... 83
Figure 4.4. Mission Bay SW outfall with mudcrete reef (cement/mud-sand mix) surrounding the pipes to naturalise it in the environment (Source: S. Risler, Feb 2010 Google). ..... 86
Figure 4.5. Kohimarama Beach, Auckland SW outfall with sandcrete reef (Source: P. Reynolds, Coastal News, Nov 2006). ..... 86

# Tables

Table 2.1. Shoreline retreat along Dorris Lesley Park between 1938 and 2015..... 38
Table 3.2. Summary of recommended options for coastal remediation of Lyall Bay. ..... 57
Table 4.1: SW Asset Coastal Process Impact Assessment ..... 60
Table 4.2: SW Asset Effectiveness Assessment ..... 60
Table 4.1: Summary of Rankings for SW Assets and Options for Required Works. Planning and Works timeline: Short-term (ST), Mid-term (MT), Long-term (LT). ..... 87

# 1 Introduction

Lyall Bay is a very important recreational asset for Wellington. It is popular for walking, running/jogging, dogs, surfing, boogie boarding, kayaking, kite surfing and wind surfing, surf-lifesaving, swimming, fishing from land, diving and spear-fishing, cycling, scenic drives, picnics, visiting cafes, outings with families and watching planes (Parks and Open Spaces, 2004; TRC, 2015).

The purpose of this project is to propose options for Lyall Bay with regard to protecting the natural and built coastal infrastructure and reinstating a functioning dune (Figure 1.1). The council has requested this assessment since storms and associated surges has caused significant damage to the natural and built infrastructure at Lyall Bay during last winter, particularly the carpark at Surfers Corner. Wave action has also eroded the rocky coast on the western side of the bay. Sand has shifted significantly, which is causing issues around buildings and stormwater outlets on the beach.

For example, the Surfer's Corner carpark was repaired in 2010. The Council spent $27,500 on repairing damage and improving the resilience of the carpark. Recent storm damage and rock clearance has cost the Council approximately $2000 per episode. Continuing damage at this level is not sustainable in the long term and decisions need to be made about the future of this area. Future options need to ensure a greater level of resilience from storm events.




**Figure 1.1. Lyall Bay, Wellington with dog walker and surfer, two of the regular users at the beach. (Source: Phillips, 9/10/15).**

This assessment provides recommendations on an appropriate response for Lyall Bay. The aim is to retain as much beach and dune amenity, access and parking, provide defence for

the road, footpath, structures and other buried and above ground utilities, and resolve the undermining of Surfer's Corner (which may include retreat from this particular carpark area).

The preliminary options assessment has been developed with consideration of the assets at risk, the assumptions and constraints listed in the council Request for Proposals in conjunction with the findings of the literature and data review (i.e. within the existing coastal processes). While there are 4 areas of concern, it is important that a holistic approach is taken that incorporates the bay-wide processes. A 'working with nature' approach has led to a hybrid solution that will incorporate hard and soft interventions. In addition, it is important to recognise that Lyall Bay is a modified built environment, rather than a natural beach, and as such will require management and maintenance much the same as terrestrial parks do.

## 1.1 Project Scope

The project goals and objectives as defined in the Request for Proposals include:

1. A coastal engineering report that provides workable solutions for erosion issues at Lyall Bay.
    a. To investigate options for restoration of dunes at Lyall Bay to maximise their effectiveness in absorbing wave action and protecting natural and built infrastructure.
    b. To investigate options to protect the rocky shoreline, grassed area and trees on the western side of the bay.
    c. To investigate options for the shifting of sand around the bay and dealing with current infrastructure within the beach environment.
    d. To consult with key internal and external stakeholders as part of the investigative process.

2. To provide cost estimates for these options and make final recommendations for Council to take to the community for discussion.

Lyall Bay was divided into 4 areas of interest to address (Figure 1.2):

1. Section A: Surfers Corner carpark
2. Section B: Surfers Corner to playground
3. Section C: Playground to 249 Queens Drive
4. Section D: Dorrie Leslie Park




**Figure 1.2. Lyall Bay, Wellington (Source: WCC, 2015).**

The scope of the project includes several issues/special considerations:

- Investigations into past literature and research/modelling on coastal issues and wave patterns in Lyall Bay;
- Stormwater outlets – their impact and effects on the coastal processes and their effectiveness as functioning stormwater outfalls in this environment;
- Consideration of information already available on the potential effects of proposed airport extension;
- Consideration of options to protect buildings on beach, and;
- Potential impact of sea level rise (SLR).

The assets at Lyall Bay that are considered potentially at risk from SLR and increased storm surges:

- Beach area – new Mean High Water Mark would lessen beach area;
- Beach area and dunes – subject to increased erosion;
- Dune plantings and any environmental benefits to flora and fauna;
- Buildings on beach area;

- Sea Wall;
- Lyall Bay Parade and footpath;
- Lyall Bay Playground;
- Dorrie Leslie Park;
- Stormwater infrastructure;
- Other above and below ground built infrastructure.

**Project Assumptions:**

- Some car-parking can be removed;
- Some road reserve may be made available for car-parking;
- Retreat from Surfers Corner is an option;
- Infrastructure for surfers and dog walkers can be moved;
- The concrete block wall and mesh fence in Section B can be redesigned;
- Stormwater pipe infrastructure (both road and catchment) can be modified.

**Project Constraints:**

- The roading infrastructure and existing seawall will not be moved;
- Some parking must still be provided;
- Beach and dune amenity and function must be retained;
- The heritage Lyall Bay sea wall in Section C cannot be modified;
- Facilities for surfers and dog walkers, including parking, must still be provided;
- Some dune plants will be available for the 2016 planting season, but significant numbers of plants will not be available until the 2017 winter season.

This report outlines options and recommendations for each area, and also provides cost estimates for the recommended options. These options were developed through the scope above and included meetings with key internal stakeholders (i.e. Council managers) and external stakeholders (e.g. residents', community associations, Tangata Whenua, businesses, sports clubs, environmental groups, and beach users), which included the development of a power-point presentation and an information flyer describing the project and each option; these were used when consulting with the wider community (Appendix 1 includes the information flyer that was emailed to stakeholders). This was undertaken to

determine a comprehensive understanding of all the issues, and importantly provided the opportunity for the local people and stakeholders to include their views and opinions.

# 2 Review of Existing Information

When considering Lyall Bay it is important to be aware that it is a highly modified beach environment that has been developed since early last century. This leads to a number of constraints and changes when coastal processes are considered:

- The dune field has been replaced by people/houses/buildings;
- The bay has been contained/confined within walls, roads and parking;
- Stormwater discharges into the bay through over 20 different outfalls, and;
- The eastern third of the bay has been reclaimed for the airport, and a further 350 m of reclamation is proposed in the near future.

These constraints reduce the beaches ability to respond naturally to extreme events and mean the beach will always require on-going management and maintenance; similar to terrestrial parks.

This section provides a summary of the existing information in relation to coastal processes (waves, winds, tides, sediment transport, etc.) and coastal issues at Lyall Bay, and includes:

- Physical processes (Mead *et al*., 2003; NIWA, 2015);
- The Lyall Bay Integration Project (Parks & Open Spaces, 2004);
- Surfer's Corner Carpark (Spencer Holmes, 2010);
- Potential impacts due to the airport extension (NIWA, 2015; DHI, 2015a,b; Mead, 2015);
- Analysis of Historical Aerial Photographs, and;
- Potential impacts of sea level rise.

## 2.1 Coastal Processes

The main driver of beach change in Lyall Bay is wave-energy, often generated by wind. Lyall Bay is exposed to occasional large wave events from the southern quarter. However, wave energy is 'lost' to the sides of the Bay as waves propagate from the Cook Strait into the beach through the process of refraction, or bending, into the shallower sides of the Bay. This results in smaller wave heights at the beach than at the entrance to the bay, as well as a wave height gradient with greatest wave heights in the middle of the bay (since they have been less impacted by refraction) and decreasing wave height towards the sides of the bay (Figure 2.1). One of the effects of this is the sorting of sand and gravel, with the centre of the beach having the coarsest sand and gravel, which gets finer and less gravelly towards the east and west (Pickrill, 1979).

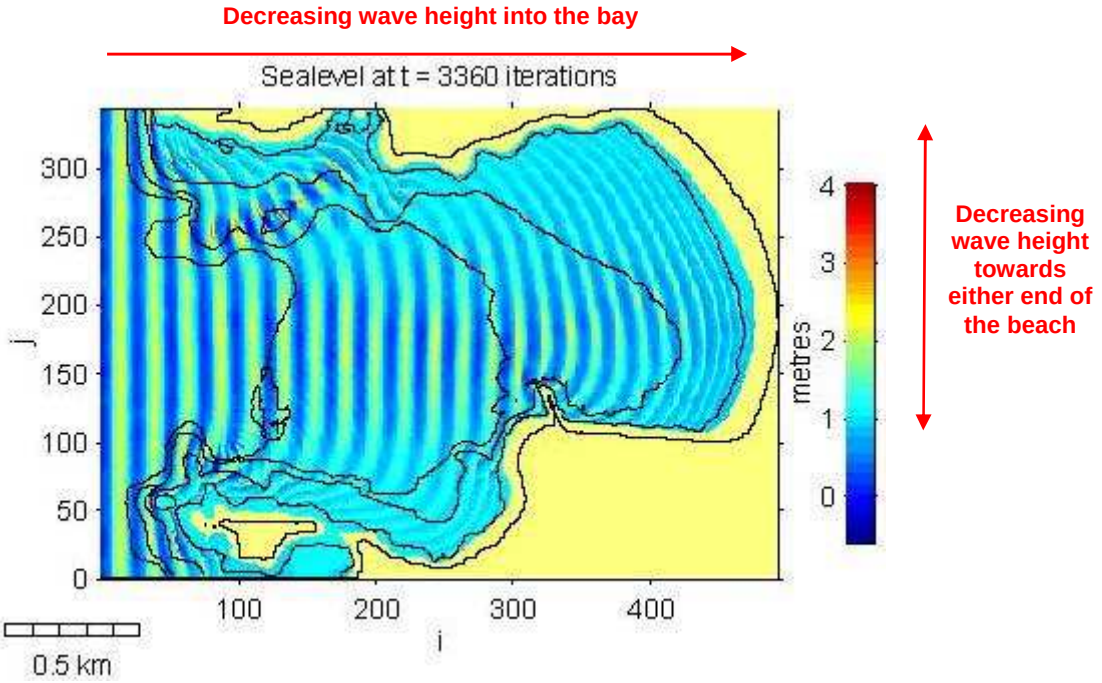



**Figure 2.1. Output from a boussinesq model showing the refraction of wave crests and the loss of wave energy as waves propagate into Lyall Bay, and the alongshore wave height gradient (especially at the western end).**

The process of refraction also aligns the waves to the seabed contours, which means that by the time they break at the beach, they are breaking parallel to it. As a result, there is very little alongshore sediment transport along Lyall Bay beach. This is supported by the satellite image and aerial photograph analysis, which found that the beach position is the same on either side of stormwater structures that protrude across the intertidal beach (i.e. there is no 'groyne-effect' of loss of sand on one side and build up on the other which would occur with alongshore sediment transport).

The strong bi-modal winds at Lyall Bay also have a large impact on the beach. Wellington is known as New Zealand's "Windy City", which is well supported by the available data (e.g. NZ Metservice, 1981). When wind speeds exceed 5 knots, winds blow 60% of the time from the north and 38% from the south and 2% from the remaining directions (Figure 2.2). Northerly winds often lead to accretion at Lyall Bay, with the combination of long-period waves and offshore winds (which blow the surface water offshore, bringing the bottom water shoreward), transporting sand shoreward. It is noted that there is only a very small supply of 'new' sand that can be transported into Lyall Bay (Carter and Lewis, 1995). The southerly onshore winds cause erosion of the beach, especially when strong (i.e. storm conditions).

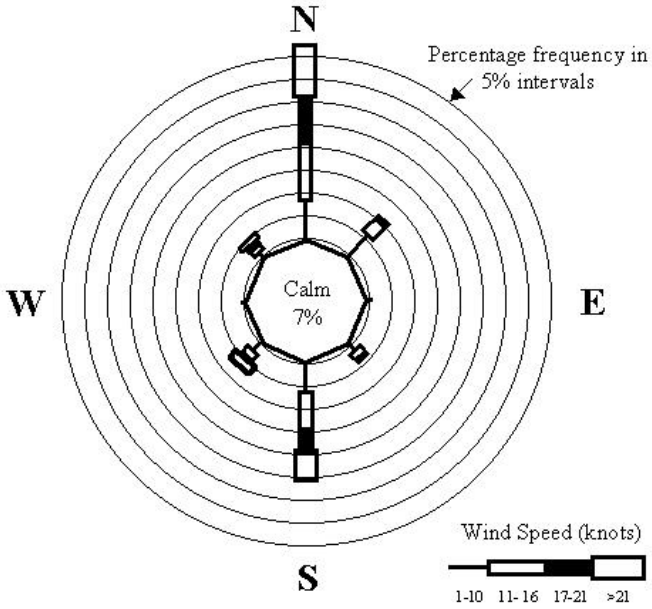



**Figure 2.2. Wind-rose for Lyall Bay (NZ MetService, 1981).**

Due to the many modifications to the beach system, especially the loss of the natural dune plants, Lyall Bay eroded significantly from the 1930's (detailed in Section 2.5). The re-development of the narrow dune system in the mid-1990's has helped to reverse the trend of erosion by retaining sand within the beach system and providing a buffer zone during storm events (i.e. a volume of sand that can be eroded during storms). However, as has been seen during the winter storms of 2015, Lyall Bay beach is presently still vulnerable to acute erosion events.

While waves and winds drive the main processes in Lyall Bay, the full suite of coastal processes at Lyall Bay are detailed in Appendix 1, which is mostly extracted from Mead *et al*., (2003). More recent investigations (e.g. NIWA, 2015), provide some added information such as wind-driven currents.

## 2.2 The Lyall Bay Integration Project (Parks and Open Spaces, 2004).

This report includes a summary of the recreational use of Lyall Bay outlining recent developments and important issues relating to the eastern end of the beach including the foreshore area and the built edge of Lyall Parade (i.e. the reserve area across the road from Lyall Bay abutting the buildings).

A range of recreational beach activities are reported, including surfing, bodyboarding, swimming, picnicking, sun bathing, kayaking, water skiing, walking, sitting on the beach, surf

skiing, jet skiing, windsurfing, jogging and running, playing on the beach (cricket, football etc.), dog walking and sitting in cars watching the surf (Figure 2.3).

At the time of writing, there were several proposed and active developments at Lyall Bay: an artificial surf reef had Resource Consent, and had a proposed location approximately 250 m off Kingsford Smith St. The project was seeking funding. Also an airport retail park with bulk retail outlets was being developed between Cochrane Street and Tirangi Road utilising the ex-Woolworths building. In addition, there were a number of proposals for cafes, restaurants and other commercial water front developments. While the artificial reef never got the funding to be implemented, the retail park and several cafes have since been developed at Lyall Bay.

Parks and Open Spaces (2004) considered the key issue with the land between the built edge of Lyall Parade and the road itself was that the recreational reserve has a limited use for recreation as it narrows to a thin strip approaching Cochrane St to the east. The form of the industrial buildings there is such that the coastal setting is ignored with entrances being to the north, while south facing walls are bleak and tall, probably for protection from wind-blown sand.

This sand had built up steep sided dunes that had been planted with marram and were thought to be creating wind turbulence. Councils and local residents had proposed a walkway though the dunes with seats and picnic tables, kiosks and apartments. This option was not recommended as these facilities would need to be constantly cleared of wind-blown sand and it is questionable whether a beach separated picnic and play area would be used, particularly by children due to the associated danger of crossing the road and also shading from the large “formidable” industrial buildings.

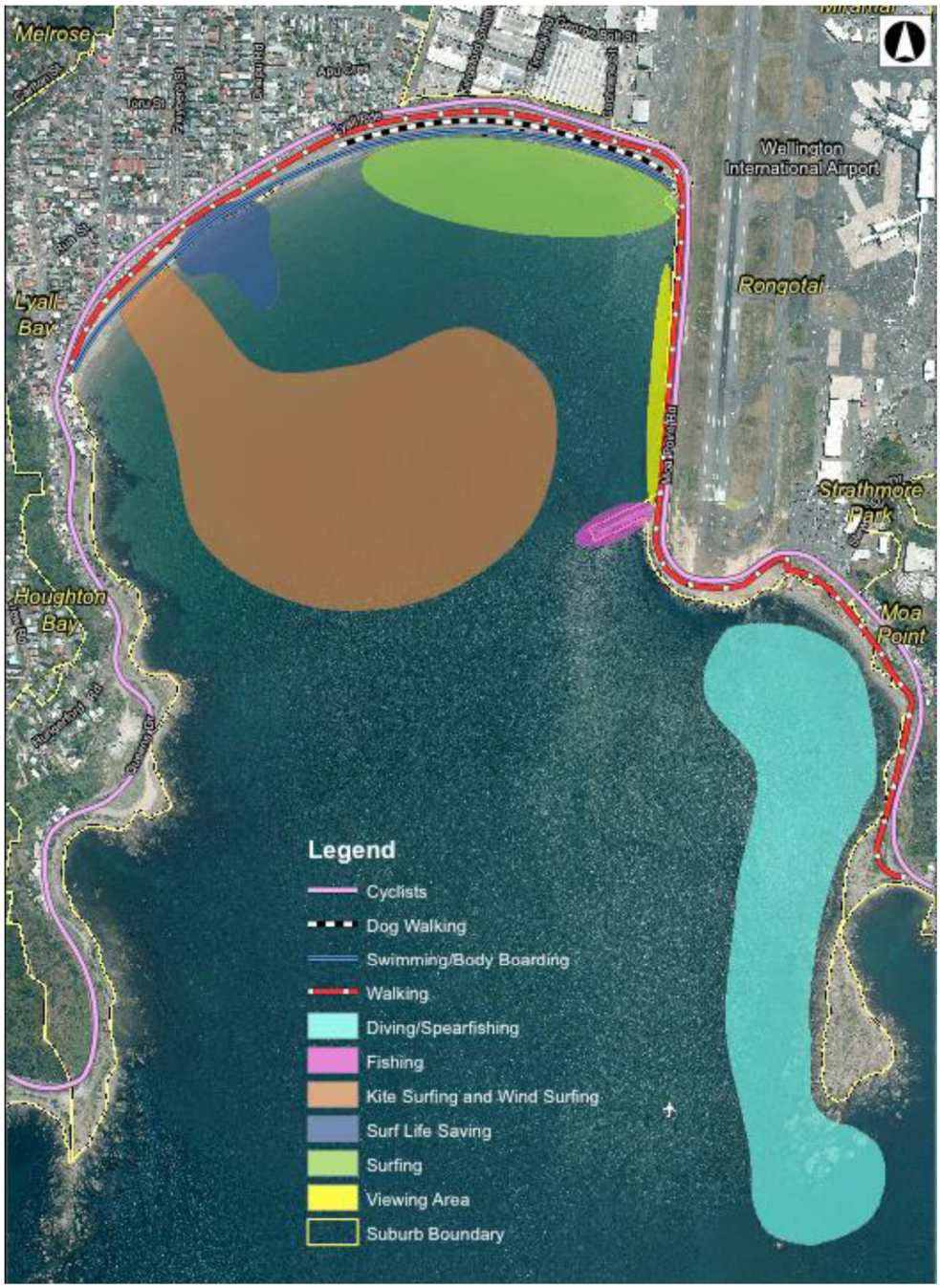



**Figure 2.3. Activities in and around Lyall Bay (Mitchell Partnerships, 2016).**

With regard to dune management and restoration, two approaches were outlined in the report, which incorporate both the landward and seaward side dunes of Lyall Parade. The first is a relocation of Lyall Parade 15-20 m landward providing space for the dune on the seaward side to widen. The second option was to maintain the present dune system divided in two by the road. Further research was suggested to support any decisions made. Included in this research should be an investigation into the vulnerability of the "Surfers Corner" carpark to a 20 to 100-year storm.

Moving Lyall Parade carriageway landward was the proposed solution and carries significant advantages including a restored and strengthened natural character of the area, enhanced recreation and leisure opportunities, an improved built edge with increased commercial opportunity and a re-orientation toward the beach, a more attractive general environment which is more in line with 'surf and sea' activities, a healthier dune system and a better coastal amenity for Lyall Bay residents and the Wellington community as a whole. This is illustrated in Figure 2.4 to Figure 2.6.

The report highlights the recreational importance of Lyall Bay to Wellington city, the need to widen the dunes in order to create a healthier dune system, as well as the vulnerability of the Surfer's Corner carpark. In this present study, moving the road landward to accommodate this recommendation is not being considered (a project constraint). However, the vulnerability of Surfer's Corner carpark has been assessed (Section 4.3), and other methods to increase the health of the dunes are also recommended.

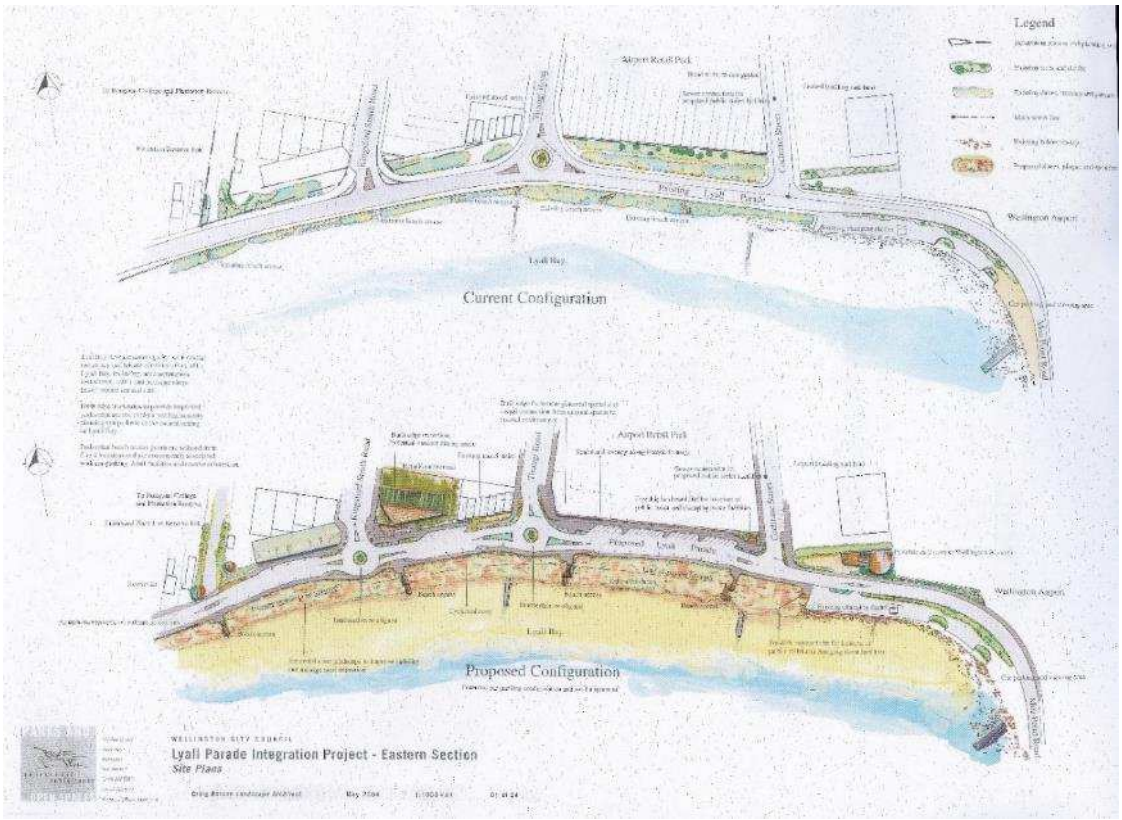



**Figure 2.4. Current and proposed configurations of the eastern Lyall Bay foreshore (Mitchell Partnerships, 2016).**

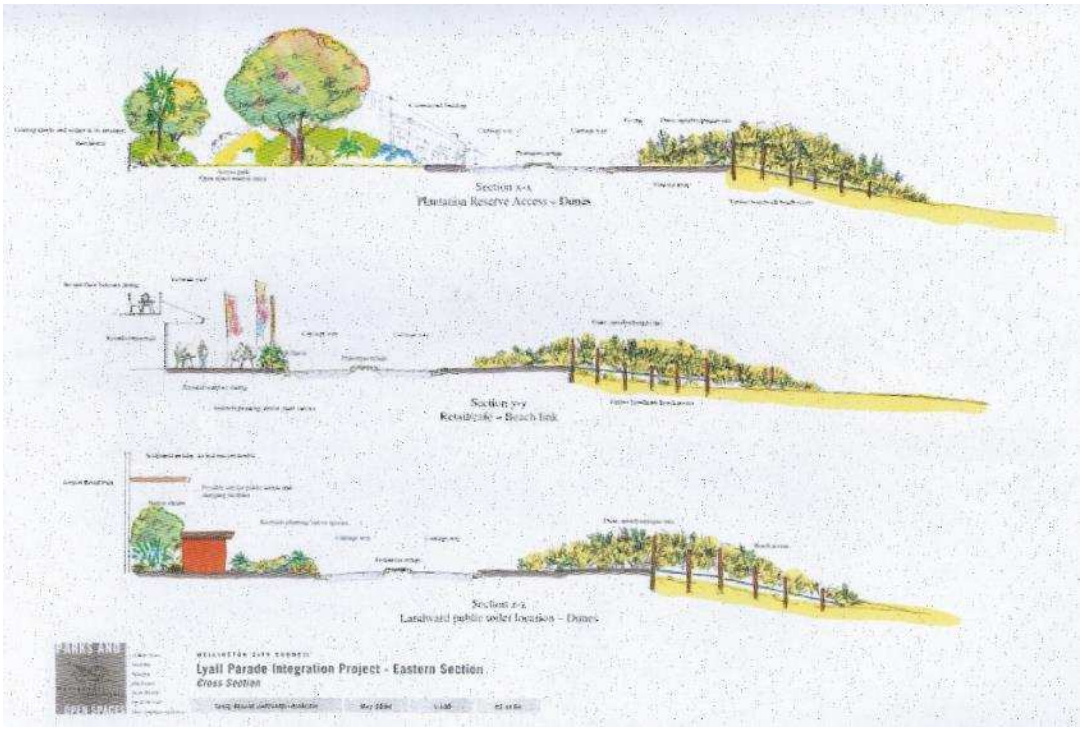



**Figure 2.5. Proposed configuration cross sections (Mitchell Partnerships, 2016).**




**Figure 2.6. Proposed foreshore sketch of the eastern section of the bay (Mitchell Partnerships, 2016).**

## 2.3 Surfer's Corner Carpark (Spencer Holmes, 2010)

This report describes the storm damage to the seawall at the western end of the "Surfers Corner" carpark on 18/08/2010. The existing wall is 1.2 m high by 56 m long and is comprised of horizontal timber planks (200 x 50 mm) secured to vertical timber posts (200 x 100 mm) placed 1.5 m apart (Figure 2.7).

Three remedial works options were presented along with associated costings:

1. Repair the existing damaged section of the wall with some improvements (concrete buttress and geotextile filter cloth) ($31,500);
2. Repair the existing damage and upgrade the wall – remove the backfill and debris from the entire length of the wall, reinstate all wall timbers and backfill according to the Option 1 specifications, and add a 1:2 slope rip-rap buttress is installed in front of the wall to dissipate wave energy ($87,000), and;
3. Remove the wall, retreat from beach area and reduce carpark size – this last option sees a demolition of the entire wall structure and a removal of the garden area adjacent to the road. A new mass block marine grade concrete wall is installed at least 2 m back from the existing wall which also repositions the carpark and garden 2 m towards the road. A wider 5 m rip rap buttress at a slope of 1:4 is placed in front of the wall for wave dissipation ($221,500).

Spencer Holmes (2010) concluded that the timber of the wall had at least 10-15 years of life left (excluding similar damage by southerly storms), and recommended that Wellington City Council as a minimum course of action, undertake immediate repairs according to Option 1 and that interim safety measures are put in place while remedial works are completed.

Since the Spencer Holmes (2010) report, further damage to the Surfer's Carpark seawall has occurred due to southerly storms, with an ongoing repair cost to the WCC. Given the seaward location of the carpark that leads to impacts on coastal processes and continual damage/repair (Figure 2.8), here the recommendation is to relocate the carpark to the reserve on the landward side of the road (the narrow reserve against the buildings referred to by Parks and Open Spaces (2007), and reinstate coastal dune vegetation (Section 4.3).



**Figure 2.7. Extent of damage to seawall – facing west**

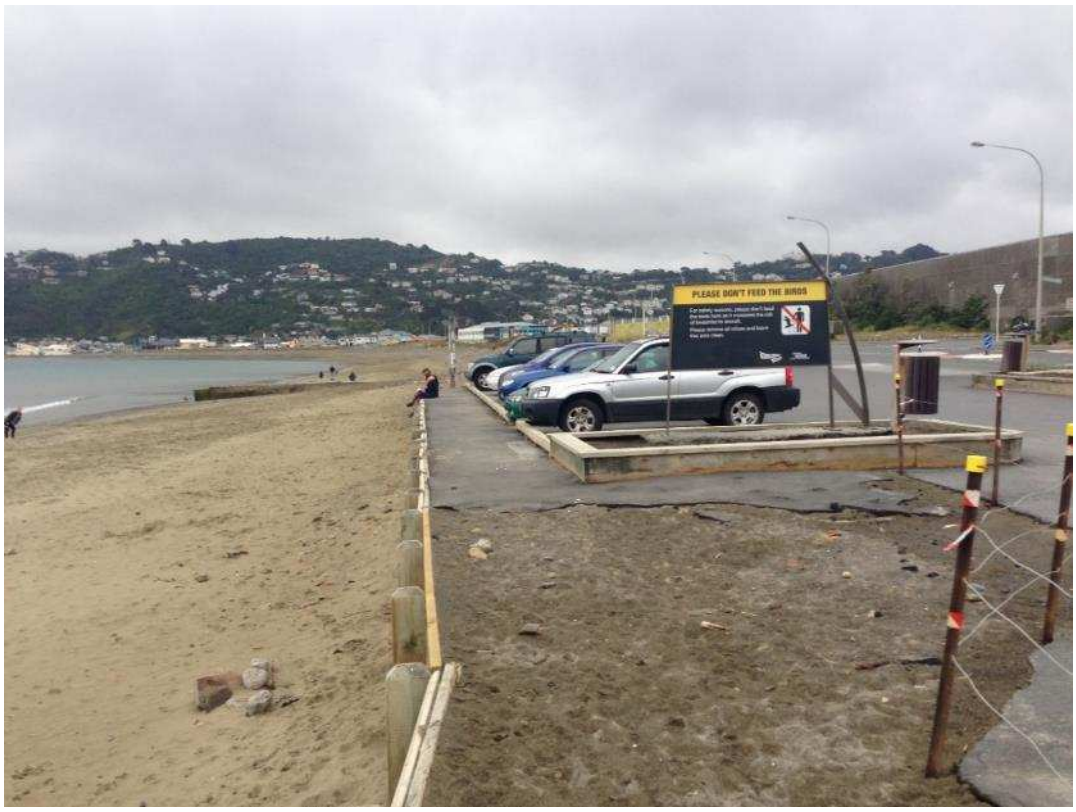



**Figure 2.8. Recent storm damage to the Surfer's Corner carpark (December 2015).**

## 2.4 Potential Impacts Due to the Airport Extension

The work of DHI (2015a) and NIWA (2015) has indicated that there will be change to wave and current patterns in Lyall Bay due to the airport extension. There is currently some uncertainty surrounding the extent and magnitudes of the changes to waves and sediment transport within the bay. The changes are subtle, since the airport extension is not in the direct pathway of waves entering the long pocket beach of Lyall Bay; it is to the east and south of the existing breakwater spur that currently protrudes westward into the bay (Figure 2.9).

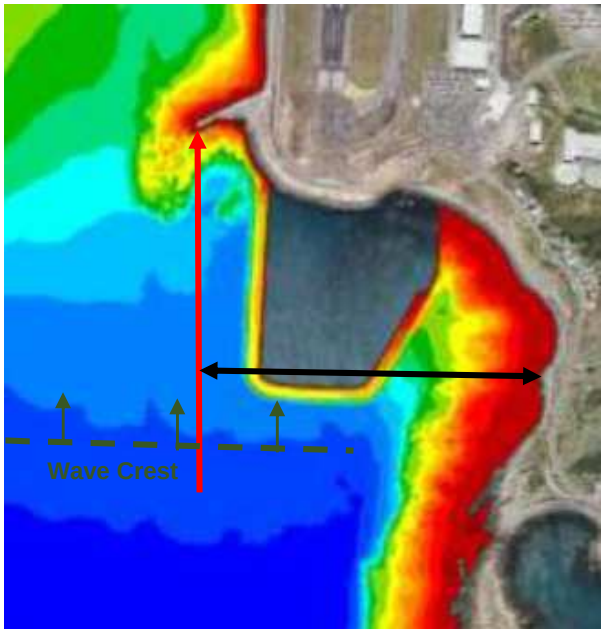



**Figure 2.9. The proposed extension does not directly impact on wave energy entering Lyall Bay, since it is to the east and south of the existing western breakwater spur; wave energy to the east of this (indicated by the black arrow to the right of the red arrow) does not propagate into the beach at Lyall Bay. Airport Rights is a big-wave surfing break located off the southern end of the airport, in the area of the proposed extension (Background image source, DHI, 2015a)**

DHI's (2015a) assessment concludes that the presence of the proposed airport extension will reduce the 'peakiness' within Lyall Bay, which will have a consequent reduction on the number of surfable waves. The process of refraction tends to align wave crests to the seabed contours, resulting in waves that break simultaneously along the crest, or close-out, which is not conducive to good surfing – good surfing waves break in a peeling motion, not all in one go. Peakiness, or variable height along the wave crest helps to ensure that waves do not close-out – wave breaking is depth-limited, so when a wave crest has differential heights the highest part of the wave crest (the peak) will break before the other parts of the

wave and result in peeling. If the peakiness is reduced, then the number of peeling waves conducive to surfing is reduced within the bay.

The results of model simulations with and without the airport extension for 3 representative wave events conducive to surfable waves within Lyall Bay (which were considered with input from the Wellington Boardriders), show that the western and middle bay are the most effected by the airport extension (a reduction in surf rides is expected to be between 18-27% and 14-29%, respectively) (DHI, 2015a). The reduction in surf rides at premier surf break within Lyall Bay, the Corner, is estimated to be lower at 4-8% (DHI, 2015a). In addition, Airport Rights a big-wave break off the southern end of the runway will be lost due to being covered by the airport extension.

To address the reduction in surfing quality in Lyall Bay, DHI (2015a) have proposed the development of a wave focusing structure to reintroduce peakiness into Lyall Bay (Figure 2.10).

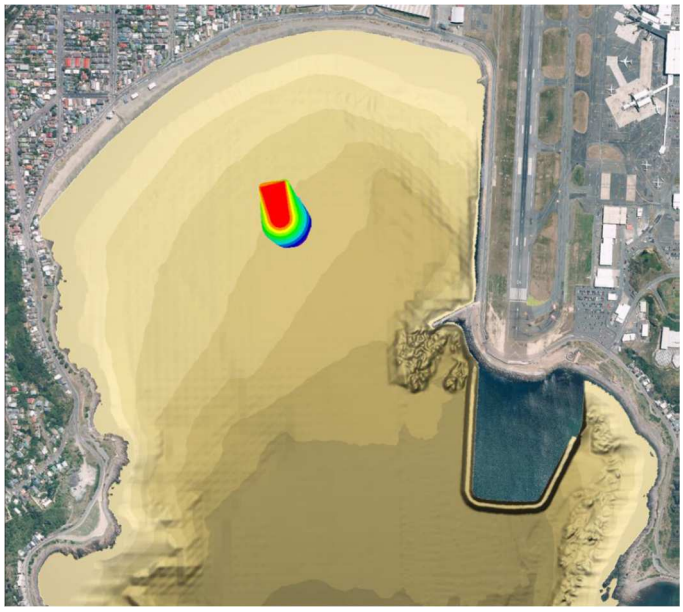


**Figure 2.10. Preliminary indication of the wave focussing structure proposed to mitigate the loss of surfing amenity in Lyall Bay. (Source, DHI, 2015a)**

With respect to how this will impact on the beach at Lyall Bay, based on the body of literature on the subject, there is likely to be a small impact on the beach in the form of a slight widening in the lee of the structure. Offshore submerged structures result in the development of a salient, or a widening of the beach in the lee of the structure (e.g. Adams and Sonu, 1986; Pilarczyk, 1990; Pilarczyk and Zeidler, 1996; Van der Meer and Pilarczyk, 1998; Smith *et al*., 2001; Black and Andrews, 2001a, b; Harris, 2002; Pilarczyk, 2003;

ChiranJeev and Mani, 2003; Ranasinghe and Turner, 2004; Weppe *et al*., 2011; Mead and Borrero, 2011; Mead *et al*., 2011), as long as the structure is outside the 'normal' surf zone (Black and Mead, 2003; Rangasinghe *et al*., 2006). This would be a positive outcome in terms of beach remediation and enhancing the robustness of the beach at Lyall Bay, since the central part of the beach is the most vulnerable and experiences the most damage during storm events due to the higher waves in this area; a wider beach would provide an increased buffer zone.

DHI (2015b) presents a preliminary shoreline impact assessment due to the presence of the proposed wave focussing structure. While it is noted that the wave focussing structure has not yet been designed in detail (hence the impacts of the final structure may differ), DHI (2015b) conclude that there will be a small reduction in the width of the beach in the lee of the wave focussing structure due to its presence, and consequent widening either side of this (Figure 2.11). This finding by DHI (2015b) is contrary to any previous investigations pertaining to the impact of offshore submerged structures that are located seaward of the usual surf-zone). This is likely due to the methodology employed by DHI (2015b), since the application of the N-Line model in this case seems to have been applied in the absence of the existing body of science pertaining to coastal processes.

Review of DHI (2015b) indicates that the N-Line model used to provide the preliminary impact of the wave focussing structure should not be used for this kind of assessment. N-Line models apply alongshore sediment transport calculations to determine erosion/accretion; they are not applicable to the present case, where there is very little alongshore sediment transport. Therefore, the results of DHI's (2015b) preliminary assessment of shoreline impact should be viewed with caution – a morphological model would be more appropriate for this assessment, and will likely indicate contrary results.

The N-Line model used does not incorporate the actual evolution of the shoreline (Kaergaard and Fredsoe, 2013a), it has not been validated or successfully calibrated (Kristensen *et al.*, 2012; Kaergaard and Fredsoe, 2013), it is most applicable in cases where alongshore transport dominates (Kaergaard and Fredsoe, 2013b) (alongshore transport is negligible at Lyall Bay; across shore transport dominates), and also does not incorporate wave-driven currents and circulation patterns that are critical for beach response behind offshore submerged structures (Black and Mead, 2003; Rangasinghe *et al*., 2006). In addition, because the focus will locally increase wave heights in its lee, the waves will break further offshore. As a result, the wave set-up at this location is reduced (especially during storm events when waves will break on the structure), which will also result in a widening of the beach (Black and Mead, 2003).

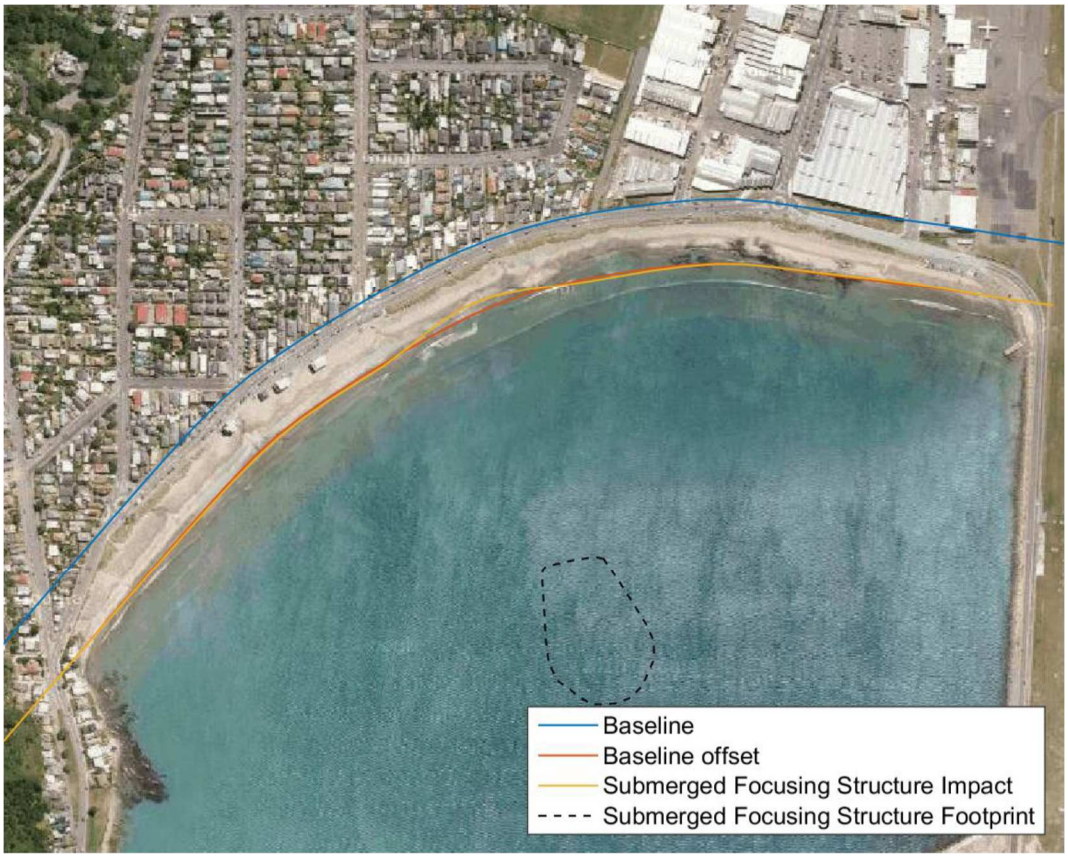



**Figure 2.11. Summary figure of DHI (2015b) preliminary beach response investigation.**

## 2.5 Aerial Photograph Analysis

Aerial photographs and satellite images were georeferenced to common control points and the location of the high tide mark and vegetation were digitised to determine the magnitude and direction of beach change between 1938 and 2015.

Between 1938 and 1984, the beach at Lyall Bay retreated/eroded up to 55 m, due to both wind-blown loss of sand and the loss of the dune system (i.e. the inability of the beach to respond to extreme events due to the loss of the dune system) (Figure 2.12). By the mid-1980's there was very little dune area remaining (Figure 2.13), and the seawall was damaged along several parts of the beach during southerly storms (Figure 2.14).

The beach then widened/accreted some 15-20 m over the past 20 years (Figure 2.12) following the establishment of dune plants in the mid-late 1990's. At this time, sand was pushed up the beach, planted with marram grass and fenced off to protect the plants (Figure 2.15 and Figure 2.16).

Recent storms have impacted heavily of the dune system – this project is looking to reinstate a functioning dune, which means continuing to widen/grow the dunes seaward. As has been shown from the aerial photograph analysis, over the past 20 years Lyall Bay beach has widened due to the redevelopment of the dune system. As the evidence of an accreting beach suggests, Lyall Bay is a sink for sand that is slowly transported into the bay from the Cook Strait (Carter and Lewis, 1995); this provides a source of material to slowly widen the dune field and increase the robustness of Lyall Bay beach.

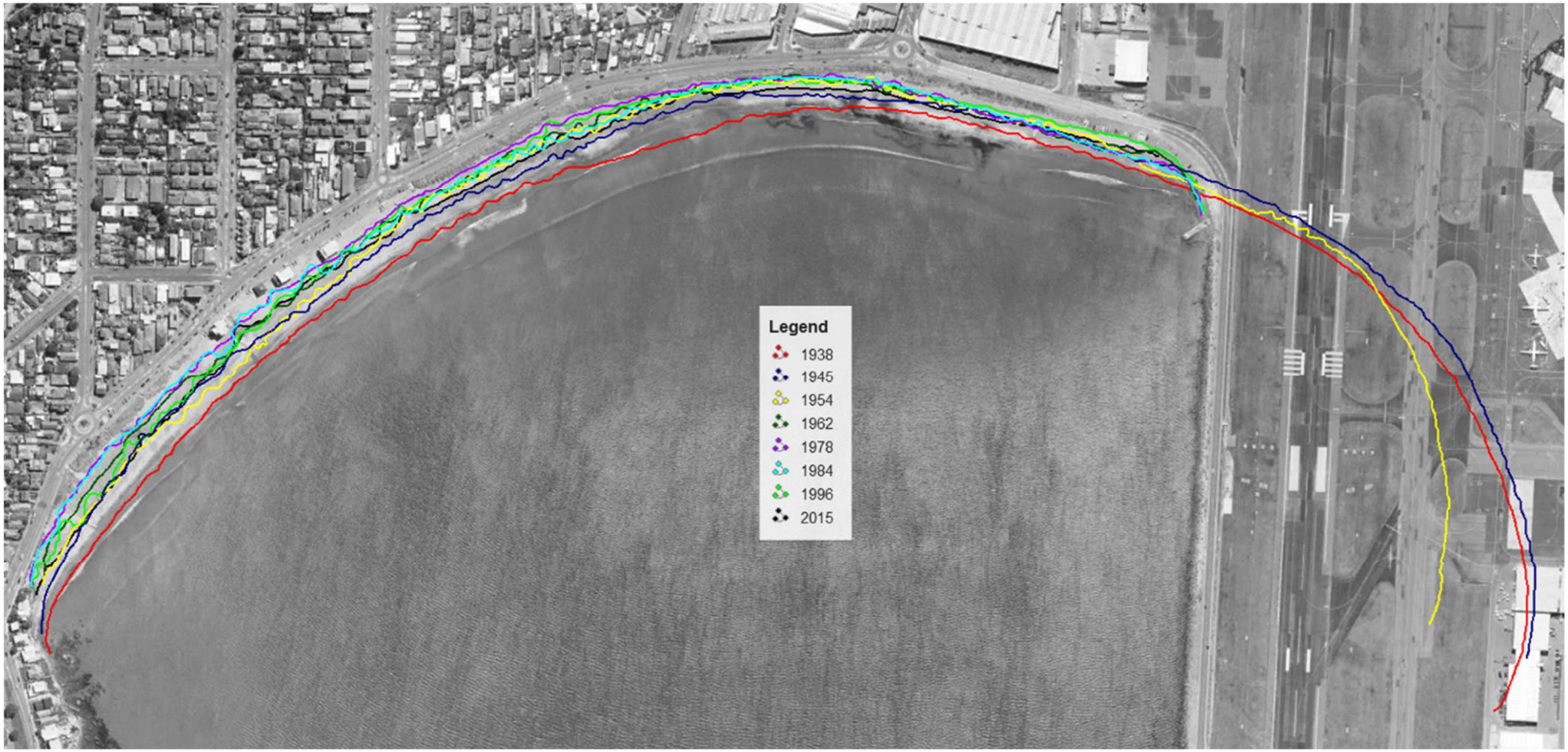



**Figure 2.12. Historical shoreline change from 1938 to 2015 for Lyall Bay beach.**

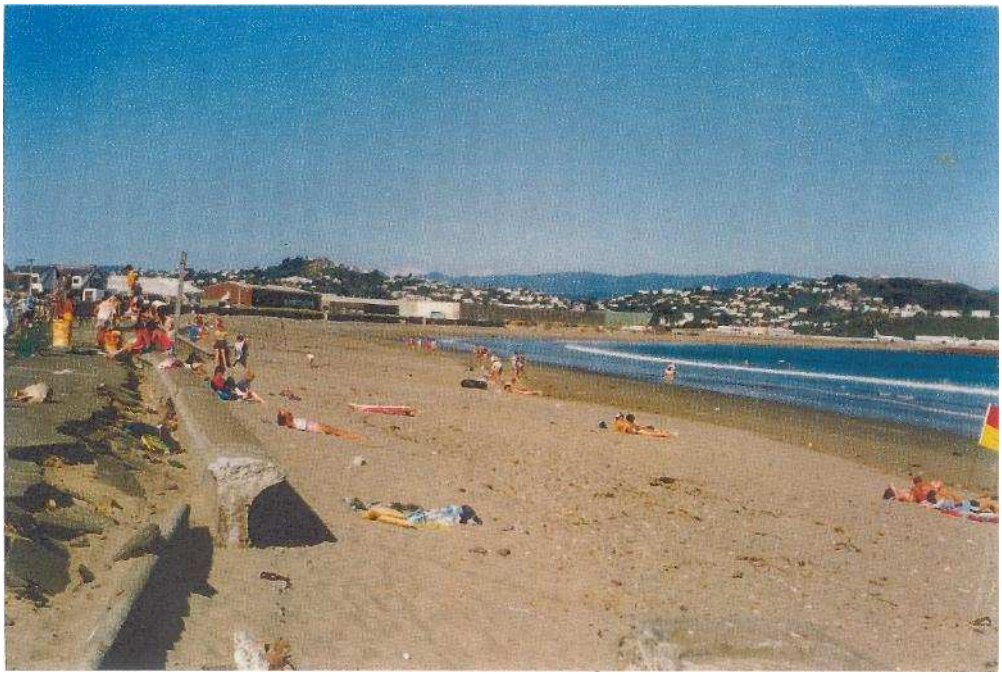


**Figure 2.13. Central Lyall Bay in January 1986; very little dune area remained and the seawall had failed (Source, John Lawson).**



**Figure 2.14. The undermined seawall in May 1985 (Source, John Lawson).**

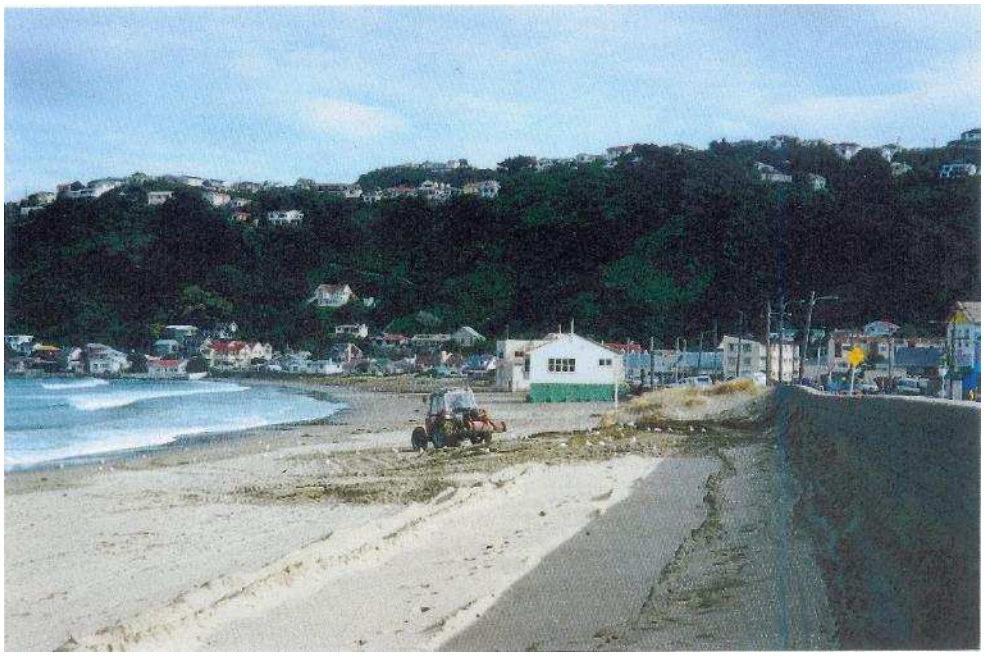


**Figure 2.15. Machinery was used to push up beach sand and create a narrow dune in mid-1996 (Source, John Lawson).**

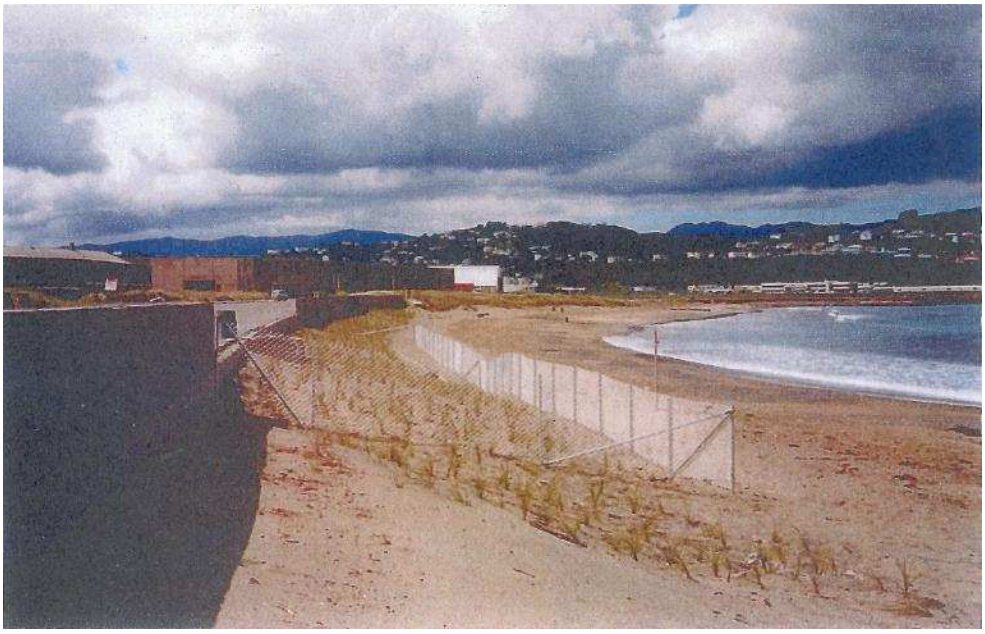


**Figure 2.16. The narrow dune was planted in marram grass and fenced off (Source, John Lawson).**

The aerial photograph and satellite image analysis of the Dorris Leslie Park coast indicates slow/chronic erosion since 1938 (Figure 2.17). Along this part of the Lyall Bay coast, the materials are a mixture of clay, sandstone and bedrock (Figure 2.18), which along with the nearshore fringing reefs mean that erosion is slow and episodic. Erosion rates range from ~2 m to ~8 m during the past 80 years (Table 2.1), an average of 6 cm/year.

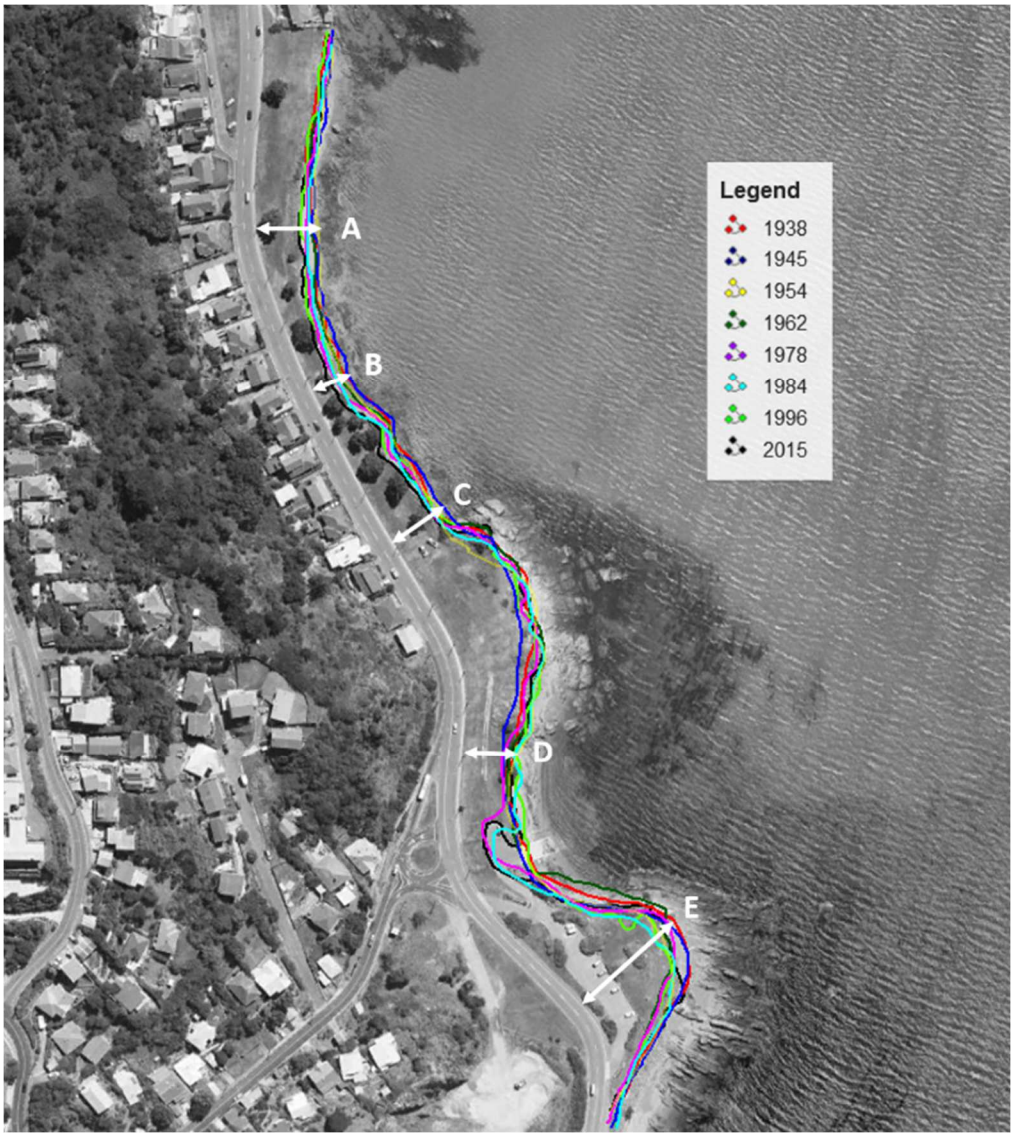



**Figure 2.17. Historical shoreline change from 1938 to 2015 at Dorris Leslie Park.**

**Table 2.1. Shoreline retreat along Dorris Lesley Park between 1938 and 2015.**

| Profile | Retreat (m) |
|---|---|
| A | 4.18 |
| B | 8.33 |
| C | 2 |
| D | 2.82 |
| E | 6.98 |



**Figure 2.18. The chronically eroding coast along much of Dorris Leslie Park (Phillips, 2015)**

## 2.6 Impacts of Sea Level Rise (SLR)

While the present study is focussed on the short-term issues with beach erosion at Lyall Bay, it is important to consider the impacts of SLR. Although there is some debate and uncertainty with respect to climate change and global warning, where SLR is concerned it is an undisputable fact; sea level is rising and it is rising at an increasing rate (there are over a century of historic data for New Zealand, and records back to 1700 in the northern hemisphere). Current predictions indicate sea level rise of 0.9 m by 2100 should a 'business as usual' approach be taken (i.e. no reduction in greenhouse gas emissions), with the melting of land-based ice (ice-sheets) potentially increasing this by 0.2 m during this period (IPCC, 2014).

In simple terms, as the water level rises, the impacts on beaches and coasts will be greater and beaches will retreat. The basic principle can be described as an equilibrium model which assumes that as sea level rises, the equilibrium beach profile is moved upward and landward conserving mass and the original shape of the beach profile (Shand *et al*., 2013).

There are a variety of empirical methods to predict shoreline recession due to SLR (e.g. the Bruun Rule (Bruun, 1962), the Komar Approach (Komar *et al*., 1999), with predicted values of SLR being applied to determine the extent of shoreline retreat in the future (e.g. IPCC, 2014; MfE, 2008). However, applying these methods at Lyall Bay is difficult due to the human interventions and modifications that have occurred over the past 80 years or so. For example, the erosional trend from 1938 to 1984 identified from the analysis of historical aerial photographs (Section 2.5) was due to multiple human impacts, and was then reversed due to human intervention (i.e. re-instatement of a vegetated dune system in the mid-1990's). With respect to the changing erosional trends and improving resilience to the impacts of SLR, de Lange and Jenks (2007) have put forward the potential to 'grow' dunes at a higher rate than SLR. In a situation such as Lyall Bay, dune management has the potential to 'buy-time' to combat the impacts of SLR. However, at some stage in the future other action will be required (e.g. managed retreat, managed advance, construction of barriers, etc.).

The modern approach to SLR adaptation is to develop a series of responses based on triggers that consider where the sea level has risen to and/or the kind of impact it is having. Once a trigger is reached, an appropriate response is applied. For example, the project to protect London (the Thames Barrier Project, Thames Estuary 2100 (UKEA, 2012)). In the TE2100 Plan, a 'managed adaptive' approach has been adopted. This involves making several interventions over time to manage risk, in contrast with making "a single, major investment in flood defence infrastructure or activity to achieve a reduction in risk which lasts until the end of the century" (PCE, 2015).

At Lyall Bay an SLR adaptive management plan would likely be part of a city-wide response (many coastal parts of Wellington, especially in the Lyall Bay/Kilbirnie/Rongati area, are low-lying), which could include triggers linked to say the average position of the mean high water spring (MHWS) tide mark in relation to the seawall, i.e. the level of threat to the seawall, which is the last line of defence. The basis of any adaptive management plan is monitoring data. At present there is no on-going beach profile monitoring for Lyall Bay; it is recommended that beach monitoring is initiated at Lyall Bay to underpin future management of the beach.

# 3 Preliminary Options Assessment and Recommendations for the Beach and Park

In conjunction with the review of existing information, the site was visited on 2 occasions to consider the existing status of the beach (access, erosion, walls, dune-health, etc.) and Dorris Leslie Park, as well as the stormwater outlets (Section 4). As described in the project scope (Section 1.1), these investigations are focussed on developing options for the restoration of the dunes to maximise their effectiveness in absorbing wave action and protecting natural and built infrastructure; options to protect the rocky shoreline, grassed area and trees on the western side of the bay; and options for the shifting of sand around the bay and dealing with current infrastructure within the beach environment.

The options developed through the various investigations to work within the existing coastal processes with regard to protecting the natural and built coastal infrastructure and reinstating a functioning dune are considered for both the entire bay (holistic options), then for each of the 4 specific areas and each stormwater outlet in the following sections. Options for the stormwater outlets are considered in Section 4. Cost estimates to undertake the recommended options are included in Appendix C.

## 3.1 Baywide Options

1. Do nothing. This option requires continued repairs to the Surfer's Corner carpark, continued damage to dunes that are easily accessible, continued removal of beach sand from the road and back to the beach, not addressing the liquefaction and consequent enhanced erosion of the beach where stormwater outlets discharge above the high-tide mark, as well as continued chronic erosion of Dorris Lesley Park. These issues will be exacerbated by continued sea level rise (SLR). Therefore, increasing the robustness of the existing dune system is recommended rather than doing nothing.
2. Stormwater outlets around the bay are of varying types and those discharging above the high-tide mark have a detrimental impact on the dunes and beach – local liquefaction results in erosion (Figure 3.1). Since there is very little alongshore sediment transport (Section 2.1), the stormwater outlets that have been lengthened and discharge into the intertidal zone do not impact on coastal processes and do not impact on dunes. While a range of longer-term options have been accessed (Section 3.3 below), the best option in the short term to increase the robustness of the dune system is to lengthen the stormwater outlets so that they discharge into the intertidal

zone. Burial through the beach and dune above the high-tide mark is preferred in order to not result in a hindrance to access along the beach. Recommendations have been made for each of the 21 outlets around the bay, which are detailed in Section 3.3.2 below.

3. Currently, the dunes are planted with marram grass and occasional pingao. Marram grass 'grows' vertical dunes, which are not as advantageous as wide low dunes in terms of buffering the impacts of storm events; 'tall' dunes do not allow storm waves to run-up them and partially 'percolate' down through the dune sand, which reduces back-wash and consequent loss of sand (de Lange and Jenks, 2007). Steep marram grass dunes have a tendency to quickly erode into a vertical scarp which exacerbates erosion due to reflection; during the most extreme events, the beach sand can be moved offshore into depths that mean it takes significant time frames for the beach to recover. Spinifex is similar to Marram, although it grows wide low dunes and is very tolerant to saltwater inundation. The addition of spinifex and gradual removal of marram grass will increase the effectiveness/robustness of the dune system, both through changing the morphology of the dune and due to the better suited plant species.
4. Many of the beach access ways are perpendicular to the footpath that backs the dunes/beach (Figure 3.1). As a result, sand can easily be blown out of the beach system during strong southerlies. In extreme wave events, waves can also run-up these access ways that open directly on to the beach; the constricted pathway also results in funnelling, that is an increase of potential run-up and discharge into the street. All access ways should be angled to reduce wind-blown sand loss and funnelling during extreme wave events, and to increase the effectiveness/robustness of the dune system (Figure 3.2). Including new access ways in the Surfer's Corner area, some 24 are required for the full length of the beach.
5. Additional signage and ropes/bollards to encourage people to stay off of the dunes is also recommended to reduce the damage that foot-traffic does to the dune plants (Figure 3.1 and Figure 3.3); 'footpaths' are evident through many areas of the existing dunes. It is also important that people are aware that dogs should also be kept out of the dune area – they represent additional foot-traffic and can quickly damage areas with digging. A review of the dog-walking area could consider relocating it to the western end of the bay where the dune/erosion threats are less severe (due to the smaller wave climate and consequent smaller sand grain sizes and lower gradient beach) and the beach is more conducive to walking; i.e. the gravel swash-ridges across the beach are not present, the beach gradient is flatter with finer grained sand. In addition, consideration could be given to the development

of public education boards close to key access points (e.g. Surfer's Corner, mid-beach (such as at the location of a potential viewing platform), at the playground/SLSC buildings) that summarise the beach management strategy.

6. Because the Lyall Bay beach system has been so highly modified by human impacts, it cannot always respond naturally to storm events. Therefore, the beach requires management such as the redistribution of sand following storm events using appropriate equipment (e.g. a Maxi-scoop) and regular inspection and clearing of stormwater drains. This is much the same as at any terrestrial park, where the grass is mowed regularly, fallen trees are removed, etc., i.e. regular maintenance is required. By following the recommended options, it is likely that less wind-blown sand will have to be removed from the roads and replaced on the beach and that over time an increasingly robust dune system will be developed, both of which will help maintain the valuable beach amenity and lead to a reduction in on-going beach management and maintenance inputs.
7. A simple beach monitoring programme (i.e. beach profile surveys) is also recommended for assisting with beach management and developing an adaptive management plan to address sea level rise in the future.



**Figure 3.1. An aerial perspective of Lyall Bay showing the straight access pathways and an example of the erosion cut caused by discharging stormwater above the high tide mark. Paths through the dunes can also be seen; foot-traffic damage dune plants and so reduce resilience of the dunes. Inset; signage to instruct people to stay off the dunes.**



**Figure 3.2. An existing angled access way at Lyall Bay (Mead, 2015)**



**Figure 3.3. Angled access ways and ropes/bollards have already been put in place at Lyall Bay during the repair works after the 2015 winter storms (Mead, 2015).**

## 3.2 Section A – Surfer's Corner

The existing carpark at Surfer's Corner is currently too far seaward; it regularly interacts with wave action which results in enhanced erosion (through wave reflection and a deficit of beach material) and consequent damage to the carpark (e.g. Spencer Holmes, 2010)

(Figure 2.8). As a result, it is often within the zone of wave run-up and surf. This is detrimental to both coastal processes and asset management – when waves hit the vertical wall of the carpark reclamation they reflect wave energy and drag sand offshore, which also impacts on the integrity of the carpark and the need for ongoing repairs (Figure 3.4). There is also anecdotal evidence that the seaward extension of the carpark impacted negatively on the surfing wave quality of the breaks in this area known as 'The Corner' by reducing the counter-current against the airport reclamation (Mead *et al*., 2003).




**Figure 3.4. The high tide mark is at the base of the wooden wall and rock revetment at the Surfer's Corner carpark and as a result is within the surfzone during extreme events which exacerbates erosion and results in structural damage (Mead, 2015).**

**Recommendations:**

In order to reinstate a functioning dune and increase the robustness of the beach, the recommended option is the removal of the western ~110 m of the carpark and replanting the upper-shore with spinifex and pingao (Figure 3.5). The road reserve on the opposite side of the road (between Tirangi Road and Cochrane Street) is available for conversion to a carpark to compensate for the removal of the Surfer's Corner carpark. As noted by Parks and Open Spaces (2004), the roading reserve is not conducive to recreational use due to the location on the southern side of tall industrial buildings (i.e. this area is shaded much of the time, except in the summer months). In addition, it is understood that the café across the

road from the existing carpark (Loose as a Goose) was to construct a carpark on the eastern side of their site (Figure 3.5); currently café customers utilise the Surfer's Corner carpark.

In order to keep foot-traffic off the dunes and further protect the dune plants (and so increase the robustness of the system to respond to storm events), it is also recommended that a wall (~100 m in length) adjacent to the footpath and similar to that which extends along much of Lyall Bay, should be constructed with 3 access points (Figure 3.5). In combination with the dune planting, the footpath wall will reduce the volume of wind-blown sand onto the road. The existing rock riprap adjacent to the stormwater outfall and below the existing carpark that will remain (approximately 80 m), will require re-contouring to tie in with the reinstated dune area.

It is noted that the natural curve of the beach was removed/compressed with the construction of the road (pre-1938) from Tirangi Road to the airport reclamation (Figure 2.12). While not within the scope of this study, in the long-term the realignment of the road more shoreward should be considered (Parks and Open Spaces, 2004).

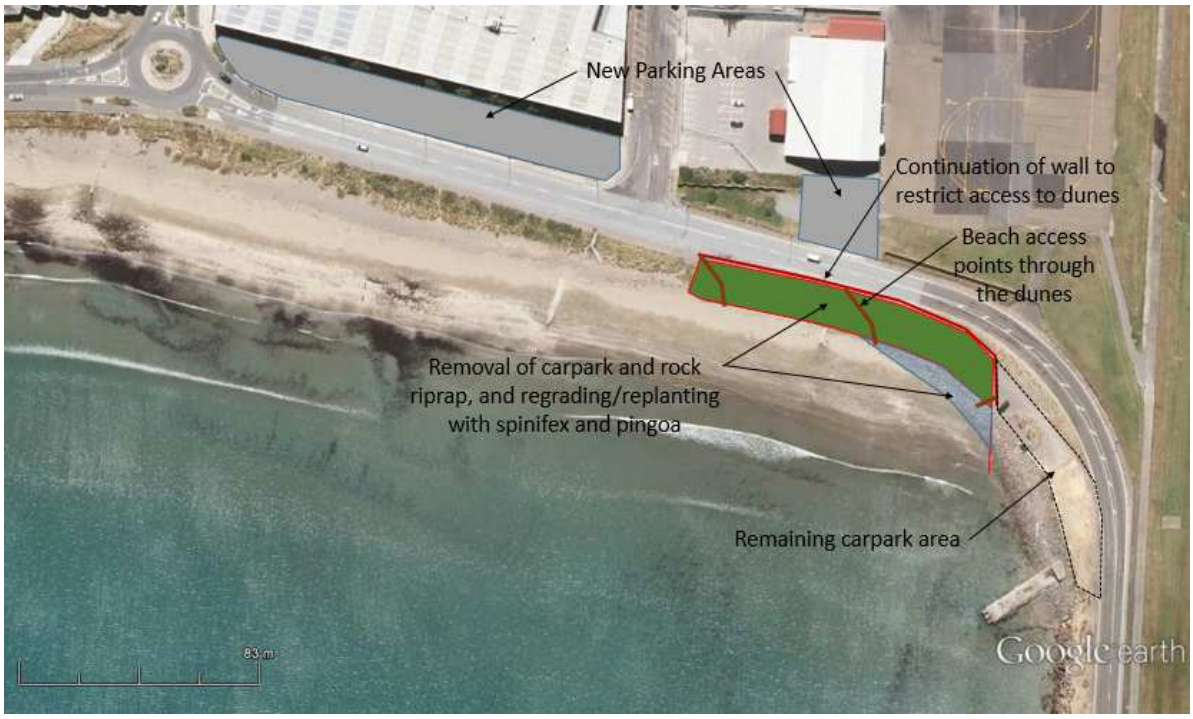



**Figure 3.5. Recommended modifications to the Surfer's Corner area. The existing carpark is currently too far seaward, which has negative impacts on the beach (causes loss of sand through reflection off the hard structure), and leads to repeated damage to the carpark. It is recommended that it is removed and the area is reinstated with sand/dune plants, and that the road reserve is converted to carparks.**

## 3.3 Section B – Surfer's Corner to Playground

This area, also known as 'The Bend', is the most exposed area of the beach and receives the largest waves. As described above, the eastern part of this stretch of beach (from approximately Kingsford Smith Street) was reduced when the road was first constructed (pre-1938), and as a result has the narrowest dune field and was most impacted by the storms of 2015 (Figure 3.6). In addition, the dune area from Surfer's Corner to Tirangi Road is not backed by a wall, and so there are many tracks through the dunes (despite the 4 access ways) reducing the health of this stretch due to plant damage.

There is also a 60 m stretch in the middle of this section of the beach that has no wall and is only backed by a steel-mesh fence since the wall was removed in the 1990's, and the dune area adjacent to the playground in the west of this section is also negatively impacted due to easy access and walking on the dunes (Figure 3.6). Offshore of this stretch of the beach is also the proposed location of a wave-focussing structure to compensate for the reduction in wave quality that the airport extension will cause.

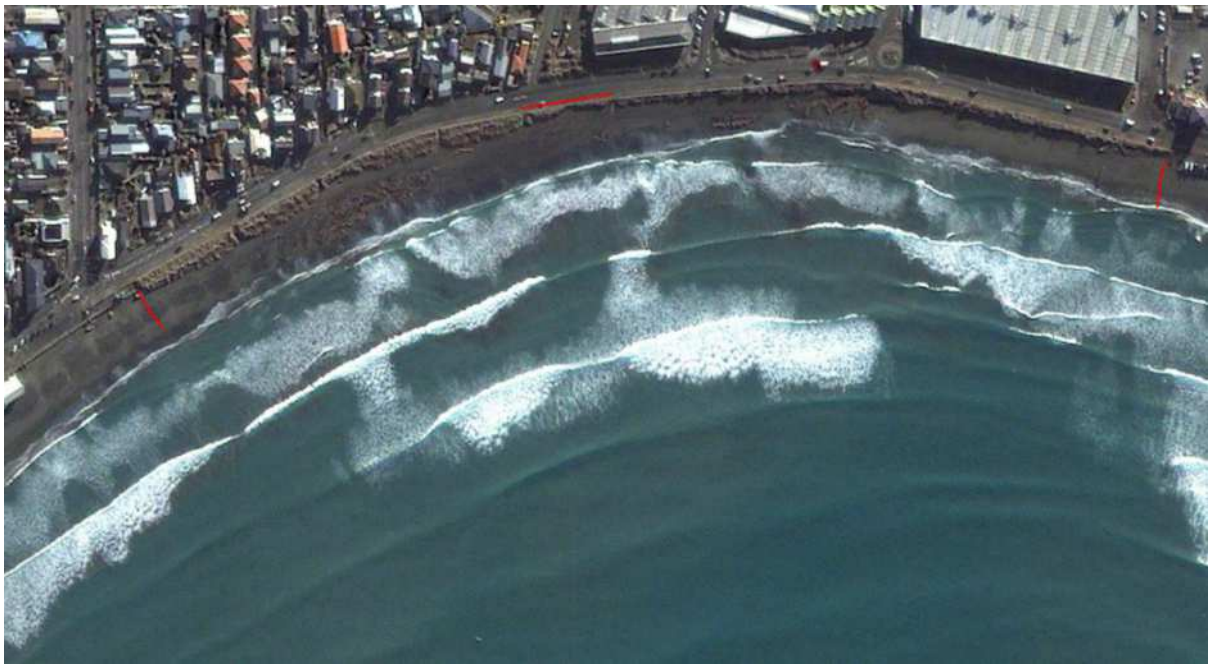


**Figure 3.6. Section B from Surfer's Corner to the Playground. The red line in the middle of the area indicates the location of the approximately 60 m stretch where the seawall is currently missing**

**Recommendations:**

The recommendations for this area include restricting access by lengthening the wall towards Surfer's Corner, replacing the footpath wall where it was removed in the 1990's and potentially heightening the wall in the central section (Figure 3.7). This stretch of the beach has experienced the greatest increase in beach width due to the establishment of the dunes, but also the highest amount of damage due to it being in the most energetic part of the beach. Limiting access to the eastern and western dunes along this section of the beach will increase the health of the dunes in these area. The seawall should also be extended along the eastern area adjacent to Surfer's Corner (~210 m in length) and be rebuilt in the middle ~60 m section to reduce the loss of wind-blown sand (which was confirmed during consultation) (Figure 3.8).

Introducing more spinifex into the dune system is recommended to develop wider dunes (rather than the high dunes developed by marram grass), and there is also the option of increasing the height of the wall to 1.5 m along the central part of this section (~350 m) to provide a higher backing to accommodate a wider and higher dune (i.e. a greater volume of sand and more resilience). At present, the dune is higher than the wall in some places, and also has a fence to prevent access (Figure 3.9). This is the area of highest waves (Section 2.1), which result in the highest run-up and erosion levels during storms, and so continuing to widen the dune through planting and sand-retention is required to increase its effectiveness as a storm buffer. Heightening the wall should be weighed against loss of sea views, although it is noted that some residents along this stretch of the beach have previously expressed a desire to have the height of the wall increased. Should the wall be heightened to increase the capacity of the dunes, consideration could be given to a raised viewing platform with an access ramp for the elderly and wheel chairs.

The dune next to the playground is currently very impacted by foot-traffic, which is assumed to be accessed from the eastern end of the playground area (Figure 3.10). This access to the dune should be prevented by fencing to reduce dune damage (Figure 3.6).

Finally, should the wave-focussing structure be constructed, it will very likely have the impact of subtly widening the beach in its' lee, which could effectively result in a wider dune system in the central area of this stretch of beach.




**Figure 3.7. Recommended options for Section B.**



**Figure 3.8. Beach sand 'leaking' onto the footpath along the ~60 m of fencing where the wall was removed in the 1990's – it is recommended that this section of wall is replaced to reduce loss of sand due to the wind.**



**Figure 3.9. The dune in Section B where there is a wall present is in many places higher than the wall, and also topped by a fence to restrict access. Increasing the height of the wall to 1.5 m would assist with continued dune development, although this should be weighed against visual impacts (i.e. loss of sea view).**




**Figure 3.10. The dune adjacent to the playground is currently very impacted by foot-traffic, which is assumed to be accessed from the eastern end of the playground area. This access to the dune should be prevented.**

## 3.4 Section C – Playground to 249 Queens Drive

This section of the beach is the most modified and is shown to be highly variable with respect to beach position (Figure 2.12), has an area of reclamation behind 4 buildings on the beach, and similar to the eastern section of the middle part of the beach (Section B), the western corner of the beach has been cut-off/reduced by the construction of Queens Drive from the Queens Drive roundabout to Sutherland Road (Figure 2.12). The high variability is in part due to the absence of a planted dune from the playground to Maranui SLSC/café (Figure 3.11).

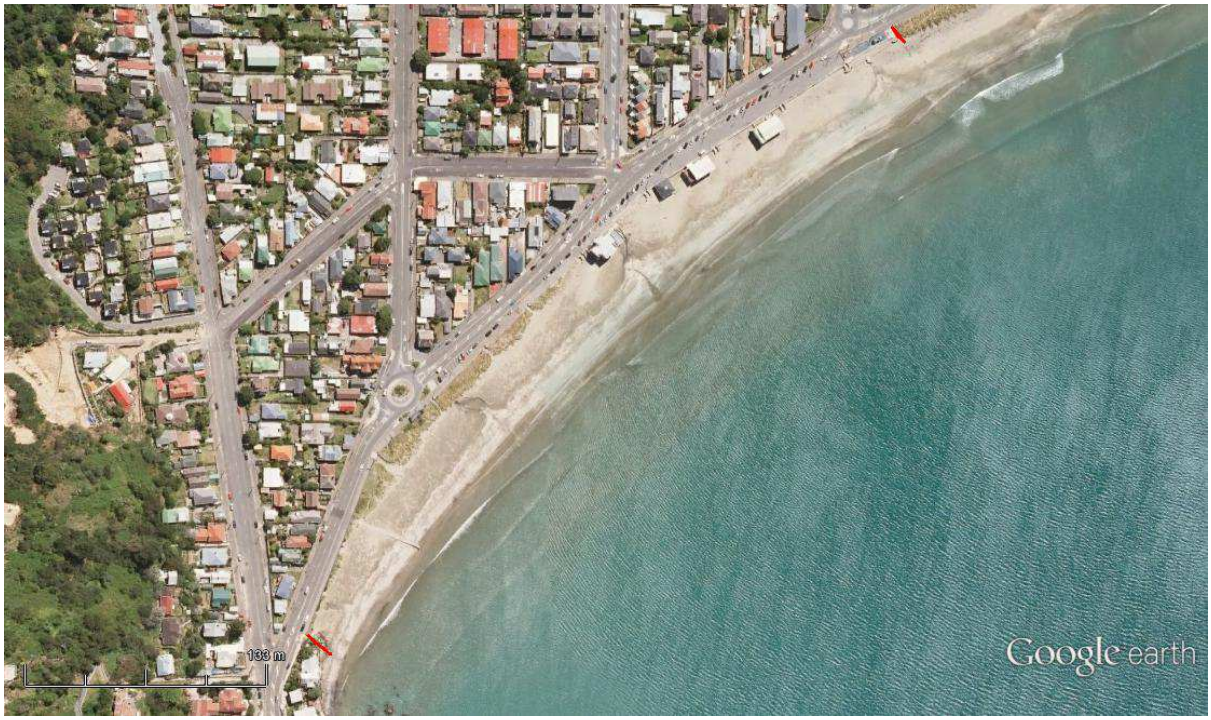



**Figure 3.11. Section C – Playground to 249 Queens Drive.**

**Recommendations:**

Although there are no dune plantings along the eastern part of this section, the beach has widened significantly in the past 20 years (Figure 3.12), very likely as a consequence of the reinstated dunes increasing the overall volume of sand within the confines of Lyall Bay beach. It is recommended that dune planting is undertaken in front of the playground and between the buildings and fenced off except for access ways to limit access to the dunes; i.e. similar to what has been done in Section B. This will reduce the variability to sand in this

area and potentially help reduce the issues with access to the SLSCs due to piled up sand following accretion events.



**Figure 3.12. The beach in Section C has widened along with the rest of Lyall Bay beach following the reinstatement of the dune's in the 1990's, and today covers many of the original access ways.**

Even so, as recommended as part of the bay-wide options, the beach requires management such as the redistribution of sand following storm events using sand-moving equipment (e.g. a maxi-scoop or front-end loader) and regular inspection and clearing of stormwater drains in this area. Similarly, although it is part of the recommendations for stormwater outlets, outlets adjacent to the playground and Maranui SLSC/café require extending out into the intertidal zone to reduce flooding of the SLSC and liquefaction/erosion (Figure 3.13). The western part of this section is the most sheltered part of the beach due to the process of refraction and the fringing reef in front of the buildings on Queen's Drive, although continued planting of spinifex and fencing of the dune area is recommended to increase the width of the dune in front of the wall along this section of the beach.

In the medium to long term, the 4 buildings on the beach will need to be removed. It is noted that there is presently sufficient space to relocate these structures (Figure 3.14), should that be the decision in the future.



**Figure 3.13. The stormwater outlet next to the Maranui SLSC is one of the most troublesome in Lyall Bay; it outfalls at the base of the seawall (i.e. is the more landward than others), is very close to the building and has a relatively high discharge rate compared to others. Burying and lengthening to the intertidal zone will reduce the negative impacts on beach stability and amenity.**



**Figure 3.14. The footpath area behind the existing buildings on the beach is wide enough to allow for relocation.**

## 3.5 Area D –Dorris Lesley Park

This western section of Lyall Bay is mostly typified by a gravel/soil substrate above a gravel beach which is perched on a fringing reef (Figure 3.15). The northern 220 m of this area is a grassed reserve with Pohutakawa trees along the edge of the gravel beach (Figure 3.16). Over time, chronic erosion has created a scarp of up to 2 m high so that today many of the Pohutakawa trees are at risk of being completely undermined and falling seaward (Figure 3.17). Further south of this grassed section, the fringing reef becomes wider and chronic erosion has cutback the foreshore up to 8 m in the past 80 years (Figure 2.17), so that now some of the infrastructure is being impacted, and significant areas of the park are vulnerable to acute erosion during storms (Figure 3.18). The southernmost 300 m of the park has recently been protected by a tipped rock revetment to safeguard the coastal road and carpark (Figure 3.19).



**Figure 3.15. Section D, Dorris Lesley Park is mostly typified by a gravel/soil substrate above a gravel beach which is perched on a fringing reef.**



**Figure 3.16. The northern section of Dorris Lesley Park (Phillips, 2015).**



**Figure 3.17. The retreat of the coast in the norther section of Dorris Lesley Park has resulted in a scarp of up to 2 m in height and now several Pohutakawa trees are at risk of being completely undermined and falling seaward (Phillips, 2015)..**



**Figure 3.18. The fringing reef becomes wider and chronic erosion has cutback the foreshore up to 8 m in the past 80 years so that now some of the infrastructure is being impacted, and significant areas of the park are vulnerable to acute erosion during storms (Phillips, 2015).**



**Figure 3.19. The southernmost 300 m of the park has recently been protected by a tipped rock revetment to safeguard the coastal road and carpark (Phillips, 2015)..**

**Recommendations:**

The northernmost area of the grassed part of the park has experienced relatively little erosion, and it is recommended that some re-grading of this area (~100 m) where the scarp is <0.5 m high is undertaken and coastal plants such as flaxes are planted to help reduce future loss of soil (Figure 3.16). Where the Pohutakawa trees are threatened by undermining and the high beach scarp is present, armouring with similar materials as have been applied to the southern part of the park is recommended (i.e. tipping rock on a geotextile filter cloth to prevent undermining and loss of fine materials behind the rock (Figure 3.19)). In the central area of the park, it is mainly the small headland on which the stone statue, Moai, is located that is the most vulnerable to future erosion. The options in this area are to either move the statue and seating landward, or place tipped rock revetment around this area. The latter is recommended given the current vulnerability of the site, which will increase with ongoing SLR; this area cannot recover like the sandy sections of Lyall Bay. Some 280 m of revetment will be required for area of Pohutakawa trees (~180 m) and small headland (~100 m) combined.

## 3.6 Summary of Recommended Beach Options

Table 3.1 summarises the recommended options for the whole beach and the 4 specific sections of Lyall Bay. Note, detailed stormwater option recommendations are provided in Section 3.2.2. Cost estimates for the items in Table 3.1 are listed in Appendix C, with the exception of the development of a beach management team and beach profile monitoring. The cost to heighten of the central part of the seawall (some 350 m) has also been excluded from the total budget, since there are a range of affected parties that would require further consultation (an estimate is provided below the main budget).

**Table 3.1. Summary of recommended options for coastal remediation of Lyall Bay.**

| Area | Recommended Options |
|---|---|
| **Baywide** | 1. Do nothing.<br>2. Lengthening of stormwater outlets.<br>3. Incorporation of spinifex and removal of marram grass.<br>4. Upgrading of beach access ways (~24).<br>5. Increased signage instructing people to stay of the dunes along with roping off.<br>6. Development of a beach maintenance team.<br>7. Beach monitoring (profiles). |
| **Section A** | 1. Removal of ~110 m of existing carpark.<br>2. Relocation of parking spaces to road reserve.<br>3. Reinstatement of foredune and plants (spinifex and pingao) once carpark removed.<br>4. Installation of seawall to 'support' the new stretch of dune |

| | |
|---|---|
| | (~100 m) and reduce foot-traffic.<br>5. Installation of 3 beach access ways. |
| **Section B** | 1. Extension of the seawall from the eastern end to meet up with the new seawall at the former Corner carpark (~210 m).<br>2. Replacing the seawall along the ~60 m length that it was removed from in the mid-1990's.<br>3. Introduction of more spinifex and pingao into the dunes.<br>4. Prevention of access to the dune from the eastern end of the playground.<br>5. Heighten the middle section of the seawall to ~1.5 m (~350 m).<br>6. Upgrade beach access ways (11). |
| **Section C** | 1. Establishment and fencing off new dune area where it is currently not present between buildings and in front of the playground (~200 m).<br>2. Establishment of appropriate access ways from the existing historic seawall access ways (10 in this section).<br>3. Continued planting and fencing to the west of the buildings where the dune is currently narrow. |
| **Section D** | 1. Re-grading of the ~100 m northern part of the park and planting with coastal species (e.g. flax).<br>2. Tipped rock revetment along the section of undermined Pohutakawa trees (~180 m).<br>3. Tipped rock revetment around the eroding headland of Moai to meet up with the existing revetment (~100 m). |

# 4 Preliminary Stormwater Options Assessment

## 4.1 Introduction

This section of the report focuses on the present condition of stormwater infrastructure on Lyall Bay beach (Figure 1.1), and remediation required (e.g. outfalls, pipelines, pipeline outlets, manholes, etc.). This is ranked according to impact and effect on coastal processes, and the effectiveness of the outfall as a stormwater outlet. This will provide the council and community with options for future prioritisation and timeline and budgetary planning (from short to long term).

In particular council has requested information on:

> *Stormwater outlets – their impact and effects on the coastal processes and their effectiveness as functioning stormwater outfalls in this environment.*

In a previous assessment of Lyall Bay by Parks and Open Spaces Ltd (2004) it was found that in the early 1990's money was available for dune planting, which was relatively successful. However, in the area in Surfers' Corner, the capacity for the plants to establish quickly is restricted by the turbulence created by the seawall. The stormwater outlets along the dunes, above the high tide mark, also appear to erode the beach and likely prevent sand accretion due to liquefaction. This section assesses the erosion potential of the stormwater outlets.

## 4.2 Asset Investigation

The stormwater assets discharging to Lyall Bay have been listed from Surfers' Corner in the east to Dorrie Leslie Park in the west. For each, the main features have been photographed and asset data provided. Ranking has been provided for: 1) the impact and effect on coastal processes (Table 4.1), as well as 2) the effectiveness of the actual function of the stormwater outfall (Table 4.2). This is then related to a schedule that considers no works required on the asset through to urgent works required.

## Impact and Effect on Coastal Processes

**Table 4.1: SW Asset Coastal Process Impact Assessment**

| Ranking | Coastal Process Impact and Effect | Works Requirement |
|---|---|---|
| 1 | Very Low | No works required |
| 2 | Low | No works required - monitor |
| 3 | Moderate | Monitor and programme if works required |
| 4 | High | Required in the near future - Programme works |
| 5 | Very High | Urgent – schedule works |

## Effectiveness as a Functioning Stormwater Outfall in this Environment

**Table 4.2: SW Asset Effectiveness Assessment**

| Ranking | SW Outfall Effectiveness | Works Requirement |
|---|---|---|
| 1 | Very high | No works required |
| 2 | High | No works required - monitor |
| 3 | Moderate | Monitor and programme if works required |
| 4 | Poor | Required in the near future - Programme works |
| 5 | Very poor | Urgent - schedule works |

## 4.2.1 Stormwater Asset Investigation

**No. 1**
**Asset ID:** SWP015426, SWP000113, SWP014657
**Type:** Stormwater pipelines and outlets
**Description:** 3 x 1300mm dia. concrete circular, 29.80m length
**Location:** Section A: Surfers Corner
**Date Inspected:** 9/10/15
**Other:** In planning to possibly be extended



**Figure 4.1. The beach at Lyall Bay with the pipelines in the distance (left) and the 3x1300mm dia. outlets that discharge the airport runway stormwater (right) (Source: Phillips, 2015).**



**Figure 4.2. GIS view of the pipes and outlets (left) (Wellington City Council GIS, accessed 17/11/15), and the 3 storm water outlets close to the airport (Source: Phillips, 2015).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 3 | Erosion occurring around the structure. Aesthetically unpleasing. Assess for possible sandcrete or cover with rocks/stones to naturalise |

| | | |
|---|---|---|
| | | and blend into environment. |
| **SW Outfall Effectiveness** | 2 | Highly effective |

**No. 2**
**Asset ID:** SWP014589
**Type:** Stormwater pipeline and outlets (SW sump lead)
**Description:** 225mm dia. concrete circular pipes 23.03m length
**Location:** Section A: Surfers Corner
**Date Inspected:** 9/10/15

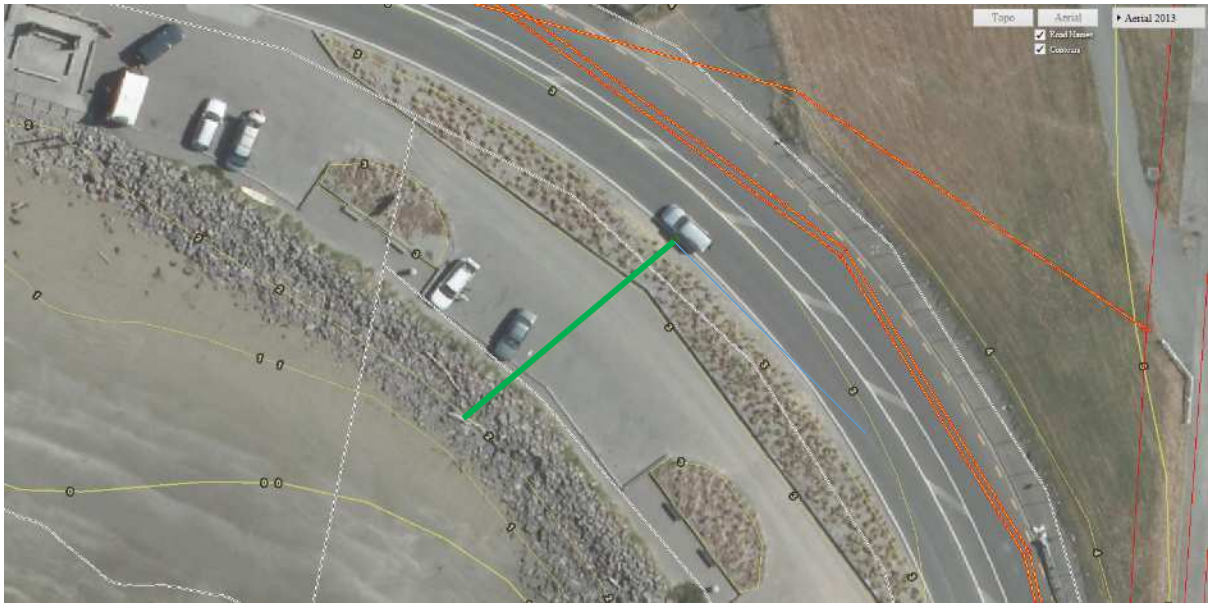



**Figure 4.3. Stormwater sump lead 225mm dia. concrete pipe (Wellington City Council GIS, accessed 17/11/15).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 3 | Localised erosion possible and SW debris on beach. Should be extended beyond dune field to prevent ongoing erosion as part of re-development of beach front or diverted to Outlet No. 1 if feasible. |

| | | |
|---|---|---|
| | | Or soakage of base-flow under beach with overflow (Flow, G/W and soil permeability dependant). |
| **SW Outfall Effectiveness** | 3 | Moderately effective – Monitor. Debris and sand could block the outlet. |

**No. 3**
**Asset ID:** SWP014592
**Type:** Stormwater pipeline and outlet (SW sump lead)
**Description:** 225mm dia. concrete circular pipes 23.03m length
**Location:** Section A: Surfers Corner
**Date Inspected:** 9/10/15



**Figure 4.4. Stormwater outlet 0.225m dia. with concrete rectangular casing (left)(Source: Wellington City Council GIS, accessed 17/11/15).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 2 | Fairly low impact as in the inter-tidal zone, with some localised erosion possible. Could be extended out of upper beach area as part of re-development as will impact on dune restoration. Or assess for possible diversion to Outlet No. 1 or soakage of base-flow under beach with overflow (Flow, G/W and |

| | | |
|---|---|---|
| | | soil permeability dependant). |
| **SW Outfall Effectiveness** | 3 | Moderately effective – Monitor |

**No. 4**

**Asset ID:** SWP002877
**Type:** Stormwater pipeline and outlet
**Description:** 600mm dia. circular pipe with concrete rectangular encasing 62.56m length, Invert Level 0.26m
**Location:** Section B: Surfers Corner to playground
**Date Inspected:** 9/10/15



**Figure 4.5. Stormwater outlet 0.6m dia. with concrete rectangular casing (left) (Source: Phillips, 2015), and the GIS view of the stormwater infrastructure (right) (Source: Wellington City Council GIS, accessed 17/11/15).**




**Figure 4.6. The stormwater outlet with broken concrete visible (left) and the actual pipe with reinforcing steel visible (right)(Source: Phillips, 2015).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 3 | Moderate impact, with some potential to act as a localised groyne and walking barrier. Aesthetically unpleasing. Potentially naturalising with sandcrete option. Repair required of concrete surround. Assess diversion to Outlet No.1 or join with No. 5. |
| **SW Outfall Effectiveness** | 3 | Effective – works required to repair damage to concrete surround. |

**No. 5 Asset ID:** SWP022448
**Type:** Stormwater pipeline and outlet
**Description:** 750mm dia. circular pipe with concrete rectangular encasing 106.9m length, Invert Level 1.53m
**Location:** Section B: Surfers Corner to playground
**Date Inspected:** 9/10/15
**Other:** Pipe has sand build-up in the pipe



**Figure 4.7. Stormwater outlet 0.75m dia. with concrete rectangular casing (left) (Source: Wellington City Council GIS, accessed 17/11/15), and the pipe on the beach (right) (Source: Phillips, 2015).**



**Figure 4.8. The stormwater outlet (left) and sand in the pipeline (right)(Source: Phillips, 2015).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 3 | Moderate impact located at mid-tide. Some erosion and scour of beach. Aesthetically unpleasing. Naturalising with sandcrete a potential option. |
| **SW Outfall Effectiveness** | 3 | Moderately effective – presently half-filled with sand, which will clear if enough gap for water to flow. Gate or flap not really an option in surf-zone and saltwater as hinges seize, however a rubber Wastop from Hynds could be further investigated as a potential option that would need trialling. Assess joining with No. 4. |

**No. 6**
**Asset ID:** SWP038855
**Type:** Stormwater pipeline and outlet (SW sump lead)
**Description:** 225mm dia. concrete circular pipes 18.13m length
**Location:** Section B: Surfers corner to playground
**Date Inspected:** 9/10/15



**Figure 4.9. Stormwater outlet 0.225m dia. with concrete rectangular casing (left)(Source: Wellington City Council GIS, accessed 17/11/15).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 4 | Low impact on large-scale coastal processes, however high impact and effect on dune. Needs to be extended at least past dunes to prevent ongoing erosion. The indented area at outlet can be seen in the dune field. Ideally flow can be diverted to Outlet No. 5 and outlet removed, or baseflow under beach and outlet extended. |
| **SW Outfall Effectiveness** | 3 | Moderately effective – Monitor. Potential to block with mobile dune sand. |

**No. 7**
**Asset ID:** SWP032975
**Type:** Stormwater pipeline and outlet (SW sump lead)
**Description:** 225mm dia. concrete circular pipes 9.90m length
**Location:** Section B: Surfers Corner to Playground
**Date Inspected:** 9/10/15




**Figure 4.10. Stormwater outlet 0.225m dia. with concrete rectangular casing (left)(Source: Wellington City Council GIS, accessed 17/11/15).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 4 | Low impact on large-scale coastal processes, however high impact and effect on dune. Needs to be extended past dunes to prevent ongoing erosion. The indented area at outlet can be seen in the dune field. Assess potential diversion or soakage. |
| **SW Outfall Effectiveness** | 3 | Moderately effective – Monitor.<br>Potential to block with mobile dune sand. |

**No. 8**

| | |
|---|---|
| **Asset ID:** | SWP032310, SWP038997, SWP038996, |
| **Type:** | Stormwater pipeline and outlet (SW sump lead) |
| **Description:** | 315mm dia. PE100 circular pipe 12.96m length<br>315mm dia. PE100 circular pipe 12.73m length<br>315mm dia. PE100 circular pipe 13.0m length<br>750mm dia. concrete circular pipe 12.73m length |
| **Location:** | Section B: Surfers corner to playground |
| **Date Inspected:** | 9/10/15 |

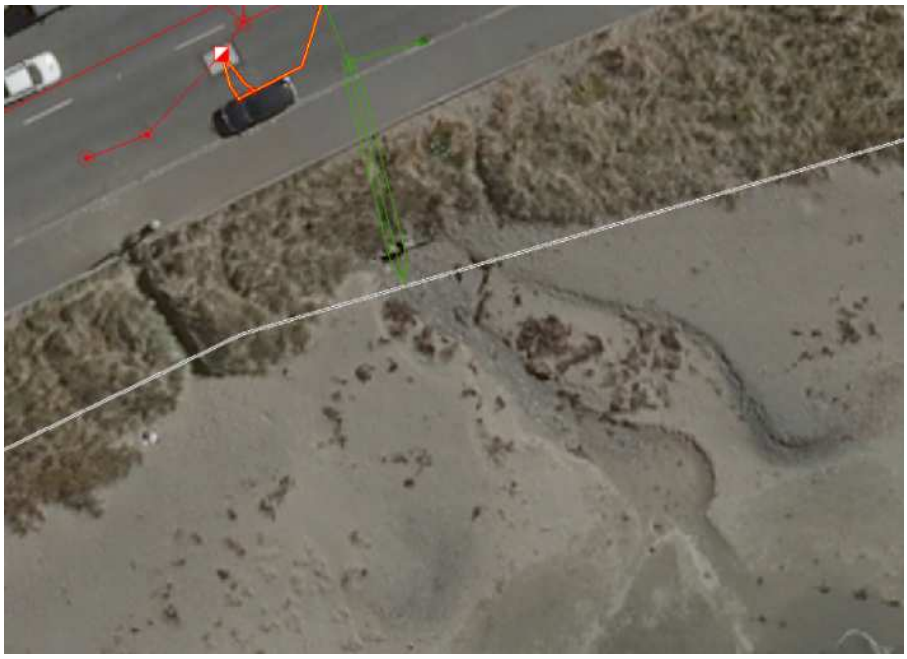


**Figure 4.11. Stormwater outlet 0.75m dia. with concrete rectangular casing (left)(Source: Wellington City Council GIS, accessed 23/11/15).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 4 | High impact on large-scale coastal processes, and high impact and effect on dune field, so liquefies the sand throughout the intertidal zone which increases erosion/loss of sand. Needs to be extended past dunes to prevent ongoing erosion, preferably to the inter-tidal zone. The indented area at outlet can be seen in the dune field, as well as large fan eroded area on beach with significant scour. Assess diversion to Outlet No. 9. |
| **SW Outfall Effectiveness** | 4 | Moderately to poorly effective – Monitor. Potential to block with mobile dune sand, and causes significant stromwater debris and contaminants on beach. |

**No. 9. Asset ID:** SW300741
**Type:** Stormwater outlet chamber with 3 pipelines
**Description:** 2050mm dia. chamber
315mm dia. HDPE 27m length pipe
525mm dia. Concrete 13.69m length pipe IL. 1.44m
315mm dia. HDPE 27.0m length pipe
**Location:** Section B: Section B: Surfers corner to playground
**Date Inspected:** 9/10/15



**Figure 4.12. Stormwater outlet with manhole (left)(Source: Wellington City Council GIS, accessed 23/11/15) and erosion on beach (right)(Source: Phillips, 2015).**




**Figure 4.13. Stormwater outlet on the beach (Source: Phillips, 2015).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 4 | High impact on coastal processes and dune field since it is high on the beach, and so liquefies the sand throughout the intertidal zone which increases erosion/loss of sand. Needs to be extended to prevent ongoing erosion. The indented/eroded area at outlet can be seen in the upper beach, as well as large eroded fan area on beach with significant scour. |
| **SW Outfall Effectiveness** | 4 | Moderately to poorly effective – Monitor. Potential to block with mobile sand, and causes significant stromwater debris and contaminants on beach. |

**No. 10**
**Asset ID:** SWP027070
**Type:** Stormwater outlet (Sump lead)
**Description:** 225mm dia. concrete 10.25m length pipe
**Location:** Section C: Playground to 249 Queens Drive
**Date Inspected:** 9/10/15



**Figure 4.14. Stormwater outlet 0.225m diameter (Source: Wellington City Council GIS, accessed 23/11/15).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 3 | Low to moderate impact with some localised erosion possible depending on flow, and impact adversely on buildings. Pipe could be extended or flow diverted to other larger outlet (grade dependent) so well clear of the buildings. |
| **SW Outfall Effectiveness** | 3 | Moderately effective – Monitor. Stormwater could have some difficulty flowing through build-up of sand. Adverse effect of stormwater debri and contaminants on beach. |

**No. 11**
**Asset ID:** SWP027062, SWP027063
**Type:** Stormwater rectangular box outlet with 2 pipelines
**Description:** 1500mm dia. Concrete 9.49m length IL. 1.48m.
1050mm dia. Concrete 9.36m length IL. 1.84m.
**Location:** Section C: Playground to 249 Queens Drive
**Date Inspected:** 9/10/15



**Figure 4.15. Stormwater outlets with concrete rectangular casing (left) (Source: Wellington City Council GIS, accessed 17/11/15), and the outlets on the beach (right)(Source: Phillips, 2015).**




**Figure 4.16. The stormwater outlet (left) and scour and erosion near the building (right) (Source: Phillips, 2015).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 5 | High impact on coastal processes and beach since it is high on the beach, and so liquefies the sand throughout the intertidal zone which increases erosion/loss of sand. Needs to be extended to prevent ongoing erosion or relocated away from the building. The indented/eroded area at outlet can be seen in the upper beach, as well as large eroded fan area on beach with significant scour. |
| **SW Outfall Effectiveness** | 5 | Poorly to moderately effective. Causes significant erosion at corner of the building, and stormwater debris and contaminants on beach. White bags look aesthetically unpleasing, providing minimal protection. |

**No. 12**
**Asset ID:** SWP038854
**Type:** Stormwater outlet with pipe
**Description:** 225mm dia. Concrete circular 9.22m length.
**Location:** Section C: Playground to 249 Queens Drive
**Date Inspected:** 9/10/15




**Figure 4.17. Stormwater outlet 0.225m dia. pipe (Source: Wellington City Council GIS, accessed 17/11/15).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 3 | Low impact with some localised erosion. Some adverse impact on the dunes, would be ideal to extend further down beach or divert to a larger combined outlet, or assess soakage potential with overflow. |
| **SW Outfall Effectiveness** | 3 | Moderately effective – Monitor. Stormwater could have some difficulty flowing through build-up of sand in upper beach. |

**No. 13. Asset ID:** SW15538, SWP012915
**Type:** Stormwater outlet and pipeline
**Description:** 375mm stoneware 51.35m length
**Location:** Section C: Playground to 249 Queens Drive
**Date Inspected:** 9/10/15



**Figure 4.18. Stormwater outlet 0.375m dia. with concrete rectangular casing (left) (Source: Wellington City Council GIS, accessed 17/11/15), and the pipe on the beach (right) (Source: Phillips, 2015).**



**Figure 4.19. The stormwater outlet and sand/debris in the pipeline (left), and scour and erosion on the beach in the dune field (right) (Source: Phillips, 2015).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 5 | High impact on coastal processes and beach since it is high on the beach, and so liquefies the sand throughout the intertidal zone which increases erosion/loss of sand. Needs to be extended or flow diverted to other outlet to prevent ongoing erosion. The indented/eroded area at outlet can be seen in the upper beach, as well as large eroded fan area on beach with significant scour. |

| | | |
|---|---|---|
| **SW Outfall Effectiveness** | 5 | Poor effectiveness. Causes significant erosion, and stormwater debri and contaminants on beach. Pipe is filled with sand and debri, and the flaps do not appear to be stopping the egress of materials into the pipe, rather holding SW debri in the pipe. Assess WaStop installation. |

**No. 14**
**Asset ID:** SWP023865
**Type:** Stormwater outlet and pipeline
**Description:** 225mm Reinforced concrete 18.13m length
**Location:** Section C: Playground to 249 Queens Drive
**Date Inspected:** 9/10/15




**Figure 4.20. Stormwater outlet 0.225m dia. pipe (Source: Wellington City Council GIS, accessed 17/11/15).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 4 | High impact with some localised erosion possible of the dune, and would be ideal to extend further down beach at least well past the toe of the dunes, or divert flow to Outlet No. 15, or assess soakage potential. |
| **SW Outfall Effectiveness** | 3 | Moderate effectiveness –Stormwater could have some difficulty flowing through build-up of sand in upper beach, and scour and erosion of the dunes. |

**No. 15. Asset ID:** SWP023869
**Type:** Stormwater outlet
**Description:** 600mm dia. Concrete 53.73m length
**Location:** Section C: Playground to 249 Queens Drive
**Date Inspected:** 9/10/15
**Other:** A gate/flap was once installed to stop sand egress.



**Figure 4.21. Stormwater outlet 0.60m dia. with concrete square casing (left) (Source: Wellington City Council GIS, accessed 17/11/15), and the pipe on the beach (right) (Source: Phillips, 2015).**



**Figure 4.22. The stormwater pipeline looking from the upper beach (left) and from along the beach (right) (Source: Phillips, 2015).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 3 | Moderate impact, with some potential to act as a localised groyne, and erosion from large outflows. Aesthetically unpleasing, although boardwalk is a good feature for amenity, but hard to walk past/over pipe structure at lower outlet section. Naturalising with sandcrete a potential option at the outlet end of pipe structure. |

| | | |
|---|---|---|
| **SW Outfall Effectiveness** | 2 | Effective. Some sand build-up in pipe, which could have an adverse impact. Holes drilled along the sides allow water to flow out if blocked, and likely slurry some sand out which may then assist to clear the line. It appears a gate or flap has been tried, but is no longer in position. Wastop could be an option to consider. |

**No. 16**
**Asset ID:** SWP023862
**Type:** Stormwater outlet and pipeline (Sump Lead)
**Description:** 150mm dia. Earthenware pipe 21.85m length
**Location:** Section C: Playground to 249 Queens Drive
**Date Inspected:** 9/10/15

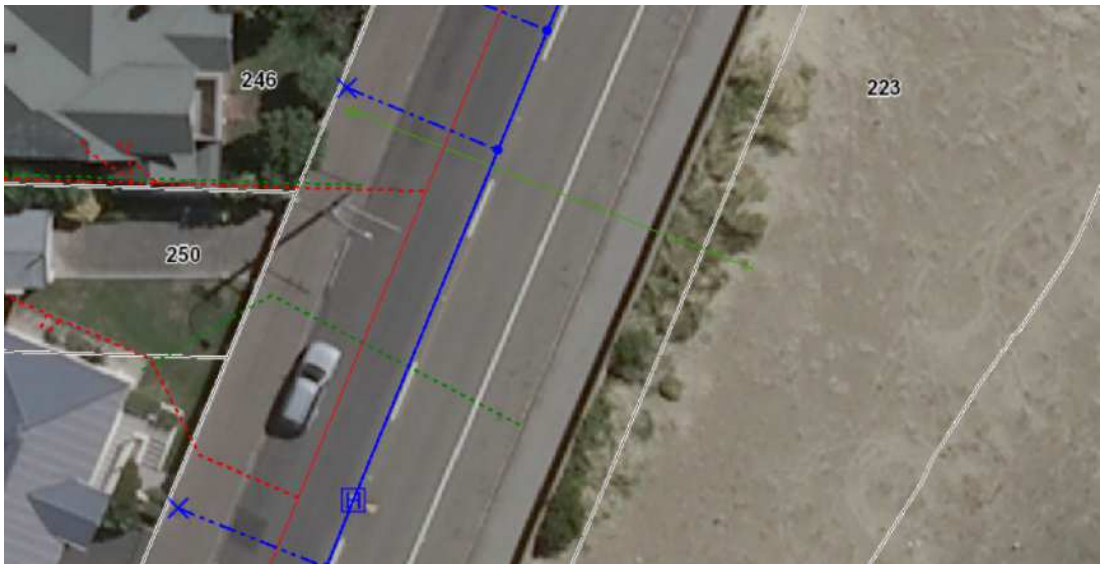



**Figure 4.23. Stormwater outlet 0.150m dia. with concrete rectangular casing (left)(Source: Wellington City Council GIS, accessed 17/11/15).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 2 | Low impact with some localised erosion is possible, however it is located at the forward edge of the dune and only a small 0.15mm dia. pipe. |
| **SW Outfall Effectiveness** | 2 | Effective as only minor flow – Monitor. Stormwater could have some difficulty flowing through build-up of sand in upper beach. |

**No. 17**
**Asset ID:** SWP032974
**Type:** Stormwater outlet and pipeline (Sump Lead)
**Description:** 225mm dia. Concrete pipe 3.34m length
**Location:** Section C: Playground to 249 Queens Drive
**Date Inspected:** 9/10/15



**Figure 4.24. Stormwater outlet 0.225m dia. pipe (Source: Wellington City Council GIS, accessed 23/11/15).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 4 | High impact with some localised erosion possible of the dune, and would be ideal to extend further down beach. Erosion fan visible in the aerial, with scour through the upper beach, and liquefied sand which increases erosion and loss of sand. Assess potential diversion or soakage. |
| **SW Outfall Effectiveness** | 3 | Poor to moderate effectiveness – Stormwater could have some difficulty flowing through build-up of sand in upper beach, and scour and erosion of the dunes. Stormwater debris and contaminants on the beach. |

**No. 18**

| | |
|---|---|
| **Asset ID:** | SWP016018 |
| **Type:** | Stormwater outlet |
| **Description:** | 225mm dia. Concrete 45.76m length |
| **Location:** | Section D: Dorrie Leslie Park |
| **Date Inspected:** | 9/10/15 |



**Figure 4.25. Stormwater outlet 0.225m dia. concrete pipe (left)(Source: Wellington City Council GIS, accessed 17/11/15), and the pipe on the beach (right)(Source: Phillips, 2015).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 1 | Very low impact with discharge onto rock covered shoreline, however poor aesthetically so ideal to lower invert level under the beach and extend to low tide reef area. |
| **SW Outfall Effectiveness** | 3 | Stormwater is able to flow onto the beach fairly efficiently, however the concrete pipe section could be broken off in storm conditions. Lowering with more cover would make it more robust. |

**No. 19**

| | |
|---|---|
| **Asset ID:** | SWP015268 |
| **Type:** | Stormwater pipeline |
| **Description:** | 225mm dia. Concrete pipe 92.57m length |
| **Location:** | Section D: Dorrie Leslie Park |
| **Date Inspected:** | 9/10/15 |
| **Other:** | Section of pipe has been eroded away |



**Figure 4.26. Stormwater outlet 0.225m dia. concrete pipe (left) (Source: Wellington City Council GIS, accessed 17/11/15), and the pipe on the beach (right) (Source: Phillips, 2015).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 5 | High impact with some significant localised erosion taking place on the bank, and would be ideal to extend further down beach at a lower level with cover over pipe. A pipe section has already broken off when the GIS is viewed. Scour and erosion around the pipe outlet on bank, which is going to exuberate further in the future. |
| **SW Outfall Effectiveness** | 5 | Poor effectiveness – Stormwater is eroding the bank, however water is able to discharge easily from the pipe but will keep eroding and another section of pipe could erode out. |

**No. 20**

| | |
|---|---|
| **Asset ID:** | SWP002199 |
| **Type:** | Stormwater outlet |
| **Description:** | 225mm dia. Concrete pipe 14.0m length |
| **Location:** | Section D: Dorrie Leslie Park |
| **Date Inspected:** | 9/10/15 |
| **Other:** | Pipeline has been extended onto beach |



**Figure 4.27. Stormwater outlet 0.225m dia. pipe (left) (Source: Wellington City Council GIS, accessed 17/11/15), and the pipe on the beach (right)(Source: Phillips, 2015).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 3 | Very low impact with discharge onto rock covered shoreline. Could be naturalised with sandcrete to blend better into the environment, rather than the concrete pipe visible at the moment. Presently poor aesthetically on the natural unmodified beach. |
| **SW Outfall Effectiveness** | 4 | Stormwater is able to flow onto the beach fairly efficiently, however the concrete pipe section could be broken off in storm conditions. The concrete surround has lost its full cover and needs urgent repair, as a pipe section could break off in future. Pipe could be at a lower invert level to low tide to be more robust with more cover. |

**No. 21**
**Asset ID:** SWP039520
**Type:** Stormwater outlet
**Description:** 300mm dia. Concrete pipe 17.20m length
**Location:** Section D: Dorrie Leslie Park
**Date Inspected:** 9/10/15



**Figure 4.28. Stormwater outlet 0.30m dia. pipe next to boast ramp (left) (Source: Phillips, 2015), and the pipe and outlet on the beach (right)(Source: Phillips, 2015).**



**Figure 4.29. Stormwater outlet 0.30m dia. with concrete square casing (Source: Wellington City Council GIS, accessed 17/11/15).**

| Criteria | Ranking | Reason |
|---|---|---|
| **Coastal Process Impact and Effect** | 3 | Very low impact with discharge onto rock covered shoreline at low to mid tide. Could be naturalised with sandcrete to blend better into the environment, rather than the concrete surround, as aesthetically very poor. Pipe could be at a lower invert level under the beach next to the ramp and extended to both hide pipes and be more robust in storms, and/or outlet naturalised to blend into the environment. |

| | | |
|---|---|---|
| **SW Outfall Effectiveness** | 2 | Stormwater is able to flow onto the beach efficiently, however extending further into the inter-tidal zone is an option. |

## 4.3 Stormwater Options

This assessment has not categorized the structural condition of the stormwater asset. However, it has been noted and shown in a number of the photographs that maintenance is required on many of the SW outlets, ranging from general maintenance through to broken concrete and reinforcing steel being exposed that requires more extensive repair works. Also scheduled checks and maintenance should be undertaken at the beach outlets through the year, to ensure outlets are clear of debris, rubbish and sand build-up, and following storm events to again clear outlets of debris/rubbish/sand and reinstate any localised beach area that has been eroded through stormwater flows and scour[1].

The quality of the discharge from the stormwater outlets has also not been investigated; however, as this is a beach environment with high public use, improving the quality of the water from the catchment should also be a goal of the council and community. This could range from continued public education on what not to put in the stormwater drains, through to regular cleaning and maintenance of catchpits, Enviropods in catchpits, and treatment devices such as Storm-filters and Downstream Defender/Up-flo manhole systems to remove fine sediment, heavy metal contaminants, hydrocarbons and gross pollutant debris from the stormwater flow and discharge. These treatment systems are available from companies such as Hynds Environmental and Stormwater 360, and detailed technical information, system performance and cost (Capital and Operating) will require consideration before any option is implemented. Also space is limited in the Lyall Bay beach area and so any treatment methods would have to be both practical and fit for purpose. Consideration should also be given to the use of WaStops on stormwater outlets to prevent sand ingress to the pipes, which can potentially cause blockages. These are constructed of rubber and are more durable in the coastal environment than typical flap gates, which fail through corrosion of the hinges and wave impact.It is understood that at present, the goal is to consider beach impacts and how to protect the natural and built infrastructure and reinstating a functioning dune. However, such methods to improve water quality at a heavily patronised beach should be considered in future stormwater planning for Lyall Bay.

The stormwater pipes and outlets could also be altered to fit in more with the natural character of the beach landscape with the use of sandcrete to naturalise and disguise the outfalls as natural rocky reef. This has been very successfully utilised on the Auckland City eastern beaches such as Mission Bay (Figure 4.30 and Figure 4.31). Although an added expense, this could be included in long-term planning to assist in creating an environment where stormwater infrastructure blends into the beach in a manner which is still highly

[1] Note, this would be minimised with extension of outlets into the intertidal zone.

functional yet more aesthetically pleasing on a beach with highly valued public amenity, and natural aesthetics.



**Figure 4.30. Mission Bay SW outfall with mudcrete reef (cement/mud-sand mix) surrounding the pipes to naturalise it in the environment (Source: S. Risler, Feb 2010 Google).**



**Figure 4.31. Kohimarama Beach, Auckland SW outfall with sandcrete reef (Source: P. Reynolds, Coastal News, Nov 2006).**

An option that requires consideration and more detailed investigation is the potential to use soakage under the beach from the smaller outlets (i.e. catch-pit leads). This would require geotechnical investigation to determine permeability and infiltration rates of the beach sub-soils, as well as the location of the groundwater table. Porous sand may allow the soakage of water through sub-surface drains for either all or part of the flow (if the total of flow is fairly low – catchment size dependant) or just the base-flow with an overflow on the surface for the extra flow. This form of disposal has been successfully utilised on Auckland beaches from catch-pits. However, it is noted that attention must be given to potential liquefaction, which would exacerbate sand loss during storm events.

### 4.3.1 Stormwater Outlet Rankings

To determine the priorities for remediation and future resilience of stormwater assets on Lyall Bay beach, a matrix system has been utilised that ranks the important factors with a score, to ultimately define the future priorities for the stakeholders.

**Options:**

1. Do Nothing;
2. Assess Possible Diversion to larger Existing Outlet if Grades Allow, or Assess Outlet Soakage under Beach for Base or all Flow, or into the Inter-tidal Zone for Dispersion / or Do Nothing if not Feasible;
3. Address potential localised erosion to structure;
4. Lengthen at least into the inter-tidal zone if currently in the dune field;
5. Possibly naturalise with mudcrete/sandcrete.

**Table 4.3: Summary of Rankings for SW Assets and Options for Required Works. Planning and Works timeline: Short-term (ST), Mid-term (MT), Long-term (LT).**

| No. | Asset No. | Section | Impact | Effectiveness | Options | Recommendations |
|---|---|---|---|---|---|---|
| 1 | SWP015426<br>SWP015426<br>SWP000113 | A | 3 | 2 | 3<br><br>4 | Design/install localised erosion protection for structure (ST-MT).<br>Potentially lengthen more into inter-tidal zone. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | SWP014657 | | | | 5 | Possibly sandcrete (LT). |
| 2 | SWP014589 | A | 3 | 3 | 2 | Assess Diversion to No. 1 outlet (Fall dependant), or assess Base-flow Submerged Outlet under Beach and Overflow Extension as only a 225mm dia. pipe (low flow dependant), or total line extension to prevent dune toe erosion.<br>Works likely in conjunction with carpark relocation. |
| 3 | SWP014592 | A | 2 | 3 | 2 | Assess Diversion to No. 1 outlet, or Base-flow Outlet under Beach and Overflow Extension, or extend; likely in conjunction with carpark relocation works. |
| 4 | SWP002877 | B | 3 | 3 | 2,<br>5 | Assess diversion to No 1 or 5 outlet or one new shared larger outfall (dependant on fall) (MT).<br>Possibly sandcrete (LT). |
| 5 | SWP022448 | B | 3 | 3 | 2,<br>5 | Assess diversion to one new larger outfall shared with Outlet No. 4 (dependant on fall) (MT). Assess a Wastop.<br>Possibly sandcrete (LT). |
| 6 | SWP0038855 | B | 4 | 3 | 2 | Assess Diversion to Outlet No. 5 and remove outfall, or Baseflow under Beach Outlet and Extend Overflow; or Extend SW line to prevent dune erosion (ST). |
| 7 | SWP032975 | B | 4 | 3 | 2 | Assess Diversion to No. 5 or 8 outlet (fall dependant), or Base-flow Outlet under Beach, or Extension to prevent dune erosion (ST). |
| 8 | SWP032310<br>SWP038997<br>SWP038996 | B | 4 | 4 | 2, 4 | Assess Diversion to No. 9 outlet (fall dependant) and increase outfall size, or Extension to prevent dune and beach erosion (ST). |
| 9 | SW300741 | B | 4 | 4 | 4 | Extension into inter-tidal zone (ST-MT). |
| 10 | SWP0270070 | C | 2 | 3 | 2, 4 | Assess Diversion to No. 11 or 12 outlet (fall dependant), or Extension to prevent dune erosion (MT). |
| 11 | SWP027062<br>SWP027063 | C | 5 | 5 | 2, 4 | Assess Diversion to No. 12 Outlet well clear of buildings (fall dependant), or extension to prevent erosion and scour at building foundation (ST). |
| 12 | SWP038854 | C | 3 | 3 | 2 | If Outlet 11 to remain assess diversion to that or No. 13 or 15 (Fall dependant), or assess Base-flow Submerged Outlet |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | under Beach with overflow extended as only a 225mm dia. pipe (low flow dependant), or total line extension to prevent dune erosion (ST). |
| 13 | SW15538<br>SWP012915 | C | 5 | 5 | 2, 4 | Assess diversion to Outlet No. 15, or total line extension to prevent dune erosion (ST). Assess Wastop. |
| 14 | SWP023865 | C | 4 | 3 | 2 | Assess diversion to Outlet No. 15 (Fall dependant), or assess Base-flow Submerged Outlet under Beach with overflow extended as only a 225mm dia. pipe (low flow dependant), or total line extension to prevent dune erosion (ST). |
| 15 | SWP023869 | C | 3 | 2 | 5 | Sandcrete a potential option for naturalised outlet. |
| 16 | SWP023862 | C | 2 | 2 | 2 | Assess diversion to Outlet No. 15 (Fall dependant), or assess Base-flow Submerged Outlet under Beach with overflow extended as only a 150mm dia. pipe (low flow dependant), or total line extension to prevent dune toe erosion (MT). |
| 17 | SWP032974 | C | 4 | 3 | 2 | Assess diversion to Outlet No. 15 (Fall dependant), or assess Base-flow Submerged Outlet under Beach with overflow extended as only a 225mm dia. pipe (low flow dependant), or total line extension to prevent dune toe erosion (ST). |
| 18 | SWP016018 | D | 1 | 3 | 4 | Extend line at a lower invert level under the beach to the low tide reef area, to remove poor aesthetics of pipe on rocky beach and make outlet more robust to storms (MT). |
| 19 | SWP015268 | D | 5 | 5 | 4<br>5 | Extend line at a lower invert level under the beach to the low tide reef area, to remove poor aesthetics of pipe on rocky beach and make outlet more robust to storms and prevent bank erosion (ST). Sandcrete the outlet to naturalise into the reef. |
| 20 | SWP002199 | D | 3 | 4 | 2, 4<br>5 | Assess diversion to Outlet No. 21. If not feasible extend line at a lower invert level under the beach to the low tide reef area, to remove poor aesthetics of pipe on rocky beach and make outlet more robust to storms (Repair pipe cover in ST, and MT for other works).<br>Sandcrete the outlet to naturalise into the reef. |
| 21 | SWP039520 | D | 3 | 2 | 4 | Extend further into inter-tidal zone |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | 5 | potentially at a lower invert under the beach, and/or naturalise with sandcrete next to ramp (MT-LT) |

### 4.3.2 Summary of Recommended Stormwater Outlet Options

1. There is a range of different types and sizes of outfalls on Lyall Bay beach, and as shown in Table 4.3, each has some effect (minor to significant) on beach hydrodynamics and erosion, amenity, environmentally, as well as aesthetically.
2. The assessment of their impacts on coastal processes and effectiveness has ranked each outlet on a scale of 1 to 5 for Impact: (1) Very Low to (5) Very High and Effectiveness: (1) Very high to (5) Very Poor.
3. Impacts on coastal processes vary at each pipeline and outfall. Where they are discharging high on the beach, they cause erosion (a 'bite' out of the dune field) because they liquefy sand and make it more easily eroded. Outlets that discharge into the intertidal zone don't impact on the dunes or beach processes since there is very little alongshore sediment transport.
4. Effectiveness also varies across the range and size of the outfalls. To be more effective outfalls should ideally be extended to the inter-tidal zone, and combined as much as practicable to reduce the number of pipes and outfalls on the beach. This is dependent on ground levels, gradients and invert levels of the stormwater infrastructure. Extending the pipelines should also allow the pipes to have more sand cover and not act as a barrier to pedestrian access along the beach. Lyall Bay beach is regularly used by many people and removal of barriers is an important aspect of enhancing the amenity on the beach.
5. It appears a number of gates and flaps have been utilised in the past on the outfalls to prevent sand egress into the pipelines, but are no longer in place. Only one is still in existence, and appears to be preventing outflow of woody material and debris which is clogging the pipe. Hynds WaStops are a more recent product that is being utilised on coastal stormwater outlets, however a more robust assessment would be required on the effectiveness in high energy coastlines. Wellington City is successfully using these devices in lower energy estuarine areas in the city.
6. Another option considered is to divert all stormwater to a central retaining reservoir or at one each end of the beach where the large outlets are currently in place (e.g. Aqua cells under the wide footpath (that backs the SLSC buildings), or a number spread along the beach, where sediment can be settled out and discharged through

one large outlet further offshore or through the existing outlets with peak flow detained for the 10 year storm event and flow controlled with an orifice (or required event i.e. 2, 5 or 10), or base-flow (depending on the actual quantity and amount of available space for tanks). Soakage from the tanks could be a potential dispersal option. Overall this is an expensive option and dependent on gradients across Lyall Bay to provide suitable fall for the infrastructure to function, and likely only feasible if other civil works were being undertaken in areas where the cells could be laid under the ground as part of the project. This appears on initial inspection to not be viable given the flat grade of the area, and would require detailed investigation of actual specific ground and invert levels, and cost benefit assessment undertaken.

7. Environmental aspects that have been considered are to have a goal of improving the stormwater quality to the highest level possible using the Best Practicable Options for the beach and budget. This could include: At source mitigation in the catchment; with marked catchpits identifying them as stormwater that flows to the beach, regular cleaning of the road catchpits and Enviropods installed in them, as well as proprietary devices such as Storm-filters and Downstream Defenders. These would remove sediment, hydrocarbons and gross pollutants from the discharge to the beach. These are unlikely to be issues for Lyall Bay, however just to note two questions for consideration are; Do council officers consider that the stormwater system has any illegal wastewater connections in the contributing catchment that could be discharging to the beach? Also are there sewage pump station overflows that could be discharging, and could these be eliminated in long-term planning and budgeting with upgraded systems?
8. Another environmental factor is the aesthetics of the structures on the beach, is consideration to naturalising these with the use of either rocks/stones attached to the pipe surface or sandcrete applied to create reef structures. The sandcrete is a mix of sand (can be “dirty” land based) and cement (9%). The sandcrete core is covered with plastic mesh, and sprayed under pressure with 100 mm of high strength gunite. This is then sculpted using hand tools to achieve texture and details required for the structure. Natural oxides can be blended to colour the structure and achieve a natural appearance. This type of sand or mudcrete construction has been used successfully both on the Auckland city beaches and also in the Whangateau Harbour north of Auckland to create shore platforms that can withstand the coastal forces and not erode, whilst looking natural in the coastal environment.

# References

Adams, C. B., and C. J. Sonu, 1986. Wave Transmission across Submerged Near-Surface Breakwaters. *Proceedings 20th Coastal Engineering Conference*, ASCE, 1729-1738.

Beca Carter-Caldwell Connell, 1980. Moa Point Wastewater Treatment Plant and Outfall Study. Report prepared for the Wellington City Corporation, January 1980.

Black, K. P., and C. Andrews, 2001a. Sandy Shoreline Response to Offshore obstacles Part 1: Salient and Tombolo Geometry and Shape. *Journal of Coastal Research*, Special Issue 29: 82-93.

Black, K. P., and C. Andrews, 2001b. Sandy Shoreline Response to Offshore obstacles Part 2: Discussion of Formative Mechanisms. *Journal of Coastal Research*, Special Issue 29: 94-101.

Black, K. P., and S. T. Mead, 2003. *Numerical Predictions of Salient Formation in the Lee of Offshore Reefs*. Proceedings of the 3rd International Surfing Reef Conference, June 23-25 2003. ISBN 0-473-09801-6

Bruun P (1962) Sea-level rise as a cause of shore erosion. J. Waterways Harbors Div 88:117–130

Carter, L and Lewis, K., 1995. Variability of Modern Sand Cover on a tide and storm driven inner shelf, south Wellington, New Zealand. New Zealand Journal of Geology and Geophysics, 38:451-470.

CE, 1976. Wellington Airport Runway Extension, Environmental Audit. Commission for the Environment, Wellington, 1976.

de Lange, W. P., & Jenks, G., 2007. Dune restoration as a mitigation strategy for the management of coastal hazards. Presented at the Conserv-Vision: the next 50 years, Conference held at Hamilton, New Zealand.

DHI, 2015a. Wellington Airport Runway Extension Surf Break Impact Assessment: Numerical Modelling, Preliminary Mitigation Investigations and Feasibility Study. Report prepared for the Wellington International Airport Authority, August 2015.

DHI, 2015b. Wellington Airport Runway Extension; Preliminary Shoreline Impact Assessment for Submerged Wave Focussing Structure. Technical Report prepared for Wellington International Airport Ltd.

Harris, L., 2002. Submerged reef structures for habitat enhancement and shoreline erosion abatement. U.S. Army Corps of Engineers Coastal & Hydraulic Engineering Technical Note (CHETN), Vicksburg, MS.

IPCC, 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, Field, Dokken, Mastrandrea, Mach, Bilir, Chatterjee, Ebi, Estrada, Genova, Girma, Kissel, Levy, MacCracken, Mastrandrea, and White (eds.)]. Cambridge University Press.

Komar, P.D., McDougal and Ruggiero, P. (1999). The Rational Analysis of Setback Distances: App. to the Oregon Coast. Shore and Beach Vol. 67 (1) 41-49.

Mead, S. T., K. P. Black and P. McComb, 2001. Lyall Bay Surfing Reef Feasibility Study. For the Lyall Bay Surfing Reef Charitable Trust, Wellington, January 2001.

Mead, S. T., and J. C. Borrero, 2011. Multi-Purpose Reefs – A Decade of Applications. *Proceedings of the 20th Australasian Coasts and Ports Conference*, Perth, Australia, 27-30 September 2011.

Mead, S. T., E. Atkin and D. J. Phillips, 2011. *Preliminary Investigation of Offshore Focussing Reefs.* Funded by UNITEC, August 2011.

NZ MetService, 1981. The Climatology of Wellington Airport. NZ Meterological Service Publication No. 171 (1), ISSN 0110-6937.

MfE, 2008. Coastal Hazards and Climate Change. A Guidance Manual for Local Government in New Zealand. 2nd edition. Revised by Ramsay, D, and Bell, R. (NIWA). Prepared for Ministry for the Environment. viii+127 p.

Ministry of Transport, 1975. Wellington Airport Runway Extension Environmental Impact Report. Prepared by the Civil Aviation Division, Ministry of Transport.

NIWA, 2015. Wellington International Airport Runway Extension: Coastal Processes Assessment. Report prepared for the Wellington International Airport Authority, August 2015

NZ MetService, 1981. The Climatology of Wellington Airport. NZ Meterological Service Publication No. 171 (1), ISSN 0110-6937.

Parks & Open Spaces, 2004. Lyall Bay Integration Project. Prepared for Wellington City Council, July 2004.

PCE, 2015. Preparing New Zealand for rising seas: Certainty and Uncertainty. Preparing New Zealand for rising seas: Certainty and Uncertainty, November 2015.

Pickrill, R. A., 1979. Beach and Nearshore Morphology, Lyall Bay, Wellington. NZOI Oceanographic Report, No. 13, April 1979.

Pickrill, R. A., and J. S. Mitchell, 1979. Ocean Waves Characteristics Around New Zealand. New Zealand Journal of Marine and Freshwater Research, 13(4): 501-520.

Pilarczyk, K. W. & R. B. Zeidler, 1996. Offshore Breakwaters and Shore Evolution Control. Ppublished by A. A. Balkema, Rotterdam. 560p.

Pilarczyk, K. W., 2003. *Design of Low-Crested (Submerged) Structures – An Overview*. Proceedings of the 6th International conference on Coastal and Port Engineering in Developing Countries, Colombo, Sri Lanka, 2003.

Ranasinghe, R., Turner, I.L. and Symonds, G 2006. Shoreline response to multi-functional artificial surfing reefs: A numerical and physical modelling study. Coastal Engineering 53: 589-611.

Smith, J.T., Harris, L.E., and Tabar, J., 1998. Preliminary evaluation of the Vero Beach, FL prefabricated submerged breakwater. Beach Preservation Technology '98, FSBPA, Tallahassee, FL.

United Kingdom Environment Agency, 2012, Thames Estuary 2100, managing flood risk through London and the Thames estuary, London.

Van der Meer W. and K. W. Pilarczyk, 1998. *Stability of Low-Crest and Reef Breakwaters*.

WCC, 1974. Wellington Airport Environmental Impact Report. Wellington City Council, March 1974.

Weppe, S., T. Healy, B. Scarfe and D. Immenga, 2009. Shoreline response to an offshore submerged multifunction reef at Mount Maunganui, New Zealand. Proceedings of the 19th Australasian Coasts and Ports Conference, Wellington, NZ, 16-18 September 2009.

# Appendix A. Consultation Mail-Out

# Appendix B. Lyall Bay Coastal Processes

## Geological Setting of Lyall Bay

Wellington's south coast is relatively exposed, and has an energetic wave climate from the south (Pickrill and Mitchell, 1979; Beca Carter-Caldwell Connell, 1980) and is mostly comprised of rocky reefs and cliffs, with intermittent pocket sand beaches. Lyall Bay is the largest of these crescent-shaped pocket beaches and is oriented due south and flanked by large headlands to the east and west (Figure B1.1). The large headlands at either end of the beach, that extend for significant distances offshore as submerged reefs (Figure B1.1), effectively shelter it from waves from all directions except due south.

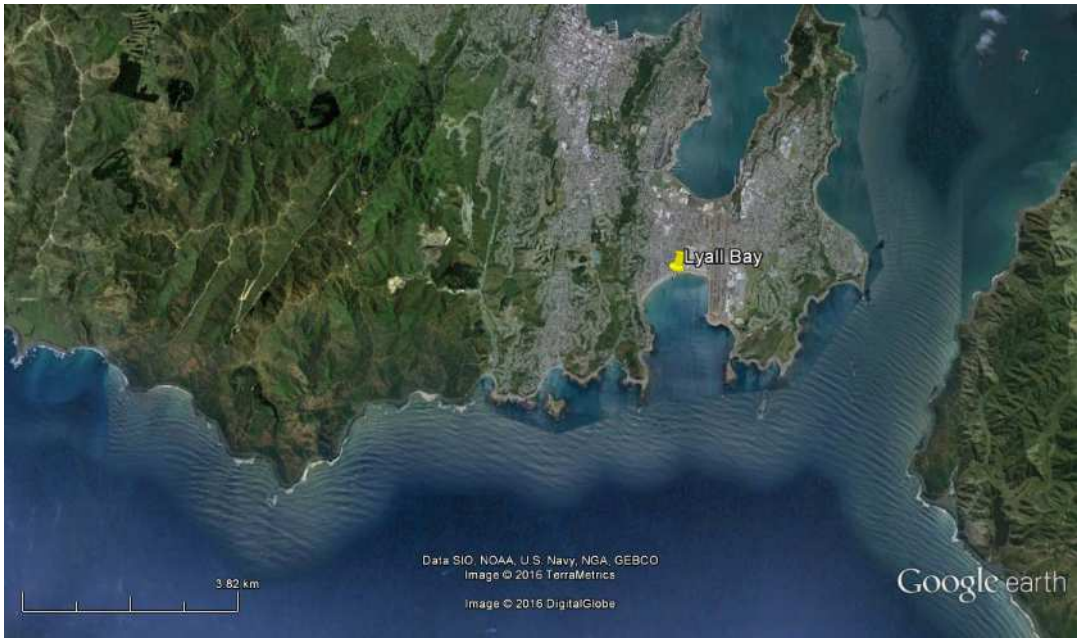



**Figure B1.1. Lyall Bay is the largest of the pocket beaches along Wellington's south coast.**

Lyall Bay is formed by the southern edge of the tombolo (or sand bridge) that connects the Miramar Peninsula to mainland North Island (Figure A1.1) – the area was previously another entrance to Wellington Harbour (Carter and Lewis, 1995). This tombolo has formed due to uplifts caused by earthquakes in the past 500 years, and the continental shelf and flanking cliffs have continued to supply sediment to the tombolo causing it to prograde southward and seaward until it attained its current state (Pickrill, 1979; Carter and Lewis, 1995). The large headlands at either end of Lyall Bay also effectively 'trap' the sediment within the bay, and so the sediment

budget within the bay is relatively stable and sediment transport mainly occurs in onshore/offshore directions (Pickrill, 1979). During high-energy wave conditions the mass transport of water shorewards leads to the formation of a strong recirculating rip current that transports sediment offshore (Pickrill, 1979). In calmer wave conditions sediments are transported back towards the beach (Pickrill, 1979). Indeed, Carter and Lewis (1995) found that the general distribution of sediment types in the Wellington shelf area are relatively stable.

Over the past century human activity has had large impacts on the state of the Lyall Bay coastal area. The main impacts on the Lyall Bay shoreline have been due to development of the dune area for housing and industry and the construction of the Wellington (previously Rongotai) airport. Development of the dune system effectively removed the natural buffer zone that absorbed the erosional effects of storm events and replenished the beach system during calm periods. This has resulted in problems of seawall erosion and wind-blown sand (Pickrill, 1979), although the introduction of marram grasses along the base of the seawall has helped to alleviate this problem (Figure B1.2).



**Figure B1.2. Marran grass dunes along the Lyall Bay seawall.**

Almost one third of the shoreline was lost due to the reclamation of the eastern end of Lyall Bay (1952-59) for construction of the Wellington airport (Figure B1.1). This resulted in a change in the plan shape of the bay (a deepening in the centre) due to the alteration of the eastern hinge, or control, point (Pickrill, 1979), although the bay seems to have remained fairly stable since the first response to the airport reclamation.

**Wave Climate**

At Lyall Bay, wave energy has a strong effect on the circulation system and hence sediment transport and general morphology of the beach. On the south coast the wave climate is strongly bimodal, featuring a locally generated north and north westerlies waves being funnelled southward through the Cook Strait, and longer-period southerly swell and storm waves from more distant sources moving northward (Pickrill, 1979; Pickrill and Mitchell, 1979; Beca Carter-Caldwell Connell, 1980). Lyall Bay's orientation and the shelter provided by the large headlands at each end of the bay mean that it is only exposed to waves from the south. Indeed, the persistent southerly swell is ubiquitous on the southern coast (Carter and Lewis, 1995). Superimposed on the persistent southerly swell are local wind waves generated by winds funnelled north or south by the regional topography (Carter and Lewis, 1995). Those from the open ocean to the south enhance the southerly swell. In Lyall Bay, winds from the north are small because of the limited fetch and the protection afforded by Wellington's hills (Carter and Lewis, 1995).

Sea state observations and wave-rider buoy data from two different locations (Pickrill and Mitchell, 1979; Beca Carter-Caldwell Connell, 1980; A. Laing, pers. comm.) were analysed to provide a wave climate for Lyall Bay. The sea state observations by the Wellington Harbour Board, were recorded from Beacon Hill (above Breaker Bay on the south coast) daily at 0600, 1200, 1800 and 2400 hours for a 7-year period from 1969 – 1976 (Pickrill and Mitchell, 1979; Beca Carter-Caldwell Connell, 1980). Two wave-rider buoys were deployed for 1 year 2 km offshore of Lyall Bay from October 1978 to September 1979, but only 78 days of satisfactory data were obtained (Beca Carter-Caldwell Connell, 1980). The wave statistics from the sea state observations and the wave-rider data were found to be very similar (Beca

Carter-Caldwell Connell, 1980). In addition, wave climate data from a 5-year data set collected off Baring Head was provided in the form of a joint probably distribution of wave height versus wave period (Table B3.1).

Before discussing the wave climate at Lyall Bay it is important to note that some site-specific differences exist between the various wave data sources, as well as differing analysis methods. These differences combine to result in lower median wave heights and periods in the data recorded off Baring Head, compared to the data observed from Beacon Hill. The latter, however, is very similar to the limited duration wave-rider data recorded off Lyall Bay (Beca Carter-Caldwell Connell, 1980).

The Baring Head recording site has a fetch to the north of approximately 8 km to the entrance of Wellington Harbour and in some situations, when the wind is slightly west of north, a fetch of up to 20 km into the harbour. This site is also open to winds from the west, although winds from this quarter are rare. In comparison, the maximum northerly fetch for the wave-rider site off Lyall Bay is 2 km, and the visual observation data (Breaker Bay region) that was observed from Beacon Hill is even more sheltered from winds from this direction. As a result of the location of the Baring Head buoy, it receives a large amount of northerly wind waves generated by the predominant northerly wind flow. Carter and Lewis (1995) used forecasting curves for shallow water (U.S.A.C.E, 1984) to calculate waves generated by the northerly winds for a fetch of 8.7 km across Wellington Harbour. They found that the most common northerly wind waves have a significant height of 0.35 m and a period of 2.25 s and occur 14-24% of the time, whereas the largest waves, $H$ =1.4m, $T$ = 3.9s, are present <1% of the time. This most likely accounts for the larger percentage of short period waves (<3.5 s) recorded at Baring Head (7.5%) compared to from Beacon Hill (1.2%). In some situations, the northerly fetch for the Baring Head wave buoy may be up to 20 km.

**Table B1.1. Joint probably summary (significant wave height vs mean period) for 5 years of wave-rider buoy data recorded off Baring head (41 24.2'S, 174 50.6'E) in 45 m water depth (A. Laing, pers. comm.). Note, wave heights are in 0.5 m bins, i.e. the 0.5 m bin has a wave height range of 0.25 – 0.75 m. Similarly, period bins are indicated by the mid-point of the bin, i.e. the 4 s bin range is 3.5-4.5 s.**

**Mean Period (sec)**

**Wave Height**

| | **<3.5** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **>15** | | **Hs** | **%** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **<0.25** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 |
| **0.5** | 53 | 88 | 61 | 49 | 30 | 11 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 294 | 29.6 |
| **1** | 22 | 86 | 82 | 70 | 51 | 32 | 13 | 2 | 0 | 0 | 0 | 0 | 0 | 3 | | 361 | 36.4 |
| **1.5** | 0 | 8 | 34 | 40 | 38 | 27 | 14 | 4 | 0 | 0 | 0 | 0 | 0 | 1 | | 166 | 16.7 |
| **2** | 0 | 0 | 14 | 22 | 17 | 14 | 8 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | | 80 | 8.1 |
| **2.5** | 0 | 0 | 2 | 21 | 8 | 6 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | | 42 | 4.2 |
| **3** | 0 | 0 | 0 | 12 | 8 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | | 26 | 2.6 |
| **3.5** | 0 | 0 | 0 | 2 | 9 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 13 | 1.3 |
| **4** | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 6 | 0.6 |
| **4.5** | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 3 | 0.3 |
| **5** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 1 | 0.1 |
| **>5.5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 |
| | | | | | | | | | | | | | | | | 992 | 100 |
| **Tz** | 75 | 182 | 193 | 216 | 167 | 98 | 44 | 12 | 1 | 0 | 0 | 0 | 0 | 4 | 992 | | |
| **%** | 7.5 | 18.3 | 19.5 | 21.8 | 16.8 | 9.9 | 4.4 | 1.2 | 0.1 | 0 | 0 | 0 | 0 | 0.4 | 100 | | |

The methods of data collection and analysis may also account for the some of the differences between the two data sets (Baring Head wave-rider buoy and Beacon Hill observations). The wave-rider buoy records are a statistical representation of the range of waves measured over a given period (usually 20 minutes), while the observer data is usually more subjective, often noting the most dominant wave crests, but not necessarily the smaller waves that are also part of the sea conditions at the time. Studies have shown that trained observers normally record the average

of the highest one third of waves, which is known as the significant wave height[2]. The proximity of the visual observations to Lyall Bay, coupled with a degree of validation of these data by comparison with the 78-day buoy data of Beca Carter-Caldwell Connell (1980), suggest this is the most appropriate data source for the present study.

The wave conditions observed at Lyall Bay are broadly similar to those recorded on other exposed beaches of the east coasts of both the North and South Islands (Pickrill & Mitchell, 1979). The significant wave height distribution for waves off Lyall Bay is presented in Table B1.2. Off Lyall Bay, sea conditions are rarely completely calm (<0.1 only 1% of the time), with wave heights of 0.5 to 1.25 m occurring for the majority of the time (52% annually), and waves heights exceeding 1.25 m for 30 % of the year. The average and most frequent wave height was found to be 1.2 m (Table B1.1 and B1.2), which compares well with other wave climate studies (Pickrill and Mitchell, 1979) and calculations using forecast curves (Carter and Lewis, 1995). Wave height s exceed 2.5 m for 14 % of the time and a wave height of 7 m occurs at least once each year on average (Beca Carter-Caldwell Connell, 1980). There is a distinct seasonal pattern, with greater percentages of waves over 1.25 m occurring during winter and spring (Table B1.2).

**Table B1.2. Seasonal wave height distribution for the Wellington south coast.**

| Sea State condition | Wave Height (m) | Average Occurrence (%) (14-year period) | | | | |
|---|---|---|---|---|---|---|
| | | Summer | Autumn | Winter | Spring | Annual |
| Calm | <0.1 | 2 | 0 | 0 | 1 | 1 |
| Smooth | 0.1-0.5 | 19 | 20 | 18 | 12 | 17 |
| Slight | 0.5-1.25 | 55 | 52 | 50 | 50 | 52 |
| **Subtotal** | <1.25 | 76 | 72 | 68 | 63 | 70 |
| Moderate | 1.25-2.5 | 13 | 14 | 15 | 21 | 16 |
| Rough | >2.5 | 11 | 14 | 17 | 16 | 14 |

[2] Significant wave height is a common statistical representation of wave height, and is the height of the highest 1/3 of waves, which has been found to closely match the height of waves recorded by an observer (Komar, 1976).

Recorded wave periods were between 2 and 14 seconds (Figure B1.3). The mean wave period was observed to be 8.8 s with most waves being within the 7-11 s range and no apparent seasonal fluctuation (Beca Carter-Caldwell Connell, 1980 (Figure B1.3), which is very similar to that reported by other authors (Pickrill and Mitchell, 1979; Carter and Lewis, 1995). However, Pickrill (1979) found that spring had a higher frequency of longer period waves - a suggestion that is supported by anecdotal evidence from local surfers. Wave periods of less than 10 s are generated locally by winds in the Cook Strait and off the east coast of the South Island and occur 83% of the time. Longer period waves of 1 to 16 second period dominate the sea-state for some 17% of the time (Figure B1.3).

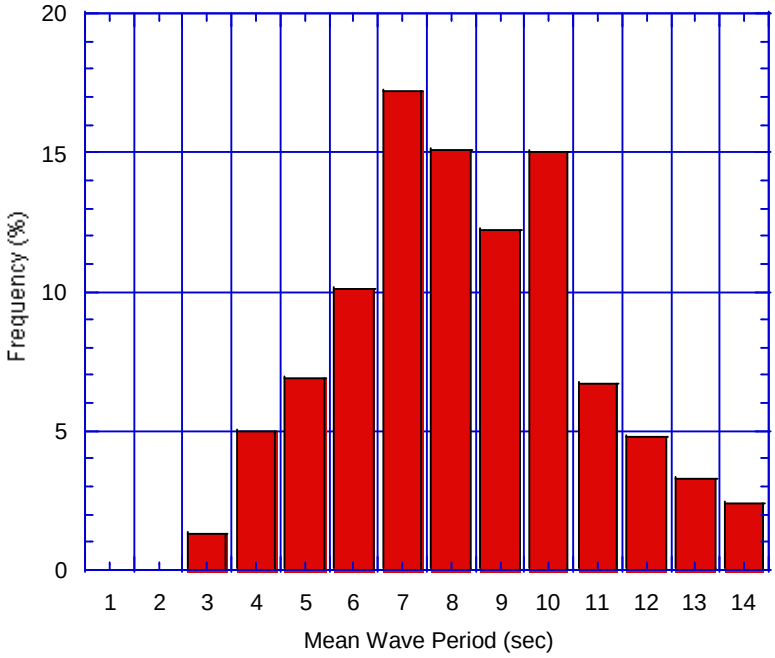



**Figure B1.3. Mean wave period from visual observations at Beacon Hill (Beca Carter-Caldwell Connell, 1980).**

An important feature of Lyall Bay is the uneven distribution of wave energy across the Bay shoreline. The process of refraction (with waves travelling slower in shallower water depths) tends to extract substantial energy out of waves at either end of bay as they propagate shoreward. As a result, there is a wave height gradient with largest wave heights in the centre of the bay and heights decreasing towards each end of the bay. This is very evident in the numerical refraction

modelling (Figure B1.4). This gradient occurs because the bay is long and narrow with steep rocky sides. Waves entering down the sides of the bay undergo extensive refraction onto the rocks in the entrance, which results in a decrease in wave height at each end of the bay (Figure B1.4). However, waves entering the centre of the bay remain reasonably unaffected by refraction and retain much of their deep-water energy. This variation in wave height across the bay is an important consideration when considering beach remediation.

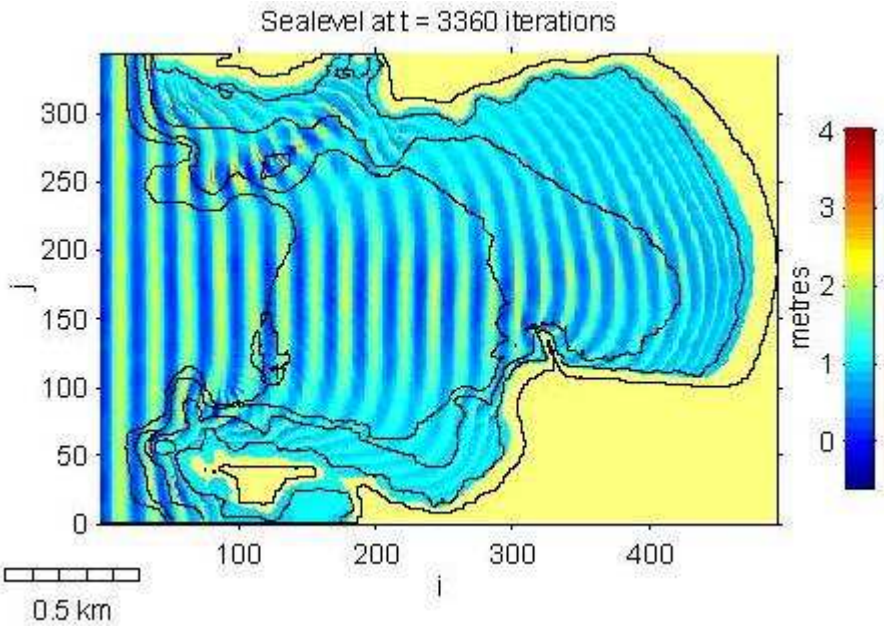



**Figure B1.4. Output from Model 3DD showing the refraction of wave crests and the loss of wave energy as waves propagate into Lyall Bay (especially the western end).**

## Tides

While waves are the dominant process controlling sediment movement and beach morphology, the tidal range and tidal currents can also influence the beach and nearshore system. The tidal range in Wellington is relatively small at only 1.55 m at mean spring tides (Table B1.3). As a resul,t there is very little translation of surf and breaker zones across the beach; the wave energy being concentrated in a relatively narrow band down the foreshore.

**Table B1.3. Tidal water levels about LAT (lowest astronomical tide), which is approximately chart datum.**

| TIDE LEVELS | ELEVATION (m)(C.D.≅LAT) |
|---|---|
| HAT | 1.88 |
| MHWS | 1.55 |
| MHWN | 1.31 |
| MSL | 0.94 |
| MLWN | 0.57 |
| MLWS | 0.33 |
| LAT | 0 |

In a confined inlet with long narrow sides, such as Lyall Bay, wave-set-up against the shore face is magnified by the constricting morphology (discussed below). During calm conditions, tidal currents are very weak with wind-driven currents dominating (surface flows following the wind direction at 2-3% of its strength). Meteorological conditions can also affect water levels, especially during intense storms causing "storm surge". Each millibar of atmospheric pressure above or below the average of 1013 millibar lowers or raises the water level by 1 cm, respectively. During strong depressions in Wellington this can be as much as 25 millibar below average, causing an "isostatic" increase in water level of 0.25 m (Beca, Connell-Caldwell Connell, 1980). Strong onshore winds and large waves will also increase the water level, especially in the narrow confines of Lyall Bay. Indeed, local surfers recall water levels up to the top of the storm-water pipes in the eastern corner of Lyall Bay during large wave conditions (H. Rait, pers. comm.). The highest recorded storm surge in Wellington Harbour was 0.95 m during the "Wahine" storm on 10 April 1968 (Beca Connell-Caldwell Connell, 1980). Low barometric pressure combined with large wave events lead to eroded beach conditions at Lyall Bay.

### Lyall Bay wind Climate

With respect to wind data, Lyall Bay is fortunate to be adjacent to the Wellington International Airport, which records wind speeds and directions continually and produces hourly average wind speed, direction and strongest gust data. The wind climate for Lyall Bay is summarised below from two sources, the NZ MetService (1981) and Beca Connell-Caldwell Connell (1980).

### Surface Winds

Wellington is known as New Zealand's "Windy City", which is well supported by the available data. Indeed, the average wind speed is about 7 $ms^{-1}$ (14 knots) and wind speed exceeds 11 $ms^{-1}$ (22 knots[3]) for 1/5$^{th}$ of the year (Beca Connell-Caldwell Connell, 1980). Strong winds occur relatively often at Wellington due to the funnelling effect of the break in the mountain chains between the North and the South Islands. Maximum gusts of 84 knots from the north and 101 knots from the south have been recorded since 1959 (NZ MetService, 1981). Winds blow mainly from the north and south, with northerly winds (offshores) predominating (Figure B1.5 & Table B1.4). When wind speeds exceed 5 knots, winds blow 60% of the time from the north and 38% from the south and 2% from the remaining directions (NZ MetService, 1981).

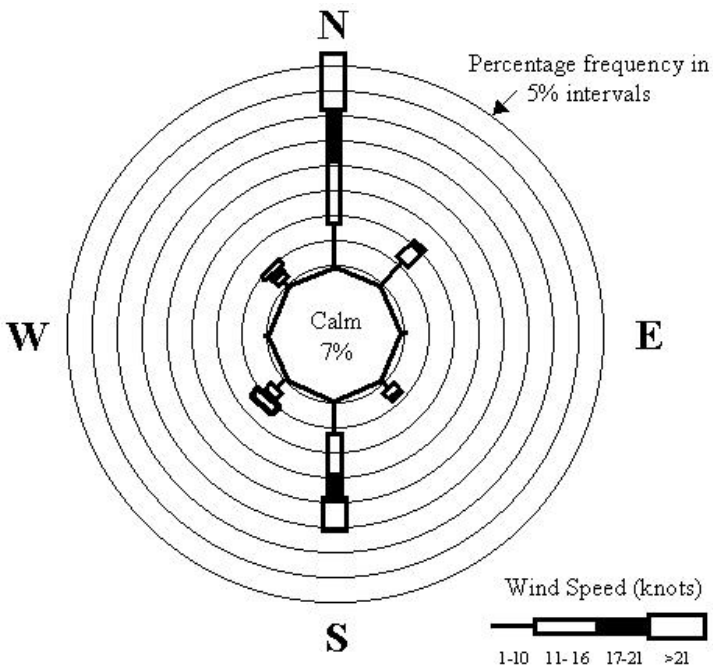



**Figure B1.5. Wind-rose for Lyall Bay (NZ MetService, 1981).**

[3] A knots equals approximately 0.515 $ms^{-1}$ (meters per second)

**Table B1.4. Wind direction frequency at Wellington Airport (from Beca Connell-Caldwell Connell, 1980). Note, 7% of the time wind conditions are calm (Fig. 3.6).**

| Wind Direction | Occurrence in Season (%) | | | | Annual average (%) |
|---|---|---|---|---|---|
| | Spring | Summer | Autumn | Winter | |
| N | 48.5 | 46.9 | 40.4 | 35.7 | 42.9 |
| S | 25.0 | 27.4 | 27.8 | 30.0 | 27.6 |
| NE | 9.5 | 8.9 | 11.4 | 12.1 | 10.5 |
| SW | 4.1 | 5.7 | 5.5 | 5.1 | 5.1 |
| SE | 3.0 | 2.8 | 4.0 | 4.2 | 3.5 |
| NW | 3.5 | 2.4 | 2.1 | 2.2 | 2.6 |
| E | 0.6 | 0.5 | 0.6 | 0.7 | 0.6 |
| W | 0.4 | 0.1 | 0.4 | 0.5 | 0.4 |
| Offshore | 61.5 | 58.2 | 53.9 | 50.0 | 56.0 |
| Onshore | 32.1 | 35.9 | 37.3 | 39.3 | 36.2 |

At Lyall Bay wind speed is between 5.5 and 11 $ms^{-1}$ for almost 50% of the time (Tab. 3.5). Seasonally, relatively higher than average wind speeds occur in the spring and summer than in the autumn and winter (Table B1.4). Strong north to northwest winds are most common in the summer period (October to January) and are usually associated with a trough approaching or moving over southern New Zealand from the west (NZ MetService, 1981). Winds from this direction reaching 60 knots or more may be expected on about 9 days a year (NZ MetService, 1981). However, strong southerly winds are most common in winter (Table B1.4. and B1.5) and are associated with ridges over the South Island and lows over the east of the North Island (NZ MetService, 1981). Southerlies are 30% more frequent than northerlies when the wind speed is over 30 knots.

**Table B1.5. Wind speed frequency distribution for Lyall Bay (from Beca Connell-Caldwell Connell, 1980).**

| Wind speed (m/s) | Occurrence in Season (%) | | | | Annual average (%) |
|---|---|---|---|---|---|
| | Spring | Summer | Autumn | Winter | |
| Calm | 5.4 | 5.3 | 7.8 | 9.5 | 7.0 |
| 0-5.5 | 22.9 | 24.0 | 29.4 | 29.3 | 26.4 |
| 5.5-11 | 47.4 | 50.7 | 44.7 | 40.5 | 45.8 |
| 11-14 | 15.2 | 14.4 | 11.1 | 11.3 | 13.0 |
| >14 | 9.1 | 5.6 | 6.9 | 9.4 | 7.8 |

Brief periods of very strong southerlies occur with the passage of line squalls in strong southwesterly air streams (NZ MetService, 1981). They are potentially hazardous because of the intensity and suddenness of wind changes from the south,

sometimes gusting to at least 50 knots in a matter of seconds from near calm conditions (NZ MetService, 1981). Southerly winds gusting 60 knots or more may be expected on about 3 days a year.

### Sea and Land Breezes

There is a significant diurnal variation in wind speed, with higher that average wind speed occurring between the hours of 9 am and 7 pm (Beca Connell-Caldwell Connell, 1980). On occasions when the pressure gradient is very weak over central areas of New Zealand and there is sufficient surface heating (i.e. during summer), a sea breeze can be expected at Lyall Bay (NZ MetService, 1981). This is most evident in the months October to April. In mid-summer the onset tends to be about 0930 N.Z.S.T. and cessation about 1800 N.Z.S.T (NZ MetService, 1981). The duration is much less in other seasons and is not common on winter. The normal direction for the sea breeze is from the southwest and the speed is typically 7 to 12 knots (NZ MetService, 1981). Such sea breezes are a typical occurrence at most surfing breaks during summer months, and as long as the breeze remains light, only slightly decreases the quality of the surfing waves (Figure B1.5).

When weak pressure gradients occur at night there is a tendency in all seasons for a light wind 2 to 8 knots from the north to develop (NZ MetService, 1981). An apparent related effect, particularly in spring and summer, is of winds in the 11 to 20 knot range that blow from the north during the afternoon often veering northeast in the evening and overnight.

### Seabed Description

Diver inspection of the seabed during deployment and servicing at the wave/current meter sites indicated that the seabed consists of a fine sand (Mead *et al*., 2001). Small sand ripples, measuring less than 20 cm peak to peak and with a trough to peak heights of less than 3 cm were observed at all sites. At site 1, some small patches of mega-ripples of coarse grain sand were observed, which coincides with the side-scan information presented in Carter and Lewis (1995) (Figure B1.6).

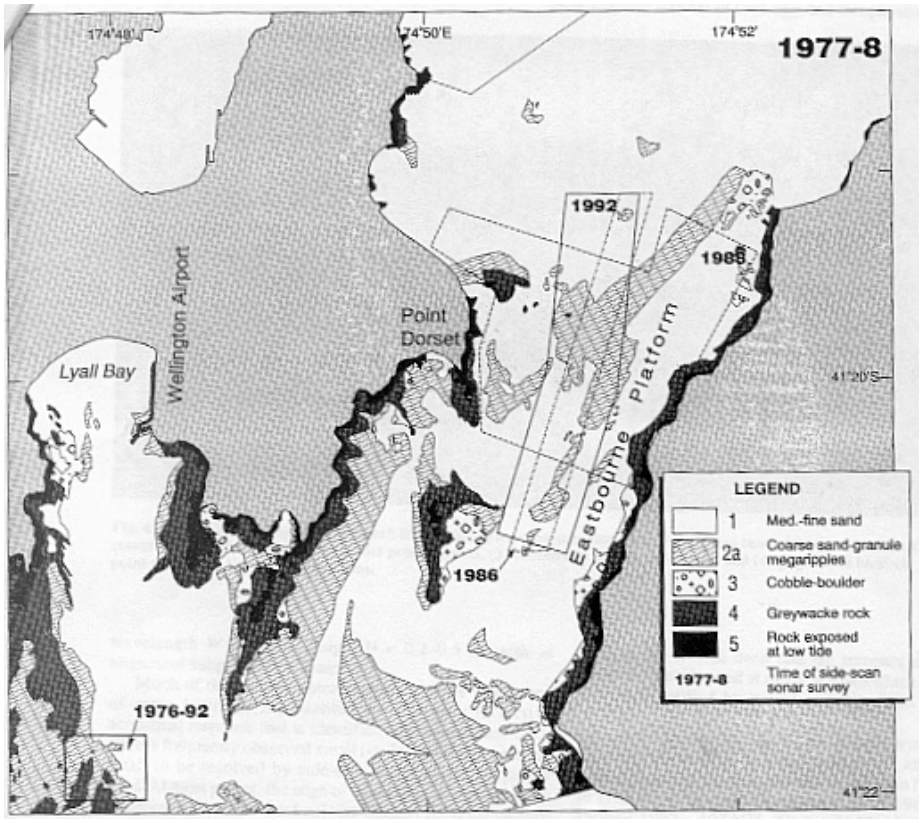



**Figure B1.6. Sediment types in the Lyall Bay area identified by side-scan sonar (From Carter and Lewis, 1995).**

## Sediment Particle Size Distribution at Lyall Bay

Sediment sample analysis for Lyall Bay (Mead *et al*., 2003) found that mean grain size ranged between 1.94 and 2.77 $\phi$. Samples were made up of a large fraction of sand, with gravel accounting for that remaining portion. The sediment is classed as fine sand (mean 2.5 $\phi$). Surfer© computer software was used to create a contour plot of grain sizes that was then overlaid with a bathymetry plot of Lyall Bay (Figure B1.7). The sand is coarsest in the high-energy centre of the bay and fines slightly towards the lower energy ends (Figure B1.7). This is a similar pattern to that described by Pickrill (1979). Coarser sand was also found off the end of the eastern breakwater, which is most likely due to the high currents associated with this area (Chapter 4), and in the middle of the bay (Figure B1.7), which agrees with the side-scan chart of the area (Carter and Lewis, 1995) (Figure B1.6).

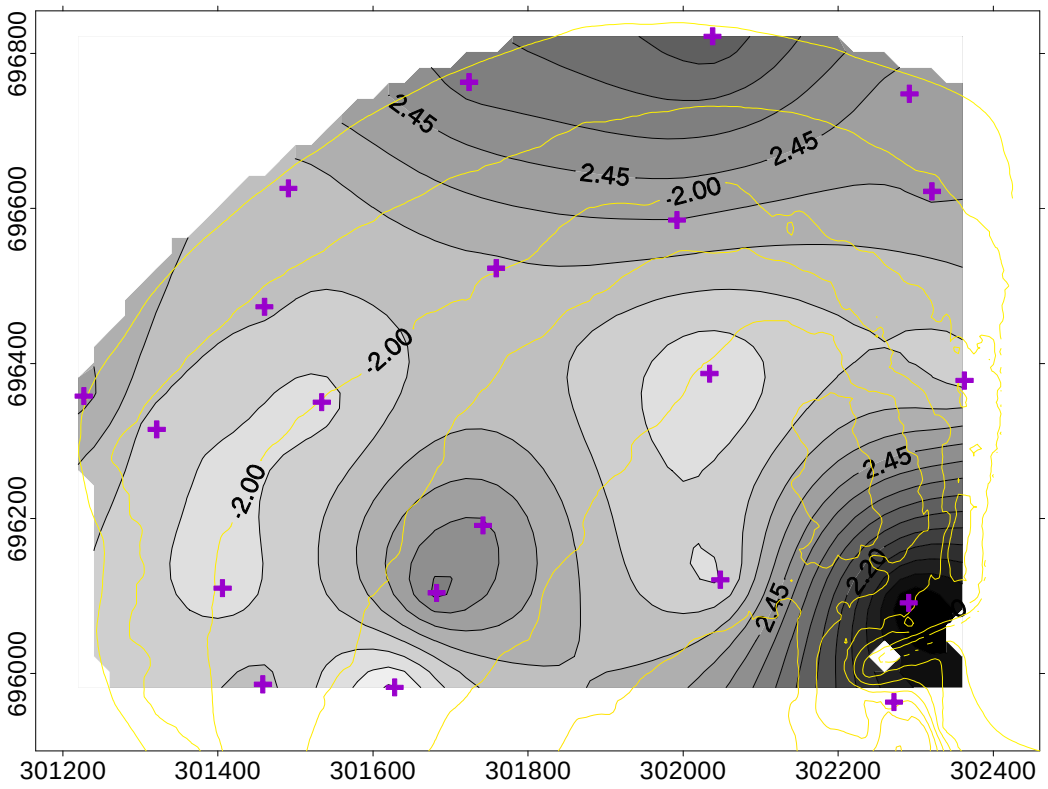



**Figure B1.7. Sediment size distribution map of Lyall Bay. Crosses indicate sample sites, bathymetry overlaid in yellow. (Source, Mead *et al*., 2003).**

## Sedimentological Setting of the Wellington South Coast (From Carter and Lewis, 1995)

The continental shelf between Cape Terawhiti and Turakirae Head (Figure B1.8) is mantled by gravel and coarse sand, reflecting the strong current flows of the Cook Strait and a low input of modern detrital sediments (Lewis & Mitchell 1980 – cited Carter and Lewis, 1995; Carter 1992 – cited Carter and Lewis). Only two rivers, Wainuiomata and Orongorongo, now discharge directly onto the shelf, and their combined sand/gravel input is c. 22,000m$^3$/yr. Of this the gravel component is entrained in the littoral drift and enters the Wellington Harbour, whereas the sand is dispersed mainly westwards into embayments and as far as Island Bay. The only other river of any consequence, Hutt River, has most of its sediment load trapped in the enclosed Wellington Harbour basin. Fine-medium sand moves along the western shelf of the North Island towards Cook Strait, but little is likely to reach Wellingtons south coast because virtually all is swept away by the energetic tides from the narrow shelf off Cape Terawhiti (Carter *et al*. 1991 – cited Carter and Lewis;

Carter 1992 – cited Carter and Lewis). Similarly, sand is unlikely to leak onto the Wellington shelf from Palliser Bay because the shelf is narrow (<2 km) and the prevailing southerly swell encourages nearshore transport back into the bay. Even so, the sediment distribution within the bays and on the inner continental shelf of the south coast (Figure B1.7) remains fairly stable through time (Carter and Lewis, 1995).

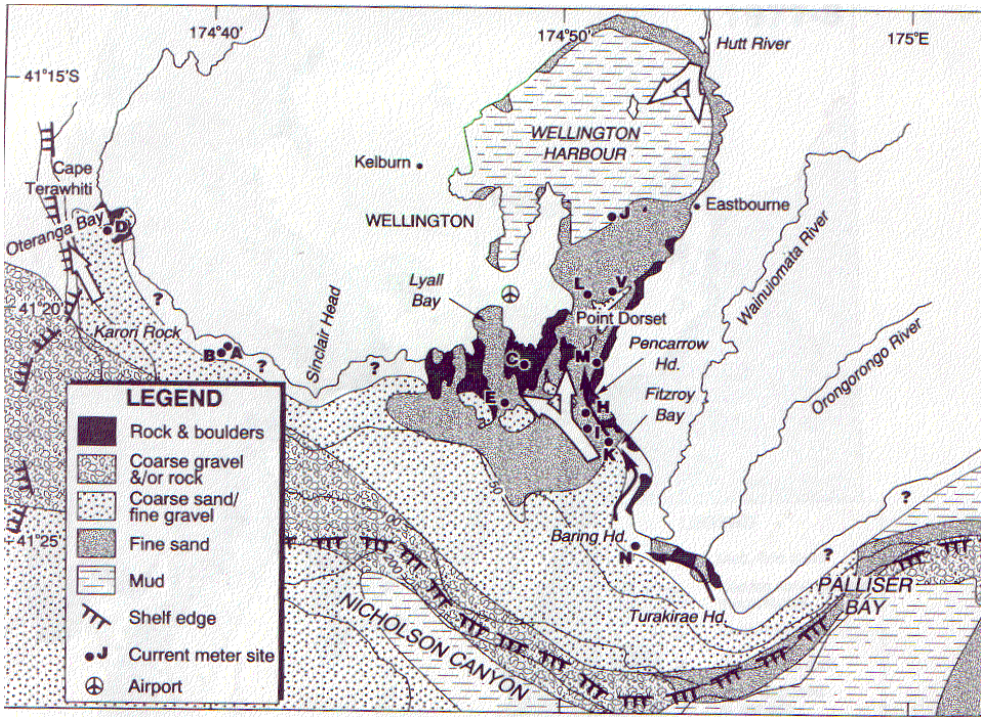



**Figure B1.8. Sediment types and sediment transport pathways on the Wellington south coast area identified by side-scan sonar (From Carter and Lewis, 1995).**

## Beach and Shoreline Stability

While many beaches in populated areas around New Zealand are subject to long-term beach profile monitoring of the fore-dune and intertidal zones, usually undertaken by the Regional Authority, very little data is available for the Wellington region. This is most probably due to the fact that the majority of the Wellington coast is composed of rocky reef and cliffs (Figure B1.1) and therefore changes very little on a human time-scale. Even though the Lyall Bay area has undergone extensive changes during the past century, especially at eastern end due to airport construction (WCC, 1974; Ministry of Transport, 1975; CE, 1976), only one set of

shoreline profile data has been recorded for a 12-month period in 1977. These data are presented in Pickrill (1979) together with an analysis of aerial photographs of the shoreline position between 1941 and 1975. Here, Pickrill (1979) is summarised and supported by environmental impact reports on the airport development and more recent aerial photography to assess the beach stability at Lyall Bay.

**Beach Stability (Vertical)**

The beach at Lyall Bay is fine grain sand, coarsest at the high-energy centre of the bay and becoming slightly finer towards the lower energy ends (described above). For most of the year the beach assumes a concave profile, steepest at the top of the beach (which is backed by a seawall) and decreasing in slope offshore. The slope of the beach is steepest in the centre and lowest at the ends, which is also due to the variation of wave energy along the beach. Offshore, the beach slope decreases and the morphology is either planar or barred, depending on the prevailing wave conditions.

Pickrill (1979) established five shore-normal transects that were surveyed at monthly intervals for a 12-month period (December 1976 to December 1977). The profiles were normally taken from the seawall to a height of 1.5-2 m below mean sea level (MSL), except during June and October 1977, when an echo sounder was used to measure the profile out to a depth of ~6 m below MSL. The wave conditions during the beach profile surveys were thought to be typical of those found on this coast (Pickrill, 1979). Changes to the beach profile during the survey period are therefore probably typical of what might be expected in any one year.

The beach morphology was found to change in response to wave energy conditions (Pickrill, 1979). During low energy conditions in the summer months, a berm formed above the MSL (e.g. Figure B1.9). During periods of higher wave energy in the winter months, these berms are planed off the beach and replaced by a broad concave profile extending the full width of the beach to elevations of 3-4 m above MSL (Figure B1.9).

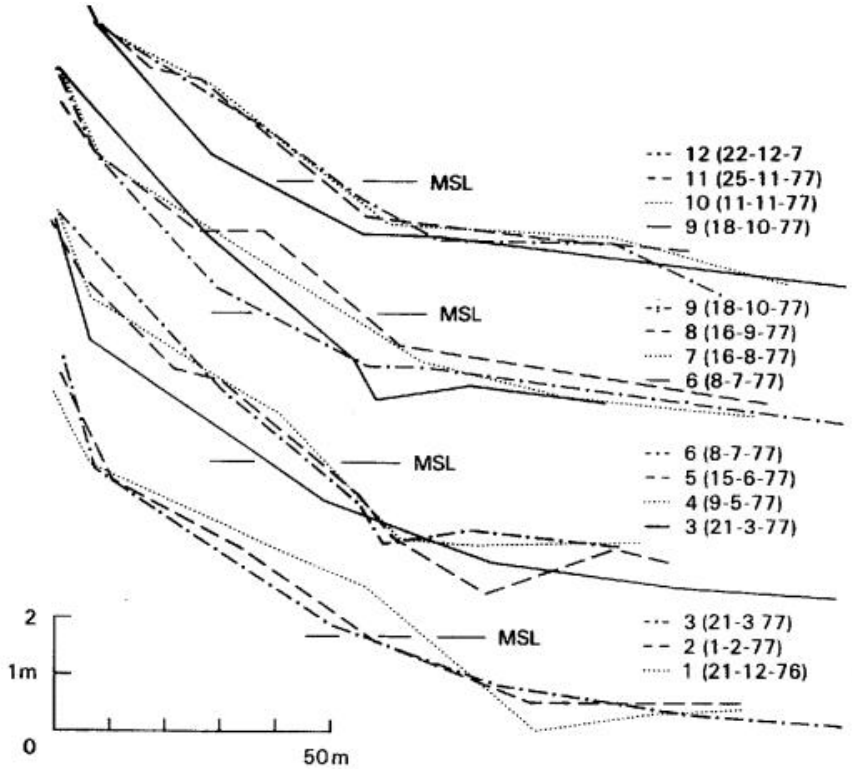



**Figure B1.9. Beach level changes at Profile III measure at Lyall Bay between December 1976 and December 1977 (from Pickrill, 1979).**

The best methods used to portray changes in the beach morphology were plotting movements of selected beach height contours through time (Figure B1.10) and sweep zone envelopes (Figure B1.11), where the highest points on all profiles and the lowest points on all profiles are joined to show the heights to which the beach rose and the lowest level from which sand was removed in 1977. In Figure A1.9 it can be seen that all five profiles show a seasonal pattern of change with accretion and seaward movement of most height contours from December through to March, followed by a period of erosion and landward contour movement from March through to July or August. The average contour movements for the entire bay show this pattern quite strongly (Figure B1.10).

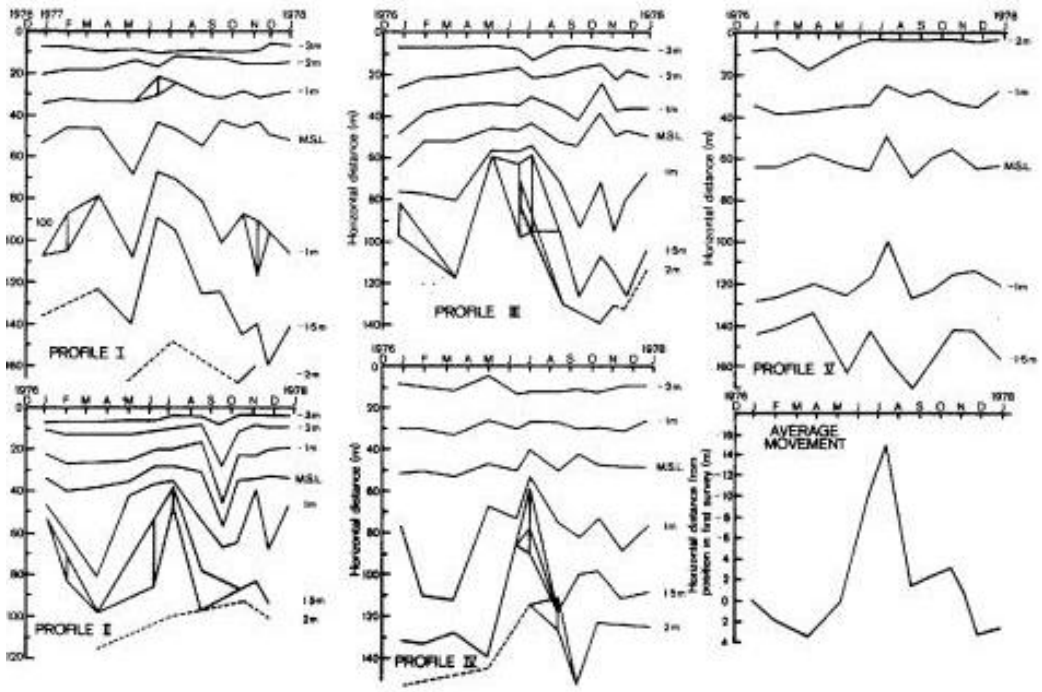



**Figure B1.10. Horizontal movements in beach contours in Lyall Bay between December 1976 and December 1977. The lower right hand graph shows the average movement in the beach face (from Pickrill, 1979).**

The sweep zone envelopes (Figure B1.11) show the maximum vertical change that occurred on the Lyall Bay beach face during the survey period. The beach takes a wide range of forms between the sweep zone envelopes. The envelopes at Lyall Bay all have a similar form, with the widest parts centred on or near the MSL (Figure B1.11). The envelopes are thickest on the narrower, higher energy, steeper profiles in the centre of the bay (3.2 m at profiles II), decreasing in thickness to the lower ends (0.6 m at profile V and 0.9 m at profile I). From the monthly profiles, the largest beach level changes between consecutive months are in the order of 2 m (Profile II) and the maximum 3.2 m at profile II occurred over a 3½ month late winter period (July to October, 1977). The two ends of the bay (profiles I and V) are the most stable (Figures B1.10 & B1.11), with the maximum change consecutive surveys of 0.7 m (49 days March-May 1977 at profile I) and the maximum change of 1.2 m occurring over a 3½ month early winter period (also profile I).

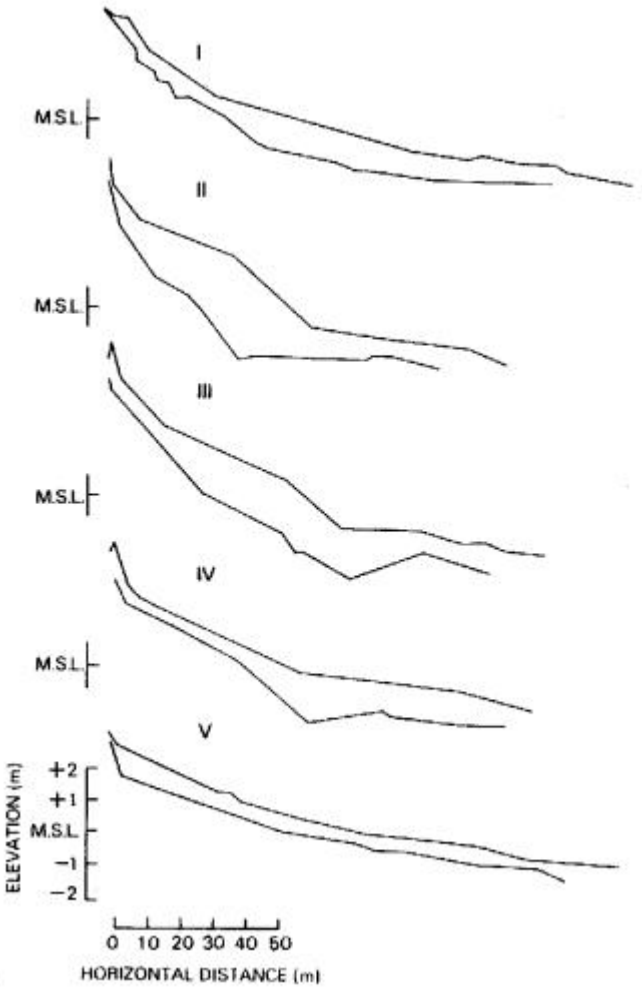



**Figure B1.11. Beach envelope curves for the five profiles around Lyall Bay surveyed monthly between December 1976 and December 1977 (from Pickrill, 1979).**

The migration of shore parallel bars is also a consideration when siting a surfing reef. On two occasions (winter and late spring), the profile monitoring was extended offshore for approximately 500 m using an echo sounder to investigate changes in the nearshore beach morphology (Pickrill, 1979). These survey lines revealed a migratory multiple bar system (two to three shore-parallel bars) that was attributed to differing levels of wave energy. The innermost bars form under low energy conditions and the more seaward bars form under periods higher energy. The majority of bar movement occurs within 300 m of MSL. As would be expected, the winter survey identified bars further offshore due to the higher wave energy during this period.

**Shoreline Stability (Plan Shape)**

Pickrill (1979) used aerial photographs between 1941 and 1975 (6 runs in all) to show the changes to the shoreline position due to the reclamation of the eastern end of Lyall Bay. Compression of the beach due to the reclamation has led to a deepening of the curvature of the bay, which has resulted in a landward retreat in the centre of the bay and consequently erosion of the seawall and footpath in this area in 1977/78 (Pickrill, 1979). At present, this area is still subject to erosion, even though the upper shore against the seawall has been stabilised with marram grass along the rest of the bay. Maximum shifts in the shoreline were found to be in this area in the centre of the bay and at the western end. However, the shoreline of the western end fluctuated onshore and offshore throughout the sample period, while the western centre of the bay remained stable. The eastern end (the location of the Corner) also remained mostly stable throughout the sample period. Pickrill (1979) suggests that the bay was a logarithmic spiral shape prior to airport reclamation and has been trying to develop a new log form similar to the pre-reclamation shape ever since. However, this is arguable as the log spiral shape was not a good fit prior to the airport reclamation (Figure B1.12), the western end has fluctuated in both directions (eroded and accreted) considerably between the aerial photograph runs and the control point of the breakwater tip was not changed by the reclamation – the breakwater runs along the natural rock barrier. In addition, the reclamation area was previously very shallow. The shallowness of the eastern bay area (prior to reclamation) and the existing reef/rock break water (control point) suggest that the changes to the bay have not been as large as would have been expected and the bay has already established a new equilibrium plan shape.

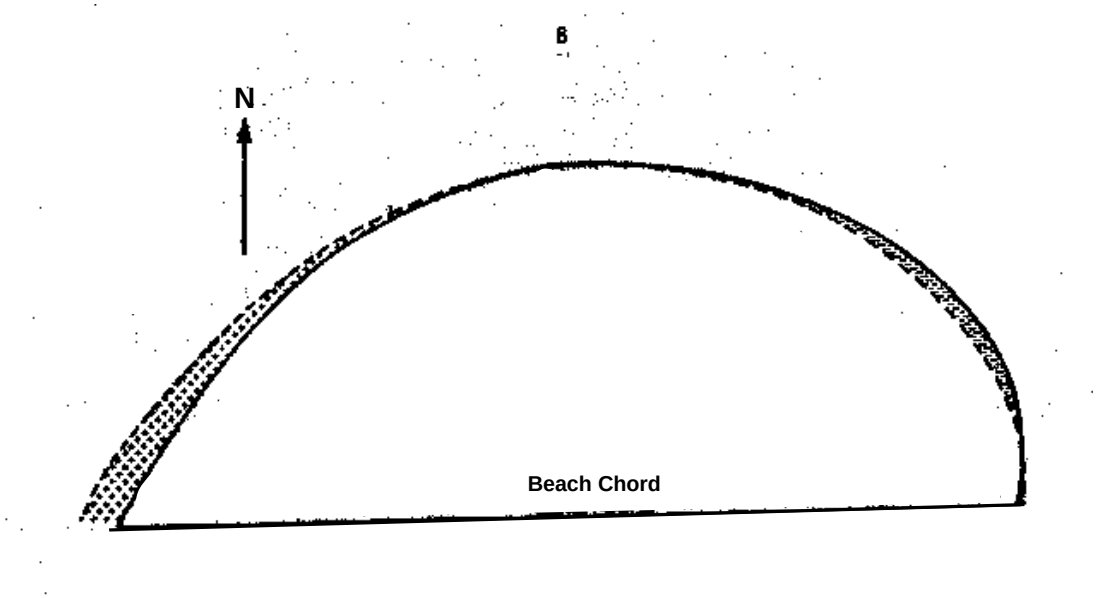



**Figure B1.12. Best fit log spiral prior to airport reclamation based on 1941 shoreline taken from aerial photographs (From Pickrill, 1979).**

Later aerial photographs (e.g. Figure 2.7 in the main report) show that the shoreline plan shape has remained similar since 1975 even though further airport extensions occurred after this time, even though there has been fluctuation of the position during this period. This is most probably due to two factors. Firstly, the area that was reclaimed to extend the runway south was very shallow rocky reef (CE, 1976), which means relatively little change to the bathymetry occurred. Secondly, the control point for Lyall Bay remained the same, i.e. the tip of the breakwater on the end of the runway.

Section 2.5 of the main report provides a detailed analysis of shoreline position between 1938 and 2015.

### Currents

Measured and model current circulation presented in several reports (Mead *et al*., 2001; NIWA, 2015; DHI, 2015a) show similar patterns. The water level along the coast is set-up or set-down due to wave breaking, which influences the currents because water 'runs' from higher levels to lower levels. The wave set-up at Lyall

Bay is greatest along the western and eastern reefs and at the 'Bend', where the wave energy is largest (Figure B1.4).

During high swell events, the general circulation pattern at Lyall Bay has stronger currents along the eastern and western sides of the outer bay, and weak alongshore currents to the east and west from the area of highest wave energy and water level at the 'Bend'. However, these currents are regularly broken by counter-rotating rip-cells, with an overall offshore trend. Along most of the length of the beach there are low currents beyond the breaking zone. Currently velocities are fairly low throughout Lyall Bay and are mostly less than 0.5 $ms^{-1}$ (Mead *et al*., 2001).

These current patterns were verified through discussion with local surfers and surf lifesavers. While there are periods of alongshore current flows, there is relatively little alongshore sediment transport along Lyall Bay beach, which is verified in the historical aerial photographs and recent satellite images, which indicate no build up or loss of sand on either side of stormwater pipes through the surfzone. Wind-driven currents circulate clockwise during southerly wind conditions, and anti-clockwise during northern wind conditions (NIWA, 2015).

# Appendix C. Cost Estimates

**Approximate costs for works over the next 3 years**

| | | 2016/16 | 2017/18 | 2018/19 |
|---|---|---|---|---|
| **Removing Surfers Corner carpark and installing a concrete block wall** | | | | |
| **Item** | **Description** | | | |
| Excavation and demolition | Excavate and remove existing seawall, asphalt and garden areas | $15,450 | | |
| Block Concrete Wall | Install new block wall (including footing) – 65m length. | $30,000 | | |
| Carpark Reinstatement (roading reserve) | Reinstate carpark area – subbase preparation and asphalt and markings. 800m2 approx | $51,500 | | |
| Gardens and planting | Reinstate gardens | $5,150 | | |
| Fences and Furniture | Reinstate fences, coastal barriers, rubbish bins, and other furniture. | $15,450 | | |
| Rip Rap/Sand Placement | Place rip-rap and sand protection - require approx 300m3 | $77,250 | | |
| Traffic management | Provide traffic and pedestrian management to undertake works. | $7,725 | | |
| Contingency | Contract contingency for unexpected works that may occur during construction | $15,450 | | |
| | | | | |
| **Replacing wire mesh section with concrete block wall (** | | | | |
| **Item** | **Description** | | | |
| New Block Wall | Install new block wall where currently fence in the middle part of the beach (no footing required) – 60m length. | $15,000 | | |
| New Block Wall | Install new block wall from existing wall to new Surfer's Corner wall (including footing) – 210m length. | $95,000 | | |
| | | | | |
| **Protection along Dorris Lesley Parkk** | | | | |
| **Item** | **Description** | | | |
| Rock Rip Rap | Rock Rip Rap (range size 450-890) approx. 180m (near pohutukawas) | $576,000 | | |
| Rock Rip Rap | Rock Rip Rap (range size 450-890) approx. 100m (Moai - Dorrie Leslie Park) | | $320,000 | |
| Regrading | Regrading eroded areas and planting | | | $100,000 |
| | | | | |
| **Realigning access ways to beach** | | | | |
| **Item** | **Description** | | | |
| Access ways | Sand ladders and fencing | | | $50,000 |
| | | | | |
| **Dune planting and protection** | | | | |

| Item | Description | | | |
|---|---|---|---|---|
| Plants | 10,000 pingao and spinifex | | | $29,500 |
| Labour | Labour costs for planting | | | $5,000 |
| Weed control | Spraying marram grass prior to planting | | | $5,000 |
| Protection | Installing fencing along dune and signage | | $10,000 | |
| | | | | |
| **Pipe extensions** | | | | |
| **Item** | **Description** | | | |
| DN450 pipe in road | 240m at cost of $700 per meter | | $168,000 | |
| DN1600 outfall | 60m at a cost of $2,500 per meter | | $150,000 | |
| DN2000 outfall | 55m at a cost of $3,500 per meter | | $192,500 | |
| DN450 outfall | 50m at a cost of $800 per meter | | $40,000 | |
| DN1050 outfall | 80m at a cost of $ 1,800 per meter | | $144,000 | |
| DN1200 outfall | 45m at a cost of $ 2,000 per meter | | $90,000 | |
| DN1350 outfall | 35m at a cost of $ 2,300 per meter | | $80,500 | |
| DN600 pipe in road | 160m at cost of $ 900 per meter | | $144,000 | |
| Manholes | 10 standard manholes at $5,000 each | | $50,000 | |
| Manholes | 4 large at $8,000 each | | $32,000 | |
| Resource Consent | Allowance for resource consent of works in tidal zone | | $70,000 | |
| | | | | |
| **Per Annum** | | **$903,975** | **$1,491,000** | **$189,500** |
| | | | | |
| **Heighten Seawall** | | | | |
| Heighten central part of block wall | Install new blocks (4 levels) along the central stretch of the beach (no footing required) – 350 m length. | $70,000 | | |