Lyall Bay Coastal Remediation

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Abstract
An investigation has been undertaken at Lyall Bay in Wellington to propose options with regard to protecting the natural and built coastal infrastructure and reinstating a functional dune. Lyall Bay is an important recreational asset for Wellington as it is popular with the community for many activities both in the water and on the beach, as well as scenic drives, visiting cafes, and plane watching with the nearby airport. The project has specifically included investigating options for 1) dune restoration to maximize their effectiveness in absorbing wave energy and protecting natural and built infrastructure 2) protect the rocky shoreline, grassed area and trees on the western side of the bay 3) the shifting of sand around the bay and dealing with current infrastructure within the beach environment.

Lyall Bay is a highly modified beach environment that has been developed since early last century, leading to a number of constraints and changes when coastal processes are considered. The dune field has been replaced with people/houses/buildings; the bay has been contained within walls, roads and parking; stormwater discharges into the bay through 20 different outfalls; the eastern third of the bay has been reclaimed for the airport, and a further 350m of reclamation is proposed in the near future. These constraints prevent the beach from responding naturally to extreme events and mean it requires on-going management and maintenance. The main driver of beach change in Lyall Bay is wave-energy with refraction aligning the waves to the seabed contours, resulting in very little alongshore sediment transport. Bay-wide remediation options have been proposed and consultation undertaken with the community and stakeholders to seek input to the best options. The beach has been divided into 4 zones and specific intervention and management options have been designed for each, however the entire beach requires holistic management for long-term outcomes.

Keywords: Coastal erosion / remediation, dune restoration, coastal infrastructure, stormwater.

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 [1].

Figure 1 Aerial view of Wellington, NZ and specifically Lyall Bay the project site.

Figure 2 The retreat of the coast in the northern 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.

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 2). 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.

Figure 3 Aerial of Lyall Bay showing the 4 sections.

Lyall Bay was divided into 4 areas of interest to address (Figure 3):

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 4 Lyall Bay beach showing carparking, no dune and a stormwater outfall.

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 (Figure 4), rather than a natural beach, and as such will require management and maintenance much the same as terrestrial parks do to ensure the beach can cater for the wide range of recreational beach activities (Figure 5).

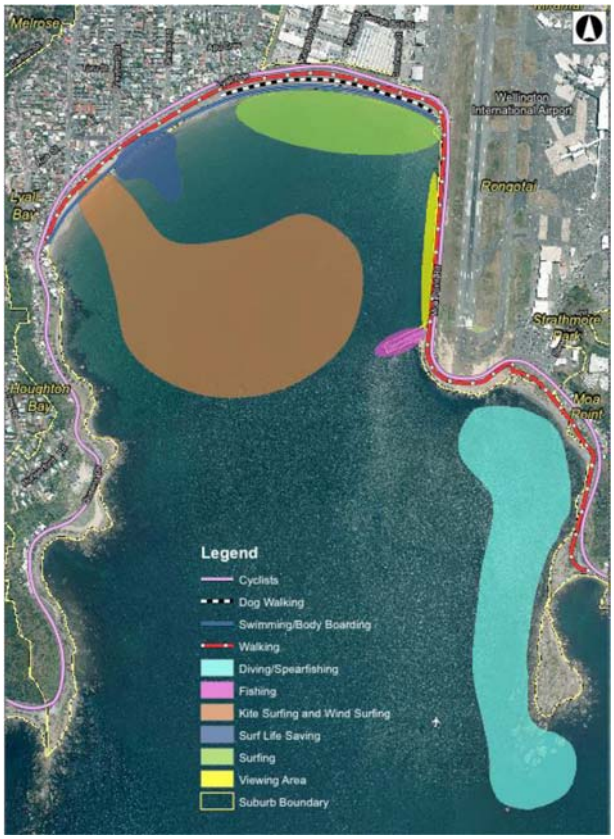

Figure 5 The various recreational areas in Lyall Bay [6].

2. 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.

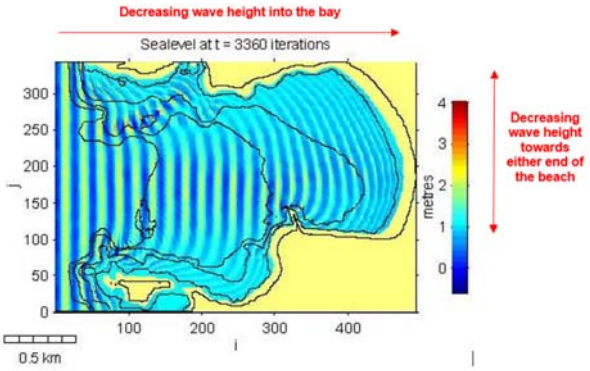

Figure 6 Model output of the wave heights in Lyall Bay.

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 (**Error! Reference source not found.**). 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 [7].

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 [5]. 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 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 [1]. The southerly onshore winds cause erosion of the beach, especially when strong (i.e. storm conditions).

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. 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 have been studied and are detailed in Mead [3]. More recent investigations e.g. NIWA [4], provide some added information such as wind-driven currents.

There is a planned extension to the Wellington airport runway and DHI [2] and NIWA [4] have indicated that there will be change to wave and current patterns in Lyall Bay. 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. DHI's [2] 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.

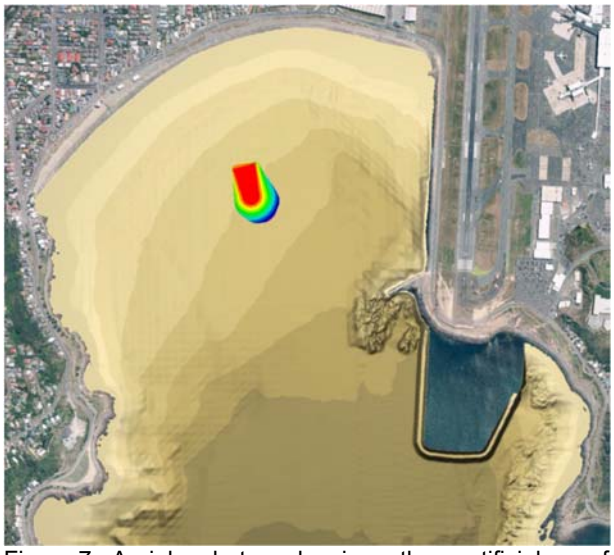

Figure 7 Aerial photo showing the artificial reef assessed by DHI [2] and airport extension.

To address the reduction in surfing quality in Lyall Bay, DHI [2] have proposed the development of a wave focusing structure to reintroduce peakiness into Lyall Bay (Figure 7). 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. 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.

2.1 Aerial Photographs

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) (**Error! Reference source not found.**). 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. The beach then widened/accreted some 15-20 m over the past 20 years 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.

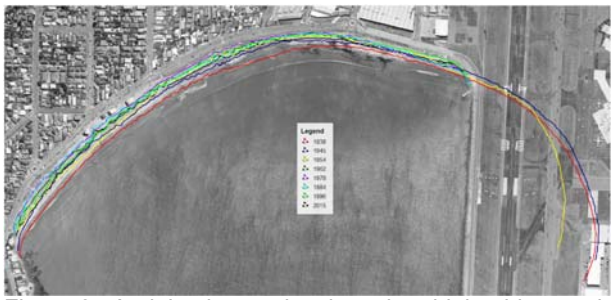

Figure 8 Aerial photo showing the high tide mark between 1935 and 2015.

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 [1]; this provides a source of material to slowly widen the dune field and increase the robustness of Lyall Bay beach.

2.2 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. 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.

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.

2.3 Recommended Beach Options

A number of recommendations have been developed for both the entire bay and each section of the beach. 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 (Figure 9).

Figure 9 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 damages dune plants and so reduce resilience of the dunes.

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 (Table 1).

Table 1. Summary of recommended options for coastal remediation of Lyall Bay.

Area	Recommended Options
Baywide	1. Do nothing. 2. Lengthening of stormwater outlets. 3. Incorporation of spinifex and removal of marram grass. 4. Upgrading of beach access ways (~24). 5. Increased signage instructing people to stay of the dunes along with roping off. 6. Development of a beach maintenance team. 7. Beach monitoring (profiles).
Section A	1. Removal of ~110 m of existing carpark. 2. Relocation of parking spaces to road reserve. 3. Reinstatement of foredune and plants (spinifex and pingao) once carpark removed. 4. Installation of seawall to 'support' the new stretch of dune (~100 m) and reduce foot-traffic. 5. Installation of 3 beach access ways.
	1. Extension of the seawall from the eastern end to meet up

Section B	with the new seawall at the former Corner carpark (~210 m). 2. Replacing the seawall along the ~60 m length that it was removed from in the mid-1990's. 3. Introduction of more spinifex and pingao into the dunes. 4. Prevention of access to the dune from the eastern end of the playground. 5. Heighten the middle section of the seawall to ~1.5 m (~350 m). 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). 2. Establishment of appropriate access ways from the existing historic seawall access ways (10 in this section). 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). 2. Tipped rock revetment along the section of undermined Pohutakawa trees (~180 m). 3. Tipped rock revetment around the eroding headland of Moai to meet up with the existing revetment (~100 m).

3. Stormwater Assessment

An assessment was undertaken on the present condition of stormwater infrastructure on Lyall Bay beach (Figure 10), and remediation required (e.g. outfalls, pipelines, pipeline outlets, manholes, etc.). The stormwater outlets along the dunes, above the high tide mark appear to erode the beach and likely prevent sand accretion due to liquefaction. The results are 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, as well as 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.

The results are then related to a schedule that considers no works required on the asset through to urgent works required. 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.

Figure 10 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.

The 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.

It was noted that consideration should also be given to the use of tide gates/flaps/WaStops etc on stormwater outlets to prevent sand ingress to the pipes, which can potentially cause blockages. 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/gunite to naturalise and disguise the outfalls as natural rocky reef, and the quality of the stormwater discharge on the heavily patronised beach could be improved through treatment both at source and prior to discharge e.g. Enviropods, catchpit cleaning, Stormfilters, Up-flo filters etc.

3.1 Impact and Effect on Coastal Processes

The impact and effect was ranked using a matrix system (Table 2 and 3).

Table 2: 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

Table 3: 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

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/gunite.

These have been summarised for each asset with the recommended works to be undertaken to reduce erosion and enhance effectiveness (Table 4).

Table 4: SW Asset Works (example)

No.	Asset No.	Section	Impact	Effectiveness	Options	Recommendations
1	SWP015426	A	3	2	3,4,5	Design/install localised erosion protection (ST-MT).

4. Summary

It can be concluded from the study at Lyall Bay that:

1. Over the past century, Lyall Bay has experienced ongoing human impacts, which has led to an increasingly modified beach system; it is constrained and impacted so that it no longer functions like a natural beach.
2. There are a variety of different areas that experience different levels of energy and consequently movement of beach sand (erosion/accretion).
3. The beach is constrained by wall and road, which in some areas is not in harmony with the beach's natural position – moving this infrastructure is not currently an option (with the exception of the Surfer's Corner Carpark).
4. Each of the 4 locations have specific intervention and management options, although the whole beach should be managed holistically – it is less robust with areas without plantings (e.g. between buildings and in front of the playground and Surfer's Corner Carpark), all stormwater outlets should be as seaward as possible, sand should be moved from areas of accretion to areas of erosion following storm events, sand on the road goes back on the beach, preferably on the foredune to encourage managed advance of the dune system, and so on.
5. All accessways should be angled to restrict wind-blown sand loss and wave run-up during storms.
6. Continual Planting – there is no large coastal source of sand, only slow input from Cook Strait, and all efforts should be made to maintain it in the beach system to ensure a healthy beach and build resilience for sea level rise.
7. Works as recommended should be undertaken on the stormwater assets to reduce erosion and increase their effectiveness.

5. References

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