STAFF TECHNICAL REPORT

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MAPUA - RUBY BAY COASTAL HAZARDS AND MANAGEMENT OPTIONS

Introduction

The Mapua – Ruby Bay communities lie mostly on the coastal plain and partly on the adjacent hills on the Tasman Bay shoreline between the Moutere Bluffs and the northern outlet channel of the Waimea Estuary. Those parts of each community that are located on the low coastal hills are relatively free from exposure to erosion or inundation risk, other than those areas within or immediately adjacent to natural drainage paths from the hills down to the coastal plain and the sea.

Recently acquired high resolution LIDAR aerial photography has enabled production of inferred 0.5m contours for the locality. This information graphically highlights the fact that the coastal plain, on which much of the community is located, is relatively low to very low lying. Land contours derived from the LIDAR data are shown in Figure 1.

This coastal plain has experienced, and remains subject to, a number of natural hazard risks. These include coastal erosion, inundation from the sea and flooding from rainfall runoff from the adjoining hinterland. These natural hazard risks are expected to increase in the future, either due to the effects of projected climate change on rainfall intensity, sea level rise and storminess, or as a result of further developments in areas potentially subject to natural hazards.

The primary hazard risks to the Mapua-Ruby Bay communities comprise the following:

- Coastal erosion along the Tasman Bay and Waimea estuary shoreline;
- Seawater inundation of land adjacent to the shoreline;
- Flooding from incident rainfall in the catchment draining towards the two communities.

The appendix contains photographs of coastal erosion, seawater inundation and freshwater flooding that has occurred in the Mapua-Ruby Bay area.

This report will examine the present and future risks from these hazards over a time period to 2100 and the impact of these potential hazards given various hazard mitigation measures.

Hazard Risks, Potential Impacts and Mitigation Options

A COASTAL EROSION

(i) Historical and future erosion rates

The Ruby Bay shoreline has been subject to persistent, long term erosion since at least 1912, the date from which Council has cadastre and aerial photographic records. Long term average erosion rates vary along the shoreline, from being less that 0.1m/year in the Pinehill Stream locality and steadily increasing southwards along the shoreline to exceed 1.0m/year south of Broadsea Ave. This aggressive erosion rate prevails for the remainder of the shoreline to virtually the western outlet of the Waimea estuary. At this point, pre-1980 phases of both deposition and erosion on the beach fronting the Mapua Leisure Park have shifted to a dominant erosion trend over the last 20 years.

From a hazard assessment and planning perspective, future shoreline locations are estimated on the assumption that coastal processes continue to act on a shoreline not modified by erosion mitigation measures. This is because hazard mitigation measures, (either structural features such as revetments or “soft engineering” measures such as beach replenishment), may cease to be maintained to meet ongoing protection needs or simply be abandoned. In these circumstances coastal erosion processes will gradually reassert themselves as the effectiveness of erosion mitigation measures declines.

At present, Council’s Tasman Resource Management Plan (TRMP) only has a Coastal Hazard Area (CHA) determined for Ruby Bay. This CHA is limited in that it excludes seawater inundation hazard and is based only on coastal erosion processes on a natural shoreline, projecting average long term erosion rates observed from 1912-1988 out to 2040.

The location of the landward extent of the Coastal Erosion Hazard line has been reviewed, using more recent survey and aerial photographic data gathered over the last 20 years. Significant sections of the shoreline have been modified by erosion protection structures within the last 10 years, most notably along the Broadsea Ave shoreline and from the southern end of the Old Mill Walkway (OMW) Reserve to the Mapua Channel. However much of the northern Ruby Bay shoreline has remained in a natural state to the present, as has the 700m long OMW reserve. Erosion rates in these areas are very similar to, or slightly greater than, the 1912-1988 long term average erosion rates on this shoreline.

A possible shoreline location by 2100 has been determined using the long term erosion rates calculated for the period 1912-2010 projected to 2100, with wave forces acting on a natural shoreline. However, no specific allowance has been made for a number of factors that are likely to influence future erosion rates compared to the past. These include:

- Topographic variability of eroded historic backshores compared to present day landforms. For example, erosion of past sand dune complexes and present day higher foreshore ground levels giving way to lower land levels behind, where one might expect erosion rates to increase.

- An increase in future erosion rates as a result of sea level rise and increased water depth adjacent to the land (and thus wave height/wave energy impacting the shoreline).

- Any changes to the predominant wind climate and frequency or intensity of storm events. While an increase in westerly winds is predicted for this region in a future climate change scenario, a predominance of present-day wind direction is still expected to prevail on this coastline.

The rationale for not making any specific allowance for the above factors on future erosion rates is that quantifying direct effects becomes speculative without undertaking extensive computer modelling of shoreline processes, particularly with respect to inundation hazard. Council has recently provided an annual budget for the next five years, to allow such investigations to be made. However, these investigations are more readily able to determine the extent of seawater inundation hazard risks than shoreline erosion rates. This is due to the complexity of simulating shoreline sediment properties, assumptions regarding sediment sources, and littoral drift/sediment transport processes. However a desktop estimate of erosion rates in a future sea level rise scenario can be made once certain shoreline parameters are determined.

Persistent long term erosion has been occurring on the Ruby Bay shoreline simply as a result of prevailing coastal processes causing an imbalance in the sediment budget ie loss rates exceeding input rates. An additional erosion mechanism in a sea level rise scenario is described by the Bruun Rule. This rule states that for a shore profile in equilibrium, as sea level rises, beach erosion takes place in order to provide sediments to the nearshore so that the nearshore seabed can be elevated in direct proportion to the rise in sea level.

Therefore the historical shoreline erosion trend at Ruby Bay is likely to increase in the future, due to the effects of sea level rise. The potential effect of sea level rise on erosion at Ruby Bay has not been quantified, as a volumetric analysis of a revised shoreline profile for a particular sea level elevation has yet to be undertaken. With LIDAR elevation data now to hand, this assessment is now more readily able to be undertaken. However, in the interim, it is reasonable to conclude that a simple projection of historic erosion rates to determine a possible future shoreline location, as has been done, is likely to result in a conservative assessment of that shoreline location

(ii) Erosion hazard mitigation – implications for the future

Shoreline erosion at Ruby Bay has been occurring persistently since at least 1912. However, it has been only since the mid 1960’s that built development adjacent to the coast has prompted erosion mitigation measures to be taken. These measures include an informal rock revetment and modest timber wall structures north of Tait St (where residential development first occurred). Other works have extended southwards since 1999 to include rock revetment construction on the Broadsea Ave reserve, rock revetment works between the Old Mill Walkway reserve and the Mapua Leisure Park and most recently in front of the Leisure Park itself. Council has just commenced construction of the remaining 510m of rock revetment structure for the 700m long Old Mill Walkway reserve, principally for erosion mitigation. This revetment, along with all the other erosion mitigation works on this shoreline, does not have sufficient height to fully prevent seawater overtopping in present-day storm-high tide conditions.

Of the 3.5 km of coastline from the Pinehill reserve at the northern end of the Ruby Bay residential area to inside the Mapua channel at the Leisure Park, all but the northern 600m of shoreline (ie 2.9 km) has been significantly modified by some form of erosion mitigation structure. These structures comprise almost entirely rock revetments, although vertical timber walls and log revetments have also been used. Council is responsible for 1100m of the 2900m of structural works present on the Ruby Bay shoreline, consisting of rock revetments on the reserve shoreline adjacent to Broadsea Ave and the Old Mill Walkway.

From the northern end of the Ruby Bay community to the Mapua channel, Table 1 below outlines the ownership of shoreline-land interface (eg Council reserve, riparian title), nature of erosion protection works (existing and under construction) and location of any protection works (eg on Council reserve, behind eroded Council reserve and effectively on the beach):

Table 1: Ownership and Nature of Protection Works on the Ruby Bay shoreline

Distance (m)	Length (m)	Property interface	Erosion mitigation	Ownership of works

0 - 460	460	Council Reserve	Nil – gravel berm	n/a
460 - 615	155	Riparian boundary, on beach	Nil – gravel berm	n/a
615 – 815	200	Riparian boundary, on beach	Timber (vertical and horizontal log) walls	Private
815 – 952	137	Council reserve (effectively on beach)	Private rock revetment	Straddles Council reserve and private land, effectively private
952 – 980	28	Riparian boundary, on beach	Gabion basket wall	Private
980 – 1390	410	Council reserve (Broadsea Ave)	Rock revetment	Council
1390 – 2080	690	Council reserve (Old Mill walkway)	Rock revetment	Council
2080 – 3100	1020	Council reserve (now on beach)	Rock and concrete revetment	Private
3100 - 3500	400	Riparian boundary (on beach)	Rock revetment	Private

Most of the shoreline of the Mapua residential area also has some form of minor erosion protection, being either rock revetment, concrete or timber wall. Erosion mitigation structures are more significant in magnitude along the shoreline 250m north of the Mapua wharf. The only Council erosion protection structure along the Mapua shoreline is the 70m long rock revetment immediately south of the wharf buildings, on the foreshore of the former Fruitgrowers Chemical site. The remaining erosion protection structures are private structures, mostly of a modest nature. North of the wharf, they are located actually or effectively on private land, while structures on the Tahi St shoreline (Grossis Point) either straddle or are located on Council reserve, with the possible odd exception located on private land due to past erosion events. Riparian title exists for 6 properties immediately south of the Council rock revetment adjacent to the wharf, with modest protection works thereafter on private land. A few Tahi St properties may still have a natural foreshore, but are now very much in the minority and are not individually identified.

Setting aside other hazard risks (eg seawater inundation, to be discussed in a section B), all of the erosion mitigation works will require periodic maintenance and potential future rebuilding, to maintain the existing shoreline location. All of the foreshore structures have been built with foundations at a depth suitable for present day sea levels and beach profiles. However, as erosion forces continue to reduce the beach volume immediately seaward of these structures, foundation integrity becomes threatened.

In the case of rock revetments, slumping failure occurs. This has already occurred on the private revetment works along the Ruby Bay shoreline and particularly south of Old Mill Walkway. Complete failure of sections of the revetment has occurred during storm events and has resulted in significant revetment reconstruction to maintain functionality. The older Broadsea Ave revetment, while exposed to lesser wave forces than the revetments further to the south, has nevertheless only been built to a modest (10-20 year) design standard. Some slumping failure (particularly at the southern end) has occurred due to storm wave attack and will also require ongoing maintenance into the future. Some reconstruction works are planned for the southern end of the Broadsea Ave revetment at Chaytor reserve, as part of the current OMW revetment construction works.

The Old Mill Walkway revetment is reasonably well founded and is well designed for the present day beach profile and also accommodates some allowance for moderate future term erosion pressures. The revetment toe has been designed to accommodate a certain degree of slumping failure without causing a loss of structural integrity of the main revetment face. However toe depth will be insufficient to prevent slumping of the revetment if erosion forces significantly lower the beach profile down to inter-tidal platform level near the revetment. The revetment will require significant rebuilding in the medium-longer term, as beach material volumes progressively diminish and expose the toe of the structure.

The privately built vertical timber walls north of Tait St will also eventually fail due to beach erosion reducing foundation depth of the pile (and log) structures. As erosion forces increase, either in response to increased storminess or greater water/wave depths nearshore as a result of sea level rise, complete rebuilding will be required. This may prompt a different type of structure such as a revetment to be built. For the most part, this can likely be achieved within the property, but a number of houses are very close to the beach.

Potentially the greatest concern for both private residents and Council in the future is the type of response to increasing erosion (and more particularly inundation) protection to those properties that currently have a natural shoreline. At present, erosion pressures are very moderate, but are expected to increase with sea level rise. Storm events continue to initiate erosion episodes that cause local residents some concern each time they occur. For now, natural berm rebuilding processes take place within a reasonable time after each event, to subdue action towards a more structural approach to erosion and inundation risk management.

As noted earlier, a narrow (approx 10m wide) Council reserve frontage exists along the northern 460m of natural foreshore. This reserve has not been developed to allow public access to or along the coast and for all intents and purposes appear part of private property adjacent. The southern 70-80% of this reserve is effectively upper gravel beach and berm, although the northern 20-30% still has a modest “dry land” component. The 155m of natural beach front south of the Council reserve and in private title located on the beach itself also has only a gravel berm providing erosion and inundation protection to the houses behind.

It is considered inevitable that some pressure will come to bear on Council in the short-medium term, to either become a party to or grant consent for some form of hazard protection work for this northern shoreline. While erosion hazard risk is relatively minor at the northern end, this increases as one heads southward, as noted earlier. These risks will increase as sea levels rise. However, before any significant sea level rise issues come to bear, it is considered that periodic erosion and inundation events during storms in the next 5-20 years at most, will prompt a desire for longer term erosion and inundation hazard mitigation.

The nature and scale of erosion and seawater inundation hazard (discussed in Section B) in this location in the future may prompt either a structural or regulatory intervention (eg planned retreat) response in the long term for the approximately 20 properties along the remaining 615m of natural shoreline. Erosion hazard risk alone, in a long term climate change scenario, poses an unacceptable threat to these properties on this natural shoreline. A northward progression of some form of structural intervention, to encompass the entire northern Ruby Bay community, or some planned strategic withdrawal, will be required to satisfactorily mitigate hazard risks to buildings by 2100.

EROSION HAZARD RESPONSE OPTIONS

Current and future natural hazard risk exposure can be mitigated by both structural intervention and regulatory management means, or a blend of both. The following are structural response options for erosion hazard risk mitigation on the Ruby Bay shoreline, with implications for both landowners and Council:

(a) Status Quo Structural Protection (No further works and no maintenance of existing works)

This option means that no new structural works will be undertaken by Council or private landowners and that the integrity and function of the existing works will not be maintained into the future. Therefore, on the Ruby Bay shoreline, approximately 1100m of Council-owned rock revetment, 1420m of private rock revetment and 365m of private other works (timber, rock and gabions) will not be maintained. Also, a total of approximately 1050m of natural shoreline from Pinehill reserve to the Toru St causeway to the Leisure Park remains unprotected from erosion.

Consequence of Option (a)

The outcome of this mitigation option is that storm activity and erosion forces will result in continued erosion of the natural beach and gravel berm at the northern end of the Ruby Bay community, and progressively undermine and render dysfunctional the existing erosion/inundation protection works. This might not begin to manifest itself for some time (perhaps 5-20+ years, depending on storm frequency, severity and competence of existing works). By 2100, shoreline retreat to or landward of approximately the line indicated in the Figure 2 attached in the appendix will potentially occur.

This scenario also significantly exacerbates existing potential seawater inundation hazards (see Section B). This is because erosion hazard mitigation structures also include an element of inundation hazard protection, as for the most part they have crest levels at or higher than the land behind. This is particularly the case for all of the revetment works (excluding the Talley property) from the Mapua Leisure Park to the northern end of the Broadsea Ave reserve.

Under this scenario, a regulatory response (development restrictions on “greenfields” land and managed retreat on developed areas) is required. This is because virtually all of the coastal properties along the full length of the Ruby Bay foreshore will be affected by erosion to either a partial or total extent. Some properties have sufficient depth to allow relocation of buildings landward out of the erosion hazard risk area, but in many cases will still be significantly adversely affected by seawater inundation hazard and thus require relocation. Retrieval and disposal of failed structural works will likely be required, for at least aesthetic if not public safety reasons. Council would no longer have any public reserve land adjacent to the coast on the Ruby Bay foreshore other than on the beach itself! Public access along the entire shoreline at high tide would eventually be available only by trespassing on private land.

This scenario is made more complex by the fact that Council has only direct control of structures on the 1100m of Old Mill walkway and Broadsea Ave reserves. A further 1800m of existing private structures currently exist. If Council decides to no longer allow (in the case of the unprotected reserve and private land at the northern end of Ruby Bay) or maintain erosion protection on these reserves, then a planned retreat policy will also need some accompanying planning mechanism that prevents construction or ongoing maintenance of private erosion/inundation hazard mitigation structures. In this scenario, further development of much of the coastal plain cannot be condoned in the long term to 2100, not so much from an erosion hazard perspective (which is significant enough in its own right), but from both a seawater and freshwater inundation perspective. These hazard risks will be further discussed in Sections B and C.

With respect to the estuary margin adjacent to the Mapua community, erosion hazard risk has historically been relatively slight. Nevertheless, most properties now have some form of erosion protection on their coastal boundary to offset the frittering erosion caused by wave lap. In many instances, erosion protection measures are more for cosmetic/landscaping purposes than a genuine need to mitigate a significant or persistent erosion trend. The most significant erosion protection structures are on the shoreline of those houses north of the Mapua wharf, where exposure to waves and onshore wind is the most severe.

Due to the relatively benign (for the most part) wave climate within the estuary, most existing structures, particularly if reasonably well built, will continue to mitigate the low level erosion hazard risk for many years to come. However, many of the properties on the western shoreline adjoining the Mapua Channel have dwellings or buildings with minimal setback to the water's edge. In this location, failure of erosion mitigation structures may have increasingly significant adverse effects on building integrity, particularly if erosion rates increase as a result of sea level rise or increase in storm frequency or intensity.

(b) Limited Increased Structural Protection
(Allow new works and maintain present works, at existing protection level)

This option means that new structural works will be undertaken by Council or private landowners for present day coastal processes on remaining unprotected shorelines, and that the integrity and function of the existing works will be maintained into the future, either through maintenance or replacement work as required. To provide a consistent level of erosion mitigation on this shoreline, this requires Council maintaining the 690m of new rock revetment on the Old Mill Walkway (OMW) to its present standard and upgrading the 410m of Broadsea Ave revetment to the OMW standard. The 1420m of privately owned rock revetment will need upgrading to the OMW standard and the 365m of other private structures will need maintaining and upgrading to the OMW standard as failure occurs. Some 1050m of natural shoreline will progressively (as erosion risk varies) require erosion protection works commensurate with the wave forces prevailing, up to OMW standard.

Consequences of Option (b)

This option effectively maintains the shoreline at its existing location. However, the structures will incur an ongoing maintenance cost under a present day wave and storm climate. This maintenance will eventually include reconstruction of some or all of the protection measures. This is because structure foundation depths are largely insufficient to provide a stable foundation for the structures in the long term. On an eroding coastline, intertidal beach platform levels will progressively edge towards the toe of much of the existing protection works, having been founded on a more elevated beach profile.

Maintenance costs of existing structures are likely to significantly increase in the future, in response to climate change effects. Greater water depths allow waves with higher energy to impact the shoreline/structures, increasing forces that can dislodge rock material from the face or crest of revetments. Revetment crest levels can be eroded due to increased frequency and volume of water overtopping the structure.

Both Council and private landowners would be committed to maintaining and potentially rebuilding erosion hazard mitigation structures. This may be acceptable as a planned special rate to the beneficiaries of this work, or the wider ratepayer community. However, the costs of providing and/or maintaining hazard mitigation structures on private land is likely to be an issue..

The effectiveness of erosion/inundation hazard mitigation structures is dependent on the entire structure remaining functional as a whole unit over the prospectively 3.5km length of the shoreline. Council may come under considerable pressure from private landowners to take over and maintain the balance 1.8-2.4km length of private works, if the adverse effects of increased erosion and particularly inundation hazard in areas where private works are abandoned are to be avoided.

The cost implications of this possible option could be very significant for Council if private works are abandoned, with the almost certain outcome of increasing erosion/inundation hazard risks to others beyond the extent of the private propert(ies) in question. No significant intensification of development of land along this shoreline, but particularly in the area south of Broadsea Ave to the Leisure Park, should be contemplated unless erosion hazard risk management measures are maintained in perpetuity, taking into account future maintenance and reconstruction needs, including toe depth, rock size and crest height (to mitigate overtopping damage and backshore seawater inundation hazard risk).

(c) Maximum structural protection
(Allow new works and enhance existing works for future wave climate)

This option is the same as for (b) above, with the exception that all existing and new works will need to be upgraded or built to meet increased design wave and coastal process conditions (compared to the present), due to sea level rise and potential increased storminess in a future climate change scenario .

Consequences of Option (c)

As for Option (b), except that all existing rock revetment works and other protection works by private land owners will likely need to be reconstructed so as to have a foundation depth around 2m lower than present, and be more robust due to increased wave forces. A deeper foundation depth is necessary because the present beach profile will shift landward as the beach erodes. There is a net loss of beach sediments from the beach system at present – hence the long term erosion trend, which will increase with higher sea level. Also, as sea levels rise, there will be a nearshore trend to a lowered beach profile, in an effort to achieve a stable beach profile adjacent to the rock revetment works.

A second consequence is that the present rock armour layer grading (both Council and privately owned) will need to be increased in size, so as to continue to provide a stable, interlocking revetment face. As sea levels rise and water depth adjacent to the structure increases, prevailing onshore storm winds will generate larger waves that will break nearer to the structure than at present. Wave energy increases in proportion with the square of the water depth, rather than directly proportionally with water depth. Thus, for example, if water depth 100m from shore on a present MHWS tide increases from around 2.5m to 3.3m with 0.8m sea level rise, water depth will have increased 32%, but wave energy will have increased at least 75%. Existing rock armour size will be much less stable in a future sea level rise storm than at present and it is likely that an additional armour layer of larger rock will be required (or at least incorporated into a rebuilt armour face), to provide ongoing structural integrity and stability.

It almost goes without saying that the costs of providing a wall designed to cope with future sea level rise wave forces will be considerably more expensive than the present day revetment configuration, due to increased depth and rock size requirements. Other forms of erosion hazard mitigation built by private landowners (gabions, timber walls etc) will also need reconstruction to a higher design standard.

Approximate Costs

Approximate present day costs of providing rock revetment protection to existing foreshore margins requiring little if any bund construction (such as the OMW foreshore) average just over $2000 per lineal metre. The cost of a rock revetment needing substantial stopbank construction to form a base (such as south of OMW to the Mapua Leisure Park) approaches $3000/m. For a 0.8m sea level rise 2100 climate change scenario, for the necessary increased depth and height of stopbank, rock armour and rock armour grading (larger grading more difficult to obtain locally), rock revetment construction costs are likely to roughly double. This does not take into account landowner issues, spatial constraints requiring additional reclamation, resource consent processes, future maintenance costs and the like.

Thus for the 3500m of Ruby Bay shoreline, construction cost of a rock revetment to meet 2100 climate needs for protection against erosion and inundation can readily exceed $20 million. For the balance 2.7km of inner estuary shoreline of the Mapua community, a number of special treatments for inundation protection may be required (eg concrete wall barriers) due to spatial limitations. While wave runup is less of an issue than on the open coast, resulting in a reduced scale of erosion/inundation mitigation structure, other issues such as spatial limitations adjacent to built development are likely to require a similarly costly response per lineal metre as the Ruby Bay foreshore. For the Mapua community, the cost of full structural mitigation of erosion and inundation hazard to the approx 2.7km estuarine shoreline in a 2100 climate, 0.8m seal level rise scenario is likely to exceed $10-15 million.

All of the approx 6.2km of Ruby Bay-Mapua shoreline is subject to erosion and inundation hazard risk at present (although to varying degrees) and these hazard risks must be dealt with in a 2100 climate change scenario. Rough order construction costs for full structural protection (excluding land issues, consent processes, structure maintenance and the like) are likely to exceed $30-35 million.

Mapua shoreline

With respect to the estuary and channel shoreline adjoining the Mapua community, all but the shoreline north of the wharf is subject to relatively minor wave lap erosion. More substantial erosion mitigation works are constructed on the shoreline north of the wharf, are more than adequate to mitigate the erosive effects of the mostly benign wave climate and with periodic maintenance should remain serviceable for many years. Relatively modest erosion mitigation structures are all that are required to preserve the often narrow separation between buildings and the shoreline. However, erosion hazard risk will also increase in this area into the future and present-day modest erosion mitigation structures will inevitably require strengthening or replacement with more appropriate structures. Overall, seawater inundation is considered to be the more significant hazard risk for the future in the inner estuary area, in response to sea level rise.

New structures could impact on the aesthetic appeal of the Channel edge.

B SEAWATER INUNDATION

(i) Land Levels and Inundation Mechanisms

The Ruby Bay – Mapua coastal plain is comprised of a number of distinguishing features including old beach ridges, but overall is very low lying. The land level of the Mapua – Ruby Bay plain is almost entirely below 4m amsl, with substantial areas below 3m amsl. The Ruby Bay community is typical of coastal developments post – 1950, with houses closely abutting the shoreline between Pinehill Reserve and Broadsea Ave. The coastal strip at the northern end of the Ruby Bay community is very narrow, with housing located in the low swale between the narrow backbeach gravel berm and the coastal cliff behind. Progressively to the south, the shoreline row of houses are built either on the frontal dune immediately behind the beach, or on the slightly lower lying land behind.

South of Broadsea Ave, a frontal dune of slightly elevated land continues south to taper away at the Leisure Park. Behind this frontal dune lies a wide and very low lying area, that would if it were not for the Toru Street causeway, be largely estuarine in nature. Landward of this, ground levels increase a little and comprise the remainder of the coastal plain on which is located part of the Mapua settlement adjacent to the foothills.

Council records now include LIDAR-derived 0.5m contours of the land above present day mean sea level and are shown in Figure 1 appended to the end of this report. The highest predicted tides (HAT) for this coastline, without any barometric pressure, wind, storm surge or other climatic effects, reach a height of 2.3m amsl. Recent analysis of Port Nelson tide records has been undertaken by NIWA (Client Report HAM2009-124 (Aug 2009) to the NCC entitled “Review of Nelson City minimum ground level requirements in relation to coastal inundation and sea-level rise”). This analysis indicates that storm surge can elevate sea levels by 0.6m and combined tidal effects (seiche, ENSO/IPO and seasonal effects) can add 0.35-0.55m sea level elevation.

Extreme value analysis of the useable post -1985 Port Nelson tide record has been undertaken. Figure 3 below shows the water levels reached during tide/storm events of increasing size (or decreasing probability). For example, an extreme present day storm event on a high spring tide, having an AEP of 0.5% (or an event that is expected to occur only once every 200 years on average) will reach or exceed a “sheltered water” height (no wave runup or other wave effects) of 15.0m (NCC datum), or 2.93m above mean sea level (NVD 1955).

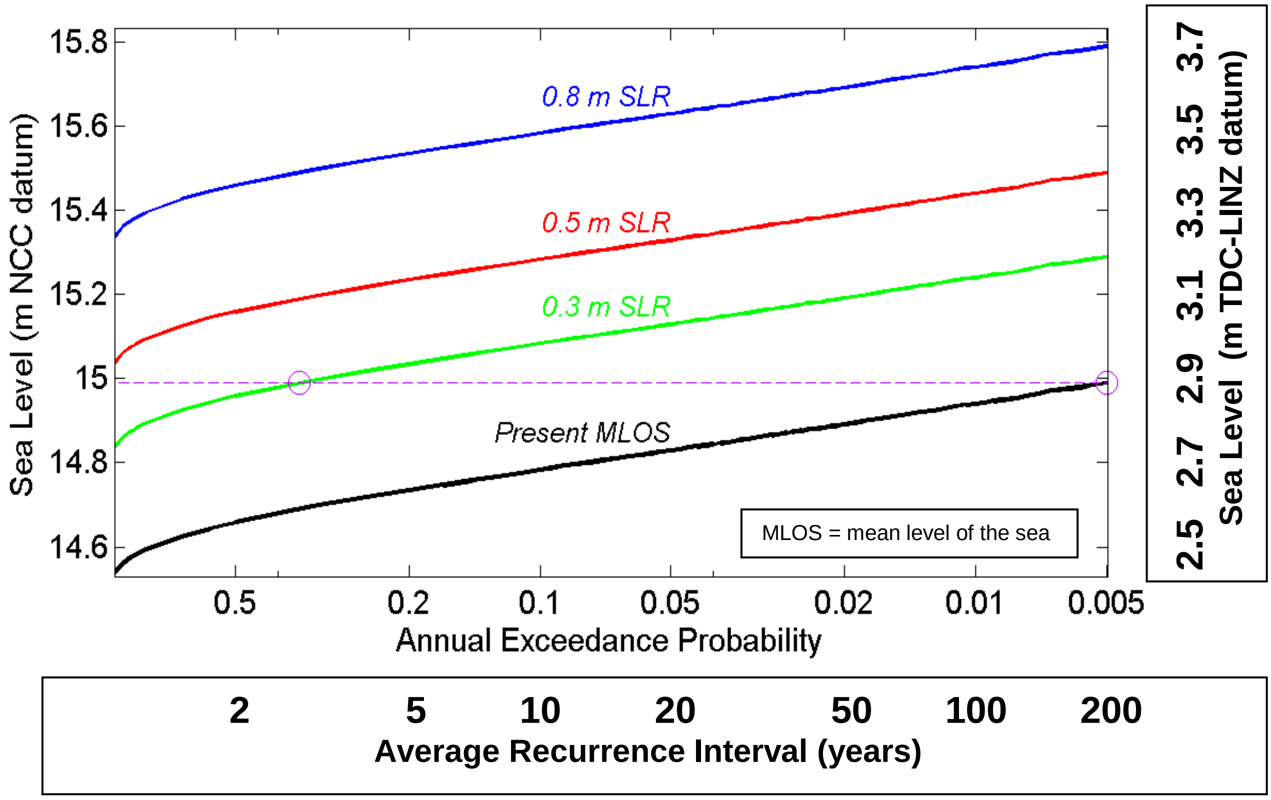


Figure 3: Storm Tide Height – Probability of Occurrence (Port Nelson)

Figure 3 also shows how the probability of reaching certain present day storm/tide water levels changes as a result of sea level rise. For example, with a 0.3m sea level rise, the same 2.93m water level reached only once every 200 years on average today has an AEP of 0.36, or a probability of being reached or exceeded once every 2.7 years on average, and will reach or exceed that 2.93m height more than once a year when sea level rise exceeds 0.5m. This situation will be closely replicated at Mapua, as the Nelson and Mapua predicted tide levels (eg MHWS and MSL tide elevations) are within 0.1m of each other.

(ii) Future outlook for Inundation Hazard Risk

Present MfE guidelines suggest that Council plans provide for a 0.5m sea level rise by 2100, with the consequences of a 0.8m sea level rise taken into account. This figure is likely to rise as ice sheet effects, largely unidentified, are further modelled. Thus, by 2100, for low to medium consequences of sea level rise on developments, peak static sea level at the top of an extreme high tide/storm event (AEP of 0.5%, assuming climate change does not affect storm surge magnitude) range from 3.43m- 3.73m amsl. When the upper 0.5m of a tide has duration of 3 hours or more, it is not difficult to envisage how susceptible to seawater inundation low lying parts of Mapua will become in the future, during an extreme tide/storm event.

As noted earlier, sea level will reach nearly RL 3.0m every 2.7 years on average for a sea level rise of 0.3m (currently projected to occur by 2050) and more than once a year for sea level rise at or exceeding 0.5m (currently projected to occur by around 2070). No wave effects have been taken into account in this calculation. However it is obvious that a particular “sheltered water” height will be reached in a smaller storm/tide event because of wave runup and wave set effects.

Wave effects are present to some degree even in this sheltered, estuarine location and with the low lying areas exposed directly to the open sea through the estuary mouth. On the open coast shoreline of Ruby Bay, wave set and wave runup effects are greater still and will increase with increasing water depth in a climate change scenario. However the effects of wave runup and set up within the estuary and on the open coast, in terms of increasing the probability of a particular "sheltered water" height being reached, have yet to be calculated. Figure 4 below shows the latest sea level rise projections to 2100.

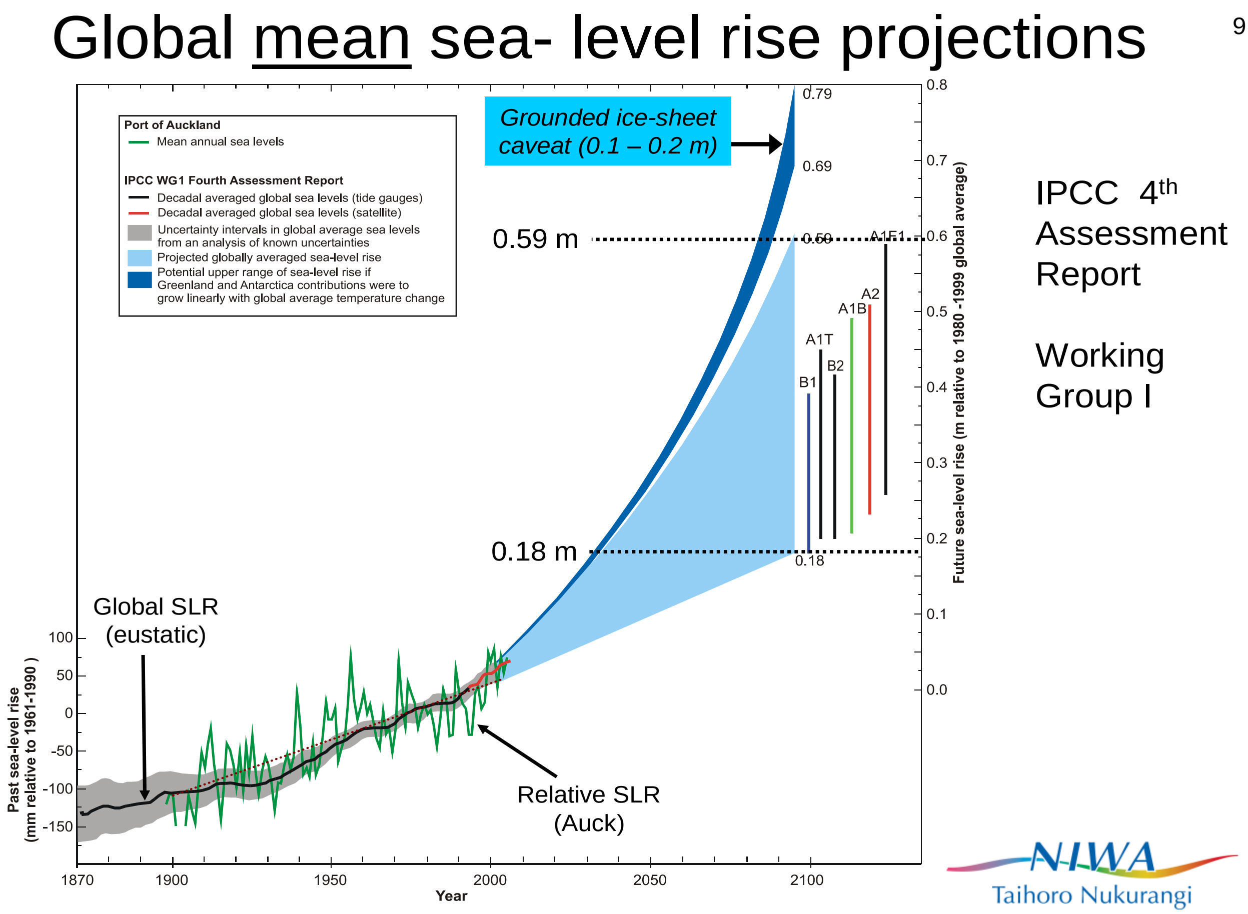


Figure 4: Global Mean Sea Level Rise Projections

(iii) Inundation mechanisms

(a) Wave run-up

Seawater inundation of the Ruby Bay – Mapua coastal plain can occur in two ways. The first is via wave runup overtopping the shoreline margin. This will be more significant on the Ruby Bay shoreline than within the estuary, where wave height will be comparatively lower. Wave runup potential increases with increasing onshore wind strength and water depth near shore. Therefore strong onshore winds coupled with extreme tides generate a wave climate on an open coast that induces a certain wave runup on the shoreline. This is further exacerbated by climate change and sea level rise effects that significantly increase inundation potential, as deeper nearshore water allows larger waves to be generated for the same wind strength. Consequently larger waves reach the shoreline unbroken, impacting on the shoreline with significantly greater energy and thus runup potential.

(b) General seawater invasion

The second mechanism of inundation is by general seawater invasion of lower lying land, either directly or by seawater back-flowing through pipe outfalls and drainage networks into the lower lying hinterland. The dominant mechanism will relate to the land level at and behind the shoreline, as well as the availability of flow pathways inland from the coast.

INUNDATION HAZARD RESPONSE OPTIONS

The existing erosion hazard mitigation works at Ruby Bay (and to a lesser extent at Mapua) also mitigate inundation hazard risk. This is because the erosion mitigation works (rock revetment, timber wall and gabion structures) are built to a height that is the same as or higher than the land behind. On the Mapua estuary shoreline, most erosion protection works tend to be at or less than the land level behind and therefore do little to mitigate inundation hazard risk.

On the Ruby Bay shoreline, all of the rock revetment works from Tait St to and including the Leisure Park provide significant inundation hazard mitigation, due to the crest level of the revetment (around 4.5m amsl) being at least 1-2 m higher than the land level immediately behind the revetment. The private erosion mitigation works north of Tait St are built generally to the height of the gravel beach ridge (around 4-4.5m amsl) and so provide no additional inundation protection to the land behind.

The present revetment works adequately protect the Ruby Bay (and Mapua) shoreline against erosion hazard for the present wave climate. Reasonable inundation hazard protection is also provided, particularly for the land south of Tait St, although wave overtopping in a storm/high tide event already occurs. By 2100, projected sea level rise will have a significant impact on existing erosion and inundation hazard mitigation works, unless these works are reconstructed accordingly.
The requirements for continuing effective erosion hazard mitigation for a 2100 sea level have already been outlined. To satisfactorily mitigate inundation hazard for a projected 2100 sea level will require significant elevation of the backshore, or bund wall construction at alternate locations landward of the shoreline.

The inundation hazard mitigation measures necessary for a 2100 storm event vary according to whether the land at present is largely unbuilt or is existing built community. In the “unbuilt” land situation, the consequences of an inundation event are likely to be comparatively minor and temporary. Low lying land below RL 3.0 will likely be significantly affected by overland flow or ponding in such an event. The frequency of such occurrences will still be dependent on and moderated by proximity to the coast, land level and presence of any mitigation measures. However, essentially land will be flooded to some degree, but infrastructure assets and the health and safety of people and dwellings will not be significantly compromised, as housing development is very limited.

For the built areas of Ruby Bay and Mapua, the potential adverse effects of a 2100 severe storm/high tide are rather more extreme. On the Ruby Bay foreshore, wave run-up overtopping the beach crest and inundation of the low lying land (up to and exceeding land levels at RL 4.0 amsl) back to the rear coastal sea cliff will likely occur. Within Mapua, most of Tahi St and Iwa St below RL 3.5m amsl (or higher) will likely be affected by seawater inundation. The consequences of not providing effective erosion and inundation hazard mitigation measures on the existing built community of northern Ruby Bay and Mapua (particularly Tahi St and parts of Iwa St), especially within 150m of the present shoreline, include major property and infrastructural damage, failure and/or loss, as well as considerable risk to community health, wellbeing and safety.

There are several structural response options for sea inundation hazard risk mitigation:

(a) Status Quo Structural Protection
(No new works and no maintenance of existing works)

On the Ruby Bay foreshore, the existence of a natural shoreline over the northern 600m and erosion mitigation works constructed on the balance of foreshore to the Leisure Park has already been described (refer to Erosion Option (a)). Little if any inundation hazard mitigation works exist beyond prevailing land levels on the estuary shoreline adjacent to the Mapua community.

The erosion mitigation works have a crest height of 4.0m - 4.5m amsl, with the concrete wall immediately south of the Old Mill Walkway being around 5.0m amsl. Apart from two properties that have been significantly infilled, land levels behind the erosion protection works are at least 1m lower than the crest level of erosion mitigation structures facing that land. This is especially the case for almost all of the land south of the concrete wall south of the Old Mill walkway reserve, where swales between remnant dune features are 2m or more below the crest of the rock revetment.

Consequences or Option (a)

During storm events coinciding with high spring tides, all of the erosion mitigation structures are overtopped to some degree by wave runup. At the northern end of the Ruby Bay beach, there is a long history of periodic wave runup overtopping parts of the backshore gravel ridge. This has caused significant seawater inundation in the low swale within several of the properties. Relatively minor inundation hazards have been experienced by the bulk of the remaining properties along the foreshore north of Tait St..

However, southwards along the coast, the partial sheltering effect of the Kina Bluff and slightly elevated intertidal platform is lost, with greater wave action and wave runup occurring. The Broadsea Ave reserve and frontage of the foreshore properties have been significantly affected by seawater inundation. During Cyclone Drena in Jan 1997, significant volumes of seawater overtopped the clay bund wall on the reserve frontage, flowing through to Broadsea Ave and causing significant ponding in the street. The clay bund was of similar height to the existing rock revetment. So far, seawater inundation hazard has narrowly avoided affecting most of the backshore residents along the avenue.

South of the Old Mill walkway, significant inundation of the low lying land behind the erosion protection works and the rear dune system has occurred by wave runup overtopping the revetment works. In the Cyclone Drena event, significant inundation of the low lying land well inland of the clay bund wall occurred, although the wall provided somewhat less defence against overtopping than the current revetment. Even the higher land level of the property protected by the concrete has been affected by seawater inundation to a minor degree. This is due to the near-vertical nature of the seawall. Waves impacting on the seawall are forced upwards, with water then being driven inland by the strong onshore wind.

In summary, varying degrees of seawater inundation of the backshore and hinterland of Ruby Bay has periodically occurred. Erosion mitigation measures have acted to limit but not fully negate inundation risks. If no further erosion protection works are built and the existing works are not maintained, then the inundation hazard risks will significantly increase into the future, via two possible mechanisms.

The first mechanism is by wave runup causing periodic overtopping of an intact backshore gravel berm or erosion mitigation structure. The severity and frequency of this occurrence will increase as a result of any climate change and sea level rise, or increased storm intensity or frequency.

The second and much more significant mechanism for increasing inundation risk arises from the progressive erosion or failure of backshore gravel berms or erosion mitigation structures. As these structures fail, the generally lower lying land behind these features or structures becomes increasingly exposed to seawater inundation, in both aerial extent and volumetric terms.

Council has information from past coastal process modelling for erosion management purposes, that indicates that seawater inundation potential is not fully avoided (other than spray effects) until revetment structures are over a metre higher than present (for existing climatic conditions). It has not undertaken any computer model simulations of potential seawater inundation scenarios, but there is now budgetary provision in the annual plan to undertake coastal process modelling over the next 5 years.

In the interim, a qualitative assessment has been undertaken of the potential extent of periodic maximum seawater inundation. This is based on a 2100 climate with 0.8m sea level rise, in an extreme high tide storm event. The extent of possible inundation is assessed, taking into account the topography of the coastal plain, distance from the shoreline, and whether or not current erosion/inundation mitigation measures remain functional.

The estimated extent of inundation shown in Figure 2 attached in the appendices reflects a scenario where it is assumed that erosion protection structures have failed and no future hazard mitigation works are built. In this extreme tide/storm/sea level rise scenario, “worst case” seawater inundation of nearshore land by wave run-up/overtopping, combining with hinterland inundation from either landward penetration of waves or simple inland flow due to low land levels, is mapped. A nominal upper level of RL 3.5m is mapped for the maximum extent of hinterland seawater inundation in this scenario. Land at RL 4.0m and higher but immediately adjacent to the coast will be dominated by wave runup effects. Land around RL4.0m within 200-300m from the coast may also be affected by overland flow or inundation, but progressively reducing with increasing distance from the coast. Inundation of land more distant from the coast may occur up to RL 3.0m.

In this option of no further provision or maintenance of foreshore hazard mitigation works, occupancy of all shoreline properties south to at least the Old Mill walkway becomes progressively more subject to hazard risk and eventually becomes untenable as one approaches a projected 2100 climate. This is a direct result of the effects of severe and likely increasing persistent erosion and periodic extreme seawater inundation hazards.

It is important to note that the extent of potential inundation hazard shown in Figure2 is both an unmodelled, qualitative assessment and is for an extreme tide/storm/0.8m sea level rise scenario. The extent of inundation is only postulated and is also periodic, having an annual probability of occurrence. The extent of inundation can only be assessed through coastal inundation modelling and is a logical next step to pursue, particularly for the low lying parts of Mapua. In addition, the annual probability of inundation occurrence will gradually increase up to the extreme tide/storm/0.8m sea level rise scenario, as that scenario develops.

With respect to the estuary shoreline adjoining the Mapua community, little to no seawater inundation mitigation measures exist in tandem with the erosion protection measures on this shoreline, as most erosion mitigation measures are at a relatively low level. Seawater inundation risks will increase beyond that potentially caused by the coincidence of storm activity during a high spring tide/flood event in the Waimea River, principally as a result of climate change and sea level rise.

Grossis Point and southern Iwa St are locations vulnerable to inundation, particularly in a 2100 scenario of 0.8m sea level rise/storm event/high tide. Most of the Tahi St present day residential area is located on land around 3m amsl. Present day HAT coincident with a maximum recorded storm surge in Tasman Bay alone reach a similar elevation. Under this option, Tahi St will be significantly affected by seawater inundation hazard prior to and certainly in a 2100 scenario with sea level rise at or higher than 0.8m, to a point that continued occupation will become untenable..

(b) Limited Increased Structural Protection
(Allow new works and maintain present works at existing level)

This scenario has very similar issues with respect to the potential threats and costs of maintaining the integrity of existing structures as for the erosion hazard risk. However, maintaining the integrity of existing erosion mitigation measures into the future does not also mitigate existing or future seawater inundation hazard risk to land or foreshore dwellings.

The more significant hazard risk faced by the property owners along the 600m long natural shoreline at the northern end of the Ruby Bay community is inundation rather than erosion, both in the present day and most likely in the future. Because of extant inundation hazard risks, several houses have been built or added to in recent years with minimum floor level requirements. However, in a future climate scenario, as sea levels rise and/or storminess increases, wave overtopping of the existing backshore barrier will increase in frequency and inundation hazard risk will gradually intensify.

Buildings along the northern shoreline are located on a thin sliver of land between the road and open coast. For the remainder of the foreshore properties a little further to the south to Broadsea Ave, subdivision or simply the presence of a landward property or road restricts options for inundation risk management. Many dwellings are set back on the property to the extent practicable and some also have floor levels that elevate the structure well above low lying land levels, or are located on a remnant dune ridge. Some of these buildings have either replaced or are significant renovations to the original structure on the site. However, most buildings on this section of shoreline were the first buildings to be built at Ruby Bay, beginning in the 1940-1950s. They have inappropriate floor levels to mitigate future inundation hazard risk to the building, and are often sited on lower lying land in close proximity to the shoreline.

Even with appropriately set floor levels to mitigate inundation risk to the building, the land on which they are sited will be progressively more affected by inundation hazard and become less functional as a residential site. The only way to mitigate the 2100 inundation hazard risk to the land is to provide an elevated backshore barrier to prevent wave overtopping. This barrier will need to be significantly higher than the existing backshore level, perhaps 1.5-2.0m higher than present. This has significant cost implications for both private land owners as well as Council, as all of the shoreline will need to be elevated to a similar height.

Perhaps for some of the very northern properties, and potentially for a number of other properties in close proximity to the shoreline down to the southern end of Broadsea Ave, if erosion/inundation hazard mitigation measures are built or retained with their crest level to only present day elevation, the inundation risk is very likely to become untenable in a 2100 climate scenario, due to wave overtopping. Inundation risk is also very likely to extend a significant distance inland, affecting at least all the properties between the shoreline and Stafford Drive (and to the coastal cliff at the very northern end) from Pinehill Rd to Tait St, and all of Broadsea Ave.

Further to the south of Broadsea Ave, seawater inundation overtopping existing revetment structures will significantly affect all of the low lying land back to the rear dune system, potentially penetrate into the very low lying land to the rear of these dunes through any low access, and significantly affect all of the Mapua Leisure Park.

The Toru Street causeway to the Leisure Park is a key impediment to seawater inundation of the low lying land behind the Ruby Bay backshore. While the causeway is at little risk from coastal erosion forces, it has the potential to be overtopped by seawater in a 2100 climate change scenario. Significant overtopping will occur in a 2100 climate if a severe storm event coincides with very high spring tides, a scenario that will also cause overtopping of the land margin at both ends of the causeway.

In summary, maintaining existing or building new foreshore erosion/inundation mitigation structures to existing crest elevations is an adequate (but not complete) hazard mitigation measure for the present. Periodic wave overtopping will occur along the Ruby Bay shoreline during storm events coinciding with high tides, which will affect a modest number of properties to some degree. Structure maintenance will need to continue indefinitely into the future, to maintain structure integrity and some degree of hazard mitigation. However, under the influence of climate change - sea level rise, the frequency and severity of wave overtopping increases. Wave forces on the structures as well as erosion forces at the base of the structures also increase. These factors will progressively lead to greater maintenance requirements and probable reconstruction, resulting from partial collapse of revetment armour rock or complete failure altogether.

As noted earlier, with respect to the estuary shoreline adjoining Tahi St and Iwa St little to no seawater inundation mitigation measures exist. The incidence of wave overtopping the structures north of the wharf area will increase here as for the open coast. For Tahi St properties, new works will be required to mitigate inundation hazard risk. Hazard mitigation measures available to the community include progressive elevation of floor levels wherever possible, or managed retreat. A more invasive mitigation measure ultimately involves the construction of a tide exclusion barrier entirely surrounding the peninsula. This will be an interesting and potentially costly engineering exercise that may be problematic to implement, depending on the nature of the barrier proposed (vertical wall or earth bund), due to the proximity of housing development to the shoreline.

Managed retreat is a practical but probably unpalatable option for most landowners. However, it is an effective inundation hazard mitigation measure in the long term, given the severity of the inundation hazard risk by 2100. Inundation hazard may be avoided if over time a “no rebuild or removal” policy is introduced into planning documents now. Any bare ground, such as the former Fruitgrowers Chemical site, should have an appropriate minimum FGL so that any development on that land is not subject to inundation risk in the 2100+ future.

(c) Full Hazard Mitigation
(Allow new works and enhance existing works for future wave climate)

Fully mitigating potential coastal erosion and seawater inundation hazard risks to the Mapua - Ruby Bay shoreline will involve enormous structural intervention over more than 6km of shoreline. Existing revetment and wall structure foundations will need to be more deeply entrenched, probably to a depth at least 1-2m lower than present. Crest elevations also need to be increased to at least 1.5-2.0m higher than present along the Ruby Bay shoreline to the Waimea estuary channel. Around the inner estuary shoreline, the Toru Street causeway will need raising at least 1m and the low lying parts of the Mapua community will require new inundation hazard mitigation structures to be built. The cost of this will be enormous (likely to be in the tens of millions of dollars in today's terms).

It is prudent to consider the possibilities of a mixed planning and structural mitigation response to erosion and seawater inundation hazard risk, particularly in combination with and in response to a third hazard risk faced by parts of Ruby Bay-Mapua - that of floodwater inundation resulting from rainfall runoff from the land.

(d) Mixed Structural and Land Infill Options

As described earlier, the Ruby Bay – Mapua coastal plain comprises both built and essentially unbuilt land and has variable (but generally low) land level. The existing and potential future erosion and inundation hazard risks are variable, both in extent and location. Seawater and freshwater inundation (see Section C) is a particular hazard risk to significant areas of low lying built and unbuilt land. There is potential for inundation hazard risks to be reduced or mitigated by raising land elevation through land filling. However the potential for (and consequences of) land filling in conjunction with other structural options for inundation (and to a lesser extent erosion) hazard risk mitigation vary for existing built and unbuilt land and the degree of land filling that occurs. Land filling is a necessary prerequisite for development in all situations, but the consequences of doing so may be unacceptable in some locations. Mixed structural response options and consequences of each include:

(i) Land Filling – West of Seaton Valley Stream to Stafford Drive/Aranui Rd

Land bounded by the Seaton Valley Stream, Stafford Drive, Aranui Road and the northern end of Iwa St is reasonably set back from the coastal margin (and therefore coastal inundation effects). Land levels are mostly above RL 3.5m amsl and therefore reasonably safe from freshwater inundation risk, as shown in Fig.2. This land could be potentially further developed, with modest filling of the lower land levels on undeveloped land areas (to RL 4.0m+), to provide for servicing cover requirements and mitigation of risks associated with ponding from incident rainfall. Some modest stopbank bunding may be required adjacent and west of the Seaton Valley Stream, to prevent any risk of seawater inundation from the NE and SE, as well as from floodwater breakout from the Seaton Valley stream.

(ii) Land Filling –East of Seaton Valley stream and Stafford Drive

A strip of land approximately 150-200m wide east of Stafford Drive, south of Broadsea Ave and immediately east of the Seaton Valley Stream and north of the estuary inside the Toru

St causeway may potentially be able to be further developed. The potential for further development is more critically dependent on significant land filling to mitigate potential flooding and seawater inundation hazards risk than land west of Seaton Valley stream. This land is lower lying than land in (i) above, being mostly between RL 2.5-3.5m, and is located nearer the coast and estuary. Land filling to RL 4.0-4.5m+ as well as more substantial stopbank bunding on the eastern and southern margins would be required to mitigate freshwater and seawater inundation risk. Both land filling and bund construction may, however, increase the inundation risk potential on other areas to the north, east and south and inundation modelling is required (particularly for seawater inundation risk) to confirm the practicality and effect of filling in some or all of this area.

(iii) Land Filling – South of Broadsea Ave and west of the foreshore margin

This option requires substantial filling of the lowest lying land on the Ruby Bay-Mapua plain prior to any development occurring. This area currently functions as a detention area for freshwater flooding from the Seaton Valley Stream and is subject to significant seawater inundation risk both at present (nearer the coast) and particularly in a future 2100 climate change scenario. No infilling should occur in this area without first modelling the effect of removing floodwater detention capacity in this area and increasing flood hazard risk onto adjacent land. In addition, this land would require significant erosion and inundation protection to be provided along the foreshore, to avoid the effects of wave runup and seawater inundation risk in this area. Land would also need to be filled to RL 4.5m or more, so as to provide sufficient land elevation for adequate provision and functioning of infrastructure services. This option is considered unlikely to be feasible from both a land fill cost perspective and due to the adverse effects of removing floodwater detention capability.

Other smaller scale land filling scenarios are present within the Ruby Bay – Mapua floodplain. These include:

(iv) Land Filling – Ruby Bay Built Development Area

Land filling in low lying areas east (and to a lesser extent west) of Stafford Drive in Ruby Bay is generally not a viable proposition. This is because the effect of filling low lying land in these areas will, in almost all cases, reduce ponding or detention storage volume for stormwater runoff and/or wave runup and therefore exacerbate flooding risk on the remaining low lying land adjacent. This is particularly so for the low lying land between Stafford Drive and the coast, where some form of detention storage will likely be required, more so particularly in a future 2100 sea level rise scenario. This occurs due to stormwater outfalls to the coast become increasingly submerged at higher tides and therefore have reduced outflows, unless pumping or similar is provided. Similarly, the risk of wave runup into low lying areas presently periodically occurring will further increase unless comprehensive inundation protection is provided.

(v) Land Filling – Mapua Built Development Area

Land filling in the built area of Tahi St is potentially possible as the area is generally all at a similar level, with few areas acting in a detention capacity during periods of high intensity rainfall. Land filling, provided it did not shed incident rainfall onto adjacent property, would have no effect on neighbouring land, but would elevate land further from the effects of inundation from the sea.
In other parts of Mapua contain areas of low lying land, however, that cannot be readily filled because (as in Ruby Bay) it will exacerbate flood hazard risk on adjacent property.

Land filling can only occur on a case by case basis, where additional drainage provision occurs to offset potential adverse effects on adjacent land. Such areas include the low lying swale land in Iwa Street.

C FLOODWATER INUNDATION

(i) Catchment Runoff

Council has recently completed rainfall runoff modelling and inundation studies for the catchments draining into Seaton Valley and the Tait St area. This work was undertaken as part of both the design upgrade for the Seaton Valley Stream channel between Stafford Drive and the estuary and upgrade of the stormwater runoff reticulation/drainage network servicing Ruby Bay. A variety of floodwater inundation scenarios were modelled. These included a design rainstorm occurring in a present day climate (ie current sea level) and level of development, through to future full development of zoned land with 0.5 and 0.8m sea level rise. All modelling work assumed that presently proposed works to upgrade the stormwater reticulation in south Ruby Bay, Seaton Valley drainage works and Leisure Park causeway culvert works, were undertaken.

The causeway is modelled as a wall of infinite height. Therefore the extent of flooding is influenced by the amount of seawater that can backflow into the upper estuary through the one remaining ungated culvert pipe, rather than also by overtopping the Toru St causeway. The tide level also controls the rate at which floodwater can exit from the area upstream. For a future development scenario and 0.5-0.8m sea level rise, in land downstream of Stafford Drive, floodwaters pond to an elevation of just under RL 2.5m (if the Lower Seaton Valley (LSV) land upstream of Stafford Drive is excluded from detention storage) or less than 0.1m lower if LSV land is used fully for floodwater detention. The effect of 0.5 and 0.8m sea level rise amounts to a maximum of 39mm at the causeway, to 1mm at Stafford Drive. In summary, for a range of development and climate change scenarios, the extent of flooding does not significantly vary and reaches an elevation just under RL 2.5m amsl in the low lying area upstream of the causeway and northwards to Ruby Bay.

The extent of floodwater inundation modelled at Ruby Bay changes modestly but not significantly depending on the model parameters chosen. Discernible localised effects do occur, having around 0.2m elevation difference. However occurrence and essential character of the inundation pattern under varying development and sea level rise scenarios does not fundamentally alter, particularly in terms of properties affected.

Figure 2 in the appendix attached shows the maximum extent of floodwater inundation that occurs for the worst case scenario modelled, being full future development of the current and proposed zones in an extreme 100 year annual recurrence interval rainfall event and 2100 climate with 0.8m sea level rise. The areal extent of this flooding pattern is modestly but not greatly different from that which would occur in the present day in an extreme rainfall event.

The effect of removing significant flood-prone areas from inundation hazard risk has, other than for the LSV land, not been modelled. The low lying land north of the causeway is subject to both floodwater and seawater inundation hazard risk. Filling of significant areas in this location will have both present and future potential adverse effects of more than a minor nature on the balance land. It may also extend the flood hazard risk area onto land that is not presently subject to that risk. Resolving the effects of significant filling would require further inundation modelling to be undertaken.

SUMMARY AND CONCLUSIONS

The Mapua – Ruby Bay communities are located on a low coastal plain and extend onto the adjacent hills. The coastal plain, however, is exposed to existing coastal erosion, seawater inundation and floodwater inundation hazard risks. The coastal erosion hazard risk is a persistent one, while seawater and floodwater inundation hazard risks are related to events that are episodic. Prevailing hazard risks will remain but also progressively increase both through time and particularly with projected climate change influences such as sea level rise manifesting itself.

Coastal erosion hazard and historical erosion rates are well identified on this shoreline. Shoreline erosion has been projected to 2100 using historic average long term erosion rates on a “natural” shoreline. No allowance has been made for the inevitable increase in erosion rate in the future. Erosion rates will increase in response to climate change, potential increased storminess and sea level rise, and in response to topographic changes (ie erosion in low lying land is faster than higher land). Similarly, floodwater inundation risk is reasonably well identified through recent computer inundation modelling work. However, seawater inundation hazard has only been qualitatively assessed on the basis of past historical events and examination of the local topography. Seawater inundation modelling can (and should) be undertaken to more accurately identify the extent, frequency and severity of inundation hazard risks associated with particular events or development scenarios.

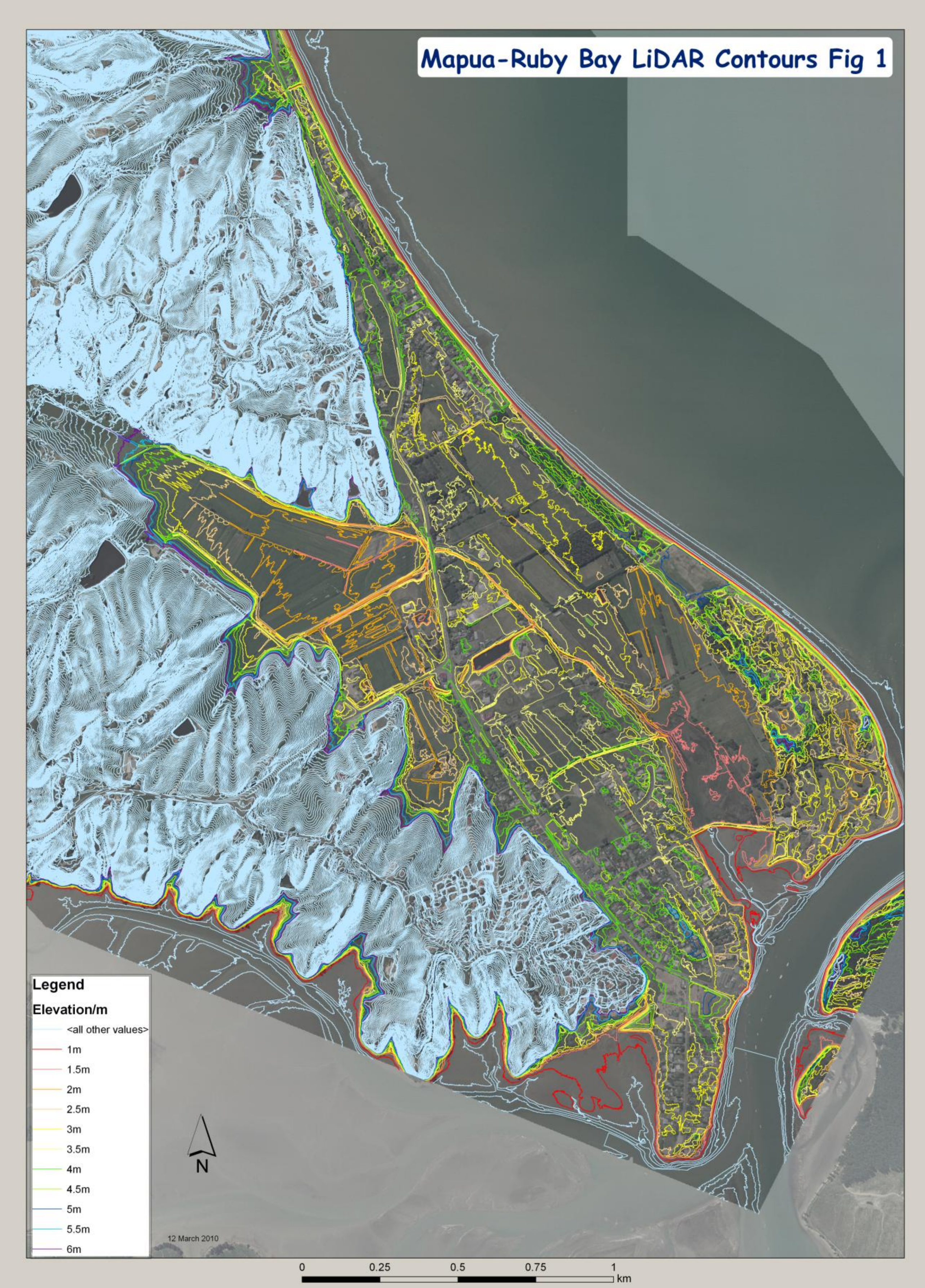
Hazard risks can be managed by a number of means and some hazard mitigation measures have already been implemented. These measures include planning policies and physical works. For all but 600m or so of the 3.5km long Ruby Bay foreshore, erosion hazard has been significantly mitigated by the construction of timber walls and principally rock revetments. All but 1.1km of these structures are privately owned and built. All of these structures require an ongoing maintenance commitment to retain functionality. These structures also reasonably but by no means completely mitigate inundation hazard risks for present day wave climate conditions, due to insufficient elevation. Continuing and future erosion and inundation hazard risk to this shoreline and the land behind is fundamentally linked to the collective ability of Council and private land owners to fund maintenance of existing works and provide any new structural measures on an effective and enduring basis.

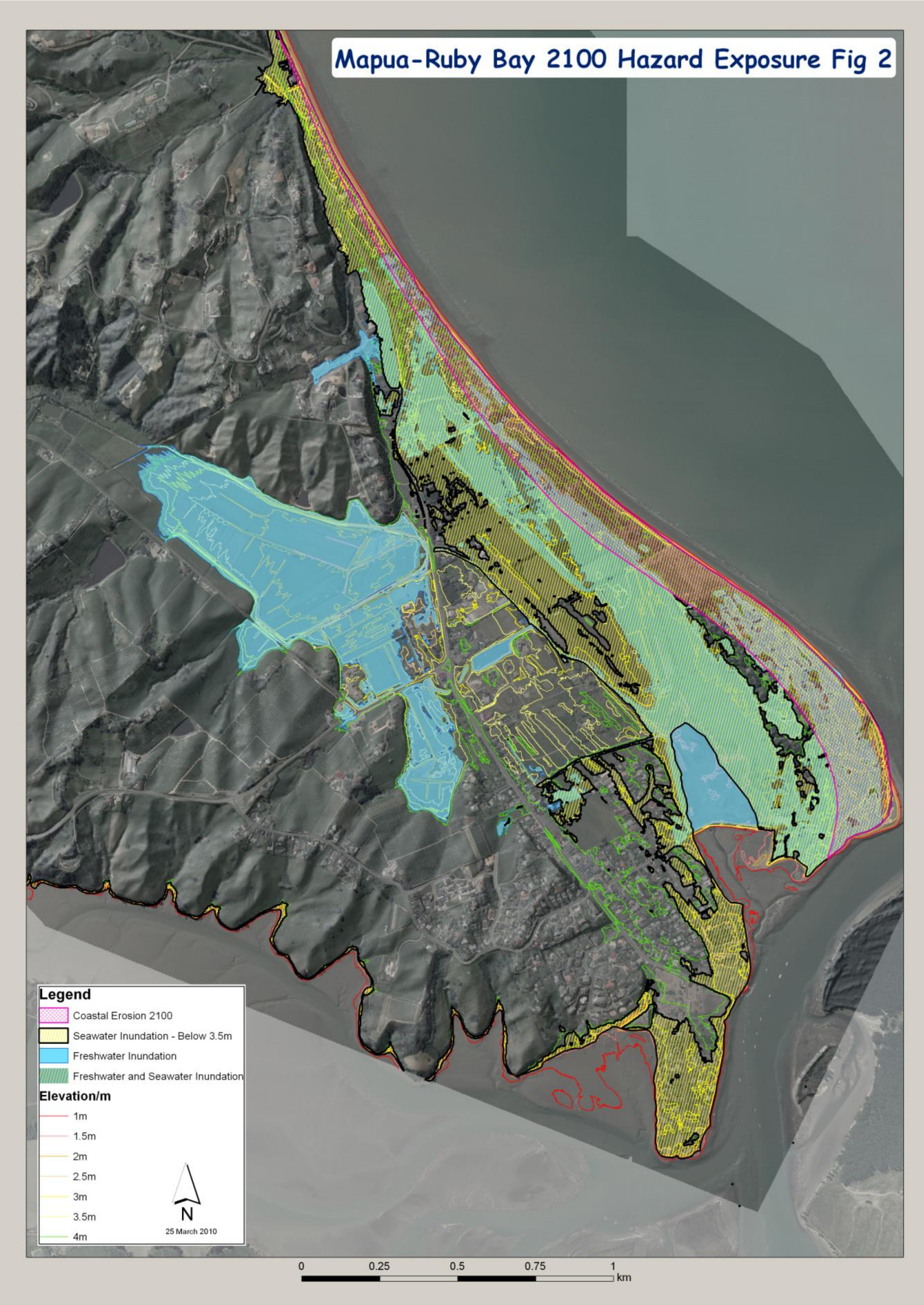
As climate change effects and sea level rise increases, the ability for present-day hazard mitigation measures to provide ongoing hazard risk mitigation to the land and developments behind significantly decreases. Present levels of hazard mitigation will require significant funding for maintenance in the long term, and further substantial sums of money for additional works are required to mitigate the effects of climate change. Future works including increasing foundation depth, crest height and rock armour grading (due to increased erosion forces, wave energy and runup potential) will be required, to maintain appropriate hazard mitigation levels. This work must extend uniformly and over the full length of the shoreline of both Ruby Bay and Mapua for comprehensive hazard risk management to the locality to be retained. Such mitigation measures have enormous and persistent practical and financial implications for both Council managed and privately owned land.

The estuarine margins of the Mapua community are particularly susceptible to increasing future climate change-induced hazard risk. At present, some reasonable erosion protection works exist along the shoreline to the north of the wharf, being the area most exposed to wave forces penetrating through the estuary channel mouth. The balance of the Mapua shoreline has very modest to no erosion protection at all. With sea levels rise in the future, the risk of seawater inundation of land below RL 3.0-3.5m during an extreme tide/storm event increases markedly.

In the case of the Mapua community, analysis of the frequency and severity of elevated sea levels as climate change progressively occurs is required and is recommended, so as to determine the probability and extent of inundation risk to the land adjacent to and inland of the estuary into the future. Investigation of potential inundation hazard mitigation measures for the low lying parts of the Mapua community is also recommended. Until this work is undertaken, it would be prudent to be cautious with respect to the nature and extent of allowing either an intensification of existing developed areas or new developments on land below an RL 3.5m, particularly in the absence of investigation of, commitment to and implementation of effective, appropriate and enduring hazard mitigation measures.

Exposure to floodwater and seawater inundation hazard risk to some parts of the Mapua-Ruby Bay plain may be able to be mitigated through land filling. The potential for this option (in combination with structural measures) depends on the location and degree of built development existing, the degree of hazard risk exposure and effects of land filling on risk transfer. Land filling is likely to be most tenable (from a hazard mitigation perspective) on the higher land further set back from the coast and estuary, provided flood hazard risk is not exacerbated on adjacent land and appropriate bund protection works are provided to mitigate potential seawater inundation risk. However, opportunity for land filling in Ruby Bay and parts of Mapua is very limited unless comprehensive drainage improvements are made and shoreline erosion and wave overtopping inundation is prevented. This is due to land stability and the effect of removing detention storage requirements that subsequently exacerbate flood hazard risk to adjacent land.

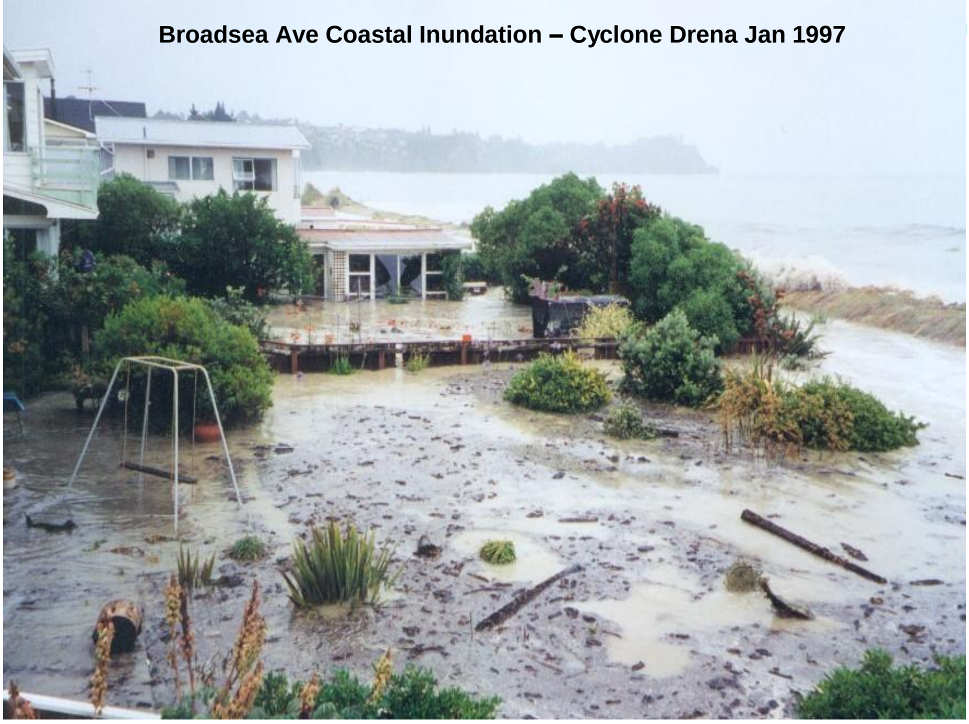

Mapua-Ruby Bay LiDAR Contours Fig 1
Legend
Elevation/m
<all other values>
1m
1.5m
2m
2.5m
3m
3.5m
4m
4.5m
5m
5.5m
6m
N
12 March 2010
0
0.25
0.5
0.75
1
km



Mapua-Ruby Bay 2100 Hazard Exposure Fig 2
Legend
Coastal Erosion 2100
Seawater Inundation - Below 3.5m
Freshwater Inundation
Freshwater and Seawater Inundation
Elevation/m
1m
1.5m
2m
2.5m
3m
3.5m
4m
N
25 March 2010
0
0.25
0.5
0.75
1
km


Erosion – Old Mill Walkway 2006


Broadsea Ave – Chaytor Reserve - Cyclone Drena Jan 1997



Broadsea Ave Coastal Inundation – Cyclone Drena Jan 1997

Broadsea Ave Inundation – Cyclone Drena Jan 1997

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Surface Flooding - Lower Seaton Valley Mapua
June 2003