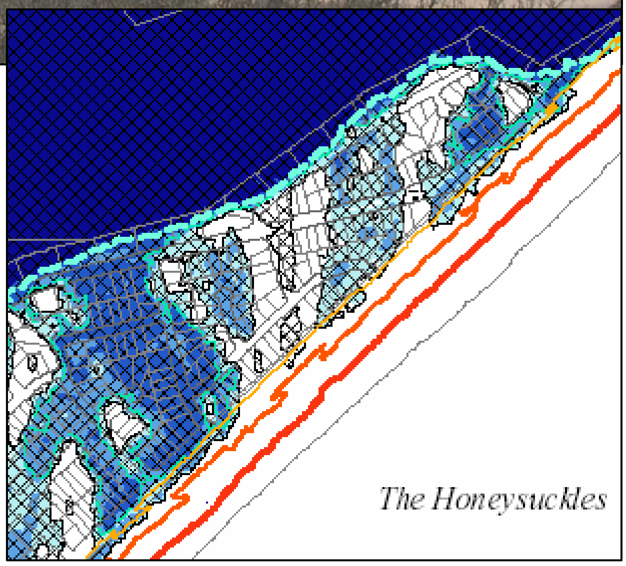
CLIMATE CHANGE and SEA LEVEL RISE IMPLICATIONS:
Ninety Mile Beach and Lake Reeve – Honeysuckles to Paradise Beach

Wellington Shire Council
March 2008 Final Report



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Cover Photo: Ninety Mile Beach near The Honeysuckles
(Photo courtesy of C. Holmes, Parks Victoria)

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1 INTRODUCTION

1.1 Climate Change and Sea Level Rise

Sea level rise and altered weather patterns due to global climate change have the potential to cause significant impacts along Ninety Mile Beach between The Honeysuckles and Paradise Beach, Victoria, Australia. The recently released Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC, 2007a, 2007b), and more detailed studies undertaken by CSIRO (Gippsland Climate Change Study, 2005 & 2006), have strongly emphasised the need to better understand the impacts of climate change and potential coastal impacts at a local level.

The potential implications of climate change and sea level rise on both private and public land must be considered prior to implementation of proposed changes to land use patterns along Ninety Mile Beach.

1.2 Background - Wellington Coast Subdivision Strategy

Wellington Shire Council has completed a Wellington Coast Subdivision Strategy (GHD, 2003, 2007) to determine future land use options for high density, inappropriately subdivided land along Ninety Mile Beach between The Honeysuckles and Paradise Beach (Figure 1). Settlements and localities along this section of Ninety Mile Beach include The Honeysuckles, Glomar Beach, Flamingo Beach, Lett's Beach, The Wreck Beach, Delray Beach, Golden Beach and Paradise Beach.

Land use issues contributing towards the need to undertake a review include:

- very large number of small allotments (11,700 lots),
- lack of services (no water, no sewer, no power),
- poor road and drainage infrastructure,
- flood prone land,
- inability to dispose of domestic effluent onsite in accordance with regulations,
- high environmental and conservation values,
- increased demand for coastal land, and
- land owner expectations regarding development rights.

Previous allotment restructures have resulted in single-lot tenements and multi-lot tenements, where either a single lot or various multiple lots are required respectively for dwelling building purposes within these coastal settlements/localities.

The Wellington Coast Subdivision Strategy presented 4 options. Following extensive public consultation, Council adopted a modified version of Option 4, which has a preferred Settlement Structure that focuses on consolidation of allotments in the 'Urban Nodes' of The Honeysuckles, Golden Beach and Paradise Beach. Other areas have been designated for further restructure into Low Density Residential, Rural Living, Rural Conservation, Land Subject to Inundation, or Coastal Dunes Buy-back as illustrated in Figure 2.

To date the preferred Settlement Structure has not come into effect under the Wellington Planning Scheme. The details of how development, restructure and land transfers will proceed have not been finalised, nor have planning scheme amendments been prepared. Council is currently assessing the repercussions of the Strategy for the thousands of landowners involved. A high level task force including State Government representatives is addressing various aspects of implementing the Strategy and working to achieve a long term whole-of-government solution.

1.3 Scope and Study Area

This brief report summarises the likely impacts of climate change-induced sea level rise on land forming the old and inappropriate subdivision along Ninety Mile Beach between The Honeysuckles and Paradise Beach. It is based largely on recent work commissioned by the Gippsland Coastal Board for Stage 2 of the Gippsland Climate Change Study.

The purpose of this report is to:

- Identify the extent of likely coastal erosion caused by climate change and sea level rise for land along Ninety Mile Beach between The Honeysuckles and Paradise Beach; and
- Identify the extent of likely flooding in Lake Reeve resulting from climate change-induced sea level rise and increased lake water levels in the Gippsland Lakes.

This information will assist Wellington Shire Council in deciding a) where development should be allowed in the context of the Wellington Coast Subdivision Strategy preferred Settlement Structure; b) what the most appropriate allotment size should be; and c) what if any, siting controls should be implemented.

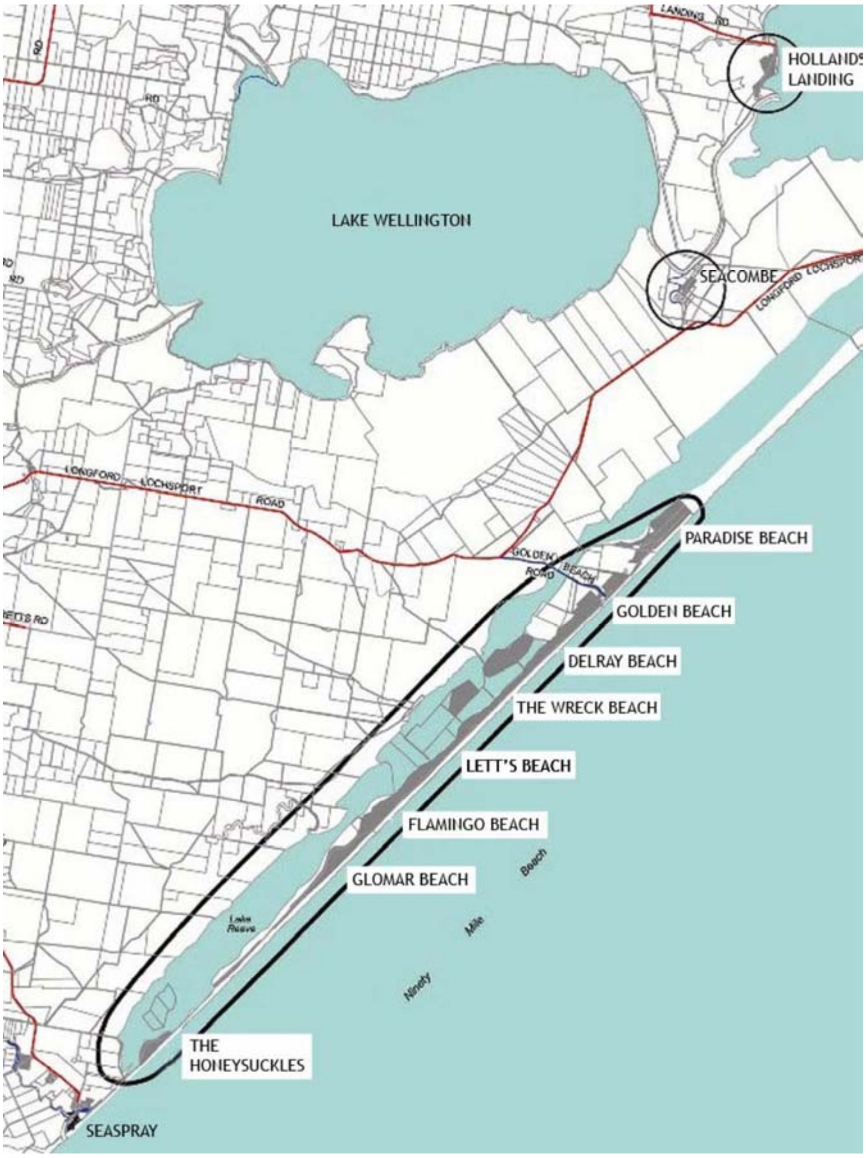


Figure 1: Study Area (taken from GHD, 2003)

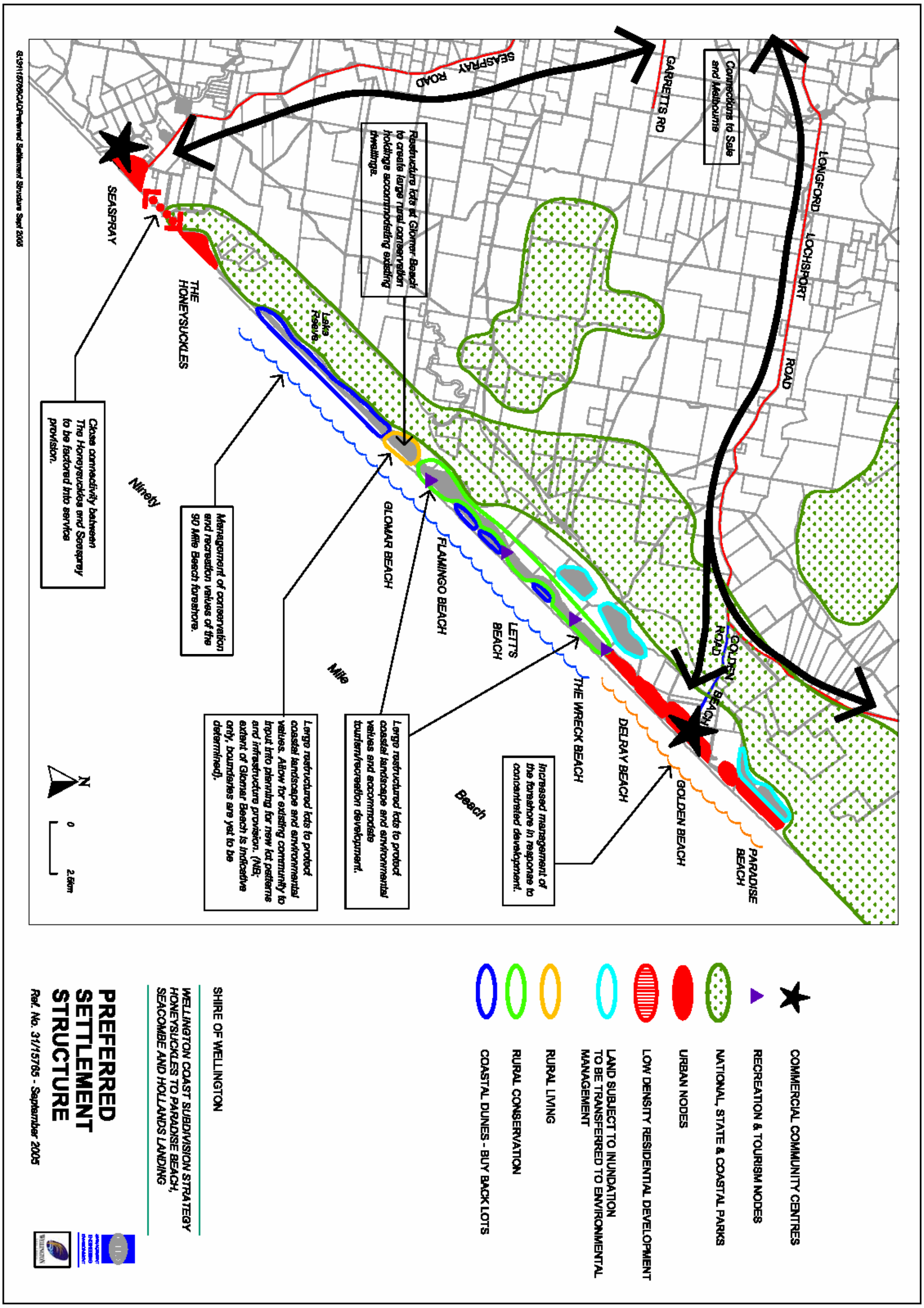


Figure 2: Preferred Settlement Structure Plan (WSC, GHD, 2005)

2 NINETY MILE BEACH

2.1 Description

An understanding and description of the Ninety Mile Beach coastal environment is crucial to appreciating the likely impacts of sea level rise and climate change along this dynamic coastline. Riedel and Sjerp (2007) provide the following description based on a recent coastal erosion study undertaken for Parks Victoria from McLoughlins Beach to Seaspray, and on earlier investigations by Rosengren (1981 and 1984) and Bird (1980 and 1993).

Dunes along Ninety Mile Beach form part of a complex barrier lagoon system that has formed between Corner Inlet and Lake Tyers since Pleistocene times (~10,000 to 1.8 million years ago). A large coastal embayment that previously existed along the Gippsland coast during Pleistocene higher sea levels approximately 80,000 years ago has progressively been enclosed as successive periods of sea level change (first a sea level drop followed by a rise to approximately the present level in the Late Quaternary) and the onshore movement of sand from the ocean floor created a series of dune barriers across the mouth of the embayment.

The youngest, Outer Barrier, is of Holocene age (less than 10,000 years old) and comprises the dunes seen today along the entire length of the Ninety Mile Beach. Behind these barrier dunes, the enclosed former coastal embayment now takes the form of estuarine water bodies, lakes and shallow wetlands such as Lake Reeve, Lake Wellington, Lake Victoria, and the more isolated Lake Denison and Jack Smith Lake. Gradual infilling with alluvium has formed a low lying coastal plain behind the dunes that is only marginally above present sea level.

It is upon these dunes and adjacent inland low lying coastal plains that the settlements and localities of The Honeysuckles, Glomar Beach, Flamingo Beach, Lett's Beach, The Wreck Beach, Delray Beach, Golden Beach and Paradise Beach have been created by extensive and inappropriate subdivision.

Figure 3 illustrates a typical Ninety Mile Beach profile where dunes of the Outer Barrier form a single, narrow, sparsely vegetated ridge backed by a low lying coastal plain. This is very similar to the dune profile at The Honeysuckles. Figure 4 illustrates Lake Reeve when dry and the significantly wider dune sequence north of Paradise Beach.

Figure 3: Typical Ninety Mile Beach dune profile, similar to single narrow dune at The Honeysuckles (from Riedel and Sjerp, 2007)

Figure 4: Wide dunes and Lake Reeve (dry), north of Paradise Beach

During the past 150 years sections of dunes along Ninety Mile Beach have been breached by either ocean storm waves (eg First Blowhole in Bunga Arm) or outflow from larger wetlands/lakes (eg Lake Denison and Jack Smith Lake). There is also aerial photographic evidence that the Ninety Mile Beach dunes were breached in other locations prior to white settlement (eg eastern end of Lake Reeve).

Any future sustained breach (ocean break-through) of the narrow barrier dune system, for example at The Honeysuckles, would potentially have major ramifications in terms of inundation by ocean water, wave attack and flooding of the low lying built-up areas immediately behind the dunes (Ethos NRM, 2007.

2.2 Erosion History

The threat of erosion to settlements along Ninety Mile Beach between The Honeysuckles and Paradise Beach needs to be considered not only in the context of climate change-induced sea level rise, but also from the perspective of historic erosion patterns.

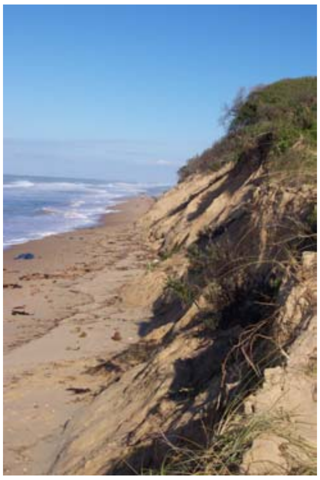
Sections of Ninety Mile Beach currently show visible evidence of erosion (Riedel and Sjerp, 2007). Most dunes exhibit an eroding, often steep or cliffed foredune indicative of recent erosion by storm waves. There are relatively few locations where an incipient dune demonstrating dune growth is evident.

Black organic-rich swamp sediments are exposed on the beach and under eroded foredunes at several locations along Ninety Mile Beach (Riedel and Sjerp, 2007). This is clear evidence that the barrier dunes formed along the seaward margin of wetland lagoons (such as Lake Reeve) have been eroded in ‘recent’ times (probably tens to hundreds of years, rather than thousands). It is possible that what today remains as a single dune ridge, previously comprised a much wider sequence of several parallel dunes that had partly overrun the wetland / lakes.

Bird (1980) demonstrated that since the mid-19th century (1845) sandy shorelines along the Victorian coast have generally receded due to erosion. On the Ninety Mile Beach, shoreline erosion in the order of 50-100 metres is quoted to have occurred since the mid-1840’s. Riedel and Sjerp (2007), using aerial photographic comparisons between 1941 and the current shoreline position, demonstrated that significant coastal erosion has occurred south west of Seaspray. A similar scenario is likely to exist between Seaspray and Paradise Beach.

Storms along Bass Strait in June 2007 caused massive erosion of the Ninety Mile Beach dunes, resulting in steeply cliffed dunes and shoreline retreat (A. Schulz & C. Holmes, *pers. comm.*). Beach erosion at Seaspray directly threatened the surf life saving clubhouse. Figures 5 & 6 illustrate erosion of the single-crested narrow dunes near The Honeysuckles.

Ninety Mile Beach has been and remains subject to erosion through processes possibly unrelated to climate change-induced sea level rise. Erosion induced by sea level rise will only serve to exacerbate the current erosion-dominated regime.



Figures 5 & 6: Erosion of the single-crested narrow dunes near The Honeysuckles. Taken following storms in June 2007 (Photos courtesy of C. Holmes, Parks Victoria)

3 CLIMATE CHANGE AND SEA LEVEL RISE

3.1 Global Climate Change

The following section is taken from the recent assessment of sea level rise implications for the Gippsland Coast (Water Technology & Ethos NRM, 2007).

Little doubt now remains that global climates are changing. The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the United Nations' Environment Program and the World Meteorological Organisation. It is responsible for providing the international community with authoritative advice on scientific, technical and economic issues relating to climate change.

IPCC's *Third Assessment Report* (TAR) (IPCC, 2001) concluded that global warming had accelerated in recent decades. The recently released Fourth Assessment Report (4AR) *Climate Change 2007: The Physical Science Basis – Summary for Policy Makers* (IPCC, 2007a) and *Climate Change Impacts, Adaptation and Vulnerability* (IPCC, 2007b) increases the level of scientific certainty upon which climate change projections are made and provides stronger evidence that the majority of global surface warming is attributable to increases in greenhouse gas emissions associated with human activities.

Table 1 summarises the IPCC Fourth Assessment Report (IPCC, 2007a) in the context of potential global impacts.

Table 1: Summary of relevant IPCC Fourth Assessment Report conclusions (IPCC, 2007a)

IPCC Fourth Assessment Report Conclusions (IPCC, 2007a)
• There is unequivocal observational evidence of; - global warming (11 of the last 12 years were among the warmest years on record), - increased ocean temperatures, - widespread melting of snow & retreating of sea-ice and glaciers, - widespread changes in precipitation amounts, - changes in wind patterns, - changes in extreme weather, including droughts, and - rising global sea levels over the 20th century of ~ 0.17m. • Global average surface temperatures are projected to increase by between 1.1°C and 6.4°C by the end of the 21st century. • Global average sea level is projected to rise; 0.18m to 0.38m (Low emission scenario) 0.26m to 0.59m (High emission scenario) higher than present by the end of the 21st century. • Climate change will adversely affect water resources, agriculture, forestry, fisheries, ecological systems, human settlements and human health in many parts of the world. • Global warming and sea level rise will continue for centuries due to timescale lags associated with climate processes, even if greenhouse gas emissions were stabilised.

3.2 Climate Change in Australia and Victoria

Climate change observations throughout Australia are summarised by Hennessy *et al.* (2006), citing numerous authors:

- From 1910 to 2004, the Australian-average maximum temperature rose 0.6˚C and the minimum temperature rose 1.2˚C,
- The north-western two-thirds of Australia has become wetter since 1950, while southern and eastern Australia has become drier. Droughts have become hotter and therefore more intense.
- From 1950-2005, extreme daily rainfall has increased in north-western and central Australia and over the NSW western tablelands, but decreased in the southeast, southwest and central east-coast.

Summaries produced by the Department of Sustainability and Environment in 2004 of projected climate changes for West Gippsland are provided in Table 2, although the information is based on earlier CSIRO climate models.

Table 2: Summary of projected climate changes for West Gippsland (Source: CSIRO/DSE, 2004) Note: Based on earlier CSIRO climate models.

Summary of projected climate changes for the West Gippsland

Temperature

- annual warming of 0.2 to 1.4°C by 2030 and 0.7 to 4.3°C by 2070
- day time maximum temperatures and night time minimum temperatures will rise at a similar rate
- warming will be similar throughout the seasons
- a 10 to 100% increase in the number of hot summer days (over 35°C) by 2030 and a 30 to 400% increase by 2070
- a substantial reduction in the number of frost days by 2030 and a 40 to 100% decrease in frost days by 2070.

Precipitation

- annual precipitation decreases likely (+3 to -10% by 2030 and +10 to -25% by 2070)
- extreme heavy rainfall events may become more intense

Drought

- droughts are likely to become more frequent and longer, particularly in winter-spring
- dry conditions that currently occur on average one in every five winter-springs may increase to up to one in three years by 2030
- due to hotter conditions, droughts are also likely to be become more intense

Water resources and fire

- the total alpine area with an average of at least one day of snow cover per year is expected to decrease by 10 to 39% by 2020, and 22 to 85% by 2050. Areas with at least 30 days of snow cover are expected to decrease by 14 to 54% by 2020, and 30 to 93% by 2050. Areas with at least 60 days of snow cover are expected to decrease by 18 to 60% by 2020 and 38 to 96% by 2050
- increased evaporation rates
- drier soil likely, even if precipitation increases
- hotter, drier conditions likely to increase bushfire risk
- decreased average run-off in streams

Winds, storms and sea level rise

- winds are likely to intensify in coastal regions of Victoria, particularly in winter as a result of more intense low pressure systems. Low pressure systems off the east coast of Australia may become more frequent
- sea level rise of 7 to 55cm by 2070 (0.8 to 8.0cm per decade) (Note: Based on earlier CSIRO climate models)

3.3 Sea Level Rise

Observational records indicate that global sea levels have risen an average of 1.8 mm per year between 1961 and 2003, and that the rate has increased to 3.1mm per year between 1993 and 2003 (IPCC, 2007a,b). Church and White (2006) demonstrated that global sea levels rose by approximately 0.17m during the 20th century. This rate of sea level rise, caused by global warming, is more rapid than that caused by 'natural' long term (geological time scale) sea level change associated with glacial and inter-glacial episodes, and smaller scale fluctuations that have occurred during the Holocene (last ~10,000 years).

Global warming is predicted to cause increasing sea level rise resulting from further thermal expansion of the oceans and melting of ice sheets. The IPCC Fourth Assessment Report (IPCC, 2007a) projects that global sea level will rise between 0.18m to 0.38m, or 0.26m to 0.59m by the end of the 21st century, for a low or high emissions scenarios respectively (IPCC, 2007a). Accelerated melting of the Greenland and Antarctic ice sheets will increase the upper ranges of projected sea level rise by a further 0.1m to 0.2m (IPCC, 2007a), or even greater (Rahmstorf, 2007).

Studies by CSIRO as part of the Gippsland Lakes Climate Change Study Project have provided further detailed analysis for south eastern Australia of the effect:

– of climate change on coastal wind and weather patterns (McInnes *et al*., 2005a);
– on storm surges (McInnes *et al*., 2005b); and the
– of extreme sea levels in Corner Inlet and the Gippsland Lakes (McInnes *et al*., 2006).

In summary, these studies found that, at worst, the Gippsland coast is likely to experience increased wind speed, increase dominance of southwesterly frontal synoptic weather patterns, increased storm surge, increased storm tide heights, and increased frequency and intensity of extreme events. In the worst-case predicted wind speed scenario, storm tide height would increase by up to 0.20m by 2070, and sea level will rise up to 0.49m by 2070 (for a high emissions scenario).

Table 3: Summary of various projected sea level rises along the Gippsland Coast

Projected Sea Level Rise - Gippsland Coast
• IPCC, 2007a: Global range = 0.18m to 0.59m by end of the 21st century with additional 0.1m to 0.2+m for accelerated ice sheet melt
• CSIRO/DSE, 2004: Gippsland range = 0.07m to 0.55m by 2070
• CSIRO/McInnes et al., 2006: up to 0.49m by 2070 (for high emissions and high wind strength increase scenario)
• Rahmstorf, 2007: Global sea level rise in excess of 1.0m by 2100 (based on continued temperature increase and melting of polar ice sheets)
• West Gippsland Catchment Management Authority: 0.49m by 2070 (interim policy position based on CSIRO data)
• Victorian Coastal Council (2007): 0.4m to 0.8m by end of the 21st century (Draft policy position based on high emissions scenario and increased melting of polar ice sheets)
(note differing time scales)

The IPCC Fourth Assessment Report (2007a) is, by virtue of its consensus nature, a relatively conservative projection of anticipated global sea level rise. Several researchers (Rahmstorf, 2007; Hansen, 2007; and CSIRO & Bureau of Meteorology, 2007) have highlighted that sea level rise is likely to be greater than that projected by the IPCC because of recent observational trends (continued high emissions and melting polar ice sheets), and due to 'positive feedback loops' (increasing ocean temperatures preventing reforming of polar ice sheets, with the resultant loss of solar reflection further heating ocean waters).

In the absence of a definitive state-wide policy position on projected sea level rise, the West Gippsland Catchment Management Authority has adopted 0.49m rise by 2070 as an interim policy position based on CSIRO data (Wayne Gilmore, WGCMA, *pers. comm.*).

Based on IPCC projections and the further work by Rahmstorf (2007), Hansen (2007) and CSIRO & Bureau of Meteorology (2007) the revised draft Victorian Coastal Strategy (Victorian Coastal Council; Draft Strategy, November 2007) adopts as policy for planning purposes along the entire Victorian coast, a projected sea level rise of 0.4m to 0.8m above present sea level by the end of this century.

The recent Garnaut Climate Change Review prepared for the Australian Government (Garnaut, 2008) further highlights that global temperature, CO_2 emissions and sea level rise observations are all trending towards the upper limits of existing projections.

4 POTENTIAL IMPACTS OF SEA LEVEL RISE AND FLOODING IN LAKE REEVE

4.1 Beach Erosion and Sediment Transport on Ninety Mile Beach

Work by Water Technology & Ethos NRM (2007) highlighted that climate change-induced sea level rise, together with changes in wind climate (wind speed and direction), changes to storminess and storm intensity, and changes to ocean wave climate will have a significant influence on coastal erosion and the shape of the coastline, and will be a direct threat to many coastal assets along the Gippsland coast.

In broad terms, there are two main forms of erosion that will result from sea level rise along Ninety Mile Beach: a) erosion caused by rising water levels; and b) erosion from changes in sediment transport patterns.

Changes in Sediment Transport Patterns

Changes to coastal processes and geomorphology will have marked impacts along the Gippsland coast. For example, changes in storminess and storm intensity will affect wave climate and sediment transport processes, potentially changing the position of sand bars and shifting the focus of erosion. Coastal erosion will be further exacerbated by increased storm surge and mean sea level, as larger waves are able to propagate closer to shore and cause greater erosion further up the beach face. Mean sea level change will also affect the vertical position of daily tidal variations and change intertidal boundaries.

There are two key direct or first order impacts of climate change-related increases in wave climate (due to changes to wind speed/direction) on geomorphological processes:

- **Increased Gross Sediment Transport** - With greater incident wave energy, larger amounts of sand can be mobilised. The increase in gross longshore transport will result in greater variability of the beach position and profile both annually and seasonally.

- **Increased Nett Sediment Transport** – Predicted changes to predominant wind direction on top of increased mobilisation will lead to changes in nett transport east or west along parts of the coast. Where there is insufficient sand supply to support this increase, the likely result will be coastal erosion and shoreline retreat. Other areas may experience significant accretion.

East of Wilsons Promontory, along Ninety Mile Beach, significant increases in gross and nett eastward sediment transport – in the order of 60% more sand transported to the east are predicted under a high emissions scenario (Water Technology & Ethos NRM, 2007). Table 4 lists the gross and nett sediment volumes (m^3) likely to result at Seaspray.

Table 4: Gross and Nett sediment transport volumes (m^3) likely to result at Seaspray (Source: Water Technology & Ethos NRM, *in prep.*)

Seaspray	Sediment Transport Potential			
	East	West	Gross	Nett
Existing	548000	443000	991000	105000
2070 mid emissions	578000	450000	1028000	128000
2070 high emissions	686000	518000	1204000	168000
% Change in Mid Scenario Transport	5%	2%	4%	22%
% Change in High Scenario Transport	25%	17%	21%	60%

In addition to increased seasonal variability in beach width/shape, large changes in nett transport will result in significant re-distribution of sand along these beaches. Typically erosion and shoreline recession will occur at the western end of beach cells (Corner inlet to Paradise Beach), and deposition further in the east (Paradise Beach to Lakes Tyers). The coastline along Ninety Mile Beach between The Honeysuckles and Paradise Beach is therefore likely to experience a nett sediment deficit – resulting in erosion. Changes in sediment transport patterns would be expected to continue until a new stable beach profile evolves at an elevated sea level, but will also depend on a continuing supply of sand from the southwest.

Erosion from Rising Water Levels

In addition to the nett beach erosion caused by changes to coastal sediment transport patterns discussed above, increased water levels (due to sea level rise) will also result in shoreline erosion as beach slope and profile adjust to altered water levels (Figure 7). Typically, 1cm of mean sea level rise results in 50cm to 100cm of shoreline retreat, based on the Bruun Rule (Bruun, 1962), depending on local wave conditions and sand dune characteristics (or for every 10cm of sea level rise, shoreline recession of between 5 to 10m could be expected).

Using the Victorian Coastal Council's 0.8m upper sea level rise draft policy position discussed in Section 3.3, the shoreline position along Ninety Mile Beach due to elevated water levels alone (Bruun Rule) could retreat by as much as 40m to 80m.

The existing beach face is in places only approximately 50m wide, and varies considerably with storm events. Erosion of 40m to 80m would likely result in direct wave attack on the dune system, similar to that experienced during storms of June 2007 (Figure 5 & 6). Most of the dunes along Ninety Mile Beach, including those seaward of Shoreline Drive within the study area, are relatively large (up to 25m high), steep, vegetated and wide. Hence, there is a considerable 'bank' of dune material available for erosion and an increased chance for the beach/dunes to recover from erosion between storms. However, where the dunes are narrow and/or low, the landward extent of erosion could be significant and sustained for longer periods.

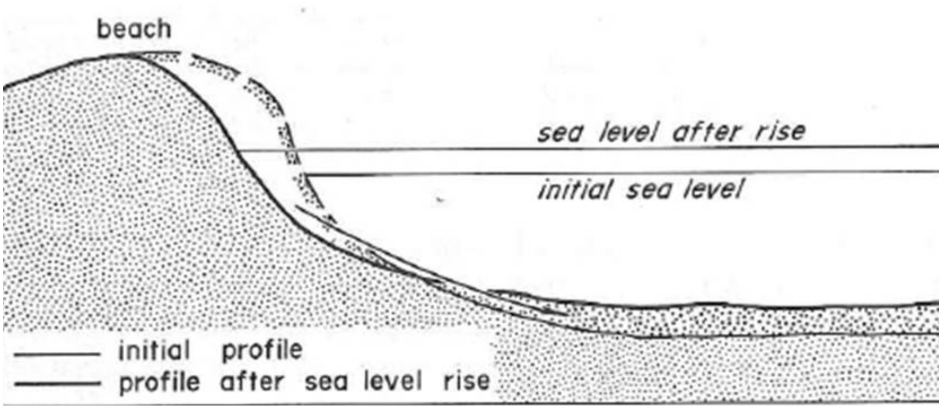


Figure 7: Beach profile response to sea level rise (after Swartz, 1967)

The extent of ocean beach erosion caused by the combination of sea level rise and storm surge has been calculated for this study using storm tide information (McInnes *et al.,* 2005a,b) superimposed upon the recently acquired LIDAR high resolution digital terrain model for Ninety Mile Beach (vertical accuracy of <0.1m). Based on a median 'Bruun Rule value' of 7.5m shoreline retreat for every 0.1m water level rise, the extent of shoreline erosion has been calculated for three scenarios, which are illustrated in Figures 13 to 21 as different 'Ocean Storm Tide Inundation' lines:

- 1 in 100 year storm tide level without a sea level rise component (1.4m AHD) – shown as thick red line
- 1 in 100 year storm tide level with a 0.49m sea level rise component (1.89m AHD) – shown as orange line
- 1 in 100 year storm tide level with a 0.80m sea level rise component (2.2m AHD) – shown as thin yellow line

The three 'Ocean Storm Tide Inundation' lines are explained in Figure 8, below.

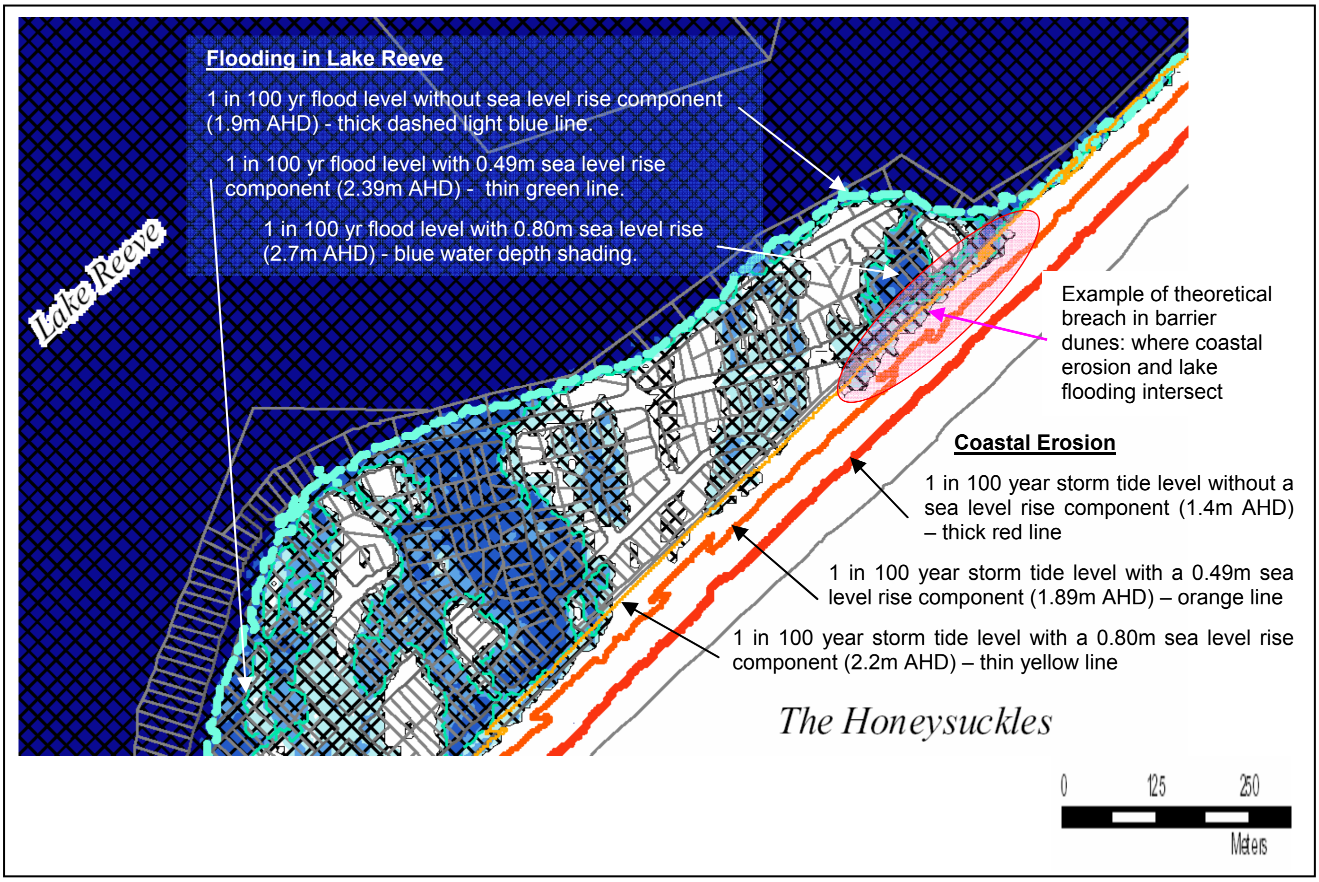


Figure 8: Enlargement of maps (Fig 13 to 21) illustrating Ocean Storm Tide and Flooding Inundation lines for three scenarios

The 'Ocean Storm Tide Inundation' line in Figures 13 to 21 illustrates the extent of likely beach and dune erosion along Ninety Mile Beach, based on applying the Bruun Rule for beach recession. Maximum beach recession for the worst-case scenario of a 1 in 100 year storm surge event at high tide and 0.8m sea level rise (using the Victorian Coastal Council's 0.8m upper sea level rise draft policy position), is in the order of 125 metres (thin yellow line). The extent of beach erosion is also dependent upon beach and dune morphology, which is not totally taken into account by the Bruun Rule.

4.1.1 Threatened Locations

Unconsolidated beach and dune sand along Ninety Mile Beach will pose little resistance to erosion from elevated water levels and wave attack, particularly during storm events when storm surge and wave runup is greatest. The most vulnerable sites – those where the landward extent of erosion is greatest and sustained for longer periods – are low-lying areas where wave runup and erosion will occur rapidly, and at locations where the coastal dune is low and narrow.

The 'Ocean Storm Tide Inundation' lines in Figures 13 to 21 illustrate that whilst much of the beach and seaward extent of the dunes are subject to erosion, there is no immediate threat to private property or to Shoreline Drive, except at The Honeysuckles where erosion and shoreline recession extends inland such that the majority of coastal dunes are lost.

The most dramatic potential impact of coastal erosion will result from the breaching of coastal dunes which currently protect low-lying plains, intermittent lakes and wetlands immediately behind the dunes. Once eroded, and if the breach is sustained (remains open), the lack of these protective barrier dunes will result in rapid inundation by sea water, increased wave action, increased marine influence, greater tidal variation, and substantially increased inundation/flooding of low-lying areas (Ethos NRM, 2007). A sustained breach in the dunes could occur following several large storm events, in rapid succession, such that the eroded beach/dunes do not have an opportunity to reform. The location most threatened is the low band of narrow dunes that extend northeast from Seaspray (Figure 9), seaward of The Honeysuckles settlement and on towards the Glomar Beach. This section of dune is prone to being breached in a similar fashion to what has occurred (historically and in the past 150 years) at other narrow dunes along Ninety Mile Beach such as Jack Smith Lake, the channels near Rotamah Island, and the First Blowhole in Bunga Arm.

Figure 9: Ninety Mile Beach dunes near The Honeysuckles
(Photo courtesy of C. Holmes, Parks Victoria)

If the barrier dunes at The Honeysuckles suffer a sustained breach, the low-lying private land, including that which has already been developed with houses and/or sheds will, in all likelihood, be prone to increased inundation and flooding. The extent of flooding will be dependent on the exact breach location and the duration for which the breach remains open. The size and occurrence of a breach in the barrier dunes on Ninety Mile Beach is also dependent upon dune morphology and the extent to which dunes migrate inland as sea level rises.

Flooding of Lake Reeve with ocean water through a sustained breach in the dunes at or near The Honeysuckles could potentially cause substantial increased flooding of other low-lying areas along the southern shores of Lake Reeve from Glomar Beach to Paradise

Beach, particularly the 'islands'. If the breach occurs at high tide and at a time when Lake Reeve is full of water (or partially full), the resultant inundation could be extensive.

The combined effect of concurrent extreme erosion during a severe storm along Ninety Mile ocean beach and extreme flooding in Lake Reeve is the scenario most likely to result in a breach of the barrier dunes. Flooding along the shores of Lake Reeve is discussed in the following section.

A simplistic indication of where the dunes are most likely to breach is provided in Figures 13 to 21 by the intersection of the maximum beach erosion line (yellow line) and the maximum lake flood height line (blue shaded area), which is where theoretically the entire dune is eroded away. Four sites meet this criteria; at The Honeysuckles (illustrated in Figure 8), either side of The Honeysuckles and two sites north east of The Honeysuckles. Several other locations exist where a 'theoretical' breach almost occurs.

Figure 10 illustrates a schematic cross section through the dunes where a breach could potentially occur.

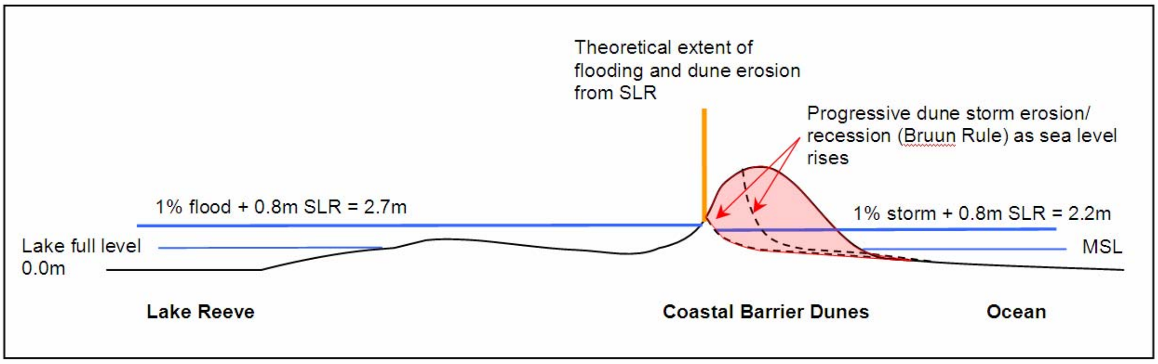


Figure 10: Schematic cross section through narrow low dunes on Ninety Mile Beach, illustrating extent of flooding and erosion due to 0.8m sea level rise

4.2 Flooding in Lake Reeve

Lake Reeve is connected to the balance of the Gippsland Lakes via convoluted channels at the eastern end, near Rotamah Island. A hydrological assessment of the lake (SKM, 2004) highlighted that whilst the lake is dry a majority of the time, inflows do occur from both the Gippsland Lakes and from local catchment steams (particularly Merrimans Creek and Carrs Creek). There are numerous hydraulic barriers across Lake Reeve, including islands and causeways, which impede water flow between four distinct 'cells'. Culverts under each causeway allow limited water exchange. Importantly however, Lake Reeve fills entirely during flood events in the Gippsland Lakes and from local floods (high rainfall), with all barriers being over-topped (Figure 11) (SKM, 2004) – as was the case during the June 2007 Gippsland Lakes floods, Figure 12 (W. Gilmore, *pers. comm.*; A. Schulz, *pers. comm.*).

Figure 11: High water levels (1995) at Track 10 Causeway across Lake Reeve
(From SKM, 2004, photo courtesy of Jan Fowler)

Figure 12: Extensive flooding in Lake Reeve, east of Paradise Beach, during June 2007 Gippsland Lakes floods. Loch Sport in foreground.
(Source: East Gippsland Catchment Management Authority)

Increased flooding in Lake Reeve could, as described above, occur from inundation of ocean water through a breach in the dunes at or near The Honeysuckles, or further along Ninety Mile Beach. In addition, the hydraulic connection between Lake Reeve and the remainder of the Gippsland Lakes may be enhanced if existing narrow channels at the eastern end are scoured/widened, or increased water levels allow greater flow rates between water bodies.

Sea level rise and climate change-induced extreme flood events in the Gippsland Lakes (eg 1 in 100 year floods) could also result in the average water level within Lake Reeve being greater than its current position.

Increased extreme rainfall events in the Merriman Creek catchment at a time when the creek mouth is closed could redirect flood flows into Lake Reeve, thereby further increasing water levels.

Lake Reeve could therefore experience far greater variability in water level, including significantly higher flood levels when the Gippsland Lakes experience high river inflows.

The extent of flooding inundation along the southern shores of Lake Reeve has been calculated for this study by using the West Gippsland Catchment Management Authority declared flood levels at Loch Sport (1.9m AHD; W. Gilmore, *pers. comm.*), superimposed upon the LIDAR high resolution digital terrain model for Ninety Mile Beach (which has a vertical accuracy of <0.1m). Figures 13 to 21 illustrate a 'Lake Reeve Flood Inundation' line for three scenarios:

- 1 in 100 year Gippsland Lakes flood level without a sea level rise component (1.9m AHD) - shown as thick dashed light blue line.
- 1 in 100 year Gippsland Lakes flood level with a 0.49m sea level rise component (2.39m AHD) - shown as the thin green line.
- 1 in 100 year Gippsland Lakes flood level with a 0.80m sea level rise component (2.7m AHD) - shown as blue shading representing different water depths.

The West Gippsland Catchment Management Authority (W. Gilmore, *pers. comm.*: Victorian Planning Provisions Practice Note, DoI, 2000):

- Do not allow any new subdivisions within areas prone to 1 in 100 year floods.
- Require that new dwellings on existing allotments must have;
    - a floor level at least 0.3m above the 1 in 100 year flood level (ie. 2.2m AHD for Lake Reeve),
    - vehicle access no deeper than 0.8m water depth (for escape/rescue purposes) during a 1 in 100 year flood, and
    - water surrounding the dwelling no more than 0.5m deep (for safety reasons) during a 1 in 100 year flood.

4.2.1 Threatened Locations

The 'Lake Reeve Flood Inundation' line in Figures 13 to 21 illustrates that there is very significant flooding of low-lying land, including large areas of private land, some of which has already been developed with dwellings. The worst effected areas are all low-lying areas along the Lake Reeve shoreline, particularly at The Honeysuckles, Glomar Beach, between The Honeysuckles and Glomar Beach, parts of Flamingo Beach, the Islands, parts of Delray Beach, and the northern end of Paradise Beach. The Longford Road Causeway would also be threatened.

4.3 Impacts to Built Infrastructure

The preceding discussion demonstrates that climate change and sea level rise along Ninety Mile Beach is likely to result in significant shoreline recession due to beach and dune erosion by the end of this century.

In addition, increased water levels and flooding within Lake Reeve are likely to result from increased flood levels in the Gippsland Lakes and possible inundation by ocean water through a potential newly formed breach in the Ninety Mile Beach barrier dune system.

This erosion and flooding will have a direct impact on built infrastructure located between The Honeysuckles and Paradise Beach. Examples include:

- Erosion of coastal dunes and undermining of public camping and recreation areas managed by Parks Victoria
- Possible undermining of Shoreline Drive where it is located close to the beach, due to erosion of coastal dunes
- Flooding of low-lying buildings and sheds, particularly at The Honeysuckles, parts of Delray Beach, and the northern end of Paradise Beach
- Flooding and subsequent failure of low-lying septic tanks and/or domestic effluent disposal fields (refer discussion below)
- Break along Shoreline Drive if the barrier dunes at The Honeysuckles are breached - results in significantly reduced vehicle access
- Break along the Causeway on Longford to Golden Beach Road over Lake Reeve - results in significantly reduced vehicle access
- Disruption to vehicle access at other low points in existing road/track network
- Failure of existing culverts and local drainage

4.3.1 Domestic Effluent Disposal

All private land within the study area is reliant upon onsite disposal of domestic wastewater. There is no reticulated sewerage infrastructure. Increased flooding of low-lying allotments will reduce the capacity for on-site disposal.

Standards for on-site disposal of domestic wastewater are set by the Environment Protection Authority through the Septic Tank Code of Practice – Publication 891 (EPA, 2003a), the Land Capability Assessment for Onsite Domestic Wastewater Management – Publication 746.1 (EPA, 2003b), and the State Environment Protection Policy (SEPP) - Water of Victoria.

The Code of Practice and Land Capability Assessment guidelines stipulate that (in summary):

- Minimum allotment size should generally be no less than 10,000 m^2 (1 hectare)
- Seasonal water tables should never rise to within 2m of the surface
- Setbacks from open water should be no less than 60 metres, or 30 metres with an approved (and maintained) domestic wastewater treatment plant.

The East Gippsland and Wellington Shire Domestic Wastewater Management Plan (RMCG et al, 2006) highlights the highly porous dune sands underlying Golden Beach and Paradise Beach and poor wastewater management practices, as significant threats to water quality and biodiversity values of the entire coastal strip. The report recommends that further development be prohibited close to Lake Reeve and where ground water is shallow. The report acknowledges that the adverse impacts to groundwater from on-site wastewater disposal through porous sands are reduced with increasing depth of sand above the water table. A minimum height of 2 metres above groundwater was recommended, consistent with EPA requirements.

Wellington Shire Council (P. Medhurst & A. Watson, *pers. comm.*) requires that all new dwellings within the study area:

- Install EPA-approved domestic wastewater treatment plants with appropriate maintenance regimes,
- Incorporate effluent disposal fields that are located at least 2 metres above groundwater as determined by backhoe excavation,
- Incorporate effluent disposal areas that comprise planted beds with a maximum surface area for evaporation, and
- incorporate effluent disposal fields that are at least 30m from the ‘lake full’ shoreline of Lake Reeve.

Assuming the groundwater is hydraulically connected to the water level in Lake Reeve, dwellings should only be developed where there is a ‘freeboard’ of 2 metre or greater above the flood level in Lake Reeve. Detailed topographic information now available through the Ninety Mile Beach LIDAR high resolution digital terrain model, in conjunction with information regarding the extent of sea level rise and flooding described in preceding sections, allows accurate delineation of land which is less than 2 metres above mean water level with a 0.8m sea level rise component, as illustrated in Figures 13 to 21 (hatched area). The substantial areas covered by the hatch in Figures 13 to 21 will have groundwater at shallow depths and will therefore not comply with EPA requirements. Groundwater levels will be further elevated during flood events but only for short durations.

The mapping component of this study has not taken into account the necessity to have all ground-based effluent disposal fields located at least 30 metres from open water.

The EPA-recommended minimum allotment size of 10,000m^2 is based on the approximate total land mass required for a typical dwelling with shed, driveway, garden, effluent disposal field, secondary / reserve effluent field, retention of native vegetation, and allows for setbacks from allotment boundaries and buildings.

5 COASTAL SUBSIDENCE

Land subsidence ranging from centimetres to several metres has been recorded in a diverse range of environments. Land subsidence occurs as a result of either tectonic movements involving a net lowering of the land surface over thousands of years (as in south eastern England), or from the extraction of underground water, oil and/or natural gas resulting in a collapse (compaction) of underlying strata and hence a lowering of the land surface – such as is the case surrounding the Latrobe Valley open pit coal mines where ground water from the Latrobe Aquifer is extracted for dewatering purposes. The extent of subsidence is a function of the amount of fluid extracted, the geological characteristics of the aquifer from which fluid is extracted and overlying strata, and the rate of aquifer recharge (both natural and artificial). Remedial actions to reduce land subsidence include a cessation of fluid extraction and/or artificial recharge to the aquifer (Water Technology & Ethos NRM, *in prep.*).

Along the Gippsland coast, a concurrent lowering of coastal land due to subsidence will clearly exacerbate the effect of any sea level rise.

The extent of coastal subsidence expected to occur along the Gippsland coast is not fully understood. A number of studies have quantified the level of fluid extraction from the Latrobe Aquifer in Gippsland and made predictions regarding the potential level of coastal subsidence (SKM 1995, 2001a, 2001b). The later investigations concluded that the risk of subsidence along the Gippsland coast is substantially less than the originally predicted maximum of up to 2 metres in approximately 70 years time if no remedial action is taken. More recently, work undertaken by CSIRO (Hatton *et al*., 2004: Underschultz *et al*., 2006) highlights possible causes for falling water levels in the Latrobe Aquifer and provides recommendations for future work.

A Ground Elevation Project implemented in South Gippsland by the Department of Natural Resources and Environment (Minerals and Petroleum Division), comprises a network of highly accurate survey benchmarks for monitoring ground movement along the 100km coastal strip between Port Albert and Loch Sport. Surveys completed for the period June 2004 to 2006 have not detected any statistically valid land subsidence (other than at the Latrobe Valley open pit coal mines) (AAMHatch, 2006).

There is a lag interval between extraction from the Latrobe Aquifer and possible commencement of subsidence, which is in part dependent on the geological characteristics of the aquifer and the overlying strata, that to date have not been investigated in detail (although funding for such an investigation was announced by the Australian Government in 2006).

6 SUMMARY AND CONCLUSIONS

Climate change and associated sea level rise along Ninety Mile Beach has the potential to impact significantly on land forming the old and inappropriate subdivision comprising the settlements and localities of The Honeysuckles, Glomar Beach, Flamingo Beach, Lett's Beach, The Wreck Beach, Delray Beach, Golden Beach and Paradise Beach (Figure 1).

This report, which is based largely on recent work commissioned by the Gippsland Coastal Board for Stage 2 of the Gippsland Climate Change Study (Water Technology & Ethos NRM, *in prep.*), will be used to inform future land use options and in implementation of the Wellington Coast Subdivision Strategy (GHD, 2003, 2005) preferred Settlement Structure. A land capability analysis being prepared by GHD for Wellington Shire Council will assist in determining where future development should be allowed and the nature of that development, including allotment size and siting controls.

Dunes along Ninety Mile Beach form part of a complex barrier lagoon system that has formed between Corner Inlet and Lake Tyers, near Lakes Entrance. The dunes, which in places are relatively low and very narrow, serve to protect low-lying land, wetlands and lakes, including Lakes Reeve, located immediately inland of the beach. Settled areas are located both on the dunes and on low-lying areas fringing Lakes Reeve.

Previous studies (Riedel and Sjerp, 2007; Bird, 1980) demonstrated that Ninety Mile Beach has been, and remains subject to erosion through processes possibly unrelated to climate change-induced sea level rise. Erosion induced by sea level rise will only serve to exacerbate the current erosion-dominated regime.

The Intergovernmental Panel on Climate Change (IPCC) concluded that there is now unequivocal observational evidence of global warming and sea level rise.

High emissions scenario projections include:

- Global sea level rise in the range 0.26m to 0.59m by the end of the 21st century with additional 0.1m to 0.2+m for accelerated ice sheet melt (IPCC,2007a and b).
- South eastern Australia storm tide height increase of up to 0.20m by 2070, and sea level rise up to 0.49m by 2070 (McInnes et al., 2005a,b)
- Global sea level rise in excess of 1.0m by 2100, based on continued temperature increase and melting of polar ice sheets (Rahmstorf, 2007)
- West Gippsland Catchment Management Authority interim policy position based on CSIRO data of 0.49m by 2070
- Draft Victorian Coastal Strategy projected sea level rise for planning purposes of 0.4m to 0.8m by the end the century (VCC, 2007)

Under a worst-case, high emissions scenario, changes to weather and wave climate in Bass Strait are likely to result in the Ninety Mile Beach coast between The Honeysuckles and Paradise Beach experiencing a nett sediment deficit – hence resulting in erosion (Water Technology & Ethos NRM (*in prep*.)).

Based on a median 'Bruun Rule' value of 7.5m shoreline retreat for every 0.1m water level rise, the extent of shoreline erosion caused by the combination of sea level rise and storm surge is illustrated in Figures 13 to 21 as an 'Ocean Storm Tide Inundation' line for three scenarios:

a) 1 in 100 year storm tide level without a sea level rise component;

b) with a 0.49m sea level rise component; and

c) with a 0.80m sea level rise component.

Maximum beach recession is in the order of 125 metres.

Figures 13 to 21 illustrate that much of the beach and seaward extent of the dunes are subject to erosion, although there is no immediate threat to private property or to Shoreline Drive, except at The Honeysuckles where erosion and shoreline recession extends inland such that the majority of coastal dunes are lost.

The most dramatic potential impact of coastal erosion along Ninety Mile Beach will result from the breaching of coastal dunes which currently protect low-lying inland plains and separate Lake Reeve from Bass Strait. A sustained breach in the dunes could occur following several large storm events, in rapid succession, such that the eroded beach/dunes do not have an opportunity to reform. The **location most threatened is the**

low band of narrow dunes that extent northeast from Seaspray (Figure 9), seaward of The Honeysuckles and on towards the Glomar Beach. Figures 13 to 21 suggest that four sites – The Honeysuckles, either side of The Honeysuckles, and two sites north east of The Honeysuckles – are prone to breaching due to the combined effects of concurrent extreme erosion along Ninety Mile ocean beach and extreme flooding in Lake Reeve:

Sea level rise and climate change-induced extreme flood events in the Gippsland Lakes could result in the average water level within Lake Reeve increasing. Figures 13 to 21 illustrate a 'Lake Reeve Flood Inundation' line for three scenarios using Gippsland Lakes flood levels. The 'Lake Reeve Flood Inundation' line illustrates that there is potential for very significant flooding of low-lying land, including large areas of private land, some of which has already been developed with dwellings. The **worst effected areas are all low-lying areas along the entire Lake Reeve shoreline, particularly at The Honeysuckles, Glomar Beach, between The Honeysuckles and Glomar Beach, parts of Flamingo Beach, the Islands, parts of Delray Beach, and the northern end of Paradise Beach**. The Longford Road Causeway would also be threatened.

Beach erosion and increased lake flooding will have a direct impact on built infrastructure located between The Honeysuckles and Paradise Beach. Examples include: undermining of public assets on coastal dunes; possible undermining of Shoreline Drive; flooding of low-lying buildings; flooding and subsequent failure of low-lying septic tanks; flooding or a break along the Longford to Golden Beach Road Causeway, and other roads; and failure of local drainage.

Increased water levels in Lake Reeve will result in onsite domestic wastewater disposal practices in large areas of private land not complying with EPA requirements for a minimum depth to the seasonal groundwater of 2 metres.

Along the Gippsland coast, a concurrent lowering of coastal land due to subsidence will clearly exacerbate the effect of any sea level rise.

7 Recommendations and Limitations

This study highlights the potential impacts of climate change-induce sea level rise along Ninety Mile Beach between The Honeysuckles and Paradise Beach. The following recommendations are made in the context of existing and future investigations.

- The findings of this study should inform future land use decisions being made to implement the Wellington Coast Subdivision Strategy preferred Settlement Structure and to determine suitable areas for future development.
- Consideration should be given to:
  - limiting or prohibiting future development that is subject to climate change-induce coastal erosion and/or lake flooding
  - establishing suitable development buffers in the vicinity of identified major erosion points, particularly at potential breaches of the barrier dunes
  - limiting or prohibiting development in areas where groundwater levels, including an allowance for sea level rise, are less than 2.0m below the natural ground surface

- Domestic wastewater disposal fields for future development incorporating EPA-approved wastewater treatment plants should not be located less than 30m from open water.
- Future restructure of allotment densities and minimum allotment sizes should take into consideration the amount of land required for a typical dwelling with shedding, driveway, garden, effluent disposal field, secondary / reserve effluent field, retention of native vegetation, and allow for setbacks from allotment boundaries and other buildings.
- A dune monitoring program should be established (using both land-based survey and aerial LIDAR data) to determine changes in the position and condition of high risk locations along the Ninety Mile Beach dune system.

Assumptions and Limitations

- Ocean storm tide line information is based on CSIRO Marine and Atmospheric Research, McInnes *et al.*, 2005.
- Coastal erosion and recession analysis is based on a an assumed 'Bruun Rule' value of 7.5m shoreline retreat for every 0.1m water level rise. No allowance has been made for wave setup and runup, or dune dynamics (landward migration of dunes as sea level rises) under extreme storm surge events.
- Additional techniques ('Storm Bite' analysis) using LIDAR data are available to more precisely identify the extent of beach erosion and volume of dunes lost at specific locations.
- Potential dune-breach sites are based on concurrent occurrence of a 1 in 100 year (1% AEP) ocean storm event, 1 in 100 year (1% AEP) Lake Reeve flooding event, and 0.8m Sea Level Rise by end of 21st century.
- Lake Reeve flooding analysis is based on the West Gippsland Catchment Management Authority declared 1 in 100 year flood level (1% AEP) for Loch Sport, from the Gippsland Lakes Flood Level Modelling Project (Grayson *et al.* 2004).

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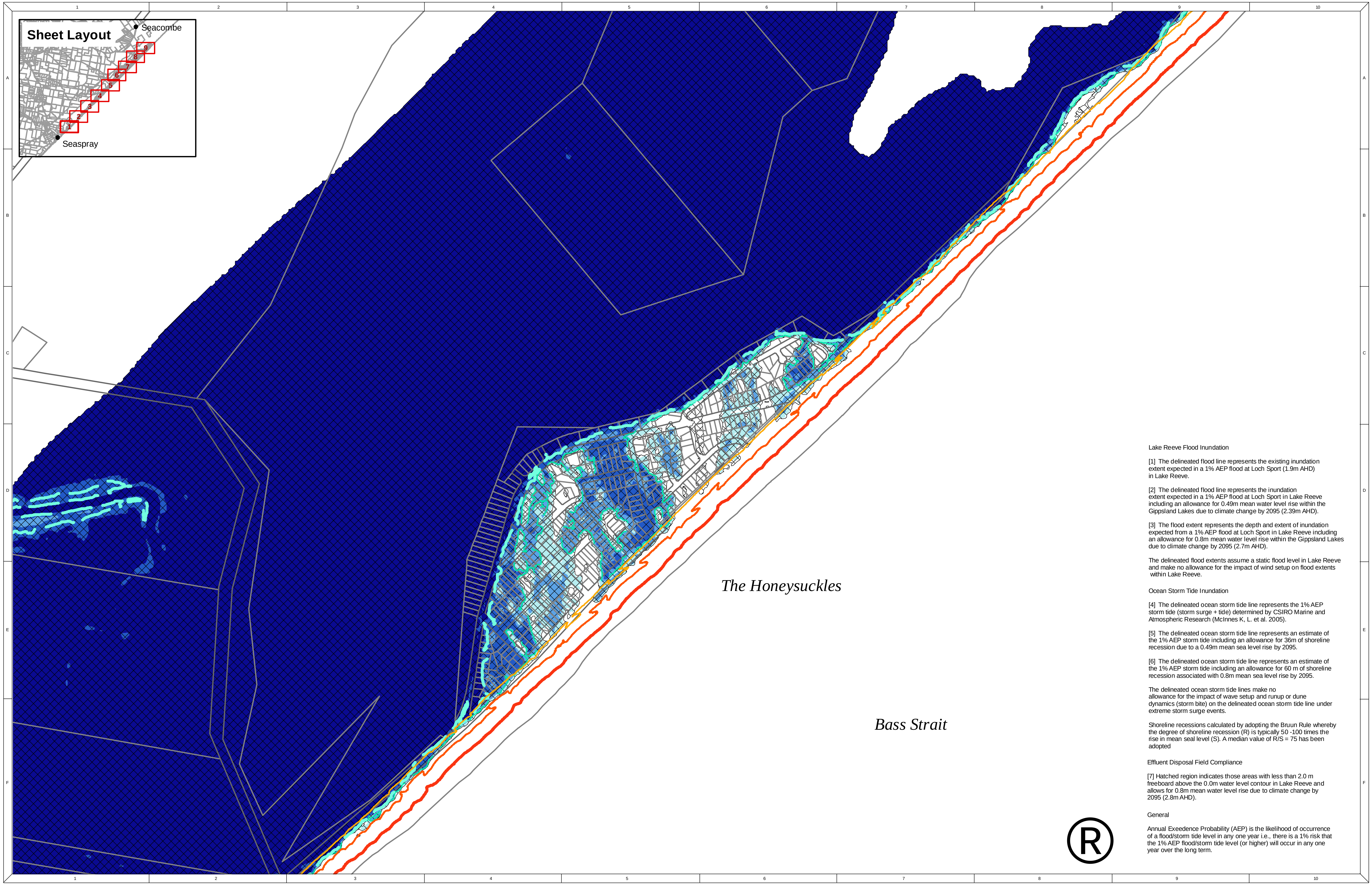

Lake Reeve Flood Inundation

[1] The delineated flood line represents the existing inundation extent expected in a 1% AEP flood at Loch Sport (1.9m AHD) in Lake Reeve.

[2] The delineated flood line represents the inundation extent expected in a 1% AEP flood at Loch Sport in Lake Reeve including an allowance for 0.49m mean water level rise within the Gippsland Lakes due to climate change by 2095 (2.39m AHD).

[3] The flood extent represents the depth and extent of inundation expected from a 1% AEP flood at Loch Sport in Lake Reeve including an allowance for 0.8m mean water level rise within the Gippsland Lakes due to climate change by 2095 (2.7m AHD).

The delineated flood extents assume a static flood level in Lake Reeve and make no allowance for the impact of wind setup on flood extents within Lake Reeve.

Ocean Storm Tide Inundation

[4] The delineated ocean storm tide line represents the 1% AEP storm tide (storm surge + tide) determined by CSIRO Marine and Atmospheric Research (McInnes K, L. et al. 2005).

[5] The delineated ocean storm tide line represents an estimate of the 1% AEP storm tide including an allowance for 36m of shoreline recession due to a 0.49m mean sea level rise by 2095.

[6] The delineated ocean storm tide line represents an estimate of the 1% AEP storm tide including an allowance for 60 m of shoreline recession associated with 0.8m mean sea level rise by 2095.

The delineated ocean storm tide lines make no allowance for the impact of wave setup and runup or dune dynamics (storm bite) on the delineated ocean storm tide line under extreme storm surge events.

Shoreline recessions calculated by adopting the Bruun Rule whereby the degree of shoreline recession (R) is typically 50 -100 times the rise in mean seal level (S). A median value of R/S = 75 has been adopted

Effluent Disposal Field Compliance

[7] Hatched region indicates those areas with less than 2.0 m freeboard above the 0.0m water level contour in Lake Reeve and allows for 0.8m mean water level rise due to climate change by 2095 (2.8m AHD).

General

Annual Exeedence Probability (AEP) is the likelihood of occurrence of a flood/storm tide level in any one year i.e., there is a 1% risk that the 1% AEP flood/storm tide level (or higher) will occur in any one year over the long term.

NOTE
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Meters

Scale
1:10,000

Lake Reeves Flood Inundation [notes 1-3]
- 1% AEP Flood Level (1.9m AHD) [1]
- 1% AEP Flood Level + 0.49m sea level rise (2.39m AHD) [2]
- 1% AEP Flood Level + 0.8m sea level rise (2.7m AHD) [3]
  - < 0.25m
  - 0.25 - 0.5m
  - 0.5 - 1.0m
  - >1.0m

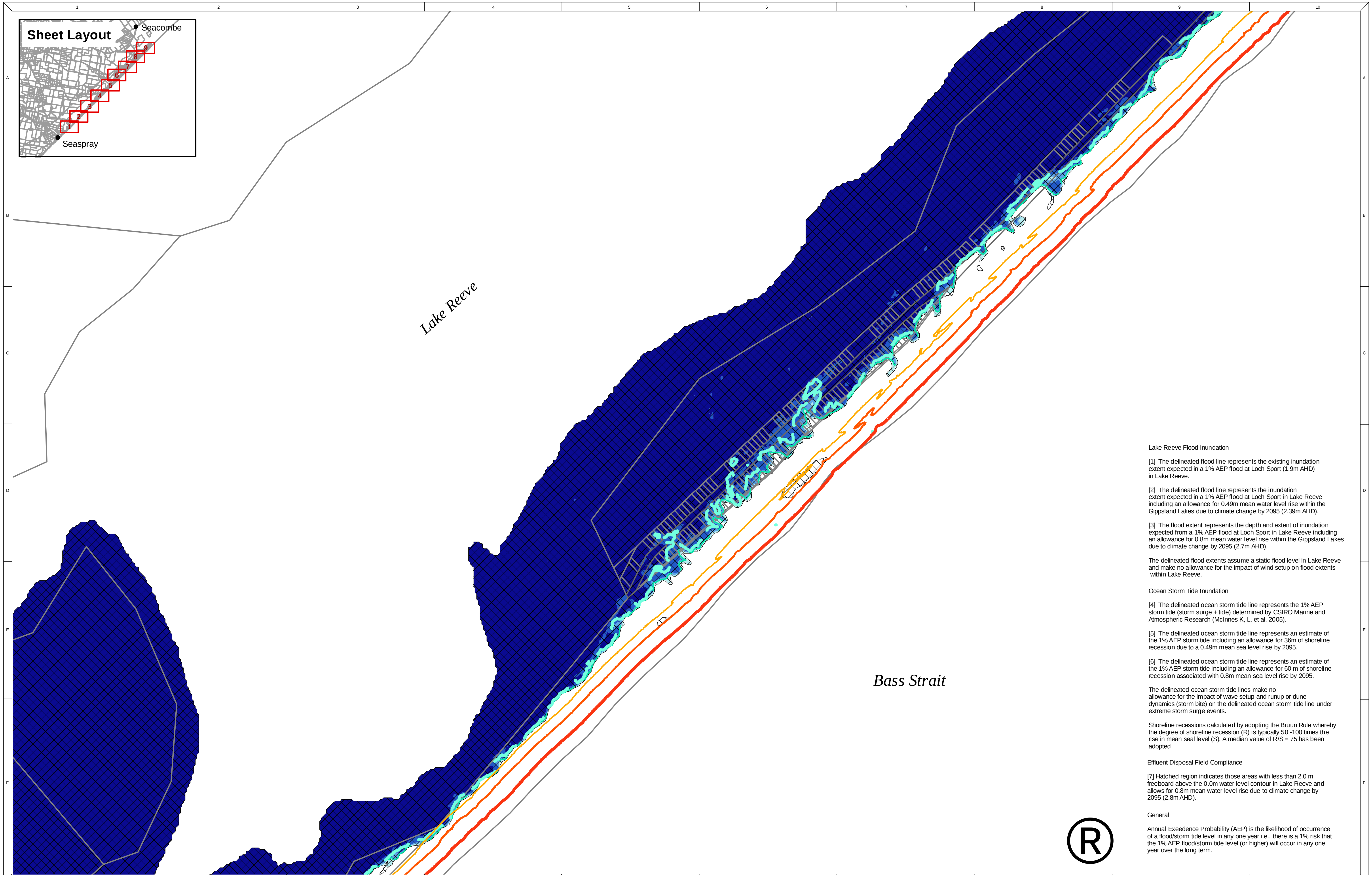
Ocean Storm Tide Inundation [notes 4-6]
- 1% AEPStorm Tide Level (1.4m AHD) [4]
- 1% AEP Storm Tide Level + 0.49 sea level rise (1.89m AHD) [5]
- 1% AEP Storm Tide Level + 0.8m sea level rise (2.2m AHD) [6]

Effluent Disposal Field Compliance [note 7]
- Less than 2.8m AHD

ETHOS NRM
WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

WELLINGTON COAST
1% AEP FLOOD, STORM TIDE AND SEA LEVEL RISE INUNDATION

REFERENCE: J724
DATE: Mar 12, 2008
SHEET 1 OF 9
DRAWING NUMBER: 1



Lake Reeve Flood Inundation

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[2] The delineated flood line represents the inundation extent expected in a 1% AEP flood at Loch Sport in Lake Reeve including an allowance for 0.49m mean water level rise within the Gippsland Lakes due to climate change by 2095 (2.39m AHD).

[3] The flood extent represents the depth and extent of inundation expected from a 1% AEP flood at Loch Sport in Lake Reeve including an allowance for 0.8m mean water level rise within the Gippsland Lakes due to climate change by 2095 (2.7m AHD).

The delineated flood extents assume a static flood level in Lake Reeve and make no allowance for the impact of wind setup on flood extents within Lake Reeve.

Ocean Storm Tide Inundation

[4] The delineated ocean storm tide line represents the 1% AEP storm tide (storm surge + tide) determined by CSIRO Marine and Atmospheric Research (McInnes K, L. et al. 2005).

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[6] The delineated ocean storm tide line represents an estimate of the 1% AEP storm tide including an allowance for 60 m of shoreline recession associated with 0.8m mean sea level rise by 2095.

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Meters

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1:10,000

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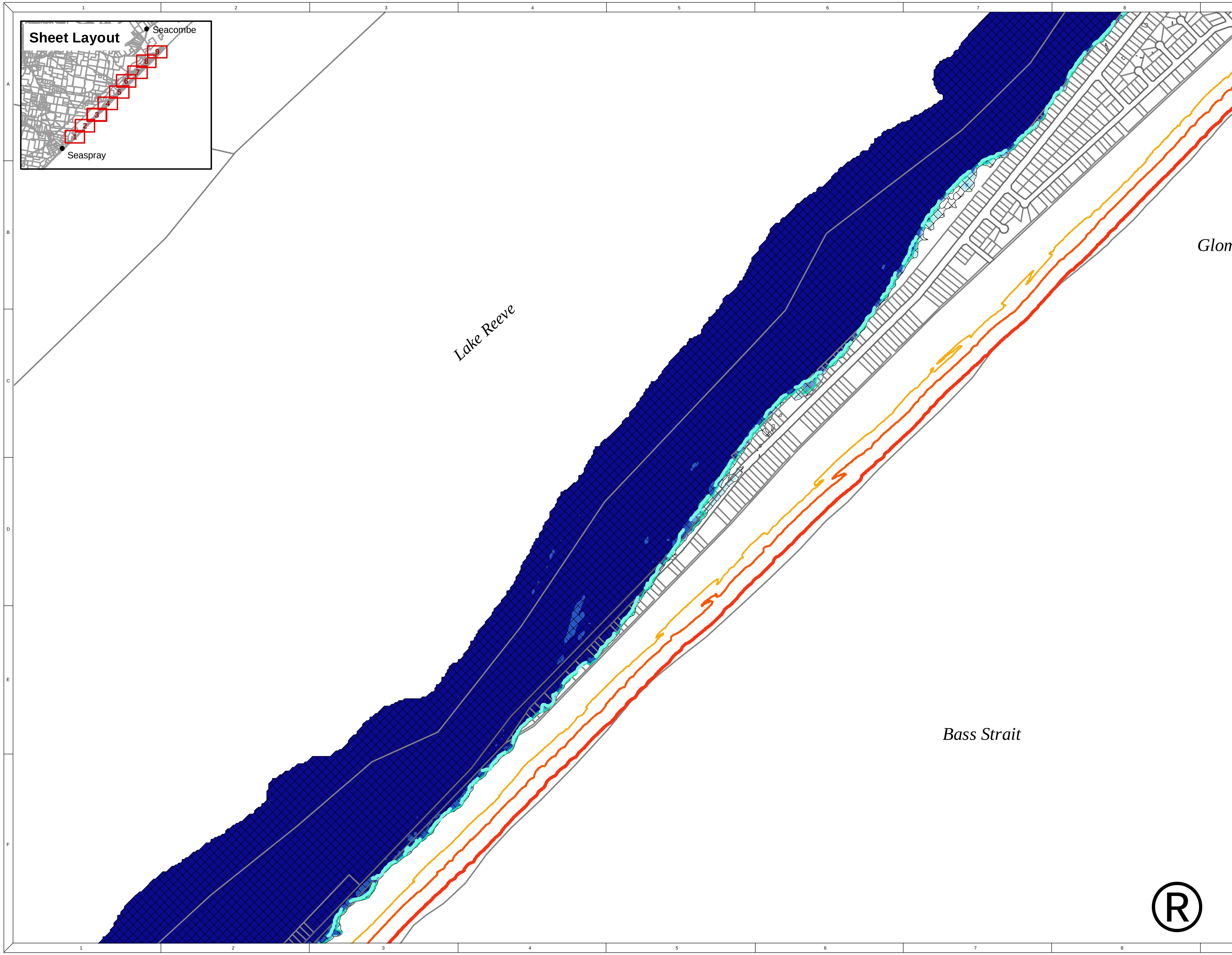
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

WELLINGTON COAST
1% AEP FLOOD, STORM TIDE AND SEA LEVEL RISE INUNDATION

REFERENCE: J724

DATE: Mar 12, 2008 | SHEET 2 OF 9 | DRAWING NUMBER: 1



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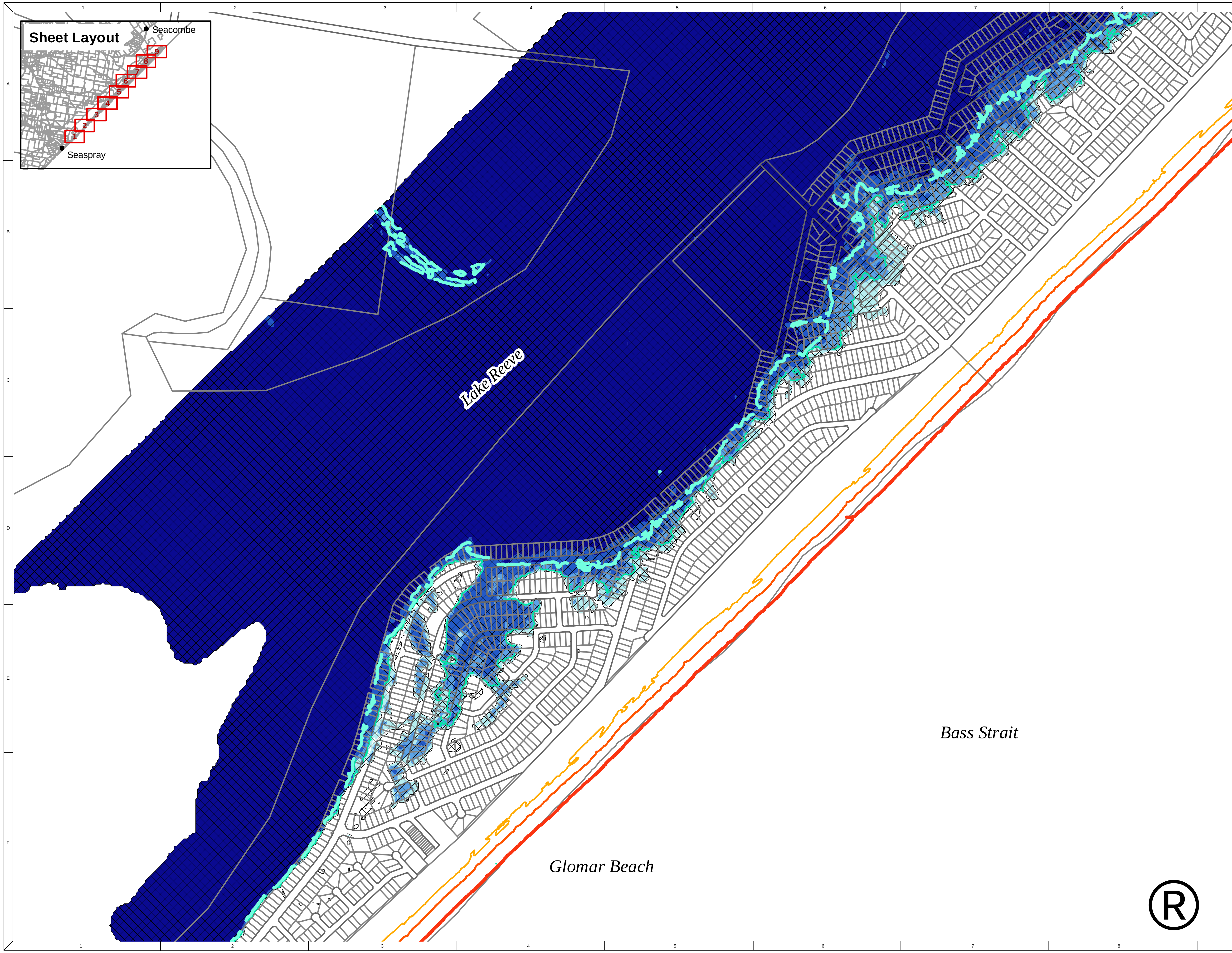
1% AEP FLOOD, STORM TIDE AND SEA LEVEL RISE INUNDATION

REFERENCE: J724
DATE: Mar 12, 2008
SHEET 3 OF 9
DRAWING NUMBER: 1



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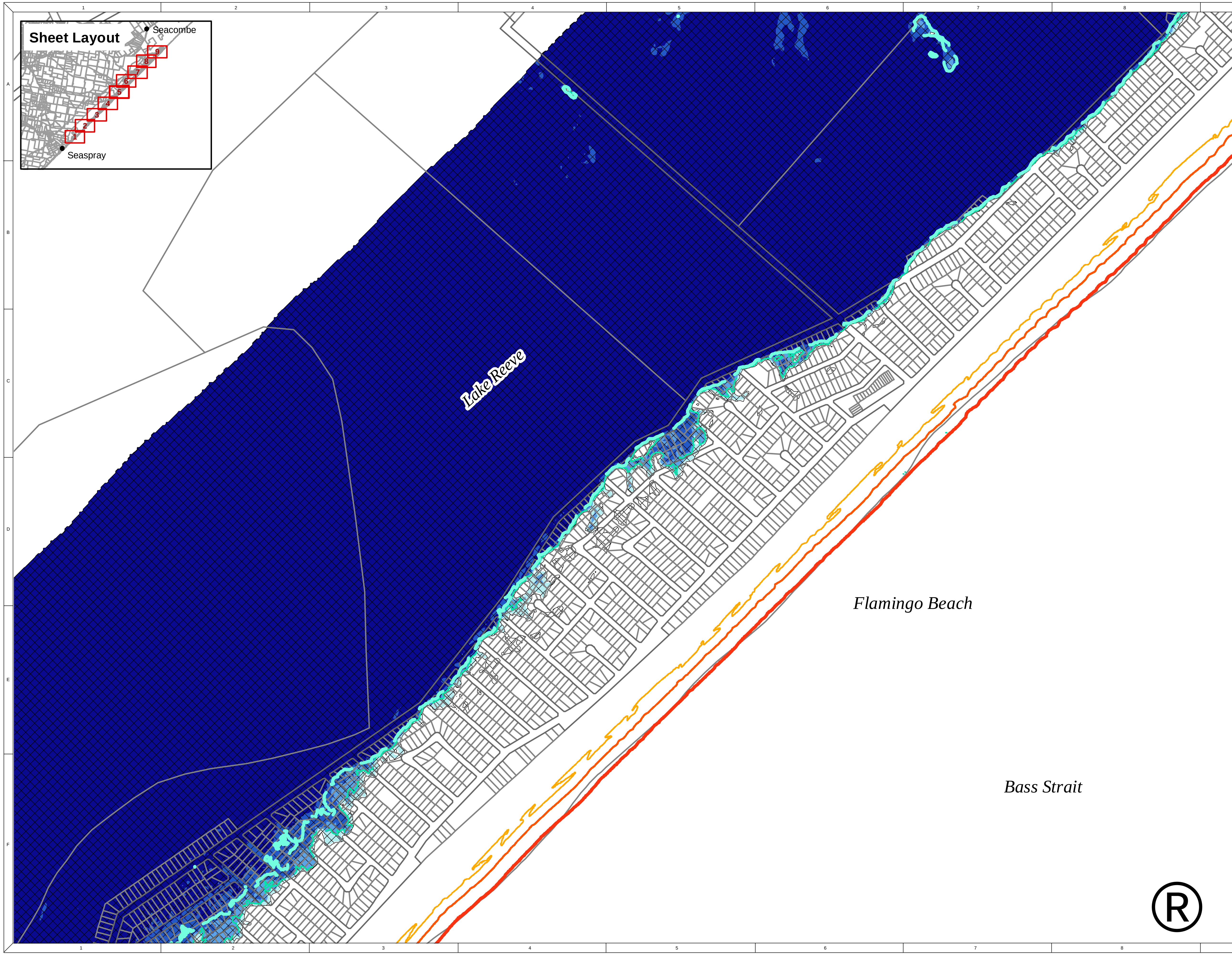

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1% AEP FLOOD, STORM TIDE AND SEA LEVEL RISE INUNDATION

REFERENCE: J724
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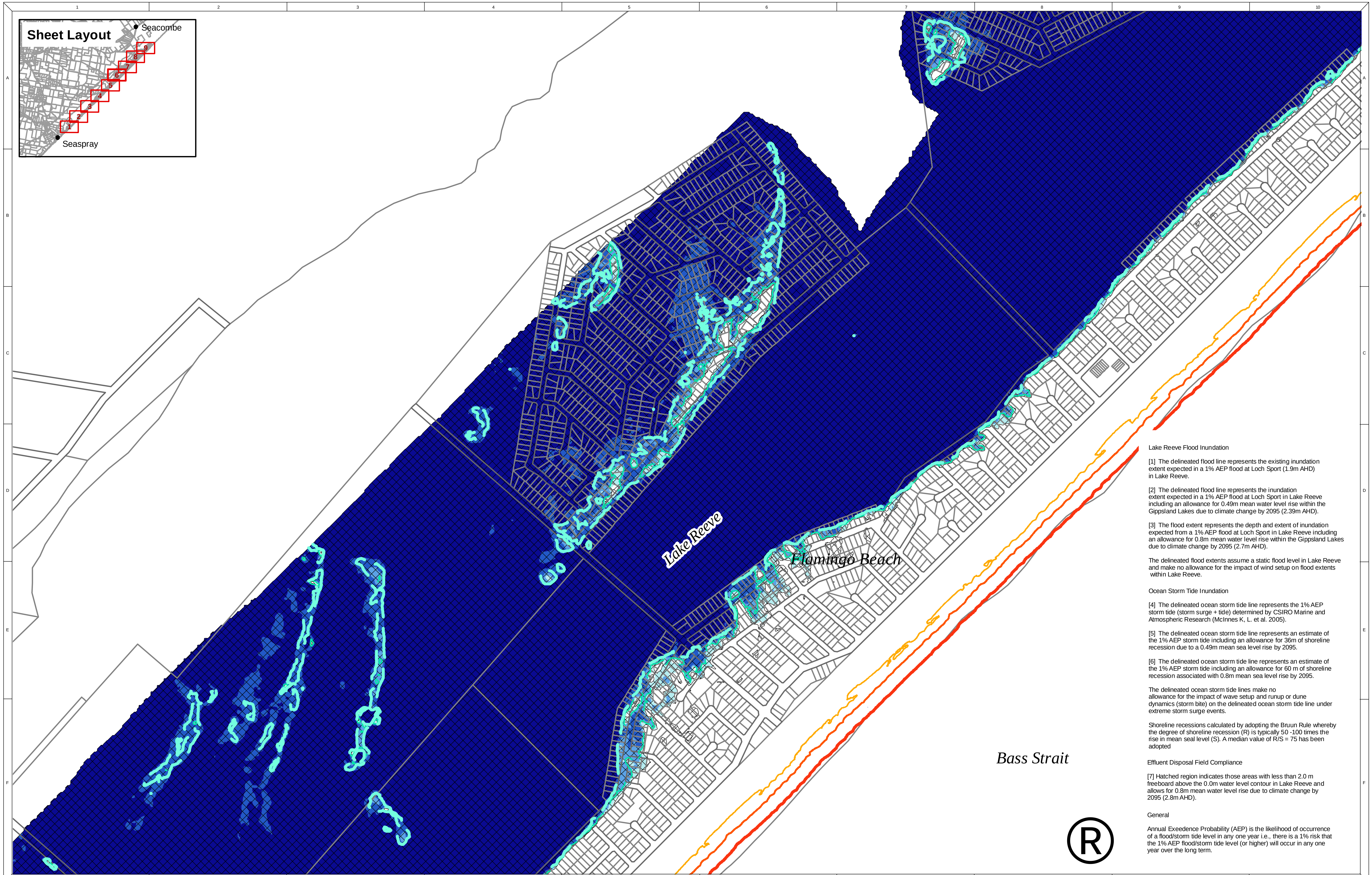

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WELLINGTON COAST
1% AEP FLOOD, STORM TIDE AND SEA LEVEL RISE INUNDATION

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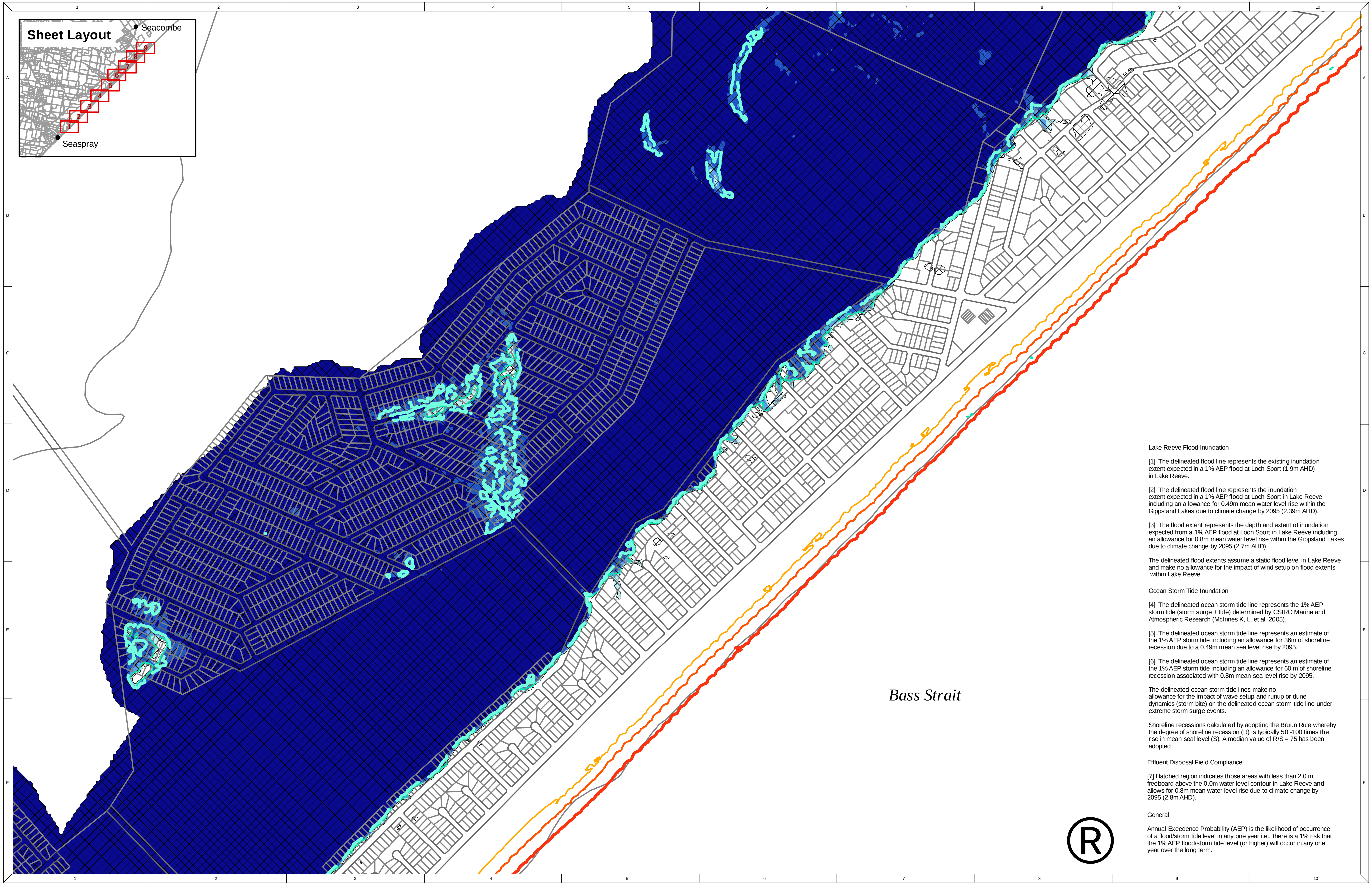

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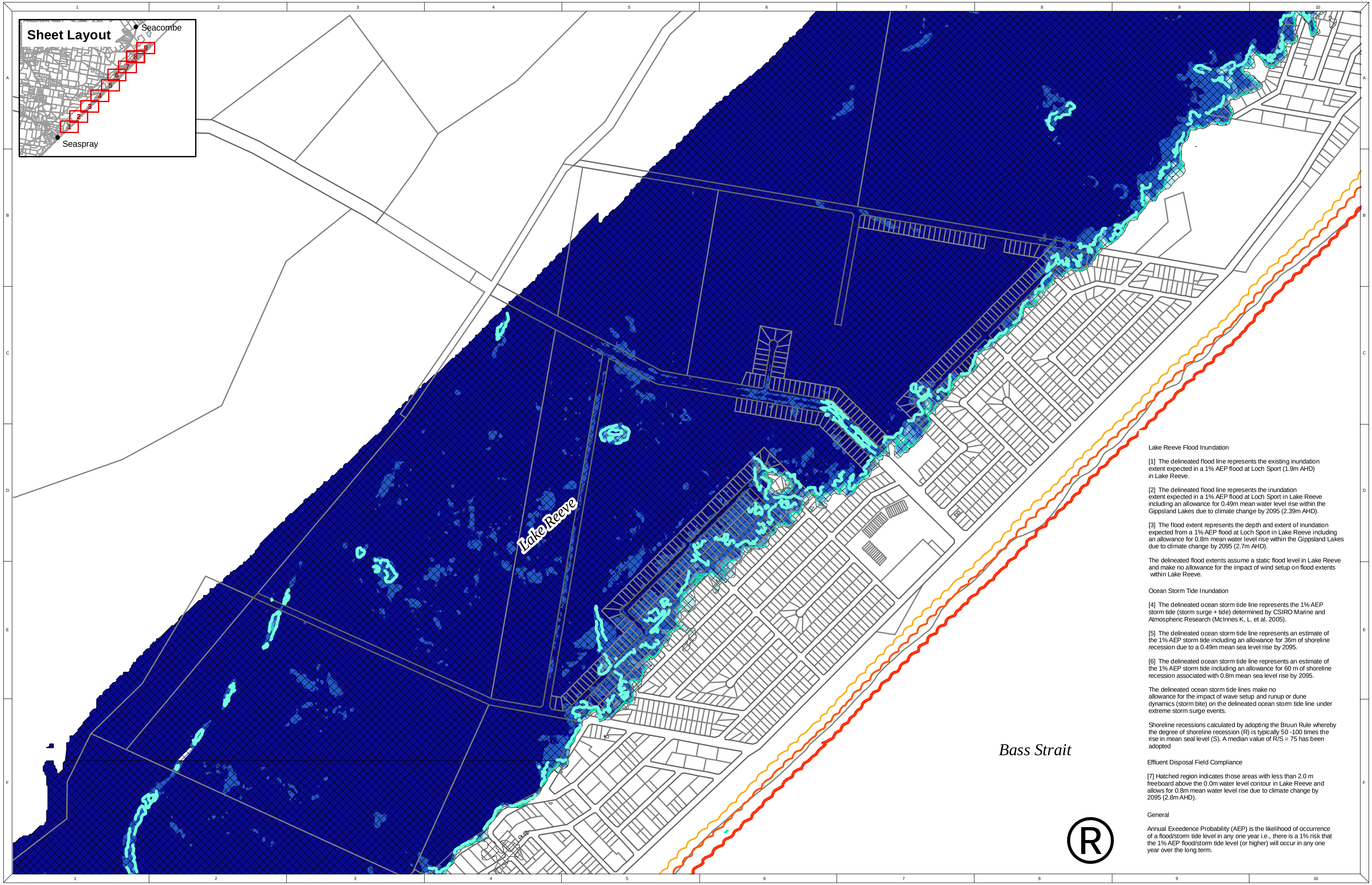

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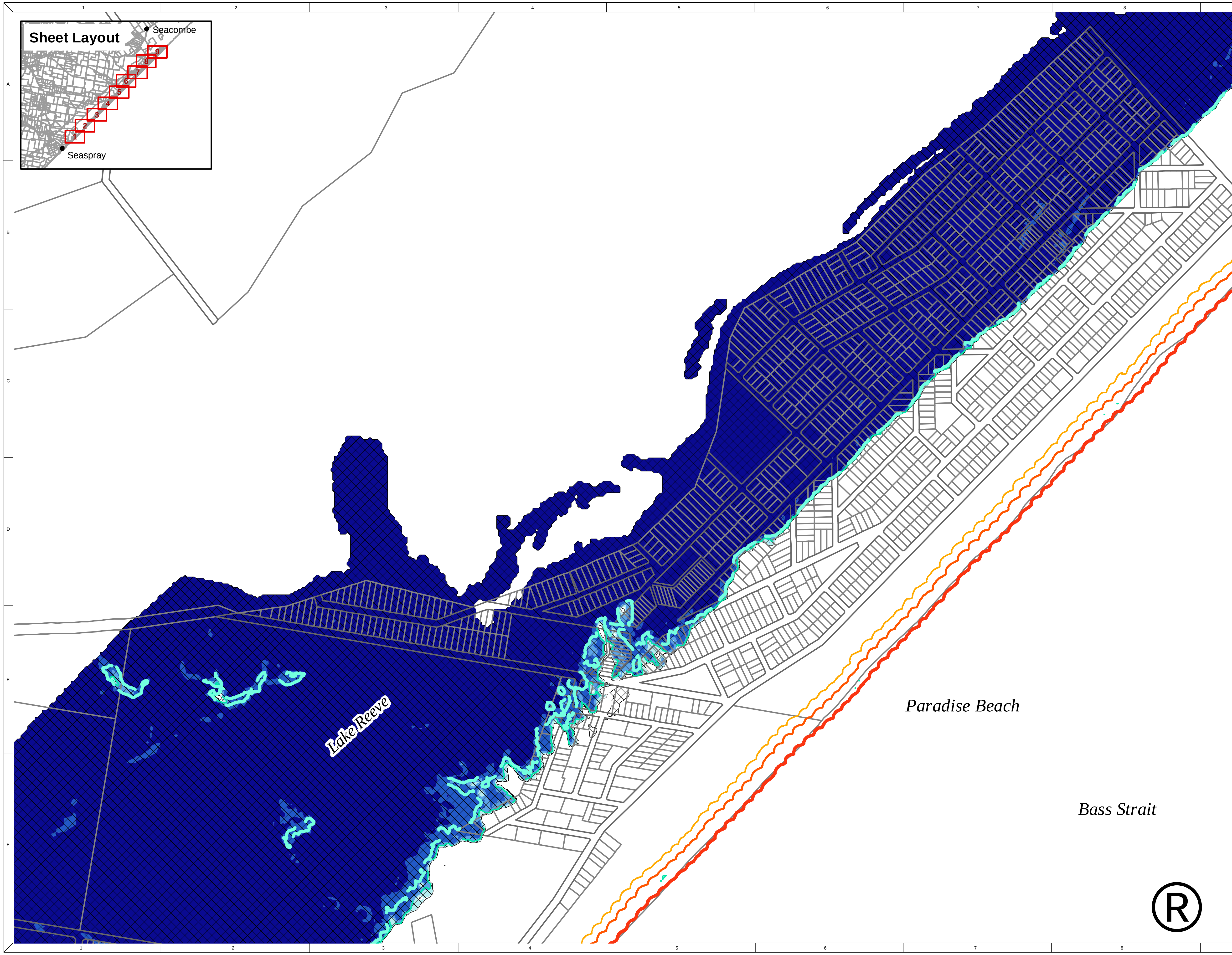

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- 1% AEP Flood Level + 0.49m sea level rise (2.39m AHD) [2]
- 1% AEP Flood Level + 0.8m sea level rise (2.7m AHD) [3]
  - < 0.25m, 0.25 - 0.5m, 0.5 - 1.0m, >1.0m

Ocean Storm Tide Inundation [notes 4-6]

- 1% AEPStorm Tide Level (1.4m AHD) [4]
- 1% AEP Storm Tide Level + 0.49 sea level rise (1.89m AHD) [5]
- 1% AEP Storm Tide Level + 0.8m sea level rise (2.2m AHD) [6]

Effluent Disposal Field Compliance [note 7]

- Less than 2.8m AHD

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WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

WELLINGTON COAST
1% AEP FLOOD, STORM TIDE AND SEA LEVEL RISE INUNDATION

REFERENCE: J724

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