Report

Lake Taupo Erosion Study – Stage 4

Received by Taupo District Council for public consultation purposes

report

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Prepared for

Taupo District Council
& Environment Waikato (Clients)

By

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1 Introduction

1.1 Background to the Study

The Lake Taupo Erosion Study (referred to as the Erosion Study) forms a key component of the wider review and management planning for a comprehensive Lake Taupo Foreshore Risk Management Strategy (referred to as the Risk Strategy). This wider Risk Strategy investigates hazards and risk relating to shoreline erosion, lake shore inundation and fluvial flooding of lake tributaries. The focus of the Erosion Study is to provide background for supporting information to assist in the development of the erosion component of the Risk Strategy.

The Erosion Study is a four phase project. Phases 1 - 3 of the study are complete. The phases have identified the risk areas around Lake Taupo, have involved the production of broad erosion risk maps and have identified the primary contributing factors to erosion.

The Stage 4 report is based on findings from the Stage 3 component, which focused on understanding the key contributing factors to erosion risk and the identification of erosion hazard levels around the lakeshore. The final stage of the study involves identifying whether any assets (properties, pipelines, reserves, ramps and so forth) are at risk, to enable the development of a risk based strategy for managing the erosion hazard around the lakeshore. It sets out options for appropriate physical works and/or land use controls that may be necessary to manage any hazards and issues associated with erosion.

The report sets out the technical criteria that have been used to guide the selection of appropriate management solutions for any particular location around Lake Taupo. The criteria will also be used as required in the future to assess management solutions. Specific priority sites are evaluated in terms of the preferred management approach using a qualitative approach for the assessment of management response options.

The following diagram (Figure 1) shows how these stages fit into the process of developing the Lake Taupo Foreshore Risk Management Strategy.

The Lake Taupo area is geologically young and dynamic with continuing tectonic and volcanic activity. The shape of the lake shore has evolved naturally over time as evidenced by historic landforms around the lake edge. Natural processes (including wind, rainfall, and tectonics) continue to shape the lakeshore resulting in areas of erosion and accretion.

Within this context of natural change, human influences have increasingly impacted on the shore. The natural processes of erosion and accretion combined with human influences need to be taken into consideration in forming the basis for decisions on the management of the lake shoreline. Understanding these influences on the lake is critical to the future planning and management of development along the lake shoreline. A key management consideration is that future planning should be looking towards managing development in erosion prone areas, rather than being solely responsive to erosion issues as they arise.

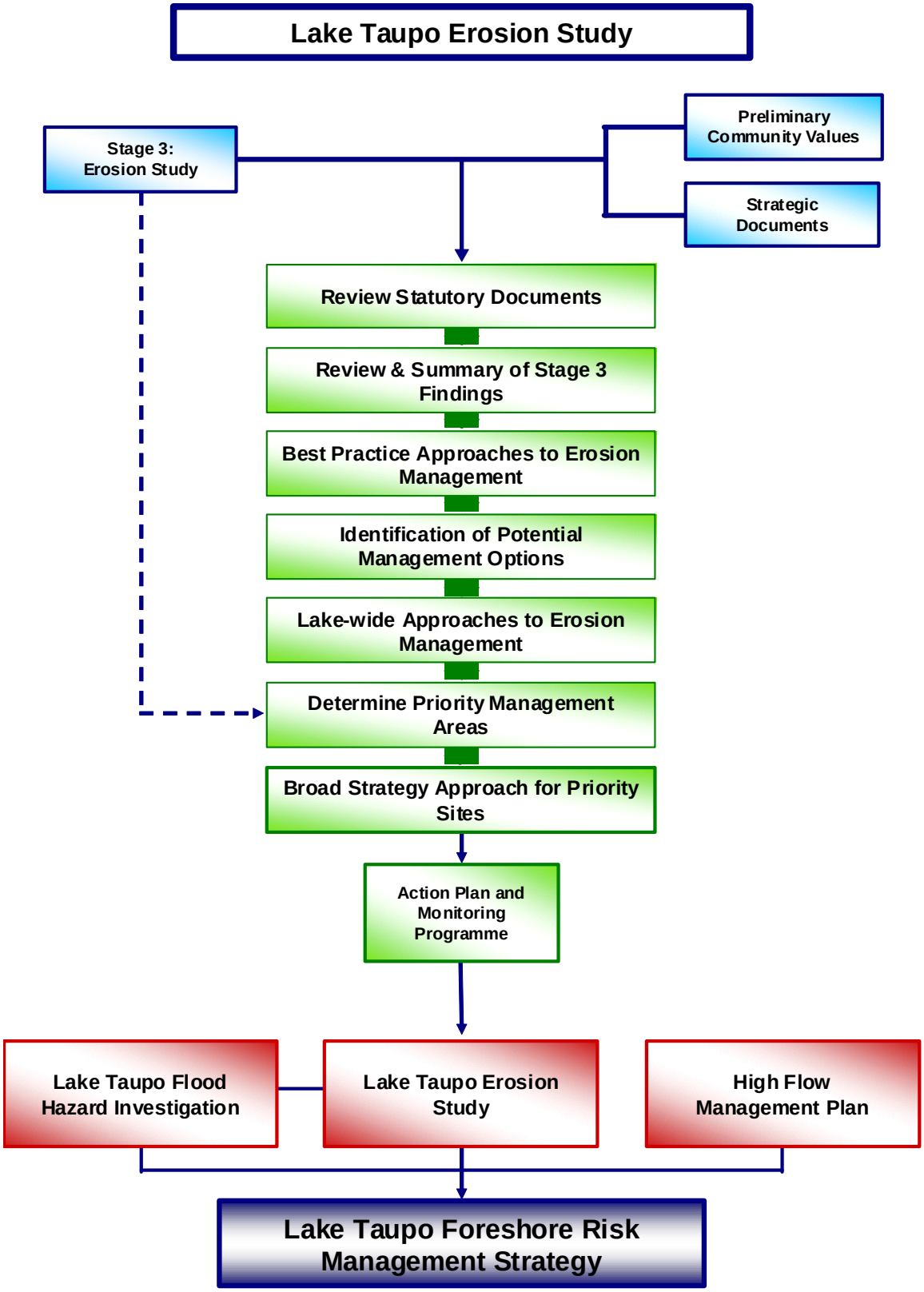


Figure 1. Lake Taupo Erosion Strategy

1.2 Scope of the Study

The Stage 4 study consists of the following sections:

- Section 1 provides the background to this study, the overall approach and where it fits in the legislative context.
- Section 2 describes the lake shore dynamics and erosion processes affecting the Lake Taupo shoreline.
- Section 3 provides a summary of the main conclusions from the Stage 3 findings.
- Section 4 sets out principles that have been used to guide assessment of lake shore erosion management options.
- Section 5 provides generic information on shoreline protection methods, to aid in the selection of appropriate management solutions for any particular location around Lake Taupo.
- Section 6 sets out the most appropriate response options to the erosion hazards through the preparation of a lake wide erosion management strategy.
- Section 7 provides an evaluation of management options for priority management areas.
- Section 8 sets out an action plan and a summary of the monitoring programme required in order to better understand the erosion processes.
- Section 9 outlines the key recommendation and conclusions for the study.

1.3 Tangata Whenua

Ngati Tuwharetoa is tangata whenua for Lake Taupo and statutory owners of the bed of Lake Taupo and its river and stream tributaries. Ngati Tuwharetoa's involvement by way of leadership and guidance is critical to the management of erosion around the lake and ultimately the successful development of the Risk Strategy. The Ngati Tuwharetoa Trust Board's specific role in the project is as follows:

- Advising on key issues relating to lakeshore management;
- Actively participating as a partner in policy development and hazard management decision-making processes regarding lakeshore management;
- Enhancing working partnerships with Environment Waikato, Taupo District Council and other stakeholders in respect to the management of flooding and erosion on the lake;
- Ensuring that the Board drive the decision making process on those issues that put into effect the 2020 Lake Taupo-nui-a-tia Action Plan; and
- Represent Board interests regarding accretion and erosion issues pertaining to lakeshore management and how this should be managed.

1.4 Assumptions and Limitations of the Study

This report is based upon the scope and sources of information made available for this particular study. The report therefore is based on the accuracy and completeness of the information provided at the time of the review.

Opinions and conclusions are based upon our understanding and interpretation of current information, and should not be constituted as legal opinions. This report should not be copied or used for any other purpose other than was originally intended or used for any other purpose without the approval of a Director of Beca.

1.5 Strategy Approach and Methodology

1.5.1 Objectives of the Study

The Stage 4 report will form the basis for the development of the Risk Strategy. The intention is to develop a strategy for the management of the interface between the land and water in the future. The objectives of the Stage 4 study incorporate:

- Establishment of priority risk areas based on erosion data collected in the Stage 3 study;
- Development of suitable management options for appropriate priority risk areas;
- Recommendation of appropriate land use controls;
- Development of an action plan setting out means for improving the management of erosion at Lake Taupo in the future; and
- Determination of a process for the ongoing measurement and monitoring of shoreline erosion around Lake Taupo.

The study contributes towards the establishment of an overall management framework for Lake Taupo (part of the management planning for the comprehensive Lake Taupo Risk Management Strategy), taking consideration of environmental, economic and community values.

1.5.2 Methodology

In preparing Stage 4 of the study, the following methodology has been undertaken:

- Review and summary of Stage 3 findings
  - This summary provides the basis for the need for a management strategy and guides the scope of work for Stage 4;
- Review of relevant legislative documents to provide context to the study.
- An initial assessment of visions and values from relevant existing documents and survey responses to a questionnaire. [Note that a separate process for further consultation is being undertaken by Taupo District Council (TDC) and Environment Waikato (EW) for the Risk Strategy. This will include an agreed programme for iwi liaison.]

- Determination of priority management areas
  - Desktop analysis was undertaken of land uses at identified areas, along with 'lifeline' services and other important community infrastructure (i.e. defence structures, roads, reserves etc.) and any implications these present to ongoing management. A high level review of Taupo District 2050 to identify any future development areas was carried out to ensure recommended management options and data collection take account of future development and infrastructural requirements and vice-versa. Based on the Stage 3 erosion risk and complimentary land use analysis, priority sites are identified.
- Identification of potential management options
  - The assessment of potential management options started at a lake wide level and then a list of generic lakeshore erosion management options were developed. The generic options that are considered appropriate for the Lake were then refined and assessed for suitability at priority/growth areas. This is illustrated through the development of a matrix, and will take into consideration local factors and processes.
- Assessment of management options
  - At a priority area level the range of options is assessed for suitability, and the appropriateness of options is based on the shoreline processes, land use, existing assets and infrastructure, planning requirements, general amenity values and natural character. A matrix of solutions is produced for each priority area, and a summary discussion sets out the advantages and disadvantages of the various options with an indication as to the suitability for use for a particular location. Recommended options are set out for each priority area.

1.6 Legislative Context

As a strategic document, the Erosion Study will provide overarching direction to both the district and regional council when considering and managing the risk associated with erosion at key locations around Lake Taupo.

The focus of the study as a non-statutory document is to go beyond the Resource Management Act 1991 (RMA) and to include wider consideration of Council's responsibilities under legislation such as the Local Government Act 2002 along with the need to tie in with other existing management documents including regional plans, the District Plan, Long Term Council Community Plans (LTCCP), structure plans, reserve management plans and local community plans (i.e. the Taupo-nui-a-Tia Action Plan) and asset management plans.

The following section briefly outlines the legislative context of the Erosion Study. Appendix B sets out in further detail the relevant legislative context. In summary, the legislation, statutory documents, non-statutory documents and other mechanisms all recognise the implications of foreshore erosion hazards, and provide a framework by which growth and development can be managed to reduce the risk (avoid and mitigate) and impacts of natural hazards on people and their property.

1.6.1 Resource Management Act 1991

Section 5 of the RMA sets out the purpose of the Act, which is "the sustainable management of natural and physical resources". Further guidance and principles that have relevance for activities occurring and associated management of the lake foreshore area provided in Sections 6–8 of the RMA.

- Waikato Regional Policy Statement

The Regional Policy Statement (RPS) sets out issues, objectives and policies in relation to the Waikato Region, many of which are relevant to the management of natural hazards. Foreshore erosion is not specifically identified in the 'Natural Hazard' section as a natural hazard issue that occurs within the Waikato Region. The Erosion Study is one method that identifies areas of potential risk (lakeshore erosion) and associated natural hazard management options. The RPS seeks to ensure new subdivision and developments are designed to avoid or mitigate the adverse effects of natural hazards.

- Waikato Regional Plan

The Waikato Regional Plan (the Regional Plan) is the formal mechanism for managing the Regional Council's statutory responsibilities relating to the effects of activities upon air, land water and the coast. A number of resource management issues are identified in the Regional Plan that relate to natural hazards. Relevant to this study is the River and Lake Bed Module which includes objectives, policies, rule and/or other methods regarding the effects of structures within the lake bed and associated bed disturbance.

- Hazard Risk Mitigation Plans

The RMA gives regional councils responsibility for undertaking hazard assessment and for preparing and implementing risk mitigation plans for natural hazards. EW has and continues to prepare and implement risk mitigation plans for natural hazards in the Waikato Region however no specific plans currently exist for erosion around Lake Taupo. This study will guide the future development of hazard management for Lake Taupo.

- Taupo District Plan

The Taupo District Plan is the formal mechanism for managing the District Councils statutory responsibilities relating to the effects of land use, subdivision, and activities on the surface of lakes and rivers. The following sections of the District Plan are relevant:

  - Natural Hazards – 3l.2.1, 3l.2.2 – this section highlights that lakeshore erosion can occur as the level of a lake rises and falls. The objectives and policies under this section are aimed at managing/preventing developments within known erosion prone areas.
  - Foreshore Protection – 4e.2.1 – this section addresses foreshore protection by requiring any building[1] within a Foreshore Protection Zone[2] is assessed as a Discretionary activity and Council will base its assessment on its nature, scale,

[1] Building excludes any structure constructed for erosion control purposes.
[2] Defined in the Taupo District Plan as being *"20m measured horizontally from the landward boundary of the from the 'bed' (as defined in the Act) of any identified lake or river, or for Lake Taupo, measured from the Nui-a -Tia boundary, whichever is the further inland."*

form and intent, its necessity and alternative locations, and its visual and aesthetic effects (as opposed to the effects associated with lakeshore erosion).

- Local Government Act 2002

The Local Government Act (LGA) 2002 provides the general framework, obligations, restrictions and powers under which local authorities operate. The key sections of the Act are Sections 93 – 97. These sections provide for Long Term Council Community Plans that describe the activities of local authorities. This can include descriptions of local authority activities as well as providing for the management of natural hazards.

- Waikato Regional LTCCP

Under the LGA, EW has prepared a Long Term Council Community Plan (the Regional LTCCP). The Regional LTCCP identifies groups of activities and objectives (which are supported by specific activities) that have relevance to the management of natural hazards. Specific activities identified by EW include:

a. Regional Hazards - the objective of the regional hazards group of activities for EW is to identify, plan for and reduce the risks from hazards and emergencies throughout the region. This includes developing policy for hazards, raising public awareness and putting in place site and hazard-specific reduction measures.
b. Land and Soil - reducing erosion and sediment and avoiding or reducing the effects of accelerated erosion, also to reduce the adverse effects from destabilised river banks and lake beds.

- Taupo District LTCCP 2006 - 2016

The LTCCP, under the section headed "Lakes and River Systems", explicitly recognises the Councils role with respect to protecting and managing the Lake Taupo lake system. While this includes a number of environmental initiatives, the plan notes specific activities in relation to flood and erosion investigations and control work (currently being developed as part of the Lake Taupo Foreshore Risk Management Strategy). This includes activities such as the construction of breakwaters, seawalls and beach replenishment where appropriate. The LTCCP, for 2006 – 2016, notes the continuation of the development of the Lake Taupo Foreshore Risk Management Strategy along with the development of objectives, policies, rules and/or other methods in the District Plan to control the use of land for the avoidance or mitigation of natural hazards.

1.6.2 Ngati Tuwharetoa Environmental Iwi Management Plan

The Ngati Tuwharetoa Environmental Iwi Management Plan was produced by the Tuwharetoa Maori Trust Board (TMTB) in 2003 and is particularly relevant because the TMTB is the trustee and Ngati Tuwharetoa Iwi are the owners of the Lake Taupo lake bed and its tributaries. The underlying theme of the plan is to strengthen the partnership between TMTB (owner/trustee) and EW who has management responsibility for the lake bed.

The plan identifies the unnatural control of lake levels, and land degradation and inundation as a result of artificial control of lake levels as issues but does not go into any

further depth because the plan is designed in response to statutory procedures i.e. formulating regional and district plans and resource consents.

1.6.3 2020 Taupo-nui-a-Tia Action Plan

This integrated sustainable development strategy was developed in response to the need to improve ecosystem sustainability and to protect the health of Lake Taupo-nui-a-Tia. 2020 Taupo-nui-a-Tia was a three-year project initiated by the Lakes and Waterways Action Group, Ngati Tuwharetoa, Taupo District Council and the wider Taupo community. An underlying theme is the need to strengthen the partnership between the various bodies that have a statutory and customary management responsibility for the lake bed and its wider catchment.

2 Conceptual Lake Erosion Processes

2.1 Lake Shoreline Dynamics

Various factors contribute to the potential for erosion along the shores of Lake Taupo. Natural processes include the geology of the lakeshore and lake and shoreline influences such as wind and waves, sediment inputs from rivers, and the extent to which the shoreline has come into equilibrium with the environment. Human influences can also have a significant impact on the potential for shoreline erosion through catchment activities such as land use, the manipulation of river flows into the lakes and lake levels, river protection work. Local human effects through development, and structures disrupting the equilibrium and dynamics of sediment movement and budgets, also influence shoreline erosion.

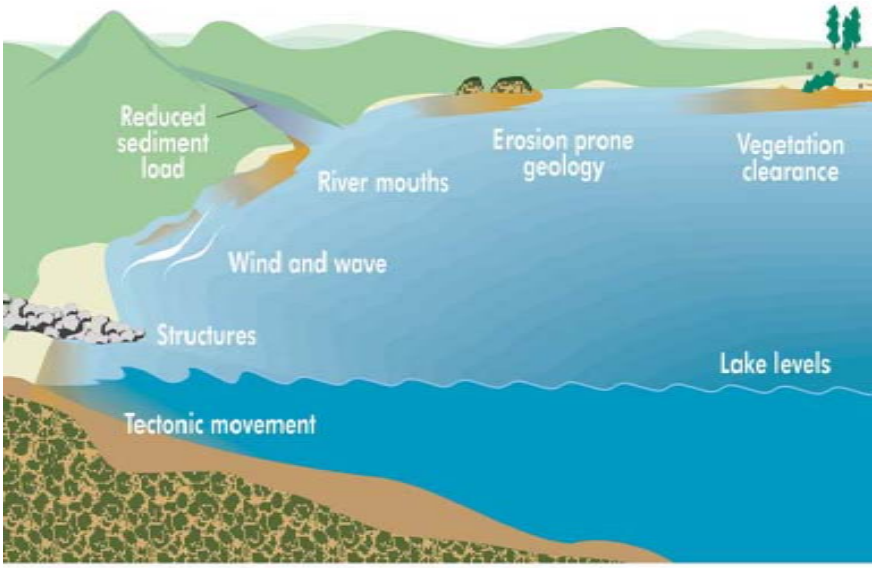


Figure 2. Contributing factors to erosion

It is important to note that shorelines go through natural cycles of erosion and accretion. When investigating erosion it is important to view any perceived erosion within this context.

The response of a lake shoreline to erosion is dependent on the shoreline geology, which broadly falls into 3 categories: hard rock; soft rock or clayey banks; and soft shorelines (sand or unconsolidated material). From a shoreline management perspective, hard rock shorelines do not erode. Soft rock or clayey bank shorelines potentially erode but to a lesser degree than soft shorelines. When erosion occurs the landform is lost as it cannot recover. Often a soft shoreline forms at the base of soft rock or clayey bank shorelines. The following discussion is on erosion processes of soft shorelines, which is relevant to the context of the erosion occurring along Lake Taupo's foreshore.

The sands and sediment that make up soft shorelines are continually moving. Strong winds on the lake cause storm waves which refract and break on the shoreline at an angle, transporting sediment in the direction of the incident wave. This is referred to as littoral drift. If this drift is not matched by sediment inputs to the system, such as sediment in the nearshore zone or from rivers, then the shoreline profile changes. If the drift is greater than the sediment inputs, erosion will occur. Conversely if the drift is less than the sediment inputs, accretion occurs. Transfer of sediment from river mouths and the nearshore zone is a highly complex process.

Because the timing of storm wave events and sediment discharges from river systems, do not always coincide, the shoreline will naturally fluctuate. These fluctuations can appear as periods of time when the shoreline erodes and then later recovers as accretion occurs. These short term fluctuations are natural shoreline responses and should not be seen as long term erosion. Such fluctuations may be periodic and persist for 1 to 2 decades. This is why long term monitoring is important and even though erosion may appear to persist for several years it may still be cyclical. From a shoreline management perspective, it is important to differentiate between shoreline fluctuations and irrecoverable long term erosion. This differentiation is sometimes only possible after about 15-20 years of monitoring data is collected for a specific area.

The main delivery mechanism for sediment from a catchment is through runoff following rainfall, particularly severe events which result in floods, and in turn result in land and river erosion. The magnitude of erosion can be influenced by land use and land management practices. Contemporary practices such as river training, protection such as fencing off watercourses from livestock, re-vegetation and creation of dams, tend to reduce sediment delivery. Large dams can significantly reduce the amount of sediment passing down stream due to the sediment settling out in the dam once the velocity of the water decreases.

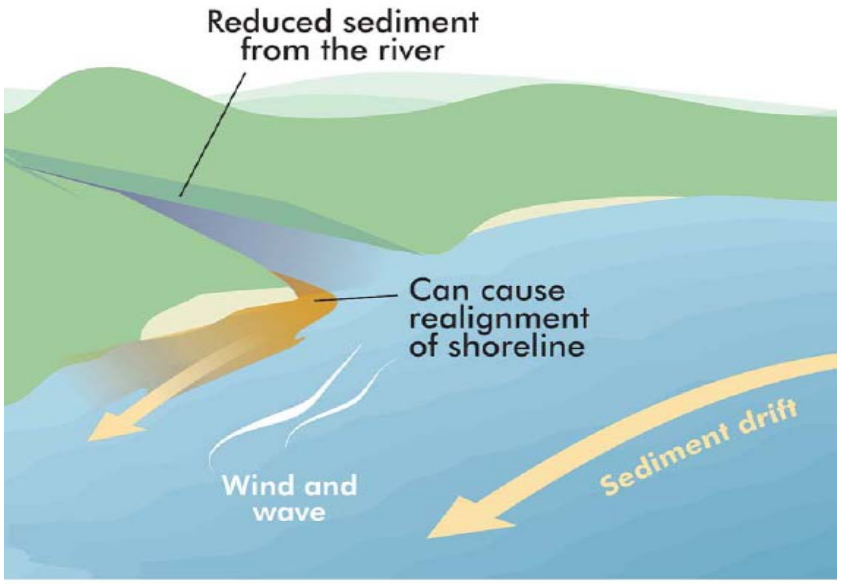


Figure 3. Potential effects of reduced sediment from rivers

Based on these concepts the over all conclusions about shoreline erosion on Lake Taupo are:

- More erosion of land results when storm waves occur with elevated lake levels;
- Erosion can be more focused on a shoreline with lesser fluctuating lake levels, this results from the wave energy continually being applied to a more narrow band of the beach, focusing the erosive energy;
- Many shoreline protection measures are located in the natural shoreline fluctuation zone;
- Subsidence caused by longterm tectonic movement will cause accelerated shoreline erosion in some places;
- Land and river erosion supplies sediment to the lake system which is a sink for sediment (i.e. the overall lake system is accreting). Even though the lake as a whole is accreting, the significant water depth and other processes mean that the lake edge may still erode. This erosion is however likely to be localised. Moreover, surplus sediment can be stored in the nearshore system and act as an additional source for sediment, buffering severe stormwave events and lessening the level of shoreline erosion; and
- Lake Taupo erosion rates are generally less than those that occur on exposed ocean beaches.

2.2 Implications of Shoreline Erosion

Eroding lake shorelines have a range of impacts, including:

- Loss of public (Crown and Council) foreshore land;
- Loss of private land where the public foreshore has completely eroded away;
- Loss of private land where no public foreshore existed;
- Threat to physical assets such as public and private buildings, boat ramps, roads/tracks/walkways, car parks, drainage infrastructure, recreational facilities and amenities;
- Threat to public safety;
- Loss of native vegetation, exotic species and reduction in lake foreshore habitat; and
- Threat and possible loss to cultural and historic sites of significance.

3 Summary of Stage 3 Findings

The following section provides a summary of the main conclusions from the Stage 3 study findings.

3.1 Causes of Erosion

As outlined in Section 1, the Lake Taupo area is geologically young and dynamic with continuing tectonic and volcanic activity. The shape of the lake shore has evolved naturally over time as evidenced by historic landforms around the lake edge, and natural processes continue to shape the lakeshore resulting in areas of erosion and accretion.

The factors contributing to erosion around Lake Taupo vary considerably from site to site. Geological resistance to erosion, sediment supply and wind generated waves dominate the natural influencing factors for lake processes, but in their own right do not necessarily cause erosion where the system has come to equilibrium. In most cases there is insufficient historical monitoring data to differentiate between natural fluctuations and long-term erosion.

a. Geology

The study findings outline that the dominant geology along the shoreline of Lake Taupo will largely determine the relative resistance of that point of shoreline to erosion. Those areas that have unconsolidated deposits such as pumice alluvium are significantly more susceptible to erosion. Eastern and southern shorelines have a low resistance to erosion due to their geology (soft sediment pumice) and western and northern shorelines have a moderate to high resistance because of their more resistant geology(welded ignimbrite).

b. Wind

Predominant wind direction and wave directions exert more energy on shorelines facing a west and southwest direction. These are often the shorelines that also have unconsolidated deposits

c. Tectonic subsidence

Historical assessments have indicated that the impact of subsidence and uplift is currently being offset by adequate sediment supplies and littoral drift, resulting in only minor impact on erosion in most areas. Depending on the availability of sediment in the future the potential for this to change remains.

d. Land Use/Soil Conservation

Due to the highly permeable soils within much of the lake catchment, the impact of land use on erosion is reduced. This is because the amount of overland flow is minimal for most storm events. Higher levels of erosion occur during high intensity events when the pumice soils are easily eroded by surface flow. Sediment delivery to the lake shoreline is therefore episodic. Therefore the Stage 3 study found that the impact of soil conservation works is unlikely to significantly reduce the sediment supplies and increase the risk of shoreline erosion, compared to predevelopment levels.

In some locations following historical land use change (i.e. when the native vegetation was cleared for farming) there was an increase in sediment input into the lake. The effects of

this are now being reduced as less sediment is being put into the system because of changes in land use controls and soil conservation. Some of the areas that may have experienced accretion during the periods following increased sediment inputs could now see a change as the sediment inputs return to previous levels.

e. Lake Level Regime

The Lake Taupo water level is managed within a 1.4 metre range for use in the Waikato hydro electric scheme. Lake level analysis has shown that the control of the lake level results in periods when the lake is held higher than it would be naturally. Over the long term this is mostly balanced out by other periods when the lake level is drawn down below what it would have been naturally, resulting in similar lake level regimes if compared on a yearly basis. The overall range of lake level under control is reduced with extreme lake levels no longer occurring. The Stage 3 report also identifies that in more recent years the lake levels have been held higher than natural during summer months, which can coincide with extreme wind events, increasing the risk of erosion in some locations. Typically the windiest period is in spring when the lake level is generally lower. 2007-2008 has reversed this trend with the lake level being lower than the natural level over summer.

f. Development / Structures

There are some localised erosion issues associated with structures such as ramps and groynes around the Lake. This is most prevalent in the areas around Taupo Township. Development in close proximity to the shoreline, within what may be natural shoreline fluctuation zones, has led to the placement of erosion control structures to protect individual properties. Many of the structures are not adequately designed and have resulted in adjacent erosion issues. In addition, there have been significant reductions in sediment supplies from hydro dams placed in rivers (e.g. Kuratau, Hinemaiaia) feeding Lake Taupo. This is considered likely to be contributing to potential erosion issues. Shorelines within the relevant sediment compartments might be expected to be impacted as they adjust to the reduced sediment inputs.

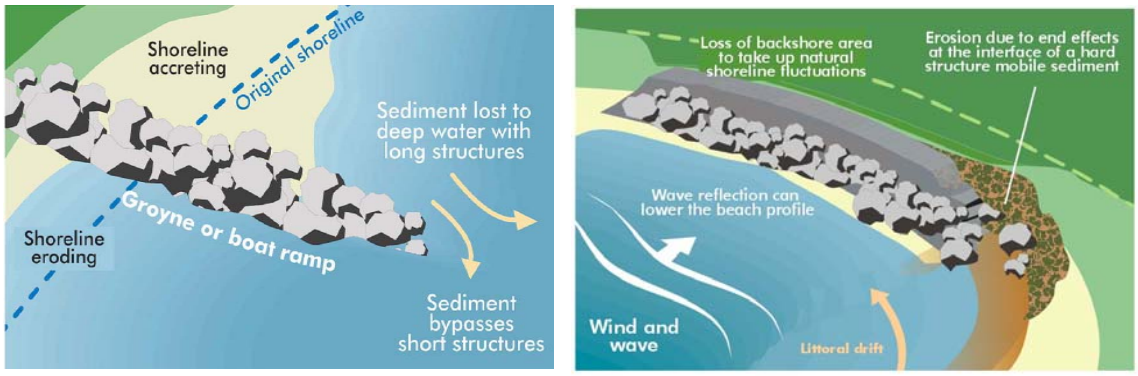


Figure 4. Erosion issues associated with structures

g. Operational issues and Maintenance

Some current operational and maintenance practices associated with structures, such as sediment removal from ramps, are recommended to be reviewed. Taupo is unique in that the boat ramps on the lake are managed by the Department of Internal Affairs. Current

practices such as those undertaken at the ramp at Two Mile Bay where sediment that accumulates behind and on the ramp is removed from the lake may be contributing to down drift erosion issues. This practice should be reviewed to take into consideration the sediment deficit issues in the area.

Other maintenance activities such as the removal of pest plants from the shoreline of the lake also need to be reviewed taking into consideration their effect on erosion. When significant sections of vegetation are removed, replanting with suitable species or successional planting should take place to mitigate any increase in erosion risk. The management of other species such as willow, and their effect on sediment transport should also be considered. Appropriate guidelines and the necessary planning provisions should be developed to support this practice.

Current operation of boats on the lake doesn't appear to be having a significant effect on erosion. However, the impact of boat wake on shoreline erosion should be considered if any significant changes to the type of boats or level of operation occur.

3.2 Hazard Assessment & Mapping Summary

For the purposes of the Stage 3 hazard assessment, the shoreline was divided into 44 broad units. The erosion hazard level is classified as very low, low, moderate or high. The breakdown of units was based on changes in geology, land form and aspect, exposure to different levels of lakeshore process attributes, and reported/measured historical erosion trends. The hazard assessment was carried out by undertaking a systematic review of available information (mapped on GIS/aerial photograph background) for each shoreline unit. In parallel to this a weighted attribute approach (using geology, historical erosion trends, tectonic deformation, wave height, and long-shore sediment transport) was used to provide a tool for assisting in developing a consistent quantified approach to apportioning hazard levels. A summary of the results is given below and the erosion hazard areas are shown below in Figure 5.

a. High Risk Units

Nine units are considered to be at high risk of shoreline erosion:

- Waikato River to Wharewaka Point (incl. Taupo Township), Waitahanui, Hatepe, Motutere and Te Rangiita along the eastern shoreline;
- Kuratau and Whareroa on the western shoreline; and
- Whangamata Bay (incl. Kinloch) and Whakaipo Bay on the northern shoreline.

All nine units are comprised of unconsolidated deposits, are likely to experience wave run-up at the higher end of the range and have historical incidents of erosion. Except for Whakaipo Bay all units have had a moderate to high degree of development, but there is more awareness of erosion in these areas.

For Hatepe and Te Rangiita the high risk areas are predominantly around the river mouth areas and may be linked to natural fluctuations in the river mouth dynamics and the interaction with lake shore processes.

b. Moderate Risk Units

Some fifteen units were identified as being predominantly of moderate risk of shoreline erosion. These units are spread around the circumference of the lake, tending to occur in sedimentary bays comprising weak geology (unconsolidated deposits that readily erode).

Some moderate risk units have experienced localised erosion cycles (e.g. Acacia Bay) but further work is needed to determine whether these are long term erosion trends.

c. Low Risk Units

Fourteen of the forty-four units were identified as predominantly having a low risk of shoreline erosion. The majority of the north western shoreline is plotted as low risk, dominated by the headlands which comprise dense volcanic flows and ignimbrites that are relatively resistant to erosion. Five units of low risk also occur along the eastern shoreline. This is likely due to the occurrence of accretion and/or the lack of reported erosion for some units.

d. Very Low Risk Units

Seven of the forty-four units were identified as being of predominantly very low risk of shoreline erosion. Excluding Te Anoputarua Headland (southwest of Te Rangiita) all of these areas occur along the western shoreline of Lake Taupo (making up approximately 50 % of this shoreline). The very low risk rating is in large due to the presence of strong, erosion resistant geology (dense volcanic flows and welded ignimbrites).

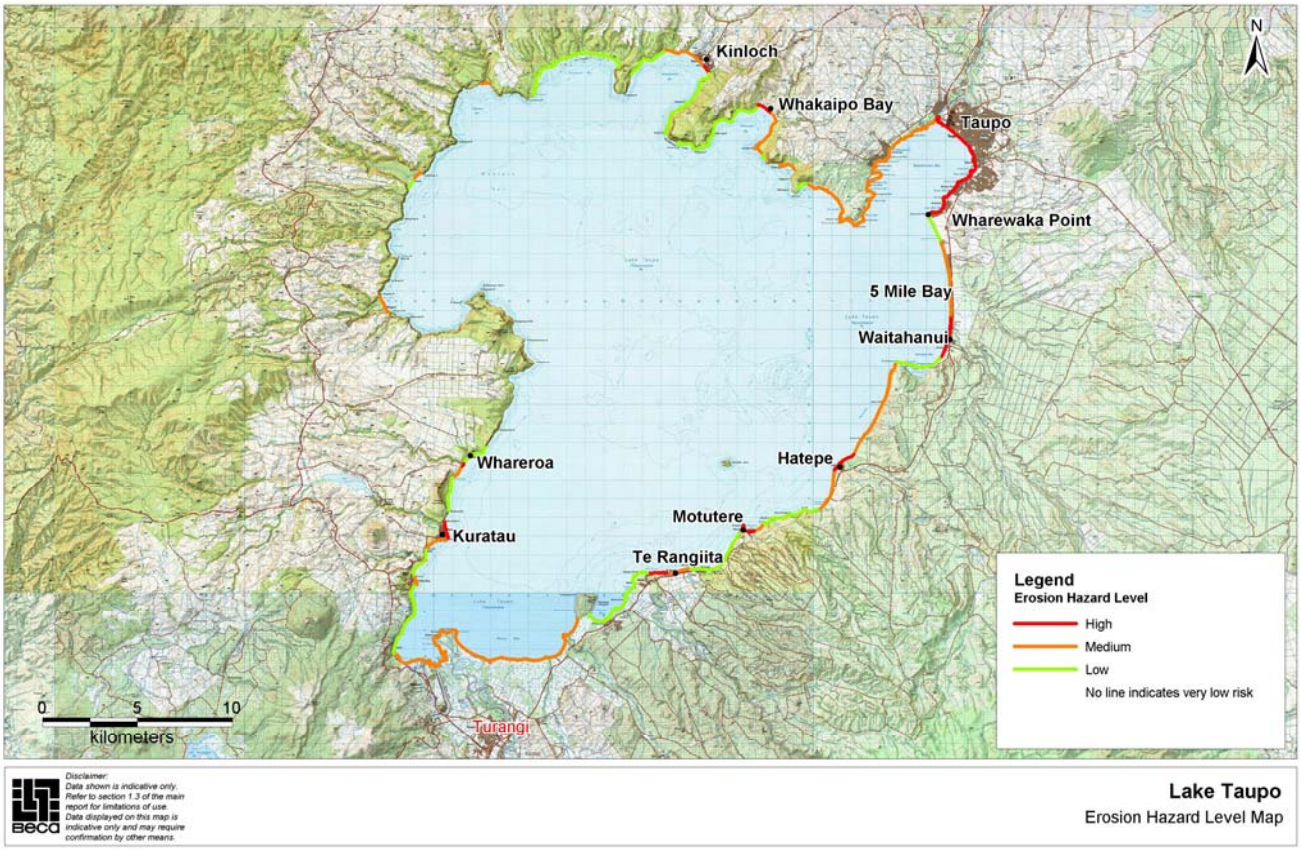


Figure 5 - Lake Taupo Erosion Hazard – Summary Map

3.3 Limitations and Information Gaps

Historically there has been very little information available relating to the lake processes affecting the shoreline or supporting data on erosion history. This has resulted in development of the shoreline without regard to the natural fluctuations of the shoreline and the level of erosion risk, or implications of development on adjacent shoreline areas.

The most significant gap in the information required is long-term repeatable survey information on the profile of the shoreline. The current information is both short in duration and the extent is limited. The collection of this data will allow better understanding of the longer-term trends and cycles in the position of shoreline.

Additional information that would also contribute to better understanding of the processes driving erosion and the design of appropriate protection measures include: sediment budget modelling, wave height monitoring, and monitoring of performance of erosion control options.

Erosion is most evident during periods of high wind when coinciding with high lake levels. However, providing quantified contributions for the various human factors is not practicable given the current information, the complexity of the shoreline processes, and variability for each specific location. The level to which some of the main factors are influencing erosion is indicative only and requires further long term data and site specific investigation for verification.

From a shoreline management perspective, it is important to differentiate between shoreline fluctuations and long term erosion. It is also important to ensure development does not take place within these fluctuation zones.

3.4 Monitoring and Data Collection

One of the key findings of the Stage 3 report was that at present the available data is insufficient to identify the relative impacts of the different causes of erosion around Lake Taupo to any degree of certainty. Monitoring record lengths are relatively short (i.e. 5 years) and spatially limited. As there is a desire to better understand the shoreline processes, relative impacts of the different the causes of erosion and to better quantify the rates of change, this report will set out a series of measures by which the data may be improved. Such measures are likely to include data collection by means of:

- Beach profiles and nearshore bathymetry;
- Establishment of profile volume changes and development of sediment budgets;
- An assessment of the differences – if any – between the modified and natural lake levels; and
- An assessment of the changes in sediment in offshore reserves (e.g. river mouths)

Together these measures will form a monitoring program that can be used to identify any changes in shoreline erosion rates in high and medium risk areas. The monitoring data should be consolidated annually and the programme revised to ensure the locations and frequency are capturing any observed changes. A more comprehensive review of the data, methodology and management should be undertaken every 5 years.

4 Responses to Erosion Management

4.1 Background

The management of lake shore erosion can be controversial and complex, especially given the conflicts of interest relating to public and private values which exist in the lake shore environment. Historically, erosion risk to lake side development or private property has predominantly been managed by reactive responses through the use of hard structural options such as seawalls and groynes. Whilst in some situations such management approaches may be an appropriate response to the lake erosion risk there are many situations where a more proactive and sustainable method should be implemented.

4.1.1 Past Responses to Erosion Management at Lake Taupo

Past responses to erosion at Lake Taupo have generally been reactive, responding to erosion issues as they arise rather than planning for the prevention of future erosion. Historically, the response to erosion risk has been the responsibility of individuals rather than through a Council-led response.

Lack of a comprehensive response to lake-wide areas has resulted in a large quantity of hard structures in the lake foreshore. Evidence of this can be seen at various development sites around Lake Taupo but is most notable through the Taupo Township area (e.g. Two Mile Bay to Wharewaka Point).

Management options have been applied to resolve individual erosion issues rather than solve a wider issue, with regard to the cause or potential consequences for other areas of the lake. This has resulted in an ad-hoc approach to erosion control along the shoreline. The current Regional Plan allows for this through its rules which currently permit erosion control structures along 50 metres of every kilometre of shoreline. It allows as a Controlled activity erosion control structures along 200 metres of every kilometre of shoreline. Erosion control structures along more than 200 metres of one kilometre of shoreline are a Discretionary activity.

4.2 Approaches to Erosion Management

There are many shoreline erosion management solutions which have been developed, tested and evaluated in the engineering, scientific and shoreline protection management literature. Erosion management options include the status quo (do nothing) option, non-structural activities, structural works and a combination of these options. The range of options and the approach advocated in determining which option should be considered preferable is set out below.

4.2.1 Hierarchy of Management Response

For erosion management related to the coastal environment, national policy and best practice directs any assessment of management options according to a clear hierarchy of responses. This hierarchy of response, as stated in the New Zealand Coastal Policy Statement (NZCPS), is considered to be transferable in terms of developing an approach to lake shore erosion management. The hierarchy of erosion response options is advocated

for the assessment of options (where Tier 1 is most preferred and Tier 3 is least preferred), and is based on the following:

- Tier 1: Non Structural Options
  - Aims to manage activities through land use strategies in the lake shore environment so as to avoid the creation of an erosion hazard, through consents, policies and regulatory actions.
- Tier 2: Soft Structural Options
  - Aims to protect lake shore development and activities by re-establishing or maintaining the natural form of the lake foreshore environment (a 'natural' shoreline approach as opposed to 'physical' structures).
- Tier 3: Hard Structural Options
  - Structures which often alter the physical processes which cause lake foreshore erosion in order to reduce erosion rates and erosion risk to land use and development.

While the Tier 1 Options (most preferred) are more easily applied to undeveloped land, its implementation in areas where the shoreline has already been developed is more difficult. Although more rarely undertaken, remedial planning techniques such as planned retreat can be used where the strategic drivers outweigh the difficulties in implementation. Based upon the hierarchy of response in the NZCPS, the focus in developed areas is usually on protecting assets, in which case soft structural options are recommended to be undertaken where possible, as opposed to hard structural options. The hierarchy of erosion responses is illustrated in Figure 6 below:

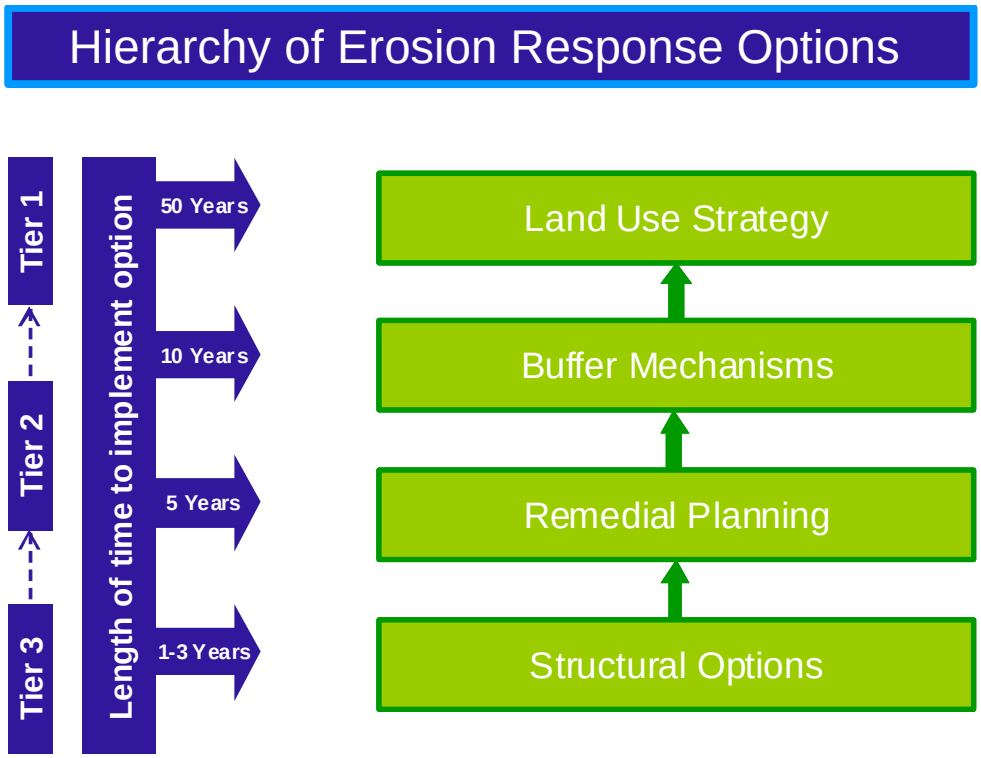


Figure 6. Hierarchy of Erosion Responses

The table below identifies the management options referred in this study. A more detailed discussion of them follows in Section 4.3.

Table 4.1 – Lake Shore Erosion Management Options

Status Quo	Non Structural	Soft Structural	Hard Structural
Do nothing	**Land Use Strategy** **Buffers** ■ Restrictive zoning Setbacks ■ Reserves **Remedial Planning** ■ Planned retreat ■ Transferable Development Rights **Lake Level Regime** **Dam sediment management**	**Beach Replenishment** **Re-vegetation**	**Seawalls** **Groynes** **Offshore breakwaters**

4.3 Identification of Potential Management Options

This section provides generic information on shoreline protection methods, to aid in the selection of appropriate, integrated and sustainable management solutions for any particular location around Lake Taupo. The guidelines outlined in this section offer generic detail in terms of erosion management solutions. In many cases the best solution is one that incorporates a combination of the options. Examples of this are referred to in section 4.3.4.

There is a wide range of shoreline management options that may be employed to combat erosion around Lake Taupo. The options discussed in this section can be broken down into three categories, based on the three Tiers detailed above in Section 4.1.

- Non-Structural Options generally focus on planning techniques that aim to manage development close to the shoreline to minimise the potential erosion hazard.
- Soft-Structural Options include works that aim to re-establish or maintain the existing natural shoreline environment, subsequently reducing the erosion hazard.
- Hard-Structural Options include works that alter or influence the natural shoreline process, resulting in a reduction in the rate of shoreline erosion and a reduction in erosion hazard.

Although hard-structural works can be very effective in reducing shoreline erosion hazard, they can also have a number of undesirable environmental impacts. As soft-structural options have fewer of these adverse impacts, they are generally preferable to hard-structural works. It is important that any solution takes local conditions into account.

It may be the case that no works are suitable and it is more appropriate to let the shoreline erode, in this case non-structural planning options such as setbacks and development restrictions could be used.

Prior to conducting any shoreline management, it is essential to fully understand the erosion processes at work in the area. This is a multi-step process that should consider if there is actually an erosion hazard (i.e. determine if there are any existing developments or essential services at risk of erosion), determine the causes of the erosion and the level of erosion (risk), develop an understanding of the environmental context (i.e. the relative importance of natural, social and physical processes), selection of an option and determination of any environmental impact.

4.3.1 Status Quo/ "Do Nothing" Option

The status quo option of continuing with out new intervention should not be overlooked when considering the range of options for a particular erosion site. It is often appropriate where there are minimal assets at risk and a lack of understanding remains regarding the erosion processes for that location. In these cases it is important to continue monitoring and improve the understanding of shoreline dynamics to allow a more informed decision to be taken in future.

By understanding the causes of erosion, both natural and man-made, the status quo becomes the benchmark case against which erosion responses can be judged.

Advantages include:

- Avoids potentially unnecessary structures and disturbance to the shoreline;
- Allows natural fluctuations in the shoreline position to occur; and
- Reduces immediate capital cost expenditure.

Disadvantages include:

- Can lead to further erosion and increased costs for remediation later; and
- Threat/risk to public and private property and infrastructure remains.

4.3.2 Non-Structural Options

Non-structural options are most appropriate in areas where there is little or no existing development, or areas where structural solutions are inappropriate, for social, cultural, environmental or economic reasons. Non-structural options are typically in the form of planning and development controls and may feature either the formation of buffer zones or remedial planning techniques.

Land Use Strategy

The objective of a land use strategy is to determine what, if any development should take place, so that development is consistent with the assessed erosion hazard (i.e. placing limits on development in erosion hazard zones). A strategic approach to managing shoreline activity to mitigate erosion should be a component of any integrated hazard management plan.

Buffer Mechanisms

Buffer mechanisms involve the prediction of the future shoreline over a given period of time and the limitation of development lake-ward of that point. These options allow the shoreline to fluctuate naturally and are based on the management of activity rather than natural processes.

The width of a buffer zone, determined based on historical erosion rates, should be sufficient to allow for:

- Implementation of erosion management techniques, that may reduce or reverse the erosion trend;
- Total expected erosion over the designated time period;
- Short-term fluctuations and Extreme events; and
- Design factor of safety.

Buffer mechanisms seek to prevent an erosion hazard from developing, rather than to manage it and as such are more suited to undeveloped sites. Buffer mechanisms include restrictive zoning, setbacks, and use of reserves.

i. Restrictive Zoning

This management strategy controls development in an identified area through land use zoning in the relevant district plans. This zoning may put restrictive uses upon the land, preventing areas prone to erosion being developed for residential or commercial purposes, for example. There are both advantages and disadvantages to the use of restrictive zoning.

Advantages include:

- Retention of private land ownership;
- Identification of restrictive zones in district plans clearly identifies appropriate and inappropriate activities;
- Allowing development in keeping with local environmental requirements while maintaining a minimum building standard;
- Can be specific to particular concerns; and
- Can be used to identify a coastal hazard zone.

Disadvantages include:

- Control of private use rights:
- Control rather than prevention of activities;
- May only be applicable to future development; and
- Inflexible (district plans may only be completed on a ten-yearly interval).

ii. Setbacks

Setbacks are a means of controlling specific activity within a specified distance from the shore. The setback distance will move with changes in the shoreline and MHWS, so will not be a constant width. Setbacks are generally defined within the District Plan.

Advantages include:

- They can be activity specific, so can include all structures, or only specific buildings / structures;
- They can move with the shoreline; and
- Private ownership of the affected shoreline is retained.

Disadvantages include:

- Setbacks may be defined for broad areas and may not allow for localised areas of erosion, therefore setback distances may be general rather than location specific.
- Setback lines may encroach on existing development, in which case it cannot be undertaken without also addressing public interest concerns and potential compensation issues.

iii. Reserves

Reserves are generally publicly owned land managed by the Crown, Regional Councils or Territorial Authorities. Examples of reserves include esplanade, recreation, local purpose, road or conservation reserves. A reserve may be placed between private land and the shoreline, with the type of reserve determined by the legislation that it is obtained and managed under. An esplanade reserve is a strip of land 20m wide, taken from the shore. Unlike a marginal strip under the Conservation Act, an esplanade strip does not move with the eroding shoreline and therefore is not an effective control on development if the shoreline starts to erode. Reserves are generally created during land sub-division.

Advantages include:

- Establishment of public ownership and control over the eroding shoreline, allowing integrated management;
- Promotion of public access to the shoreline; and
- Allows for re-establishment of native shoreline vegetation.

Disadvantages include:

- They do not move with the coast, so may be lost over time; and
- The cost of acquiring and managing a reserve may be high and should be weighted against the potential benefit.

Remedial Planning Techniques

As the name would suggest, remedial planning techniques are measures that deal with shoreline erosion once it has become an apparent problem. The aim is to retract development and create a buffer zone. Remedial planning techniques include planned retreat and use of transferable development rights.

i. Planned Retreat

This technique provides a timeframe for the establishment of a buffer zone and the retraction of development. It may allow temporary development, providing for staged removal.

ii. Transferable Development Rights

Transferable development rights support setbacks and restrictive land zoning to compensate for the loss of development land in the buffer zone, possibly allowing for intensive development landward in compensation for no development along the shoreline.

Lake Level Regime

Like all lakes, Lake Taupo's level rises in response to the weather. Since 1941, when the Taupo Gates were commissioned, outflows from the lake have been used for power generation and because of this the water level is considered managed. While the lake level has been managed for more than 65 years the philosophy has been to operate the lake within its natural range. Further, the lake level is still largely driven by weather events which are independent of the power company's management of the lake level.

Lake level analysis reported in the Stage 3 report shows that the control of the Lake level results in periods when the Lake is held higher than it would be naturally. Over the long term this is mostly balanced out by other periods when the Lake level is drawn down below what it would have been naturally, resulting in the managed lake level regime being similar to the natural regime. In addition the overall range of the lake level under control is reduced with extreme high lake levels reduced by hydro management. Whilst annual lake level regimes are also similar to natural levels, seasonal differences are apparent, with higher than natural levels sometimes occurring in the late summer months and lower than natural levels occurring in winter and spring.

The Stage 3 report also identifies there is some evidence that when the lake is held at high levels and there is strong wind there is increased erosion in some locations. A review as part of this report shows average wind speeds to be typically highest in spring when the Lake level is typically lower and generally calmer in summer and autumn when the Lake level is typically higher. An analysis of coincident wind and extreme lake level events at Waitahanui indicated that the top ten highest wind events more frequently occurred during periods when the actual lake level was held above the natural level, in some cases by a significant difference from the simulated level. In some locations around the Lake erosion has been largely attributed to a limited number of events when the Lake is high and there are strong winds.

The Stage 3 report also identifies that for the years prior to its publication the lake level has been held a little higher than natural in summer. This may potentially exacerbate erosion as this is when there are some extreme wind events. This trend has been reversed in 2008, with a lower than natural lake level over summer. However, because, of the complexity of the environmental systems in operation during those high wind events and a lack of monitoring information, there is a degree of uncertainty about how much high lake levels contribute to foreshore erosion.

One possible way of partially addressing the erosion issues around Lake Taupo would be to alter the way that the lake level regime is operated. This could take the form of a general reduction of the maximum operating level over the entire year. Alternatively, a more targeted response would be to lower the maximum operating level over the summer and early autumn months.

A review of the lake level management regime for erosion purposes would require a compelling case built on very robust scientific information about the cause and level of effect on the environment. This option would require a significant change to current resource consenting approvals, which have been approved for 35 years. The resource consent which authorises the lake management does have specific provision for review of the conditions. Environment Waikato, as the consenting authority, is responsible for determining if a review is necessary and if so, undertake the review in accordance with the requirements of the consent and the RMA. The conditions of the consent cannot be changed to the extent that the consent cannot be implemented. The process would require assessment work, consultation and hearings, with the outcome being far from certain. There would also be costs for other participants in consultation and from being involved in the formal process.

Although a change in lake level regime, to reduce the probability of higher lake levels during high wind events may be considered as an erosion management option, there are a number of matters that need to be weighed up.

Advantages include:

- This option may help to reduce the risk of foreshore erosion in a number of locations around the Lake and could be included as part of a suite of management options, providing a possible alternative in some areas to site specific structural erosion management.
- More of the lakeshore would be exposed for longer periods which might provide greater recreational opportunities.
- Compared to other management options, this option may be seen as having no direct costs to the rate payer however there will be indirect costs that need to be considered (as discussed above and below).

Disadvantages include:

- There is little information to indicate how effective this option would be given the complexity of the environmental systems at work. It is unlikely to be a solution to all the erosion issues around the lake, in particular those areas where erosion is the result of sediment depletion, man made structures, or vegetation removal. There is additional risk of other unintended consequences and reduced sediment transport at some locations.
- Lake level management is still largely driven by the weather. Large rain and wind events will still result in a combination of higher lake levels and increased wave action, despite the operating level of the lake being lower. More specifically the lake level will often rise as a result of weather regardless of the Taupo gates being wide open.
- If the lake level management regime were to be lowered it may produce the following range of environmental effects:
  - Potentially altering habitat on the foreshore e.g. wetlands and at the mouth of tributaries' to the lake. This may have an affect on biodiversity, for example wetland vegetation and smelt spawning.
  - Alter the lake shore amenity and landscape with more of the foreshore exposed for longer periods.

  - Increased foreshore exposure may lead to increased plant pests. Exotic plant pests are often quicker than native species at colonising newly cleared/disturbed areas.
  - In some areas, navigation may be affected e.g. Kinloch marina, Taupo boat harbour and Moturoa. Access to boat ramps and jetties may also be constrained by decreased water depth.
- This option could address one of a number of causes but because of the lack of information and uncertainty there is a risk that if the lake level is not managed well that it may concentrate wave action within a narrower range of the foreshore zone, increasing erosion.
- This option is likely to affect power generation, including timing and total generation capacity. More water may need to be spilled through the Waikato Hydro system to meet the lower consent level (i.e. less storage would be available) thereby reducing total generation capacity. Any loss of generation capacity needs to be considered within the context of the national importance of renewable energy generation, as identified within New Zealand's climate change commitments.

4.3.3 Soft-Structural Options

All structural options introduce physical works into the coastal environment, with soft-structural options reducing erosion risk by means of accommodating existing shoreline processes. Soft-structural options use naturally occurring materials such as sand and vegetation to maintain the existing characteristics of the shoreline.

Beach Replenishment / Nourishment

Beach nourishment is used to create a wider beach berm by means of increasing or redistributing the volume of sediment along a beach. The wider beach reduces the risk of erosion by providing an increased buffer, accommodating both short term fluctuations and long term erosion. In general it is preferable to use the same size or coarser sediment than the native sediment, in order to mimic the lakeshore processes and to reduce nourishment volumes. When considering beach nourishment it is important to understand the likely frequency and volumes for further nourishment to maintain the desired beach characteristics.

Advantages include:

- Improved amenity and aesthetic values, and usability;
- Reversible;
- Minimal undesirable shoreline effects; and
- Emulation of natural shoreline processes.

Disadvantages include:

- Beach nourishment is only suitable for soft shorelines (e.g.

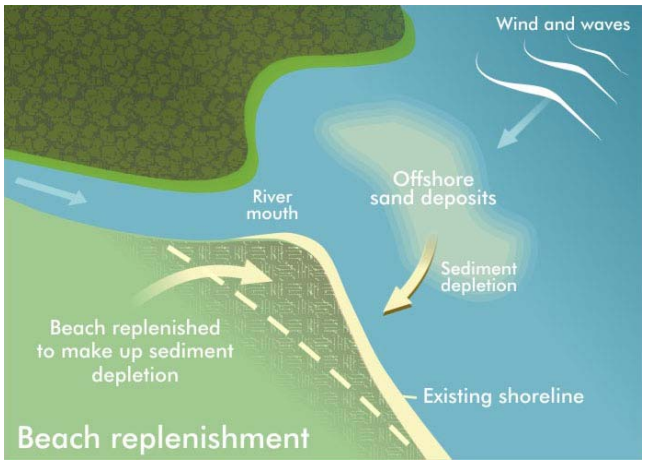


Figure 7. Beach replenishment

'sandy or gravelly' shorelines).

- By itself nourishment will not halt shoreline erosion and, once the design life is reached, further sediment replenishment is required to maintain a stable beach;
- Nourishment schemes are subject to short term fluctuations, particularly during storm events when sediment will be lost from the beach; and
- Large volumes of sediment will need to be sourced for the nourishment program.

Re-vegetation

Re-vegetation involves the replanting of shoreline areas where existing vegetation has been removed. Vegetation can assist in reducing the risk of shoreline erosion by improving slope stability and binding sediment. Existing vegetation may be protected by means of binding and under-planting to generate a viable long-term vegetation composition and structure.

At some locations around Lake Taupo, it is noticeable that where shoreline vegetation has been removed the shoreline is indented compared to the adjacent vegetated shoreline.

Advantages include:

- Re-vegetation is applicable to all types of shoreline (both hard and soft sediment);
- Re-vegetation can result in habitat/ecosystems enhancement;
- Indigenous plant species can be used in re-vegetation;
- Has the potential to improve the quality of storm water and road runoff before it enters the lake.

Figure 8. Re-vegetation

- Re-vegetation can assist in improving amenity; and
- Re-vegetation schemes can be used as a good means of involving local communities in erosion protection schemes.

Disadvantages include:

- Re-vegetation has the potential to impact on current access to the foreshore by restricting vehicles and pedestrian access (particularly during establishment);
- Using non-native vegetation or non-local sourced native vegetation may harm the genetic integrity of local native species, and some non-native vegetation may be less likely to be tolerant of local conditions;
- Re-vegetation has the potential to impact on views of adjacent properties;
- Weed control and on-going maintenance will need to be budgeted for; and
- During the vegetation establishment period, artificial shelter will be required on exposed sites.

4.3.4 Hard-Structural Options

Unlike soft-structural options, hard-structural options introduce physical works into the shoreline that alter the physical processes that cause erosion, with the similar overall objective of reducing erosion. They are typically constructed of materials such as rock, concrete or timber and significantly alter the character of the area in which they are placed. As a result hard-structures can have undesirable environmental impacts along the shoreline. Because of the types of material used in hard structures and the extent of them they can generally be more difficult to reverse or remove in future.

Seawalls

Seawalls are fixed structures constructed parallel to the shoreline that provide land protection from wave and current action and maintain a fixed shoreline position. They can be constructed of rock, concrete or timber, depending upon the specific site conditions.

Advantages include:

- In hard shoreline areas, seawalls can improve slope stability by reducing the energy of wave attack.

Disadvantages include:

- Seawalls offer no protection to the beach in front of them and may increase the rate of beach loss by lowering of the beach, resulting in a smaller or no beach;
- The seawall may contribute towards shoreline erosion by sealing any landward sediment source;
- There is typically a negative effect on local amenity and the natural character of the shoreline following construction of a seawall;
- If seawalls are used for small sections of shoreline only (i.e. to protect individual properties rather than an eroding shoreline), there is the risk of erosion continuing adjacent to the wall, and a small headland being formed; and
- Seawalls are more costly to reverse than some of the other options.

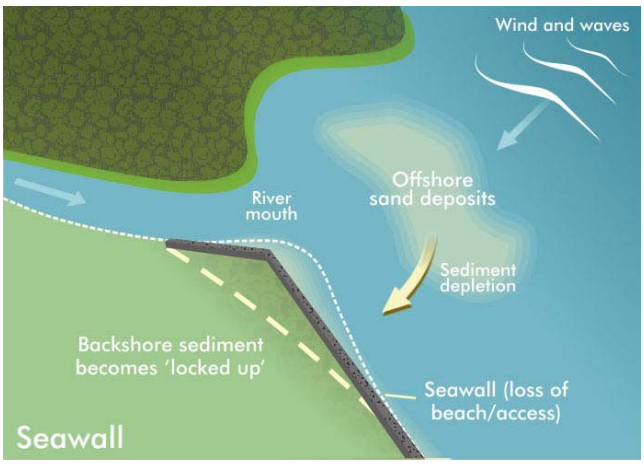


Figure 9. Seawall

Groynes

Groynes are structures constructed perpendicular to the shoreline, designed to stop the littoral drift of sediment and increase the size of the beach. The placement of groynes will initially interrupt the movement of sediment down-drift until a sufficient volume of sediment has built up in front of the groyne that sediment bypassing can occur. Groynes are typically constructed of rock or timber. Groynes can only be used on soft shorelines, and are generally more effective where there is a predominant long shore drift.

Advantages include:

- Maintenance of a beach, improving amenity value;

- If used in combination with down-drift beach nourishment there may be no negative down-drift effects;
- If permeable groynes are used, some littoral drift will continue and there will not be such a reduction in the volume of sediment received down-drift.

Disadvantages include:

- Until sediment bypassing occurs, the sediment supply to areas down-drift is cut, which may lead to more pronounced erosion;
- If groynes are long or into deep water sediment can be directed offshore rather than being confined to the littoral zone.
- The change in beach profile that results from construction of a groyne field can cause a discontinuity of the shoreline;

Figure 10. Groynes

- Groynes can segment the shoreline and reduce the visual amenity; and
- Harder to reverse.

Offshore Breakwaters

Offshore breakwaters are structures constructed parallel to and offshore of the shoreline. They can be constructed out of rock, concrete or geotextile bags filled with sand.

The structures work directly by dissipating or reflecting wave energy, resulting in refracted and reduced wave energy leeward of the breakwater. This can lead to a build up of a stable sediment mound (known as a salient or tombolo) on the shoreline behind the breakwater. Offshore breakwaters are suitable for all types of shoreline, although on soft shorelines there can be continued erosion adjacent to the build up of sediment behind the breakwater.

Advantages include:

- Minimal visual impact in a lake; and
- Does not inhibit land access along the shoreline.

Disadvantages include:

- Expensive to design and construct as they are offshore; and
- Is a potential navigation risk.

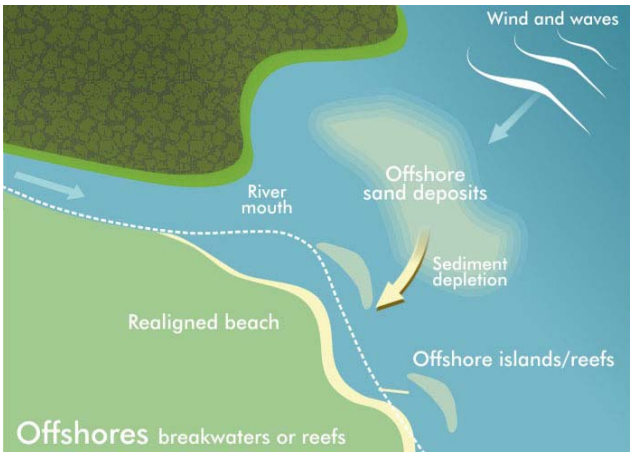


Figure 11. Offshore Breakwaters

In many cases it will be appropriate to consider the use of a combination of options, such as breakwaters and beach nourishment,

or remedial planning and structures in order to achieve the most appropriate erosion mitigation.

Design of Hard Structures

Where hard protection structures are already in place, or are proposed to be constructed, it is important that they do function as protection, and do not adversely affect the lakeshore environment. For example as seen in Figure 12 below poorly designed structures can cause secondary erosion issues in adjacent areas. If structures are not designed properly, they can induce localised erosion/scour in adjacent locations. All structures should be designed for the known water-level variations at their particular site. The US Army Corp of Engineers, Coastal Engineering Research Centre, produced a guideline for construction and maintenance of shore-protection structures for works built on the Great Lakes.

The guidelines are as follows:

- Provide adequate protection for the toe of the structure so that it will not be undermined.
- Secure both ends of the shore protection for the toe of the structure so that it will not be undermined.
- Secure both ends of the shore protection works against flanking.
- Check foundation conditions

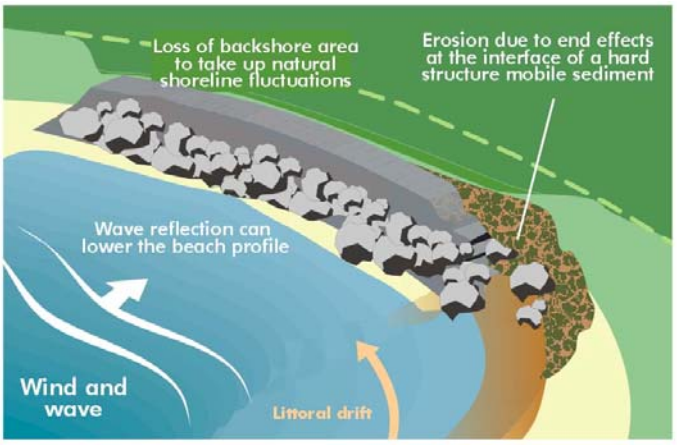


Figure 12. End effects on seawalls

- Use material that is dense and heavy enough that waves will not remove pieces of the protection.
- Build revetments high enough that waves do not regularly overtop the structure.
- Make sure the voids between individual pieces of protection are small enough that underlying material is not washed out by waves.

It is also important to use local material such as a quarried rock which has a proven record in the environment. In addition, using similar material for structural works provides a consistency of approach and introduces a consistent character for the shoreline works.

Once designed and constructed it is also important to monitor a structures, performance and repair and maintain them proactively. This also applies for soft options. These structures should be treated as assets, and should be managed using similar systems for other types of assets, like those used for infrastructure utilities. This maintenance and monitoring will prolong the life of the asset, and can prevent major failures resulting in significant replacement costs. Additionally this monitoring can be used to determine the effectiveness of different options and optimise future structure design.

If structures are found to be causing erosion in adjacent areas or downdrift, consideration should be given to moving or replacing the structure.

4.3.5 Combination of Options

When considering a response to lake shore erosion, it should be recognised that a combination of management options may provide a more effective solution than the use of a single management option. The following table provides a summary of common combinations of management options that are suitable for the lake foreshore environment. The approach to the combination of options is based upon the approach outlined in the Auckland Regional Council – Coastal Erosion Management Manual (2003).

Table 4.2 – Combination of Options Summary

Combination of Management Options	Advantage of Combination
Buffers and Remedial Planning	In cases where development has already occurred, the establishment of a buffer will require the use of remedial planning techniques (e.g. relocation/planned retreat). Removing existing buildings and activities will enable the buffer option to be established in developed areas.
Remedial Planning and Hard Structural Options	Remedial planning can take a long time to implement and become effective solutions. Hard structural options can be used in the mean time to provide a short term solution to erosion.
Beach Nourishment and Groynes	Groynes are often used in association with beach nourishment. Groynes may aid in the retention of new sediment, potentially increasing the length of time that this option will be an effective solution.
Beach Nourishment and Re-vegetation	Re-vegetation may aid in the retention of new sediment, potentially increasing the length of time that this option will be an effective solution

The implementation of a particular erosion management option or combination of erosion management options is usually guided by the level of development (if any) within the identified area at risk. It also takes into consideration the level of existing erosion protection works. Erosion management options for developed areas are usually more difficult to implement, as built up areas may have high priority asset risks which need immediate solutions, thereby restricting the range of options available in the short term.

In many cases while non structural options are identified as the ideal solution to the problem, structural options or a combination of option may be necessary to facilitate the protection of assets in the short term. It is generally easier to implement a (wider) range of erosion management options in undeveloped areas, relative to developed and built up areas. This is because implementation time can be generally be of a longer period, with less risk to assets.

4.4 Best Practice for Lake Shore Erosion Management

The following section sets out best practice principles that have been used to provide a basis for determining management options for lake shore erosion. These principles are based on the 'Seven Principles for Planning and Design for Tsunami Hazards' (developed as part of the USA National Tsumani Hazard Mitigation Programme, March 2001). Although these were developed for Tsunami Hazards they are still applicable to lake shoreline hazards generally. These Principles are used later in the report to support the lake wide management approaches.

Principle 1 - Know your community's lakeshore erosion risks: hazard, vulnerability and exposure

Lake shore erosion risk is a function of the nature and extent of the erosion hazard, the amount of development or the number of people exposed to the hazard, and the vulnerability of facilities and people to damage. Understanding the community's erosion risk (i.e. what is at risk and the degree of vulnerability) forms the basis for developing non structural management options such as land use strategies and strategies that can mitigate lakeshore erosion risk.

Principle 2 – Identify the cause(s) of lake shore erosion

For erosion management it is important to identify the cause(s) of erosion and distinguish between short term fluctations and long term shoreline erosion. Management response options should address the cause.

Principle 3 – Avoid new development in erosion hazard areas to minimise future losses

Lake shore erosion risk can be mitigated by avoiding or minimising the exposure of development through land use planning. This is achieved by preventing or restricting new development in areas identified as being at risk to lakeshore erosion, and requiring the protection of natural defences. This strategy is especially effective in undeveloped areas, and provides an opportunity to create and maintain a natural protective buffer and viable lake foreshore/beach area, including provision for public access to the lake and shoreline.

Principle 4 – Locate and configure new development that occurs in erosion hazard areas to minimise future losses.

Where new development cannot be avoided (or already exists) it can be managed to minimise the erosion risk. This principle does not prevent erosion from occurring by addressing the cause(s) of the erosion, but provides a range of options to minimise potential erosion damage. Techniques are focussed around controlling the location and nature of new development and may include progressive strategic re-location of structures

Principle 5 – Design and construct new buildings and structures to minimise damage

Where buildings and structures are to be located in the lake foreshore hazard area, design and construction can reduce loss of life, property and structural damage particularly from hazard events that involve periodic inundation. (e.g. floor levels for flood and erosion risk).

Principle 6 – Protect existing development from losses through redevelopment, retrofit, and land use strategies

For existing lakeside communities, protecting existing development and infrastructure may be the only real mitigation option that is available. Changes in land use and infrastructure may provide opportunities to assist with making communities less vulnerable to erosion risk in the future. Techniques may include redefining permitted land uses, changing zoning standards, changing building uses and occupancies, retrofitting and rehabilitation of buildings and structures.

Principle 7 – Take special precautions in locating and designing key infrastructure and facilities to minimise damage.

Key infrastructure such as roads and utility systems such as telecommunication, water supply and power infrastructure need to be planned and designed to minimise any potential damage from lake erosion hazard.

5 Lake-wide Approach for Erosion Management

5.1 Background

Where erosion risk areas around Lake Taupo have been identified or prioritised, the next step is to assess and decide on the most appropriate response options to the hazards through the preparation of an erosion management strategy.

As outlined previously, past responses to erosion at Lake Taupo have generally been reactive, responding to erosion issues as they arise rather than planning for the prevention of future erosion. Historically, the response to erosion risk has been the responsibility of individuals rather than through a Council-led response. There has also been public expectation for Council to commit to maintain protection structures at relatively high cost. This lack of a comprehensive strategic approach to responding to lake-wide areas has resulted in a large quantity of hard structures in the lake foreshore. This has led to expectations on council to put erosion structures in place because they originally allowed development to occur near the shoreline.

The general hierarchy of management options is advocated in terms of a lake-wide approach as outlined in Section 4.1. However, whilst non-structural options may be identified as the ideal solution to the problem, structural options may be necessary to facilitate the protection of assets in the short term.

Existing development and the potential for future development of an area is a significant factor in determining the appropriate management response, as is the extent of land between lake foreshore and development, and the risk of erosion that exists. The expectations of protection of property, and existing use rights that are afforded by Section 10 of the RMA have to be considered within the wider context of the roles and responsibilities of regional and district councils in relation to the avoidance and mitigation of natural hazards under the RMA and the Building Act and also Part II of the RMA (the purpose and principles of the RMA).

In addition, the legal situation regarding the ownership and control of the lake bed is complex and needs further consideration in terms of a lake-wide management approach. Ownership of the lake bed has been returned to Ngāti Tūwharetoa by the Crown. The settlement does not change public rights of access, navigation or fishing, but is seen as recognition of Ngāti Tūwharetoa's traditional tribal authority (mana whenua) over the lake bed. As a result they play a pivotal role in approving works to manage foreshore erosion.

This report recommends technical erosion management options for particular locations around the Lake Taupo foreshore. These technical management options will provide a base for further discussion with communities to determine which management option(s) may be the most appropriate for them given their local context and values. Taupo District Council together with Environment Waikato will be undertaking further consultation with communities on the recommended technical management options within the context of developing a Lake Taupo Foreshore Risk Management Strategy.

5.2 Climate Change Impacts of Erosion Drivers

The 'Coastal Hazards and Climate Change: Guidance Manual for Local Government in New Zealand' 2004 identifies potential impacts of climate change of coastal areas of New Zealand. An understanding of the potential impacts of climate change on lake shore environments can be gained from this manual through the analysis of likely impacts of coastal hazards. The most significant difference is through:

Responses to changes in wave climate

- Changes to wave direction could be caused by a shift in wind climate.
- A new wave regime will result in changes in the movement of sediment which may result in previously stable shorelines starting to erode unless the availability of sediment keeps up.
- Different types of shoreline will react in different ways to changes in the hazard drivers depending on their geomorphology. For example the impact of a change in wind direction could significantly affect a small pocket sand beach by moving the sediment from one side to the other.

Responses to changes on sediment supply to the lake

- Effects of climate change on fluvial erosion and sediment transport processes will have a large influence on the behaviour of depositional sand and gravel beaches.
- Changes in frequency and intensity of rainfall events may result in increased or decreased volumes of sediment arriving to the shoreline. For example, more intense storms may result in increased sediment supplies, and accretion in some areas.

5.2.1 Storms / Wind

Information presented by NIWA at the IPENZ Course "Incorporating Climate Change Predictions into Engineering Design", July/August 2006 included an assessment on the impacts on storms effecting New Zealand.

NIWA highlighted that the IPCC 3rd Assessment indicated that there was considerable uncertainty in future changes in intensity of storms effecting New Zealand as a result of climate change. The possible effects include increased likelihood of some tropical storms reaching New Zealand, and the potential for those that do to have increased intensity and duration. This has been predicted to have some increase in severe wind risk, e.g. the highest wind speed occurring annually might increase by about 3% by the 2080s, and an increase (10%) in westerly winds. An increase in wind can increase wave heights and impact rates of sediment movement, which if not offset by additional sediment supplies could result in erosion.

5.2.2 Rainfall

The Ministry for the Environment report entitled: Climate Change Effects and Impacts Assessment: A guidance manual for local government in New Zealand, sets out a methodology for assessing the impact of climate change on rainfall. For the Waikato region the predicted rise in air temperatures (0.1 to 1.4 Deg C – for the 2030s and 0.4 to 3.8 Deg C for the 2080s) and the corresponding effect on the annual mean rainfall was an increase in 4.5% for the 2030s and 13% for the 2080s scenario. Additionally rainfall events in some

areas would increase in their intensity. These increases in rainfall could result in increased sediment supplies reducing the risk of erosion. However, to understand the effect of rainfall changes on sediment supply would require significant additional assessment and would vary within the different catchments around the lake. A significant level of uncertainty would still remain.

The effects of the change in rainfall on lake levels has been assessed by OPUS in the Draft District Flood Hazard Study – Stage 1 and 2a, 2007, produced for Taupo District Council and Environment Waikato. OPUS assumed the change in rainfall results in the same percentage change in flows into the lake and assessed the resultant flood levels on this basis. The ability to calculate the expected change is complicated due to the control of the lake level by the operators. OPUS identify that for most scenarios the increase in runoff will be compensated for increased outflows through the gates. However for large events the gates will become a hydraulic restriction resulting in higher lake levels. The OPUS study identifies potential increases in lake level for particular extreme events in the order of a couple hundred millimetres. Depending on the correspondence of these higher lake levels and the wind speed at the time there could be an increase in erosion risk in some areas. The complexity of the variables and level of analysis at this time does not allow the effect of this on erosion to be determined at this time.

5.2.3 Natural Climate Variability

As well as the possible impact on the drivers of erosion due to climate change it is also important to put this in context with natural climate variability. This includes the normal variability in timing between wind/wave events, and the rainfall events bringing sediment down rivers to the lakeshore. In addition, interannual impacts of the El Nino - Southern Oscillation can be an important driver of rainfall and wind. A comparison of Southern Oscillation Index (SOI) with wind patterns and lake level (NIWA 2001), showed that during the positive (LaNina) phases there was an increased correlation between high lake levels and increased wave runup on the southwestern shores (Kuratau) but lower on the northeastern shores. In addition, there can also be longer term influences such as the Interdecadal Pacific Oscillation (IPO) which can impact the wind, rainfall and river flows.

5.3 Guidelines for Evaluation

Before evaluation of management options can be undertaken, some general guidelines (based on the Auckland Regional Council Coastal Erosion Management Manual philosophy) should be applied in terms of evaluating options for specific sites. These guidelines have informed the prioritisation and evaluation process for priority sites in this report. The following guidelines also support the overarching principles promoted as 'Best Practice for Erosion Management' as outlined in Section 4.3:

- Confirm lake shore erosion as a problem before implementation of management options.
- Identify the cause(s) of lake shore erosion and ensure that any management response option will address this cause.
- Recognise changes due to human intervention which have caused lake shore erosion and rectify them where possible.

- Recognise that there is some uncertainty regarding the lake physical/natural processes operating and that a precautionary approach should be taken in assessing the likely or potential impacts of remedying or mitigating lake foreshore erosion management activities and the consequences of doing nothing.
- Recognise that there may be the requirement for more site specific studies (e.g. sediment budget analysis to assess processes before allowing development or structures).
- Development of 'best practise' guidelines for use of materials and design of hard structures are required for implementation where hard structural management approaches are to be followed. This includes guidelines for non-protection structures around the lake which may influence lake erosion processes (e.g. boat ramps, jetties).

5.4 Land Use Planning and Policy

The following section sets out both key considerations (general guidelines) and preferred management option approaches for different land use scenarios which are located around the lake foreshore. Two land use scenarios are presented, the first where land is predominantly rural and undeveloped, and second where development currently exists. Both scenarios 1 and 2 require further shoreline monitoring and hazard mapping before they can be undertaken.

5.4.1 Scenario 1 – Un-Developed Sites (Rural areas)

The Tier 1 option is more easily applied where there is little existing development but land use intensification is proposed (e.g. green field developments in rural areas). In such areas it is necessary to provide an appropriate buffer between the shoreline and the proposed development to maintain natural defences against shoreline erosion, to preserve the natural character of the lake shore and maintain public access to the lake.

Non-structural options are most readily categorised by the timeframes over which they are implemented. Long term planning or land use strategies require the longest timeframes for implementation, with buffer mechanisms requiring less time.

Both of these options require significant attention to the effects on any stakeholders. It is therefore important to have the best understanding possible of the processes operating to allow the most appropriate mechanisms to be implemented. In many places around Lake Taupo this understanding has not yet been achieved.

Key Management Strategy (Scenario 1) – Avoid new development in erosion risk areas and fluctuation zones

- Avoiding new development in erosion risk areas is the most preferred approach, this can be achieved through the following land use planning strategies:
  - Zoning of erosion risk areas for protection or open space uses – recreational access and parks/reserves.
  - Council to acquire erosion risk areas for protection or open space uses (may include requiring easements and/or land swaps.
  - Restrict development through land use regulations – i.e. through zoning with land use restrictions and controls. Implementation may be achieved through regional and district plans (i.e. specific zoning of erosion hazard areas with policies to avoid or control development rules to prohibit development and/or regulation through subdivision rules and built on existing district plan provisions for shoreline erosion through use of setbacks).

5.4.2 Scenario 2 – Developed Lake Shoreline (New Erosion Hot Spots)

When the lake shoreline is already developed the situation is more complicated. Focus is often placed on protecting existing assets and development by using hard structural approaches such as seawalls. If structural protection options are to be implemented, soft structural approaches should be given priority over hard options.

The current District Plan approach to natural hazards is to control development in areas where there is an identified risk from a natural hazard. Where it is not possible to avoid or mitigate the risk, activities may not be appropriate in these locations. In the past, development has occurred in areas subject to the effects of natural hazards and this has required development of structural protection works to protect the investment made by the community and individuals in these areas.

Structural options may be appropriate when used as a management 'package' where structural works are a short term solution and used in conjunction with a longer-term planning option.

Key Management Strategies (Scenario 2) - Control the location and nature of developments and regulate the design and construction of buildings and structures in erosion risk areas.

- Avoid new development in erosion risk areas.
- If avoidance is not possible, place an emphasis on location, configuration, building design and securing of areas for open space and protection of existing facilities.
- For residential areas with vulnerable communities and facilities, protect existing facilities.

If avoidance is not possible or there is a degree of existing use, the physical configuration of structures and uses on-site can reduce potential loss of life and property damage. Techniques include progressive strategic location of structures and open spaces, interactions of uses and landforms and design of landscaping.

5.5 Dam Management Regimes

The placement of dams or reservoirs on rivers and streams flowing into the lake will reduce the available sediment within that compartment as the larger sediments and sand drop out behind the dam in the lower velocity water. This process can often be seen in the form of deltas, which form at the inlets to the dams. The removal of this sediment is often required to maintain the storage capacity of the dam. The use of long-term bathymetry surveys of the reservoir bed level behind the dam can be a useful technique in order to better understand the volume of sediment being retained. If the reduction in sediment supply is not offset by sediment from other sources (e.g. nearshore sediment) then the equilibrium position of the shoreline may change as the shoreline adjusts to the new sediment balance.

Returning the sediment trapped behind the dam back into the system downstream of the dam can sometimes work to offset this sediment imbalance. Depending on how this management measure is implemented, it can be onerous and have other unintended effects on the downstream river dynamics and/or river ecology. The practicalities of this and these potential issues would need to be weighed against any potential benefits. Other options also exist for more direct use of the sediments that are retained behind the dams for beach replenishment projects.

5.6 Lake Level Regime

The outflows from Lake Taupo are used for power generation and therefore the water level of the lake is considered to be managed. A change in the management of the lakes water level regime provides an alternative lake wide option to manage erosion. The intention of changing the lake level regime would be to reduce the lake level when there is an increased probability of extreme wind events, such as those that have historically occurred during summer and early autumn. There is a degree of uncertainty about how much high lake levels and other causes contribute to foreshore erosion, this is because of the limited monitoring information available and the complexity and individuality of the environmental systems in operation at each area where erosion is occurring. It is therefore difficult to establish the extent that the lake level should be lowered and which areas that are eroding will benefit from this action.

Implementation of a lake wide monitoring programme and development of sediment budgets will provide the long term scientific data that is needed to better assess how much lake level management, along with other factors such as sediment depletion and vegetation removal, are influencing erosion in specific areas. Change in lake level regime as a possible option for addressing one of a number causes of erosion needs to be considered in context of the advantages and disadvantages discussed in Section 4 of this report. The implications of such a change would also need to be discussed with Ngati Tuwharetoa as owners of the lake bed.

6 Priority Management Areas

This section identifies the situation at priority locations and provides a focussed range of options and assesses the implications of their implementation. This will allow a more considered discussion to take place with the residents and stakeholders for each priority management area, and better understanding of the consequences of different options. With this understanding, and further site specific analysis and option assessment, a tailored solution can be developed in preparation for implementation if required.

The focus of the approach in this section and the options considered have primarily been around the management of the effects of lakeshore processes causing erosion (e.g. replacing lost sand with beach nourishment). It is also important to consider the underlying causes. Some of the causes may be global issues (e.g. reduced sediment supplies, lake level regime, weather patterns) and more difficult to address. In the long term addressing the causes will provide a better outcome than continually trying to mitigate the effects. However, there is a degree of uncertainty regarding how each of the identified causes is contributing to erosion. This is due to a lack of historical data and monitoring of sediment compartments and the complexity of the underlying processes.

6.1 Identification of Priority Management Areas

The sites that have been considered in further detail below were selected through an assessment of high risk sites from Stage 3, a review of assets at these key sites, and a review of the Taupo District 2050 Growth Management Strategy.

During the Stage 3 study a broad assessment was carried out identifying an erosion hazard level for the entire lakeshore. The results of this indicated nine compartments in which a high level of erosion hazard was identified. These included:

No	Site
1	Kuratau
2	Waitahanui plus Five Mile Bay
3	Whareroa
4	Whangamata Bay (Kinloch)
5	Motutere
6	Taupo Township
7	Whakaipo Bay
8	Te Rangiita
9	Hatepe

The assets located near the shoreline at these sites were then reviewed to provide a better understanding of the risks associated with erosion for the respective areas.

In addition the Taupo District 2050 Growth Management Strategy was analysed to ensure potential areas of future growth and their relation to the lakeshore was identified.

A qualitative evaluation of management options was undertaken for 5 of the priority management areas identified above. These sites include:

- Kuratau, Whareroa, Waitahanui, Motutere, and Kinloch

Some further discussion is also provided on the other key sites, (e.g Taupo township, Whakaipo Bay etc) however it was considered that the qualitative assessment at this stage, without having a thorough understanding of these sites through further investigations and monitoring, would not add further value.

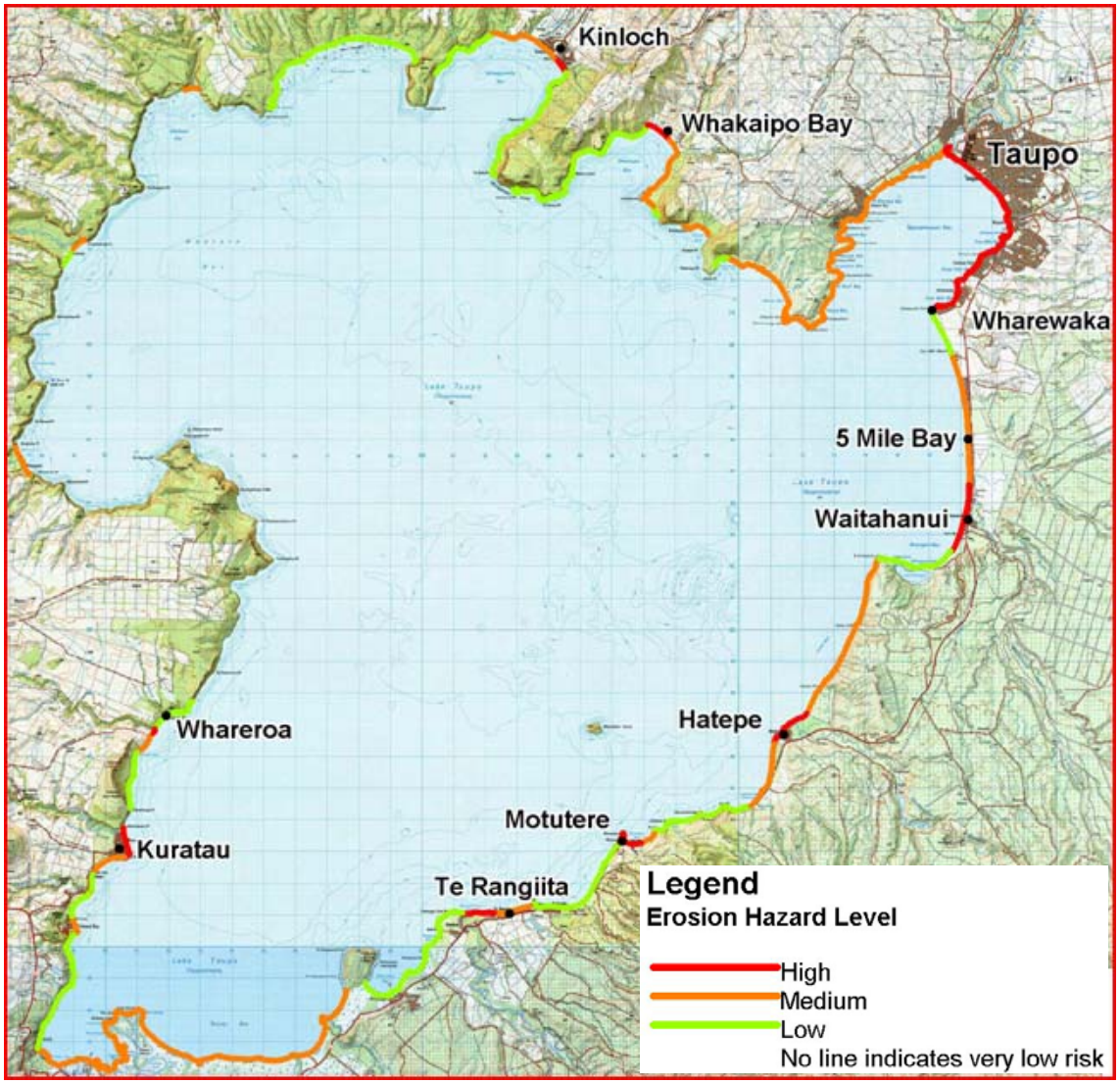


Figure 13. Priority Management Areas

6.2 Methodology for Evaluating Options for Priority Management Areas

The management options covered in Table 4.1 have been assessed against a range of criteria. (Refer to Table 7.1) These criteria have been carefully selected and developed based on sustainable development principles. The hierarchy of erosion response (Section 4.2.1) and best practice principles (Section 4.4) were also used to help inform the options assessment.

Table 7.1 Lake Shoreline Management Option Criteria

No	Criteria	Explanation
1	Amenity Values	Refers to people's 'sense of place', visual aesthetics of the option, public access, recreational impacts such as walking, boating etc.
2	Public Access	The level of impact on access to and along the Lake Foreshore and water, including boat access..
3	Public Safety	Level of impact on public safety from the option e.g. navigation safety, or risk to property owners.
4	Natural Character	Extent of impact on natural landforms, ecology/ecosystems and natural processes in the lake environment.
5	Lake Processes - Local effects and effectiveness	Suitability of the management option with respect to erosion being experienced and degree to which it is 'proven', local to the erosion area.
6	Lake Processes – Lake wide effects and sediment compartment	Extent of impact on natural lake shoreline processes such as wave action and sediment budgets and movement, and impacts on the wider sediment compartment.
7	Reversibility of Option	How easy is the option to reverse and restore the affected area back to the original state if required.
8	Structure Construction, Works and Maintenance Costs	Initial capital costs associated with construction of engineered structures and maintenance/works associated with the option over a specified time frame (e.g. 50 years).
9	Private Property Considerations	Includes cost of property relocation or purchase associated with some options, such as planned retreat.
10	Protection of Public Infrastructure	How likely the option will provide protection of assets for public roads, reserves, water, sewerage, electricity, gas, impacts on the cost to Council to relocate and restore this infrastructure and services.

The criteria cover a range of potential impact categories including items stated as matters of national importance in the RMA (e.g. public access, natural character etc.) matters considered important for lake front property owners (e.g. purchase of property) and more tangible and documented values that may be important for the wider community (e.g. natural character and lake and shoreline amenity).

There are a range of other issues which will also need to be considered when assessing further any recommended management option for a specific area. This includes the local context and values based views of the local and wider public, cultural values, values important to tangata whenua and other Regional and District Council principles. The

technical assessment carried out here has specifically excluded these at this stage as further consultation with the community is required before such values could be added to the options assessment.

The options were assessed using available data, current knowledge and based on a specified time period (e.g. 50 years) and the impact of the option over that period. The management options were given a High, Medium, Low positive or negative grading (depending on whether the impact of the option on that criteria is positive or negative). For some criteria it was considered that there are potentially both positive (+ve) and negative (-ve) impacts from the option.

6.3 Evaluation for Priority Management Areas

For the purposes of this report, the assessment of each option against the criteria is shown in a matrix format. The following sections set out the final evaluation matrices developed for each priority management area. The qualitative assessment has been based on the consensus view of the project team (Beca), followed by review and comments from the wider project team (EW/TDC). A summary explanation for each evaluation exercise is also set out to accompany each matrix. Appendix A contains the full assessment details for each of the evaluation exercises, and definitions for each impact category.

6.3.1 Kuratau

a. Location description

The section of shoreline immediately South of the Kuratau River mouth has experienced the highest levels of recorded erosion on Lake Taupo since the Cheal Consultants beach monitoring surveys were undertaken in 2004.

This section of shoreline is situated at the northern end of the Kuratau sediment compartment. (Refer to Figure 14 below.) This compartment spans from Werowanga Point in the North to Pukawa in the South, where the narrow shelf is bounded at either end by deeper water. The main sediment source into the compartment is the Kuratau River, although this has been significantly reduced, since the construction of the Kuratau dam in the early 1960's. The net movement (longshore sediment transport) of sediment is in the southerly direction, although movement of sediment is capable in both directions.

The development of Kuratau has occurred over the flat and gently sloping floodplain area. These low lying areas were formed from the natural deposition of sediment originating from the Kuratau River over time. The beach largely retains a natural sandy character with few erosion control or other structures. The full length of the shoreline has a reserve area between the foreshore and private land of approximately 20 - 40m in depth and is predominantly grassed with some trees and bushes.

During land development in the early 1900s significant clearance of bush was undertaken for forestry. This resulted in significant erosion within the upper catchment and increased sediment loads. This erosion has since largely been controlled through landuse controls and stabilisation.

Photo 1. Kuratau [2003]

b. Erosion Risk Areas and Causes

The length of shoreline identified as high risk during Stage 3 of the Study extends from the Kuratau River mouth in the north approximately one kilometre to the South. Factors leading to a high risk being apportioned for this area included the soft underlying geology, observed historical erosion, and reduced sediment supplies from the Kuratau River. Additionally, as the area is in close proximity to the river mouth the potential for increased natural fluctuations would also be expected.

The full length of the north/south running shoreline has been identified as high risk, however it is the first few hundred metres at the northern end where the greatest level of erosion has occurred.

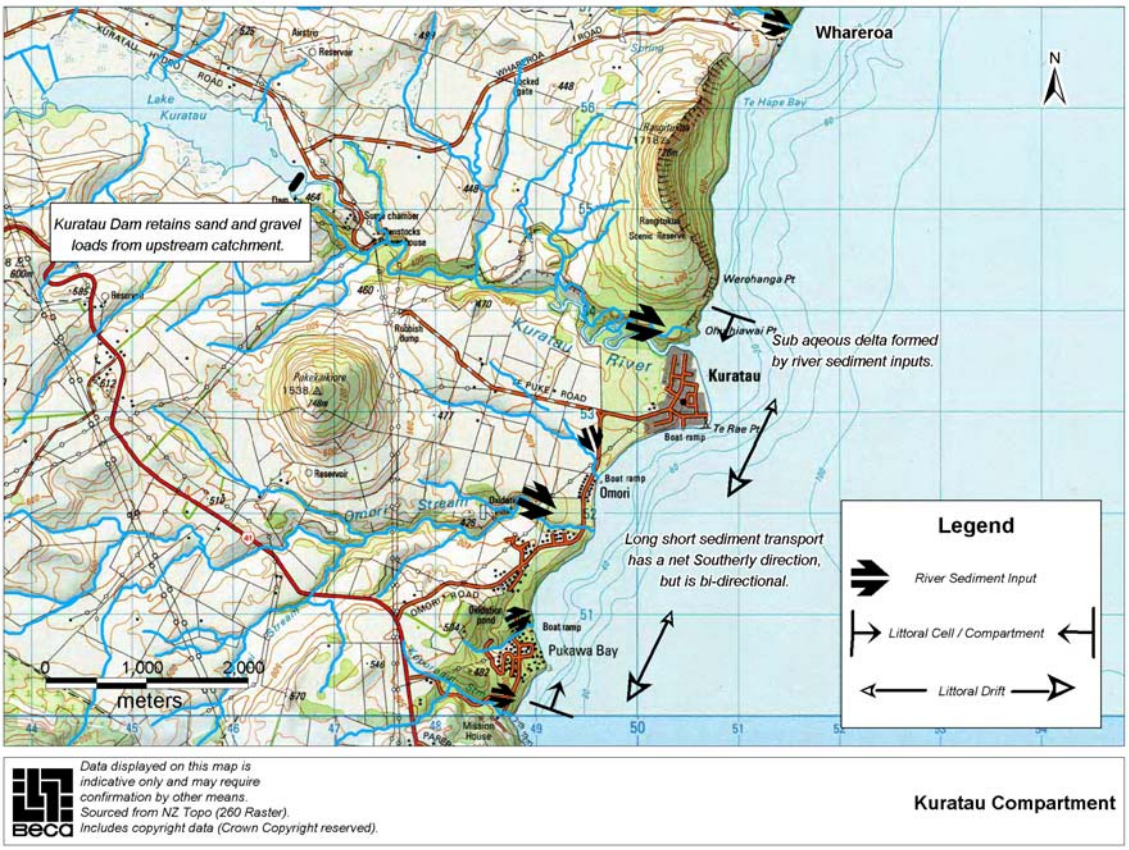


Figure 14. Kuratau Compartment

Based on the survey plans from 1963 compared to the 2006 surveys, the average erosion rates at the north end near the river mouth have been between 0.2 – 0.5 m/yr, with up to 20m of erosion. For the period between the 2004 and 2006 Cheal Consultants surveys the erosion rate was significantly increased, with erosion in excess of 4m occurring in a year. This increase in erosion rate over the short term may not be reflective of the likely longterm rate of erosion.

Some of the observed erosion, particularly close to the river mouth, is likely to be associated with the natural fluctuations and river mouth dynamics. However, it appears there is likely to be additional longterm erosion beyond these fluctuations. Based on the location of the erosion, the predominant wind generated wave direction, and the reduced sediment supply coming from the Kuratau River, it is suggested that the shoreline may be realigning itself to adjust to a new equilibrium position based on the new sediment supply rate. Although the dam was installed in the early 1960's, it has not been until more recently that the erosion has become more significant. This may be due to some of the other potential contributing factors which have occurred more recently, including recent destabilisation due to an increase in the occurrence of high lake levels and high wind events, removal of vegetation, removal of historical soft groynes and erosion fences, and the possible depletion of offshore sediment deposits.

It should also be noted that river bank erosion control measures are being utilised in the lower Kuratau River. This will also limit any sediment reaching Lake Taupo as a result of stream bank erosion which may have offset some of the losses due to the dam.

Due to the complexity of the processes, the limited shoreline monitoring data and sediment budget information has not been able to directly identify the relative proportion of the causes.

A comparison of Southern Oscillation Index (SOI) with wind patterns and lake level (NIWA 2001), showed that during the positive (LaNina) phases there was an increased correlation between high lake levels and increased wave runup on the southwestern shores (Kuratau) but lower on the northeastern shores.

If the beach is realigning itself due to a reduced sediment supply, this erosion would be expected to halt as the new equilibrium position is found. Natural fluctuation in the shoreline position would still however be expected. The final equilibrium position is uncertain at this stage (and therefore the continuing levels of erosion), although it appears to be moving towards a more NW-SE alignment. A detailed sediment budget analysis for the area has been recommended and would assist in better understanding its future position. Ultimately longterm monitoring is required to actually document the shoreline fluctuations and where it is with respect to an equilibrium position.

c. Assets at Risk

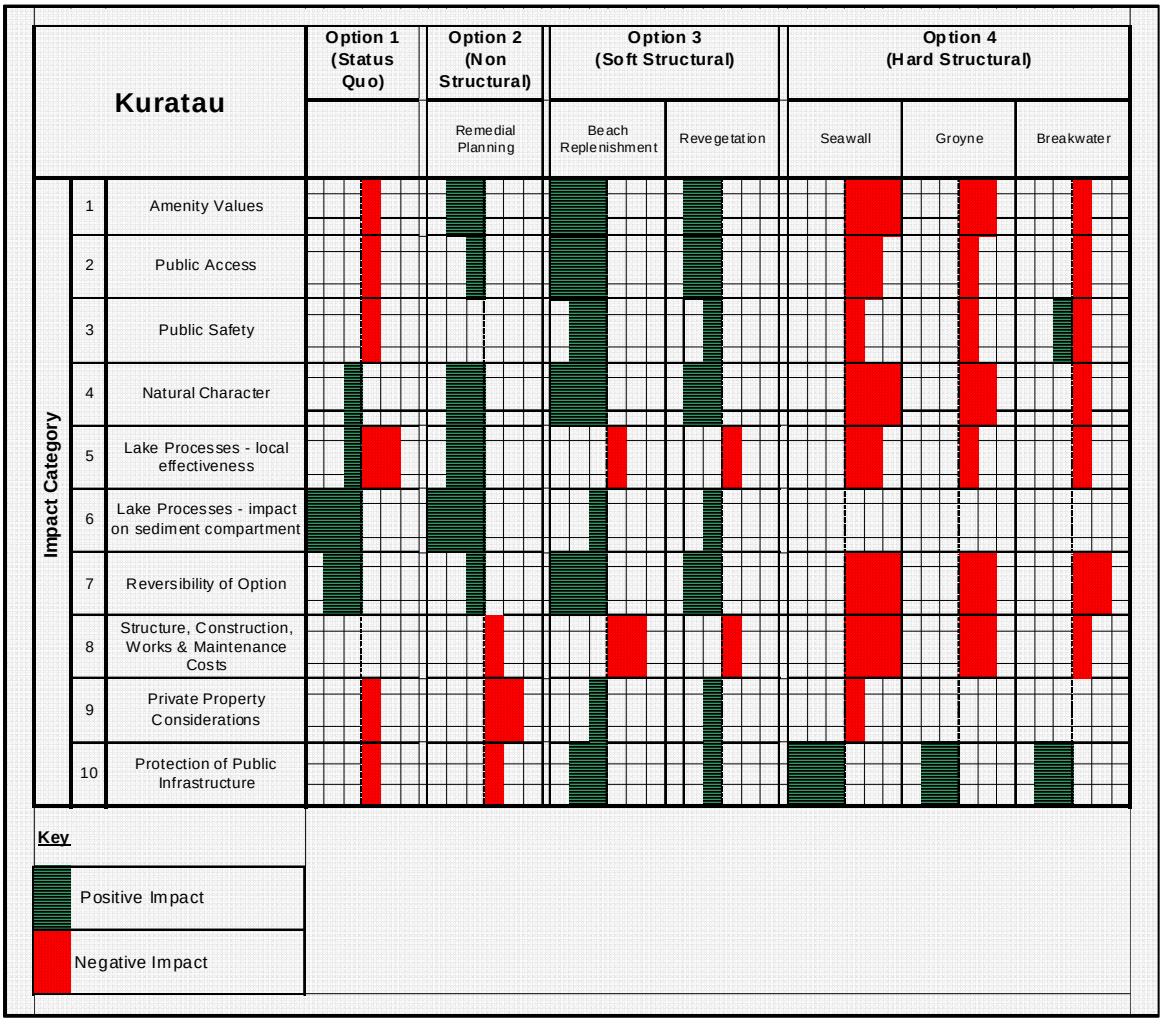
The length of the Kuratau shoreline has a reserve which is approximately 20-40 metres in width with 29 residential houses which have been built immediately at its rear. Along the length of shoreline near the river mouth, the reserve area has been lost to erosion which has significantly decreased the width of the reserve in front of approximately 5 houses. Although the houses are not yet at immediate risk, the available reserve area is.

The reserve is an asset for a range of amenities but could be recognised as an effective buffer between the foreshore and the houses. In responding to the physical environment at the site, some of the reserve may be lost over time. Therefore while it is serving as a buffer part of the asset will be lost.

A number of small stormwater outfalls exist. A car park and playground are located within 15m of the shoreline. A wastewater sewer runs parallel to the shoreline along the rear of the reserve. In the northern end where the erosion is more significant this could eventually be at risk. If erosion were to reach the pipe it is likely that its depth will mean it is unlikely to be exposed, however manholes may be at risk. The remaining services are located on the landward side of the houses.

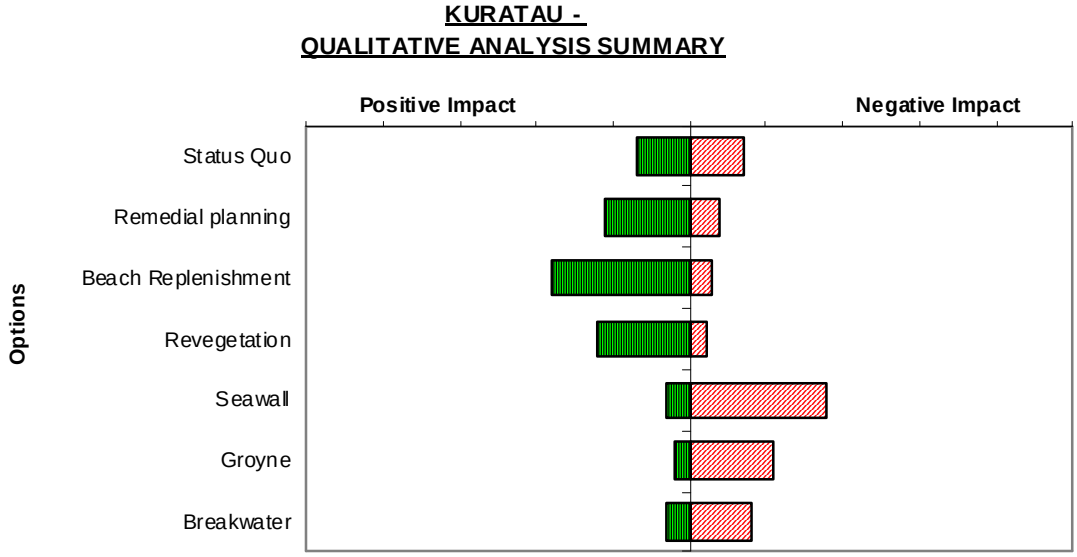
Evaluation matrix for Kuratau

How to use the Matrix – Each option along the top of the matrix has been assessed against the criteria down the left hand side of the table based on whether or not it will have a positive or negative impact (red represents negative, green is a positive impact). The length of the bar indicates the degree of impact. The gradings are either High (long bar), Medium, or Low (short bar). No bar would indicate that there is no impact or not assessed in this study



d. Kuratau Qualitative Analysis Summary

The graph below shows, in summary form, the results of the qualitative matrix for Kuratau. The results show that the soft structural options having the greatest positive impacts with the least negative impacts. The hard structural options have similar levels of positive impacts to each other, with the seawall having the greatest level of negative impact. The status quo and remedial planning options have medium level of positive impact relative to other options.



The shoreline at Kuratau is relatively free of structures and development, with a reserve along the full length. This reserve effectively provides a buffer zone which allows continued monitoring of the shoreline movement without the need to take immediate responsive actions, this however is dependant on what value the community attributes to the reserve.

The status quo option of not intervening at this location is therefore worth consideration. However, the erosion may continue until a new equilibrium is reached which could in places be within private property near the river mouth, eventually placing houses at risk.

Whilst Kuratau has had the benefit of a buffer mechanism created by the reserve, further non-structural options at Kuratau would be limited to remedial planning techniques as the rear of the reserve is now fully developed. If significant erosion continued there may eventually be a need to purchase or relocate houses landward of their current location. Due to similar reasons to the status quo option as well as the significant cost to council remedial planning options are not preferred at Kuratau.

With limited structures and development, the beach and amenity value of the shoreline for recreational purposes is important to residents and visitors to the area. The consideration of structural options therefore needs to acknowledge these values. At a location like Kuratau there can tend to be a preference to support softer options that reduce the impact on the natural character, amenity and access. Additionally, the reversibility of the softer

options typically is easier than the hard structural options which both physically and publicly can be difficult. The scoring in the table above reflects this with re-vegetation and beach replenishment having the greatest positive and least negative impacts.

The primary disadvantages with beach replenishment on its own is that it may be working against the natural tendency for the beach to realign itself by moving sediment southwards, faster than it is being replaced from the river. Therefore the on going volumes and cost of continued replenishment could be considerable. Beach replenishment would likely be accompanied by re-vegetation to assist in securing the newly placed sediments. This may act to prolong the duration that the replaced sand stays in place, but is unlikely to produce a stable beach alignment.

If further inaction is not considered acceptable the options of beach replenishment and re-vegetation may buy some time and allow for further analysis of the shoreline processes and justification for the implementation of a combined solution such as using beach replenishment with containment structures such as groynes or the use of an offshore breakwater. The money used for the initial beach replenishment may however be lost and further replenishment would be required along with the installation of any containment structures.

We have not specifically assessed the option of preventing the accumulation of sediments behind the dam through more extreme options such as the removal of the dam. Whilst this may address one of the potential causative factors it is considered to be beyond a practical solution for the level of impact.

Photo 2. Kuratau scalloped beach, August 2005

A better understanding is needed of the complex processes in action at this site through monitoring and a sediment budget, before predicting the equilibrium position. This is a complex process and will require an assessment of the sediment budget for the area. This is best covered in a site specific study. This should take into consideration in more detail the sediment inputs into the system from the Kuratau River, the local wind and wave environment and sediment transport rates.

e. Summary of Recommendations

Based on our current understanding, if action is considered necessary, the recommended approach to the preferred option would be as follows:

1. Continue monitoring.
2. Confirm understanding of processes and the potential extent of any realignment through completion of the site specific study and a sediment budget analysis.
3. Based on this indentify likely form and extent of preferred solutions. (soft structural options are most likely to be most appropriate with a combination of beach replenishment, re-vegetation, and possible containment structures.)
4. Review options with local and regional stakeholders and implement the preferred option if appropriate and monitor performance.

6.3.2 Waitahanui (and Five Mile Bay)

a. Location description

Waitahanui is located at the southern end of the Five Mile Bay sediment sub-compartment within the wider eastern shore compartment. The focus area for erosion at Waitahanui is the length of shoreline immediately to the south of the Waitahanui Stream mouth. The main sediment sources for the compartment are the Hinemaiaia, White Cliffs and the Waitahanui Stream. Sediment is capable of being transported both north and south, however there is a net northward drift, as is evidenced by the sand bar at the Waitahanui Stream mouth. The stream mouth and spit is a highly valued location for trout fishing.

The beach at Waitahanui is already considerably modified with houses built at the rear of the foreshore, and various private erosion control structures (e.g. rocks, timber walls or concrete walls). Many of the houses have concrete ramps to the boundary, followed by timber ramps over the foreshore. These structures have been constructed on a property by property basis in a non-integrated manner.

The rest of the wider bay is largely undeveloped, with the exception of the Five Mile Bay development to the north.

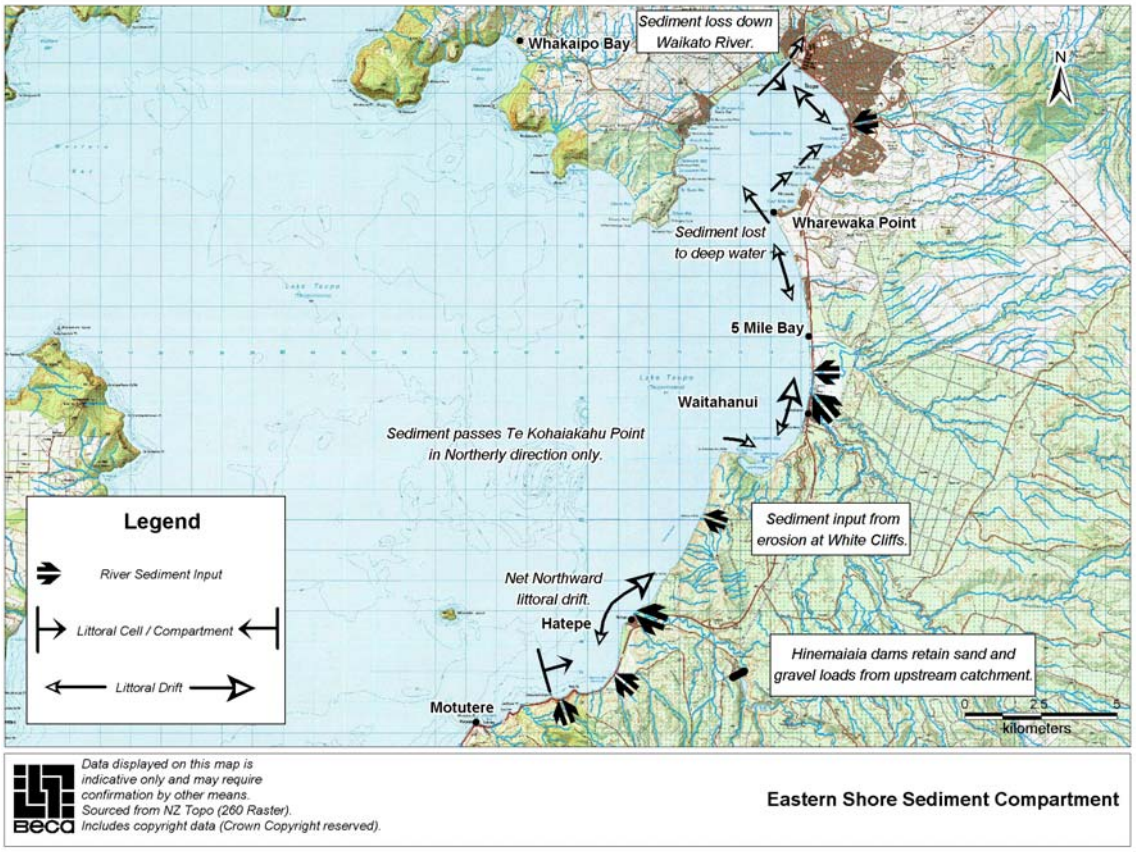


Figure 15. Eastern Shore Sediment Compartment

b. Erosion Risk Areas and Causes

Waitahanui has been the subject of a specific study undertaken by Tonkin and Taylor for Mighty River Power. This study recommended the installation of an offshore breakwater and beach nourishment to address erosion issues near the river mouth. This project is currently being implemented.

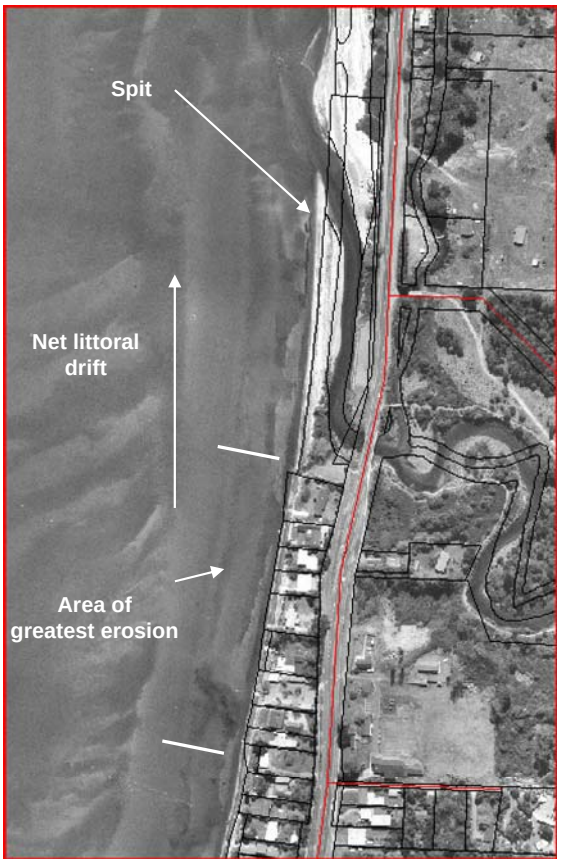


Photo 3. Waitahanui [1999]

Erosion in Waitahanui has largely been attributed to a lack of sediment from up drift areas, as well as possible rectification from a historical sediment 'bulge' formed by a large influx from the Waitahanui Stream during land development in the area. The causes of reduced sediment supply include; reduced supplies due to the dams on the Hinemaiaia, re-vegetation of the White Cliffs, and natural fluctuations in sediment cycles.

Further north at Five Mile Bay similar sediment deficit issues could be contributing to the erosion. Additionally, during Stage 3 of the study differences in the severity of erosion was observed between the areas with natural vegetation and the reserve areas with mown grass. The removal of invasive vegetative species without the replacement of with native equivalents has also be widely reported to have significantly increased the erosion rates in the Five Mile Bay development area. This area is currently identified as a moderate risk for erosion, however no beach profile surveys have been carried out. Surveys of the wider bay should be undertaken to confirm erosion rates over a wider area, and understand the broader changes throughout the Bay.

The comparison of historical survey plans of the lake edge and the recent Cheal Consultants beach profile survey show erosion of up to 0.41m/yr adjacent to the river mouth with the rate lessening heading south and away from the river. There have been no formal surveys at the Five Mile development and it is therefore difficult to determine accurate erosion rates.

The mouth of the Waitahanui, like most streams or rivers is a dynamic area, this can be seen by the cycles that the river mouth and spit go through where the discharge location can move up to several hundred metres north of the location where it breaks into the river. Areas in close proximity to the river mouth could therefore expect cyclical periods of erosion and accretion as the river and lake processes work in their own cycles.

Development within or close to the likely fluctuation zone has also meant there has been the construction of hard, shore parallel erosion protection measures of various forms along

this stretch of shoreline. Some of these structures are causing erosion problems at either end, adding secondary erosion issues.

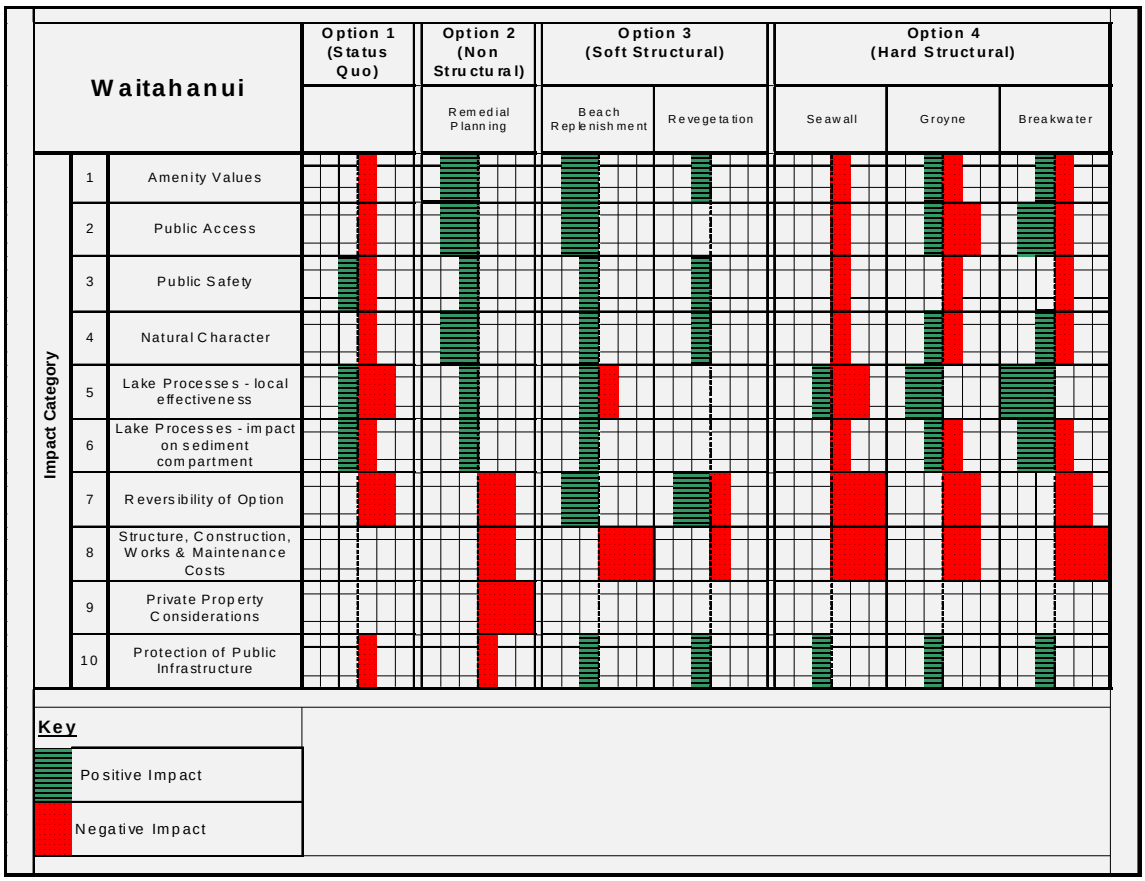
c. Assets at Risk

As described above, the area to the south of Waitahanui stream mouth has a number of homes, many of which have extensive protection structures in place. The distances from the shoreline to the houses range from approximately 10m-30m. During severe storms these low level defences would not be suitable to withstand wave forces. It also appears from the type of protection put in by the landowners that some infilling behind them has taken place. Existing seawalls and boat ramps have been undermined in many areas along Waitahanui. Along the length of shoreline with the most significant erosion the public services (e.g. sewer) are located on the landward side of the houses. Further to the south there is approximately 420m of sewer between 20 – 40 m from the shoreline. Two main stormwater outfalls exist along the area of risk.

Photo 4. Waitahanui boat ramp, August 2005

Evaluation matrix for Waitahanui

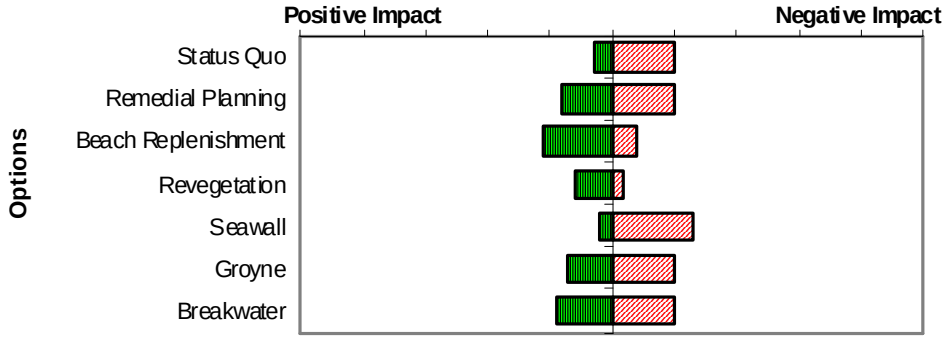
How to use the Matrix – Each option along the top of the matrix has been assessed against the criteria down the left hand side of the table based on whether or not it will have a positive or negative impact (red represents negative, green is a positive impact). The length of the bar indicates the degree of impact. The gradings are either High (long bar), Medium, or Low (short bar). No bar would indicate that there is no impact or not assessed in this study



d. Waitahanui Qualitative Analysis Summary

The graph below shows, in summary form, the results of the qualitative matrix for Waitahanui. The results show that the soft structural options have the least negative impacts. Beach replenishment is shown to have the greatest positive impacts relative to other options. Hard structural options are shown as having a high level of negative impact, with the seawall having the greatest level of negative impact and least positive impact. While status quo and remedial planning have relatively high levels of positive impacts, remedial planning is also shown to have a medium level of negative impact.

WAITAHANUI -
QUALITATIVE ANALYSIS SUMMARY



The shoreline at Waitahanui is considerably modified, with a large number of holiday homes with a variety of individual protection structures (rocks, timber, concrete walls). It is probable that some of these homes have been developed within the natural fluctuation zone of the shoreline. As short term erosion has occurred, individual properties have responded by putting up protection structures in front of their properties.

The status quo option of not intervening with a wider strategic intervention would likely result in continued periods of cyclical erosion and the further development of individual erosion control structures. Secondary erosion problems around existing structures will also likely continue. This is likely to adversely impact recreational, amenity and natural character values at Waitahanui over time.

Non-structural options at Waitahanui would be limited to remedial planning techniques as the rear of the reserve is developed. Remedial planning would be a longer term positive option which would involve major relocation of private property to the other side of the State Highway. If significant erosion continued there may eventually be a need to purchase or relocate houses landward of their current location. Due to the significant cost to council, the remedial planning options are not preferred at Waitahanui.

Soft options - beach replenishment and re-vegetation would be a more natural remediation response and will therefore have a more positive impact on amenity values through enhancement of visual amenity and provision of a more useable lake shoreline. However, public access may be restricted due to re-vegetation works while plants are being established. Additionally, the reversibility of the softer options typically is easier than the hard structural options which both physically and publicly can be difficult, but they do have ongoing associated costs. Soft options are likely to be the most appropriate for Five Mile Bay in the developed areas, and non-structural options and planning techniques in those areas yet to be developed.

If shore parallel structures (sea walls) were to be considered further it may be beneficial to take a more integrated approach and implement structures that encompassed several properties. Whilst this may improve the performance and aesthetics, it is unlikely to

achieve a desirable outcome at this location. A groyne or break water could be used to reduce the movement of sand away from the areas facing erosion.

Groynes would likely have a greater visual impact but would be less costly. Either option would likely require beach replenishment to prevent erosion of adjacent areas.

The project implemented in Waitahanui by MRP for a breakwater and beach replenishment is consistent with the evaluation criteria used here. It will be critical to monitor the breakwater to determine its effectiveness and any potential impacts. Although less significant there is still some erosion further to the south of the area that the breakwater is located. This area should also continue to be monitored to confirm the longer term trends and any changes here. If successful, a combined breakwater/beach replenishment solution could be applicable at other similar locations around the lake.

Whilst the breakwater is addressing the immediate erosion issues, implementation of non structural planning techniques may be beneficial in the adjacent undeveloped areas of Five Mile Bay. This is particularly relevant at Waitahanui as it has been indentified as one of the future growth areas in the Taupo Growth Strategy. This potentially includes approximately 200 residential lots, as well as the potential for a waterways style development.

It is critical that future development takes account of the lake processes and shoreline change in this area. In particular the interaction of any proposed inland waterways development on the shoreline will need to be understood. The implementation of the growth areas should prevent similar issues of development in close proximity to the shoreline. It is therefore particularly important that these undeveloped areas also have monitoring undertaken.

e. Summary of Recommendations

Based on our current understanding, if action is considered necessary, the recommended approach to selection of preferred options would be as follows:

1. Monitoring in conjunction with MRP relating to the breakwater and beach replenishment performance and effect down drift.
2. Formal monitoring (beach profile surveys) of Five Mile Bay and analysis of erosion rates and causes, introduction of re-vegetation; and
3. Investigate non structural planning techniques and monitoring in undeveloped areas within Five Mile Bay.

6.3.3 Whareroa

a. Location description

The main area of focus at Whareroa is the area to the south of the river mouth along the reserve towards the boat ramp. The Whareroa Stream / Lakefront Reserve runs parallel to the shore over this length and is between 20 – 40m deep. The reserve is generally low lying and appears to be formed of sediments that have deposited at the base of the cliffs. The existing areas of residential development at Whareroa are set back some 40-70 m and are high up on the cliff to the rear of the reserve. There are further areas currently under development to the north of the existing houses. The reserve is still retained in these areas. An access road exists towards the southern end which leads to a boat ramp. The reserve is mainly grassed with some large individual trees including poplars. The beach is mostly natural with few erosion control or other structures. The exception is around the boat ramp where rock and revetments have been placed to protect the ramp from erosion to the north.

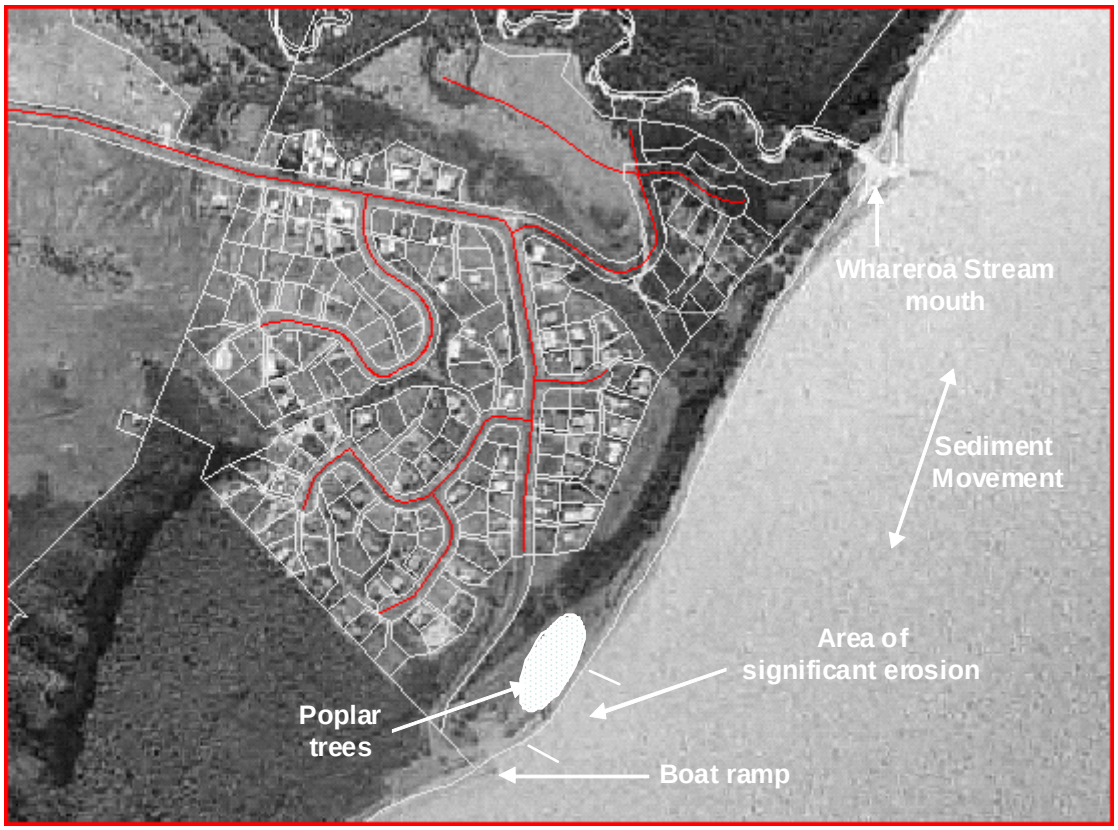


Photo 5. Whareroa [1999]

b. Erosion Risk Areas and Causes

Whareroa Bay has predominantly been identified as at 'moderate' erosion risk, having experienced localised erosion cycles. A localised area directly to the north for approximately 100m has been identified as 'high' risk and has encountered more significant erosion in the recent past. There has been limited site specific investigations or analysis undertaken historically for this area. The erosion has largely been attributed to effects the boat ramp is having on the sediment movement. However further work is needed to determine what other factors are at play and whether these are long term erosion trends.

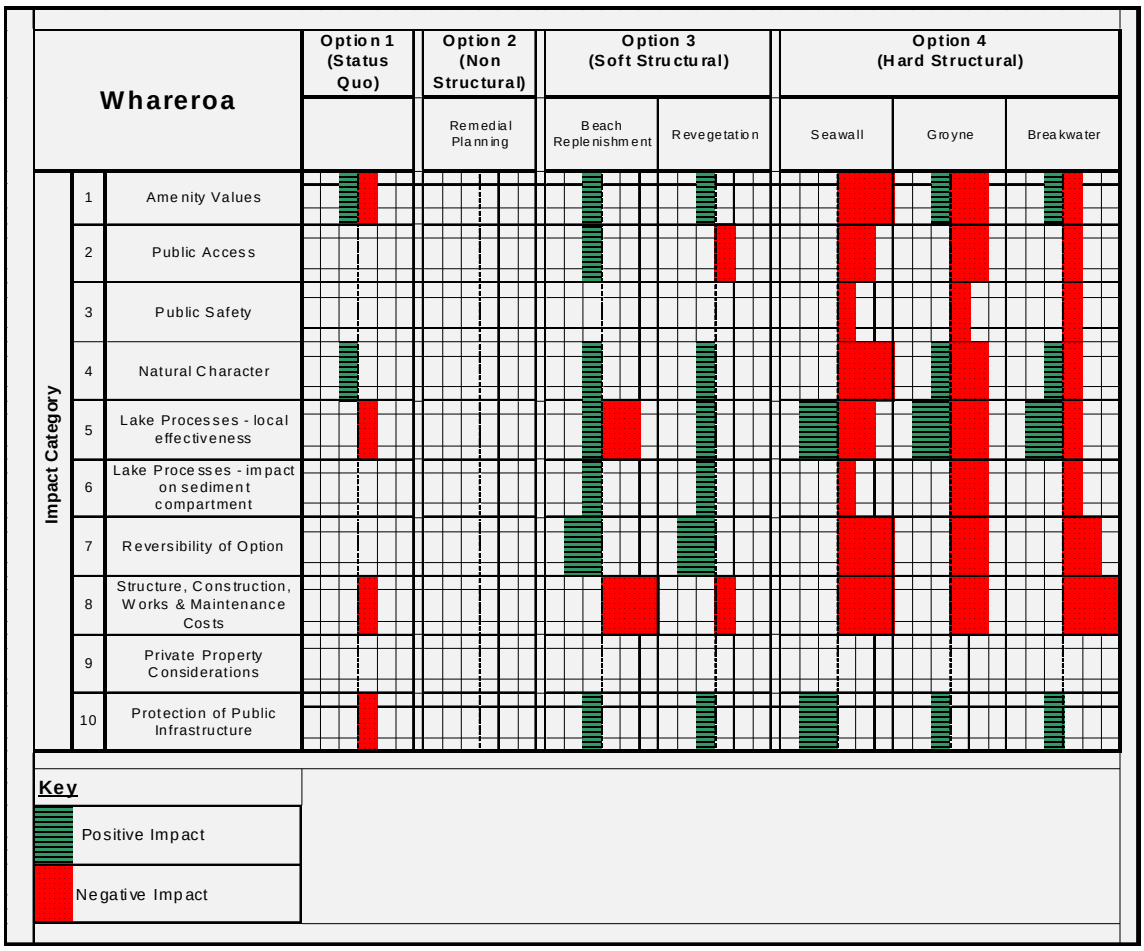
c. Assets at Risk

The key asset at risk from erosion hazard is the public reserve that runs along the foreshore. Some existing poplar trees which are considered to be of high visual amenity value to the local community are also at risk. Other services and water supply boreholes etc are currently located well back from the shoreline. The ramp itself has required responsive protection measures to prevent cutting at the side.

Photo 6. Whareroa shoreline, July 2006.

Evaluation matrix for Whareroa

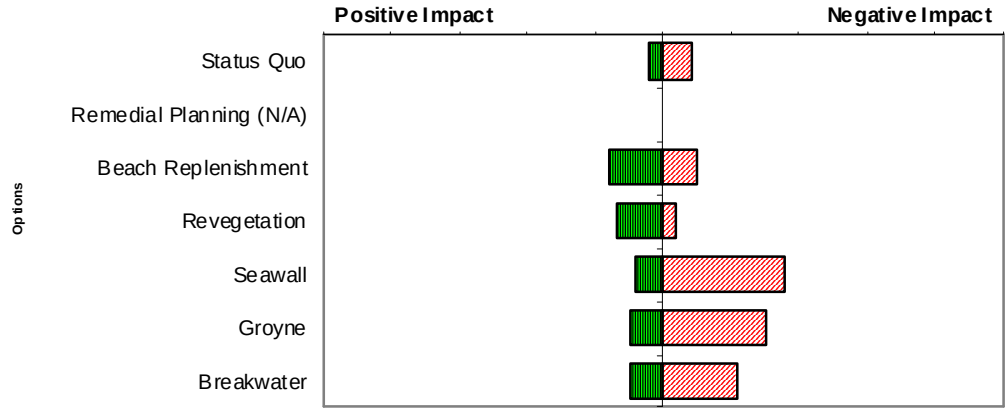
How to use the Matrix – Each option along the top of the matrix has been assessed against the criteria down the left hand side of the table based on whether or not it will have a positive or negative impact (red represents negative, green is a positive impact). The length of the bar indicates the degree of impact. The gradings are either High (long bar), Medium, or Low (short bar). No bar would indicate that there is no impact or not assessed in this study



d. Whareroa Qualitative Analysis Summary

The graph below shows, in summary form, the results of the qualitative matrix for Whareroa. The results show that the soft structural options have the greatest positive impacts with the least negative impacts. The hard structural options have similar levels of positive impacts to each other, with the seawall having the greatest level of negative impact. The status quo option has almost the least negative impacts but also has limited positive benefit. While the non-structural / remedial planning option is not considered applicable in this management area, as there is a reserve which is already in place and this could act as a buffer and there is minimal existing development.

WHARAREOA -
QUALITATIVE ANALYSIS SUMMARY



The shoreline at Whareroa is relatively free of structures and development, with a reserve along the full length. Similar to Kuratau, this reserve provides a buffer zone which allows continued monitoring of the shoreline movement without the need to take immediate responsive actions. Furthermore the development is largely at high level along the cliffs.

Whilst Whareroa has had the benefit of a buffer mechanism created by the reserve, further non-structural options would be limited as the rear of the reserve is to be developed and existing properties are already set back sufficiently without the need for remedial planning techniques.

With limited structures and development the beach and amenity value of the shoreline for recreational purposes is important to local and visitors to the area. Further consideration of options therefore needs to acknowledge these values. At a location like Whareroa there can tend to be a preference to support softer options that reduce the impact on the natural character, amenity and access. Additionally, the reversibility of the softer options typically is easier than the hard structural options which both physically and publicly can be difficult. The scoring in the table above reflects this with re-vegetation and beach replenishment having the greatest positive and least negative impacts.

Beach replenishment would likely be accompanied by re-vegetation to assist in securing the newly placed sediments. This may act to prolong the duration that the replaced sand stays in place, but is unlikely to produce a more stable beach alignment.

In addition to investigation options for mitigating the effects of erosion, further investigation of the potential effects the boat ramp is having on the erosion should be undertaken. Consideration of changes to the boat ramp to prevent it from significantly disrupting the sediment movement or relocation could be considered acceptable.

As the area has a significant buffer zone and the existing use of structures is limited, building new major hard structures to address erosion should be avoided. A trial re-vegetation could be considered as a complimentary solution to the buffer zone.

e. Summary of Recommendations

Based on our current understanding, if action is considered necessary, the recommended approach to the selection of preferred options would be as follows:

1. Initiate monitoring in this location to confirm longer term trends;
2. Review boat ramp and adjacent areas and assess if changes to the ramp will assist in reducing the erosion effects; and
3. Consider a trial re-vegetation programme.

6.3.4 Kinloch (Whangamata Bay)

a. Location description

Kinloch is situated in the Whangamata Bay, which forms a pocket bay compartment that acts independently of adjacent bays. The main sediment inputs into the bay are from the Otaketake and Whangamata Streams. Large influxes of material are reported to have been flushed into the bay during development in the 60's and 70's, including a reported farm dam break. Much of this material appears to have been trapped behind the groyne at the western marina entrance, where the land has accreted almost 40m. The net littoral drift is towards the east as evidenced by the build up of this sediment.

The area of focus from an erosion point of view is the length of shoreline immediately to the east of the marina entrance. The full length of this area has a reserve approximately 20 - 30 m deep. To the western end, where the erosion is most prevalent the reserve is backed by a road and then houses. The reserve is predominantly grassed with approximately 25 individual protected trees including poplars.

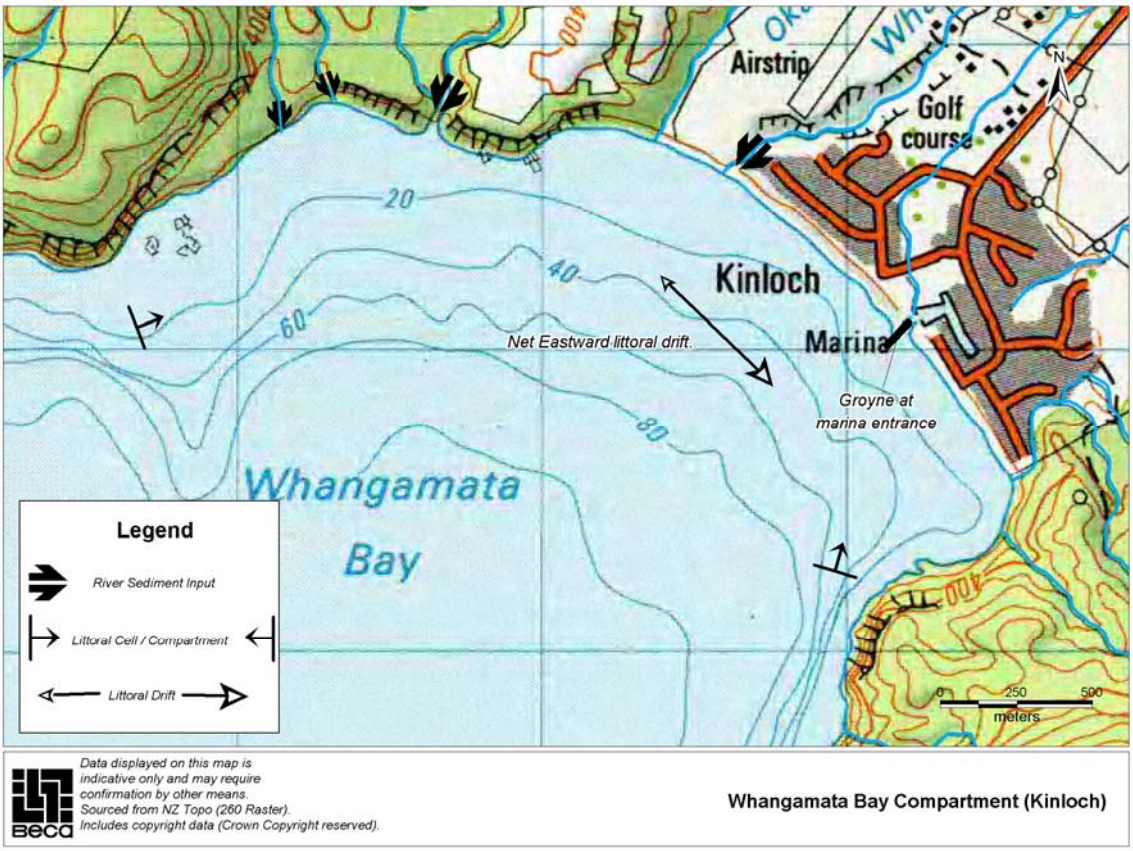


Figure 16. Whangamata Bay Compartment (Kinloch)

b. Erosion Risk Areas and Causes

Following periods of high lake levels and wind events in 2004, significant erosion occurred immediately to the east of the groynes at the marina entrance. Following these events rock revetment was placed in this area to prevent further erosion and protect the poplar trees.

These erosion episodes immediately to the east of the marina entrance during high lake levels have been attributed to sediment bypassing this length of the shoreline. This is due to the presence of the groynes at the marina entrance as well as a reduction in the sediment entering the system since the early significant influxes.

The Kinloch area has had a shorter-term trend of tectonic subsidence, and since 1979 has been dropping approximately 7mm on average compared to Acacia Bay. Although this does not appear to be causing major erosion issues at present, if this trend continues it is considered that this may cause problems in the long term.

c. Assets at Risk

At Kinloch, the area of erosion is relatively confined to the downdrift side of the marina leeward breakwater. The main items at risk are approximately 4-5 poplars and the reserve area itself. A reasonable buffer still exists before the road and houses. Services such as water and sewer are also well clear of the area at risk.

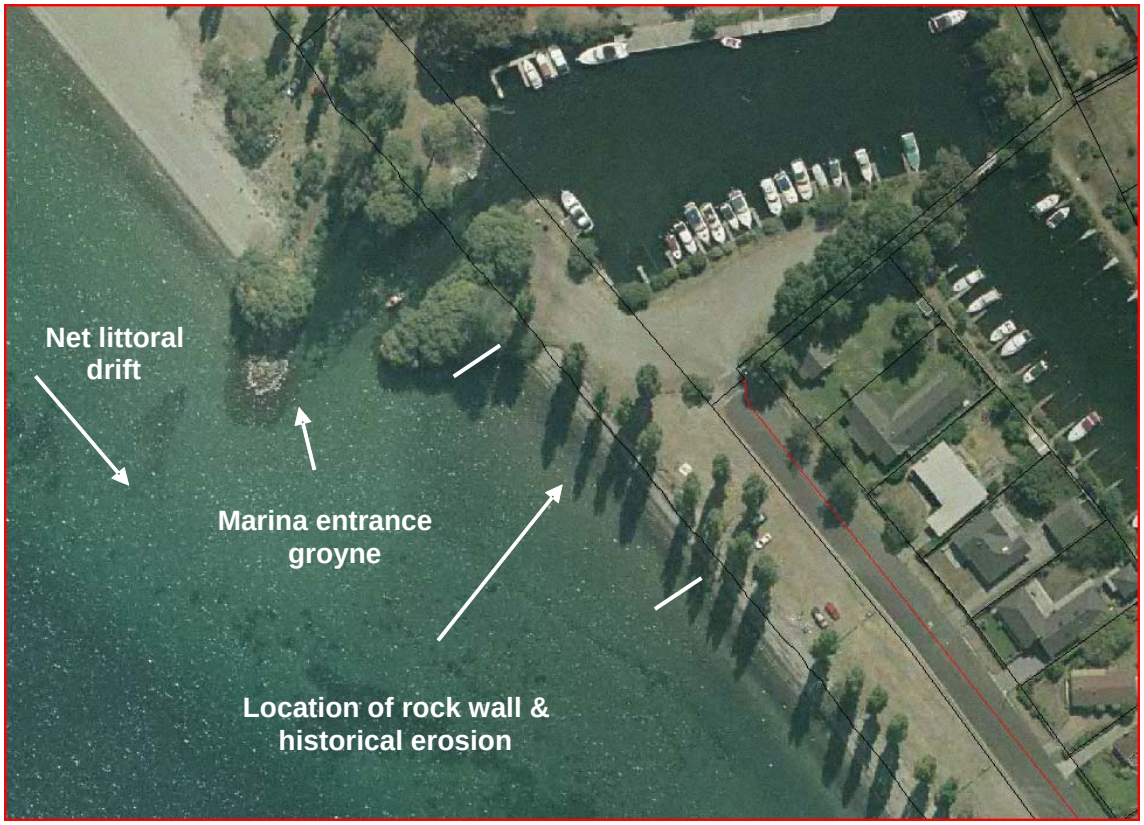
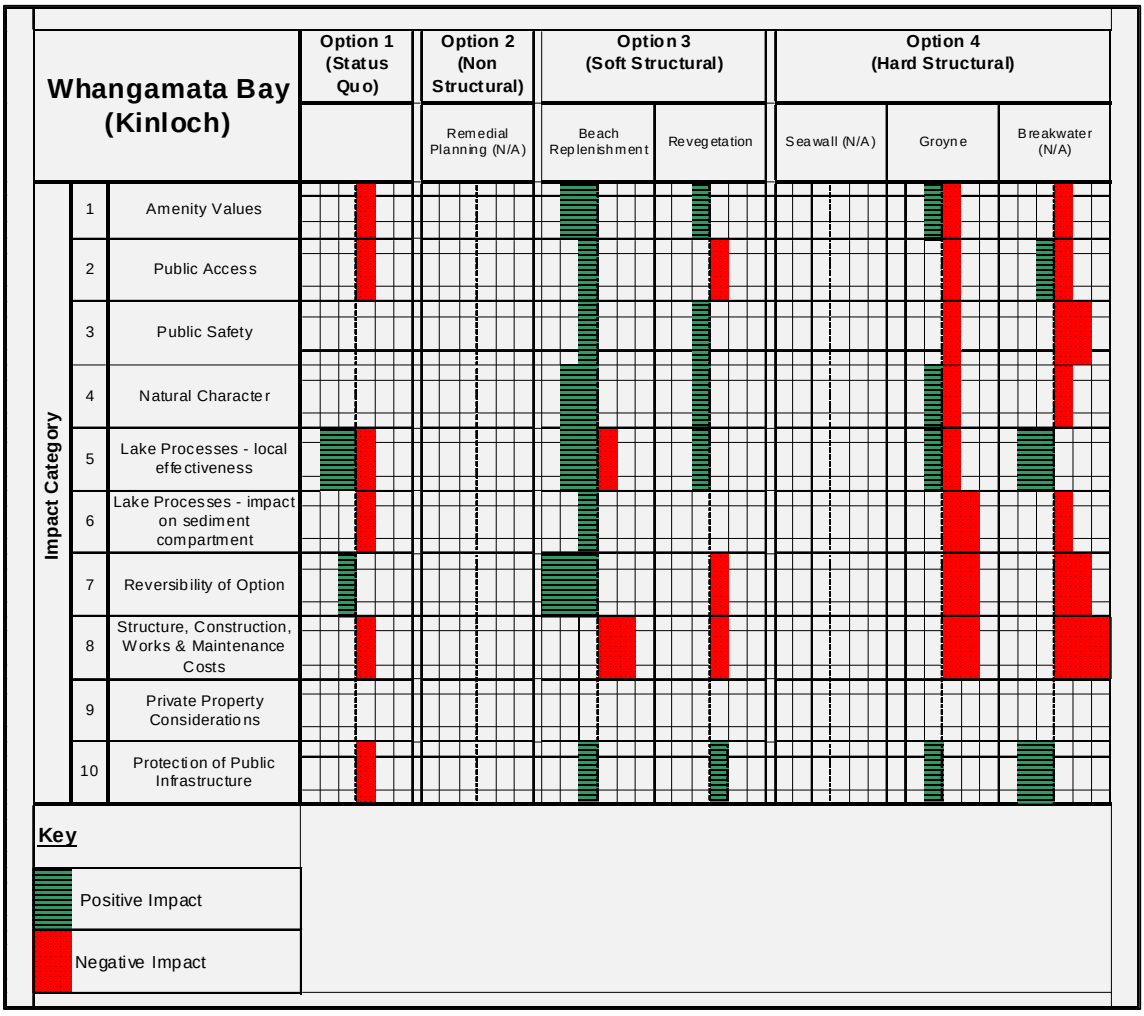


Photo 7. Kinloch shoreline, [2003]

Evaluation matrix for Whangamata Bay (Kinloch)

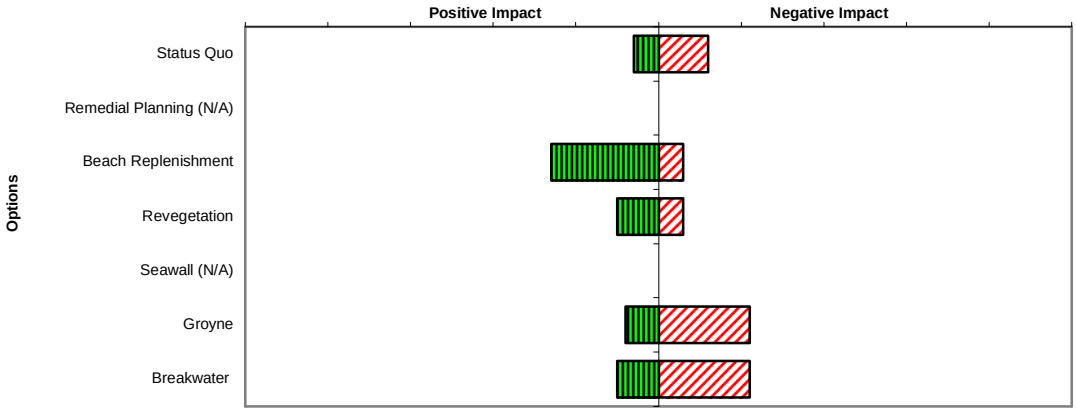
How to use the Matrix – Each option along the top of the matrix has been assessed against the criteria down the left hand side of the table based on whether or not it will have a positive or negative impact (red represents negative, green is a positive impact). The length of the bar indicates the degree of impact. The gradings are either High (long bar), Medium, or Low (short bar). No bar would indicate that there is no impact or not assessed in this study



d. Whangamata Bay (Kinloch) Qualitative Analysis Summary

The graph below shows, in summary form, the results of the qualitative matrix for Whangamata Bay. Non structural options were not considered applicable in this management area based on the current level of erosion and because a reasonable buffer already exists. The results show that the soft structural options have the greatest positive impacts with the least negative impacts. A seawall exists so hasn't been specifically assessed, options for enhancing the wall are discussed further below. The other hard options have the greatest level of negative impact with only minimal positive impact. The status quo option has a moderate level of negative impact relative to the other options and has the least positive impacts of the options available.

WHANGAMATA BAY (KINLOCH) - QUALITATIVE ANALYSIS SUMMARY



The situation at Kinloch is one of a post implementation phase of the installation of a rock seawall in response to erosion events in 2004. As part of the expansion of the marina there were also plans to carryout beach nourishment in front of the revetment creating a buried seawall. This process was held up due to getting approvals for the nourishment. The result is that the wall has assisted in stabilising the erosion area, however the character of the beach and access has been affected. Secondary or localised erosion / scour has also occurred at the end of this rockwall structure (i.e. 'end effects').

At this site beach nourishment would be achieved by taking sand from the west side of the marina and placing it on the east side. It is effectively a sand by-passing system, bringing the overall beach into equilibrium by transferring the sand held back by the marina entrance.

The shoreline at Kinloch is relatively free of structures and development along the length of the esplanade reserve. Similar to Kuratau and Whareroa, this reserve provides a buffer zone which allows continued monitoring of the shoreline movement without the need to take immediate responsive actions. The exception to this is some of the trees which are in close proximity to the shoreline.

Opportunity for further non-structural options would be limited as the rear of the reserve is already developed and currently properties are already set back sufficiently without the need for remedial planning techniques.

With limited structures and development the beach and amenity value of the shoreline for recreational purposes is important to local and visitors to the area. Further consideration of options therefore needs to acknowledge these values.

Consideration of further options needs to take into account the wall already in place. An inspection of the wall should be carried out to assess its performance within recent years. If it is considered to be providing effective protection then two principal options exist. If the visual and access impact of the wall isn't significant, the status quo option of leaving it in place and monitoring would be recommended. If the wall is considered by the local

community to have a significant impact on the amenity and character of the beach then options of burying the wall and beach replenishment should be considered further.

Although not directly assessed an option of addressing the causative factor of removing the groynes at the marina entrance exists. As the groynes are understood to be essential for maintaining access into and protecting the marina, and the value of the marina to the local area is significant this is unlikely to be considered a viable option.

e. Summary of Recommendations

Based on our current understanding, if action is considered necessary, the recommended approach to the selection of preferred options would be as follows:

1. Monitor performance of the wall and in particular any end effects and internal soil erosion.
2. Continue to investigate options for undertaking beach replenishment in front of the wall if its aesthetic impacts are not acceptable.

Photo 8. Kinloch rock wall, August 2005

6.3.5 Motutere

a. Location description

A reserve (Motutere Point Reserve - waterfront reserve) runs parallel along to Motutere Point. Motutere Bay Recreational reserve then extends along waterfront areas east of the point. The rear of the reserve is bounded by the State Highway along the main length (430m) and is approximately 30m from the shoreline at its closest point. Around the point the reserve is significantly narrower and the rear of the reserve is bounded by residential properties.

Motutere exhibits a stepped beach profile and small reef offshore at the point, with net sediment drift that is northwards within this sediment compartment. At Motutere, there is a campsite and trailer park located along the reserve. Rock walls built in front of private properties to protect against erosion are located along the Point, and there are a number of small informal wooden structures providing protection to the campsite area. There is one main boat ramp servicing the campsite, along with a number of smaller ramps along the houses.

Photo 9. Motutere rock wall and wooden structure mix, August 2005

Sediment movement is predominantly towards the north but can move in both directions. The sediment compartment analysis undertaken by NIWA (2001) shows a loss of sediment at the point, limiting the availability of incoming sediment from the south due to the headland.

b. Erosion Risk Areas and Causes

At Motutere, erosion has been reported after short-term events, however the area is reported to recover quickly. The erosion has been focused predominantly towards the south end of the beach near the point. Further north the beach surveys have shown both erosion and accretion trends. The beach has shown an increased erosion rate over the 2004-2005 period, however informal reports indicate less erosion recently.

There has been little specific analysis or investigation into the causes of erosion at Motutere and therefore there is little data to assess. The beach and sediment movement has shown a high response to changing wind/wave directions, this will likely be due to the effects of the point and wind/wave dynamics on the sediment movement in the area. These short term fluctuations are evidenced around the boat ramp where significant erosion has occurred on the down drift side, however when inspected several days later the beach has recovered.

At this stage there is insufficient information to indicate that there is long term chronic erosion, and it is more likely that the natural erosion cycles are affecting the reserve and properties created along the shoreline. The creation of the reserve and the effects of vegetation removal and replacement with mown grass, the interruption of the sediment movement by the ramp and other minor structures may be disrupting the natural dynamics of the sediment processes.

c. Assets at Risk

The primary elements at risk are the reserve itself. There are various camp site structures in the reserve, however they are generally of a temporary nature. The boat ramp itself has sustained failures and required repairs. Additionally towards the point there are about 15 houses on the lakefront, 15-30m to the rear of the shoreline. A Pa exists in the point reserve area. There is no significant sewers near the shoreline, however a water supply intake pipe and structure exists approximately 20m from the shoreline.

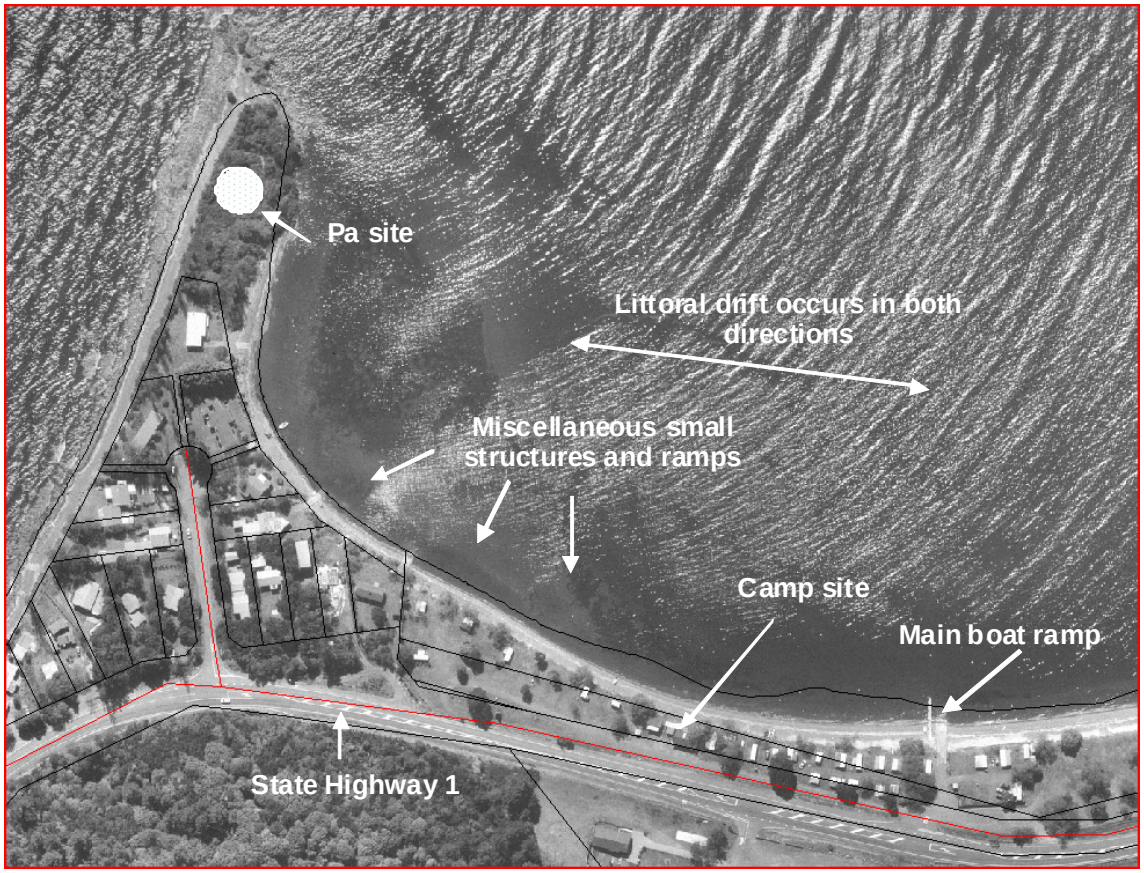
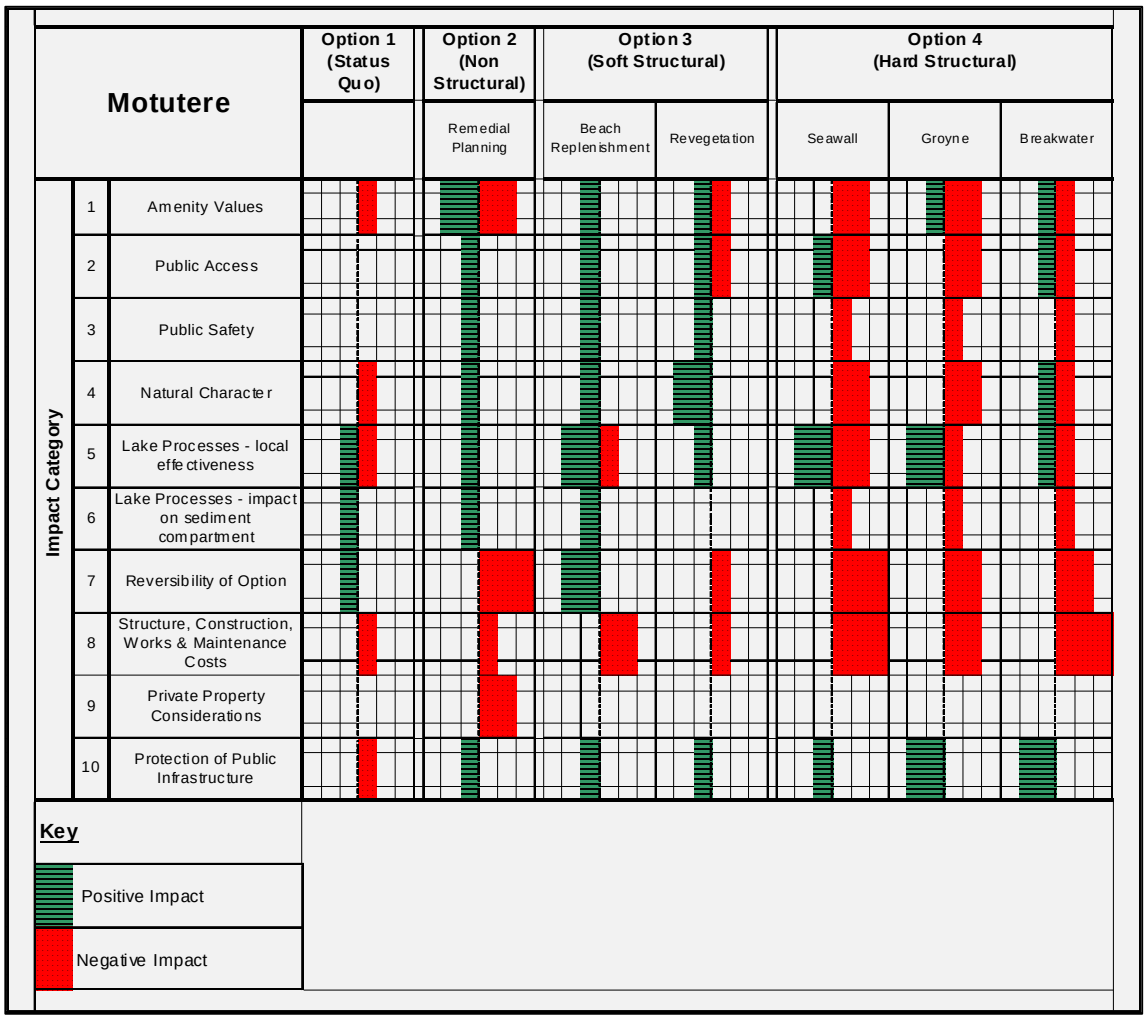


Photo 10. Motutere [1999]

Evaluation matrix for Motutere

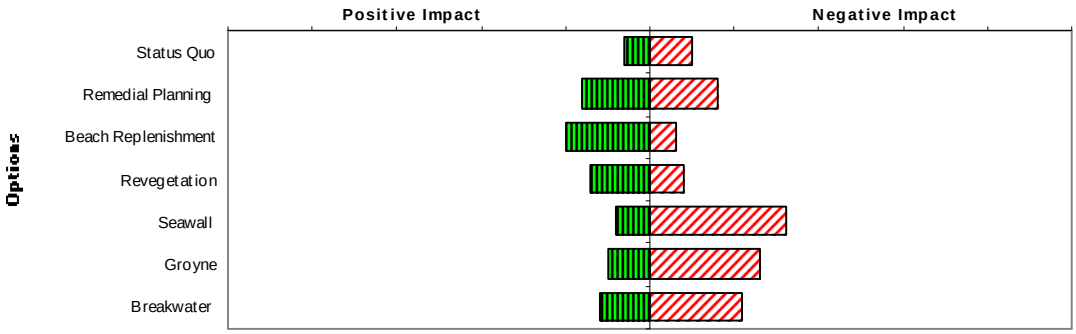


d. Motutere Qualitative Analysis Summary

The graph below shows, in summary form, the results of the qualitative matrix for Motutere. The results show that the soft structural option of beach replenishment has the greatest positive impact with the least negative impact. The hard structural options have similar levels of positive impacts to each other, with the seawall having the greatest level of negative impact. The status quo and remedial planning options have a medium level of negative impact relative to other options with the status quo option having the least positive impacts of the all the options available. As previously stated the beach has been quick to recover after short-term erosion events.

The foreshore at Motutere is relatively unmodified along the esplanade reserve, however a multitude of rock wall structures are situated along the western side of the Point and to a lesser extent on the east.

MOTUTERE -
QUALITATIVE ANALYSIS SUMMARY



The status quo option of not intervening at this location could be considered a preferable option if the erosion events are shown to be cyclical fluctuations. Under the status quo, the lakefront beach area will experience periodic retreat in storm events and it is likely that this may temporarily impact recreational values at Motutere in the short term until the lake foreshore recovers. Fluctuations of erosion cycles around the beachfront area and point feature will continue, and secondary erosion problems around existing rock structures will continue.

Non-structural options at Motutere would be limited to remedial planning techniques. Under this option, there would be significant capital costs associated relocation and/or purchase of the properties around the point away from the existing pa site.

Hard structural options are not the preferred option at this location because of their impact on the amenity and natural character of the beach. Further construction of rock sea walls or groynes along the grassed reserve can potentially further reduce public access to the shore, and possibly necessitate access structures (walkways and steps) to avoid clambering over groynes and seawalls.

Beach replenishment would be a more natural remediation response than hard structures and will therefore have an increased positive impact on amenity values. Replenishment will enhance the visual amenity and provide a more useable lake shoreline. Consideration should be given to replenishment accompanied by re-vegetation. This may act to prolong the duration that the replaced sand stays in place.

Additionally, the reversibility of the softer options typically is easier than the hard structural options which both physically and publicly can be difficult. However it is likely some form of structure to extend the effectiveness of the nourishment would be required, as placing sand near a natural point could lead to a rapid loss of material.

e. Summary of Recommendations

1. At this point, it is recommended to monitor this location for 5 years to better establish the fluctuation / erosion regime.

6.3.6 Taupo Township (Tapuaeharuru Bay)

The shoreline around Taupo Township has undergone substantial modification as the development around the lake has spread. Due to the highly modified state and the high profile and value to the public of this area, it warrants further attention at a comprehensive level, followed by specific attention at individual issue sites.

a. Location description

The Tapuaeharuru Bay shoreline extending from Wharewaka Point to the Waikato River forms a sub-compartment of the wider Eastern Shore compartment identified by NIWA (NIWA 2000). The geology of the shoreline at Taupo Township is characterised by unconsolidated deposits / Alluvium, which has low resistance to erosion. The Eastern Shore compartment extends South to Bulli Point and also at the Waikato River to the North. Historically two of the main sediment sources into the wider compartment have been the Hinemaiaia River and the White Cliffs. In recent times the inputs have been reduced due to the dams on the Hinemaiaia, and re-vegetation of the White Cliffs (NIWA 2000).

The available sediment within the compartment is sparse and moves northwards along a series of small sub-compartments that are interrupted by multiple groynes, both man made and natural and ultimately sediment is lost down the Waikato River, where it is pulled in by the current.

b. Erosion risk areas and causes

There is significant development in what is likely to be a natural fluctuating area of shoreline. Erosion has occurred along the shoreline in a number of places during July 1998 where lake levels were high. Reduction in sediment inputs from the Hinemaiaia River and the White Cliffs and interference from numerous groynes and hard structures have led to sediment deficits that have contributed to erosion. Many of the protection structures do not incorporate good design guidelines and in some cases cause erosion in adjacent areas. (Refer section 4.3.3 for further guidance about good structure design.) Some secondary factors such as sediment removal, vegetation removal, and increased high lake level/wind events are also contributing to erosion in some areas.

c. Assets at risk

The majority of the shoreline is backed by a lake front reserve, however this is limited in width in many areas. Near Waipahihi and Two Mile Bay, SH1 is immediately adjacent to the shoreline, with carparks in some areas. The majority of the reserve areas are either backed by SH1, private residences or hotels and inns. A walkway follows the shoreline along most of its length, and portions of it have historically been at risk following significant erosion events like the one in 1998. In terms of services there are many stormwater outfalls along the shoreline, some providing small obstructions to sediment movement. In several lengths of the shoreline between Four Mile Bay and Waipahihi wastewater lines are situated within the reserve areas. In particular, lengths of wastewater lines just north of Kaiwaka Pt were exposed and at immediate risk following the storms in 1998. There are a number of sites which have cultural significance including sites on Lake Terrace and Kaiwaka Pt below local hapu burial grounds / Urupa.

In some areas where erosion has occurred, the risk is to the reserve itself. Whilst reserves can be effective buffers, ongoing erosion can result in a loss of the reserve asset itself.

In addition to the various assets and infrastructure listed above, there is also risk to a number of the erosion control structures themselves. Many of the structures have not been designed appropriately and suffer from erosion at the ends or at the toe (Kirk 2000).

Photo 11. Taupo Township mix of structures, May 2005

d. Summary and Way forward

Some of the key issues and observations regarding Tapuaeharuru Bay include:

- Erosion in multiple places was evident during July 1998 high lake level episode.
- The shoreline and backshore is generally formed from geology with low resistance to erosion.
- Historically there has been significant modification to much of the shoreline, including alteration of its shape, and installation of shore parallel and perpendicular erosion structures. Many of these structures do not meet good practice for shoreline structures and therefore are in some cases causing erosion downdrift or at either end.
- There has been significant development within what is likely to be a natural fluctuation zone for the shoreline.
- Man made embayments and structures are probably not in equilibrium with the predominant south-west wind generated waves.
- A range of different structures have been employed which has resulted in an inconsistent approach to shoreline management.

- Most of the erosion is in reserve area, along footpaths, although the State Highway is close in some areas.

e. Summary of Recommendations

As mentioned above, the approach to managing the shoreline of Tapuaeharuru Bay warrants special attention and this needs to be initially undertaken at a baywide level. A management plan should be undertaken setting out the community values for the area. This plan could include:

- Identification of the desired shoreline characterisation and prioritisation for different areas. For example this could identify those areas where natural beach and swimming was important, as compared those areas where hard structures were considered acceptable and the protection of assets being the priority.
- Following this a new shoreline configuration could be undertaken, including beaches and headland structures. One result of this could be the use of beach nourishment to restore/create an aesthetic beach environment, with headland structures to assist in reducing the loss of sediment.
- The development of a consistent approach to any hard protection where it is necessary is recommended.
- Asset surveys of existing structures to understand their performance, and expected life.
- Monitoring of beach profiles to better understand the lake processes in this area.
- Modelling of the wave climate and refraction/diffraction/shoaling processes so as to better describe the equilibrium state of the bay.

Photo 12. Taupo Township beach, August 2005

6.3.7 Whakaipo Bay

Whakaipo Bay is a deep pocket bay bounded on the west by the Whangamata Bluffs and Tehunatara Pt on the east. The gravel and sand beach is largely undeveloped with the length of the beach forming a recreation reserve (Sec 47 Blk 4 Tuhingamata), with grass and sparse bush. A water extraction site exists towards the east end of the beach. The sediment sources to the beach include the Mapara Stream and a number of other small streams.
A review of aerial photographs from 1961 and 1993 showed erosion of between 5-15m at the western end of the beach (NIWA 2000). It was also noted that in the 1980's there has been tectonic tilting in the area that may have contributed to the change in form of the beach. There are currently minimal assets at risk at Whakaipo, however, inland the Mapara area has been identified as a key growth area in the Taupo District 2050 growth strategy. This will result in increased usage of this area and potential pressure for infrastructure near the shoreline. A better understanding of the varying nature of the shoreline is needed before making decisions on development in close proximity to the beach. Although not picked up during previous surveys, beach profiles should be undertaken at this location to more accurately define the changes to the beach. Additionally the development upstream needs to take into account any potential effects on sediment supplies to the beach.

a. Summary of Recommendations

Based on our current understanding, if action is considered necessary, the recommended options are as follows:

1. Instigates shoreline investigation / monitoring;
2. Implementation of non-structural planning options as required to prevent development within close proximity of the shoreline.

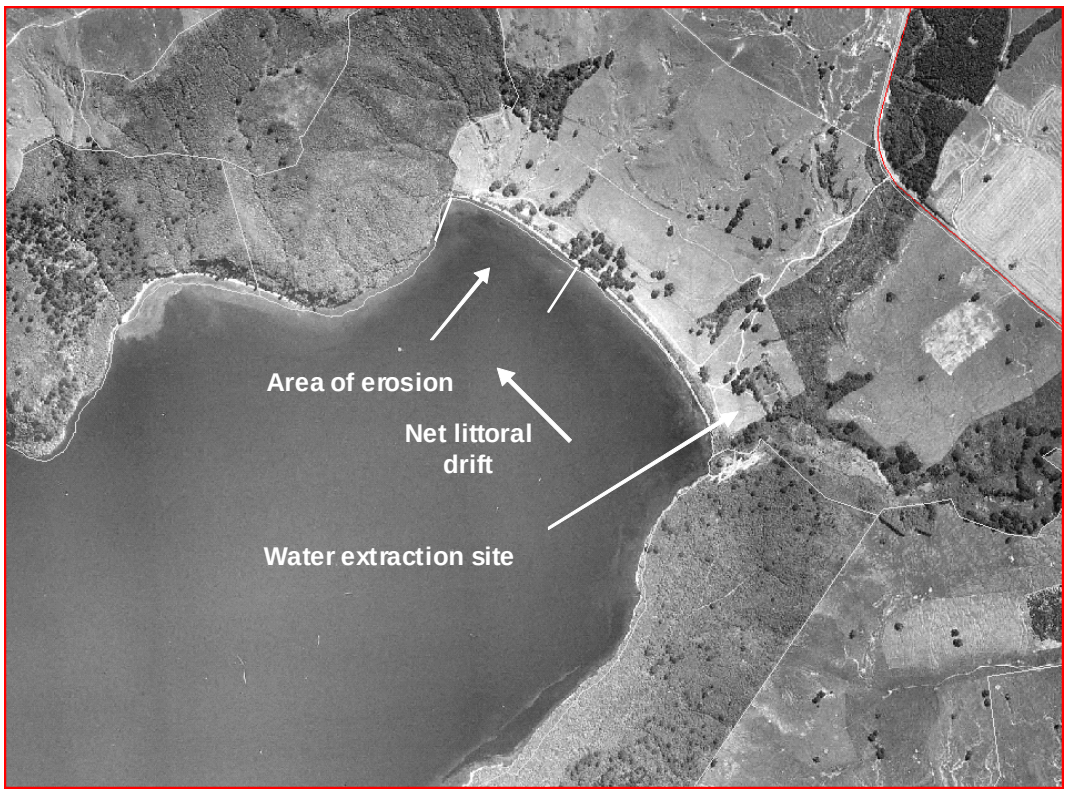


Photo 13. Whakaipo Bay, [1999]

6.3.8 Te Rangiita

The primary area of erosion at Te Rangitta is the length of shoreline immediately to the east of the Tauranga Taupo River mouth, extending beyond Mac Rd to the Te Rangitta Reserve. This area has historically shown fluctuations (1946, 1958, 1993 aerial photographs NIWA 2001) and is considered to be predominantly based on the variations related to the proximity to the river mouth. Since the river mouth was artificially relocated in 1958 the cuspate feature has continued to erode. Ongoing gravel management takes place upstream in the Tauranga Taupo by SH1, this may be removing material that would have otherwise made it to the shoreline.

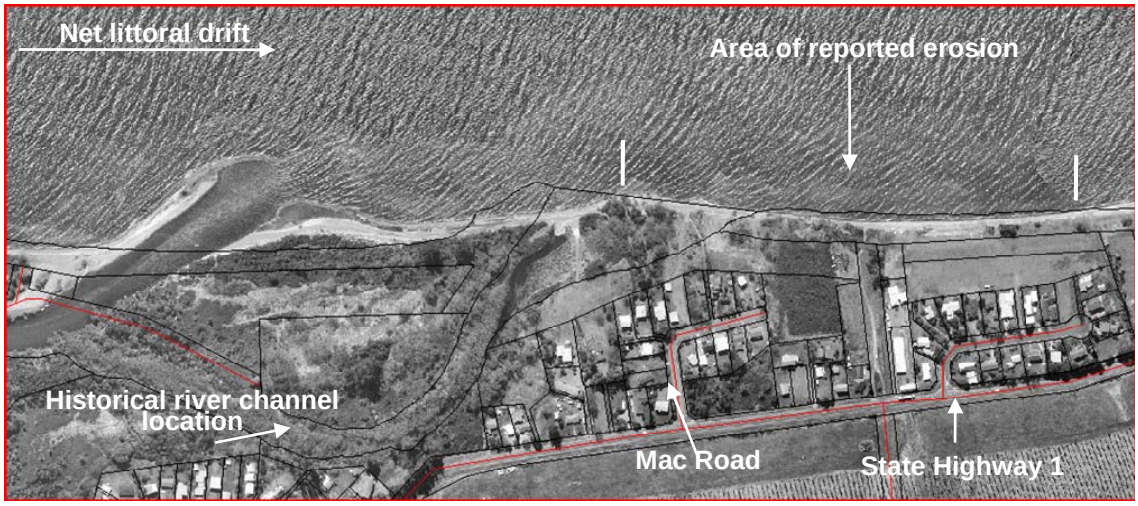


Photo 14. Te Rangiita, [1999]

The land use along the area of erosion is predominantly reserve (Te Rangitta Reserve), an unconstructed road reserve, and the former silted up mouth of the river. There are limited assets at immediate risk in this area, however some reserve area is being lost and a council toilet exists.

Beach profile monitoring has not previously been undertaken at Te Rangitta, but is recommended in future to better quantify the extent of natural fluctuations and any continuing erosion following the removal of the river mouth. Investigation of vegetation types and the response to erosion may be appropriate in this location, as recent erosion has occurred in the reserve areas with short grass only. Continued monitoring is recommended for this location prior to undertaking any further action.

a. Summary of Recommendations

Based on our current understanding, prior to undertaking any further action to implement management options the following are recommended:

1. Instigate beach profile monitoring,
2. Consider soft options such as re-vegetation along grass reserve areas.

Photo 15. Te Rangiita shoreline, January 2007

6.3.9 Hatepe

Near Hatepe at the Hinemaiaia river mouth, the shoreline appears to be stable with no scarps along the foreshore. A stormwater pipe headwall has been in the same location for 20-30 years. Even though over that period of time sediment outputs have been reduced by the hydroscheme, there is no evidence at present of erosion in this area. Sediment available in the nearshore may be assisting offsetting losses from the river. It is understood that the river mouth can change direction depending on the prevailing wind and stream conditions, however there is a net northerly littoral drift for the compartment. Some erosion has been reported to the south of the river mouth, but it is largely attributed to the natural variability of the river.

Previous shoreline monitoring has not been undertaken in Hatepe, and this is recommended prior to any implementation of erosion options. Any river training works to manage the location of the mouth of the river should also consider the potential for any impacts on sediment supplies to the beach system.

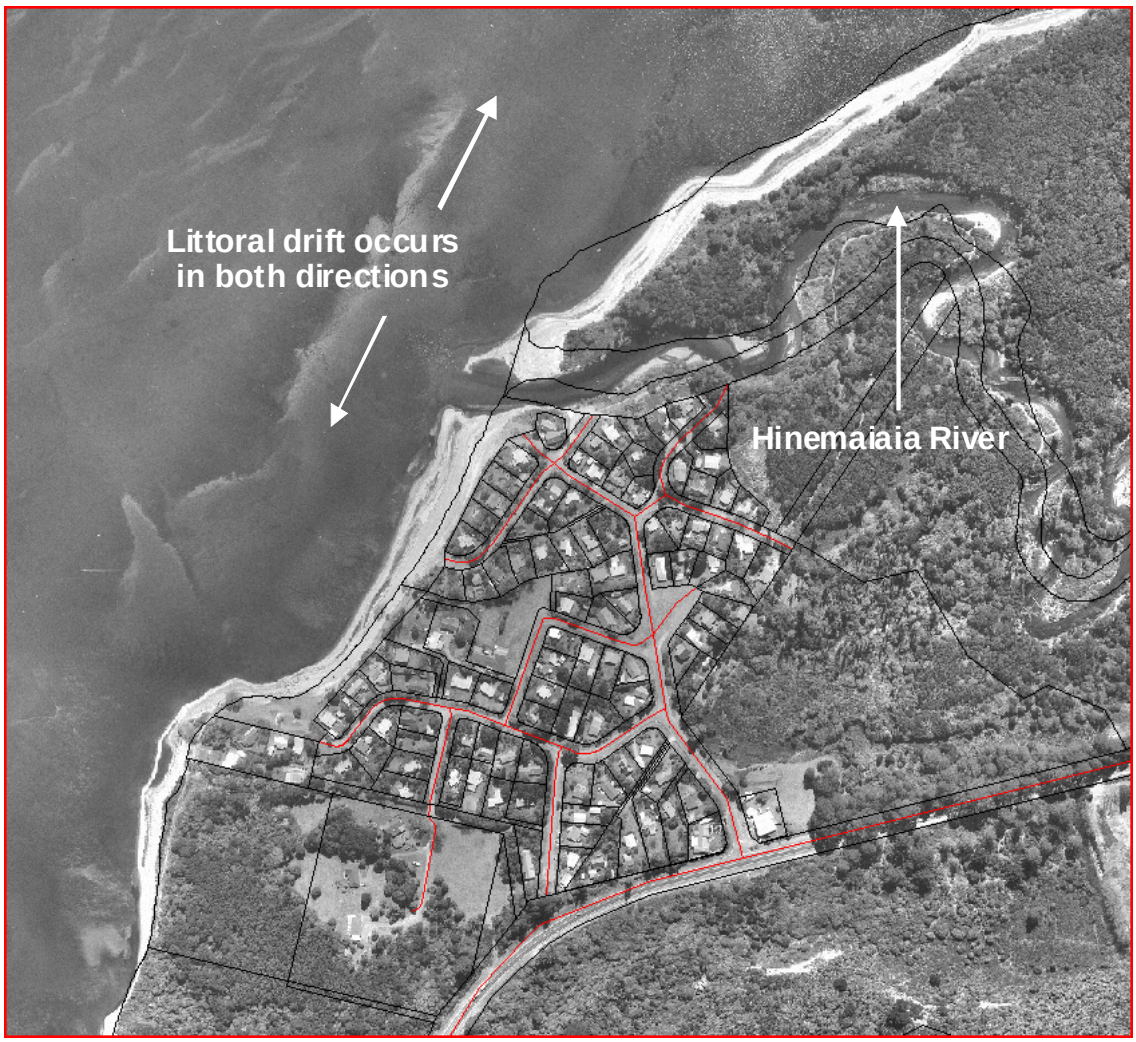


Photo 16. Hatepe, [1999]

a. Summary of Recommendations

Based on our current understanding, if action is considered necessary, the recommended option is:

1. Undertake shoreline monitoring prior to actioning any particular options.
2. If erosion is found to be unacceptable carryout a site specific study to determine the most appropriate response.

Photo 16. Hatepe Beach looking north, April 2007

6.4 Estimated Costs for Management Options

This section provides estimate costs associated with a number of common hard and soft structural options for erosion management. Costs are primarily based on similar work carried out in the Taupo District. This section applies these estimated costs (on a pro rata basis) to some high priority erosion areas to provide examples for consideration. Further site investigation of each of the high priority areas, along with taking into consideration the community's views on the recommended option, would be required before the true costs of a management option can be established. It is also noted that this section does not consider the ongoing management and maintenance of erosion management options.

6.4.1 Rock Protection

Rock protection works have been used for decades as a means of protecting shorelines (particularly on the coast) against wave-induced erosion. For the Taupo District, there has been a significant decrease in rock supply and an increase in carting costs in recent years. This has largely been due to limited supply, increasing distance between source and destination, higher fuel prices and lack of competition. Recent unit rocks, including placement within the lake are in of $250 per cubic metre. Similar river protection works are in the order of $1,300 per metre as an all up cost.

6.4.2 Beach Replenishment

Beach replenishment involves the placement of suitably sized sediment directly onto a beach as a means of providing an instant supply of sediment to re-stabilise the beach profile. Without headlands or confinement structures, it usually takes multiple placements to be effective. As with rock supply, this option relies on readily available sediment, preferably in close proximity to the affected area to reduce transportation costs.

Based on recent worked examples, the likely costs of carrying out beach replenishment in the Lake Taupo foreshore environment are outlined in the following table. Upfront costs plus $65 per cubic metre for a medium scale project costs are likely to be $170,000 in total.

Task	Rate ($)	Quantity	Total ($)	Comment/assumptions
Project Management	5,000	2	10,000	
Investigation, design, consents and consultation	100,000	1	100,000	Assuming consent application does not go to Environment Court.
Establishment of earthworks Equipment	35,000	1	35,000	Includes site preparation, barge and digger
Drawings & modelling	10,000	1	10,000	
Site access	6,000	1	6,000	
Supply and placement of sediment	65/ m^3	Site specific	N/A	Carting and placement of sediment.
Reinstatement of site	5,000	1	5,000	

6.4.3 Offshore Breakwater (Reef)

Offshore reefs are used in some localities to promote the onshore build up of sediment to help create a larger area of beach by reducing the wave energy. Reefs are usually

constructed from large angular rocks which are placed in the near-shore zone via a barge/digger operation. Depending on the physical environment, the reefs can either be above or below the water surface. Reefs are generally designed not to impede the natural passage of sediment along the beach, which is an important aspect for down-drift areas. Based on a recent work example, the likely costs of carrying out an offshore reef project in the Lake Taupo foreshore are given in the table below and represent an all up cost of $260,000 for a 20 metre long reef.

Task	Rate ($)	Quantity	Total ($)	Comment/assumptions
Project Management	5,000	2	10,000	
Investigation, design, consents and consultation	100,000	1	100,000	Assuming consent application does not go to Environment Court.
Geo-textile	12/ m^2	370 m^2	5,000	Assumes a 20m linear reef complex
Rock armour	260/ m^3	485 m^3	130,000	
Barge	3,000	5 days	15,000	

6.4.4 Estimated Costs for Erosion Management Options at High Priority Sites

The table below presents the estimated costs, using the information above, for erosion management works at a two of high priority erosion sites. Reported costs are initial capital works only and do not include/allow for ongoing maintenance costs.

Site	Assumptions*	Physical Works Option		Cost ($)
Kuratau	Length of shoreline affected is 300m (high risk area only) Offshore reef length required is 40m Good access to site Resource consents required.	Rock protection	300 x $1,300	390,000
		Beach replenishment	$65/$m^3$ x 5,000 m^3 plus $170,000	500,000
		Offshore reef	2 x $260,000	520,000
		Re-vegetation	4,000 plants	30,000
Whareroa	Length of shoreline affected is 100m (high risk area only) Offshore reef length required is 20m Good access to site Resource consents required	Rock protection	100 x $1,300	130,000
		Beach replenishment	$65/$m^3$ x 2,000 m^3 plus $90,000	$220,000
		Offshore reef	1 x $260,000	260,000
		Re-vegetation	2,000 plants	15,000

** Source: Beca Stage 3 Report*

This table provides indicative estimates only. A more in depth site specific investigation is required to better understand which management option or combination of options would suit the location given a better understanding of the erosion problem and the community's views.

7 Action Plan

The following provides a summary of those actions recommended to assist Taupo District Council and Waikato Regional Council (Environment Waikato) to further develop the Lake Taupo Foreshore Risk Management Strategy.

- Consultation
  - To further develop the framework for a strategy by taking the preferred options presented in this report to iwi and the community for comment and discussion, as well as increase awareness and understanding of the wider Lake Taupo Risk Management Strategy at a local and regional level. The purpose of this is to provide a local context and establish community values.
- Feasibility Study
  - Following identification of the most preferred option or combination of options following community consultation, the options will require further feasibility assessments (including field investigations and design) to make sure the options or combination of options is viable and practical for implementation at each priority location. Further investigative or pre-feasibility work into preferred options and preliminary design for engineered options will enable confirmation of costs and impacts.
- Funding Policies
  - Investigations to identify the allocation of funding and where the potential costs should fall for selected options.
- Implementation Plan
  - Develop an implementation plan for the preferred options and include timeframes against actions. Long term planning or land use strategies require the longest timeframes for implementation. Implementation may need to be achieved through changes to regional and district plans (i.e. specific plan changes relating to zones for erosion hazard areas and policies to avoid or control development rules to prohibit development and/or regulation through subdivision rules and built on existing district plan provisions for shoreline erosion through use of setbacks).
- Review Regional and District Plan rules regarding the status and conditions for being able to place structures in the foreshore.
  - Explore methods for requiring appropriate design guidelines and good practice to be followed for structures.
- Include the assessment of potential effects on sediment supplies to the beach systems when undertaking catchment management and erosion control.
- Review practices for maintaining boat ramps and removal of sediment to ensure it is not lost from the system.
- Review vegetation removal policies to ensure an increase in erosion risk doesn't occur.

7.1 Monitoring Strategy

The following is a summary of the Lake Taupo Erosion Study - Draft Monitoring Programme (included in Appendix C).

The Stage 3 Erosion Study identified that one of the main factors limiting the ability to better understand the erosion processes and contributing factors was the lack of background monitoring data. The monitoring strategy seeks to remedy this limitation.

The following types of monitoring are often carried out to provide information relating to erosion issues:

- Beach Profiles
- Near-shore Bathymetry Surveys
- Visual Inspection
- Asset Surveys
- Vegetation Surveys
- Wave Monitoring and modelling
- Lake Level Monitoring
- Wind Monitoring
- Tectonic Movement
- Sediment Budgets

A schedule of monitoring locations has been identified. This monitoring focuses on baseline monitoring with the purpose of developing a long-term data set which will assist in better understanding the erosion processes and contributing factors. A summary plan showing the monitoring locations is included.

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Glossary

Accretion	Accumulation of sediment which builds up land. May be the result of either natural (e.g. by the action of wind / littoral drift) or artificial (e.g. by the action of humans) activity.
Bathymetry	The measurement of water depth at various places in a body of water i.e. underwater topography.
Beach nourishment	The process of replenishing a beach, where sediment has been lost to littoral drift, by artificial means through moving material (usually sand) from other sources to the affected area.
Dynamic Equilibrium	Lake beaches are dynamic and adjust their form in response to changes in lake level and wave environment. The net result of sediment movement can be erosion or accretion, or a quasi-stable shore, where the beach responds to changes in the wave environment by changing shape or form but without a long-term change in beach position. Dynamic equilibrium is a long-term conditions where erosion or accretion is in balance and the net position of the lake shoreline, despite minor fluctuations, remains stable.
Embayment	An indentation in a shoreline forming a bay.
Erosion	A general term for the removal of material from exposed surfaces by the action of natural processes.
Fluvial	Of, relating to, or inhabiting a river or stream. Produced by the action of a river or stream.
Foreshore	Any land covered and uncovered by the ebb and flow of the lake.
Groyne	A structure generally perpendicular to the shore line built to control the long shore movement of beach material.
Hazard	The interaction of lake and shoreline processes with human use, property or infrastructure, the action of which adversely affects or may adversely affect human life, property or assets.

Incident wave	A wave travelling through or moving landward.
LiDAR	Light Detection and Ranging is a remote sensing system used to collect topographic data. It can be used to document topographic changes along shorelines.
Lifeline Services	Critical services on which a community relies, including water, electricity, gas, sewage and transportation.
Littoral Drift	The movement of beach material in the littoral zone by waves and currents. Includes movement parallel (long shore transport) and perpendicular (onshore-offshore transport) to the coast.
Long shore transport	Transport of waterborne sediments in a direction approximately parallel to the coast by long shore currents.
Natural Hazard	Natural hazard means any atmospheric or earth or water related occurrence (including earthquake, tsunami, erosion, volcanic and geothermal activity, landslip, subsidence, sedimentation, wind, drought, fire, or flooding) the action of which adversely affects or may adversely affect human life, property, or other aspects of the environment. *(RMA definition)*
Near Shore	Section of a beach profile which is between lakeward of the breakpoint of the waves and the landward limit of wave action over which sediment is transferred. Comprises the breaking zone, surf zone and swash zone.
Refraction	The process by which the direction of a wave moving in shallow water at an angle to the bottom contours is changed. The part of the wave moving shoreward in shallower water travels more slowly than that portion in deeper water, causing the wave to turn or bend to become parallel to the contours
Revetments	Structures placed on banks or cliffs in such a way as to absorb the energy of incoming water.
Risk	Risk is a measure of vulnerability of a particular area to natural hazard event of a given size and magnitude. Evaluation of risk is based on records of past events. Risk is expressed in terms of

	likelihood (chance or probability) of an event of given size occurring. Risk is also used to measure the severity of an impact on something. i.e. no current development but some slow erosion = low risk, lots of development presently and fast erosion = high risk.
Real Time Kinetic	RTK is a process where GPS signal corrections are transmitted in real time from a reference receiver at a known location to one or more remote rover receivers.
Sediment Budget	An estimate of the various inputs, losses and internal transfers of sediment that occur within a beach or nearshore compartment or system. A net loss to the sediment budget occurs when outputs exceed inputs. A net gain to the sediment budget occurs when inputs exceed outputs.
Soft Shorelines	Shorelines comprised of mobile sediments (from sand to coarse gravel). Soft shorelines are usually referred to in the coastal literature as beaches.

Appendix A

Site Specific Qualitative Analysis Summaries

1 Kuratau

Impact Category	Option Assessment – Key notes
Amenity Values	Under the status quo, the lakefront beach area will experience continued retreat. This is likely to adversely impact recreational values at Kuratau over time. Hard structural options will potentially reduce visual amenity and public amenity in terms of lake shoreline users ability to use the lake and shore. Beach replenishment and revegetation is a more natural remediation response and will therefore have a more positive impact on amenity values through enhancement of visual amenity and provision of a more useable lake shoreline.
Public Access and Public Safety	There is currently a grassed reserve along the lakefront beach margin, further retreat will adversely impact on public access under the status quo. Hard structural options depending on design can potentially further reduce public access to the shore, and possibly necessitating access structures (walkways and steps) to avoid clambering over groynes and seawalls. Breakwaters do not impact on public access. Soft options like beach nourishment are likely to have a moderate positive impact through the maintenance of areas for public access.
Natural Character	The hard structural options can have a high negative impact on natural character. Groynes and seawalls can be highly visible and can potentially reduce natural character, particularly along lesser developed parts of Kuratau. Beach replenishment and revegetation generally maintains and potentially enhances natural character, although the degree in which varies depending on level of modification to the natural state of lake shore (e.g. use of exotic species for revegetation option may enhance natural character to a lesser extent than with indigenous plantings).
Lake Processes	Beach replenishment could be seen as replacing the reduction of sediment in the system thereby maintaining previous lake processes. There maybe some negative effects, however, from the source of sediment for replenishment. Revegetation tends to be more successful in areas of low level erosion or where loss of foreshore is due to wind erosion and the sediment can be retained in the backshore. Hard structural options have the potential to negatively impact natural lake processes locally, however to a lesser extent for lake wide processes. Seawalls are better described as land protection structures and eventually act as if the lakeshore were a cliff as most of the sediment would be lost if erosion persisted. Groynes and breakwaters interfere with lake wave patterns, and induce localised effects such as sediment scour around these structures. Groynes tend to perform better in areas with longshore drift which may well suit this site.
Reversibility of Option	Hard structural options are graded as high negative, as these options cannot be reversed without significant adverse financial costs. For instance, a seawall is not easily removed as it will involve disturbance associated with construction works, cost of removal of the structure and rehabilitation of the lakeshore. Also expected that there will be large amounts of public resistance once a hard structure is in place due to its perceived input in the protection of public and private assets.

Structure, Construction, Works & Maintenance costs	There are no capital works costs associated with Options 1 and 2. Costs of construction and ongoing maintenance are high for beach replenishment, and hard structural options. Off shore break waters could have a high cost. The status quo has high negative impact on Council, due to the community placing increasing pressure on Council, the on-going commitment of resources and liability issues to property at risk. All hard structures require on-going maintenance and commitment by TDC, particularly beach replenishment, unless containment structures are used.
Private Property Considerations	There are no relocation costs or property purchases associated with the status quo option. The most significant capital costs are associated with the remedial planning option, with significant cost with relocation and/or purchase of property (approx 5 – 10 properties). Negative impacts on private capital with the remedial planning option. Hard structural options may increase private capital to those houses directly at risk through the protection the structure offers. However those properties not at risk may be disadvantaged due to the loss of amenity.
Protection of Public Infrastructure	The existing lake shore reserve area currently provides some form of protection to the land immediately behind it and to Council roads etc. Under a sea wall option, the public reserve may experience some localised erosion associated with end effects of a sea wall structure. However, the road and reserve immediately behind a seawall will be protected from erosion.

2 Waitahanui

Impact Category	Option Assessment – Key notes
Amenity Values	Under the status quo, fluctuations of erosion cycles around the beachfront area and spit feature will continue, and secondary erosion problems around existing structures will continue. This is likely to adversely impact recreational values at Waitahanui over time. A mixture of hard structural options constructed by private landowners will potentially reduce visual amenity and public amenity in terms of lake shoreline users ability to use the lake and shore. Beach replenishment and revegetation would be a more natural remediation response and will therefore have a more positive impact on amenity values through enhancement of visual amenity and provision of a more useable lake shoreline.
Public Access and Safety	Further retreat will adversely impact on public access under the status quo as more protection structures would be constructed to halt continued retreat. Hard structural options depending on design can potentially further reduce public access to the shore, and possibly necessitating access structures (walkways and steps) to avoid clambering over groynes and seawalls. Breakwaters do not impact on public access. Soft options like beach nourishment are likely to have a moderate positive impact through the maintenance of areas for public access. Remedial planning although a longer term option would be the most positive option in terms of providing for public access, this would involve major relocation of private property to the other side of the State Highway.
Natural Character	The hard structural options can have a moderately negative impact on natural character, as the existing natural character has already been adversely affected by the existing hard structures at Waitahanu. Beach replenishment and revegetation generally maintains and potentially enhances natural character, although the degree in which varies depending on level of modification to the natural state of lake shore (e.g. use of exotic species for revegetation option may enhance natural character to a lesser extent than with indigenous plantings). The remedial planning option would have the most positive impact in terms of enhancing natural character at Waitahanui.
Lake Processes	Beach replenishment would have a minor positive effect and could be seen as replacing the reduction of sediment in the system thereby maintaining previous lake processes. Hard structural options have the potential to negatively impact natural lake processes locally, however to a lesser extent for lake wide processes. Seawalls are better described as land protection structures and eventually act as if the lakeshore were a cliff as most of the sediment would be lost if erosion persisted. Seawalls at Waitahanui have a moderate negative impact in terms of lake wide processes as they act to 'lock' sediment in behind them. Groynes and breakwaters interfere with lake wave patterns, and induce localised effects such as sediment scour around these structures.

Impact Category	Option Assessment – Key notes
Reversibility of Option	Hard structural options are graded as moderate - high negative, as these options cannot be reversed without adverse financial costs. For instance, a seawall is not easily removed as it will involve disturbance associated with construction works, cost of removal of the structure and rehabilitation of the lakeshore. Also expected that there will be large amounts of public resistance once a hard structure is in place due to its perceived input in the protection of public and private assets. Remedial planning is also an option that is not easily reversed, as relocated private property would involve significant cost and potentially public resistance, and therefore would not be reversed in the long term once the decision to undertake this option had been made by Council.
Structure, Construction, Works & Maintenance costs	There are no capital works costs associated with Options 1 and 2. Costs of construction and ongoing maintenance are high for beach replenishment, and hard structural options. Off shore break waters could have a high cost. Council constructed hard structures would require on-going maintenance and commitment by TDC, and similarly for soft options such as beach replenishment.
Private Property Considerations	There are no relocation costs or property purchases associated with the status quo option. The most significant capital costs are associated with the remedial planning option, with significant cost with relocation and/or purchase of property. Negative impacts on private capital with the remedial planning option.
Protection of Public Infrastructure	As there is no existing lake shore reserve area , there is no significant public infrastructure that requires protection. Option 3 and 4 would provide moderate positive impact in terms of protection of the road adjacent to the lakeshore.

3 Whareroa

Impact Category	Option Assessment – Key notes
Amenity Values	Under the status quo, the lakefront beach area will experience periodic retreat. This is likely to have a minor adverse impact recreational values at Whareroa over time. Currently only a few hard structures, therefore structural options will potentially reduce visual amenity and public amenity in terms of lake shoreline users ability to use the lake and shore. Beach replenishment and revegetation is a more natural remediation response and will therefore have a more positive impact on amenity values through enhancement of visual amenity and provision of a more useable lake shoreline.
Public Access	There is currently a grassed reserve along the lakefront beach margin, further retreat will reduce some of the public access space, but not significantly to the total area. Hard structural options depending on design can potentially further reduce public access to the shore, and possibly necessitating access structures (walkways and steps) to avoid clambering over groynes and seawalls Soft options like beach nourishment are likely to have a neutral impact through the maintenance of areas for public access as public access exists already along the beach front reserve.
Natural Character	The character of the area is a modified reserve environment, and therefore not fully natural. The hard structural options can have a high negative impact on natural character, seawalls would have the highest negative impact. Groynes and seawalls can be highly visible and can potentially reduce natural character. Beach replenishment and revegetation generally maintains and potentially enhances natural character, although the degree in which varies depending on level of modification to the natural state of lake shore (e.g. use of exotic species for revegetation option may enhance natural character to a lesser extent than with indigenous plantings).
Lake Processes	As the area is largely undeveloped the best approach if possible is to keep it this way. The area of erosion in on a bulge/point and therefore the sediment movement could be sensitive to any groin structures. Beach replenishment could be seen as replacing the reduction of sediment in the system thereby maintaining previous lake processes. There may be some negative effects, however, from the source of sediment for replenishment. Revegetation tends to be more successful in areas of low level erosion or where loss of foreshore is due to wind erosion and the sediment can be retained in the backshore. This length of shoreline has been stripped of vegetation and replacing would likely assist in reducing the rate of erosion. Hard structural options have the potential to negatively impact natural lake processes locally, however to a lesser extent for lake wide processes. Seawalls are better described as land protection structures and eventually act as if the lakeshore were a cliff as most of the sediment would be lost if erosion persisted. Groynes and breakwaters interfere with lake wave patterns, and induce localised effects such as sediment scour around these structures. Groynes tend to perform better in areas with longshore drift which may well suit this site.

Impact Category	Option Assessment – Key notes
Reversibility of Option	Hard structural options are graded as high negative, as these options cannot be reversed without significant adverse financial costs. For instance, a seawall is not easily removed as it will involve disturbance associated with construction works, cost of removal of the structure and rehabilitation of the lakeshore. Also expected that there will be large amounts of public resistance once a hard structure is in place due to its perceived input in the protection of public and private assets. Beach replenishment and revegetation are the highest positive impact options in terms of reversibility. Land use and buffers and remedial planning are not applicable, as no further remedial planning or set backs are necessary.
Structure, Construction, Works & Maintenance costs	There are no capital works costs associated with Options 1 and 2. Costs of construction and ongoing maintenance are high for beach replenishment, and hard structural options. Off shore break waters could have a high cost. All hard structures require on-going maintenance and commitment by TDC, particularly beach replenishment.
Private Property Considerations	There are no relocation costs or property purchases associated with the various options. In the case of additional development along Whareroa, use of setbacks could be beneficial in terms of ensuring new property is not at risk in the future.
Protection of Public Infrastructure	The reserve, boat ramp and trees are the main public infrastructure at this location. A philosophy of whether the reserve should be acknowledged as a buffer or protected in its own rights needs to be considered.

4 Kinloch (Whangamata Bay)

Impact Category	Option Assessment – Key notes
Amenity Values	Hard structural options will potentially reduce visual amenity and public amenity in terms of lake shoreline users ability to use the lake and shore particularly as there are few structures at the moment, and its high amenity value. Beach replenishment and revegetation is a more natural remediation response and will therefore have a more positive impact on amenity values through enhancement of visual amenity and provision of a more useable lake shoreline. The covering/burying of the existing wall would be a key advantage.
Public Access	There is currently a grassed reserve along the lakefront beach margin, further retreat would adversely impact on public access under the status quo, although currently there is plenty of space. Hard structural options depending on design can potentially further reduce public access to the shore, and possibly necessitating access structures (walkways and steps) to avoid clambering over groynes and seawalls. Breakwaters do not impact on public access. Soft options like beach nourishment are likely to have a moderate positive impact through the maintenance of areas for public access and return it back to its pre erosion state.
Natural Character	The hard structural options can have a minor negative impact on natural character. It should be acknowledged that the current state is still one of a developed reserve, rather than natural bush, but still of high value. Groynes and seawalls can be highly visible and can potentially reduce natural character, particularly along lesser developed parts of Kinloch. Beach replenishment and revegetation generally maintains and potentially enhances natural character, although the degree in which varies depending on level of modification to the natural state of lake shore (e.g. use of exotic species for revegetation option may enhance natural character to a lesser extent than with indigenous plantings).
Lake Processes	Beach replenishment could be seen as replacing the reduction of sediment in the system thereby maintaining the supply of sediment that is getting bypassed or trapped behind the groin. There maybe some negative effects, however, from the source of sediment for replenishment. Hard structural options have the potential to negatively impact natural lake processes locally, however to a lesser extent for lake wide processes. Groynes and breakwaters interfere with lake wave patterns, and induce localised effects such as sediment scour around these structures.
Reversibility of Option	Hard structural options are graded as high negative, as these options cannot be reversed without significant adverse financial costs. For instance, a seawall is not easily removed as it will involve disturbance associated with construction works, cost of removal of the structure and rehabilitation of the lakeshore. Also expected that there will be large amounts of public resistance once a hard structure is in place due to its perceived input in the protection of public and private assets. Beach replenishment is the most easily reversible option. Option 2 – Land use buffers and remedial planning is not an appropriate/necessary option as private property is located behind the existing reserve area and sufficient setback exists for protection.
Structure, Construction, Works & Maintenance costs	There are no capital works costs associated with Options 1 and 2. Costs of construction and ongoing maintenance are high for beach replenishment, and revegetation. As the wall is already in place, this potentially reduces the cost of a buried wall option, provided it has been appropriately installed.

Impact Category	Option Assessment – Key notes
Private Property Considerations	There are no relocation costs or property purchases associated with the status quo option. Private property not directly or adversely affected by beach replenishment, revegetation options (neutral impacts).
Protection of Public Infrastructure	The existing lake shore reserve area currently provides some form of protection to the land immediately behind it and to Council roads / houses etc. Therefore only minor to moderate positive impacts from the hard options in terms of protection of public infrastructure.

5 Motutere

Impact Category	Option Assessment – Key notes
Amenity Values	Under the status quo, loss of the lakefront beach area will experience periodic retreat in storm events. This is likely to adversely impact recreational values at Motutere in the short term until the lake foreshore recovers. Hard structural options will potentially reduce visual amenity and public amenity in terms of lake shoreline users ability to use the lake and shore. Beach replenishment and revegetation is a more natural remediation response and will therefore have a more positive impact on amenity values through enhancement of visual amenity and provision of a more useable lake shoreline.
Public Access	There is currently a grassed reserve along the lakefront beach, and under the status quo there is unlikely to be a discernable impact on public access and safety. Hard structural options depending on design can potentially further reduce public access to the shore, and possibly necessitating access structures (walkways and steps) to avoid clambering over groynes and seawalls. Breakwaters do not impact on public access. Soft options like beach nourishment are likely to have a moderate positive impact through the maintenance of areas for public access.
Natural Character	The hard structural options can have a high negative impact on natural character. Groynes and seawalls can be highly visible and can potentially reduce natural character, particularly along lesser developed parts of Motutere i.e. around the eastern portion of the point, near the pa site. Beach replenishment and revegetation generally maintains and potentially enhances natural character, although the degree in which this varies depending on level of modification to the natural state of lake shore (e.g. use of exotic species for revegetation option may enhance natural character to a lesser extent than with indigenous plantings).
Lake Processes	Beach replenishment could be seen as replacing the reduction of sediment in the system thereby maintaining previous lake processes. There maybe some negative effects, however, from the source of sediment for replenishment. Hard structural options have the potential to negatively impact natural lake processes locally, however to a lesser extent for lake wide processes. Seawalls are better described as land protection structures and eventually act as if the lakeshore were a cliff as most of the sediment would be lost if erosion persisted. Groynes and breakwaters interfere with lake wave patterns, and induce localised effects such as sediment scour around these structures. However, overall hard structural options would have a high positive impact in terms of local effects on maintaining/retaining sediment in the shore sediment compartment.
Reversibility of Option	Hard structural options are graded as high negative, as these options cannot be reversed without significant adverse financial costs. For instance, a seawall is not easily removed as it will involve disturbance associated with construction works, cost of removal of the structure and rehabilitation of the lakeshore. Also expected that there will be large amounts of public resistance once a hard structure is in place due to its perceived input in the protection of public and private assets. Soft options are more easily reversible, with the least negative impact.

Impact Category	Option Assessment – Key notes
Structure, Construction, Works & Maintenance costs	Costs of construction and ongoing maintenance are high for beach replenishment, and hard structural options. The status quo also has moderate negative impact on Council, due to the community placing increasing pressure on Council, the on-going commitment of resources and liability issues to property at risk. All hard structures require on-going maintenance and commitment by TDC, particularly beach replenishment, unless containment structures are used.
Private Property Considerations	There are no relocation costs or property purchases associated with the status quo option, or with options 3 and 4. The most significant capital costs are associated with the remedial planning option, with significant cost with relocation and/or purchase of property, to relocate back further southwards of the point and away from the pa site.
Protection of Public Infrastructure	The existing lake shore reserve area currently provides some form of protection to the land immediately behind it and to Council roads etc. Under a sea wall option, the public reserve may experience some localised erosion associated with end effects of a sea wall structure. However, the road and campsite/reserve immediately behind a seawall will be protected from erosion in the future, a more positive impact than beach replenishment or revegetation options.

Appendix B

Legislative Context

Legislative Context

1.1.1 Resource Management Act 1991

Section 5 of the RMA sets out the purpose of the Act, which is "the sustainable management of natural and physical resources". "Sustainable management" is defined as:

> *managing the use, development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic and cultural well-being and for their health and safety while*
>
> *a. sustaining the potential of natural and physical resources to meet the reasonably foreseeable needs of future generations; and*
>
> *b. safeguarding the life-supporting capacity of air, water, soil and ecosystems; and*
>
> *c. avoiding, remedying or mitigating any adverse effects of activities.*

Further guidance and principles that could relate to lake-level management are provided in Sections 6–8 of the RMA, and include:

- Section 6(a): the preservation of the natural character of the coastal environment (including the coastal marine area), wetlands, and lakes and rivers and their margins, and the protection of them from inappropriate subdivision, use and development
- Section 6(b): the protection of outstanding natural features and landscapes from inappropriate subdivision, use and development
- Section 6(c): the protection of areas of significant indigenous vegetation and significant habitat of indigenous fauna
- Section 6(d): the maintenance and enhancement of public access to and along the coastal marine area, lakes and rivers
- Section 7(b): the efficient use and development of natural and physical resources
- Section 7(c): the maintenance and enhancement of amenity values
- Section 7(d): persons exercising statutory requirements under the RMA must have regard to the intrinsic values of ecosystems.
- Section 7(f): the maintenance and enhancement of the quality of the environment

While the RMA is the primary statute for the management of the natural and physical resources, several other statutes may also affect activities occurring in the lake foreshore area. It may be necessary to obtain approvals for any works within the lake shore foreshore area pursuant to other legislation, such as:

- Building Act 2004;
- Conservation Act 1987;
- Historic Places Act 1993;
- Local Government Act 1974; and

- Reserves Act 1977.

1.1.2 Waikato Regional Policy Statement

The Regional Policy Statement (RPS) sets out issues, objectives and policies in relation to the Waikato Region, many of which are relevant to the management of natural hazards. Natural hazards are identified as a significant resource management issue for the Waikato Region. Despite this, foreshore erosion is not specifically identified in the 'Natural Hazard' section as a natural hazard of issue that occurs within the Waikato Region.

Section 62(1)(i) of the RMA sets out the specific contents of a regional policy statement relating to the avoidance and mitigation of natural hazards. The RPS states that:

"Community awareness of the causes and effects of natural hazards and the precautions that should be taken during natural hazard emergencies is generally low. If this low level of awareness is not addressed, the effects of natural hazards could be exacerbated".

Minimising the adverse effects associated with natural hazards, and increasing the resilience of the community and public awareness of the causes and potential effects of natural hazards events, is also an objective for the Waikato Region. Implementation methods of relevance to this study include:

1. *Through regional plans, district plans, civil defence plans and hazard specific mitigation plans, identify (among other factors) areas of risk and natural hazard management options.*
2. *Liaise with operators of major dams to ensure integrated management of flood storage within hydro lakes.*
3. *Establish, maintain and improve the Region's hazard warning system.*
4. *Advocate through environmental education and regional plans the revegetation of severely eroded areas.*
5. *Maintain the existing flood control, land drainage and catchment schemes.*

The Lake Taupo erosion study is one method that identifies areas of potential risk (lakeshore erosion) and associated natural hazard management options. In addition, the RPS seeks to ensure new subdivision and developments are designed to avoid or mitigate the adverse effects of natural hazards. Other implementation methods being undertaken by EW include assisting local authorities to compile natural hazard registers. The RPS also seeks to raise public awareness of the causes and effects of such events and ensure that the community are prepared for civil defence emergencies. Environmental education is used to raise the level of community awareness of the risks associated with natural hazard events, and advocacy for the adoption of land use practices that avoid or mitigate the adverse effects of natural hazard events.

1.1.3 Waikato Regional Plan

The Waikato Regional Plan is the formal mechanism for managing the Regional Council's statutory responsibilities relating to the effects of activities upon air, land water and the coast. It identifies those resource management issues of relevance to the region and from these outlines objectives, policies, and rules as well as implementation methods

and anticipated environmental results. A number of issues are identified in the Regional Plan that relate to natural hazards. Relevant to this study is the River and Lake Bed Module which includes objectives, policies, rule and/or other methods regarding the effects of structures within the lake bed and associated bed disturbance.

In more detail the Regional Plan identifies that structures and activities can adversely affect bed and bank stability. The plan aims to manage the adverse effects of structures to achieve a net reduction in the adverse effects of destabilisation of river and lake beds (Section 4.2) and manage the adverse effects of activities to maintain bank and bed stability except where positive environmental benefits arise (Section 4.3) through resource consents, environmental education and advocacy for good practice.

The plan currently permits erosion control structures along 50 metres of every kilometre of shoreline. It allows as a Controlled activity erosion control structures along 200 metres of every kilometre of shoreline. Erosion control structures along more than 200 metres of one kilometre of shoreline are a Discretionary activity.

Notably, deposition of any substance in, on or under the bed and reclamation of the bed are provided for as a discretionary activity where they fail to meet permitted or controlled activity standards.

1.1.4 Hazard Risk Mitigation Plans

The RMA gives regional councils responsibility for preparing and implementing risk mitigation plans for natural hazards. EW has and continues to prepare and implement risk mitigation plans for natural hazards in the Waikato Region however no specific plans currently exist for erosion around Lake Taupo.

1.1.5 Taupo District Plan

The Operative Taupo District Plan 2007 (the District Plan) is the formal mechanism for managing the District Council's statutory responsibilities relating to the effects of land use, subdivision, and activities on the surface of lakes and rivers. It identifies those resource management issues of relevance to the district and from these outlines objectives, policies, and rules as well as implementation methods and anticipated environmental results. The following sections of the District Plan are relevant:

- Natural Hazards – 3l.2.1, 3l.2.2

Under the 'Natural Hazard' section it is highlighted that lakeshore erosion can occur as the level of a lake rises and falls. The objectives and policies under this section are aimed at managing/preventing developments within known erosion prone areas.

- Foreshore Protection – 4e.2.1

In the 'District Wide' rules, section 4e.2.1 addresses Foreshore Protection. Any building[1] within a Foreshore Protection Zone is assessed as a Discretionary activity and Council will base its assessment on its nature, scale, form and intent, its necessity and alternative locations, and its visual and aesthetic effects (as opposed to the effects associated with lakeshore erosion).

[1] Building excludes any structure constructed for erosion control purposes.

The District Plan Maps show the Foreshore Protection and Residential Foreshore Protection Zones, which runs adjacent to the foreshore for the complete circumference of the Lake. The Foreshore Protection Zone is defined under the District Plan as 20 metres as measured horizontally from the landward boundary of the bed (as defined in the RMA) of any identified lake and river, or for Lake Taupo measured from the Nui-a-Tia boundary, whichever is the further inland. The zones is applied to both publicly and privately owned land. The only gaps in the zone appear where a road reserve is located adjacent to the shoreline.

- Land Development – 3e.2.1

Under the 'Land Development' section of the Proposed District Plan, clause 3e.2.1 highlights the need to avoid, remedy or mitigate the effects of stormwater disposal upon the receiving environment and explains this has the potential to cause flooding or cause detrimental environmental impacts.

However it is also noted in several documents that the geology of the area is very permeable being of high pumice content and therefore lends itself to a high level of natural absorption. This also reduces sediment load as runoff is filtered through the pumice substrate.

- Other Sections

The sections for 'Residential', 'Town Centre Environment' and 'Industrial' zones contain specific stormwater controls requiring that all stormwater be disposed of on-site. The assessment criteria address potential upgrades of the stormwater system and the associated environmental effects.

1.1.6 Local Government Act 2002

The Local Government Act (LGA) 2002 provides the general framework, obligations, restrictions and powers under which local authorities operate. The key sections of the Act are:

- Section 14 - Gives local authorities the power to make by-laws, including for the purpose of promoting health and safety.
- Section 163 - Specifies powers in relation to removal of 'works' in breach of bylaws;
- Sections 93 – 97 - Provide for Long Term Council Community Plans that describe the activities of local authorities. This can include descriptions of local authority activities as well as providing for the management of natural hazards.

1.1.7 Waikato Regional LTCCP

Under the LGA, EW has prepared a Long Term Council Community Plan (the Regional LTCCP). The Regional LTCCP incorporates into one document all the work intended to implement other key planning documents, such as the Regional Plan and the Regional Coastal Plan.

The Regional LTCCP identifies groups of activities and objectives (which are supported by specific activities) that have relevance to the management of natural hazards. Specific activities identified by EW include:

a. Regional Hazards

The objective of the regional hazards group of activities for EW is to identify, plan for and reduce the risks from hazards and emergencies throughout the region. This includes developing policy for hazards, raising public awareness and putting in place site and hazard-specific reduction measures.

– Civil defence emergency management – preparing for, responding to and enabling recovery from civil defence emergencies.
– Emergency response – preparing for and responding to inland pollution, marine oil spill and river flooding emergencies.
– Flood warning – providing a river level and rainfall monitoring network to deliver timely, accurate and reliable flood management information.
– Dam safety – identifying dams for safety, and developing regional dam safety policy.

b. Land and Soil

– Reducing erosion and sediment – avoiding or reducing the effects of accelerated erosion, and reducing the adverse effects from destabilised river banks and lake beds.

1.1.8 Taupo District LTCCP 2006 - 2016

The LTCCP, under the section headed "Lakes and River Systems", explicitly recognises the Councils role with respect to protecting and managing the Lake Taupo lake system. While this includes a number of environmental initiatives, the plan notes specific activities in relation to flood and erosion investigations and control work (currently being developed as part of the Lake Taupo Foreshore Risk Management Strategy). This includes activities such as the construction of breakwaters, seawalls and beach replenishment where appropriate.

The LTCCP, for 2006 – 2007, notes the continuation of the development of the Lake Taupo Foreshore Risk Management Strategy along with the development of objectives, policies, rules and/or other methods in the District Plan to control the use of land for the avoidance or mitigation of natural hazards.

1.1.9 Ngati Tuwharetoa Environmental Iwi Management Plan

The Ngati Tuwharetoa Environmental Iwi Management Plan was produced by the Tuwharetoa Maori Trust Board (TMTB) in 2003 and is particularly relevant because the TMTB is the trustee and Ngati Tuwharetoa Iwi the owners of the Lake Taupo lake bed and its tributaries. The underlying theme of the plan is to strengthen the partnership between TMTB (owner/trustee) and EW who has management responsibility for the lake bed.

The plan identifies the unnatural control of lake levels, and land degradation and inundation as a result of artificial control of lake levels as issues but does not go into any further depth because the plan is designed in response to statutory procedures i.e. formulating regional and district plans and resource consents.

1.1.10 2020 Taupo-nui-a-Tia Action Plan

This integrated sustainable development strategy was developed in response to the need to improve ecosystem sustainability and to protect the health of Lake Taupo-nui-a-Tia. 2020 Taupo-nui-a-Tia was a three-year project initiated by the Lakes and Waterways Action Group, Ngati Tuwharetoa, TDC and EW, and the wider Taupo community.

Again, an underlying theme is the need to strengthen the partnership between the various bodies that have a statutory and customary management responsibility for the lake bed and its wider catchment. Briefly, the strategy and action plan identifies a range of community values which have relevance in the consideration of the LTES. In particular, the following values are noted as having relevance to the study:

- Foreshore reserves – provide public access to the lake and the ability to enjoy its margins, while also providing buffers in urban areas to protect public and private views;
- Outstanding scenery – the views and vistas of Lake Taupo-nui-a-Tia are enhanced by many foreshore reserves, areas of native and introduced vegetation and topography of the lake margins. The lack of human-made eyesores or prominent structures contributes to the scenic qualities of the area; and
- Recreational opportunities - Lake Taupo-nui-a-Tia and its margins are accessible to a wide variety of passive and active recreational activities.

Appendix C

Monitoring Strategy

Lake Taupo Erosion Study - Draft Monitoring Programme

1 Background

This monitoring schedule has been compiled for inclusion in the Lake Taupo Shoreline Erosion Management Strategy report.

The Stage 3 Erosion Study identified that one of the main factors limiting the ability to better understand the erosion processes and contributing factors was the lack of background monitoring data.

The most significant gap is in long-term repeatable monitoring of the shoreline profile and its movements. The collection of this data allows better understanding of long-term trends and cycles in the shoreline position. It will eventually allow differentiation between areas where the shoreline is experiencing short-term fluctuations and those experiencing long-term trends. These shoreline variations and longer-term trends are important inputs into planning for development controls such as set backs, as well as the appropriate design of structures in the foreshore.

The monitoring data should be consolidated annually and the programme revised to ensure the locations and frequency are capturing any observed changes. A more comprehensive review of the data, methodology and management should be undertaken every 5 years.

2 Monitoring Good Practice

Before any erosion monitoring program is set up, the overall objectives and goals should be clearly established to ensure funds are spent effectively. The goals of a monitoring program may include, but are not limited to:

- Estimation of a base line erosion rate;
- Collection of data in preparation for future studies;
- Improve understanding of retreat processes so as to manage retreat;
- Development of design parameters for structures in the shoreline;
- Identification of how a potential new erosion structure may perform;
- Identification of potential down shore impacts of a possible new structure; and
- Monitoring the effectiveness of existing structures.

It is essential that location specific rather than generic objectives be agreed upon before starting the implementation of a monitoring and review program. As an example, a

specific monitoring objective exercise may be to determine, following nourishment, whether the profile of the beach reverts to the pre-nourishment benchmark situation and if, so, how long it takes. Using such specific objectives, a monitoring program can be tailored to effectively meet the requirements, specifying such details as who will carryout the monitoring, what will be monitored, sampling frequency, methodology, accuracy, repeatability, presentation of data and triggers for further action.

3 Types of Monitoring

The following sections provide a brief description of types of monitoring that are often carried out to provide information relating to erosion issues, and its general relevance to Lake Taupo.

3.1 Beach Profiles

Profiles may comprise beach, backshore, dune or cliff profile surveys and may be taken by means of emery poles/tape, GPS, total station, RTK GPS etc.

The use of remotely sensed data such as LiDAR, may be more appropriate for tracking erosion of coastal cliffs, and can be used in conjunction with profile sections to get a better understanding over a wider area. Repeatable photos should also be taken in both direction for each profile to allow a visual comparison of the changes.

3.2 Near-shore Bathymetry Surveys

Bathymetric surveys should be done in conjunction with beach profile surveys to ascertain the rate of change below the water line. These surveys should be undertaken at the same times and in the same locations as profile surveys. Additionally, they can be used to extend over a wider area than the beach profiles and can assist in the estimation of volume changes along the shoreline or in front of river mouths. Bathymetry information is also important for understanding the extent of movement of sediment around structures or natural features such as headlands. The need for additional survey information at individual structures should be identified at the start of any site specific studies.

3.3 Visual Inspection

Visual inspections are wide ranging and include site visits, comparison of site photographs or comparison of ortho-rectified aerial photographs to compare the shoreline location. Existing aerial photographs for Lake Taupo have only allowed accuracy to approximately 10m. Future aerial photographs will allow better resolution/comparison than this, although the beach profiling and LiDAR data will provide more accurate information.

3.4 Asset Surveys

There are many existing erosion control structures around Lake Taupo. In order to maintain the effectiveness of these structures it is recommended that a periodic asset survey program be initiated so that any damage can be identified prior to failure. This can assist in reducing expensive reinstatement costs for failed structures. Such a program would involve regular inspection of each structure around the lake to develop a long-term condition record, which could be incorporated within GIS. Management of erosion control

assets should have similar protocols to asset management principals for other infrastructure assets such as services (e.g. water, sewer, roads etc).

3.5 Vegetation Surveys

A contributory factor towards shoreline erosion can be the removal of vegetation, so vegetation surveys could be conducted to determine any changes in vegetation coverage along the shoreline. These surveys may involve recording the location, proximity to the shoreline, type and size of vegetation. This monitoring could be done on a seasonal basis in priority areas and annually in other areas.

The objective of the vegetation surveys would be to assess the performance of different vegetation types, so any future re-vegetation program in the future may be better selected.

3.6 Wave Monitoring

Wave height can be monitored using wave buoys, which would need to be installed at appropriate locations in the lake. Installation of monitoring buoys may be expensive and are most useful if they are maintained for significant periods of time to allow a range of wind events to be monitored. Wave monitoring would be useful for verifying wave height calculations or calibrating a wave model for the lake.

3.7 Lake Level Monitoring

The level of Lake Taupo is monitored to the nearest millimetre on an hourly basis. The lake level is monitored relative to the Moturiki datum, and is recorded at the lake exit to the Waikato River in Taupo township.

Continued measurement of lake level is important for future comparisons of lake level regime.

3.8 Wind Monitoring

Wind speed and direction is continuously recorded at the Taupo aerodrome, with the information available from NIWA. No specific additional monitoring is required although it would be useful to have additional data from the south of the lake. There is currently a wind record at Turangi, but it is a short record.

3.9 Tectonic Movement

Taupo has a high level of tectonic movement and over the long term this has the potential to effect the level of erosion in some areas. Shorter term trends of tectonic subsidence vary in some locations around the Lake to the longer term trends e.g. Kinloch. Continued monitoring of subsidence and uplift should be carried out to better understand the potential effects on erosion risk, as well as other issues such as flooding. This work is currently already being undertaken by GNS, however reviews of this data should be undertaken on a regular basis.

3.10 Sediment Budgets

While not strictly monitoring, sediment budgets are an important tool to understand the shoreline processes and any potential constraints on shoreline management. Sediment

budgets can be a substantial exercise and should therefore be limited to priority areas, or areas with works planned in the future. If sediment replenishment is considered, a sediment budget should be considered essential.

Sediment budgets are best undertaken as part of any shoreline works. Therefore it may be appropriate to do budget analysis for one or two sites per year on an ongoing basis.

3.11 Sediment Analysis

The analysis of sediment size and grading will allow more accurate assessment of littoral transport rates and help define the requirement for any beach nourishment sources.

4 Prioritisation of Monitoring

Because erosion is occurring at multiple locations around Lake Taupo and due to the extensive length of shoreline, it is not possible to monitor all areas desired. It is therefore important that the monitoring work is prioritised to ensure adequate information is collected. Priority should be given to erosion risk areas that have existing development, are planned for development in the future or are adjacent to an essential service (such as a highway) and have a medium to high susceptibility to erosion.

5 Monitoring Schedule

Based on the findings from Stage 3 of the study and the above criteria a schedule of monitoring locations has been identified below. This monitoring focuses on baseline monitoring with the purpose of developing a long-term data set which will assist in better understanding the erosion processes and contributing factors.

5.1 Future Growth Areas

The Taupo District 2050 Growth Strategy sets out the future growth areas proposed for development within the Taupo District. It is important that a baseline of shoreline information is collected for these areas to enable appropriate land use controls to be implemented if relevant, and ensure that they take into consideration any shoreline movement and erosion risk.

The northern growth area is estimated to accommodate 80% of future growth in the district. The main areas in close proximity to the Lake shoreline include: Kinloch, Taupo Town, Acacia Bay/Nukuhau, and Waitahanui.

The South Eastern and South Western Growth areas account for and estimated 10% of growth over the coming 20 years. This will include western areas: north of Whareroa, west of Omori and within Kuratau. The area to the north of Whareroa appears to be closest to the shoreline. The South Eastern areas of Motuoapa South are well away from the shoreline. Additionally the proposed Southern Growth areas are set back away from the lake edge.

5.2 Monitoring Frequency

When setting the monitoring frequency it is important to understand the reason for the monitoring and what the short and longer term goals for the monitoring are. The

monitoring frequency is most relevant to the beach profile surveys, as these are attempting to build a longer term (10 years +) record of the movement of the shoreline. In many cases around the Lake there is no or only short term records. As a baseline of data is captured the frequency of monitoring can be reviewed and in some cases reduced to a level which will be maintained over the longer term.

For beach profile monitoring we recommend an initial frequency of at least yearly for all medium to high priority sites. Other sites should be monitored on a less frequent basis which may be between every 2-4 years.

Beach profile monitoring should also be designed to pick up any seasonal variations in the shoreline position, and therefore in priority areas bi-annual monitoring should also be undertaken. Depending on budget allowances this can be carried out on alternate years or at other frequencies. Monitoring following storm events should also be undertaken to allow better understanding of the effects of specific wind/wave/water level conditions, and the range of change that may occur during a single event or series of events.

Monitoring Summary Table – Frequency and Priorities

Location	Beach profiles *	Bathymetry	Sediment analysis	Wave height monitoring	Asset Surveys	Sediment Budgets
Kinloch	Annual		During two annual surveys		Annual	9
Kuratau	Annual/Bi-annual	2 yearly	During two annual surveys	1 year	Annual	1
Taupo Eastern Shore	Annual/Bi-annual		During two annual surveys		Annual	8
Taupo Western Shore	Annual		During two annual surveys	1 year	Annual	6
Te Rangiita	Annual				Annual	2
Hatepe	Annual	2 yearly	During two annual surveys		Annual	7
Waitahanui	Annual/Bi-annual		During two annual surveys	1 year	Annual	3
Five mile Bay	Annual				Annual	11
Motutere Bay	Annual/Bi-annual				Annual	4
Whareroa	Annual/Bi-annual		During two annual surveys		Annual	5
Whakaipo Bay	Annual				Annual	10

Priorities

1 High
2 Medium
3 Low

* Note : In addition to the planned annual / bi-annual beach profile surveys, surveys should also be undertaken following severe storm/erosion events (5-10 yr probability of exceedence), at priority 1 sites.

Lake Taupo Erosion Monitoring Schedule

Beach Profile Monitoring

Location	Frequency	Extent of survey	Priority	Surveys on Record
Kinloch	Annual	As per previous Cheal Consultants Survey	1	'04,'06
Kuratau	Annual/Bi-annual	From Kuratau River Mouth around point to 100m West of boat ramp.	1	'04,'06
Taupo Eastern Shore	Annual/Bi-annual	Acacia Bay to Waikato River	1	
Taupo Western Shore	Annual	Waikato to Wharewaka Point	2	'04,'06-limited
Te Rangiita	Annual	Either side of river mouth and to Mission Point, Waitetoko/Mission Bay	2	
Hatepe	Annual	Over extent of high risk area	2	
Waitahanui	Annual/Bi-annual	Over high risk section	1	'04,'06
Five mile Bay	Annual	1km intervals to Waitahanui, with 250m interval over developed sections	2	
Motutere Bay	Annual/Bi-annual	West of development on Motutere Point to Bulli Point	1	'04,'06
Whareroa	Annual/Bi-annual	To cover high and medium areas. Consider areas further north if soft shorelines	1	
Whakaipo Bay	Annual	Over full extent of beach area	2	

Bathymetry Surveys

Location	Frequency	Extent of survey	Priority	Surveys on Record
Kuratau River Mouth	2 yearly	Area of underwater delta, including overlap with beach profile sections	2	None
Hinemaiaia River Mouth	2 yearly	Area of underwater delta, including overlap with beach profile sections	2	None

Sediment Sampling Analysis

Location	Frequency	Extent of survey	Priority	Surveys on Record
Kinloch	During two surveys	Alternate beach profile locations - to be optimised during specification of work	3	2004
Kuratau	During two surveys		3	2006
Taupo Eastern Shore	During two surveys		2	None
Taupo Western Shore	During two surveys		3	None
Hatepe	During two surveys		2	None
Waitahanui	During two surveys		2	None
Five mile Bay	During two surveys		3	None
Whareroa	During two surveys		2	None

Wave Analysis

Location	Duration		Priority	Surveys on Record
Taupo Bay	1 year		3	None

Waitahanui	1 year		3	None
Kuratau	1 year		3	None

Asset Surveys

Location	Frequency	Comment	Priority	Surveys on Record
Kinloch	Annual	Priority and frequency dependent on TDC asset management priorities	3*	None
Kuratau	Annual		3*	None
Taupo Eastern Shore	Annual		3*	None
Taupo Western Shore	Annual		3*	None
Te Rangiita	Annual		3*	None
Hatepe	Annual		3*	None
Waitahanui	Annual		3*	None
Five mile Bay	Annual		3*	None
Motutere Bay	Annual		3*	None
Whareroa	Annual		3*	None
Whakaipo Bay	Annual		3*	None

Sediment Budget Analysis

Location	Priority	Comment		Surveys on Record
Kinloch	9	Frequency as budget and erosion works require		1
Kuratau	1	Programme of one per year reasonable		
Taupo Eastern Shore	8	Priority to be monitored and may vary following future erosion trends and issues		
Taupo Western Shore	6			
Te Rangiita	2			
Hatepe	7			
Waitahanui	3			Part
Five Mile Bay	11			
Motutere Bay	4			
Whareroa	5			
Whakaipo Bay	10			

6 Costs

The table attached to this Appendix sets out some preliminary estimates for undertaking the monitoring recommended in this schedule. The costs are based on the data collection and basic reporting only. Further analysis and reporting hasn't been included. Additionaly it has been assumed that a number of the activities could be undertaken in conjunction. For example the sediment samples collected when undertaking the beach profiles.

The costs are set out for each of the activities so that the overall scale of the costs could be understood and then depending on budget availability, the monitoring could be scheduled according to priority and an annual cost developed. An initial prioritisation is included in the Monitoring Summary Table above.

For the beach profile costs ideally we would be able to do the priority sites twice a year and the others once a year. It may be that there is only budget for some of the lower priority sites every other year for example. Additionally there are options for reducing the number of sections surveyed, for example for some repeat surveys possibly only every other profile line is undertaken. Some budget should be set aside for any new sites that appear, or to cover for unplanned survey immediately following severe erosion events at priority sites.

The Bathymetry survey costs might be incurred every two years or so to allow a trend of available sediment to be tracked.

The sediment sampling is assumed to be undertaken on the back of the profile surveys. Many of these could be delayed until it is proposed to do a specific study at a location. The wave monitoring is more of a one off cost and should not need repeating on a regular basis. Two periods (e.g. summer/winter) of three months each would be recorded. This could then be used to help calibrate wave heights/run-up an applied to the long-term wind data.

The asset surveys are different to the other data collection in many ways as it can he used for up keep / maintenance of the structures to prolong their life, as well as assessing the performance of different options. As many of the erosion structures are private the council needs to consider how it wants to approach the Asset Management of erosion structures.

The sediment budget analysis is a precursor / component of any site specific study into erosion options and therefore could be scheduled to take place depending on available budgets. For example one or two per year.

References:

California Coastal Commission (1997) Procedural Guidance Document: Monitoring.

Ministry for the Environment (2004), Coastal Hazards and Climate Change: A guidance manual for local government in New Zealand

Taupo District Council (2006) Taupo District Growth Plan 2050