

An Overview of Natural Hazards in the Hauraki District

Including a qualitative risk assessment



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Executive summary

The purpose of this report is to provide an overview of natural hazards in the Hauraki district as a basis for guiding and prioritising work activities by Hauraki District Council (HDC) and Environment Waikato (EW) for 2006/07 and beyond. This report also provides a useful insight into the district's natural hazards as part of the scheduled review of the Hauraki District Plan.

Both agencies have responsibilities for the management of natural hazards in accordance to a complex set of statutory responsibilities, but primarily via the Resource Management Act 1991.

Known natural hazards in the Hauraki district are identified and explained. Hazard scenarios are defined for each natural hazard and existing risk management controls are outlined. A preliminary (qualitative) risk analysis is then undertaken, and an evaluation of the risk from each natural hazard is made as a basis for prioritising risks. This approach is very similar to the hazard assessment that was carried out for the Thames Coromandel district as part of the Thames Coast Flood Risk Mitigation project.

River flooding hazards pose the greatest risk in terms of potential loss of human life, social disruption, economic cost and infrastructure damage. Coastal flooding has the second highest risk, and earthquakes have the third highest risk. The report also identifies various factors/considerations that are likely to affect natural hazard planning such as climate change, sea level rise, and tectonic deformation.

1 Introduction

1.1 Purpose

This report provides an overview of the significant natural hazards currently affecting and likely to affect the Hauraki district. An assessment of the natural hazards will provide guidance to HDC and EW in prioritising natural hazards work activities for 2006/07 and beyond.

The report provides:

An initial assessment of all existing natural hazard risks affecting the Hauraki district. It is acknowledged that the Hauraki Plains is vulnerable to flooding from different sources including the Piako and Waihou Rivers, coastal flooding, and earthquakes. Flood protection and drainage schemes have been constructed over the past 80 years to reduce flood risks and allow for development of the plains for both rural and urban uses

An initial qualitative risk assessment which identifies the risk to life and property in broad terms

An identification of gaps and priorities

A basis for developing effective district plan provisions regarding natural hazards, including how the outcomes/objectives of reducing river flood hazard risk in the district will be achieved.

This report follows on from and complements a report that was presented to the HDC in March 2005 which outlined the key drivers for hazard management, provided an overview of hazards within the Hauraki district and discussed new directions for river flood risk management. In addition, that report outlined potential risks and implications for the Piako River and a way forward for a joint hazard management partnership within the district. This report therefore sits within a wider context of hazard management and community outcomes.

Both HDC and EW have ongoing natural hazards commitments in the district – particularly river flooding. This report presents an initial hazard analysis for the key natural hazards, and puts river flood risks into perspective with other natural hazards as a basis for developing a proposal to guide work activities for both Councils.

The key drivers identified as being critically important for addressing hazard management are:

the current review of the Hauraki District Plan and district growth priorities
development of national river flood risk management directions, including the Central Government Review and development of the New Zealand Standard
EW's direction with respect to river flood risk management including development of a regional flood risk management strategy and working with district councils during their district plan reviews.

1.2 Scope of report

This report overviews the key natural hazards of the Hauraki district including river flooding, coastal flooding and erosion, earthquakes, volcanic, tsunami, debris flows and severe storms. 'Other hazards' such as land subsidence, land instability and contamination and rural fire have not been included due the relatively low level of risk, the site-specific nature of the hazards and generally high level of existing mitigation.

1.3 Background

In 2004, HDC indicated to EW its intention to undertake a district Plan change to allow further residential development in Ngatea. HDC requested comment from EW on the proposal and in response, staff from EW outlined a number of general concerns to HDC primarily with regard to climate change, river and coastal flooding potential, stopbank instability and the trends in river flood risk management in New Zealand.

In late 2004, EW undertook an initial flood hazard risk assessment for the Lower Piako area around Ngatea. At this time, it was recognised that an initial hazard risk assessment would not provide a comprehensive assessment of the flood hazard risks in the area. For this reason, it was agreed that in order to provide a comprehensive, quantitative flood hazard risk assessment, a longer-term combined project to assess all natural hazards in the area was desirable.

A combined approach to assessing the long-term hazard risks within the Hauraki district was confirmed in principle in 2005. Since this time, staff from both HDC and EW have been working jointly towards provision of information to inform the district plan review and set in place a long-term programme for hazard risk management within the district. While this programme has yet to be finalised, it will involve the following:

Overviewing the natural hazards of the Hauraki district as a basis for prioritising work (this report)

Providing river flood scheme information design standards, proposed designations and intended work programmes

Laying the foundation for risk assessments in key growth areas via information such as Light Detection and Ranging (LIDAR)

Preparing a series of flood hazard maps and planning provisions which are to be incorporated into the Hauraki District Plan

Developing a long-term work programme as the basis for both councils' Long-Term Council Community Plan's (LTCCP)'s.

1.4 Statutory and legal framework

The local government agencies primarily charged with managing natural hazards as they affect the Hauraki district are HDC and EW. Agency responsibilities include developing policy and implementing strategies and mechanisms to avoid or mitigate the effects of hazards. Other agencies such as the Department of Conservation (DOC) also have a role in hazard management, through the provisions of the New Zealand Coastal Policy Statement; and the Ministry of Civil Defence and Emergency Management through its enabling legislation.

The statutory framework guiding EW and HDC is primarily determined by the Resource Management Act 1991. Other relevant statutes include the Local Government Act 2002, the Soil Conservation and Rivers Control Act 1941, the Land Drainage Act 1908, the Building Act 2005, the Public Works Act 1981, the Civil Defence Emergency Management Act 2002, and the Hauraki Gulf Marine Park Act 2000.

Details of the current statutory and legal framework are provided within Appendix 1.

1.5 National drivers for hazard management

There are several key drivers impacting the way in which hazards are being managed and will increasingly be managed in the future. These key drivers are:

Recent flood events and changes to river flood risk management towards a more comprehensive risk management approach such as the Central Government Review and New Zealand Standard

Emergency management focus on hazard risk reduction, the treatment of residual risk and an all hazards approach

Increasing community expectations for flood management and linkages with community outcomes

Climate change impacts to existing hazards and requirements for adaptation to the effects of climate change

Increasing land use change towards urban development on flood plains and in some places conversion from forestry to pasture.

1.6 Key hazard planning considerations for HDC

In addition to the statutory framework and national drivers, there are a number of other considerations that are or will affect natural hazard planning for the Hauraki district, including:

Continuing population growth in known natural hazard areas

The proximity of existing development to rivers and streams

A growing number of resource consent applications for development in marginal areas

Incorporating climate change and sea level rise into research, planning and operations (protection schemes etc)

Increasing property values - Insurance/rating implications

Translating central government risk management guidelines into legal/effective policies via the regional and district plans

Consideration of land use planning controls (primarily via district plans), including existing use rights

Increasing exposure of lifelines infrastructure (such as roading, water reticulation etc)

Heavy reliance on physical works for flood protection

Maintaining public awareness and understanding.

2 Profile of the district

The Hauraki district (map below) lies at the base of the Coromandel Peninsula, bordered on the east by the Pacific Ocean and on the west by the Firth of Thames and the Hauraki Gulf. The district covers an area of approximately 1144 square kilometres, incorporating the major townships of Waihi, Paeroa, Ngatea and surrounding communities. The population as at 2006 was 17,193 people. The Hauraki district benefits from its central location, with Auckland, the Coromandel Peninsula, and the Bay of Plenty at its doorstep.



Figure 1 Map of the Hauraki district (from HDC web site)

The district is also an important transportation corridor between the major cities (and ports) of Auckland and Tauranga. Four state highways run through it (SH2, SH25, SH26, SH27) with many local roads acting as important thoroughfares and/or alternative routes during emergencies.

2.1 Physical setting

2.1.1 Geology

The Waihou River originates in the Mamaku Plateau/Kaimai Ranges south of Matamata, and together with the Waitoa and Piako Rivers (which originate in the hills to the south and east of Cambridge respectively), meanders down the Hauraki Plains to the Firth of Thames. Approximately 12km wide and 30km long, the plains are very flat and low, rising to only 4m above sea level at Paeroa, which is 20km inland. They are in stark contrast to the steep Coromandel and Kaimai Ranges which rise above them to the east, and the more rounded Hunua and Hapuakohe Ranges to the west.

The Hauraki Plains and adjacent ranges have formed as a result of geological forces dating back to the Miocene (refer map below). These forces continue to shape this

distinctive landscape. In fact, the Hauraki Plains sits within an active rift valley which over time is extending its width as a result of ongoing tectonic processes. This process has given rise to about five “sharp” earthquakes in the last 9,000 years which has resulted in the subsidence of the western depression by a total of 2.1m. In contrast, the Hunua Ranges have been rising at approximately 10cm every 1,000 years.

The poor internal drainage and high water table of the Hauraki Plains have largely resulted in the development of heavy, waterlogged gley soils. Over the years, this has created the need for extensive land drainage works and river protection schemes (excerpt from Chapter 2 - “Waihou Journeys”).

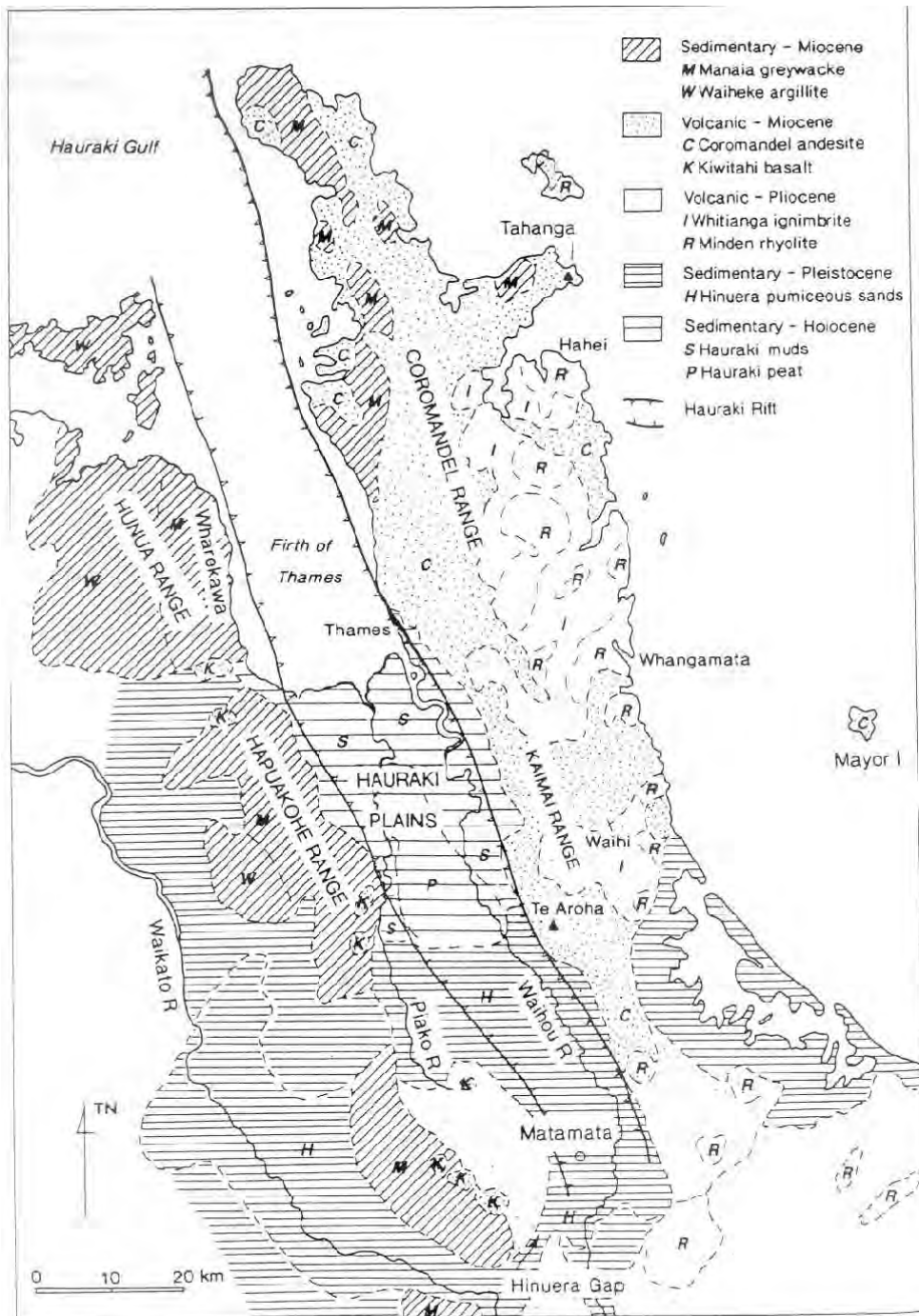


FIG 2.1 Geomorphology of the Hauraki Plains (based on Healy et al. 1964; Scholefield 1973; Suggate et al. 1978; Thornton 1985)

Figure 2 Geological setting of the Hauraki Plains

2.1.2 Climate

The climate of the Hauraki district is generally one of very warm summers and moderate winter temperatures. Humidity is reasonably high, reflecting the close proximity of the coast and frequent periods of heavy rainfall.

The district receives most of its rain in the winter months and rainfall patterns are closely related to elevation and exposure to north-westerly and north-easterly air flows (as depicted below). The narrow catchment of the Waihou River shows a sharp increase from 1,200mm per annum on the plains to over 2,550mm on the top of the Coromandel Ranges. Rain falls on more than a third of all days, although periods of over five days without rain commonly occurs in late summer and early autumn, which are associated with stationary anticyclones (excerpt from Chapter 2 - “*Waihou Journeys*”).

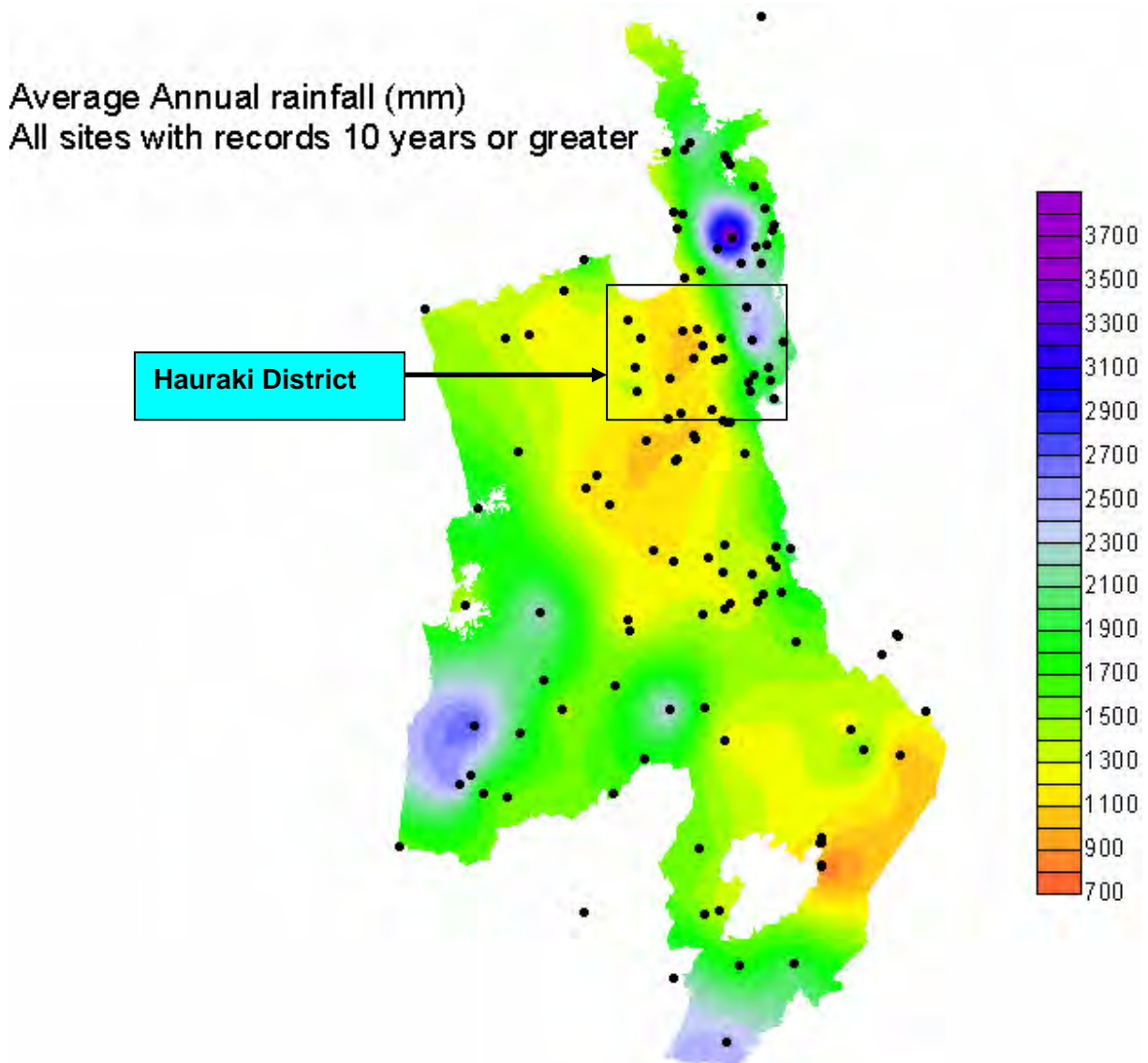


Figure 3 Regional average annual rainfall based on Environment Waikato’s regional rainfall network.

2.1.3 Facts and figures

(Source: Statistics NZ Website, Census information 2006, unless otherwise stated)

<i>Land Area</i>	<i>1,144 square metres</i>
<i>Population**</i>	<i>17,193</i>
<i>Urban/Rural Distribution</i>	<i>50.8/49.2% respectively</i>
<i>Households</i>	<i>6,666</i>
<i>Businesses*</i>	<i>1,115</i>
<i>Unemployment Rate*</i>	<i>9.1%</i>
<i>Median Income*</i>	<i>\$15,200</i>
<i>Local Roading**</i>	<i>422km (sealed) 128.8km (unsealed) 880.8km (total) 125 (bridges)</i>
<i>Productive Forestry**</i>	<i>2,866 hectares</i>
<i>Major Rivers</i>	<i>Waihou, Piako, Waitoa, Ohinemuri, Waitakaruru</i>
<i>Coastline</i>	<i>Approximately 27km</i>
<i>Capital Value**</i>	<i>\$2,062,130,334 \$715,653,074 (35% of the total capital value) falls within the flood hazard zone currently identified in the Hauraki district).</i>

* 2001 Census information

** As at July 2006.

3 Natural hazards in the Hauraki district

The Hauraki district is similar to many areas of New Zealand in that it is subject to a number of natural hazard risks. Our present understanding of natural hazards within the district stem from a number of sources including:

- Local knowledge and experience – particularly with river flooding, coastal flooding, and severe storm events
- Detailed investigations of specific hazards
- River flood engineering, mapping and surveying work
- General hazard studies such as earthquake risks
- The regional hazard risk analysis completed as part of the Civil Defence Emergency Management Group Plan.

The Hauraki district is particularly at risk from geological and meteorological based hazards. An assessment of the probability and the effects of natural hazard events can be based on:

- Knowledge of the history of past occurrences
- Comprehensive hazard analysis
 - *EW's Thames Coast River Flood Risk Management and the Lake Taupo Foreshore Risk Management Strategy projects are an example of recent work in this area*

Significant natural hazards that currently pose either an existing or potential threat to the Hauraki district and its communities (forming the basis of this section) are:

1. ***River and stream flooding***
2. ***Coastal erosion and flooding***
3. ***Severe storm***
4. ***Earthquakes***
5. ***Tsunami***
6. ***Volcanic eruptions***
7. ***Debris Flows***

While our present knowledge and understanding is limited, the impacts from the hazards listed above could all have significant impacts on the district in various ways.

3.1 Current and previous research

Known research that has been carried out to date pertaining to natural hazards in the Hauraki district include:

- IGNS - Earthquake Hazard Assessment for the Waikato Region 1996
- IGNS - Volcanic Hazard Assessment for the Waikato Region 1997
- Maunsell - Piako Stopbank Stability Project: Phase 1 Options and Recommendations Report 2007



Figure 4 A schematic of the Hauraki Plains showing the flood risk areas, major fault line, and the Firth of Thames coastal margin.

3.2 Flood hazards

The most common natural threat to the district is river and stream flooding (Table 4). Flooding is and has been a historical threat to the Hauraki district with most rivers and streams posing a potential hazard. Civil Defence emergencies have been declared for a number of flood related incidents affecting the district, the most notable being the 1981 Paeroa flood event.

The Hauraki district is particularly vulnerable to flood events due to:

- Its geographic (northern) location making it susceptible to storms of tropical origin
- The orographic effect of the Kaimai and Coromandel ranges which “attract” high intensity rainfall events on a regular basis
- Many catchments that drain the ranges are steep and short, creating flood events that are generally of short duration
- Much of the Hauraki Plains is very low-lying and are therefore subject to high groundwater tables (ponding) and flooding that result from flows that exceed protection scheme design standards
- Rising sea levels and climate change (i.e. increased rainfall) have potential to greatly exacerbate flooding issues in the district
- Existing development is situated in close proximity to the banks of rivers.

3.2.1 Background

Potential run-off, and hence flooding, is lessened by groundwater storage, evapotranspiration and the amount that is able to be absorbed by soil and vegetation. Notably in this district is the vast extent of wetlands that act as “sponges” for large amounts of rain water. The passing of intense cyclones can produce sustained heavy rainfall across along with high winds and, when soils are already saturated by previous

falls, the result is high run-off. Under these conditions, the steep streams that drain the Coromandel and Kaimai Ranges are capable of producing very high river levels.

Major floods that have occurred this century have tended to be concentrated in either late summer in association with storms of tropical origin (in some case ex-cyclones) or in winter due to high water tables. However, attempts to control flooding over the last 80 years, combined with drainage and deforestation, have radically altered the patterns of water run-off, so that flood events in the past have been different in both terms of volume and timing.

Tidal rise and fall also has a profound effect in an area as low as the Hauraki Plains. This would have been made significantly worse after the latest subsidence by 40cm of the western, and probably the eastern, depressions, which occurred some time between 200 and 600 years ago. As the monthly spring tides vary between 1.5 and 1.8 m above mean sea level (actual levels are affected by several factors, including the equinoxes in March and September, wind direction and cyclones), the low-lying land bordering the Waihou River and the shoreline of the Firth of Thames was subject to frequent flooding (excerpt from Chapter 2 - "*Waihou Journeys*").

3.2.2 River and catchment management

Flood hazards are currently heavily influenced by river and catchment management schemes within the district as follows:

- The Waihou Valley Scheme
- The Piako River Scheme
- Lower Piako stopbank instability assessment.

The objective of EW's river and catchment management services is to create and maintain stable and healthy river and stream systems, protect communities, maintain the productive potential of land and enhance the public amenity and environmental values of river and streams throughout the region.

EW provides the following services:

- Flood protection – minimising the potential impacts (social, cultural, economic and environmental) of floods
- River management – managing natural processes that affect rivers and streams, such as blockages that may cause erosion, flooding or change of the waterway's course
- Catchment works in the form of soil conservation to reduce the effects of accelerated erosion, and to effectively manage existing protection schemes
- Catchment oversight – managing the Waihou/Piako catchment management zone and supporting its subcommittee
- General information and advice.

EW's approach to how it undertakes its river and catchment management responsibilities is currently evolving into a more integrated catchment-based approach.

3.2.3 The Waihou Valley Scheme

The Waihou River forms the major river system of the Hauraki district and indeed the wider Thames Valley/Hauraki Plains. It is a long narrow system located on the eastern side of the plains and largely drains the western slopes of the Mamaku, Kaimai and Coromandel Ranges. It rises from headwaters in the Mamaku Ranges in the south and

generally flows northwards via the towns of Te Aroha and Paeroa eventually flowing into the Firth of Thames (Figure 5).

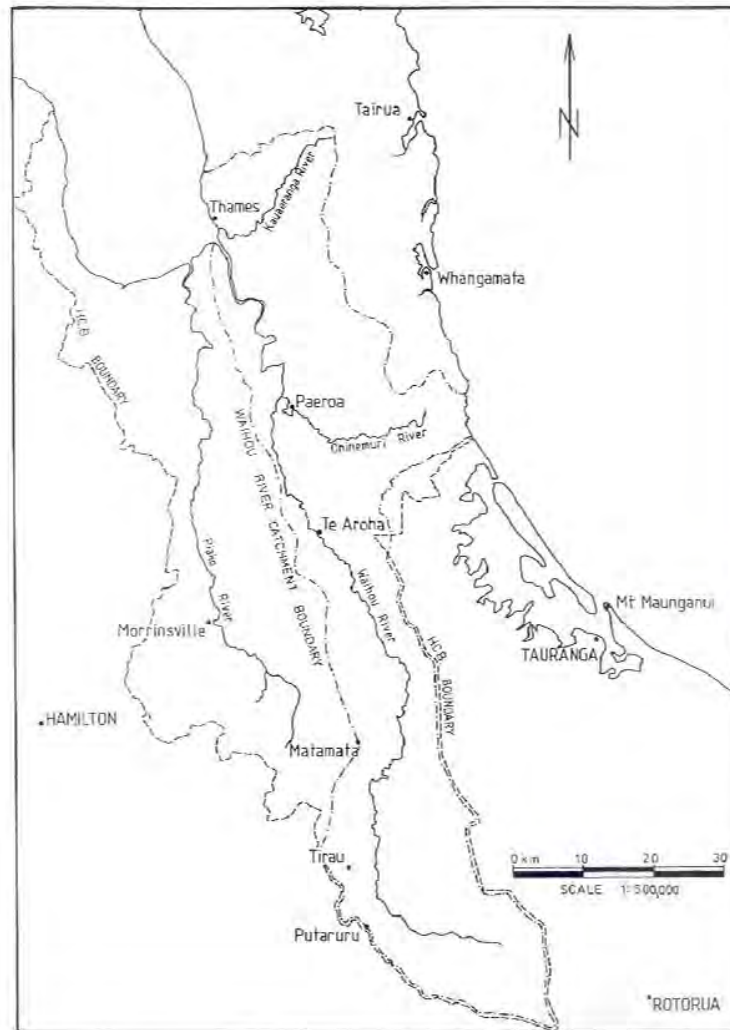


Figure 5 Map showing the boundaries of the Waihou River catchment. (From Waihou Journeys, see bibliography)

The river has a very flat gradient in its lower reaches, falling only 7m in the last 70km, in stark contrast to the tributary catchments to the east draining the ranges which are short and relatively steep. South of Te Aroha, the river is confined with a well incised terraced valley but in the northern plains zone, its natural flood plain has been confined by stopbanked floodways. The Waihou Valley Scheme also includes the Kauaeranga River and several smaller streams which are not within the Waihou River catchment.

The river has a total catchment area of 200,000 hectares (or 2,000km²) and the scheme includes the urban areas of Matamata, Te Aroha, Paeroa, Waihi and Thames. The Waihou Valley Scheme provides for a comprehensive, total catchment works programme that includes substantial floodway and stopbank systems and drainage outlets, willow clearing and erosion control in the upper river and tributary streams, and significant watershed protection retirement and soil conservation measures in the upper catchments and mountain zones.

The scheme is the largest in New Zealand and since its inception in 1965, and commencement in 1971, has taken 25 years to complete. The key features of the scheme include:

- 10 million cubic metres of earthworks

- 260km of stopbanks
- 370 kms of channel works
- 69 floodgates
- 20 pump stations
- 200km of standard fencing
- 150km of electric fencing
- 500 hectares of planting
- Over \$4 million spent on soil conservation planting and fencing
- The scheme would cost well over \$200 million to replace in today's dollars.

(source: *Waihou Valley Scheme Asset Management Plan 1997*).

The river has for the last 20,000 years drained the Hauraki Plains, and although it has not always followed the same course, it has largely kept within the eastern depression. The position of the coastline has also changed overtime, as indicated by ancient beach deposits/ridges which are now quite a way inland. The latest such transformation probably occurred around 600 years ago as a result of massive deposits of volcanic ash from the Kaharoa Eruption, both airborne and carried by heavily laden rivers.

The Waihou River rises and falls with the tide as far upstream as Paeroa near the confluence with the Ohinemuri River (a distance of about 36 km). The main tidal influence however is felt only as far upstream as the Hikutaia River confluence (excerpt from "*Waihou Journeys*").

Purpose for the scheme

The highly productive flat lands of the lower Thames Valley extend over a distance of about 100km from Matamata in the south to the Firth of Thames with an average valley width of approximately 23km. The Hauraki Plains in the north is a large flood plain subject to inundation from either the Piako or Waihou River systems, or from tidal flooding. In 1938, tide levels reached in excess of 3 metres and covered much of the lower Hauraki Plains.

In their natural state, floodwaters from both the Waihou and Piako Rivers used to converge into one contiguous ponding area covering an extensive are of the Hauraki Plains. Due to high water tables and low gradient, much of this "ponding water" would have stayed in situ for many weeks if not months causing widespread disruption and financial losses to farmers due to the effect on grass growth. The scheme consists of many "sub-zones", but overall it has the following objectives:

- An effective minimum 100 years protection level to rural and urban areas from main river flood flows
- An effective 100 year level of protection from high tides under the current regime to areas adjacent to the tidal reaches
- A minimum 10 year protection level from major tributary rivers and streams in rural areas
- A minimum 50 year protection level from major tributary rivers and streams in significant urban areas
- Drainage by gravity and/or pump assisted outlets to ensure a maximum of three days ponding in a 10 year return period storm for rural areas (grass dies after 3 consecutive days underwater)
- Upper catchment protection through reforestation and soil conservation protection measures.

Further information pertaining to the Waihou Valley Scheme can be found in the following documents:

- A. Waihou Valley Scheme Asset Management Plan, EW, Volume 1, Main Report, 1997
- B. Taming the Waihou, Graham Watton, 1995.
- C. Waihou Journeys.

3.2.4 The Piako River Scheme

The Piako river scheme provides flood protection to the central and western parts of the Hauraki Plains. The scheme comprises approximately 160 km of stopbanks, 59 floodgates, 32 pump stations and substantial channel excavations and works. The scheme was designed to protect the area from a 50-year flood event of the Piako River and 100-year tidal floods.

The scheme was constructed in the 1960's and 70's by excavating, widening and deepening the river channel and using the excavated material to build the stopbanks very close to riverbanks leaving minimal berm width and restricting the floodplains.

The original scheme design standards can be summarised as follows:

- a. The foreshore stopbanks and the Piako River channel and tributaries, from the Firth of Thames to the Ngarua Canal including Awaiti Canal, provide protection against 100-year (1% annual exceedance probability or AEP) event of high tidal surge, and 50-year (2% AEP) floods within the Piako River system.
- b. The emergency ponding zones provide flood protection against annual events for the initial ponding zone, 5 to 10 year (20% - 10% AEP) events for the first ponding zone, and 15 to 20 year (6.7% - 5% AEP) event for the second ponding zone.
- c. Scheme stopbanks above the ponding zones and up to Paeroa-Tahuna Road provide protection against 15 to 20 year (6.7% - 5% AEP) flood events.
- d. Drainage by gravity and/or pump assisted outlets to ensure a maximum of three days ponding in a 10-year (10% AEP) event.

These standards were reviewed by way of hydraulic modelling of the Piako and Waitoa rivers in 1998 and tested in actual flood events over the years with the following results:

- The foreshore stopbanks and the Piako River channel and tributaries, from the Firth of Thames to the Ngarua Canal, provide adequate protection against extreme tidal surge. The July 1995 high tide of (RL 2.5 m) was assessed to be a major event, assessed at approximately 2% AEP.
- The flood-way formed by the Piako River channel, tributaries and associated stopbanks from the Firth of Thames to the Ngarua Canal, has adequate capacity to accommodate flood events of an AEP of 1% (i.e. 1 in 100-year event) with adequate freeboard.
- The Piako River and tributaries upstream of the ponding zones (including the Waitoa River), have adequate capacity to accommodate a minimum of 10-year (10% AEP) flood event flows. The scheme stopbanks provide higher standards (6.7% - 5% AEP), while some areas are not stopbanked. These ponding zones remain important to downstream protection standards.

The increased channel/floodplain capacity and hence higher protection standard is due to channel deepening. This deepening is due to a number of factors including the daily tidal influence, the restricted floodplain and the soft riverbed material.

More information on the Piako River Scheme can be found in “*Piako River Scheme Asset Management Plan, Volume 1, EW Internal Series, 2002*.”

A number of technical investigations have been carried out on the scheme since 1959. More recently, a hydraulic review was undertaken by Barnett and MacMurray (May and August 2006) and an Options and Recommendations Report on the Stopbank Instability Issue was completed by Maunsell in February 2007.

3.2.4.1 Current issues – stopbank instability

An options and recommendations report prepared by Maunsell (completed in February 2007) provided further assessment on the stopbank instability issue on the lower Piako River. The report confirmed that:

- A number of sites identified in the earlier (preliminary) assessment by Tonkin and Taylor has been downgraded in priority
- The extent of the high risk sections identified in the earlier assessment has been reduced
- One additional high and medium risk area has been added
- There is a 3.3km section of the left bank downstream of Phillips Road/Puhanga Island Road and through Ngatea that is classed as high or very high priority.
- Despite the high or very high risk classifications, there were no significant visual indicators of stopbank instability that indicates imminent failure.

As part of this work, a hydraulic model has been developed by EW to identify initial flood risks in the Ngatea area, including:

- River flood levels of 100-year and 500-year events within the Piako Catchment with 500-mm sea level rise.
- Coastal flood levels of a 100-year event with 500-mm sea level rise.
- Coastal flood levels of a 500-year tsunami event in the Pacific and the extent of its effect on the Piako River.

The initial hydraulic modelling report has provided the following preliminary results in terms of flood levels:

- The scheme stopbanks at their current design height provide adequate protection for the 50-year, 100-year and 500-year river flood events in the Piako River from the Firth of Thames to Ngarua Canal, including Ngatea. This includes protection for both current climate and with anticipated rises in flood events due to climate change and sea level rise.
- The scheme stopbanks at their current design height provide adequate protection against a 100-year tidal surge event now and with the anticipated 500mm rise in sea level in the long term. Despite this, the freeboard height needs to be reviewed and some further topping is likely to be necessary.
- Preliminary results indicate that the foreshore stopbanks will be overtopped in a 500-year tsunami event by up to 1.8 metres at the Firth of Thames. The tsunami wave is likely to travel 17km up the Piako river channel, overtopping all stopbanks within the first 12km reach. Stopbanks at Ngatea are expected to be overtopped by 600 - 800 mm in an event of this size. (*Note: The tsunami scenario is based on the assumption that it would happen at a high tide with a 500-mm sea level rise (RL 1.9-m), which is the worst case 500-year scenario*). At mean sea level with a 500-mm sea level rise (i.e. RL 0.50m), overtopping is likely to be 300mm only.

- The report also indicates that a 500mm rise in sea level is likely to have environmental effects on the ponding zones including high salinity and reduced flood storage capacity. (*Note: This is based on the assumption that all other factors such as channel morphology and floodplain remain unchanged*).
- Internal Ponding – The scheme currently provides protection from internal ponding through a system of flood-gated drainage outlets and pump stations. This level of service will be significantly reduced with the expected sea level rise and increased intensity of rainfall due to climate change. This issue hasn't been investigated at this stage and requires review in the future.

3.2.4.2 Scheme integrity

It is obvious from the above that the scheme assets and works are key for addressing the majority of the flood hazard risks within the Hauraki Plains, for significant events. The reliability of the scheme assets is dependent on the continuous maintenance and renewal of the assets including topping of stopbanks to their design levels.

While channel deepening has increased the waterway capacity and perceived protection standard, it has increased berm erosion and reduced channel and stopbank stability. This was demonstrated in 2004 by the slip failure of a 120-m section of the Rawerawe stopbank, which has since been topped up.

Following the stopbank failure, further geotechnical investigations were undertaken by Tonkin & Taylor Consultants in April 2004 covering the whole lower reach up to Ngarua Canal, including the Awaiti Canal. The results of these investigations were reported under three risk categories – high, medium and low.

In response to the channel and stopbanks stability issues, EW initiated a programme of investigative works over two financial years (2004/05 and 2005/06) to establish the following:

- The factors contributing to channel degradation.
- The extent and rate at which the channel is degrading.
- When and at which bed levels is the channel likely to stabilise.
- What issues will arise throughout the natural process of sedimentation and degradation, and expected changes in river morphology.
- The long term effects of sea level rise and climate change on the scheme
- The available options to reduce and manage the risks of channel and stopbanks stability.
- Quantitative and qualitative risk assessment.
- The preferred course of action/actions for sustainable management of the Scheme.
- Development of a risk management strategy and associated plans for the Hauraki plains.

3.2.5 Potential effects of natural hazards on protection schemes

As covered earlier in this section, the Hauraki Plains is a very active area in both a geological and meteorological sense. With this in mind, the Waihou and Piako River flood protection schemes are potentially at risk from:

- Earthquakes that result in a sudden/dramatic uplift or subsidence of adjacent land
- Tectonic process that are slowly lifting and/or depressing the plains
- Large tsunami events that could result in large pressure bores going up the river channels, possibly overtopping some stopbanks in the major events
- Sea level rise effects (the Intergovernmental Panel for Climate Change (IPCC) is recommending we plan for a 0.5m rise over the next 100 years)
- Climate Change effects, largely stemming from an expected increase in both frequency and magnitude of high intensity rainfall events (perhaps giving an

estimated 20% increase in river flows over the next 50 years, as adopted in Europe).

While some processes occur slowly over time, some happen instantaneously (such as earthquakes) and can have a significant (sometimes beneficial) effect on the performance levels of the schemes. These factors need to be kept in mind in future (long term) planning decisions.

3.2.6 Other work

A range of 'other work' has been or is being undertaken to support the flood hazard risk assessment process. These include (but are not limited to):

- LIDAR surveys (for the procurement of accurate ground level elevations)
- Modelling (to estimate the speed, depth and direction of flood flows)
- Regional flood risk management strategy (to provide key directions for policy and decision making in regard to the long term management/treatment of flood risks)
- Categorisation of flood risks (to provide policy guidance on how flood risks should be prioritised in terms of risk).

Appendix 5 provides more information on each of the above.

3.2.7 Hauraki district flood hazards - summary

A summary of the key variables that assists in the understanding of the flood hazard situation in the Hauraki district is outlined in the following table:

Table 1 key variables of the flood hazard in Hauraki district

Aspect	Feature	Comment
Total size of district	1,144km ²	Assessed from Geographic Information System (GIS) database
Rivers	Waihou, Piako, Ohinemuri, Waitakaruru	All enter the Firth of Thames.
Known Flood Hazard areas (Figure 7)	~610km ²	Assessed from GIS database
Capital value	~\$2,062,130,334	~\$715,653,074 (or 35%) is within known flood hazard areas
Currently identified flood hazard areas (refer map below)	610km ² (or 55% of total district)	Assessed from GIS database (N.B. currently identified areas only)
Waihou/Piako River and Catchment Management Zone area within HDC	1075km ²	Assessed from GIS database
Coromandel Management Zone area within HDC	105km ²	Assessed from GIS database
Lower Waikato Management Zone area within HDC	15km ²	Assessed from GIS database
Rainfall	Averages about 1200mm	Greatly affected by

	on the Plains and up to 2,500mm in the ranges	topography
Climate Change & Sea Level Rise	The Hauraki Plains is very low lying and a rise in sea level by 0.5 metres over the next 100 years could have a significant impact on flood schemes and the infrastructure of towns	Climate change is a world-wide phenomena and is likely to exacerbate flood hazards across the Waikato region
Catchment changes (pre-European)	Clearance of indigenous forest first occurred during Maori occupation of the area	Resulted in increased run-off, erosion, and increased the sedimentation load of rivers (<i>Waihou Journeys</i>)
Catchment changes (post-European)	Changes have been extreme since the first European settlers arrived. Main factor has been the continuing clearance of forests and development of towns	Resulted in accelerated rates of run-off, erosion, sedimentation of rivers and floods. As a remedy to create pasture and prevent flooding, extensive drainage and flood protection works were undertaken (<i>Waihou Journeys</i>)
Geology	Uplift and subsidence has occurred in various places across the Hauraki Plains. The hydrothermal activity which once dominated the Waihi area gave rise to the rich gold deposits that are mined today	The Hauraki Plains is considered to be one the most tectonically active zones in the North Island

Figure 7 illustrates the areas currently identified as being prone to flooding in the Hauraki district. As can be seen, the highest risk of flooding is posed by the Waihou, Piako, and Ohinemuri River systems.

3.3 Coastal erosion and flooding hazards

Beach areas on the Coromandel Peninsula have been heavily developed over the last 40 years and development has occurred very close to the beachfront. In some areas property has been placed within the zone of natural beach erosion and accretion. Natural protection from erosion provided by dunes has been removed to improve views. In some cases native sand binding plants that helped beach and dune recovery after storms has also been removed. As a result some coastal property is threatened by erosion and in some cases structures have been built to protect beachfront property. These structures often adversely affect the beach and prevent or detract from people's activities on the beach.

The effects of coastal hazards are expected to be compounded by the effects of projected sea level rise over the next 100 years. It is anticipated that beach systems may begin a long-term erosion trend. The sea level rise will also increase risks from coastal flooding on the western Coromandel Peninsula and the northern part of the Hauraki Plains, the effects of which may be exacerbated by riverine flooding at sites such as Ngatea.

The areas within the Hauraki district that are at risk from coastal erosion and flooding are generally confined to the small stretch of coastline at Whiritoa (situated on the east

coast of the Coromandel Peninsula) and the northern part of the Hauraki Plains (which is bounded by the Firth of Thames).

3.3.1 Whiritoa

The beach at Whiritoa is an enclosed system (meaning that sand is neither gained or lost) and is therefore considered to be “stable”. The beach does not appear to be experiencing any long term erosion or accretion trend. The beach is vulnerable to severe storms that can cause high sea levels (storm surge) and high energy waves and any associated erosion with these events are usually of short duration. Coastal flooding is not seen as being a significant issue for Whiritoa.

3.3.2 Hauraki Plains

Flooding from the sea of low lying areas around the margin of the Firth of Thames results from the combination of astronomical tides with wave action and storm surge effects. Elevated sea levels arising from tide and storm surge effects are usually distributed over a large area. However, wave effects are typically localised and can vary significantly dependent on wave exposure of the site. Natural buffers such as mangroves can also significantly damp wave effects.

The May 1938 storm is significant in that the highest known flood levels in the southern Firth of Thames were recorded during this event.

The foreshore stop-banks then fronting the Hauraki Plains were breached in 15 separate areas, most significantly in the vicinity of Pipiroa on the eastern Hauraki Plains near the Piako River. Newspapers recorded that “extraordinary tides coupled with NE gales topped the stopbanks by 2ft,” noting the event as the worst flooding in the history of the Hauraki Plains.

This extreme water level is currently adopted as the best present estimate of the 1% AEP extreme water level around the southern Firth of Thames, though the annual probability of the level is unknown (EW, 1995; 1999). However, as the extreme sea level measured during this event is the highest on record the annual probability could well be considerably less than 1%.

The significance of the May 1938 event in terms of existing design levels warrants further investigation of this event, including collation of information from any relevant, archived files dating from this period.

Further information can be found in EW’s Technical Report 02/06 “*Coromandel Beaches: Coastal Hazards and Setbacks Recommendations*” by Dahm and Munro, April 2002.

3.4 Severe storm hazards

Historically the western side of the Kaimai and Coromandel ranges has been renowned for the cyclonic winds their topography engenders. Extreme wind events have caused considerable damage and many injuries. Low depressions stationary off the west coast of Northland can produce severe easterly gales and weather conditions often peculiar to the Hauraki Basin area. Historic events include those of 1936 and in 1978 when stronger than usual winds struck the region. In 1978, winds of 140 knots were registered on top of Mount Te Aroha.

The Hauraki Plains, being located on the western side of the Kaimai and Coromandel Ranges, is vulnerable to frequent high wind events due to the orographic influence of the ranges which tend to have a “squeezing” effect during easterly storm events.

3.5 Earthquake hazards

Earthquakes may be caused by the relative movement of the earth along faults, and by volcanic processes. Energy is released during an earthquake. This radiates away

from the source as a seismic wave. It is this wave that is felt during an earthquake. The felt strength (intensity) of an earthquake generally decreases as the distance from the source increases.

In 2005, The Institute of Geological and Nuclear Sciences (IGNS) undertook a study of the earthquake risk to the people and infrastructure of the Hauraki district. They assessed losses and casualties due directly to earthquake damage.

The study concluded that:

- The Hauraki district sits within an area of low seismicity
- The probabilities of the district experiencing various levels of losses and casualties (dead plus seriously and moderately injured) due to all earthquakes that could affect the district are as follows:

Table 2 Probabilities of district levels of losses and casualties due to all earthquakes

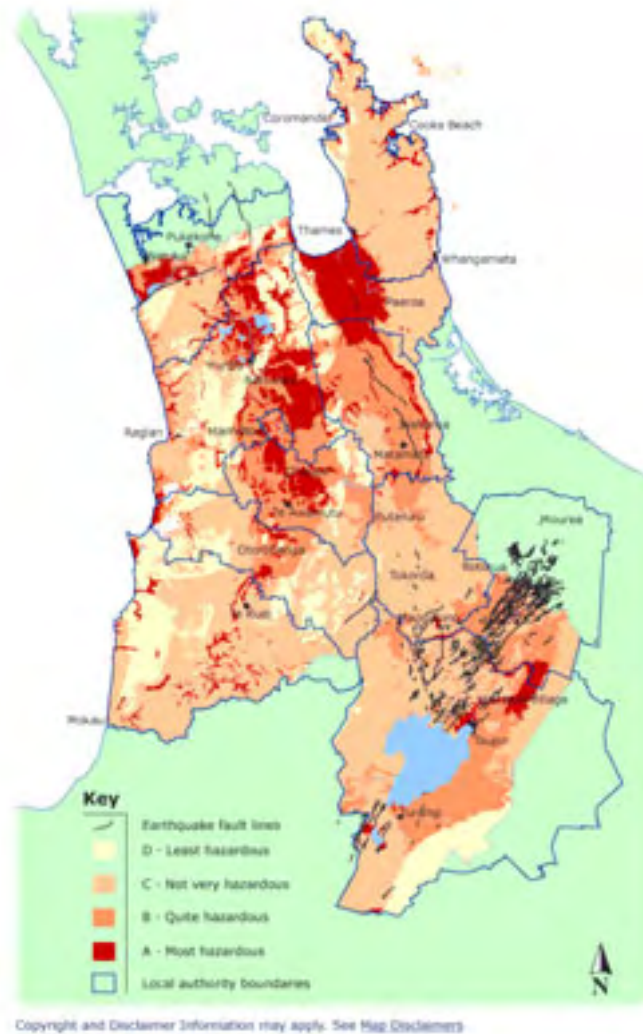
Return Period (years)	Annual Probability of Mean Loss or Casualties	Mean Loss (\$millions)	Mean Number of Casualties
100	0.01	5	0
500	0.02	30	0
1000	0.001	50	1
5000	0.0002	110	7

- For a scenario earthquake on the Kerepehi Fault, it is estimated that the mean loss will be \$60 million and the probable number of casualties will be zero to two.

3.5.1 The Kerepehi Fault

Earthquakes are often felt in most parts of the Hauraki district, with the greatest known threat coming from the Kerepehi fault. An event here is likely to result in very similar effects to the 1987 Edgecumbe Earthquake in terms of spread and severity. The Kerepehi Fault is an active fault trending N-NNW through the Hauraki Plains between Kerepehi and Okoroire. Surface traces of this fault extend for more than 50 kilometres.

The fault appears to be broken into at least three separate segments, the southern two of which appear capable of producing independent earthquakes up to magnitude 7.



Copyright and Disclaimer Information may apply. See Map Disclaimers

Figure 6 Earthquake risk zones and active fault lines of the Waikato region

Investigation and research on the Kerepehi Fault is continuing. A large magnitude movement on this fault is considered capable of producing a significant earthquake hazard that will affect the towns of Thames, Matamata, Morrinsville, Te Aroha, and Paeroa are all within 10 kilometres of the fault. Strategy for earthquake hazard mitigation will largely depend on the outcome of current research into this subject.

Recent research undertaken as part of HDC's dangerous buildings policy, indicates that a 10,000 year event (6.4 Mw) on the Kerepehi Fault could result in only two deaths.

Earthquakes on the Kerepehi Fault have a return period greater than 200 years, or an annual probability of less than 0.5%. There have been no recorded movements on this fault since before 1800. Figure 7 indicates the location of the Kerepehi Fault.

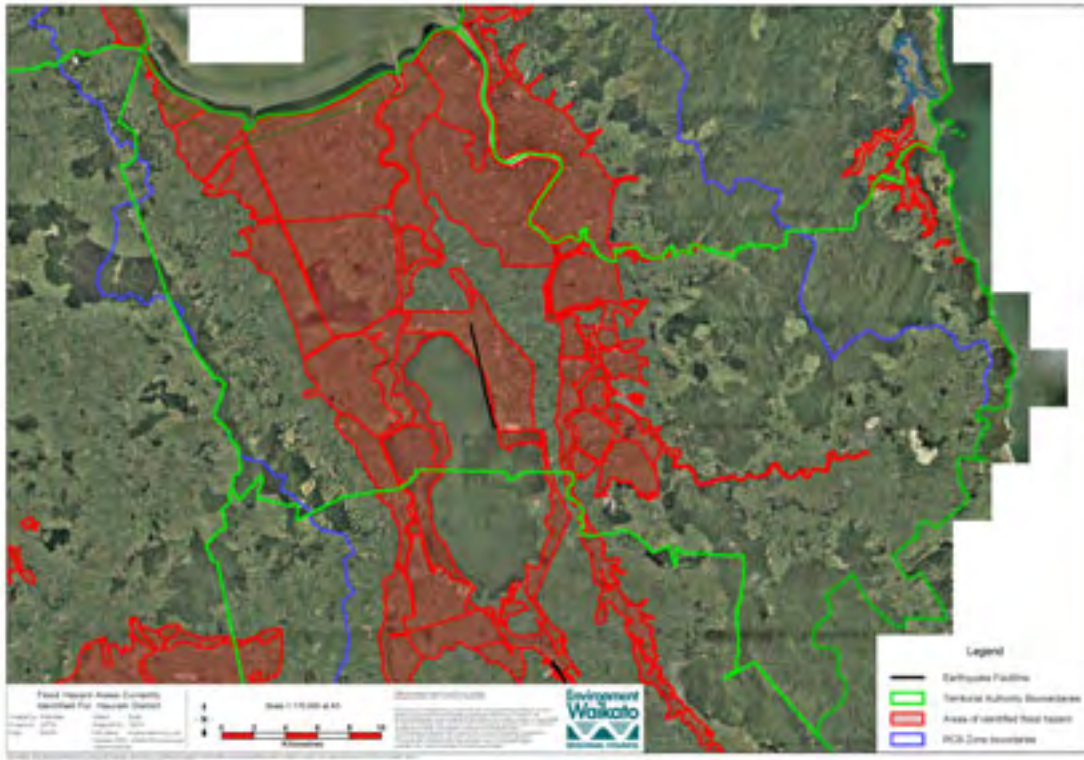


Figure 7 Map showing the currently identified flood hazard areas, active fault lines, Hauraki district boundary, and the Waihou/Piako Management Zone boundary

The vertical separation rate is $\sim 0.5\text{m}/1,000\text{ yrs}$ with a recurrence interval of 4,500-9,000 years for a 6.9Mw event. This is based on a surface rupture length of approximately 25km, an average fault slip of 2.5m, a focal depth of 10km, and a fault dip of 60 degrees. Further information pertaining to earthquake risk can be found in the following documents:

- A. Earthquake Risk Mitigation Plan, EW Policy Series Report 1997/12
- B. Earthquake Hazard Assessment for the Waikato Region, Technical Report 1996/17
- C. Estimated Damage and Casualties from Earthquakes affecting the Hauraki district, 2005, IGNS Client Report 2005/181

3.6 Tsunami hazards

A Tsunami is a wave that is generated through a disturbance of the seabed, either by an earthquake, landslide on the seabed, or from a volcanic eruption. A tsunami may be generated locally (which may itself cause some damage), or by a distant event. For example, an earthquake in Alaska in April 1964 generated a tsunami that was recorded over much of the east coast of New Zealand.

Tsunami warnings are issued by the Pacific Tsunami Warning Centre based in Honolulu, Hawaii. The centre receives information from numerous stations in the Pacific Ocean. Depending on the source of the tsunami, warnings ranging from about 12-13 hours down to 1-2 hours may be given. Locally generated tsunami will generally have little warning. For example there would be little warning of tsunami generated from an eruption of Mayor or White Island.

There is general acceptance that the north and east of the Coromandel Peninsula are at risk from tsunami. What is less well known is that the Firth of Thames has recorded at least nine tsunami events since 1868. These were all distantly generated tsunamis the largest occurring in August 1868, May 1877 and May 1960. It is worth noting that

the 1883 tsunami produced a tidal bore in the Kauaeranga River which if it were to occur today could damage or destroy the State Highway 25 Bridge. The same event would no doubt have resulted in similar damage at Pipiroa and perhaps Ngatea on the Piako River.

If an earthquake were to occur on the Kerepehi Fault it is likely that reasonably large tsunamis would be generated. In localised areas water heights would be amplified. Essentially, both the east (i.e. Whiritoa) and the west coast of the Coromandel Peninsula (i.e. Firth of Thames) are both vulnerable to tsunamis.

There is generally a good level of understanding on the region's exposure to tsunami risk primarily as a result of recent events and current research. However, much further consideration is required to determine what actions are necessary to reduce the risks, given that it's a low probability high impact event. For example, it may be considered more appropriate to concentrate on evacuation procedures rather than changing landuse.

There are currently no specific planning mechanisms in place for addressing risks associated with tsunami hazard.

3.6.1 Current research

Tsunami mitigation work is currently being undertaken as a follow-on from a joint EW and Eastern Bay of Plenty (EBOP) project that started in 2002 focusing on identifying the potential for tsunami activity, and to provide more detailed research to determine historical events for the Bay of Plenty and Coromandel eastern coastline (Stages 1 and 2). The tsunami hazard on the East Coast of the Waikato Region carries a significant level of risk.

These initial reports were commissioned following recognition by both EW and EBOP that the threat of tsunami may have been greater than traditionally thought. This view has been reinforced by the South-east Asian tsunami event of 26 December 2004 and the subsequent actions at the national and international levels.

Current work to assess inundation in Mercury Bay is in progress, and due for completion by the end of 2007. The outcomes of the project therefore will greatly assist the CDEM group in reducing the risk of the region's highest ranked priority hazard.

According to current best estimates associated with current work (outlined below), tsunami wave heights expected for the Hauraki district on the east coast is around 2.5m for a 100 year return period event and 5m for a 3,000 year return period event. The tsunami risk for the Firth of Thames is thought to be less (essentially due to the sheltering effect of the Coromandel Peninsula). However, tsunami risk from a locally generated earthquake could generate a large tsunami in the Firth of Thames affecting much of the northern Hauraki Plains area.

3.7 Volcanic hazards

The most significant volcanic threat to the Hauraki district is Mayor Island, a caldera volcano situated approximately 25km offshore from Whiritoa on the east coast of the Coromandel Peninsula. The volcano has produced many explosive and effusive eruptions during its history, the latest of which occurred about 6,300 years ago and was so large that significant amounts of tephra fell across the North Island (see figure below). Some peat lands across the Hauraki Plains have quite distinctive Mayor Island ash embedded within it (up to 20-50cm in places).

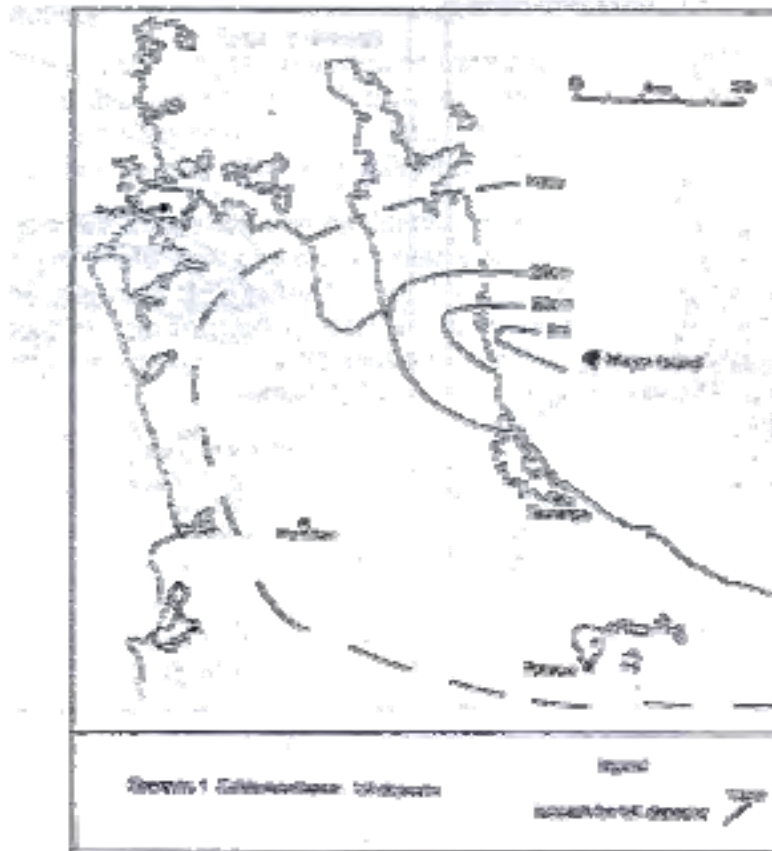


Figure 8 Map showing the distribution of tephra from Mayor Island's last known eruption approximately 6,300 years ago (From MAF Policy Technical Paper 99/2)

Ashfall from other sources is possible, such as the Taupo and Okataina Volcanic Zones. Eruptions from both centres in the past have caused widespread devastation to northern New Zealand resulting in significant changes to the Hauraki Plains due to large scale sediment deposition within the last 2,000 years.

Risks from the various sources of volcanic activity that have the greatest potential to affect the district is summarised below:

- Taupo volcanic centre
 - Erupts on average every 1,300 to 1,600 years (small)
 - Erupts on average every 2,500 to 5,000 years (medium)
 - Erupts on average every 5,000 to 10,000 years (large)
 - Last erupted 1,800 years ago

- Okataina volcanic centre
 - Erupts on average every 1,500 to 2,000 years (medium event)
 - Erupts on average every 2,000 to 5,000 years (large event)
 - Last erupted in 1886 (i.e. only 120 years ago) and is widely known as the Mt Tarawera event (predominantly basaltic in nature)
 - The last known "widespread" eruption that greatly affected the Hauraki district was the Kaharoa Eruption which occurred about 700 years ago

- Mayor Island volcanic complex
 - Erupts on average every 1,000 years (small)
 - Erupts on average every 10,000 years (large)
 - Last erupted 6,340 years ago

- Auckland volcanic field
 - Erupts on average every 1000 to 2,000 years
 - Last erupted 600 years ago
 - Unlikely to greatly affect the Hauraki district as effects tend to be localised.

On this basis, the Hauraki district could, on average, expect a significant volcanic eruption to occur once every 1,000 years.

3.8 Debris flow hazards

Very little is known about the current risk of debris flows across New Zealand, let alone in the Hauraki district. Rapid development in New Zealand has led to an increasing use of alluvial fans for residential development. There is, as yet, little appreciation of the hazards posed by infrequent but devastating debris-flows on these fans, nor is the risk of debris-flow damage a commonly-used criterion for permitting development. The 1981 Te Aroha and more recently the 2005 Matata debris flow events are good examples.

Debris-flows pose a hazard that is effectively unmanageable; during an intense rainstorm a small creek can generate several-metre-high surges of mixed boulders, sediment and trees that can leave the channel and travel anywhere on an alluvial fan.

In a typical catchment, this process might occur only once in a century or two, depending on the occurrence of sufficiently intense rain and the availability of sufficient available sediment.

To this end, EW has been approached by the University of Canterbury to carry out a debris flow risk assessment of the Coromandel and Kaimai Ranges using digital terrain modelling via a GIS platform. The aim is to delineate areas most vulnerable to debris-flow occurrence. The areas identified will then be assessed by air-photo study and field inspection to confirm the evidence for past debris-flow occurrence (thus calibrating the method), and estimate the magnitude and probability of such events. This can then be compared with the presence of existing or proposed developments to identify locations at different degrees of risk.

The methodology will then be applied to a different region, and the calibrations needed to make it work in a different climate and physiography will be developed. This procedure then becomes part of the protocol for identifying debris-flow hazard areas in any environment across New Zealand. It is anticipated that the calibration will involve field work to assess GIS-indicated debris-flow fans; seismic information to quantify the recent seismic history of the area; meteorological information to quantify the recent storm history; and geological information to quantify the local faulting and rock parameters.

The study forms part of a post graduate research project (i.e. MSc) and is not expected to be completed until late 2007.

4 Risk assessment

Having determined the most common and significant natural hazards in the Hauraki district, it is necessary to analyse and evaluate the level of risk associated with each hazard. This will allow a comparison between different hazards in order to guide prioritisation for the level of work effort. One important precursor to this exercise is determining what the outcome or goal of the hazard mitigation work should be. Suggested goals for both HDC and EW are:

- To work towards the resolution of natural hazard issues in the district
- To minimise risks from natural hazards to people and infrastructure in the district
- To determine natural hazard management priorities for the purposes of LTCCP planning.

Work actions should be determined using the combination of agency goals, current work commitments and level of risk associated with the hazard.

4.1 Hauraki hazards - risk description/scenarios

Risk analysis approaches can include checklists, judgements based on experience and records, brainstorming, flow charts and scenario analysis. One of the most intuitive ways to describe risk is in the form of scenarios, and this approach is used as the favoured method for this report. Each scenario for the identified hazards (below) is the “maximum credible event” of district significance:

- River flood: 1/100 year flood event similar to that experienced in Paeroa in 1981 (but including the Waihou and Piako Rivers)
- Coastal flood and erosion: 1/100 year storm event (Cyclone Drena-type event or worse)
- Severe storm: same as for coastal flood
- Earthquake: Magnitude 6.9 event along the Northern Kerepehi fault extension (3% chance of occurrence in the next 100 years)
- Tsunami: 1/100 year tsunami event (with a wave run-up of ~2.5 m)
- Volcanic activity: 1/1000 year event from Mayor Island which would cover most of the district in ash (weather conditions permitting).
- Debris flows: 1/500 year event (perhaps similar to the Te Aroha event of 1981).

Note that as part of the preparation of the Waikato Civil Defence Emergency Management Group Plan, HDC staff were involved in the risk evaluation process to determine (collectively with their Thames Valley emergency operating area partners), the priorities for the district and Emergency Operating Area. As a result, it was determined that tsunami, earthquake, volcanic activity (Mayor Island), river flooding, coastal flooding, and severe storms were the top six ranked natural hazards (in terms of relative level of impact) for the Thames Valley emergency operating area. The assessment outlined in this report has resulted in a similar order of priorities.

4.2 Residual risks

Remaining risk is defined as those risks that cannot be defined in more detail after elimination or inclusion of all conceivable quantified risks have been addressed. Residual risk can also be described in terms of “the bigger than event”. For example, if planning and operational measures are only implemented against the 100 year event scenario, then anything larger (such as the 200 or 500 year return period events) would essentially be considered the residual risk component.

EW aims to address the residual risk component through the proposed regional flood risk management strategy. Residual risk is a key consideration within the proposed national and regional flood risk management strategies.

4.3 Hauraki hazards - risk analysis/evaluation overview

Risk analysis and evaluation typically involves determining the likelihood of a hazard event occurring, and the consequences of the hazard event. A commonly accepted standard for risk management in New Zealand is the AS/NZS 4360: Risk Management Standard. This standard is used as the basis for this report:

1. Establish the context
2. Identify risks
3. Analyse risks
4. Evaluate risks
5. Treat risks

4.4 Existing risk management controls

A useful step in analysis is to determine what the existing activities or controls are for each known hazard scenario, and determine whether or not they are effective. Table 3 shows existing controls of natural hazards in the Hauraki district. The level of existing controls assists in determining the overall level of risk (i.e. the more controls in place generally imply reduced levels of risks and vice versa).

4.5 Risk analysis/evaluation

Problematic to any risk analysis is the level of detail and characterisation of the importance rankings. Table 4 shows a simple risk evaluation based on likelihood and consequences of each scenario. The key to Table 4 is contained in Appendix 6. While identifying that all hazards are important, there is not enough detail to prioritise the risks at a “high” level of risk.

Further analysis is required in order to prioritise risks at the “high” level. One method for doing this is the Seriousness Manageability, Urgency and Growth (SMUG) model. This model provides a method for assessing four risk factors:

1. Seriousness:
An average rating of each of the five hazard impact areas (human, social, economic, infrastructure and geographic)
2. Manageability:
A measure of how difficult a hazard's risks are to address and a measure of the level of cross-sector management effort being applied to the hazard
3. Urgency:
A return period rating, and how immediate is the need to address
4. Growth rating:
A combination of the probability of event occurrence rising and changing community exposure to the hazard.

4.6 Conclusion

As a result of the above assessment/evaluation, it is concluded that river flooding, coastal flooding and earthquakes are the highest priority natural hazards currently facing the Hauraki district.

Table 3 Existing natural hazards controls and effectiveness

	Existing natural hazards controls								
	Statutes, Regulation, Codes of practice	Policies, rules, RPS, Regional Plan	Strategic & Annual Plans	Long Term Financial Strategy LTFS	Civil Defence, Risk Mgmt. Plans	Emergency Services plans	Regional & district contingency plans	Programmes & projects underway	Lifelines studies
River flood Effectiveness	Yes 2	Yes 2	Yes 2	Yes 3?	Yes 3	Yes 3?	Yes 1	Yes 1	Yes 1
Coastal flood Effectiveness		Yes 2-3			Yes 3	Yes? 2?	Yes 2?		
Coastal erosion Effectiveness	Yes 2	Yes 2	Yes ?	Yes ?				Yes 2-3	
Severe storm Effectiveness					?				
Earthquake Effectiveness	Yes? ?				Yes 3?	Yes ?			Yes 1
Tsunami Effectiveness								Yes 2	
Volcanic Effectiveness	Yes? ?				Yes 3?	Yes ?			Yes 1
Debris flow Effectiveness								Yes 2-3	

Yes = Existing Controls in effect

Effectiveness Ratings: 1 = Low 2 = Medium 3 = High

Table 4 “Refined” Hauraki hazards risk evaluation (See Appendix 6 for key)

Hazard scenario	Likelihood	Consequence	Risk level	S					Average	M	U	G	Total	Priority
				H	S	E	I	G						
River flood	A	5	Extreme	5	5	5	5	3	4.6	4 (HM)	5	4 (HM)	17.6	1
Coastal flood	B	2	High	4	4	4	3	3	3.6	2 (LM)	4	4 (HM)	13.6	2
Earthquake	E	4	High	5	5	4	5	3	4.4	4 (ML)	2	2 (LM)	12.4	3
Severe storm	B	3	High	2	2	3	3	1	2.2	4 (ML)	4	2 (LM)	12.2	4=
Tsunami	E	5	High	4	4	4	5	4	4.2	5 (HL)	1	2 (LM)	12.2	4=
Debris flow	E	3	Moderate	4	3	3	3	3	3.2	4 (ML)	1	4 (MH)	12.2	4=
Volcanic	E	4	High	2	2	4	2	2	2.4	4 (ML)	2	2 (LM)	10.4	5
Coastal erosion	C	1	Low	1	1	2	2	2	1.6	3 (MM)	3	2 (LM)	9.6	6

Key:

S = Seriousness rating

- (H): Human costs
- (S): Social impact
- (E): Economic cost
- (I): Infrastructure costs
- (G) Geographic impact

M = Manageability rating

U = Urgency rating

G = Growth rating

5 Summary and conclusions

5.1 Summary of natural hazard risks

It is clear that while coastal flooding and earthquake are important natural hazards priorities for the Hauraki district, they do not carry the same level of risk as river flooding. The ongoing threat from river flooding (particularly at Ngatea and Paeroa) is greater in terms of social disruption, economic cost, infrastructure damage and possibly loss of human life.

Tsunami, volcanic eruptions, climate change, sea level rise, earthquakes, and tectonic deformation all have a potential to affect flood risks in the Hauraki district, particularly existing flood protection schemes. This is an important consideration for the district in light of its expected ongoing growth and the associated pressure to increase development in known flood hazard areas. These processes will therefore be a critical element of future risk management strategies.

It is recognised that other risks to urban communities exist across the district, but these generally are on a smaller scale (due to fewer people impacted, and smaller flood magnitudes).

Piako River scheme – stopbank instability

Within its lower reaches, the Piako River Scheme, like most river schemes in New Zealand, is heavily reliant on engineering solutions for flood protection. The scheme is also subject to a number of risks including:

- Stopbank instability and erosion potential. Investigations have been carried out to confirm areas/reaches at risk of failure. Options to address include increasing the height of stopbanks (although this would be limited due to soft foundations) and relocation away from the main channel to prevent further erosion and failure potential. Latest analyses have shown that the length of potentially unstable stopbanks is not as extensive as first thought.
- Large flood events, which will place higher stresses on the system
- The impacts of climate change including sea level rise and likely increases in the frequency and intensity of high rainfall events
- Gradual land subsidence on the plains and sedimentation of the channel in the lower reaches.

Work to better define the risks associated with the Piako River Scheme and river flooding hazards has been undertaken and includes:

- A short-term assessment of flood hazard risk around the Ngatea township to provide initial information to support the proposed District Plan amendment
- A long-term risk assessment of the Piako River scheme stability including channel surveys and modelling work. This work has addressed residual risk and an assessment of the likely impacts of sea-level rise and sediment movement within the channel.
- As part of the Ngatea District Plan Change, HDC undertook a detailed assessment of flood/drainage hazards around Ngatea.

5.1.1 Relationship to river & catchment management

River and catchment management has an important relationship to the ongoing assessment and consideration of Hauraki flood hazards. EW manages rivers and their catchments in partnership with local authorities and communities to control flooding and erosion and to help maintain stable rivers and streams.

Stream and river stability, soil stability and flooding are influenced by natural events and processes and people's activities over an entire catchment. Therefore, it's important that EW looks at and manages the catchment as a whole. Physical works and services need to consider land use, hazard management and environmental requirements within the catchment.

The river and catchment programmes focus on providing physical works, services and advice to landowners. We aim to:

- reduce the risk of soil erosion and flooding
- reduce the amount of sediment getting into waterways
- improve water quality
- improve river stability
- improve river environments, for example, creating a better habitat for a wider variety of plants and animals (improved biodiversity).

EW manages three main types of river and catchment works to help achieve the above aims: land management and soil conservation works, river management works and flood control works.

5.1.2 General hazard and risk considerations

The following considerations are of critical importance when assessing the flood hazards of the Hauraki district:

- While flood hazards have been identified as a primary risk, there are a number of other hazards that exist within the area. In order for a comprehensive risk assessment to be undertaken, flood hazards need to be assessed in light of other hazards such as earthquake
- Flood hazards are being compounded by the effects of climate change on storm events, river flooding and sea level rise
- The existing protection levels afforded by the Lower Piako River scheme are crucial to mitigating flood risks in the area.
- The direction of recent changes to river flood risk management suggests that mitigation based solely on engineering works is unsustainable, and that any solution will involve multiple risk mitigation actions.

5.1.3 Conclusion

The recommendations on natural hazards priorities are as follows:

- River flood risk is the highest priority hazard affecting the district and the risks associated with it should be managed as a matter of priority
- The flood risks are largely dependent upon the ongoing management of river flood protection schemes
- District growth areas and priorities are a key driver for flood risk management work
- National and regional directions on river flood risk management will increase the importance of recognising rivers and natural systems and taking a risk management approach.

Therefore, river flood issues should be addressed as a priority. There is a strong need to closely link river flood management, hazard management and district infrastructure/community development work based on district growth priorities.

Appendix 1 Statutory and legal framework

The Resource Management Act (RMA) 1991

The RMA sets in place a planning framework with respect to hazard management. The Act defines the role of central government agencies, such as the Department of Conservation, and regional and district (and city) councils such as EW and HDC respectively. The mechanisms to achieve this include a hierarchy of linked interrelated policy statements supported by non-statutory documents such as action plans developed to address individual (river flooding) or a suite of related hazards (coastal erosion and flooding).

The RMA assigns to regional councils responsibility for the integrated management of natural and physical resources within their region. Regional councils are required to control the use of land, the taking and use of water, and the planting of plants in water bodies for soil conservation, the quality of water, the quantity of water, and the avoidance or mitigation of natural hazards. Regional and district functions are specified by the Act and are outlined in *Appendix 2*.

Long-term management strategies

The RMA provides for the long-term management of hazards through various policy mechanisms, some of which are discussed above. These include, in the case of coastal hazards, the New Zealand Coastal Policy Statement and regional coastal plans, and for other hazards regional policy statements, and district plans. Policy implementation is given effect through various methods and can include non-statutory mechanisms such as education programmes, advocacy and community consultation and engagement; or statutory mechanisms such as the application of rules and standards in respect of defined zones. Monitoring strategies provide feedback on the effectiveness of the various methods employed to mitigate or avoid the adverse effects of hazards.

Short-term management responses

Section 330 of the RMA builds on powers presently available to Council pursuant to the Public Works Act 1981 (s.234) and the Local Government Act 1974 (s.708A(3)). The section permits activities in an emergency situation that might otherwise contravene the Act. The section empowers employees and agents of councils to enter upon land and take action in an emergency situation. Section 331 of the Act requires that the appropriate consent authority must be advised when emergency works have been undertaken. Resource consents must be sought where adverse effects of the activity continue. The provisions and a discussion of section 330 is outlined in *Appendix 3*.

Resource management policy statements

The RMA requires that a hierarchy of policy documents is prepared by central, regional and local government bodies with respect to resource management issues generally including the management of natural hazards. The documents are interrelated (to achieve integrated management) and the Act requires that subordinate regional and district documents are not inconsistent with each other or any national policy statement.

Regional Policy Statement (RPS)

EW's RPS incorporates policy on natural hazards. The statement indicates the dual role of the region and district in managing hazards, but that the district council is likely to take a lead role in managing responses to localised hazard events.

The RPS identifies implementation methods for the management of natural hazards relating to both the region and the district. Those relating to district councils, in summary, refer to:

- the development of objectives, policies, rules and methods in district plans to control the use of land;
- the delivery of environmental education programmes;
- the implementation of hazard mitigation plans;
- to provide information on natural hazards through land information memoranda;
- to work in partnership with the regional council.
- Similarly, those implementation methods relating to the regional council include:
- the development of specific objectives, policies, rules and/or other methods in regional plans for the avoidance or mitigation of coastal hazards;
- to take a lead role in the collection, analysis, storage and communication of coastal hazard information to territorial authorities;
- the development, in conjunction with territorial authorities and the wider community, hazard mitigation plans for managing the risks associated with coastal hazards;
- to support the development and implementation of environmental education programmes related to coastal hazards.

The text on the “Management of Natural Hazards” contained in the Regional Policy Statement is attached as *Appendix 4*.

Hauraki District Plan

Council’s proposed district plan incorporates a section on “Natural Hazards”. This section identifies natural hazard issues and the objectives, policies and methods for their management.

The primary aim of the objectives is to avoid the creation and effects of hazards, promote protection of existing physical resources and avoid, as far as practical, the establishment of hard engineering structures. Supporting policies relate, in summary, to the management of development, the identification of hazards, promotion of community awareness, and the need for contingency planning.

A range of implementation methods is identified to give effect to the policies. These include the establishment of rules relating to the management of development, identification of hazard areas, the development and review of hazard management plans, maintenance of hazard records, promotion of beach care groups and to provide information on hazards to relevant agencies.

The present HDC plan has sections which cover management of natural hazards and flood ponding zones. A full copy of the District Plan can be downloaded from Hauraki District Council’s website.

Other hazard management statutes

This section will examine in greater detail the legal obligations for EW and the HDC and the organisations' staff and elected members in terms of other relevant legislation including the Civil Defence Emergency Management Act 2003, Building Act 1991, Soil Conservation and Rivers Control Act 1941 and the Local Government Official Information and Meetings Act 1987. It will also address in brief the role of council with respect to the Reserves Act 1977 and the Hauraki Gulf Marine Park Act 2000.

Civil Defence Emergency Management (CDEM) Act 2002

This Act establishes a framework for CDEM aimed at building resilient New Zealand communities. Its purpose is to improve and promote the sustainable management of hazards in a way that contributes to the social, economic, cultural, and environmental well-being and safety of the public and also to the protection of property. It also provides for the planning and preparation for an emergency and for response and recovery in the event of an emergency.

Under the Act, HDC is a member of the Waikato CDEM Group (a consortia of local authorities working with emergency services and lifeline utilities to reduce risk across the region). It is also one of the councils that make up the Thames Valley Emergency Operating Area (TVEOA).

Soil Conservation and Rivers Control Act 1941

The provisions of the Soil Conservation & Rivers Control Act 1941 apply only to regional councils and determine their role for river and catchment management and include the following responsibilities:

- To minimise and prevent damage by floods and erosion;
- To construct, reconstruct, alter, repair, and maintain all such works it considers necessary;
- To exercise a general supervision over local authorities of any powers they exercise as to river and drainage matters;
- To give directions for the guidance of local authorities with regard to the above matters.

EW also has responsibility for land drainage in terms of the provisions of the Land Drainage Act 1908, primarily within the specified drainage areas scheduled in 1989.

Local Government Act 2002

Section 551 of the Local Government Act outlines the river clearance powers available to territorial local authorities. At present, responsibilities for these functions are generally shared.

Local Government Official Information and Meetings Act 1987 (LGOIMA)

Section 44A of LGOIMA deals with Land Information Memoranda (LIM). Any person may apply to council for a LIM in respect of any property in the district. Among the matters that must be included in a LIM is information relating to natural hazards that is known to council.

Unless there is proof to the contrary hazard information contained in a LIM shall be sufficient evidence of the correctness, as at the date of issue, of any hazard information. There is no opportunity or grounds that allow council to withhold hazard information.

These latter provisions of the Act have implications generally for council when receiving information such as reports that apply to a property or group of properties and more specifically when that information relates to hazards.

An example of this within the present context is the recent review by EW of the technical data that supports the hazard lines contained in the Hauraki District Plan and which are used as a policy mechanism to avoid the effects of coastal hazards when assessing building and/or resource consent applications.

Building Act 1991

Project Information Memoranda (PIM)

A similar mechanism as land information memoranda is contained at Part V of the Building Act. Sections 30 and 31 of the Act makes provision for persons wishing to proceed with building works to first obtain a PIM in respect of the works and the land upon which the works are to be established. As with the provisions of LGOIMA every PIM shall include information on “special features” of the land likely to be relevant to the proposed building work identifying, amongst other things, potential hazard information that falls within council’s current knowledge-base. This requirement places a great deal of responsibility on council to get it right. One of the challenges will be to ascertain the “special features” of the land that do fall within council’s knowledge. The section intends a considered response by council that will involve some research and investigation.

Building Consents

Council must refuse to issue a building consent in respect of any application for building works on land that is subject to, amongst other things, flooding or erosion or the building work itself is likely to worsen the effects of or cause erosion or flooding. If council is satisfied that adequate provision has been made to protect the hazard prone land a building consent will be issued.

Where council considers that the building works will not increase losses arising from an extreme natural event then a building consent may issue in terms of s74 of the Building Act, 2004 provided a notice to such effect is registered against the Certificate of Title of the land upon which the building works stand. The section absolves Council, its officers and elected representatives of any liability if the building works are subsequently damaged by an extreme event.

Reserves Act 1977

The Reserves Act guides district councils such as the HDC in how they manage reserve lands that fall within their jurisdiction. It provides for the acquisition, control, management, maintenance, preservation (including the protection of the natural environment), development, and use, and to make provision for public access to the coastline and the countryside.

As the administering body for coastal reserve land HDC must prepare a management plan for this land. Such plans must provide for and ensure the use, enjoyment, maintenance, protection, preservation, and, where resources permit, the development of the reserve.

Plans must be submitted to the Minister of Conservation for approval within 5 years after the date of appointment of the administering body, although this time may be extended. In preparing a management plan public notice must be given, and all submissions received must be considered.

Local authorities must also keep management plans under continuous review so that they are adapted to changing circumstances or in accordance with increased knowledge.

Hauraki Gulf Marine Park Act 2000

The Hauraki Gulf Marine Park was enacted in recognition of the importance of the Hauraki Gulf to the people of New Zealand and those living in the Auckland and Waikato Regions in particular. The coastline and Department of Conservation estate within the HDC is contained entirely within the Park's boundaries so the Act is of direct relevance to Council's business.

A key purpose of this Act is to integrate the management of the natural, historic, and physical resources of the Hauraki Gulf, its islands, and catchments.

As part of its identification of strategic issues affecting the Gulf and its catchments the forum has identified natural hazards as a significant issue.

It is worth noting that the effect of the HGMPA is that of a national policy statement constituted under the RMA. In terms of precedence it sits below the New Zealand Coastal Policy Statement and above the Regional Coastal Policy Statement.

Appendix 2 HDC/EW RMA functions

Functions, powers and duties of local authorities with respect to hazards as defined by the Resource Management Act 1991

Section 30(1)(d)(v):

30. Functions of regional councils under this Act:

(1) Every regional council shall have the following functions for the purpose of giving effect to this Act in its region:

...(d) In respect of any coastal marine area in the region, the control (in conjunction with the Minister of Conservation) of—

...(v) Any actual or potential effects of the use, development, or protection of land, including the avoidance or mitigation of natural hazards ...

And section 31(b):

Functions of territorial authorities under this Act—

Every territorial authority shall have the following functions for the purpose of giving effect to this Act in its district:

...(b) The control of any actual or potential effects of the use, development, or protection of land, including for the purpose of the avoidance or mitigation of natural hazards...

Section 62(ha) requires that a regional council in its regional policy statement defines:

For the region or any part of the region, which local authority shall have responsibility within its own area for developing objectives, policies, and rules relating to the control of the use of land for—

(i) The avoidance or mitigation of natural hazards ... and may state particular responsibilities for particular hazards ... or group of hazards ...; but if no responsibilities for a hazard ... are identified in the policy statement, the regional council shall retain primary responsibility for the hazard ...

Appendix 3 RMA Section 330

Provisions and discussion of Section 330 of the Resource Management Act 1991

Section 330 provides (emphasis added):

Emergency works and power to take preventive or remedial action—

Where—

Any public work for which any person has financial responsibility; or

Any natural and physical resource or area for which a local authority or consent authority has jurisdiction under this Act; or

(c) ...

is, in the opinion of the person or the authority ..., affected by or likely to be affected by—

An adverse effect on the environment which requires immediate preventive measures; or

An adverse effect on the environment which requires immediate remedial measures; or

(f) *Any sudden event causing or likely to cause loss of life, injury, or serious damage to property—*

the provisions of sections 9, 12, 13, 14, and 15 shall not apply to any activity undertaken by or on behalf of that person, authority, ... or mitigate any actual or likely adverse effect of, the emergency.

Where a local authority or consent authority—

(a) *Has financial responsibility for any public work; or*

(b) *Has jurisdiction under this Act in respect of any natural and physical resource or area—which is, in the reasonable opinion of that local authority or consent authority, likely to be affected by any of the conditions described in paragraphs (d) to (f) of subsection (1), the local authority or consent authority by its employees or agents may, without prior notice, enter any place (including a dwellinghouse when accompanied by a constable) and may take such action, or direct the occupier to take such action, as is immediately necessary and sufficient to remove the cause of, or mitigate any actual or likely adverse effect of, the emergency.*

As soon as practicable after entering any place under this section, every person must identify himself or herself and inform the occupier of the place of the entry and the reasons for it.

...

The Environment Court in recent decisions has made the following findings in relation to s.330:

(a) The word “likely” imports an element of probability as opposed to mere possibility or potential.

(b) The types of adverse effects are extremely diverse given the definition of “environment” in s.2 of the RMA.

Three areas of judgement fall to be applied —

Whether there is a situation under paras (d), (e), or (f) of s.330(1);
An opinion is to be formed as to the effect or likely effect upon the public work, natural and physical resource or area; and
A decision is to be taken in accordance with the concluding part of the subsection.

In each of the areas of judgement under subs (1), the person or body must form the requisite opinion, acting reasonably and responsibly in the circumstances.

- (e) By prefacing the word “opinion” with “reasonable” in subs (2), Parliament has chosen to reinforce the need for an opinion to be held reasonably. Nevertheless, an opinion under subs (1) must still be held responsibly as well as reasonably.
- (f) The concept of immediacy is encompassed, both in measures to be taken under subs (1)(d) and (e), and in the action allowed for under subs (2). Whether preventative or remedial measures under subs (1)(b) or (c), or action under subs (2) are required to be taken immediately, is a matter for case-by-case judgement. The background circumstances may, however, be expected to include evidence of a kind sufficient to lead one reasonably to the view that the relevant situation requires an immediate response.

Further observations based on case law in respect of specific provisions of s.330 include:

1. Sudden events or emergencies — subs (1)(c)

a. “Sudden emergency” test

In *Gisborne DC v Falkner*, the Planning Tribunal examined the pre-RMA Amendment Act 1993 “sudden emergency” test. It determined that damage by storms, although causing a state of danger, did not fulfil the test as they were not unexpected. The statute emphasises suddenness, and an emergency should be limited to a state of danger that is unexpected. Earlier case law determined that sudden emergencies are events that are otherwise unforeseeable. It is suggested that despite the removal of “emergency” and replacing it with “event”, these cases still assist in determining what is a “sudden event”. *Falkner* also applied subs (1) to determine who was responsible for the works on the facts of that case. The applicability of Mean High Water Springs (MHWS) as the demarcation between regional and district jurisdictions prevails.

The Court had found that where the council had failed to act for several years to address the issue of sewage disposal, for example, it could not then rely on the emergency powers of ss.330 or 330A. The statute requires that there be both immediacy and urgency.

b. Foreseeability

In *Auckland CC v Minister for the Environment*, the Environment Court held that the fact that a situation or occurrence, as contemplated by s.330(1), may have been foreseen as a possibility, does not operate to prevent an “emergency” from arising if the relevant elements or qualifying aspects are satisfied.

2. Immunity from prosecution in relation to emergency works

Section 18(2) of the RMA provides that: “no person may be prosecuted for acting in accordance with section 330”. In *Southland RC v Invercargill CC* (1996), the District Court found that persons charged with statutory functions in respect of works which cause environmental harm are to be permitted to exercise emergency powers without

fear of prosecution. Accordingly, if a prosecution is commenced, the onus is on the informant to prove that s 330 powers were not properly exercised.

This approach was not accepted in *Canterbury RC v Doug Hood Ltd* (1998), where his Honour followed the judgement of the High Court in *Bay of Plenty RC v Bay Milk Products Ltd* (1996); — the onus is on the defendants to establish that the defence of immunity is available. Two salient issues arise that are implicit but perhaps not immediately apparent in terms of the preceding discussion on s.330. The issues are:

1. Regional versus district Responsibilities

It is axiomatic that each of the authorities can only exercise authority within its own area of jurisdiction. The demarcation between regional and district jurisdictions is defined by Mean High Water Mark Springs (MHWS). A corollary of this, as it applies to an emergency situation and especially as it applies to coastal hazards, is that for a council to be able to clearly exercise its authority the MHWS needs to be defined in advance of any extreme event. Prudence would dictate that this is a sensible course of action for a council where coastal hazards are an issue to undertake in certain anticipation of the next severe storm.

2. Exercise of Section 330 Authority in Relation to Council Policy

S.330 makes it clear that any person acting in accordance with that section is immune from subsequent prosecution. It is unclear however, what the position is if a person in exercising authority in terms of s.330 on behalf of council acted contrary to council's formally adopted policy. Does, for example, a liability claim fall on the body corporate or the individual? The Act offers no assistance in this regard but the matter is important and has therefore been referred to council's solicitor for advice. It would seem however that in the absence of council policy if a person in exercising s.330 authority met the tests of forming their opinion reasonably and responsibly then this would constitute a defence against prosecution or liability claim.

Appendix 4 RPS & natural hazards

Policy One: Consistent Management of Natural Hazards

Ensure that natural hazards are managed in a consistent manner throughout the Waikato Region and roles and responsibilities of agencies are defined.

Implementation Methods:

1. The Waikato Regional Council (EW) will:
 - i. develop specific objectives, policies, rules and/or other methods in regional plans for the avoidance or mitigation of natural hazards in the coastal marine area and in the beds of rivers and lakes
 - ii. take a lead role in the collection, analysis, storage and communication of natural hazard information to territorial authorities
 - iii. prioritise risks from natural hazards across the Region for further investigation, in consultation with territorial authorities and the Region's community
 - iv. develop, in conjunction with territorial authorities and the wider community, hazard specific mitigation plans for managing the risks associated with natural hazards
 - v. implement those aspects of mitigation plans that are relevant to EW's functions
 - vi. co-ordinate responses to regionally significant natural hazard events with those of territorial authorities, network utility operators, government departments and other relevant agencies
 - vii. support the development and implementation of environmental education programmes related to specific natural hazards.

2. Territorial authorities will:
 - viii. develop specific objectives, policies, rules and/or other methods in district plans that control the use of land (except for in the beds of lakes and rivers and the coastal marine area) for the avoidance or mitigation of natural hazards
 - ix. deliver environmental education programmes on local natural hazards to their communities
 - x. implement relevant hazard specific mitigation plans through building consents and other regulatory and non-regulatory methods
 - xi. provide information on the presence of natural hazards at specific sites through land information memoranda and project information memoranda where such information is known by the territorial authority
 - xii. work in partnership with the Waikato Regional Council (EW) and their communities to ensure efficient and effective response and recovery to natural hazard events including planning for emergencies.

1. Local authorities will advocate that other agencies such as network utility operators and neighbouring regional councils work with territorial authorities and the Waikato Regional Council (EW) for the management of natural hazards through the development of partnership agreements and memoranda of understanding.

2. Local authorities will advocate that all the roles and responsibilities identified above are implemented through strategic plans, annual plans, district and regional plans, civil defence plans and partnership agreements within three years of this Regional Policy Statement becoming operative.

Appendix 5 Other work

1. Hydraulic modeling

EW has developed a comprehensive/dedicated hydraulic modeling programme in response to a rapid increase in resource consent applications and river management issues. Hydraulic modeling is carried out on a priority basis and includes both one dimensional (Mike 11) and two dimensional (Mike 21) outputs. It is seen as being one of the most crucial elements of our flood risk management approach

EW's modeling programme aims to achieve the following:

- Outputs are based on best practice and methodology and includes all available information such as hydro-met data, climate change allowances, sea level rise, and land information
- Models provide a robust and sound basis for assessing/determining likely extents of flooding from a given-sized event (or across a range of scenarios)
- Flood hazard risk maps are produced that as accurately as possible depict the flood extent, velocity, and depth of floodwaters
- District Plans use the assessed flood hazards/levels and employ a sound planning framework as a basis for reducing risks.

2. LIDAR surveys

The proposed LIDAR survey (including benefits, costs, and coverage area) of the Hauraki district is outlined in Appendix 7.

3. River flood risk management

Following the significant flood events of 2004 (re: Manawatu and Bay of Plenty), the Government commissioned a full review on how the country was dealing with and managing flood risks. Consequently, a number of projects developed and lead by the Ministry for the Environment and Local Government New Zealand were commissioned to address the issue at both the national and regional level. To this end, EW is developing a Regional Flood Risk Management Strategy as a basis for guiding policy and decision making for the region.

4. Categorisation of flood risk

To assess flood risks, it is necessary to consider the nature and degree of the potential impacts of flooding, which are dependent on the magnitude of specific hazard parameters within the overall flood hazard. During flooding, the primary hazard parameters in terms of potential impacts are:

- Flood depth: The potential impacts directly related to this parameter include:
 - Drowning (flood waters rising higher than waist level)
 - Damage (flood waters damaging property and contents as they rise)
 - Isolation (deep flood waters preventing escape by flood victims or access by emergency services)
- Flood flow velocity: The potential impacts directly related to this parameter include:
 - Drowning (flood waters flowing too fast for people to maintain balance or washing away occupied vehicles)
 - Damage (the force of fast flowing flood waters damaging structures)
 - Isolation (the force of fast flowing waters and/or debris transport preventing escape by flood victims or access by emergency services)

The severity of flooding is largely governed on the magnitude of these two primary hazard parameters. For example, the higher the combined depth and velocity, greater are the risks to people and property.

EW's flood hazard risk identification strategy defines five levels of hazard severity based on the combination of depth and velocity, as determined in the following tables:

Categorisation of flood hazard severity

Flood flow velocity	Flood depth (above ground level)			
	Less than 0.5m	0.5 – 1.0m	1.0m – 1.5m	Greater than 1.5m
Less than 0.5m/s	1	2	3	4
0.5m/s – 1.0m/s	1	2	4	5
1.0m/s – 2m/s	2	3	5	5
Greater than 2m/s	2	4	5	5

Definition of flood hazard severity categories

Severity category	Hazard category	Risk to life	Risk to property
1	Minor	No significant risk of loss of life	Minor damage to properties and contents
2	Moderate	Loss of life among the vulnerable population possible but unlikely	Moderate damage to properties and contents Possible structural damage to properties
3	Severe	Loss of life among the vulnerable community foreseeable Loss of life among the wider community possible but unlikely	Significant damage to properties and contents
4	Very Severe	Loss of life among the vulnerable community likely Loss of life among the wider community foreseeable	Major damage to properties and contents Possible structural damage to properties
5	Extreme	Loss of life among the whole community likely	Probable structural damage to, or complete destruction of, properties

Explanation

Category 1 is a minor risk area that generally only experiences low flows and/or ponding. Development in these areas may be a permitted activity with minimum floor levels applying.

Category 2 is a relatively minor risk area that experiences low flows and/or ponding but at slightly greater velocity and/or depth as in Category 1 areas. Development in these areas may be a controlled activity with minimum floor levels applying.

Category 3 is a moderate risk area that generally experiences higher flood velocities and water depth than Categories 1 and 2 posing a greater risk to people and property. Development in these areas may be a discretionary activity and be subject to very strict conditions.

Category 4 is a severe risk area that experiences significant flooding conditions due to very high velocities and water depth. These areas pose a great level of risk to people and property and are considered to be located within the primary overland flow pathway. Development should therefore be a prohibited activity in these areas.

Category 5 is an extreme risk area that experiences the most severest form of flooding conditions due to very high velocities and water depth. These areas pose the greatest level of risk to people and property and are considered to be located within the main floodway. Development should therefore be a prohibited activity in these areas.

As a general rule development within the minor to moderate flood risk could be allowed subject to floor level restrictions and set backs, while development within the severe to extreme flood risk areas should be avoided and or prohibited.

This approach enables the translation of the flood extent map (depicting the existing situation) into depth, velocity and the five risk levels.

Appendix 6 Key to Table 4

Risk analysis evaluation key

Measure of likelihood

Level	Descriptor	Description
A	Almost certain	Expected to occur in most circumstances
B	Likely	Will probably occur in most circumstances
C	Possible	Might occur at some time
D	Unlikely	Could occur at some time
E	Rare	May only occur in exceptional circumstances

Measure of consequence of impact

Level	Descriptor	Detail description
1	Insignificant	No injuries, little or no damage, low financial loss
2	Minor	First aid treatment, minor building damage, medium financial loss
3	Moderate	Medical treatment required, moderate building and infrastructure damage, high financial loss
4	Major	Extensive injuries, high level of building and infrastructure damage, major financial loss
5	Catastrophic	Deaths, most buildings extensively damaged and major infrastructure failure, huge financial loss

Risk analysis matrix – level of risk

Likelihood	Consequences				
	1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic
A Almost certain	High	High	Extreme	Extreme	Extreme
B Likely	Moderate	High	High	Extreme	Extreme
C Possible	Low	Moderate	High	Extreme	Extreme
D Unlikely	Low	Low	Moderate	High	Extreme
E Rare	Low	Low	Moderate	High	High

Appendix 7 Proposed Light Detection and Ranging (LIDAR) Survey Programme

Background

LIDAR stands for *Light Detection And Ranging* and is an example of an active remote sensing technique particularly suited to developing terrain elevation data. Geographic data can be acquired by various methods, including a variety of techniques which fall under the category of remote sensing. Remote sensing is often used as a means of collecting large amounts of data in a relatively short time frame. It is an extremely valuable source of information for many applications, including land use and land cover mapping, agricultural and environmental resource management, mineral exploration, weather forecasting, global change research, and terrain elevation.

A typical LIDAR system consists of a plane equipped with a rapidly pulsing laser unit, an accurate clock, Global Positioning System (GPS), inertial measuring unit, and associated computer/electronics equipment. A surveyed ground location within the sampling area and differential post processing allows for accurate geo-referencing of the LIDAR data.

The LIDAR instrument transmits pulses of laser light to a target; some of the light is absorbed and some is reflected back, measured, and analyzed. Differences between the properties of the light which were transmitted and those which were received are analyzed to produce the desired data. Ranges are calculated based on the difference between the time the signal left the transmitter and the time it returned to the transmitter.

Accurate geo-referencing is developed by comparing onboard GPS data with GPS of known on-the-ground control locations, differentially correcting the plane's location. The onboard inertial system allows correction for acceleration, pitch, and roll of the plane as it flies along.

Benefits

Generally, LIDAR data is used in the following applications:

- spot heights
- Digital Elevation Model (DEM), Digital Terrain Model (DTM), Digital Surface Model (DSM)
- contours
- feature extraction
- building footprints and heights
- vegetation measurements
- breakline definition
- road centre-line location and road surface modelling

LIDAR also produces value-added products such as:

- hydrologically enforced terrain models
- data fusion
- view shed analysis
- virtual reality / augmented reality
- 3D fly-through

The applications possible from LIDAR information include flood modelling, corridor

mapping, wireless network planning, transportation, power line mapping, hazard clearance, natural resource assessment, demographic profiling and urban planning.

There are a number of projects currently underway or planned under both council's LTCCP that will benefit from a LIDAR survey. These benefits are outlined below.

LTCCP project/outcome area	Benefits
Hauraki District Plan Review	<ul style="list-style-type: none"> • Better identification of planning zones or areas for the management of land use within the district (e.g. avoiding or managing high hazard areas). • Updating the corporate data base with a snap shot of highly accurate spatial (contour) information reflecting the state and condition of the environment, especially urban, infrastructure, floodplain, upper catchment and coastal information. • Determination of building footprints and heights.
Asset management	<ul style="list-style-type: none"> • Better definition of urban areas for asset management planning and modelling
Ngatea stopbank stability	<ul style="list-style-type: none"> • Accurate determination of stopbank heights and surrounding ground levels in terms of mean sea level. • Provision of high quality benchmark information to allow trend analyses if repeated surveys are carried out (say once every 5 years).
Hauraki natural hazard and risk assessment project	<ul style="list-style-type: none"> • Flood plain areas more clearly and accurately defined and will provide highly accurate input data into any agreed modelling work. • Provision of high quality benchmark information to monitor tectonic (seismic) processes within the district. Also allows trend analyses to be undertaken if repeated surveys are carried out (say once every 5 years).
Roading network	<ul style="list-style-type: none"> • Accurate determination of road heights and surrounding ground levels in terms of mean sea level. Also allows trend analyses to be undertaken if repeated surveys are carried out (say once every 5 years). • Road centre-line location and road surface modelling can also be determined.
Stormwater network	<ul style="list-style-type: none"> • Accurate determination of ground levels in terms of mean sea level to assist in overland flow modelling of storm water networks and surrounding ground levels. • Removes the need for GPS
Drainage areas	<ul style="list-style-type: none"> • Accurate determination of drainage/canal network gradients via ground contour information in terms of mean sea level.
Peat settlement monitoring	<ul style="list-style-type: none"> • High quality benchmark information which will allow trend analyses to be established if repeated

	surveys are carried out (day once every 5 years).
River channel assessment and scheme reviews (Piako and Waihou Rivers)	<ul style="list-style-type: none"> • Accurate determination of ground levels in terms of mean sea level to assist in monitoring channel movement and overland flow modelling of river systems.
River modelling	<ul style="list-style-type: none"> • Highly accurate digital terrain model and contour information necessary for hydraulic modelling, geotechnical assessments, catchment/erosion studies, flood hazard mapping information, and for assessment of performance of existing and proposed works.
Debris flow analysis (Coromandel/Kaimai Ranges)	<ul style="list-style-type: none"> • Highly accurate digital terrain model and contour information necessary for mapping susceptible catchments and modelling alluvial fan processes.
Other benefits	<ul style="list-style-type: none"> • Standardisation of datums (expressed where possible in terms of mean sea level) • All data geo-referenced from inception, which directly interfaces to GIS applications.

It is anticipated that the need for LIDAR survey data will increase as technical people/organisations become more conversant with the capabilities and advantages of LIDAR for landform, vegetation definition and bathymetry analysis purposes.

A LIDAR survey programme for the Hauraki district is currently being proposed for the 2007/08 financial year.

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