COASTAL & STORM HAZARDS WORKSHOP

Building understanding of hazards affecting coastal margins
25-26 March 2002
Quality Hotel
Hamilton

Proceedings

KNOWLEDGE

INFORMATION

AWARENESS

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WORKSHOP

NIWA
Taihoro Nukurangi

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Foreword

Coastal and Storm Hazards Workshop 2002

NIWA's Coastal & Storm Hazards Workshop was held at the Quality Hotel, Hamilton from 25 to 26 March 2002. The symposium brought together a wide variety of coastal practitioners including scientists, engineers and planners from throughout New Zealand with an interest in coastal and storm hazards research and identification/mitigation of those hazards.

Aims of the 2002 Workshop
The aims of the 2002 workshop were to provide:

- Research perspectives, via presentations, on the current state of the knowledge on various coastal and storm hazards in New Zealand, along with ideas on future research and development of tools & services.

- Practitioner perspectives, via presentations, on the shortfalls in the knowledge base, that are currently hindering progress on managing or mitigating coastal hazards in NZ, and to prioritise future knowledge-base needs (knowledge, information, databases, techniques, tools, education, policy) to improve coastal hazard management and raise communities awareness.

- A forum, via facilitated discussion groups, for researchers and practitioners to interact, identify research & development topics and help shape priorities for the next 5 years. The workshop groups explored two questions each day for different types of hazards: a) What are the priorities for future scientific work if we are to improve the assessment of risk and vulnerability? b) What other information is required if we are to increase hazard awareness and build resilient, sustainable communities?

Workshop organisation
The workshop was organised and partially funded by NIWA, with support from the Foundation for Research Science and Technology under contract C01X0015.

We are grateful to all the presenters and their organisations for their contributions and to Kevin Parnell (Univ. of Auckland), Craig Davis (Rodney DC), Hugh Leersynder (ARC), Willem de Lange (Univ. of Waikato), Richard Reinen-Hamill (Tonkin & Taylor), Brodie Young (ECAN), Andrew Laing (NIWA) and Malcolm Green (NIWA) who facilitated the discussion groups and provided summaries of proceedings. We thank Tania Billing for making most of the organisation arrangements and for her assistance with collating the proceedings, Linda Drury for coordinating displays and venue set-up, and Scott Stephens for compiling a summary of questions and workshop feedback.

The convenors were Robert Bell and Terry Hume from NIWA. The facilitator/chairperson was Jim Dahm of Coastline Consultants, Hamilton.

Outputs and outcomes
This record of proceedings comprises abstracts of the presentations, summaries of the discussions during the facilitated workshop groups, a list of participants, and the programme.

Key points from feedback through the discussion group sessions included:
- More effort on turning "hazard information" into "risk information";
- Urgent development of high-resolution topographic databases for coastal margins to ascertain inundation and socio-economic risks;
- More open access to data and in particular real-time data;
- Continuing to move from data to process-response models that cover long timescales;

- Inshore, as distinct from deepwater, wave forecasting and wave climates are required in most instances for shoreline applications;
- Importance of better weather and wind forecasts at higher spatial resolution than at present;
- Need for many localities and regions to quantify the coastal sediment budget—rates, inputs and exports—so we can assess long-term change;
- Closer links between science providers and local/regional authorities, particularly both parties working together to provide information that is easily assimilated by the general public, and science providers producing hazard/risk information that is appropriate for both the coastal marine area and adjacent coastal margins;
- Better regional predictions on future storminess, sea-level rise and climate-related changes for New Zealand as distinct from global IPCC projections;
- Dealing with the huge coastal planning issue of raising the public awareness of risks for seaside dwellers and building resilient communities;
- Better information on duration and probabilities of extreme events (including joint occurrences of processes such as tides, waves and storm surge, or combining river floods with storm surges and tides);
- More integration of coastal hazards with estuarine margins, which often contain the highest population densities;
- More widespread production and refinement of inundation and evacuation maps for low-lying coastal and estuarine areas for different risk levels to facilitate better planning, zonation of risk, and emergency preparedness;
- There is a low level of community preparedness and awareness of appropriate emergency responses for different hazards–need for community surveys and education;
- Paucity of information and data on potential socio-economic impacts of coastal hazards—need a damage database to evaluate risks. Socio-economic benefits of a "do-nothing" approach to hazard management need to also be properly evaluated, including for additional climate-change impacts;
- Concept of a national hazard centre supported to act as a clearing house for hazard information, services and data;
- Need for better flow of science through to policy e.g., forthcoming review of NZ Coastal Policy Statement, the fixing of absolute hazard lines under the RMA versus a risk-probability approach to delineating hazard zones, and integrating risk information with LIM reports under the Building Act.

Future initiatives

In August 2002, the Institute of Geological & Nuclear Sciences (GNS) and the Institute of Water & Atmospheric Research (NIWA) combined their complementary expertise to form the Natural Hazards Centre. The aim of this "virtual centre" is to provide planners and hazard managers with a "first port of call" for scientific information and services on any of the wide range of natural hazards New Zealand communities face. The second aim is to bring together expertise from a wide range of different bodies, including the Ministry of Civil Defence and Emergency Management, the Earthquake Commission, the Maritime Safety Authority, the Ministry for the Environment, the Insurance Council, Regional and District Councils, weather forecasters, emergency services, utilities, and tangata whenua, as well as researchers from universities, other CRIs, and research associations. The Natural Hazards Centre will develop a full communications strategy that will include a regular newsletter, public talks, media releases, training courses and a dedicated web page (www.naturalhazards.net.nz). It will also strengthen the growing stature of the biennial Natural Hazards Management Conferences held in even years (this year held at Te Papa).

Feedback forms from participants strongly endorsed the overall structure of the Coastal & Storm Hazard Workshop, comprising a mix of presentations and facilitated discussion groups, with perhaps more time needed on how the research could be used to implement better resource management. NIWA & GNS will look at holding these types of natural hazard workshops through the Natural Hazards Centre at regular intervals of 2 to 4 years.

Finally, these proceedings form an important document that summarises the state of the knowledge base and end-user needs and requirements for research tools and services. The Natural Physical Hazards strategic portfolio outline (SPO) sets out the investment priorities of the Foundation for Research, Science and Technology (http://www.frst.govt.nz/about/spo/hazards.pdf). This SPO is due for advancement later in 2003, when inputs such as this document will play an important role in shaping future research directions for coastal and storm hazards.

Rob Bell & Terry Hume
Workshop Convenors

ABSTRACTS

The FRST Framework and Directives for Hazards Research

Mark James
Regional Manager
NIWA - National Institute of Water and Atmospheric Research, Hamilton

This introductory talk gives an overview of the public-funded research process in New Zealand, the Foundation for Research, Science & Technology (FRST) framework, some directives for environmental protection such as hazards, the role of end-users and some recent initiatives with national centres.

The FRST process has gone through a number of changes in recent years. The most recent change in the process is a move towards greater emphasis on issues, innovation that benefits New Zealand and input from end-users in order to help formulate directions and enhance co-funding opportunities. Co-funding and leverage are particularly important now with the flat government funding for this type of research in New Zealand. FRST funds long-term strategic research and does not fund operational work. An example of operational research is the formulation of hazard management plans for a particular stretch of coastline or development of coastal plans.

The Foundation is presently reviewing a number of programmes and seeking new proposals from providers. The hazards work to be presented at this workshop contributes to the Natural Hazards Strategic Portfolio Outline (SPO) which aims to underpin hazard risk research in earthquake, volcanic, weather, land stability and coastal areas. The Hazards portfolio and programmes are scheduled for review at the end of 2003. This is later than some other SPOs because of the smaller number of industry groups, the long-term nature of the research and the small group of providers involved.

It is essential that end-users provide input to the formulation of programmes and the allocation process. Workshops such as this one on Coastal and Storm Hazards are an important part of this process and allow providers and end-users to jointly identify fundamental science that is needed to underpin hazard management. It is important here to emphasise that this fundamental work will underpin management options for the next 10-15 years and is not short-term.

NIWA's philosophy is to use an integrated interdisciplinary approach with a focus on prediction/forecasting capability to provide not only mitigation but also enable adaptation to the threats from hazards. Providing predictions, forecasts and tools and services are key outcomes of work in the Hazards programme. To do this NIWA has invested heavily in personnel and equipment such as the Cray T3E supercomputer.

A critical part of integrated environmental prediction capability for New Zealand, including hazards, is the implementation of mesoscale weather prediction. These will allow improved accuracy of forecasts, better management of resources such as hydro lake level management and prediction of air pollution, UV radiation, development and running large oceanic models and high resolution climate analysis. Components that relate directly to hazards are:

- More accurate flood forecasting.
- Improved targeting for maritime search and rescue.
- Better biohazard prediction.
- Better prediction of coastal hazards (waves and storm surge).

A major initiative by NIWA is to set up national “virtual centres” aimed at integrating skills and services with associated providers. These are not physical centres but rather provide a central point of contact focussed on end-users, enabling better information transfer and engagement with stakeholders. NIWA National Centres include: Climate, Climate and Energy Solutions, Water Resources, Fisheries and Aquaculture, and Aquatic Biodiversity and Biosecurity. NIWA are also working closely with GNS to set up a new Natural Hazards Centre focussed on all hazards i.e., hazards related to weather, earthquakes, coastal and volcanism. The main mechanism of information transfer will be through websites and regular updates such as the very successful Climate Update.

Workshops such as this are an integral and increasingly important part of the FRST process and an important opportunity to present the latest state of knowledge, identify shortfalls and help shape research directions. I urge you to make the most of this opportunity.

Overview of Coastal & Storm Hazards—The Role of Research

Rob Bell
NIWA - National Institute of Water and Atmospheric Research, Hamilton
http://www.niwa.co.nz/rc/prog/chaz/

Background

How important are coastal and storm hazards within the mixed bag of natural physical hazards or disasters around New Zealand?

One measure is the cost to the insurance industry of natural disasters (as they call them). The Insurance Council has published a disaster list[1] starting with the *Wahine* storm in 1968, which presently stands at a payout total of $1.2 billion (adjusted for inflation) over the 33-year period. While it is difficult to separate out causes of some disasters that produced multiple consequences, such as river floods, wind and coastal damage, the "payout" list is dominated by numerous river floods ($525M), even though the single biggest payout was for the 1987 Edgecumbe earthquake damage ($357M). Extreme winds account for around $150M of the payout. Coastal and maritime hazards have cost the insurance industry around $160M, although it is hard to separate out the coastal impacts for widespread storm events. This figure maybe just the tip of the iceberg as loss or damage of coastal properties in vulnerable areas is not always covered by insurance companies. Also, in the 134 years since 1868, around 300 coastal storm events have been documented for the Coromandel/Bay of Plenty region by Hay[2] and Dahm (pers. comm.).

Interestingly, the total payout for coastal/maritime hazards is dominated by the loss the ferry inter-island TEV *Wahine* and the tragic loss of 51 lives in 1968 ($125M), but the main cause was the atrocious sea conditions encountered by the vessel. A very similar sea state, with waves up to 13 m, was generated just recently off Wellington on Waitangi Day (2002) with no major maritime incidents in Cook Strait. Waves are now monitored in real-time for TranzRail ferry operations through a cooperative effort between Wellington Regional Council, TranzRail and NIWA. Unfortunately, the same storm led to the stranding of the log-carrier Jody F. Millenium at Gisborne.

Another measure of the impact of coastal/maritime hazards is loss of life or injury. New Zealand has a high rate of water-related deaths. In 2000, 135 people died, 31 (27%) in open-sea incidents, and 19 (14%) drowned at beaches or rocky shorelines. Further, ACC payout around $2M pa on injury claims for boating accidents. However, coastal erosion and coastal flooding seldom cause loss of life, because reasonable warning can be given. New Zealand is vulnerable to tsunami from remote Pacific sources and locally from seismic or landslide triggers, which potentially could cause significant loss of life. A tsunami event around the 1820s is purported to have killed many Ngai Tahu in Southland.

Complacency has crept in because generally we have had fewer coastal disasters since the late 1970s and the last notable tsunami event, triggered by the 1960 Chile earthquake, occurred nearly two generations ago. Coastal erosion and storms had some dramatic press in 1968 and the mid 1970's with the *Wahine* sinking, houses falling victim to the sea or sand spits being breached, while the most destructive storm of last century in 1936 is nearly past living memory.

Some examples of the destructive forces of coastal hazards at work are:

[1] At web site: http://www.icnz.org.nz/consumer/personal/cost.htm
[2] Hay, D.N. (1991). Storm and oceanographic databases for the Western Bay of Plenty. Unpublished MSc Thesis, Earth Sciences Dept., University of Waikato.

- July 2001 — Large waves and run-up caused major damage to coastal defences and natural gravel berms in South Canterbury along with extensive coastal flooding of farmlands;
- May, July 1978 — Series of storms combined with high tides. Destruction of sea-front protection and properties at Waiwera and Omaha North, plus severe damage to many front-row houses at Omaha North. Also caused the breach of sand spits at Mangawhai and Maketu;
- Sept 1976 — Kapiti Coast erosion leaves several houses "perched" during a severe storm;
- April 1976 — Two houses claimed by the sea at Ohiwa Spit in the Bay of Plenty, after futile attempts to hold back 8 m/yr coastal erosion of the sand spit;
- April 1968 — TEV *Wahine* sinks and widespread storm damage ($163M in insurance payouts);
- Feb 1936 — "Cyclone of 1936"—widespread wind, river flood and coastal damage, which unfortunately coincided with very high predicted tides;
- Mar 1936 — Storm tide floods much of the lower Hauraki Plains and parts of Auckland, with storm surge riding on the back of a 100-year extreme high tide.

So there is a clear case for the need of research and prudent planning to identify, understand and mitigate the varying array of coastal and storm hazards. There are also statutory requirements for regional and local government to recognize natural hazard risks in the coastal margins, plan to avoid or mitigate their effects, and limit building on hazard-prone land. Further, looming on the horizon is global warming and the associated accelerated rise in sea level that will put a different spin on hazard risks. For the coast there is no real silver lining to impending climate change.[3]

Hazards & Risk Management

Risk management is a growing "industry", so a few definitions from the Australian/NZ Standard[4] on Risk Management will be helpful to ensure consistency in our use of terms:

- *Hazard*—a source of potential harm or a situation with a potential to cause loss;
- *Consequence*—the outcome of an event expressed qualitatively or quantitatively, being a loss, injury, disadvantage or gain. There may be a range of possible outcomes with an event;
- *Likelihood*—a qualitative description of probability or frequency;
- *Risk*—the chance of something happening that will have an impact upon objectives. It is measured in terms of both consequences and likelihood;
- *Risk analysis*—a systematic use of available information to determine how often specified events may occur and the magnitude of their consequences;
- *Vulnerability*—the degree to which a system is susceptible to, or unable to cope with, adverse effects of hazards including climate change. Vulnerability is a function of the nature and

[3] Bell, R.G.; Hume; T.M.; Hicks, D.M. (2001). Planning for climate-change effects on coastal margins. Publication prepared for the Ministry for the Environment as part of the New Zealand Climate Change Programme, Publication ME 410, Ministry for the Environment, Wellington, 73 p.

[4] Risk Management, Australian/NZ Standard AS/NZ 4360:1999. 43 p.

magnitude of the hazard to which a human system is exposed, its sensitivity, and its adaptive capacity (i.e., its ability to adjust, cope or respond).

The generic risk management process is shown in Figure 1 (Fig. 4.1 from the Standard), and can be used as the framework for managing coastal and storm hazards. Regional and local government have a role in establishing the context of risk management (Step 1), although the RMA, NZ Coastal Policy Statement, Local Government Act[5] and the Building Act provide the statutory framework to work within. Research and monitoring have a role in identifying risks (Step 2), and then analyzing risks (Step 3). Resource managers have the responsibility of evaluating and treating risks (Steps 4 & 5), often with a paucity of information or a degree of uncertainty.

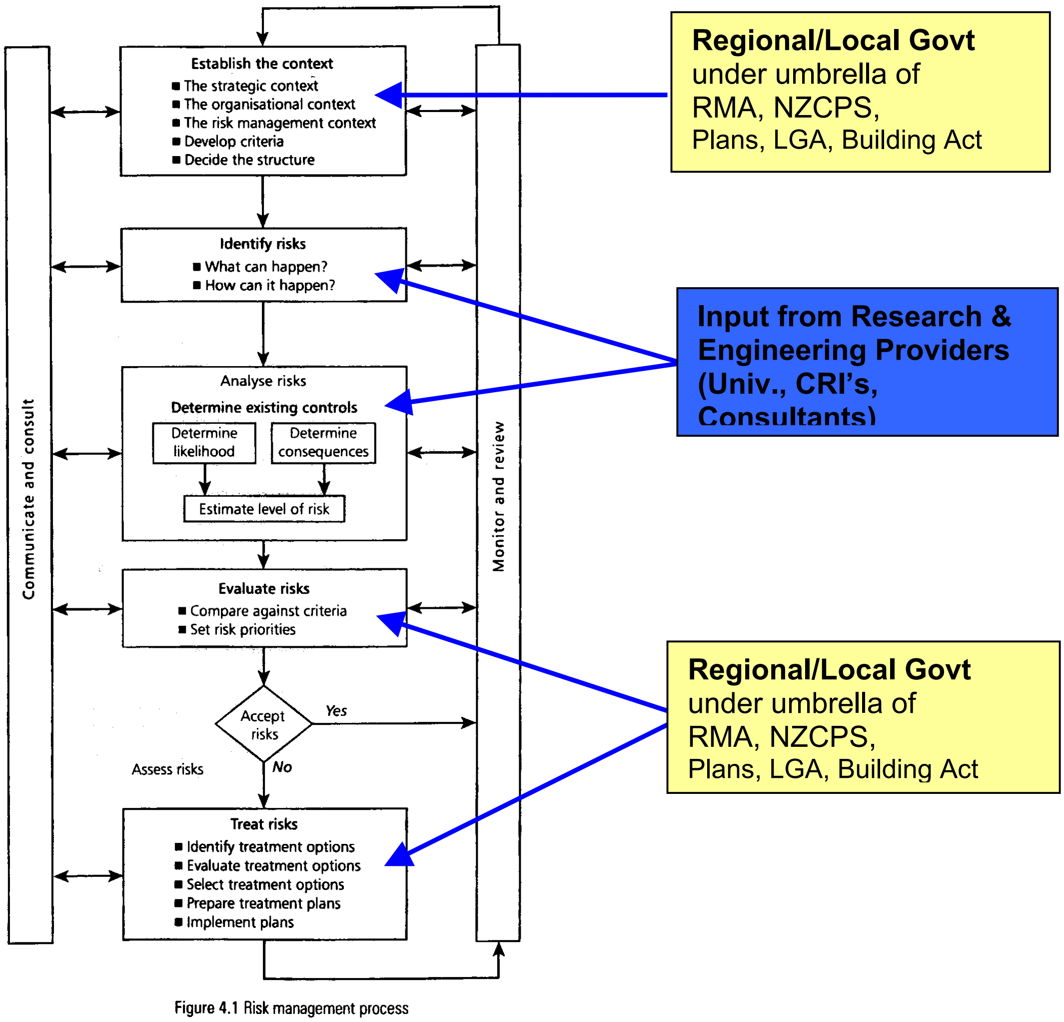

Figure 1: The Risk Management Process (AS/NZ 4360).

[5] Local Government Bill is likely to come into force on 1 July 2003, repealing parts of the LGA (1974)

Strategic Framework For Hazards Research
Any Government-funded research on coastal and storm hazards is guided by the Government's strategic directions that come through the Strategic Portfolio Outline on *Natural Physical Hazards*.[6] The Strategic Objectives have a theme of an "all-hazards" or "multiple hazards in communities" approach, which for the two types of hazards being addressed by this Workshop are:

Coastal Hazards:

- Understanding the physical processes leading to inundation and coastal erosion;
- Understanding vulnerability of the local and national economy, productive capacity and national infrastructure, including perceptions and acceptability of risk by communities.

Weather-related Hazards:

- Understanding the natural processes that cause floods, storms and droughts;
- Understanding vulnerability of the local and national economy, productive capacity and national infrastructure, including perceptions and acceptability of risk by communities;
- Developing improved modeling and forecasting skills.

Coastal Hazards
Figure 2 shows an overview of the array of hazards for coastal margins and coastal waters. Figure 3 shows the consequences of coastal hazards.

The root causes of coastal hazards (other than human error) are shown along the top row of Figure 2. These causes then drive physical changes in the ocean, coastal margin or hinterland that lead to hazards that require managing or avoiding. The hazards have been grouped into three main areas for research endeavour:

- Inundation & coastal flooding;
- Coastal erosion & sedimentation;
- Maritime/recreational hazards, including navigation, coping with oil spills, search & rescue operations, surf-zone conditions for water-contact recreation.

Storm Hazards
Figure 4 shows an overview of the array of storm hazards. The focus of the Workshop is on impacts on the coast, but storms have a wider effect than simply on the coast. For this reason we have extended the scope of the workshop to consider the wider implications of storm hazards.

The Challenge
Researchers generally need to specialize and concentrate on one particular hazard or a single aspect in order to become an expert in a topic. On the other hand, resource managers and planners are required to implement an "all hazards" approach for coastal and river margins in each region or community, often based on a paucity of information or a degree of uncertainty of the risks. The challenge for this Workshop is to extend our horizons by considering the entire array of coastal and storm hazards, prioritizing the information needs for various hazards based on what we know at present, and then developing a broad plan of research, monitoring, information needs and tools to build on for the next 5 or so years.

[6] Can be found on the FRST web site: http://www.frst.govt.nz/about/spo/hazards.pdf

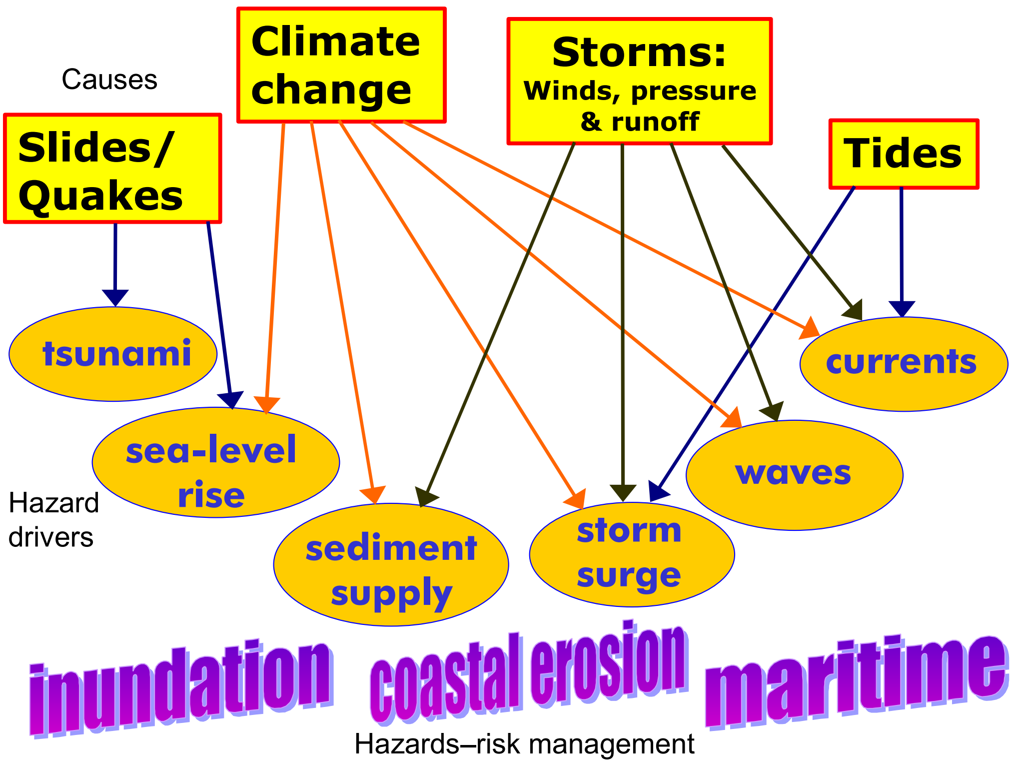

Figure 2: Interactions of the causes and drivers of the main coastal hazards that require risk management. "Maritime" hazards cover navigation, search & rescue, oil-spill operations, surf rips and recreational activities.

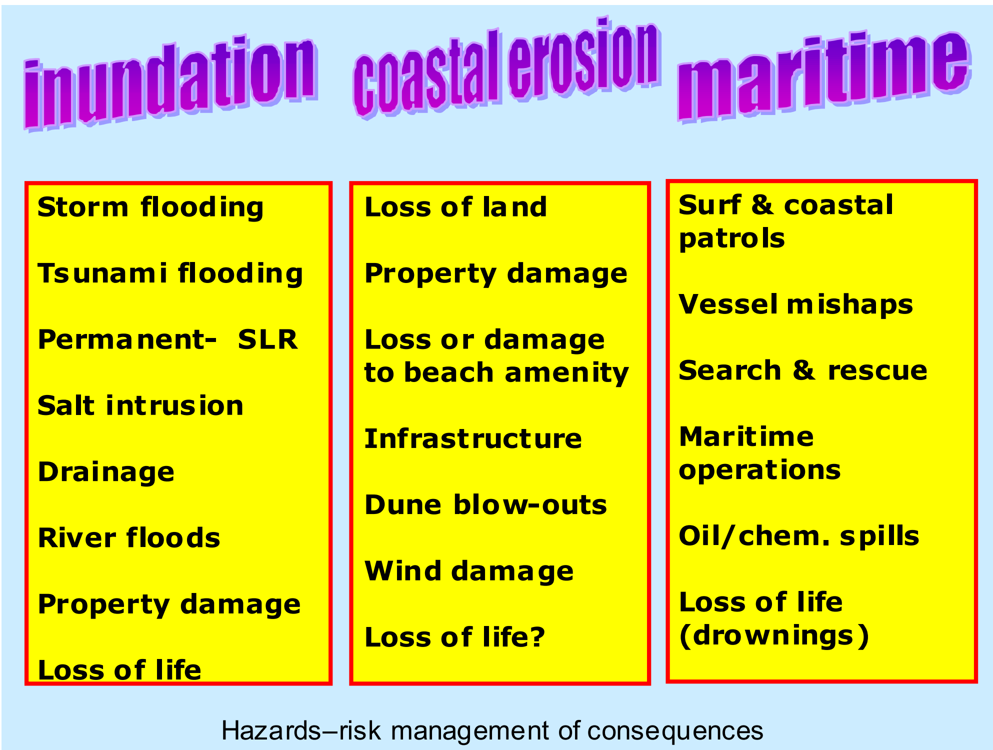

Figure 3: Consequences of coastal hazards that require risk management.

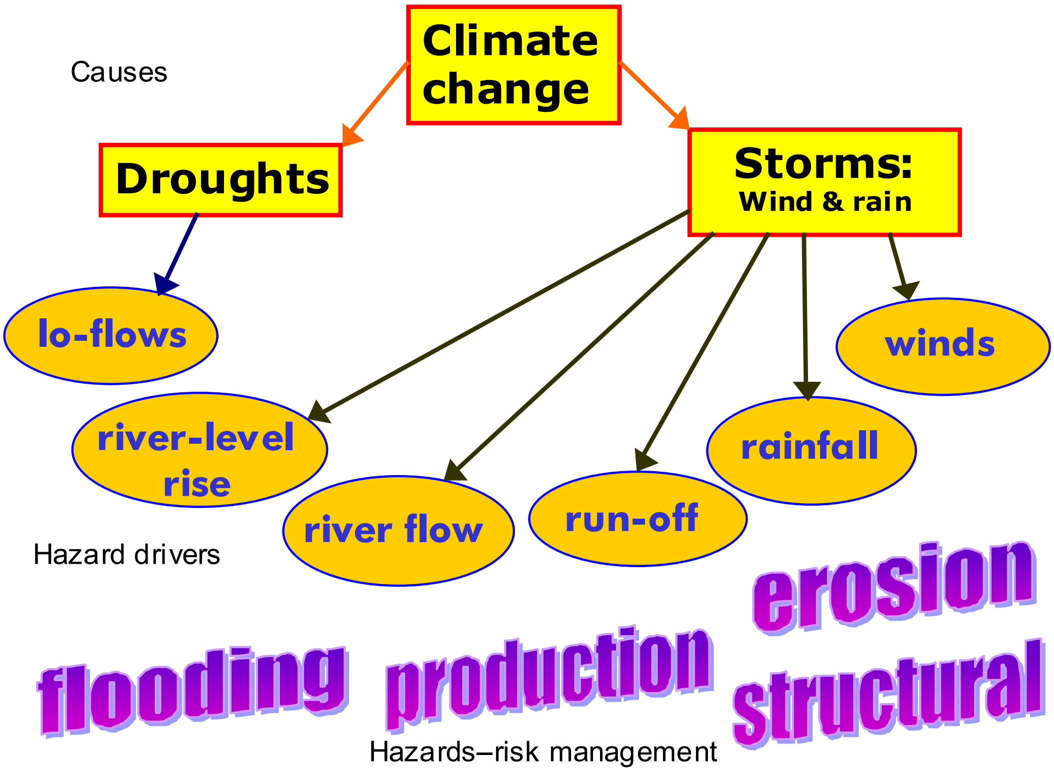

Figure 4: Interactions of the causes and drivers of the main storm & drought hazards that require risk management.

Coastal Erosion: A NIWA Perspective

Terry Hume
NIWA - National Institute of Water and Atmospheric Research, Hamilton
http://www.niwa.co.nz/rc/prog/chaz/news/erosion

This talk provides a background to coastal erosion research, outlines NIWA's approach to research on coastal erosion and provides examples of the types of studies that NIWA has undertaken.

Background and Issues Driving Research on Coastal Erosion

NIWA and its predecessors (MWD and DSIR) have been undertaking coastal research and survey for more than 30 years. Initially this was largely simple monitoring such as beach profiling coupled with observations of beach state, tide and wave climate at a variety of beaches. The Water and Soil Division (MWD) developed methodologies and undertook detailed coastal hazard mapping in several parts of the country including East Cape, Hokitika and Tairua. Coastal development and sand extraction from beaches and the nearshore were the early reason for the coastal studies. In the last 10 years studies have moved to process based studies. In this period there has been little emphasis on monitoring because national funding agencies have not supported this activity. As a consequence long-term datasets on beach change and coastal drivers such as waves are short-term, fragmented and generally in poor shape, or captured by contractual arrangements. Freely available national datasets are non-existent.

Today research on coastal erosion is driven by information requirements associated with:

- Shoreline stability and coastal hazard setbacks;
- The need to optimise methodologies for monitoring beaches and forcing processes;
- Changes to sediment budgets and supplies to the coast resulting from the extraction of seabed, beach and river sands and gravel for aggregate and minerals, changes in catchment use, dams on rivers, irrigation changing flow and sediment discharge from rivers, shellfish harvesting;
- Erosion caused by streams and storm water drains on beaches;
- Offshore structures (e.g., marine farms) changing the patterns of erosion on beaches;
- Predicting erosion cut-back distances and volumes and their frequency of occurrence;
- Beach and asset protection—beach nourishment, dune re-vegetation, effects and design of engineering works (seawalls, jetties and ports);
- Loss of natural character and public access;
- The prospect of climate change affecting the drivers of coastal processes and sediment supplies to the coast.

NIWA's Approach

NIWA's research effort on coastal erosion and hazards is driven initially by the requirements of the Government's SPO (Strategic Portfolio Outline) for Natural Hazards. In addition we recognise that coastal erosion processes are complex by nature. Coastal erosion is a component of coastal evolution that occurs in response to external forcings (e.g., waves, tides, wind, currents). It's a complex mutual adjustment between topography and fluid dynamics involving sediment transport and exchange of sediment. Fluid dynamics drive sediment transport resulting in morphodynamic change, involving progressive modification of the topography, which then modifies boundary conditions for fluid dynamics, which evolve to produce further changes in sediment transport patterns and depositional features such as beaches and bars. Coastal morphodynamic processes are a function of the feedback loop between topography and fluid dynamics that drive sediment transport producing morphological change. Hysteresis effects on beaches are little understood. The response of say a beach to a storm, depends on antecedent conditions. Two storms of equal magnitude and storm surge height may cause different amounts of erosion. To complicate matters further there can be big time lags between cause and effect. As a consequence evolution of coastal landforms is non-linear and time-dependent, and details of coastal evolution are unpredictable, unrepeatable, unreversible when considered over the long term (decades to millenia). This complexity in processes is further complicated in New Zealand by the fact our variable geology, topography/bathymetry and wave climate has given us a wide range of beach types. As a consequence of these factors and financial constraints we have to make choices about where we put our research effort.

To understand coastal erosion it is necessary to consider all the processes involved with shoreline retreat and advance. This includes the forcings by wave, tides, currents and wind, sediment storage and budgets, sediment transport, and geological setting and provenance. These processes result in the formation of various geomorphological units over a wide continuum of space and time (Fig. 1).

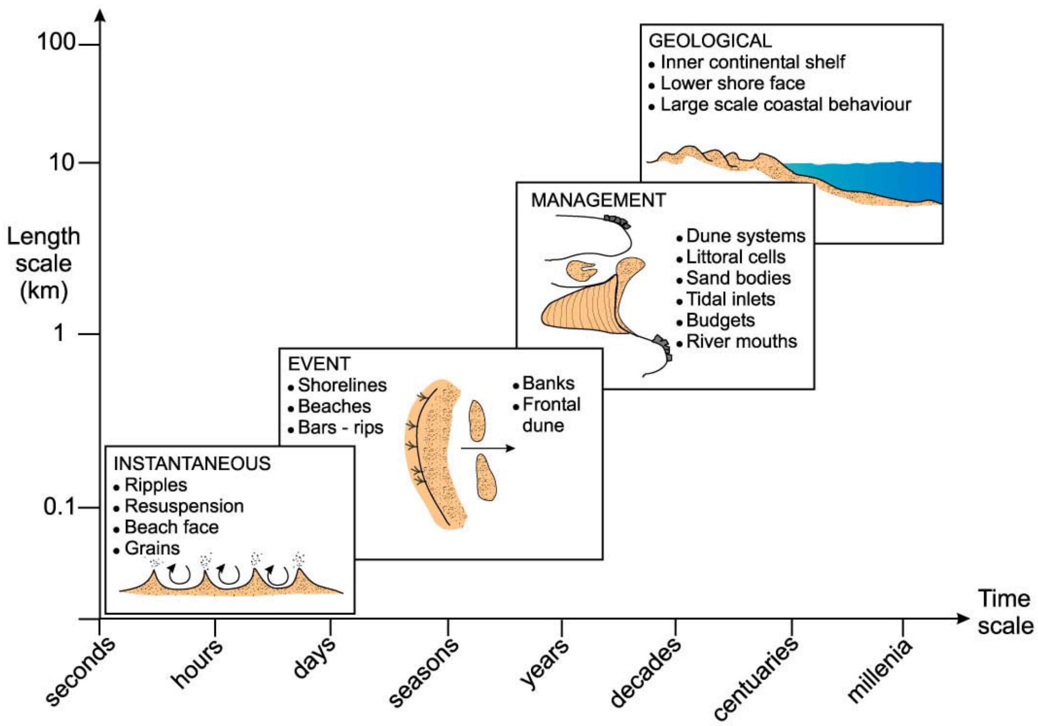

Figure 1: Space (length) and time scales at which various geomorphological units operate and systems evolve.

Management authorities are most concerned with information at annual and decadal scales. However the complex nature of sediment systems and the limited capability of existing tools dictates that to build the knowledge and tools we need to answer both research and management questions, we must spread our effort over the full range of space and time scales. Figure 1 provides a useful conceptual model for illustrating the linkages between processes at small and large-space/time/systems/scales.

The NIWA approach is to address coastal erosion on a selection of fronts in a micro- to systems-scale approach that ties in the geology with the process studies, quantities, processes and rates, use/develop a range of models (conceptual, empirical, numerical) underpinned by field studies and verification, develops tools (hardware and software), and works towards building a national picture of coastal erosion and processes for a range of geomorphological types.

Examples of NIWA research at various systems scales are presented including:

- Working at Geological and Management Scales (Fig. 1) we are building a conceptual understanding of contrasting sand systems on the west and east coasts of the northern North Island. The west coast system with its black sands has long straight beaches, pocket beaches, river mouths and tidal deltas. It has a high-energy wave climate and is an open system and components in this ‘river of sand’ are connected. In contrast the east coast system has embayed beaches, lies on a lower energy lee shore, has smaller stores of sand and there is little connection sand swapping between adjacent embayments. Different research and management strategies are appropriate for the west and east coast systems.

- Working at Management and Event Scales (Fig. 1) we are undertaking detailed field investigations in the Tairua-Pauanui embayment (on the embayed east coast) to determine the amount of Holocene sand in storage and able to buffer erosion, the amount and source of new sand coming into the embayment, and rates of shoreline erosion/accretion at various timescales. Investigations include seismic and GPR (Ground Penetrating Radar) survey of faces, and measurement of sand transport using instrument tripods. A computer controlled video Cam-Era system monitors the Tairua and Pauanui beaches and makes measurements of changes in shoreline position, changes in beach volume, movements of bars and rips and wave characteristics.

- Working at the Instantaneous Scale (Fig. 1) we are making measurements of sea-bed roughness (sediment grain size and bed form/ripple dimensions). Roughness is a key factor in the entrainment of sediment into suspension and sediment transport. We need to be able to parameterise roughness and the waves and current forces that drive seabed/sediment processes in order to accurately measure and model the cross-shore fluxes of sand from bars to the beach and exchanges with the inner shelf. Measurements are being made in the surf-zone with an instrumented sled and on the shore face (15-25 m depth) with instrument tripods.

- We are preparing an Educational CD-ROM called “New Zealand’s Sandy Coasts” that provides information on various aspects of the New Zealand coastal environment across the full space–time continuum. The CD-ROM is due for release in November 2002.

  <u>In summary:</u>

  - Coastal erosion—complex process, variety of forcings, feedbacks, large time lags between cause and effect, non-linear process, varies with geological setting.

  - We have a good conceptual understanding of coastal processes and empirical models.

  - We are short of numbers on processes (e.g., budgets), while we can model components of systems (e.g., tides), we can’t predict morphodynamic processes at management scales.

  - Long-term monitoring data is poor.

  - Investigations must take whole systems approach.

Coastal Hazards in the Auckland Region

Andrew Benson
Auckland Regional Council, Auckland
http://www.arc.govt.nz/arc/

Coastal hazards in the Auckland region and the ARC's coastal hazards programme is introduced. The key issues, the shortfalls in our knowledge base, and the priorities for future work are outlined.

There is a reasonable understanding of processes that contribute towards coastal hazards, and additional research will improve our understanding. There is need to focus on developing methodology to evaluate non-market values of our coast, raise awareness of coastal hazards in our communities, and become more adaptive and resilient. Internalisation of the costs of coastal development is necessary.

Territorial Perspective on Coastal Hazards

Derek Todd
DTec Consulting Ltd, Christchurch

There are 69 Local Territorial Authorities (LTA's) in New Zealand, 55 District Councils and 14 City Councils. Of these, only 9 are landlocked and do not have any coastline within their jurisdiction, which extends to the edge of the Coastal Marine Area located at the MHWS contour. There are four areas of responsibility for which the 60 coastal LTA's have a need for coastal hazard information:

- Land-use Planning
- Consents and Regulations
- Asset Management
- Civil Defence & Emergency Management

Each of these areas of responsibility has different information needs. These are summarized in the following table.

Area of Responsibility	Information Needs
Land-use Planning	• Need to identify coastal hazard areas by requirements of RCEP • Development of rules in District/City Plans for hazardous areas • Development of by-laws (e.g., minimum floor levels)
Consents and Regulations	• Assessment of effects for developments in the coastal environment (subdivisions, structures, dune clearance etc) • S36 Building Act requirements
Asset Management	• Protection of council assets in coastal environment (e.g., roads, outfalls) • Community protection schemes of residential property • Recreational Reserve management (e.g., dune conservation) • Port management
Civil Defence & Emergency Management	• Civil Defence Planning • Engineering Lifelines projects

The types of coastal hazards which concern the LTA's in carrying out these areas of responsibility are much the same as those which concern Regional Councils: long-term erosion, storm erosion & inundation, tsunami, sea level rise, and sedimentation if the council is responsible for a port. However, there is a great deal of variation in the level of concern about these hazards and the need for coastal hazard information. Some councils are very pro-active, having coastal hazard rules in District Plans and being involved in monitoring and information gathering programmes, while other Councils are not involved in an monitoring or information gathering and are totally silent on coastal hazards in their plans. For example, the provision of rules in District Plans to deal with sea level rise for major urban and city councils range from the setting of minimum floor levels, to foreshore setbacks, to no rules.

In general, the need of each council for coastal hazard information and planning is dependant on the following factors:

- Length of coastline;
- Nature of the hazard events and perception of risk of occurrence;

- Number and size of communities at risk;
- Size of the rating base;
- Provisions of respective Regional Coastal Plans and how pro-active the Regional Council is in hazard management and data collection;
- Other priorities for council funding;
- Political or public pressure.

In spite of these differences in the need for coastal hazard information, when information is sought, what needs to be borne in mind by information providers and researchers is that the LTA's are interested in the effects of the event and the level of risk to their area, not the detailed science of the hazard. In general, the LTA's require information on the following:

- Area and depth of inundation (storm surge, tsunami);
- The magnitude of erosion of beaches, cliffs;
- What is the probability of occurrence;
- How long will inundation last;
- What will be overland water velocities and travel times;
- When will it occur (erosion, sea level rise);
- What will be the effect on structures and infrastructure;
- How many people will be affected;
- What can they do about it.

Finally, hazard researchers and information providers need to be aware that the information provided to LTA's needs to be:

- At minimum cost as there is usually a low priority of hazards work compared to infrastructure development;
- Something they can use now (even if there are gaps in the knowledge);
- Creditable in the eyes of the public and to Council chambers;
- Defendable in council hearings and the Environment Court.

Climate-Change Impacts on Coastal Margins

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Background

"Climate change" is any significant change or trend in climate—natural or human-induced, and includes global warming. The recent Third Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) concluded that:

> "*There is new and stronger evidence that most of the global warming observed over the last 50 years is attributable to human activities*" (IPCC, 2001).[7]

Climate change will not introduce any "new" hazards to the coastal zone, but will gradually increase the risk (both consequences and likelihood) from other coastal hazards, riding on the back of an ongoing trend of rising sea level.

In New Zealand, relative sea level has been steadily trending upwards at around 0.17 m/century since the early to mid 1800s (Fig. 1). Global warming is projected to cause an acceleration of sea level (Fig. 1), mainly through thermal expansion of a warmer ocean, and melt water from glaciers and non-polar ice caps.

Climate change will affect most aspects of New Zealand's climate and surrounding ocean, including intensity and occurrence of storms, rainfall, winds, temperatures, ocean currents and wave climate.

NIWA's Coastal Hazard Programme, in partnership with the Ministry for the Environment, recently produced an in-depth summary document to assist with planning for climate-change effects on coastal margins (Bell et al., 2001).[8] This presentation largely draws on that particular publication.

Sea-Level Rise

In terms of coastal hazards, it is the trend in relative sea-level rise that is important i.e., the change in sea level relative to the local landmass, which may be stable, subsiding or being uplifted. Sea-level gauges measure relative sea-level change, while satellite altimetry measures absolute (eustatic) sea-level change. In future, these two complementary approaches will prove very useful in isolating regional differences in absolute sea level from landmass movements.

New Zealand's longest sea-level record comes from the Port of Auckland, where measurements commenced in 1899 (Figs. 1 and 2). The record shows distinct fluctuations at timescales of a few decades that closely match the 20-30 year phases of the Interdecadal Pacific Oscillation (IPO) that occurs throughout the Pacific. Sea-level rise has been minimal over the last positive phase of the IPO since the climate-regime shift in 1976. However, the IPO appears to have switched in 1998 to a negative phase, which ushers in a period over the next 20-30 years when sea levels around New Zealand will probably rise faster than the average trend of 0.17 m/century and El Niño episodes will be less prevalent.

[7] IPCC (2001). *Climate change 2001: The scientific basis.* Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881pp.

[8] Bell, R.G.; Hume; T.M.; Hicks, D.M. (2001). Planning for climate-change effects on coastal margins. Publication prepared for the Ministry for the Environment as part of the New Zealand Climate Change Programme, Publication ME 410, Ministry for the Environment, Wellington, 73 p. http://www.climatechange.govt.nz/sp/resources/resources_publications_alt.htm

Climate-change Effects on Coastal "Drivers"

Sea-level rise is the most obvious aspect that will impact on coastal hazards. However, it is only part of the unfolding story. Global warming will also effect, to varying degrees, most of the physical "drivers" or forcing agents of physical change in coastal margins, apart from tides. The "drivers" of coastal change that are expected to be influenced by climate change are:

- Winds (extreme storms and prevailing windiness);
- Waves (extreme storms and prevailing wave climate);
- Sea-level variability (seasonal, interannual ENSO and interdecadal IPO cycles);
- River flow (extreme storms and baseflows);
- Storms and cyclones (frequency, intensity, tracks, storm surge);
- Ocean and coastal currents;
- Sediment supply to the coast.

In most cases, the coastal response to climate change will be a complex mix of varying, and often subtle, changes to these drivers, rather than a seemingly simple response dictated by the rise in sea level. The most complex impacts of climate change will be on sediment supply to the coastline. Projections for heavier rainfall during storms could flush more sediment down rivers, but eastern areas are projected to be drier, with perhaps lower sediment exports. Subtle long-term changes in wave direction could have major impacts on coastal erosion.

Impacts on Coastal Stability and Response Options

Predicting shoreline response to the modification of coastal hazards in a warming world is a complex business. Simple conceptual models of shoreline response based mainly on sea-level rise (such as the Bruun Rule) are of limited use in isolation. Beach response to climate change will depend on the effects on the various coastal drivers mentioned above. A key point is that the impacts will differ between regions and even between localities, which will require LOCAL management solutions, as indeed is the case now with coastal hazards.

Human responses to cope with the increased risks from global warming on coastal margins fall into three groups (Fig. 3):

- Planned retreat;
- Adaption or accommodation (which could include a "do nothing" approach);
- Protection (or defence).

The responses will be quite different for highly developed (and hence high-risk) areas compared with relatively undeveloped "greenfields" areas (e.g., Omaha South).

The Challenge

The biggest challenge for researchers is to continue developing plausible forward projections of how climate will impact on New Zealand's climate and surrounding oceans, and then integrating those effects to predict future impact for various regions and localities.

The challenge for resource managers and planners is to find ways of getting community buy-in to long-term planning for coastal margins, particularly within the constraints of the RMA and NZ Coastal Policy Statement to preserve the natural character of the coast and maintain public access. The only good news is that there is time to plan, but the key is to allow for flexibility in plans as uncertainties in the science reduce with time.

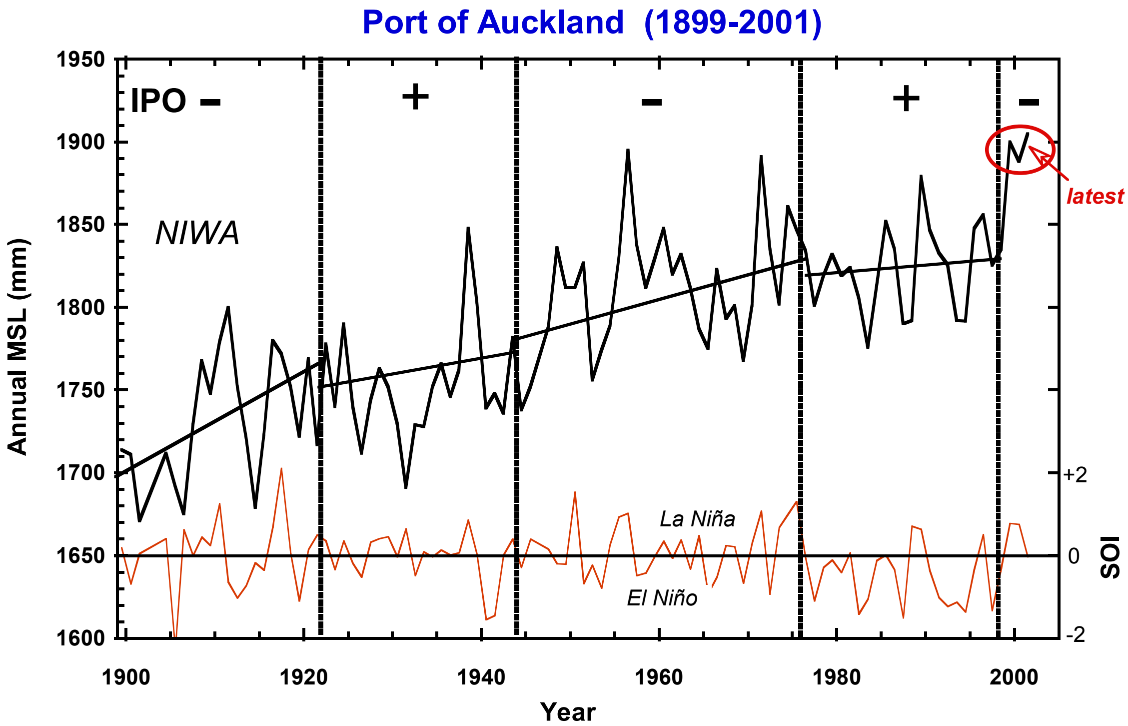

Figure 1: Annual mean sea level from the Port of Auckland since 1899 up to 2001 and annual mean Southern Oscillation Index (SOI). Vertical bars indicate the switch in phase of the Interdecadal Pacific Oscillation (IPO). The mean trend overall in sea level at Auckland has been 1.4 mm/yr, while the NZ average has been slightly higher at 1.7 mm/yr.
Data sources: Ports of Auckland Ltd., Prof J. Hannah (Otago), NIWA.

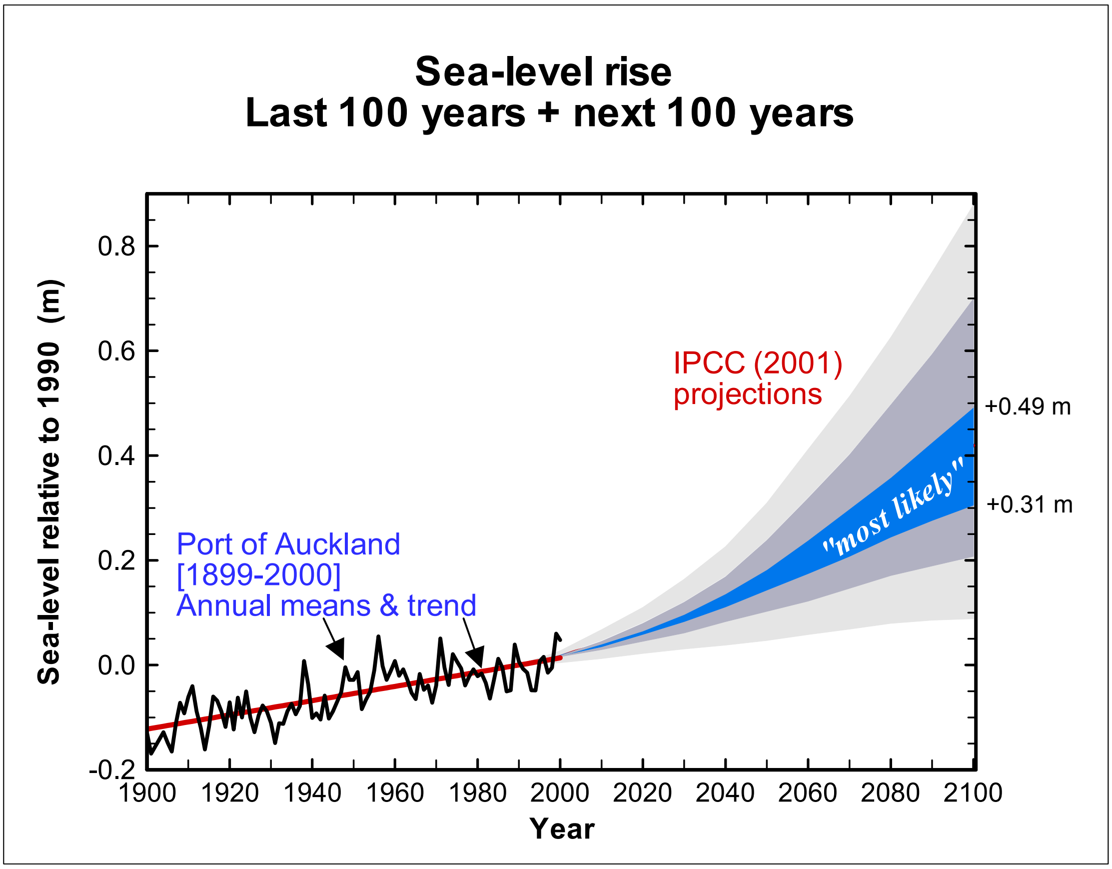

Figure 2: The relative sea-level trend for Auckland since 1899 (relative to the 1990 sea level) and the annual variability in mean sea level (Fig. 1) is spliced with the predicted IPCC (2001) projections in "global" sea-level rise up to 2100. The middle "most likely" zone spans the range of average estimates produced by a range of climate-ocean models. The least likely estimates (high and low) are the lightest-coloured zones. Note: Sea level has been plotted relative to the 1990 values (which for Auckland is 1.840 m above gauge datum). [*Source*: Bell et al. (2001), with data from Prof John Hannah (University of Otago), Ports of Auckland Ltd and NIWA].

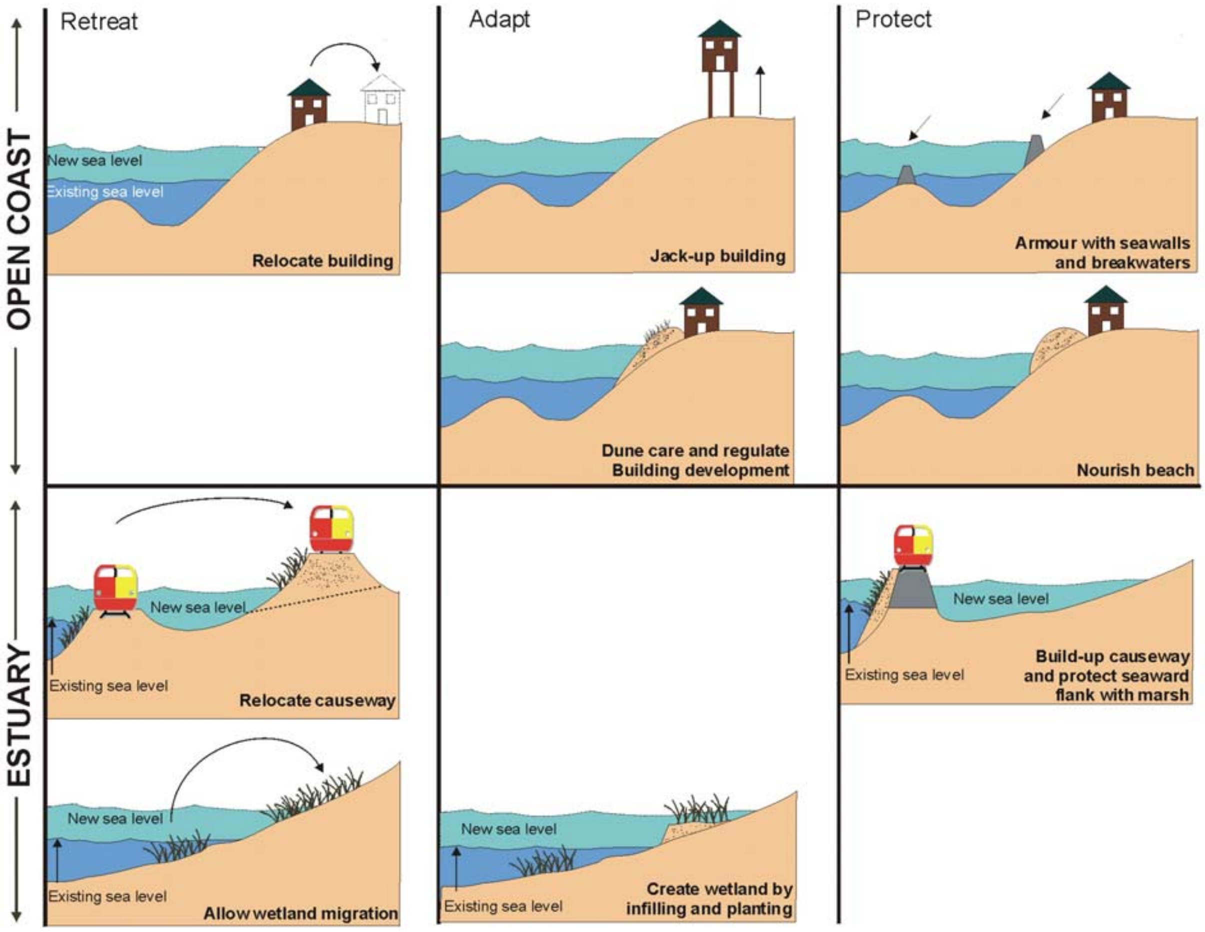

Figure 3: Response options to sea-level rise and climate change for open coasts and estuaries [From Bell et al. (2001)]

A Central Government Perspective on Climate Change Impacts, Vulnerability and Adaptation, Sea-Level Rise and Coastal Hazards

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Global Assessment of Climate Change—Sea Level

The Intergovernmental Panel on Climate Change undertakes assessment of published literature on climate change – the reports undergo an exhaustive peer-review process. Balanced geographical representation and science expert plus government peer review ensure that reports capture wide band of literature and result in balanced statements.

Some key findings

- Sea level has risen during 20th century, and 20th century warming has contributed to it.
- Globally, the rate of temperature change during the 21st century will exceed natural variations over past 10,000 years. Rise in sea level will likely accelerate in the 21st century and continue for many more centuries beyond.
- The absolute amount of sea-level rise in the 21st century is still subject to considerable uncertainties (9–88 cm total band of uncertainty, central estimates 31–49 cm).

Findings Relevant for NZ

- A series of reports commissioned or produced by the NZ Climate Change Programme to downscale information from global to national and regional level—regional variation is important.
- The IPCC report, NZ Climate Impacts Summary report, and the specific report on Climate change impacts on coastal margins focus in on coastal issues.
- NZ sea levels have risen consistent with the global trend.
- ENSO and IPO strongly influence interannual fluctuations in sea level and erosion and accretion cycles at beaches (particularly on the east coast).
- Past experience shows that coastal erosion is not a “new” hazard, but sea-level rise means precautionary planning becomes more important.
- Coastal hazards under climate change combine sea-level rise with many other drivers, including sediment supply, waves and storms.
- Coastal protection/conservation issues generally arise from a clash between development, conservation, sustainability—there is no single cause or solution.

Decision-Making Problems

- Climate change doesn't differ from "normal" hazards, but the past is no longer a sufficient guide for the future.

- Uncertainty: Deferring a decision is also a decision, equal to "assume that amount of change will be zero"—I suggest that despite uncertainty, there is little justification for ignoring climate change, given the reports by the IPCC and past observations of sea-level rise.

- Different Councils have different ability and priorities in the way they respond and plan for the future.

- Uncertainty again: so what exactly do we plan for now—how many steps do we need to be ahead without getting ahead of ourselves?

- What role should central government take to ensure regions/districts take adequate, consistent, sustainable and defensible responses?

Local/Central Government Relationship

There is a continuum of guidance and assistance measures ranging through:

- Science
- Information
- Guidance
- Capacity building
- Assistance
- Regulation

Some Suggestions and Questions

- Distribution of responsibilities: Local authorities are in charge of dealing with environmental/coastal hazards, and coastal erosion is not a qualitatively new hazard, it seems plausible that central government should provide guidance and assistance in dealing with sea-level rise, but that firm action is taken by local government?

- Assistance with information and public awareness needs: At what level, and how is it best delivered? Where is the boundary between local and national responsibility?

- Assistance with capacity: The goal is (probably) not to enforce a specific mandatory measure in all regions, but to embark on an adequate process that builds *"adaptive capacity"* i.e., ensure that regions are competent and adequately resourced to make locally relevant decisions.

- Guidance: Which form delivers most consistent results, but remains flexible to regional circumstances and changing knowledge? What role for regulation? (Note consistency of decisions would mean that councils faced with similar problems decide on similar solutions, but that solutions differ where situations are different, either in terms of coastal morphology, dwellings, ecosystems etc.)

Guidance Issues to be Resolved

- Do we know where we are now?
  - Surveys, pilot studies, best practice examples, roving experts – *networking!*
- Expert agreement on set of tools
  - Models, assumptions, detail of parameters used in models – *how to deal with conflicting expert evidence!*
- Consensus on guidance/regulation
  - NZCPS, NPS, RMA, Building Act, Climate Change policy legislation—What works best? How specific and stringent does guidance need to be?
  - Can scenarios meet the need to decide on a specific “number” for planning purposes?
- Capacity building: what process is most effective at least cost?
- Uncertainty won’t go away; there is a need to develop guidance on how to deal with uncertainty rather than wait for it to go away, because until this happens a lot of unsustainable shoreline development will have taken place.
- Co-benefits and current problems
  - How do we treat existing developments, as compared to consents for new proposals?

Some Additional Scientific Information Needs

- Database of historical sea-level rise and shoreline changes, land topography, incorporated in a GIS planning system.
- Long-term monitoring of key parameters.
- Can we have a standard hierarchical decision-making tree to determine shoreline changes and coastal hazards? Are there generally applicable approaches? (i.e., a classification of beach models that can be applied to different situations in NZ).
- Case studies/best practice of integrated assessments: sea-level rise, wave pattern, sediment supply changes (land and sea), human impacts and responses.
- Incorporation of ecological (estuary, wetland, near-shore) impacts of climate change in planning frameworks.

Hazards Associated with Severe Weather Systems

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Current State of Knowledge
As indicated by the insurance payouts associated with natural disasters presented in Overview of Coastal and Storm Hazards (R. Bell), those hazards related to adverse weather can be placed in the following order of economic importance:

- Heavy/prolonged rain;
- Wind storms (and associated wave generation);
- Hail storms;
- Snow storms;
- Freezing.

Accordingly our research into severe weather systems has focused on the first two of these. The two main storm types contributing to these hazard types are ex-Tropical Cyclones (TC), which develop between 5°S and 15°S, and subtropical storms, which develop between 20°S and 30°S.

We have established a 30-year climatology of TC's in the Southwest Pacific as shown in Figure 1. There are on average 9 per year in this region of which about 1/3 make it south of 30°S and about 1/3 of these pass near New Zealand (NZ)–giving an average of 1 TC per year affecting New Zealand. We have also looked at the location of TCs in El Niño compared to La Niña conditions. While the frequency of visits to NZ is similar (i.e., 1 per year), TC's tend to track more directly southwards and linger longer during La Niña episodes, while during El Niño phases, TC's tend to veer off more quickly to the east.

Global numerical models used by MetService NZ to predict our weather show their largest errors when predicting the development of subtropical storms. Idealised 2-dimensional experiments simulating subtropical storms reveal high sensitivity to moist processes and the location of low-altitude moisture layers in the initial conditions–possibly explaining the forecasting problems. A third component of our research is to verify and compare the performance of the three main global models that MetService NZ uses to predict weather in the NZ region. One such measure of the forecasting skill is shown in Figure 2.

Future research
Further research in these areas is needed to determine the differences between TCs that do and don't redevelop in NZ latitudes and provide forecasters with guiding rules for this process, as TCs are still not well resolved by global models. The idealised experiments for the role of moist processes in the development of subtropical depressions are being extended to 3-dimensional models. We are developing methods to more accurately determine the details of the weather produced during the passage of fronts associated with the above storm types. A data assimilation technique for using high-resolution satellite information in the NZ region is also under development and should enable a better initial picture of the key fields (like moisture, temperature and low level winds) to be incorporated in the weather prediction models. We are also extending our verification of the global models to take account of storm type.

Development of tools and services

Potential services include using 40 years of cyclone tracks in the NZ area to provide maps of return periods of a storm of more than a given intensity.

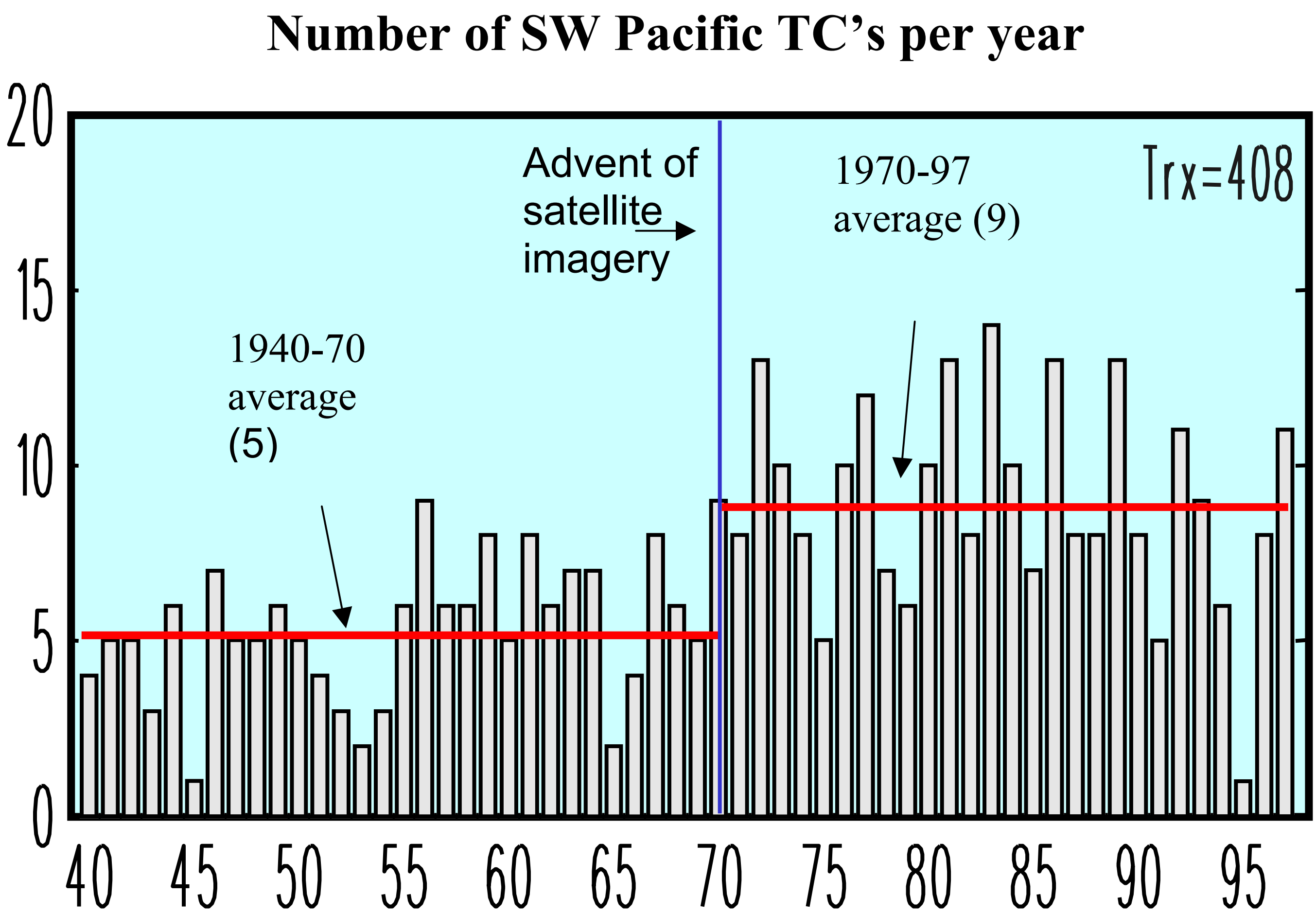

Figure 1: Annual frequency of tropical cyclones that occur in the SW Pacific

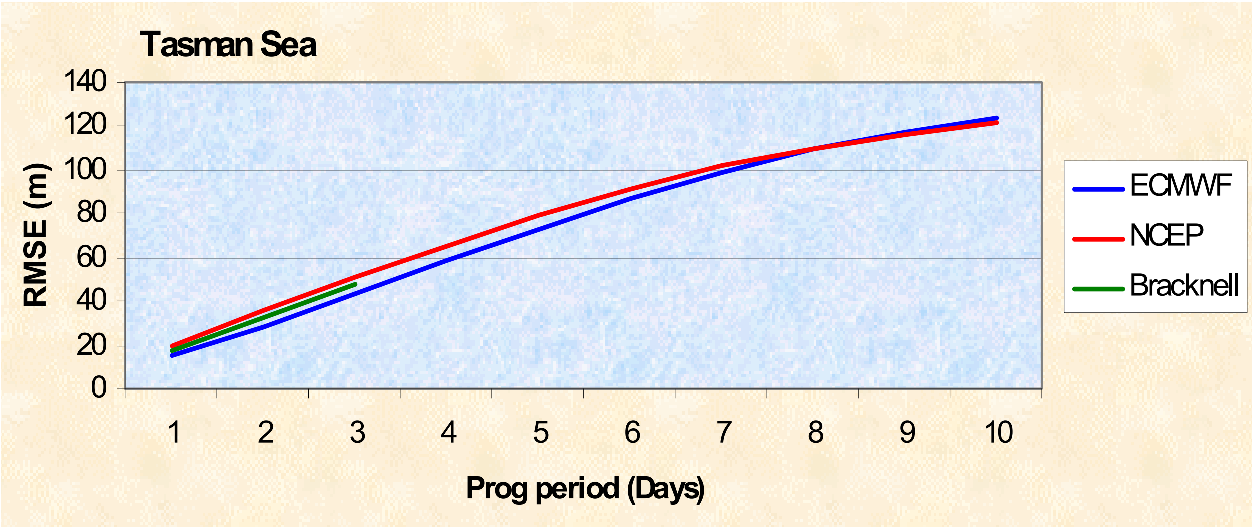

Figure 2: Measure of the forecasting skill of three global weather models used by MetService NZ in the Tasman Sea region, based on a root mean-squared error of forecast-analysis height in metres of the 1000 hPa surface versus the forecasting period in days.

Wind Hazard in Coastal Waters

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Current State of Knowledge
Wind data from land-based stations now spans over 40 years and the general characteristics of the high winds are fairly well known. Annual maximum gust speeds tend to cluster around 30 m/s. The speeds partly reflect the positions of the majority of anemometers on airfields in populated areas near the coast and partly the storm climate. Anemometers on mountains and exposed headlands do regularly record higher winds but the winds need to be understood in terms of the local speed augmentation by the hills at those points. Almost half of the annual maximum gusts in New Zealand are from directions between west and north. This is partly a result of strong airflows preceding fronts and troughs and is partly due to mountain channelling and lee effects.

Winds over the seas around New Zealand have until recently been poorly monitored and the conditions have mostly been inferred from data from coastal stations and from the weather reports from ships. Mean conditions have been reasonably well described by the intermittent data reports but data for storms have been fragmentary. In recent years, global weather models have become reliable sources of winds over the sea. They utilise not only data from coastal weather stations but also data from ships, buoys, and increasingly satellites. The models use the fundamental equations of air motion to analyse a coherent representation of the winds over the sea surface from the data. The satellite data is becoming readily available directly over the Internet and the data frequency and resolution are being improved. Despite difficulties in determining winds in severe storms from satellite data, real-time high-resolution wind plots are being produced.

Future research
Global weather models do not, at present, give an accurate representation of winds over mountains or over coastal seas near the mountains. This is partly a problem of resolution of the landform and partly a failure of the models to represent the physical processes in airflows near mountains. In New Zealand, the winds in Cook Strait are severely underestimated by the ECMWF (European Centre for Medium range Weather Forecasting) model and there is similar underestimation in other coastal waters near high mountains. Future research is needed to provide suitable data for inshore regions and local models need to be developed to simulate the wind processes more accurately.

Development of tools and services
NIWA has two meso-scale meteorological models under development: RAMS (Regional Atmospheric Modelling System) and a data-assimilating model from the U.K. Meteorological Office. The former model interpolates onto detailed NZ terrain from global model data. The latter model offers the possibility of making full use of all available wind stations and the constraints imposed by the landform to derive an accurate representation of the coastal airflow field. Potential services include real-time forecasting of wind hazards as well as of sea waves and storm surge generated by the winds. Another service being planned is the mapping of winds by direction for the coastal waters around New Zealand for speeds at a 20-year return period.

Public Attitudes and Understanding of Flood Warnings and Management in the Waikanae Floodplain

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A survey of residents' attitudes and understanding of flood warnings and management, was conducted on the Waikanae floodplain in August 2001. A total of 1000 questionnaires were delivered directly to houses in Waikanae, with a return rate of 52.4 %. The questionnaire included questions on: awareness, risk perception, previous exposure, information received concerning preparedness activities, information sought for preparedness purposes and the extent to which people engaged or plan to engage in preparedness activities. Preliminary analysis of the results shows that:

- Flooding is perceived as one of the two most likely future hazards by the vast majority of residents (the other being earthquakes), with over 70% expecting a flood sometime within the next 10 years.

- However, the majority of residents have a low level of concern about future flood events and few have actively sort more information about the hazard and how to prepare for it. There is a high level of perceived preparedness of the local council by residents (rated between very prepared and somewhat prepared).

- Less than half (45%) claim to have seen the Waikanae flood map yet over 85% were aware of at least some elements of the flood warning system. The most common action to take on receipt of a warning was to listen to a radio.

- A general set of preparedness measures for natural hazards were asked about and overall, with a few exceptions, moderate to high levels of preparedness were recorded. However to more objectively gauge preparedness, a distinction should be drawn between: a) activities likely to be undertaken to routinely safeguard family members, and b) those required to safeguard the family home and its members from less frequently occurring, but potentially more catastrophic, hazard events (e.g., floods, earthquakes, tsunamis).

To create a well-prepared and resilient community four phases of interventions have been identified:

1) **Improving the communities hazard knowledge and risk perception**. This stage can be influenced by public hazard education programmes and current initiatives appear to be moderately to highly effective.

2) **Promoting intentions to adopt preparatory measures.** Some of these factors can be influenced by hazard education programmes (e.g., outcome expectancy), but self-efficacy can only be influenced by strategies that focus on community empowerment and require collaboration between, for example, emergency management and social policy agencies. This, in turn, requires attention being directed to inter-agency collaboration. Collectively, Waikanae residents' risk perceptions and cognitions, outcome expectancy and self-efficacy are present at low to moderate levels.

3) **Converting intentions into actual behavior**. It is these variables that are the concern of the third phase of intervention. Variables within this category are not amenable to change through public education programmes and require more experiential intervention and social policy initiatives. Again the data suggests low to moderate success in this area, such as levels of household preparedness.

4) **Maintaining capability**. This was not measured by the survey.

Storm Surge and Coastal Inundation

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Storm surge is the response of the ocean to changing atmospheric pressure and winds. For New Zealand, storm surge is mainly driven by pressure changes, with winds usually having a relatively minor effect. This is in contrast to places like the North Sea and the Bay of Bengal, where wind has a major effect in producing storm surges several metres in height. The difference between these places and New Zealand is that in these overseas countries, the weather systems move slowly and the ocean has time to respond to winds that blow in one direction for days at a time against large semi-enclosed embayments. In New Zealand, our weather systems usually move rapidly across the region, giving the ocean little time to respond before the wind changes direction. This means that storm surges are governed more by the change in atmospheric pressure. Central storm pressures typically drop by up to 40 hPa in a depression or cyclone, resulting in water level rises of up to 400 mm, (estimated using the inverted barometer relationship which says that when pressure drops by 1 hPa, sea level will rise by 10 mm). Of course, this general statement needs to be qualified, both for individual events and for particular locations:

- In Cyclone *Giselle* ("Wahine" Storm), both winds and low pressure had a significant effect in producing storm surge of 500–750 mm in Wellington Harbour, and around 900 mm in Tauranga Harbour; reputedly the second largest storm surge event of last century;

- The largest observed storm surge occurred during the "Cyclone of 1936" on 2nd February 1936, generated by a deep depression reaching 970 hPa that passed over the North Island[9]. Storm surges of 900 to 1000 mm were observed in Wellington and the Bay of Plenty. Unfortunately, these very high surges also coincided with extremely high perigean-spring tides causing extensive coastal damage and inundation;

- On western coasts of both islands, storm surges generally are larger than the inverted barometer response would indicate;

- On eastern coasts of both islands, storm surges generally are smaller than the inverted barometer response would indicate;

- In northern New Zealand, sea level rises a few hours ahead of a drop in pressure;

- From the mid-North Island south, sea level responds to drops in pressure within a few hours;

- Around Banks Peninsula, the ocean does not respond directly to local changes in pressure and storm surges appear to be the result of waves propagating into the region.

The scientific reasons for the above observations are not at all clear. We are investigating this by modeling, using the NIWA Cray T3E supercomputer and a 2-D, time-stepping model (developed by Roy Walters), using the same grid developed for the tide model (described in a companion Abstract).

Given that even the largest storm surge will be less than 1 m in height, whereas the tidal range is greater than 2 m in most places around New Zealand, why is storm surge important for coastal inundation? Well, storm surge is a frequently occurring phenomenon. Indeed, depending on how you define storm surge, there can be up to 20 storm surge events in a year. Most of these are 200 mm or

[9] Brenstrum, E. (2000). The cyclone of 1936: the most destructive storm of the Twentieth Century? *Weather and Climate 20*: 23–27.

less and occur when the tide is relatively small, but occasionally a larger one will coincide with high perigean-spring tides and widespread flooding can result. Three such events occurred in 1999. On 17-April-1999, western coasts of the North Island were impacted by a 400 to 500 mm storm surge that exactly coincided with the largest perigean spring high tide of the year, resulting in flooding at Dargaville and Manukau Harbour. On 16-May-1999 a small storm surge coincided with the next perigean-spring tide, but no inundation was reported. Then on 15-June-1999, at the next perigean spring tide, a storm surge of 400 to 500 mm in height occurred along the east coast of the South Island causing flooding at Sumner, in Lyttelton Harbour and at Timaru. None of these storm surge events were significant in themselves. But their coincidence with perigean-spring tides caused flooding.

Recent work[10] has indicated that over the last 25 years, the magnitude and frequency of storm surge events have been less than occurred in the previous 25 years. This is attributed to the predominance of El Niño events during the positive phase of the 20–30 year Interdecadal Pacific Oscillation (IPO) from 1976. The IPO changed to a negative phase in 1998 and we can expect more frequent and larger storm surges in the next 20–25 years. Therefore, it is even more important that we develop an understanding of how the ocean around New Zealand responds to changing atmospheric pressure and winds.

[10] de Lange, W.P.;Gibb, J.G. (2000). Seasonal, interannual and decadal variability of storm surges at Tauranga, New Zealand. *New Zealand Journal of Marine and Freshwater Research 34*:.419–434.

Tidal Forecasting

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The tide by itself is not generally a hazard (except in very low-lying areas). But when combined with storm surges, floods or tsunami, coastal inundation can occur, especially if these events coincide with high tide. Conversely, if the events coincide with low tide, there may be no coastal inundation at all.

The tide consists of about 600 individual tides, which are known as "tidal constituents", each being attributable to a particular astronomical effect. The tide is deterministic. This means that once the tidal constituents are determined for a particular site, we can hindcast or forecast the tide level at any time for that site.

To identify all 600 tidal constituents comprising the tide, we need 18.6 years of continuous data at a site. Fortunately, however, only a handful of the 600 constituents are significant and we can identify some of these with as little as 30 days of data, but much better accuracy is achieved if at least 206 days of data are available. Traditionally, this is the way the tide has been defined for particular locations (usually, standard and minor ports) around New Zealand for the last century. However, for locations between these ports, interpolation is required to determine the tide. This interpolation is often quite inaccurate because the tide is highly variable around New Zealand. Part of NIWA's research over the last few years has been to develop a computer model for tides around New Zealand[11] that obviates the need either to interpolate between ports or to make measurements at the location where tide forecasts or hindcasts are needed. The accompanying article reproduced from The Industrial Physicist[12] explains the tide model in some detail. A summary co-tidal plot for the main lunar tide is shown in Figure 1.

From the model we have the 13 most important tidal constituents at more than 32,000 locations in New Zealand's EEZ (Exclusive Economic Zone). We can interpolate these data to produce the constituents at any latitude and longitude within the EEZ. Once we have these for a particular location, we can forecast or hindcast the tide for any time. This is the basis of NIWA's Tide Forecaster, which will be available at: http://www.niwa.co.nz/services/tides/. It enables anyone to specify a location and date and receive estimates of the high and low tides for that location and date. We can also use the tidal constituents to forecast extreme tides; for example, when individual tides are high, or the distribution of high tides over 50 or 100 years for engineering design.

Some important features of the tide around New Zealand that have been revealed by our model are:

- There is a complete 360° range of phase for the main M_2 lunar tide around New Zealand, meaning that at any time there is a high tide somewhere on the coast;
- The tide is primarily semidiurnal (occurs twice per day);
- There is a small diurnal effect that makes alternate high tides slightly larger;
- On the east coast of both islands, the fortnightly spring/neap effect is smaller than the monthly perigean/apogean effect arising from the Moon's elliptical (non-circular) orbit around the Earth;
- MHWS (mean high water spring) is poorly defined for central east coast regions, as this tide level is exceeded by a sizeable proportion of all high tides—up to 45%.

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[11] Walters, R.A.; Goring; D.G.; Bell, R.G. (2001). Ocean tides around New Zealand. *NZ Journal of Marine & Freshwater Research 35*: 567–579.

[12] Also available at: http://www.niwa.co.nz/rc/prog/chaz/news/tidalmodel.pdf

Future work will focus on finer resolution of the tide model grid in coastal and estuarine areas, and also producing a tidal current atlas.

Acknowledgement: The computer model TIDE2D used in this work was developed by my colleague Roy Walters (NIWA, Christchurch).

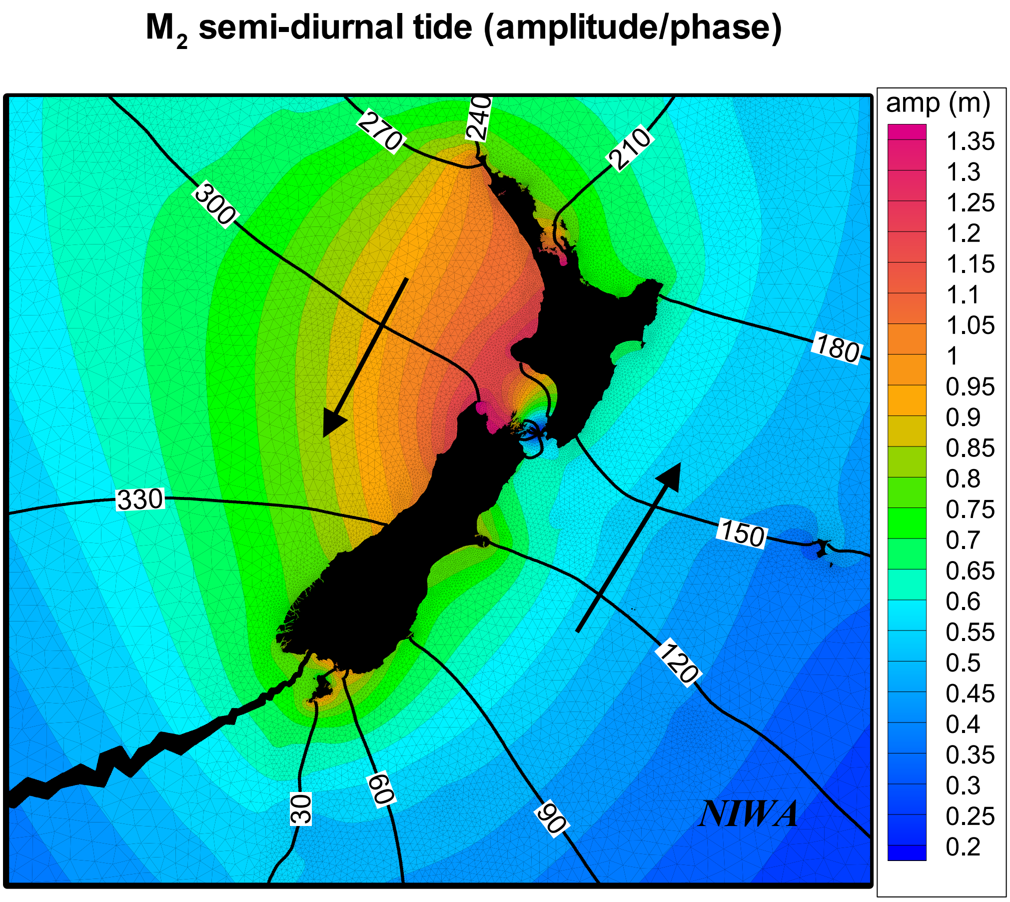

Figure 1: Co-tidal plot of the twice-daily lunar tide (M_2) with shading scaled to the tidal amplitude (half-range) in metres, and the thin black phase lines in degrees (0–360°) representing the tidal wave crest (high tide) at 30° (approx. 1 hr) increments as it propagates anticlockwise around New Zealand.

The Hazards of Planning for Coastal Hazards

David Gregory and Brodie Young
ECan - Environment Canterbury
http://www.ecan.govt.nz/Coast/coast-harbours-homepage.html

The first part of this presentation will focus on the approach of Environment Canterbury to the issue of planning responses to coastal hazards. The second part will use a recent storm as an example to illustrate some of the inherent difficulties of planning for coastal hazards even when information is available.

Part 1 - David Gregory, Environment Canterbury
With a well-established system of coastal monitoring providing credible information to District Councils, Environment Canterbury (then the Canterbury Regional Council) opted, in 1994, to prepare a Regional Coastal Plan under the RM Act that included hazard-relevant rules landward of the Coastal Marine Area. These rules were intended to control development within two Hazards Zones. The Hazard Zones are set inland from Mean High Water Springs to denote areas that are projected to be subject to erosion within a 50-year (Hazard Zone 1) and 100-year period (Hazard Zone 2). Additionally, the Plan identified Coastal Inundation Zones for coastal margins that have been flooded by the sea in the past.

What case was made for this draconian approach?

The intention of applying these rules to the whole of the regions' coastline is to achieve a consistent approach to coastal hazard management for the whole region, rather than having widely differing responses from a range of territorial local authorities.

Now, in 2002 we still find ourselves with these rules under appeal to the Environment Court. The one outstanding appeal is lodged by a wealthy businessman who has the last house on the seaward end of the South Brighton Spit. His objection is based on the "interference" of the rules with the absolute right of a landowner to decide what to do with their own land.

In addition, out of left field, come some very large-scale applications for open-sea marine farms. These may have some effects on coastal processes and coastal hazards which are very difficult to assess. When this is coupled with proposals for artificial surfing reefs and the developing literature on climate change, the hazards of planning for hazards becomes very apparent.

Part 2 - Brodie Young, Environment Canterbury
While we are attempting to plan for potential coastal process/hazard issues there are real hazard events occurring at the same time. Some of which illustrate the limitations of the data (particularly relating to storm surge and waves) we have been using for long-term planning, notwithstanding the fact that we have had a comprehensive monitoring programme underway for a number of years.

An example of this is a severe coastal storm that occurred on 19-22 July 2001. A significant amount of damage resulted from this storm. The land affected was primarily the coastal strip south of Timaru. A large proportion of this area is productive cropping land and pasture. This storm resulted in approximately 1,150 hectares of low-lying coastal land being inundated by seawater. This inundation is a direct result of the gravel beach system being overtopped by a combination of very large waves coinciding with large tides and storm surge. Seawater covered the land for several days in most places, but for up to two weeks in others. Significant alterations to the coastline also occurred, especially a section of the barrier beach fronting the Wainono Lagoon, an important wildlife area. Here the barrier has been lowered extensively as beach material has been pushed inland and into the Lagoon margin.

The storm was caused by a low-pressure system (983 hPa) with an associated slow moving front situated north-west of the Chatham Islands. This produced large north to south-easterly swells the largest of which were recorded by the Canterbury wave buoy as 8.5 metres high with periods approaching 12 seconds. Maximum breaker heights were estimated theoretically from the deepwater wave data as 5.3 metres, however waves of this height would be depth-limited offshore of the beach system. The most damaging waves are the ones that break nearest to the barrier as they produce the highest run-up and most of the beach crest overtopping. Based on water levels at the time and the depth of the nearshore step fronting the barrier, these waves were theoretically 3.4 m. Breakers of greater than 3.0 m have been shown to generate run-up of over 7.0 m above MSL on south Canterbury beaches. As the average height of the beach crest before the storm was only approximately 5.5 m there was significant beach overtopping.

The depression was fairly stationary from about July 19 to July 22 before weakening and moving away from the country to the north-east. Onshore south-easterly winds of 30 to 40 knots were associated with the low pressure system. No sea level data was available for South Canterbury as Port of Timaru's tide gauge was non-operational during this period, however data is available from the Sumner sea level recorder. The predicted high tides during the main coastal flooding event were between 2.40 m (19 July) and 2.50 m (20 July), which corresponds to 0.98 m up to 1.08 m above Mean Sea Level (MSL) at Timaru. Data from the Sumner Head sea-level recorder show maximum sea levels of 1.39 m (19 July) to 1.41 m (20 July) above MSL, which approximates to a water level of 0.41m above the predicted high tide on 19 July and 0.33 m above the predicted high tide on 20 July. Storm surge accounts for most of this (perhaps up to 0.24 m). The exact amount has not been investigated. Wave set-up as a result of strong onshore winds will also have contributed to elevated water levels along the southern Canterbury coast.

Immediately after the event the focus was on finding out the exact extent of the inundation that had occurred. As soon as weather permitted, aerial photographs and video was taken of the whole coastal area. A small team of ECan staff then spent several days interviewing numerous farmers to gain a better understanding of the storm and its impacts, as well as to discuss the functioning of our storm warning and coastal observers' network. A ground truthing survey was conducted to determine the accuracy of the flooding shown in the aerial photographs. The extent of inundation was then transferred to 1:20,000 scale vertical aerial photographs. Co-ordinates of the flooded areas were then entered into the ECan GIS for analysis. From these investigations flood extent maps for the area have been created. In virtually all areas the extent of the sea flooding during this event is significantly more than the Coastal Inundation Hazard Zones in the Coastal Plan.

Coastal cross-sections were surveyed and a large topographic survey was undertaken of an area of the Wainono Barrier. On average the elevation of the beach was reduced by 1.0 metre from it's original height with a maximum height reduction of 1.90 m. Retreat of the beach crest varied between –1.1 m and –8.2 m. The majority of sections lost both sediment volume and elevation. Because there is a deficiency in the supply of sediment to South Canterbury beaches, the landward retreat of the beach crest is an irreversible process, without some sort of human intervention such as beach reconstruction.

The areas that were flooded have been mapped and details of the storm event and its functions are discussed in an ECan Technical report. The last time that a storm and associated sea flooding of this magnitude occurred was 16 years ago in July of 1985. Who knows when it will occur again?

Tsunami Hazards

Roy Walters
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http://www.niwa.co.nz/rc/prog/chaz/news/coastal

Tsunami occur relatively frequently along the coast of New Zealand and can be characterised as temporary oscillations of sea level with periods longer than wind waves and shorter than ocean tides. They can cause coastal flooding, erosion, and loss of life in extreme events, and therefore can be significant coastal hazards.

The word tsunami is of Japanese origin ("harbour wave") and is now used internationally to signify a long-period wave that is usually generated by a sudden displacement of the ocean bottom, such as from seismic events, underwater landslides, or volcanic eruptions. Tsunami can be classified by distance from their source to the area of impact; i.e., local and remote tsunami. Locally generated tsunami have short warning times and short wave periods, and usually have a local impact; remote tsunami have long propagation times and long periods, and have a New Zealand wide effect. Characteristic periods for tsunami range from 10 minutes for locally generated tsunami to a few hours for remote tsunami. Characteristic amplitudes (from peak to trough) for tsunami range up to 15 m at the coast, although most are smaller than 1 m. On average there are 12 to 13 tsunami exceeding 1 m every century around the New Zealand coast, a similar frequency to Hawaii and Indonesia, but a third that of Japan.[13]

In the end, the amplitude of tsunami depends on the initial or incident amplitude and direction, the wave period, and how the wave interacts with the ocean and shoreline topography. Where a harbour or coastal bay resonates with a similar period to the incident wave, large amplified waves can be anticipated. As may be expected, there is a large variation in amplitude and impact of each particular tsunami along the New Zealand coast.

Several historical tsunami databases have been constructed from a variety of sources ranging from instrumental records to palaeo-tsunami deposits (W. de Lange, Univ. of Waikato; G. Downes, GNS; J. Goff, GeoEnvironmental Consultants). Some of the database is fragmentary and somewhat qualitative in nature. Nonetheless, it provides a reasonable account of the exposure of New Zealand to tsunami impacts, both in frequency of occurrence and magnitude of effects.

The current state of knowledge can be summarized as follows. The type and location of potential tsunami sources are reasonably well known. However, there is considerable uncertainty in estimating the amplitude and likelihood of a tsunami generated by these sources. This problem applies to the Pacific Ocean Basin warning systems as well. Given an initial wave amplitude, the propagation of these waves both locally and across the Pacific Ocean can be calculated accurately. However, there is again uncertainty in the local impacts and resonance effects because of the lack of detailed topographic data for both nearshore and coastal land margins of New Zealand and sea-level data from historic events.

There are several directions for future research that can contribute to the assessment and mitigation of tsunami impacts at the local and national levels. One of these is to develop a better warning system for remote tsunami; another is to assess probable wave amplitude and spatial distribution from local tsunami sources.

A warning system can be created using a combination of numerical models and time series analysis methods. The basic idea is to acquire sea level data from a distant source such as the NOAA deep-sea

[13] De Lange, W.; Fraser, R. (1999). Overview of tsunami hazard in New Zealand. *Tephra 17*: 3–9.

pressure recorders, and calculate the response of the New Zealand coast to long waves of various frequencies at the recorder sites. Then the coastal response to any given input at the recorder site can be calculated quickly from a combination of the incident wave amplitude and direction, and the response characteristics. This type of warning system is applicable to remote tsunami.

For local tsunami, the time between the event and the impact is so short (typically 10 to 30 minutes) that it is hopeless to provide any significant warning. A reasonable approach is to make local assessments of impacts and determine vulnerable areas, then make a significant effort at public education. The assessments could take many directions depending on the objectives and level of detail required. Typically these results would lead to identifying areas of risk, inundation areas, and possible evacuation routes.

University Perspective: Coastal & Storm Hazards Knowledge Base

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http://sci.waikato.ac.nz/cgi-bin/dynapage.pl?pagename=erth

New Zealand Universities have been undertaking research into coastal hazards for more than 50 years, and at some stage every University has had a coastal focus for research. Over the last decade research into coastal & storm hazards has suffered from the need to compete for resources and the perception that it generates no economic benefit. The mere existence of workshops like this one proves the fallacy of the perception. The resource issue is harder to deal with, as there is increasing pressure for Universities to compete for contract funding with Crown Research Institutes and consultants. Therefore, the future of the university knowledge base is uncertain.

Over the last few decades much progress has been made on understanding the processes that generate coastal hazards, and the impacts of different mitigation strategies. Considering the processes first, the coastal hazards examined have included coastal erosion, cliff stability and mass movement, beach state and surf zone hazards (rips & undertow), storm surge, tsunami, sea level rise, and technological impacts. However, in terms of databases Universities have valuable resources within theses produced by students, and an obligation to inform the Public.

Specific examples of these include tsunami databases for New Zealand, storm surge and storm impact databases, and assessments of coastal processes and erosion at specific locations. Considering the tsunami databases, these have collated historical data allowing assessment of overall response to tsunami around the New Zealand coast, and identified potential hazards. Subsequent tsunami modelling by various students has allowed the potential risk to be better defined: for example within the Firth of Thames and the outer Waitemata harbour. Storm impact and storm surge databases have collated information from disparate sources and the grey literature. Apart from identifying potential hazards, they provide initial data to characterise storm surge behaviour and potential storm impact.

There are coastal hazards for which little research has been undertaken. This is particularly true for technological hazards including oil and chemical spills. Little work has been done in relation to changing nutrient levels and algal blooms, although there is an increase in research into aquaculture and the impact of marine farms on the environment. However, at present the ability to predict the impact of technological hazards is low.

Mitigation methods have undergone a philosophical shift over the last few decades. This has been reflected in the RMA (1991) and NZ Coastal Policy Statement. Mitigation strategies may be loosely classified as hard intervention, soft intervention, and “do-nothing”. Hard intervention normally involves the construction of structures to limit the effects of coastal erosion and/or flooding. Some, such as stopbanks to prevent flooding of the Hauraki lowlands, are perceived to have little harmful effect. Others, such as seawalls, are perceived to cause great harm and loss of public value. The “do-nothing” approach is usually politically unacceptable. Hence, recent research has focussed on soft intervention. This includes the use of planning tools to limit exposure to hazards, coastal restoration and renourishment, and the use of structures in ways that reduce their perceived harmful impact (T-groynes and submerged offshore breakwaters).

Looking to the future, soft intervention to mitigate coastal hazards is likely to be the preferred planned approach (although hard intervention will continue to be the main reaction). There are several problems that need research. Firstly, in order to be successful it is necessary to have a good understanding of the local processes and response in order to develop the best mitigation. This requires good monitoring. Although there have been marked improvements over the last decade, with the establishment of open-coast water level recorders and wave buoys/towers, coastal monitoring is poorly resourced with limited coverage. The available data are short term and have yet to cover full climatic cycles at decadal (or even interannual) scales. There needs to be a commitment to maintaining and improving the observational network, and also to make the data available. Universities can play a role in collating and interpreting the data from disparate sources as evidenced by work on tsunami and storm surges.

Secondly, much research has focussed on the details of processes and/or response in small areas. These data are necessary to develop numerical models for predictive purposes. Meanwhile there has been little advance in simple approaches to quickly assess coastal hazard. For example, despite many recognised shortcomings, the Bruun Rule still plays a major role in assessing the impacts of sea level rise. Since more progress needs to be made with predictive numerical models, and such models are expensive to implement, parallel research into conceptual models with simpler application needs to be undertaken. It is clear that rising sea level will mostly impact by enhancing the impacts of storms and other extreme effects. Therefore, refining methods to predict storm impact may provide better assessments of sea-level rise impact. New Zealand has experienced more than a century of sea level rise, and hence has data that can be used to generate simple models for predicting future behaviour.

Recently the United States Senate has started a push to divert funding from research into the long-term effects of climate change, to areas dealing with shorter-term fluctuations and extreme events. This partly stems from concerns that other than seasonal predictions (up to 3 months ahead), climate predictions are unreliable and therefore have little credibility as a planning tool. It is also apparent than for many climate-related phenomena, the weather-scale (<30 year) fluctuations and their impacts are of greater magnitude than the century scale changes. Available data for the New Zealand coast indicate that the same is true of coastal hazards. Unfortunately there appears to be a perception that the opposite is the case. This suggests that a greater emphasis on public education is needed.

The CDEM Bill 2000—Exploring the Intention of the Bill

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http://www.mcdem.govt.nz/memwebsite.nsf

The CDEM (Civil Defence Emergency Management) Bill 2000 provides improved legislation to better manage the risks that hazards pose to our social and economic well-being.

Compared to the Civil Defence Act (1983) the CDEM Bill:

- Signals a shift from responding to events to managing hazards;
- Mandates a comprehensive approach:
  - all-hazards approach
  - the 4**R**s—Reduction, Readiness, Response and Recovery
- Promotes integration and co-ordination;
- Links better with other key legislation post 1983 and,
- Recognises infrastructural changes post 1983.

The CDEM Bill also introduces:

- A broad but clear purpose statement and underlying principles;
- New organisational arrangements at the local level, and;
- An integrated planning framework.

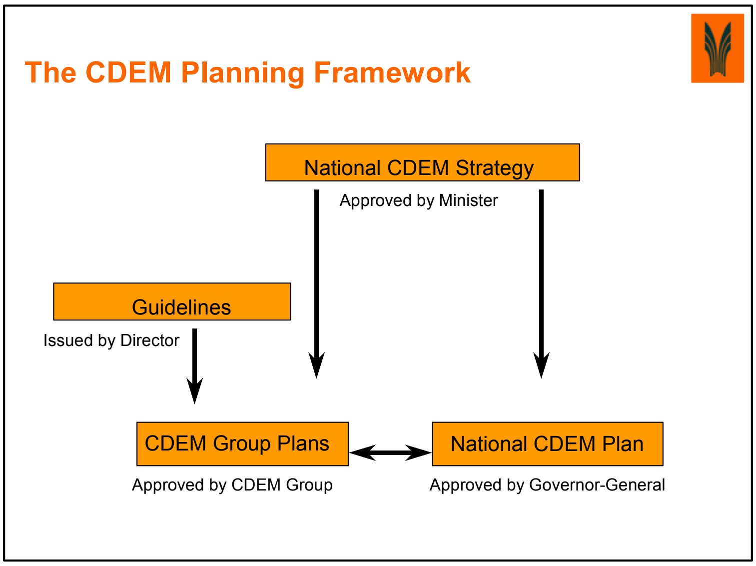
The underlying principles of the bill mean that it:

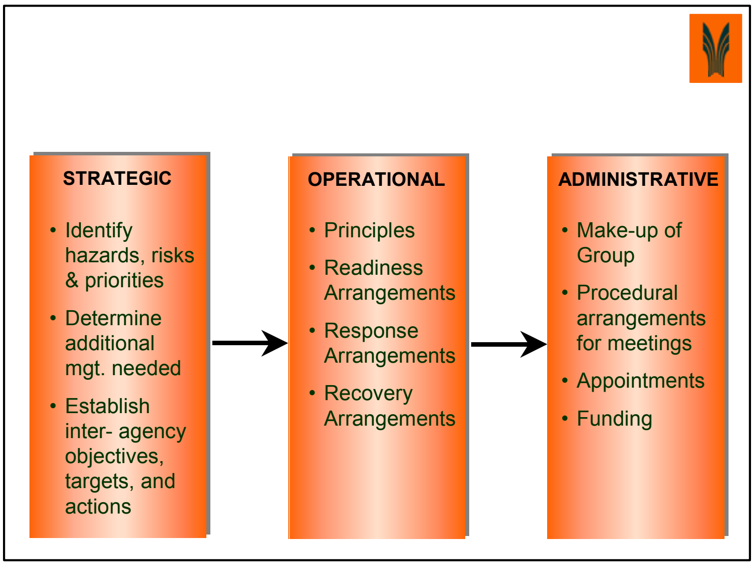
- Builds self-reliance;
- Anticipates community involvement;
- Recognises need for wider support;
- Complements the duties and functions within other legislation;
- Precautionary approach in dealing with uncertainty.

CDEM Groups are to be set up based on Regional Council boundaries. This establishes political responsibility/accountability. They are supported by a co-ordinating Executive Group, an administering authority and operational facilities/services.

CDEM Groups—Key functions
The Groups develop a group plan that provides for identification and management of local hazards, organised and effective response to emergencies and short and long-term recovery arrangements. They also work to raise awareness of, and monitor compliance with the Act, support other Groups and the development of national strategies and plans, and arrange for the necessary resources, services and personnel.

The Co-ordinating Executive Group has membership comprising CEO or delegate of each Local Authority, Senior regional representatives of Police and Fire Service, CEO of hospital and health services and others co-opted as needed. The key responsibilities are advising the Group, implementing its decisions and developing, maintaining, monitoring and evaluating the Group plan.



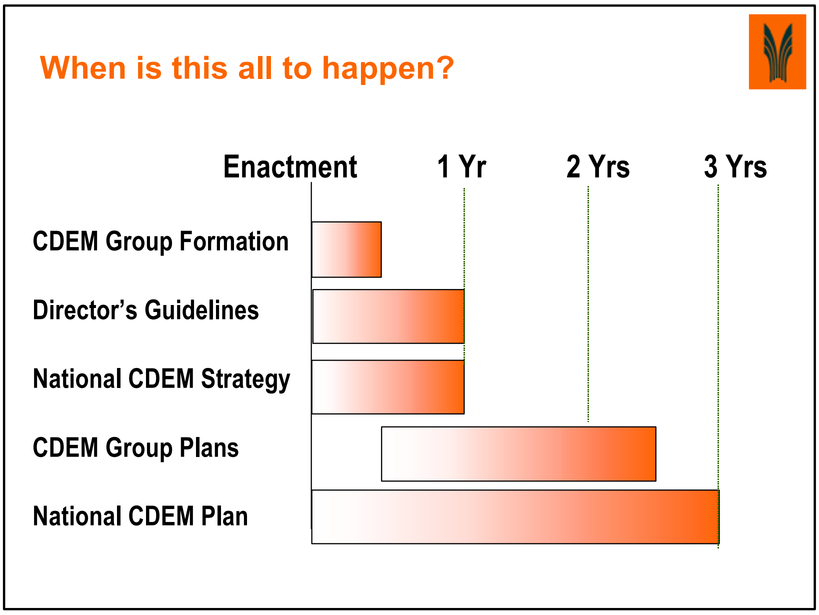


National CDEM strategy is to set out Government's priorities, improve co-ordination and integration of local and national CDEM planning, and promote other hazard risk reduction activities.

Guidelines are available to help clarify expectations and provide information and advice on how to meet legislative requirements.

The National CDEM Plan:

- Builds on local CDEM Group response and recovery planning;
- Identifies hazards and risks requiring management at a national level;
- Clarifies roles and responsibilities of national agencies, and international assistance;
- Establishes arrangements for inter-regional co-ordination of local resources during a national emergency.



<u>For a Local Authority implementing the Bill involves:</u>

- Forming a CDEM group with other Councils in your region;
- Preparing a group plan;
- Being party to fulfilling the other duties and functions of a CDEM group;
- Being capable of functioning during and after an emergency;
- Generally planning and providing for CDEM in your district.

<u>For a Government department implementing the Bill involves:</u>

- Being capable of functioning during and after an emergency;
- Meeting specific requirements in regulations and plans under this legislation, notably for service delivery agencies;
  - a role in local CDEM group response and recovery planning;
  - a role under the National Plan;

- Helping with the development and implementation of the National Strategy.

For emergency services implementing the Bill involves:

- Continuing to build 'everyday' emergency response capability e.g., CIMS;
- Participating in the development of the National CDEM Strategy and Plan;
- Providing a representative for each CDEM Group's Co-ordinating Executive Group;
- Generally supporting local CDEM planning and operational arrangements.

For the general public and business organisations implementing the Bill involves:

- No statutory duties or functions;
- However, all parties should act in self-interest to:
    - Manage their own hazards and risks as much as possible;
    - Participate in CDEM group and local Council hazard reduction and CDEM planning processes;
- Take note of CDEM public awareness information;
- Respond quickly and positively to formal hazard advisory warnings.

Summary

- Hazard management is the responsibility of all of us.
- With good planning and co-operation, we can reduce hazards and manage disasters.
- Key players must be able to continue functioning.
- The aim of the exercise is to build Community Resilience.

Wave Hazards

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Waves are a dominant agent for causing damage at the coast, so almost any attempt to quantify physical hazards at a given nearshore location will need to ask the questions:

- What are typical levels of wave action we can expect here through a "normal" year?
- What level of variability of wave conditions we can expect here?
- What is the occurrence rate of the most severe wave conditions we can expect in some long timeframe (e.g., the design life of a structure)?
- What are the characteristics of these more damaging events?

In trying to answer these questions, we need to use the past as a guide to the future to build up a picture of the wave climate from the data available, and develop our understanding of the physical processes involved, to help us interpret the data and to project that information into the future.

Wave data can come from several sources. Point measurements such as that from waverider buoys, provide data at high time resolution at individual locations. Around the New Zealand coast there have only ever been a handful of records collected of the several years duration needed to develop reliable climate information. Satellites can give a very wide (near-global) spatial extent, but the limited orbital return periods make the records somewhat sparse at any given location along the orbital track, which is further limited by land effects from providing data close inshore.

Chances are, then, that we would need to be very lucky to have good data covering a usefully long period from exactly the site we are interested in. Numerical models can play a role here by synthesising wave information in a way that allows gaps in the data to be filled in, and predictions to be made.

NIWA has used the WAM model to simulate wave generation in the New Zealand region, including the SW Pacific and Southern Ocean. Driven by accurate wind fields, the model has been used to provide a hindcast of wave conditions over the 20 years from 1979 to 1998. This allows spatial and temporal variation of wave statistics to be mapped out, including long-term averages and trends, seasonal variations and correlations with ENSO cycles.

The hindcast is primarily a deep-water simulation, while most applications require information on nearshore wave conditions. Also, it is vital that the simulations be validated by comparison with *in situ* data, generally collected near the coast. Hence techniques are required to derive synthetic record from the hindcast at a given site, taking into account nearshore effects such as refraction and sheltering by nearby land.

Because most wave damage in coastal environments occurs during a small number of the most violent storms, it is important to give an extra focus to how damaging wave conditions arise during such events. As an example, it has been noted that wave heights measured off Baring Head near Wellington often increase considerably more rapidly with the onset of strong southerly winds than would be expected from standard relationships for duration-limited growth under such onset conditions. We have used wave modelling simulations to illustrate that this effect can arise from the motion of a storm travelling towards Wellington at a speed similar to the propagation speed of the dominant waves being generated, resulting in a "resonant forcing" effect.

Engineering Consultancy Perspective on Coastal Hazards

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Issues

- Hazards are one of the aspects to consider, but other aspects such as natural character, protection of natural features, enhancing access are also important.
- Our understanding of hazards and coastal processes still developing.
- Coastal hazards cross Council and Local Territorial Authority boundaries.
- Long-term good quality reliable data sets are required.
- Data on existing hazards generally sparse and in a range of formats, and often requires expert opinion and assessment to evaluate.
- There are funding constraints.
- The public do not always accept hazards are real or significant.
- A consensus of level of risk is not always possible.
- Detailed research may not provide all the answers and may raise more questions.
- Not undertaking research will weaken our ability to understand hazards.
- Inaction promotes “knee-jerk” responses.

Identifying hazards

- Actual and potential hazards exist (e.g., storms and climate-change effects).
- Actual hazards are probably already known to Councils but maybe not be well understood or quantified.
- In situations where there is little information potential hazards effects should be subject to “best qualified guess”.
- Key priority areas are those with existing development within actual hazard areas.

Quantifying hazards

- There is a need to gain information to address key hazards, specifically where there are priority areas. This is likely to be region specific.
- Re-analysis of historic information can be useful. However, it is necessary to check that measurements are valid.
- Tying in new measurements/monitoring with older records can extend the data set for analysis.

- Calibrated models can provide a useful tool for evaluation of options and scenarios.

Priority areas for improving knowledge

- Wave climate.
- Storm surge.
- Sediment budgets.
- Sea-level rise and climate change impact.

Surf-Zone Hazards

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The surf-zone is the area of breaking waves along the coastline. During storms, strong currents, waves, elevated water levels and large variations in the water level characterise the surf-zone. These hydrodynamic effects are the cause of coastal erosion that threatens many of our east- and west-coast beaches. Strong currents in the surf zone are also a hazard to recreational users of the coast because they can cause boats to capsize and fishers and swimmers to drown. This presentation outlines the state of our knowledge-base and NIWA's approach to research on surf-zones.

Predicting currents and water level changes in the surf zone relies mainly on an accurate understanding of wave height changes in shallow water. Wave breaking as the bathymetry shallows causes spatial gradients in the wave height. These spatial gradients cause a force in the direction of wave propagation. In the cross-shore, this force is balanced by an increase in water level shoreward ("set-up") and a current flowing seaward near the bottom ("undertow"). If the waves propagate at an angle to the shoreline, the force drives a longshore current. Longshore changes in wave height, such as might be caused by longshore variable bathymetry, cause the force to focus and drive rip-currents.

No numerical or analytical models exist which can predict currents in the surf zone to the level that one would expect from a tidal model, wave refraction model or even a general circulation model. The nearshore seabed is often riddled with bars, channels, bumps and holes, causing sharp changes to waves, currents and water levels. As a consequence, it is nearly impossible to collect representative measurements for model calibration without expensive and logistically difficult instrument arrays. Moreover the exact mechanism by which energy is transferred between the waves and currents and also how that energy is ultimately dissipated is not well understood.

The pragmatic solution has been to either address the problem by improving our detailed understanding of each of the processes involved (a bottom-up approach), or to create a model based on rules and/or parameterisations which may not be correct, but provide results which successfully replicate observations (a top-down approach).

Since the top-down approach is not wholly based on physics, these models can only work in conditions that are similar to the observations that were used to develop them. Therefore, they can only be generally applicable if they have been developed with a very wide range of measurements. Despite attempts to use a wide range of conditions for development in models such as the US Army Corps of Engineers model, SBEACH, test cases in no way cover the natural variability between beaches. The parameterisations in SBEACH are developed typically for US conditions and are unlikely to function effectively in New Zealand where the wave climate and the sediment types are very different. Video monitoring of beaches pioneered by Oregon State University with their ARGUS network has increased the available data by an order of magnitude. Attempting to predict the complex patterns that have emerged from the video monitoring has sparked the development of an exciting new generation of non-linear rule based models.

The problems associated with bottom-up approaches are no less daunting. The models attempt to represent the physics more accurately and therefore can theoretically be used for predictions in situations beyond those for which they were developed. However, the physics of some of the more complex processes (e.g., breaking waves, boundary layer dynamics, the interaction between waves, ripples and sediment suspension and turbulence production both at the bed and due to breaking waves)

[14] Now with Department of Earth Sciences, University of Waikato.

are not sufficiently well understood to completely avoid the use of parameterisations. Therefore, overwhelming quantities of calibration data from each new site are required for accurate predictions. Ultimately, research will improve these parameterisations to the point that models are more generally applicable. Advanced numerical modelling groups from Delft Hydraulics and University of Delaware are collaborating with major field experimentalists from the US (Scripps, Naval Post-graduate School, Woods Hole) in the 6-year US Office of Naval Research funded NICOP programme to provide a generalised surf-zone model for use by the community of nearshore researchers.

Although much of NIWA's nearshore research is aimed at implementing overseas techniques to address New Zealand's coastal monitoring needs, we also maintain a strong research programme, in particular to improve parameterisations of surf-zone processes for numerical models (bottom-up approach). Maintaining this research arm and the associated international collaborations, is of paramount importance to ensuring that any generalised surf-zone model developed overseas will apply also to New Zealand conditions and be available to New Zealand researchers. To this end, the NIWA coastal processes group have mounted a series of major experimental campaigns, looking at: spatial and temporal patterns of profile and ripple evolution on Mangawhai Beach (1997–98); turbulence production by wave breaking at Tairua (1997–98, 2000); intra-wave sediment suspension at Napier (1999), and finally ripple evolution and the vertical distribution of suspended sediment at Tairua (2001).

A significant advancement of New Zealand's coastal monitoring abilities occurred with the introduction of the Cam-Era video monitoring network with a grant from the Ministry for the Environment (Sustainable Management Fund) in 1997. Modelled on the ARGUS network, the data that is being collected by the 10 coastal cameras that are currently operational will be used to develop statistical (top-down) models for profile, shoreline and beach state changes. While the more generalised numerical surf-zone models are still in their infancy, these statistical models—that are developed for New Zealand conditions—will provide more useful predictions for regional councils and other practitioners than models such as SBEACH.

This is a dynamic time for surf-zone research. However, NIWA is equipped with the personnel, technology and international links to stay abreast of a field that is so vital to understanding New Zealand's coastal hazards.

Maritime & Recreational Hazards

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http://www.niwa.co.nz/rc/prog/chaz/news/maritime

Background

Maritime hazards are not often considered alongside coastal erosion and coastal flooding hazards, but in terms of loss of life, they constitute a more serious hazard.

The Maritime Safety Authority (MSA)[15] is responsible for maritime operations, including search & rescue and oils spill mitigation. Water Safety New Zealand (WSNZ)[16] is the national organisation responsible for ensuring that all New Zealanders are safe in and around water–at home, in public pools, at the beach, in lakes, in rivers or out at sea.

The total insurance industry payout for coastal/maritime disasters is dominated by the loss the inter-island ferry TEV *Wahine* in 1968 ($125M) and the tragic loss of 51 lives. The main cause was attributed to loss of vessel steerage in the atrocious sea conditions of 12-14 m high waves and peak wind gusts up to 100 knots. Adequate warning of storm conditions was another issue. A very similar sea state, with waves up to 13 m, was generated just recently off Wellington on Waitangi Day (2002) with no major maritime incidents in Cook Strait (Fig. 1). Waves in this case are monitored in real-time by a wavebuoy off Baring Head to assist TranzRail with the safety aspects of Cook Strait ferry operations. The wavebuoy system is a cooperative effort between Wellington Regional Council, TranzRail and NIWA. Unfortunately, the same storm on Waitangi Day was a contributing factor to the stranding of the log carrier Jody F. Millenium at Gisborne. This incurred well over $1M in costs, which could easily have escalated if the oil spill had continued and/or the ship had broken up. One of the issues in this case is the adequacy of forecasting systems to provide sufficient warning of strong wave activity affecting the port.

Another impact of maritime hazards is the loss of life or injury from water-contact recreation. New Zealand has a high rate of water-related deaths. In the year 2000, 135 people died, 31 (27%) in open-sea incidents, and 19 (14%) drowned at beaches or rocky shorelines. ACC payout around $2M pa on injury claims for boating accidents. Admittedly, a lack of education and awareness of conditions along with risk-taking are big factors in these statistics. However, there is a role for researchers to devise improved operational forecasting systems for storms, winds, waves, currents and surf rips to provide maritime and recreational users with more informative and timely warnings.

Maritime & recreational hazards—What are they?

The various hazards associated with maritime operations and recreational activities can be broadly categorized as:

- Day-to-day navigation hazards (e.g., strong tidal rips, wave/wind conditions, seabed bathymetry, ferry wakes, navigating bars and tidal entrances);
- Vessel mishaps (grounding, collision, snaring seafloor cables or pipelines);
- Oil or chemical spills from vessels;
- Search & Rescue (missing boats and/or persons);
- Surf zone conditions and rips (bathing, surfing, fishing etc);

[15] http://www.msa.govt.nz/
[16] http://www.watersafety.org.nz/

- Engineering design and risk management (extreme design of structures, platforms, breakwaters, moorings, pipelines, cables).

In most cases, the key "drivers" or basic information needs are for nowcasting and forecasting currents, tides, waves and winds.

Strategic framework for hazards research
There isn't a direct mandate in the Government's Strategic Portfolio Outline on Natural Physical Hazards to carry out research on maritime hazards, but researchers are encouraged to look at more than just the events listed in the document. However, most coastal hazard "drivers" that apply to coastal erosion, coastal flooding and storms, also are applicable to maritime hazards. An example are the surf zone hazards described by Karin Bryan (see companion Abstract), where a computer controlled video camera system looking out over a beach can fulfil multiple functions including: (1) monitoring coastal erosion and beach behaviour, (2) monitoring and detect surf rips in real-time, and (3) providing educational information on drivers, processes and maritime hazards. An additional example is the study of waves. Waves require a large area of the SW Pacific to be modelled in order to get the full spectrum of wind waves and swell that arrive at any particular locality along the coast for say erosion studies. This information is also needed for maritime activities.

Risk management (the 4 R's)
The research sector can play a role in the "reduction" or mitigation of risk, to improve "readiness" for such events, and to assist with the "response" and "recovery" if an event occurs.

One major improvement that NIWA is working towards in the Hazard Portfolio is the development of improved modelling and operational forecasting skills. These are primarily targeted at high-resolution weather (storms, wind, pressure) forecasting, waves and currents. Tides are already at a stage where they can be predicted at any spot within NZ's Exclusive Economic Zone using the tide model (Walters et al., 2001)[17]. A case study follows on predicting coastal currents.

Coastal currents (case study)
For many maritime hazards, a crucial piece of the jigsaw puzzle is knowledge of <u>surface</u> currents. This applies to surf rips, navigation, aiding search & rescue of floating objects, predicting where oil spill might drift, and even yacht racing (assisting Volvo Ocean Race and America's Cup teams). For instance, there are a good number of oil spill tracking models around that handle oil-film behaviour, break-down processes and the effect of dispersants, but they all rely on good predictions of winds and coastal surface currents to determine where the oil slicks might drift. So until operational forecasts of currents and coastal winds can be readily produced for an area, then the use of an oil-spill model could be more misleading than useful.

The Coastal Hazards programme is focusing on two main areas for work on surface currents:

- Hauraki Gulf, where tides are weaker away from narrow channels and wind effects tend to dominate. Marsden Point is also located in the Outer Hauraki Gulf, being our main oil terminal;

- Cook Strait, where strong tidal currents and waves dominate, and which supports a strategic and busy maritime link between the North and South Islands.

Fig. 2 shows some of the model predictions for surface currents in the Hauraki Gulf for tide only, and for an 18-knot SE wind only. Work is underway to look at weekly drift patterns in different parts the Gulf for different winds. Work has also commenced on a 3-dimensional current-flow model for the Greater Cook Strait region, initially to predict tidal currents throughout the water column (including

[17] Walters, R.A.; Goring; D.G.; Bell, R.G. (2001). Ocean tides around New Zealand. *NZ Journal of Marine & Freshwater Research 35(4)*: 567-579.

the surface). Later, waves and wind-driven currents will be added, with the view ultimately to produce an operational model for forecasting currents.

The challenge

The biggest challenge for researchers developing operational forecasting models is how to assimilate real-time data into the ongoing model predictions to ensure the model remains ground-truthed. At present measurement techniques are being investigated to achieve the difficult task of measuring surface or near-surface currents, rather than currents well down the water column. Routine forecasting of surface currents in any area is some way off, but NIWA is developing the basic modelling tools and computer resources to underpin such operational models. Models for forecasting waves and weather several hours ahead are at a more advanced stage of development, which will mean operational models should available within 3 to 5 years.

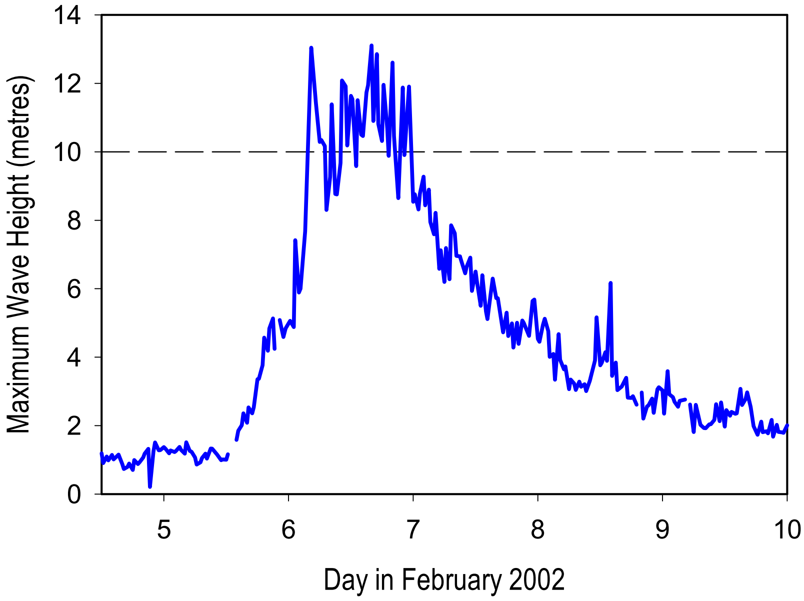

Figure 1: Maximum wave height measured by the Baring Head wavebuoy, peaking on Waitangi Day 2002. Very similar sea conditions prevailed when the T.E.V. *Wahine* foundered in 1968, except winds then were at gale force.

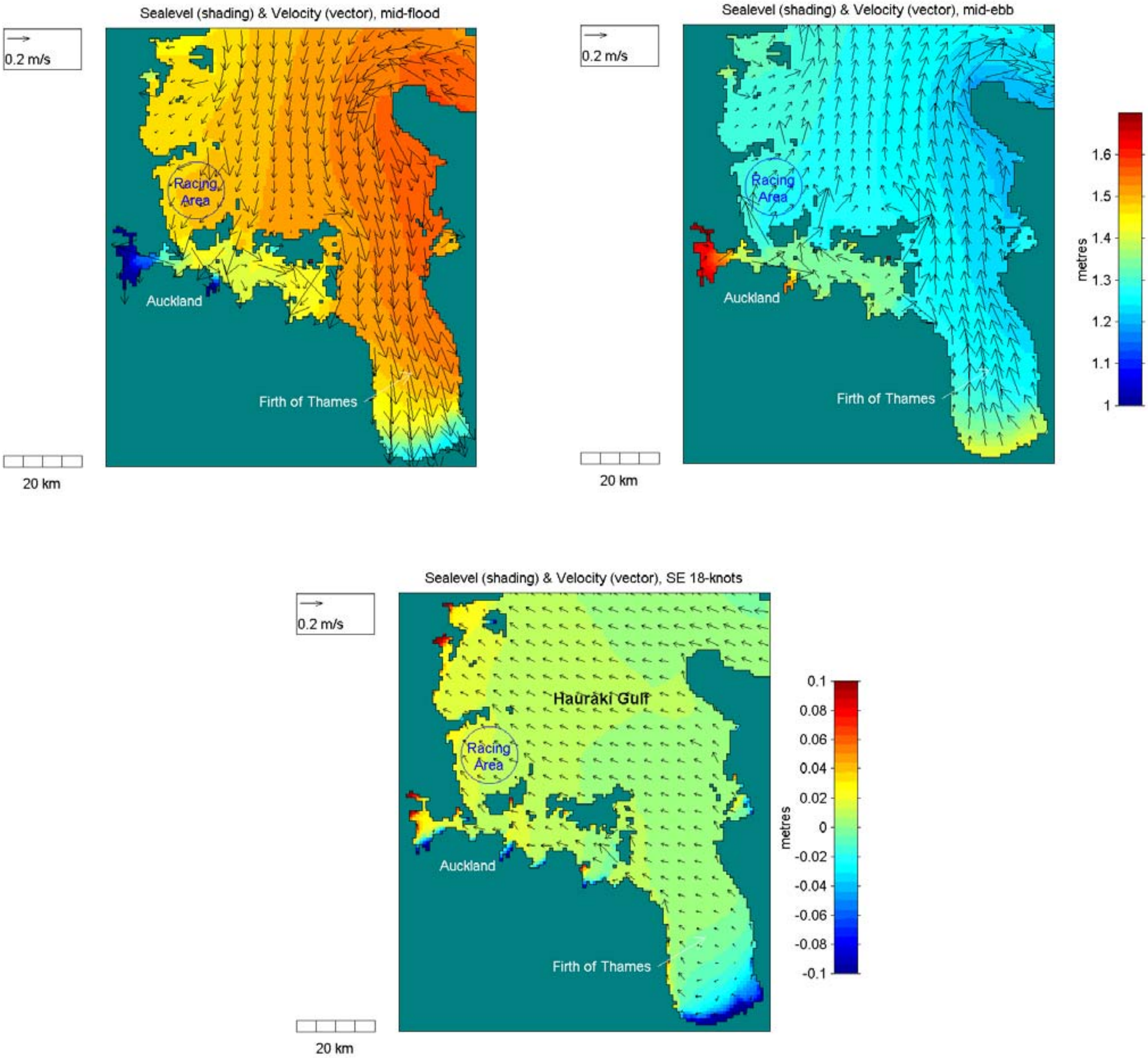

Figure 2: Mean-tide currents in Hauraki Gulf at mid-flood (top-left) and mid-ebb (top-right), and the near-surface (0–1 m) currents (bottom) under a steady SE wind of 18 knots with no tides. [Note: All current velocity arrows are to the same scale, and every 5th grid point of the 750 m model grid is shown. A much finer 100 m grid model is used for the inner Gulf and harbours.]

Monitoring: Where should the Effort Go?

Derek Goring
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http://www.niwa.co.nz/rc/prog/chaz/news/coastal

Monitoring coastal processes and their effects is an expensive and difficult business. The environment is severe, requiring rugged instruments and continual maintenance. The state of the coast can change dramatically in short order and yet cycles can operate at timescales of several decades e.g., erosion. High-tech equipment such as directional waverider buoys cost around $100K, but have a life of only a few years and have running costs of tens of thousands per year. The information these instruments are deployed to gather is often obscured by “noise”. Take for example a sea-level recorder that is used to distinguish long-term sea-level change of a mm or two a year, when sea levels at the site rise and fall by up to 2–4 m twice each day with the tide. Clearly, we cannot afford the capital, running, or the analysis costs of having many instruments. Yet, coastal processes vary widely, both spatially and temporally, and insufficient sampling can lead to “aliasing”, resulting in completely incorrect interpretation of the data.

In the long-term there is hope, as advanced remote-sensing systems (e.g., satellites) develop and become affordable. We will also learn to work smarter.

In the meantime, however, we must address the dilemma of how much monitoring to do and how often, with the limitation of scarce funding. Here is the strategy that we have employed to solve this dilemma for sea-level measurements. We have tried to generalize it so that it can be applied to other physical parameters such as waves, winds, temperature, beach profiles, and sedimentation:

1. Select a few strategic sites and make long-term, detailed and intensive measurements using the highest quality instruments at those locations;

2. Develop a model that simulates the physical processes or acquire a remote sensing device (such as a video camera or satellite), and calibrate it using the measurements from the strategic sites;

3. Validate the model by making less detailed measurements at other locations;

4. Use the model routinely to interpolate between measurement sites.

The “model” referred to above could be a sophisticated mathematical model that correctly simulates the physics or it could be a conceptual model that simply relates one variable to another by linear regression, or it could be a data assimilation model that uses data sensed by satellite or video camera that are ground-truthed using data from the strategic sites. The main point is that monitoring needs to be undertaken in association with a model of some kind, otherwise the data can only be interpreted as describing the particular parameter that is being measured for that location in space and that window of time. In some cases, that may be adequate (for example, if the monitoring is required as part of a resource consent), but almost invariably data will be needed at a different location or a different time and a model can then be used as a spatial and temporal “interpolator”.

Having decided to accept the strategy proposed above, how do we select the number and locations of the strategic sites? This is certainly the most difficult question we have faced with our sea-level recorder network. Once we established a basic network that gave widespread coverage around the country, we had to decide where else measurements should be made. We have used the following questions to decide upon new sites with the limited funding we have:

1. Is there more than one “client” for the data?

2. Will the site give information that we cannot obtain otherwise from previous monitoring?

3. Is there a problem with our model in this area?

4. Has a temporary recorder been installed as a trial?

If the majority of answers to these questions is “Yes”, then we consider a permanent recorder is justifiable, otherwise not. Thus, we rejected the idea of contributing to a recorder in Hawke Bay (because it would give us little new information on a national scale, and our tide model works adequately there), but decided instead to install a new recorder at Kaingaroa on Chatham Is (because the answer to all questions was “Yes”).

So, in summary and directly answering the question posed in the title, the monitoring effort should go to validating models that can be used to provide reliable information at locations and times that are not directly sampled by the measurements.

This type of approach will increasingly be relevant, as remote sensing is rapidly becoming the answer to monitoring coastal and ocean processes. Satellite-based systems already measure sea-surface temperature, waves, winds, sea level, ocean colour (suspended sediment?), while airborne photogrammetry or Light Detection and Ranging (LIDAR) systems are fast becoming cost-efficient ways of getting accurate beach/dune topography and nearshore bathymetry. However, there will continue to be a role for strategic on-the-ground measurements at the coast for ground truthing, and to overcome the large footprint of some satellite systems, where data cannot be obtained in the vicinity of land (i.e., nearshore waters).

Key Points from Facilitated Workshop Discussions

Workshop attendees were split into seven discussion groups to address a selection of questions in two 2-hour facilitated sessions, which were followed by reporting back to the workshop assembly. We have split the feedback into topical areas.

The following topic areas were addressed:

- **Coastal erosion hazards**
- **Climate-change effects**
- **Storm and cyclone hazards**
- **Inundation/flooding hazards**
- **Maritime/recreational hazards** (e.g., navigation, search & rescue, surf conditions, oil/pollutant spills, vessel wake impacts, engineering structures)
- **Resource management and planning for hazards**
- **Education and awareness**
- **Hazard information and data**

The discussions focused on the following components, namely:

a) Science priorities—What are the priorities for future scientific work if we are to improve the assessment of risk and vulnerability? Both research needs and also tools/databases were considered, and whether identified needs were national or regional priorities.
b) Building awareness—What other information is required if we are to increase hazard awareness, assess risk and build resilient, sustainable communities?
c) Management—What tools, databases and systems are required for better management of coastal and storm hazards at both national and regional levels?

Key points to emerge from the discussion sessions are documented below. Some of the points raised by the different groups were similar in nature, but have been duplicated here anyway to convey their importance.

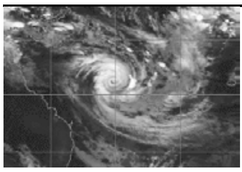
Coastal erosion hazards

- Need models to predict long-term (years, decades) shoreline and geomorphologic change on the 1-10 km scale. Also need good visualisation tools associated with these models (e.g., animations of long-term coastal evolution at the embayment scale).
- Need to look at joint/combined effects of processes, e.g., coincidence of high tide and storm surge. Hazards do not necessarily occur in isolation.
- Need a damage database. This is baseline information for assessing and predicting impacts.
- Research on coastal structures, both efficacy of structure, and effects of structure on adjacent shoreline areas, including marine farms and wharves.
- Need baseline quantification of sediment systems – rates, inputs, outputs, and storage. There is very little data available to allow quantitative assessment of sediment budgets, sediment transport rates and sediment storage for the coast. There is some evidence that these vary with climate change. The impacts of human activities (such as sand extraction) on sand budgets and shoreline stability are difficult to predictions and monitor at present.
- Systematic mapping and identification of erosion prone/risk areas so that hazard zones and causes can be established.

- Need more and more accurate wave data. The reason is that waves are principal driver of coastal processes.
- Better wave hindcasting and wave propagation models in order to fill gaps in data records and also to extrapolate spatially to take the data to where it is needed.
- Better short-term (storm event) erosion models. Existing models still struggle with 3D morphology and are not good at surge/run-up.
- Techniques for dune preservation/protection and their effectiveness are not widely understood and disseminated. Although various groups around New Zealand have researched this, clearly others are attempting to reinvent the wheel (e.g., Waiake Beach North Shore City, where a field trial to determine the suitability of various plant species for sand stabilisation is underway).
- There is a lag in the implementation of existing information and management solutions.
- Improving the network of monitoring for coastal hazards, in particular, using consistent methodologies for, and database management of, coastal erosion hazard information.
- Commonly the most "managed" foreshore areas are our beaches. More thorough knowledge of the sediment transport and storage mechanisms within these systems would be invaluable to enable a more certain and targeted management regime. There is some debate over the existing level of knowledge that tends to point to the need for a better communication of the existing knowledge base.

Climate-change effects

- We perhaps have enough data on the basic variables and effects of climate change to get on with the next step, which is to assess the applicability for New Zealand of IPCC predictions, and to establish a limited set of scenarios (that can be adapted as new information comes to hand) that we can work with. A related theme is the need to concentrate on extreme events (rather than mean conditions) and to determine if extreme events are likely to get worse. It was recognised, however, that mean conditions are still very important for some processes (e.g., wind direction and littoral drift).
- Further monitoring of sea-level rise and its effects in a consistent and co-ordinated manner.
- Climate change is happening, but the accepted probability of climate change needs to be debated and agreed through central government. At present there is a significant range in the possible results of climate change. Coastal managers and local government have to legislate, rule and make decisions daily on these effects. They have to interpret the scientific data on a best reasonable attempt basis. This interpretation is then open to challenge often with sound scientific support. Final determination is usually made on a case-by-case basis by an Environment Court Judge or legal advocate. This whole process tends to provide an inconsistent regime with non-experts making the technical judgement. It would be helpful for the scientific community to agree on a most-likely or most-reasonable scenario. This would then be a (changing) yardstick from which decisions and rules could be measured. Further, if this scenario were adopted by Central Government it would provide an agreed guideline for a consistent approach nationally.
- Effects of sea-level rise in shallow, enclosed areas (e.g., Bruun rule does not work in estuaries). Need new paradigms and rules applicable for areas other than the open coast.
- Extend focus to biological/ecological effects in coastal systems (open-coast and estuarine).
- Changes in storminess associated with climate change and the effects of any such changes.
- Information on the social impact of climate change is required (e.g., will warmer temperatures mean more people at the beach for a longer season).
- Quantifying and refining the effects of sea-level rise and climatic variability resulting from global warming at a regional level.
- Information on climate change needs to be easily digestible. The information may not be 100% accurate but regional councils want it now.



Storm and cyclone hazards

- Storm tracks—defining probabilities and improving forecasts. This was particularly important if progress is to be made in assessing associated risks for local communities. Associated hazards include flooding, waves, coastal inundation etc. but identifying the risk of direct wind damage is also a priority. Hazard maps were noted as a useful product for end-users.
- Need to look at "history"—effects of succession of events.
- Transferring hazards information into risk information. This is a top priority for community users (Councils). Running scenarios (modelling and analysis) for specific hazards was deemed a useful tool for identifying priorities for risk treatment and increasing hazard awareness. Local authorities want short-term forecasting of risks (combination of event forecasts and historical assessments of hazard occurrence).
- Inshore wave forecasting and modelling. Most users are 'at the coast', and so applications need to be developed so that deepwater wave data, forecasts and climatologies can readily be extrapolated into coastal waters.
- Reconstruction of 'pre-historic' storm events from the geological record (geomorphology and cores) to provide an extension (in establishing return periods of extreme events) to the historical record that analysis of existing wave/wind/storm records provides.
- Effects of extreme storms on infrastructure.
- Effects on "non-beaches"—dunes, estuaries, cliffs. Need to extend our focus.
- Need to address event duration. Emphasis tends to be on event magnitude, but event duration is also major control on effects.
- Better catchment-scale rainfall forecasts. NIWA are progressing on improving spatial resolution in specifying and forecasting rainfall events. A national update of rainfall climatologies was also identified as a priority for local authorities.
- The accuracy of predictions of storms and their tracks needs to be monitored, and useful error estimates made available.
- Get better information on the localised effects of bathymetry on storm surge.
- The frequency, magnitude and effect of storm events need to be defined. Such information would provide coastal managers and local government with scientific information in a more useable format, and the ability to plan for events and implement appropriate coastal management techniques. A "design storm" would allow a more consistent application of management techniques. This "design storm" could then be updated as the scientific community acquires new knowledge and data. Similar techniques are used in other design and loadings code by NZ Standards.

Inundation/flooding hazards

- Urgent need for better bathymetry for driving models and better coastal topography. High priority is high resolution (3D) mapping of coastal margins, such as that provided by the LIDAR system. Coastal topography (including nearshore bathymetry and foreshore topography) is required at better than 2 m vertical resolution. Priority on existing urban and low-lying areas with future urban growth potential or significant land-use value.
- Integration of catchment flooding with coastal flooding allowing for combined probability assessment and worst-case scenario.

- General improvement of understanding of cyclical climate patterns, long-term trends and the effects of long-term climate change. Need to improve confidence in predictions and also strengthen focus on impacts (as opposed to causes of change).
- An integrated approach to risk analysis and forecasting of inundation is required. This includes timeliness of forecasts. It is noted that the contributing factors to inundation occur on different time scales. Tides can be predicted in the long term, storm events can be predicted in days, and tsunami, in some cases, may only be predicted in hours.
- More widespread production and refinement of maps of inundation prone areas and associated risk, to facilitate better planning and zoning for inundation risk. Exploring the potential for cost sharing and collaboration in the collection of the information. This includes aerial mapping of land use patterns.
- Extend tide model to estuaries, produce tidal current speed maps, verify accuracy in shallow water, and improve resolution in shallow water.
- Better prediction of inundation – needs to be more robust and applicable to the real-world (extend beyond labs), need to be able to handle spectral seas (not just monochromatic) and wave transformation and run-up, needs to be applicable on complex shorelines and coupled with 3-D bathy (e.g., crescentic bars).
- Improve understanding of hydrodynamics over land to improve flood level estimates. Includes better understanding of dune/shoreline overtopping volumes and extent of inundation over developed land with buildings, and variable cover.
- Investigate new engineering solutions to prevent, mitigate (e.g., offshore reefs).
- Recovery following inundation—processes, rates, technologies for enhancing recovery process.
- Planning and zoning for inundation risk should be underpinned by a common framework incorporating common standards and standardised GIS use.
- Develop a better understanding of water levels near the coast (surface and groundwater).
- Run-up processes in extreme events are poorly understood
- Need for a better understanding of river mouth morphodynamics.
- Understanding the relationship between river flooding and tidal/surge levels. This is likely to require sophisticated models with an emphasis on non-linear models.
- Make greater use of tools such as Cam-Era for riverine and estuarine flooding situations.
- There is a need to understand the reasons for previous inundation prediction failures.
- Understanding any unknown consequences of mangrove expansion and associated sedimentation on estuary margin inundation.
- More information on the effects in estuarine and inland water areas. This relates to most coastal hazards but inundation and flooding especially. It was noted that the location of a large number of coastal communities is associated with river mouth and estuary situations and yet a lot of existing coastal hazards work breaks down in this area. The combination of catchment and offshore coastal hazards needs to be assessed in terms of both frequency and effect.
- Assessment and development of new responses to inundation/flooding. Continuation of the hard versus soft debate for coastal defences.

Maritime/recreational hazards

- The effects of water and land based activities on coastal hazards including the effects of vessel wakes and vehicles on beaches. Vessel wakes need accurate propagation models, better information on interaction of wakes with beaches, biological and recreational effects.
- Continued improvements required in modelling ocean surface currents for pollutant drift e.g., oil spill and Search and Rescue operations.
- Develop 5–day maritime forecast models of surface currents, waves, water level for the general public and maritime operations.

- Maritime wind fields are a key, underpinning requirement. All providers need accurate, high-resolution (in space and time) wind fields for driving models of key hazards, and for direct application (Search and Rescue and oil-spill operations).
- Tsunami are a hazard! Work on the analysis of vulnerability and on warning systems could be pursued. This includes identification and analysis of paleo-tsunami, and modelling and measuring of historic tsunami.
- Set up models and scenarios for maritime/recreational hazards for key areas and publish on the Web.
- Swimmer behaviour—better ways for swimmers to get out of trouble?
- Boat designers—is our sea-state information useful to them?
- Effects of sedimentation on port operations and navigation. Need better predictive models for long-term planning, including models that might have operational uses, better understanding of natural versus anthropogenic causes.
- Processes causing sandbar movement and the hazards this presents to coastal navigation.
- Public education is required for awareness of the risks of tsunami (locally generated). The risk is usually local and the education must also be provided locally.
- Improved accuracy of extreme event forecasting (waves, current, water level, wind speed)
- Create methodology/system for improving reliability of real-time access through bar entrances for navigation safety.
- Response models to determine beach conditions have been very successfully applied in other places (e.g., NSW) to assist in management of beaches including surf life saving applications. It was recognised that such systems require good data (particularly wave data). The analysis of long-term weather patterns can assist in planning for surf life saving and other rescue service operations. For example, if warm weather is going to be 'late' in a particular year, then staffing levels for surf clubs could be adjusted to cope with this situation.
- Coordination of information and the appropriate packaging of information for different audiences are required. Partnering in data collection supported.
- More knowledge is needed on waves and tidal currents in boating and shipping areas for navigation, safety and oil-spill management.
- Refining wave models to better predict extreme events.
- Maps of the variability of bar and shoal configurations at entrances to estuaries and rivers required for safe coastal navigation.
- Monitoring of the effects of coastal structures.
- Better access to wind information, including models that can extrapolate information from existing sites to other locations in the region.

Resource management and planning for hazards

- Need to quantify the "monetary coastal values". There is a need to get an overall cost on the process of dealing with coastal hazards so that realistic progress can be determined and decisions on where those costs should fall are made. There is a need to cost different options for coastal management and, in particular, deliberately assess the costs of the "Do Nothing" approach.
- Need to quantify the "non-monetary coastal values". There is a need to obtain indicative costs and costing methods for all the non-monetary coastal values (e.g., amenity, natural character, cultural environmental) so that comparisons can be made when assessing coastal management options.
- Need to be able to provide monetary valuation of intangible coastal assets and to express impacts in the same terms. This is necessary to participate in conventional decision-making process and policy debate.

- The need to quantify some of the non-market values associated with coastal developments so that these can be more readily accounted for in assessing development proposals and potentially used as a basis for mitigation. Factoring in the triple bottom line considerations of social, environmental and economic factors.
- Development of appropriate risk-assessment methodologies.
- Emergency preparedness—the relationships between organisations needs to be clarified and the relative roles of these organisations in providing methodologies and advice need to be better defined. Develop more formal agreements for service provision: e.g., fund expert groups from relevant institutes to be available for 24 hr service provision.
- Develop systems for early warning of extreme events.
- The lack of funding for operational science must be addressed. Research into hazards and research tools for modelling, forecasting and analysing risk need to be transferred into applied operational systems for users.
- Produce regional and national hazard maps based on current understanding. Although site-specific studies may provide better information, there is sufficient expertise to provide subjective assessments for whole coast that would be reasonable. Subsequent disputes over specific sites would then be resolved by focussed research. Hazard maps would be a useful educational tool, as well as the starting point for planners.
- It was noted that there is a need to strengthen the current policy situation (e.g., the NZ Coastal Policy Statement) with respect to climate change and natural hazards, to provide better guidance and to achieve a legally binding status.
- Need to rewrite the NZCPS hazard sections to provide more direction to resource managers.
- Political and economic dimensions can confound the scientific endeavour (e.g., local concerns over property values, the conflict between development and environmental protection). Science providers have to be careful not to be compromised by these considerations.
- Better understanding needed by local councils in issues of engineering and technical hazards. They need to know the vulnerability of facilities/lifelines even if they don't own the facility or utility.
- A greater level of involvement by the insurance industry in raising awareness of sites of risk and "internalising" the costs of high-risk development on the developer, without communities bearing these costs.
- Better "models" of community involvement and engagement. Coastal management in New Zealand is primarily an issue of managing people and our communities e.g., few coastal hazards and issues exist where the coastal margin is not populated. Typical New Zealand coastal communities also highly esteem the many values of their coastal environment. The solutions and values of that environment are currently changing. Given the above there are few if any "models" of how to best involve the community in decision-making. Consultation and involvement models tend to be related to individual consultants and organisations. A sharing and development of successful "models" in different situations would be beneficial.
- An assessment of the costs of options (including non-monetary costs) for different communities, and a consideration of the cost of doing nothing needs to be undertaken. Ways of sharing of information and transporting tools to the people and locations that need them are required, and funding for the lower levels of government (e.g., LTAs) that need to undertake or commission studies needs to be sorted out.
- Need for land use planning and social responsiveness to major events (particularly tsunami). In river floods, for example, we know what to do, in terms of management of the event and affected people. For tsunami, or other large and infrequent hazards, few such plans exist. There is, for example, no coordination of evacuation planning undertaken.
- "Differential rating" to be promoted as a means of internalising the costs of development in hazardous areas to those that develop in the zones.
- The importance of identifying hazard information on Land Information Memorandum (LIM) reports issued by territorial councils under the Building Act.
- Clear understanding of liability issues. There are differing understandings on local governments (and private citizens) legal obligations with regards to coastal hazards. This has consequent effects

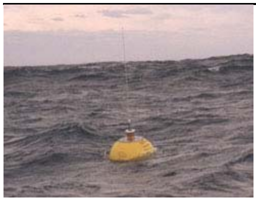
on insurance liability. Of the six LTAs in the Auckland region, half had entirely conflicting views on this.

- Barriers to the use of hazards information for planning and management include the following:
    - The scientific community appears to have a misunderstanding of the relationship between regional councils and LTAs (district and city councils). There needs to be a clear understanding so that they can target their work to meet the relevant council's needs. MHWS is a jurisdictional boundary between local and regional authorities and resulting planning documentation. This leads to inconsistencies when dealing with the coastal environment.
    - Differing knowledge bases between local government and the scientific community. Typically on the ground coastal management and land-based legislation is the domain of the LTAs. These organisations typically have staff acting as project and asset managers and planners. Technical expertise is normally contracted in. Therefore there are often few ties directly with the scientific community.
    - Political will and priorities often lie elsewhere and funding for studies is difficult to obtain.
    - Large areas of existing coastal development have been inherited by coastal managers. This is typically very expensive real estate. Management options are limited by the inherited nature of the issues.
    - There is uncertainty in risk evaluation. The difficulty in predicting an event makes risk analysis difficult and arguable. Economic and other values of the beach are indeterminate.
    - Community perception of hazard problems. We are in an era of changing solutions and there is a lack of awareness of those solutions and more confidence in the tried and trusted approaches (e.g., seawalls). Due to the time scales of coastal events there is a lack of acceptance of a problem when a dynamic shoreline is in an accretion phase. Conversely following a storm event or erosive phase there tend to be an emergency psychology that will only accept immediate "concrete" action (seawalls again!).

Education and awareness

- School-age children identified as a good target to get the environmental message across. Raise awareness of coastal hazards through education resources at school level. NIWA's CD-ROM resource (see thumb-nail image) is an excellent start. It was suggested that the Cam-Era remote video programme could also include schools. (Editors note: since the Workshop, a display at Wellington's City & Sea Museum has been set up by NIWA to display waves in Cook Strait in real time.) A model for school-age children is the joint Victoria University and GNS Quake Trackers programme (http://www.quaketrackers.ac.nz/). Coastal schools may provide locations for cameras. Inclusion of wave, tide and/or weather data would add to the resource.
- Better ways of scientists engaging with local communities—need to help locals take ownership, give them information, and help them with solutions and to draw on local community knowledge and experience (anecdotal evidence and observations can be as valuable as scientific evidence).
- Public education in hazards is an over-arching requirement, particularly to provide environmental education to the community in a form that could be easily understood. Contribute to awareness and education at all levels (school, locals, regional and central government). The development of tools for this purpose (e.g., web-based interfaces to hazards material) is a priority to facilitate public access and improve awareness.
- The scientific profile needs to be raised. This is part of improving the general public and community/council awareness of the role of science in the decision-making process.

- Greater understanding and awareness of the impacts of urbanisation on beach systems, particularly the effects of stormwater discharges.
- Comparisons needed of modified to non-modified coastlines to sharpen people's awareness.



Hazard information and data

- The establishment of a Natural Hazards Centre to package and provide one-stop shop for information was supported.
- High technology developments are also seen as a requirement for specialist access to information services (consultants and local authorities). Much of the information may be there, but presentation and packaging are seen as important factors in making it useful.
- Create online databases of existing knowledge that can be accessed by both researchers and practitioners (like GeoNet http://www.geonet.org.nz/). It should include bathymetry, topography, beach profiles, manuals such as the ARC coastal manual, tide and wave gauges, and meteorological data.
- Better topographic and bathymetric data were required for coastal areas for a variety of uses. Although these data are being collected for specific studies, the generally available data are too coarse to be of much use to coastal hazard research. It was suggested that aerial LIDAR (Light Detection And Ranging) is a new technology that would permit suitable data to be obtained, but should be applied regionally or nationally.
- Accessibility of real-time predictions/measurement for free public use.
- Extend databases to long-term monitoring.
- A need to move research from basic data collection and understanding fundamental variables, to the development of process-response models and tools, and understanding the flow on effects of changes in the basic variables. For example, if we understand likely climate change effects on rainfall, then we now need to work on river discharge and sediment supply changes that may result. In the coastal area, for example, more effort needs to go into the development of "process-response" models to determine beach change resulting from sea level rise, changes in wind direction etc. This requires the building of tools, which need to be transportable, and shared. Only once these tools are available and have been applied, can impacts and costs be established.
- Presentation of information. Coastal managers and local government are looking to obtain data in a more useful and useable format from the scientific community. LINES ON MAPS are needed and are a preferred management tool. The accuracy of the information needs to be to a detail where it can relate to property boundaries. If the existing data does not provide this accuracy it is better for the scientific community to draw the line with stated uncertainty than coastal managers make their inexpert interpretation.
- Need for a central body to coordinate and index all available information and provide this at little or no cost.
- Council data management: preservation and access. Restructuring has seen data "buried" (e.g., old Catchment Board data). Many data are not entered into databases but held by individuals. These data need to be resurrected, preserved and made available before corporate memory lapses further. Organisations can build on purpose-gathered short-term data and improve data management. It was noted that for short-term data it is important to make assessments of how representative they are and estimate associated errors.
- Hazard information needs to be more consumable e.g., identified on titles and a hazard register.
- There is a need for more and better wave data.
- Guidelines for "best practice" for data collection, analysis, storage and archiving.

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Programme–Coastal And Storm Hazards Workshop

Programme Outline:

Monday 25 March

- Research and Practitioner Perspectives 20 mins each (Coastal Erosion, Climate Change, Tides, Winds, Storms & Cyclones, Education/Awareness on Hazards & Planning).
- Facilitated workshops (on above).

Tuesday 26 March

- Research and Practitioner Perspectives 20 mins each (Storm Surge, Waves, Maritime Hazards, Engineering Sector, Tsunami, Insurance/Liability, Readiness & Response).
- Facilitated workshops (on above)

Programme details

Monday 25 March

0800–0900	Registration & Displays
0900–0915	Welcome and workshop format—Mark James, Rob Bell (NIWA, Hamilton)
0915–0930	Opening Presentation—Mark James (Regional Manager, NIWA, Hamilton) The FRST framework and directives for coastal hazards research
0930–1030	**Session 1** - Latest Research Findings & Sector Perspectives of the Knowledge Base (2 talks).
0930–0945	Overview of coastal and storm hazards – The role of research—Rob Bell (NIWA, Hamilton).
0945–1030	Coastal erosion: A NIWA perspective—Terry Hume (NIWA, Hamilton).
1030–1100	*Morning Tea*
1100–1220	**Session 2** - Latest Research Findings & Sector Perspectives of the Knowledge Base (4 talks).
1100–1120	Regional Council perspective on coastal hazards (I)—Andrew Benson (ARC Environment).
1120–1140	Territorial perspectives on coastal hazards—Derek Todd (Dtec Consulting Ltd., Christchurch).
1140–1200	Climate change and impacts on coastal margins—Rob Bell & Terry Hume (NIWA, Hamilton).
1200–1220	A central government perspective on climate change impacts, vulnerability and adaptation, sea-level rise and coastal hazards—Andy Reisinger (MfE, Wellington).
1220–1320	*Lunch*
1320–1445	**Session 3** - Latest Research Findings & Sector Perspectives of Knowledge Base (4 talks).
1320–1340	Hazards associated with severe weather systems—Mike Revell (NIWA, Wellington).
1340–1400	Wind hazard in coastal waters—Steve Reid (NIWA, Wellington)

1400–1420	Public attitudes and understanding of flood warnings and management in the Waikanae floodplain —Warren Gray (NIWA, Wellington)
1420–1445	Storm surge and coastal inundation—Derek Goring (NIWA, Christchurch)

1445–1515 *Afternoon Tea*

1515–1715 **Facilitated Workshop: Part I—Jim Dahm**
Discussion topics for break-out groups + report back:

- Coastal erosion hazards;
- Climate-change effects;
- Storm and cyclone hazards;
- Awareness of hazards and building resilient communities.

1900– *Pre-dinner drinks & Workshop Dinner (Lady Chatterley's Room, Quality Hotel).*

Tuesday 26 March

0830–1015	**Session 4** - Latest Research Findings & Sector Perspectives of Knowledge Base (5 talks).
0830–0850	Tidal forecasting - Derek Goring (NIWA, Christchurch).
0850–0910	Regional Council perspectives on coastal hazards (II) – The hazards of planning for hazards - Brodie Young, David Gregory (ECAN–Environment Canterbury).
0910–0935	Tsunami hazards - Roy Walters (NIWA, Christchurch).
0935–0955	University perspective on coastal hazards: Coastal & storm hazards knowledge base Willem de Lange (University of Waikato, Hamilton).
0955–1015	The CDEM Bill 2000 - Exploring the intention of the Bill—Mike O'Leary (MCDEM, Wellington).

1015–1040 *Morning Tea*

1040–1220	**Session 5** - Latest Research Findings & Sector Perspectives of Knowledge Base (5 talks).
1040–1100	Wave hazards—Richard Gorman (NIWA, Hamilton)
1100–1120	Engineering consultancy perspective on coastal hazards—Richard Reinen-Hamill (Tonkin & Taylor, Auckland)
1120–1140	Surf-zone hazards—Karin Bryan (NIWA, Hamilton and University of Waikato)
1140–1200	Maritime and recreational hazards—Rob Bell (NIWA, Hamilton)
1200–1220	Monitoring: Where should the effort go?—Derek Goring (NIWA)

1220–1330 *Lunch*

1330–1520 **Facilitated Workshop: Part II—Jim Dahm**

Discussion topics for break-out groups + report back: (exact Q's TBA)

- Inundation hazards;
- Maritime/recreational hazards (e.g., navigation, search & rescue, surf conditions, oil/pollutant spills, vessel wake impacts, engineering structures);
- Management of hazards.

1520–1540 *Afternoon Tea*

1540–1555 The Way Forward J Dahm, R Bell, T Hume