EARTHQUAKE HAZARD AND RISK ASSESSMENT STUDY FOR THE CANTERBURY REGION, SOUTH ISLAND, NEW ZEALAND: *OUTLINE OF PROGRAMME DEVELOPMENT*

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ABSTRACT

In recognition of the earthquake threat to Canterbury, and its statutory responsibilities, Environment Canterbury initiated a comprehensive, staged multi-year earthquake hazard and risk assessment study programme in 1997. In this paper the general framework and philosophy behind Environment Canterbury's Earthquake Hazard and Risk Assessment Programme is outlined. The results of the stage 1A earthquake source characterisation, and stage 1B probabilistic seismic hazard assessment for the Canterbury region are presented in companion papers in this volume. The programme participants have ongoing earthquake hazard research projects, and also are involved as practitioners in land-use planning and development of relevance to the Canterbury region. The coordinated programme is primarily designed to facilitate the integration of a diverse range of independent studies, so making relevant earthquake hazard and risk information readily available to a wide range of end-users, including other professionals (engineers and scientists), planners, civil defence and emergency management staff, utility operators, and developers. In addition the programme provides up to date, relevant information for public education and awareness purposes. The first stage of the programme has been completed, and includes identification and characterisation of earthquake sources, probabilistic hazard assessment, and formulation of earthquake scenarios. The long-term staged study programme will address the earthquake hazard, the risks posed, possible mitigation options and mitigation implementation methods available.

INTRODUCTION

Environment Canterbury has developed a comprehensive earthquake hazard and risk assessment study programme for the Canterbury region. The programme was developed in consultation with the Institute of Geological and Nuclear Sciences Ltd (IGNS) with input from other key stakeholders in the region including the Natural Hazards Research Centre (NHRC), University of Canterbury.

The first stage of the programme, divided into three component reports (Stages 1A-1C) have been completed over a period of three years. The results of Stage 1A (earthquake source characterisation) are summarised in a following companion paper in this issue of the bulletin (Pettinga *et al.*, this volume), and the results of Stage 1B (probabilistic hazard assessment) are also presented (Stirling *et al.*, this volume).

Successful and cost-effective regional-scale earthquake hazard mitigation programmes have been completed in other parts of New Zealand (for example, Auckland and Wellington), and a similar programme was considered appropriate for the Canterbury region (Figure 1). In developing the programme for Canterbury it was recognised that there are many potential earthquake sources located throughout a geographically large region, and that significant (and vulnerable) urban centres and infrastructure are also located throughout the region.

The staged programme (Table 1) allows for the progressive and logical assessment of the various earthquake hazard components followed by an earthquake risk assessment and an economic impact assessment. The final part of the programme will be to prepare an earthquake hazard mitigation strategy.

In addition to the strategy, an important output of the study will be a series of informative, innovative and user-friendly products including maps, explanatory booklets and brochures. The first of these, based on the completed stages 1A and 1B are now published and available from Environment Canterbury.

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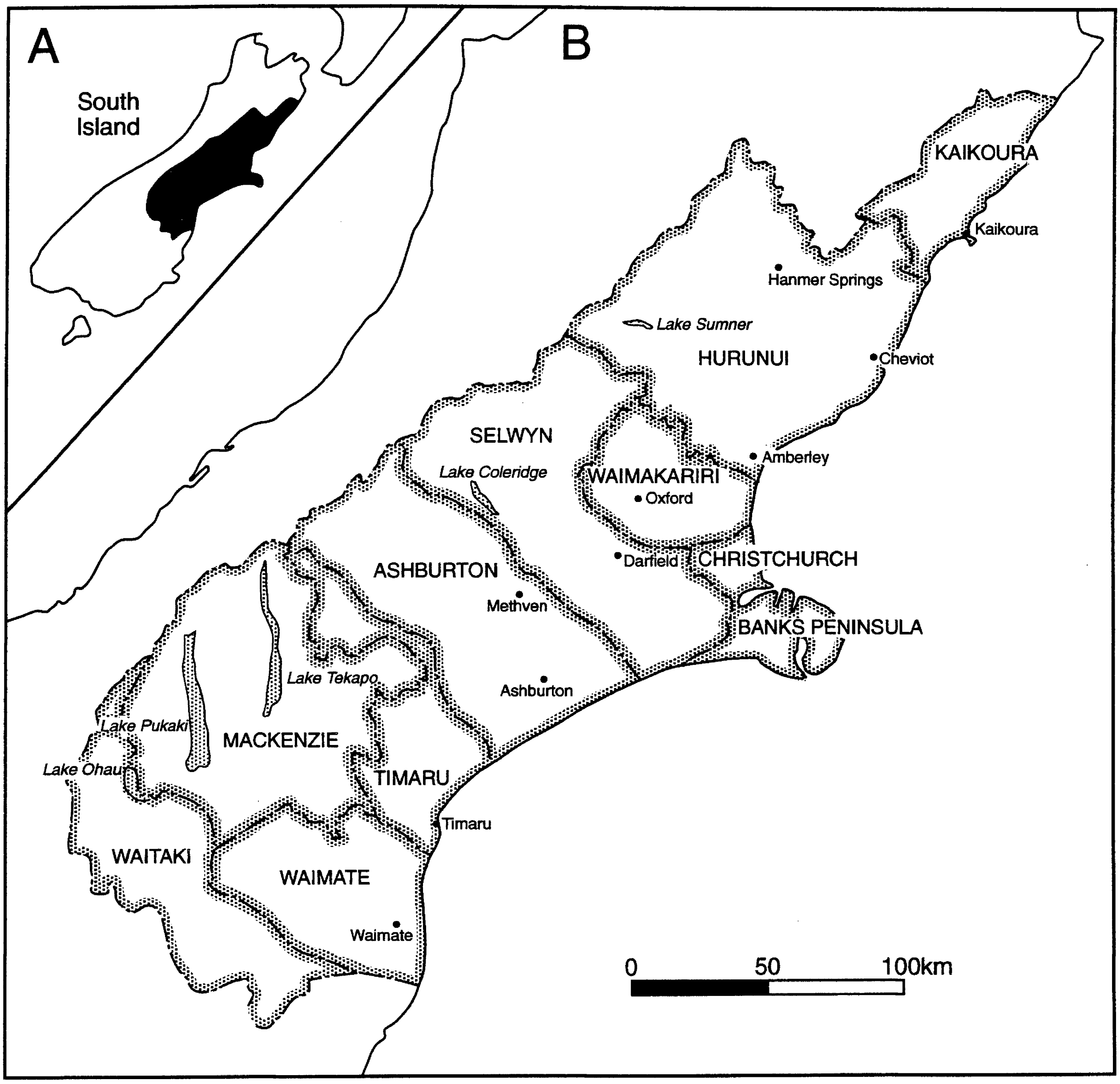

*Figure 1: **(A) The geographic extent of the Canterbury region in South Island. (B) The eleven Territorial Local Authorities within the Canterbury region, and major urban centres are also shown.***

AIM OF PROGRAMME

The fundamental outcome of any seismic hazard and risk assessment study is to reduce the vulnerability of the regional community to the impact of earthquakes by providing local authorities and other organisations, individuals, and politicians with sufficient and accurate information to make logical, justifiable, and defendable decisions. The main aim of the study is to make available information that will lead to increased public awareness of the earthquake vulnerability and risk in the Canterbury region. The desired outcome is better decision making by local authorities and the community thereby reducing exposure to earthquake risk.

The overall objectives of Environment Canterbury's long-term earthquake hazard and risk assessment study are to:

(1) Define the nature and extent of earthquake hazards in the region, including active faulting, fault-propagated active folds, ground shaking, liquefaction, slope stability, and tsunami;
(2) Identify and quantify the earthquake risk to the regional community;
(3) Present earthquake hazard information in a format that will encourage the regional community to take steps to reduce their vulnerability;
(4) Ensure that adequate information in an appropriate format is available to Environment Canterbury as well as the territorial local authorities in the region in order

to make logical, defendable and justifiable decisions for land-use planning, development, and emergency management; and

(5) To ensure all engineering and science practitioners have relevant and up to date information available or know where to source such information, so ensuring that, as far as is practical, sound and consistent professional advice is provided to end-users.

Table 1: Canterbury region earthquake hazard and risk assessment study programme.

STAGE IA-C: (1997-2000)

- Identify and characterise earthquake sources onshore (IA) *(completed)*
- Probability Hazard Assessment (IB) *(completed)*
- Earthquake Scenarios (IB) *(completed)*
- Review of historic earthquakes in Christchurch (IB) *(completed)*
- Identify and characterise offshore earthquake sources (IC) *(deferred)*

STAGE IIA-B: (2000-2002)

- Liquefaction potential and ground damage maps of selected urban areas – Kaiapoi-Woodend (IIA) *(completed)*
- Liquefaction potential and ground damage maps of selected urban areas – Christchurch (IIB) *(in progress)*
- Tsunami and Storm Surge Assessment: Timaru Engineering Lifelines *(completed)*
- Earthquake Hazard Assessment: Timaru Engineering Lifelines *(in progress)*
- Earthquake Hazard Assessment (Part of Natural Hazard Assessment): Hurunui Engineering Lifelines Project *(completed)*

STAGE III: (2002?)

- Other earthquake hazards (eg. amplified ground shaking, landslide, tsunami) *(proposed)*

STAGES IV & V: (?)

- Assessment of Earthquake Risk (buildings, lifelines, and casualties) *(proposed)*
- Earthquake impact study in terms of regional economy and society *(proposed)*

Key Programme Objectives:

Public Education
Emergency Management
Disaster Preparedness
Statutory Requirements

WHAT IS DRIVING THE PROGRAMME ?

While it is not possible to reduce the incidence of earthquakes in the Canterbury region, Environment Canterbury recognised that steps need to be taken to reduce the vulnerability of the community to their impacts. Earlier studies have highlighted aspects of the earthquake hazard either with respect to the region as a whole (e.g. Owens *et al.*, 1994), or more specifically to the Christchurch area (Elder *et al.*, 1991; Centre for Advanced Engineering, University of Canterbury, 1997). Over the last decade a significant amount of new research data has become available regarding the active tectonic setting and the related earthquake activity in the Canterbury region. Accordingly this earthquake hazard and risk assessment study is timely and is needed in order to position the community to take full advantage of the new knowledge now available from scientific and engineering investigations. Effectively, the driving force for Environment Canterbury's programme includes:

(1) Canterbury's susceptibility to significant damaging earthquakes;
(2) The general public perception that the earthquake threat is low;
(3) Local government responsibilities under the Resource Management Act 1991 and the potential consequences of failing to fulfil statutory functions;
(4) The recognition given to natural hazards in Environment Canterbury's "Regional Policy Statement";

(5) The lack of a co-ordinated approach to earthquake hazard mitigation work in Canterbury;
(6) The need to resolve several significant scientific issues and in particular the probability of occurrence of damaging earthquakes; and
(7) The lack of earthquake hazard information for urban areas in the region other than Christchurch.

In its capacity of regional planning, environmental management, and emergency management, Environment Canterbury can influence community decision-making. For this reason the Environment Canterbury believes it is well placed to take a lead role in promoting the availability and use of earthquake hazard research and hazard mitigation initiatives throughout the region.

PROGRAMME OUTLINE AND PROGRESS TO DATE

The earthquake hazard and risk assessment programme comprises five main stages (Table 1) and reflects the application driven (planning, environmental management, emergency management, and public education) information requirements of Environment Canterbury.

Stage 1 (Part A) of the study is complete (Pettinga *et al.* 1998). The aim of Stage 1 (Part A) is to identify and characterise the active geological structures in Canterbury as well as the immediate surrounding regions, capable of generating moderate to large earthquakes likely to impact on Canterbury. This involved:

(1) Compiling existing records of historical and instrumental seismicity in the region;
(2) Compiling existing information on active or potentially active faults and other tectonic structures in Canterbury and nearby that may impact on the region. As part of this stage a preliminary compilation of offshore data was also included from a review of the published literature. However, it was realised that this did not adequately account for all the major seismogenic structures offshore, especially in the light of ongoing geological oceanographic research by the National Institute for Water and Atmospheric Research (NIWA). Consequently it is planned to undertake a more comprehensive review of all known offshore earthquake source structures at a later stage in the programme. This work was planned for 2000, but has now been deferred;
(3) Undertaking aerial photograph studies and reviewing map databases for south Canterbury to determine location of active faults and other structures;
(4) Developing a methodology for a probabilistic seismic hazard assessment;
(5) Developing a methodology for defining appropriate earthquake scenarios;
(6) Outlining additional work that could be undertaken to better identify and characterise earthquake sources in Canterbury.

The significant achievements of Stage 1 (Part A) are not reviewed here, but are presented in a following companion paper (Pettinga *et al.* this volume).

Stage 1 (Part B) of the study, now also completed (Stirling *et al.* 1999), built on the results of Part 1A, and involved three components of work:

(1) A detailed probabilistic seismic hazard assessment was undertaken in order to provide estimates of Modified Mercalli Intensity (MMI), Peak Ground Acceleration (PGA), and response spectral ordinates throughout the Canterbury region for return periods of 50, 142 (nominally 150), 475 (nominally 500), and 1000 years;
(2) Because of the wide geographic extent of the region, it was decided to prepare an outline of three typical earthquake scenarios likely to impact on the region. The three scenario events selected include: i). a local moderate magnitude (~M5-6) earthquake; ii). a large (~M7-7.5) event located in the eastern foothills of the Southern Alps; and iii). a great (~M8) earthquake rupture of the Alpine Fault. These three scenarios are required for later stages of the programme in order to provide the basis for impact analysis and defining the implications for disaster preparedness and emergency management in the region; and
(3) To undertake a review of historic earthquakes which have impacted on Christchurch.

The significant achievements of Stage 1 (Part B) are also not reviewed here, but are presented in a following companion paper (Stirling *et al.*, this volume).

The aim of Stage 2 is to identify and quantify for the selected urban and surrounding areas the geographic variation in site conditions with respect to ground shaking and liquefaction potential during future earthquakes. The focus of this work will be on the main urban areas including Kaiapoi-Woodend (Stage 2A in 2000 and now completed) and Christchurch (Stage 2B planned for 2001). Further studies at other centres such as Timaru and Kaikoura may also be warranted, based on further assessment of the geological and geotechnical conditions indicative of site amplification and liquefaction susceptibility.

Stage 3 of the study will address other earthquake hazards including slope instability and tsunami. The slope instability study will be restricted to identifying and quantifying the slope failure potential in main urban areas, along significant transport and other lifeline corridors, and river gorges. The scope of the tsunami study has not been formulated at this time, but will probably include analysis of near-field and far-field tsunami hazard.

Stages 1-3 provide the information needed to undertake an assessment of earthquake risk (Stage 4). The earthquake risk assessment will involve combining hazard information with vulnerability information such as building replacement costs, building occupancies, value of domestic properties and replacement costs for lifeline services. These data will then be combined to determine monetary losses and casualty rates during earthquake scenario events.

Stage 5 of the study will look at the economic and social impact of an earthquake on the Canterbury region. This study should be of significant value to key community decision-makers. The results of the study will help set priorities for allocation of resources for future technical studies, emergency service planning, ownership and operation of community services and level of investment in community education.

The programme will culminate with the preparation of a detailed earthquake hazard mitigation strategy. The strategy will contain a series of actions or initiatives to ensure that the risks associated with earthquakes are explicitly recognised, quantified, and either accepted or mitigated. The strategy will help to define the role of Environment Canterbury with respect to earthquake hazard mitigation and the relationship it seeks with other relevant organisations in the region. It is hoped that a common framework can be developed within which priorities for action can be identified, responsibilities and accountabilities accepted and, where appropriate collaborative work programmes developed. This should lead to better communication and information exchange, and efficiencies in the use of limited resources.

The implementation of the full earthquake hazard and risk assessment programme is dependent on the allocation of financial resources through Environment Canterbury's annual plan process. The staged programme is suited to the annual funding allocation process, providing for some flexibility in terms of scheduling the multi-year work plan, and also providing for progressive accountability in terms of satisfactory standards for work completion, with clear flow-on benefits to the regional community.

As outlined earlier, one of the key aims of the programme is to ensure that information compiled at each stage of the programme is made widely available. A critical element of this strategy is to proactively develop public awareness of the earthquake hazard. The approach taken by Environment Canterbury includes:

- The preparation and publication of comprehensive technical reports at each stage of the programme;
- The formal presentation of the results contained in the report to all Canterbury region territorial local authorities, emergency management and educational organisations, as well as the media. This has been facilitated by holding formal meetings to launch each completed stage of the programme. This has proved to be a particularly successful approach, achieving excellent attendance and feedback from those attending these meetings, and a high profile in the local and national news media; and
- The preparation of information for public educational purposes. For example the large colourful Canterbury earthquake source poster (Canterbury Regional Council, 1999) which is based on the results contained in the Stage 1A and 1B reports, was widely circulated throughout the region. A further anticipated development is the preparation of an earthquake web site, targeted especially for schools to access relevant regional information about the earthquake hazard, and provide up to date readily available information in a non-technical format suitable as a science information resource.

HAZARD INFORMATION AND ITS USE - *A COMMENT*

It is an unfortunate fact that we do not always make full use of available hazard information. The reasons for this are varied, but may include factors such as staff time, financial resources, as well as information which may not be presented in a language or format that is easily understood or usable. The facilitation of improved communication between earthquake hazard experts and the community is necessary if research is to be effectively translated into actions that mitigate hazards.

Hazard information prepared by scientists or engineers is often unsuitable or unusable for immediate use by non-technical users. Most local authority planners and civil defence/emergency management staff do not have the necessary training or experience to apply earthquake hazard information. Furthermore, their experience with natural hazards is often restricted to flood related issues. Equally, users who are unfamiliar with or not proficient in using technical hazard information are likely to misuse it or, as is more common, not use it at all. Clearly there is a need for further training and improved communication in order to facilitate the use of hazard data. While technical hazard data may exist, its availability may be dependent on the provision of staff and financial resources to ensure it is fully utilised by regional and local government organisations.

Planners, civil defence/emergency management staff, utility operators, and developers all use hazard information in different ways to scientists and engineers. Therefore, there is considerable scope to be innovative, and by breaking new ground, in the way information is translated and transferred.

Providers of hazard information and those responsible for its dissemination are beginning to recognise the difficulty of applying technical hazard information for practical mitigation purposes. The New Zealand Building Code is an excellent and most effective example where this is already being done. Progress is being made and the gap between scientists and end-users is closing. Scientists have improved understanding of the potentially wide application of their findings, and planners are gaining an improved level of technical knowledge and understanding of scientific information. This process is assisted by a contestable funding regime whereby applicants for research funds benefit from showing that their work has practical application and is supported by hazard information users.

Even when hazard information is available and it has been translated and used for hazard reduction, it may still not be used effectively. Key reasons include:

- The limited available staff time;
- The limited available funding;
- The perception that the hazard was so low that the existing effort was adequate;
- The perception of potential public opposition to politically sensitive programmes;
- A lack of leadership, as well as a lack of attention from management and elected representatives due to competing day-to-day issues;
- A lack of interest or commitment.

Environment Canterbury's earthquake hazard mitigation strategy has identified the importance of having high quality scientific information as a prerequisite for effective hazard mitigation. The strategy recognises the importance of translating information, in partnership with the science providers, into a useable form and its effective transfer to non-technical users. Actions or initiatives likely to improve the effective use of scientific information by non-scientists are also being addressed by the programme, and several of the developments adopted have been outlined in the previous section above.

CONCLUDING REMARKS

In this paper we have outlined Environment Canterbury's multi-year co-ordinated programme which addresses the earthquake hazard and risk assessment for the Canterbury region. The process of establishing a long-term co-ordinated earthquake hazard and risk assessment programme has provided an ideal opportunity for research and consultancy organisations to work closely and effectively with local government.

The approach to the study programme hinges on bringing together complementary databases from different organisations for the purpose of earthquake hazard mitigation. Because of the scope of the project and the size of the Canterbury region it is considered essential that the work be staged over a period of about five to seven years, dependent on annual levels of funding support provided. The long-term framework provides flexibility for setting objectives for each future stage. The successful conclusion of the programme is dependent on performance achievements at each stage and continued funding via the annual planning process of Environment Canterbury.

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