List of Acronyms and Glossary of Terms

AEP	Annual Exceedance Probability
AGS	Australian Geomechanics Society
AFR	Annualised Financial Risk
ALARP	As Low As Reasonably Practicable
ALR	Annualised Lives Risk
ANCOLD	Australian National Committee on Large Dams
ARI	Annual Recurrence Interval
AS	Australian Standard
BCR	Benefit Cost Ratio
BRANZ	Building Research Association of New Zealand
DUAP	NSW Department of Urban Affairs and Planning
EV	Expected Value
EW	Environment Waikato
EWS	Early Warning System
FMP	Flood Management Plan
FRMP	Flood Risk Management Plan
GIS	Geographical Information System
HCB	Hauraki Catchment Board
HKGPD	Hong Long Government Planning Department
HSE	United Kingdom Health and Safety Executive
IR	Individual Risk
LOL	Loss of Life
NSW	New South Wales
NZS	New Zealand Standard
PAR	People at Risk
PLL	Probable Loss of Life
QRA	Quantitative Risk Assessment
RTA	Roads and Traffic Authority
RWB	Rural Water Board
SH	State Highway
TCDC	Thames Coromandel District Council
TNZ	Transit New Zealand
URS	URS New Zealand Limited
USBR	United States Bureau of Reclamation
yr	Year

Acceptable Risk	A risk for which, for the purposes of life or work, one is prepared to accept "as is" with no regard for its management. Society does not generally consider expenditure in further reducing such risks justifiable.
Annual Exceedance Probability	The chance of a particular event (such as a flood of a certain magnitude, or larger) occurring in any one year. Analogous to the return period.
Confidence Level	The probability that a reported value will not be exceeded, expressed as a percentage, e.g. the 95th percentile confidence level would not be exceeded in 95% of cases.
Elements at Risk (E)	Meaning the population, buildings and engineering works, economic activities, public services utilities and infrastructure in the area potentially affected by landslides.
Event	A particular occurrence that has the potential for causing an undesirable consequence or outcome. Similar to hazard except that the term event does not necessarily incorporate a frequency or probability of occurrence aspect.
Hazard	A condition with the potential for causing an undesirable consequence.
Individual Risk	The risk of fatality and/or injury to any identifiable (named) individual who lives within the zone exposed to the hazard, or who follows a particular pattern of life that might subject him or her to consequences of the hazard.
Mean	The average value of cost range or distribution. This measure of central tendency was adopted because it is the most easily visualised by experienced consultants.
Probability (P)	The likelihood of a specific outcome, measured by the ratio of specified outcomes to the total number of possible outcomes. Probability is expressed as a number between 0 and 1, with 0 indicating an impossible outcome, and 1 indicating that an outcome is certain. For example, a probability of occurrence of 1 in 100 years is equal to a probability of 0.01 per annum.
Risk (R)	A measure of the probability and severity of an adverse effect to health, property or the environment. In this QRA, risk is the product of the probability of a particular failure (or event) occurring and the consequence. The probability of the consequence, which may itself be the product of multiple conditional probabilities, is as used in the calculation of risk. When expressed in dollars, the consequence is not a realistic monetary value as its derivation includes the probability of occurrence of the consequence. A more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.
Risk Analysis	The use of available information to estimate the risk to individuals or populations, property, or the environment, from hazards. Risk analyses generally contain the following steps: scope definition, hazard identification, and risk estimation.
Risk Assessment	The process of risk analysis and risk evaluation.

Risk Cost	The cost of the consequences for those risk issues that occur over the project life. Usually expressed as a distribution or a range of cost rather than a single point cost estimate.
Risk Estimation	The process used to produce a measure of the level of health, property, or environmental risks being analysed. Risk estimation contains the following steps: frequency analysis, consequence analysis, and their integration.
Risk Evaluation	The stage at which values and judgements enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental, and economic consequences, in order to identify a range of alternatives for managing the risks.
Risk Management	The complete process of risk assessment and risk control.
Risk Quotient	The numerical product of the frequency and the consequence. For this risk assessment the ALR and the AFR are risk quotients.
Societal Risk	The risk of multiple injuries or deaths to society as a whole: one where society would have to carry the burden of an event causing a number of deaths, injuries, financial, environmental, and other losses.
Tolerable Risk	A risk that society is willing to live with so as to secure certain net benefits in the confidence that it is being properly controlled, kept under review and further reduced as and when possible.
Uncertainty	There are two types of uncertainty, the incertitude associated with the failure mode or consequence itself and that arising from the expert consultants lack of knowledge of the issue. In the risk model, these uncertainties are represented by the range or spread of distribution associated with the cost of consequences e.g. by the difference between the mean and the 95th percentile confidence levels for a consequence cost.
Vulnerability (V)	The degree of loss to a given element or set of elements within the area affected by the landslide(s). It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the hazard.
95th percentile	The 95% confidence level for a cost range or distribution, or that amount which should not be exceeded in 95% of occurrences. Generally considered to be an upper limit estimate with respect to cost.
80th percentile	The 85% confidence level for a cost range or distribution, or that amount which should not be exceeded in 85% of occurrences. It is a relatively optimistic estimate. Generally considered to a reasonable planning level for longer-term strategic decision making with respect to cost.
50th percentile	The 50% confidence level for a cost range or distribution, or that amount which should not be exceeded in 50% of occurrences. It is the median value cost. Generally considered to be a “best estimate” with respect to cost.

Appendix A

Risk Assessment Details

Contents

Appendix A Risk Assessment Details

Tables

Figures

Appendix A
Risk Assessment Details

A1.1 Introduction

This appendix provides a brief introduction to the concepts used in risk assessment and some background on the processes involved and how the results of a risk assessment may be interpreted. We also provide a discussion on the use of risk assessment as a tool in risk-based decision making and some commentary on interpretation of risk numbers. The definitions of terms used herein are provided in the Glossary of Technical Terms included at the end of the main report. The references made in this Appendix are also listed at the end of the main report.

Risk is defined in general terms as the product of the frequency (or likelihood) of a particular event and the (usually adverse) consequence of that event, be it in terms of lives lost, financial cost and/or environmental impact. Events that need to be considered in a particular risk assessment will depend on the scope of the study and to some extent what the results of the assessment will be used for. In this case the objective of the study is to evaluate the issues regarding flooding of six townships between Thames and Coromandel, specifically for flood events with an annual exceedance probability (AEP) of 1%. An AEP of 1% can be thought of as an event with a return period or average recurrence interval (ARI) of 1 in 100 years. However, the event probability is better defined using the term AEP, since this correctly implies that the event has a specific probability of occurring every year, rather than once in a certain time period.

When combined with an indication of the size of the flooding event and how often the event may occur (the frequency or probability), the hazard can be defined. The characterisation of the various hazards is predominantly carried out using hydrological and engineering techniques. Once the hazards are identified, the consequences due to the hazards are assessed. The hazards and consequences are then combined, either quantitatively or in non-product form using descriptive terms (refer to Section A1.3 for further discussion on quantitative and qualitative assessments). The following sections of this appendix provide background information on the development and conduct of risk assessment techniques, risk criteria and how to interpret risk.

A1.2 Risk Assessment Process

Risk assessment was developed as a tool for risk-based decision making in relation to the planning and design of engineering works. In general terms the steps involved in the flood risk assessment comprise:

- Definition of the problem and setting the terms of reference for the study.
- Hazard identification and frequency analysis, including:
  - identification of the event(s) that can cause an adverse consequence.
  - estimation of speed and size, in this case the area of flooding, depth of flooding and water velocity.
  - estimation of the probability (or frequency) of the event.

- Consequence analysis, including:
  - identification of the elements at risk (such as people, buildings, infrastructure etc.).
  - estimation of the vulnerability of the elements at risk.
  - assessment of the temporal and spatial variability of the elements at risk. These aspects describe how the time of day (such as day or night) or the time of the year (such as high tourist season or low season) or the location of an element at risk, influences the likelihood of a particular element at risk, such as a person, being within the potential impact zone from the hazard.
  - assessment of financial impacts as well as loss of life.
  - assessment of environmental impacts due to the identified hazards.
- Risk calculation:
  - For this study the risk was calculated quantitatively. Lives risk and financial risk are presented. The lives risk is presented in terms of societal risk and individual risk (these are defined in more detail in following sections).
  - event trees are a widely recognised tool to logically and systematically represent potential failure pathways depicting the various events and consequences that lead to the estimated number of deaths, financial or environmental consequence, and associated probabilities. Each branch point in an event tree represents a key decision point (or node), which has been identified in de-convoluting the event into a series of sequential steps. Each decision point may have alternative outcomes. A probability is then assigned to each alternative. The use of event trees simplifies the problem into manageable steps and helps to clarify the risk calculation. For this QRA the event trees have been transposed into spreadsheet form to facilitate the risk calculation for the sites examined.
- Risk evaluation, including:
  - definition of risk criteria.
  - comparison of the estimated risks with available risk criteria or guidelines.
  - options for risk amelioration works.
  - cost estimates of risk treatment works.
  - estimation of residual risk (remaining risk following risk amelioration works).
  - consultation with those parties potentially affected by the identified hazards (as necessary).

QRA has been used extensively in industries that routinely manage potentially hazardous processes, such as the nuclear, oil and gas, and chemical industries. Risk assessment was developed during the 1940s in relation to the planning and design of nuclear power facilities. More recently, QRA has been used in the engineering field, providing information for:

- land use zoning studies.
- environmental site assessments.

- development in areas potentially susceptible to landslides, including natural and man-made slopes.
- identification of the risks and planning of risk mitigation works for areas susceptible to boulder falls, rockfall, landslips and other geological events.
- dam safety evaluations and design of new dams.

One of the advantages in using a risk assessment approach is that it can focus attention on the main contributing factors to the risk. In this sense it may be useful for forensic analysis of problems and as a guide in the judicious implementation of risk management activities. However, the forensic application of risk assessment is not appropriate for judging the relative merit of historical decisions, outside of the context existing at the time those decisions were made.

Whether carried out during the risk assessment, or as a separate exercise of risk management, a key part of the process is consultation with those potentially affected by the identified risks. The consultation process should endeavour to clearly convey the risks to those stakeholders potentially affected by the hazards, and explain the basis for the risk management decisions. This assists in obtaining general acceptance of the proposed risk management plan, and can provide a check on the rigor of the risk assessment.

An example of this risk management process with respect to landslides is the work carried out on behalf of the Shire of Lillydale. This example deals with defining debris flow risk zones at Montrose, Victoria (Moon et. al, 1992). Details can be found in the aforementioned paper and a summary of the risk zoning exercise is provided in Fell and Hartford (1997). The risks to life and property for houses within relatively higher risk zones were estimated (Finlay, 1996). A result of the study by Finlay was an average annual expected loss of life of between 0.05 and 0.6. The Council reportedly undertook an extensive public consultation program with potentially affected residents. As a result of the dissemination of the risk data, the public potentially affected by land instability could more easily understand and appreciate the issues involved. Apparently, no one has moved from their house, despite the fact that the risks are considerably higher than other risks generally accepted by society (Finlay, 1996 and Finlay and Fell, 1997).

A1.3 Qualitative Versus Quantitative Risk Assessment

The approach to risk assessment can be of a qualitative nature or involve more quantitative analysis. The initial steps involving investigation and assessment of the hazards and consequences can be applied to either approach. The main difference between the two is how the risk is expressed. In quantitative terms, the risk is expressed numerically and is generally defined as the product of the probability (or frequency) of the hazard and the consequence. For a qualitative approach, the risk is commonly expressed using defined terms such as “low”, “medium” or “high” (i.e. in a non-product form) selected from a matrix relating hazard category and consequence rating. This approach is described in detail in the risk management standard, AS/NZS 4360.

Each approach has its merits. However, depending on the desired outcomes of the risk assessment one may be more appropriate than the other.

Appendix A
Risk Assessment Details

In some applications the use of a qualitative approach will allow the level of risk to be rated in one of only a handful of different risk levels. Typical qualitative analysis methods use five hazard ratings and five consequence categories and these are combined in a matrix to represent a limited number of broadly defined risk levels. Indeed, it is often the case that the majority of the risk issues being explored will fall within a narrow band of risk ratings, making it difficult to distinguish between the issues and providing only limited information to allow the issues to be prioritised. This may be appropriate if the risk assessment process only requires a relatively coarse screening of the issues. Qualitative assessments are also often used when there is a belief that it is too difficult to quantify intangibles, such as community perceptions, corporate image, public outrage etc. This need not necessarily be the case since methods are available that facilitate quantification of apparently intangible consequences and even incorporate uncertainty in the numerical estimation of input parameters.

For this project, the risks from the flooding hazard for each of the six communities need to be ranked in order to prioritise risk mitigation works and make the best use of available resources, which requires a quantitative approach.

The quantification of risk can also be useful when comparing risk at a particular site with published standards or guidelines, or other levels of risk faced by the community. However, this must be done judiciously to minimise any misinterpretation or misunderstanding of the level of risk.

Usually, the decision to carry out a quantitative risk assessment is largely influenced by the amount of data available to assess the frequency of the hazards. In this case considerable work has been carried out by Environment Waikato and Thames Coromandel District Council to analyse past flooding events and assess inundation areas, flood depths and water velocities. We have used this information as the basis for selecting the 1% AEP event and estimating the likely consequences with confidence.

To analyse the flooding risks along the Thames-Coromandel Coast we have developed a simplified model of natural hazards and their consequences that has required the approximation of the interaction of very complex processes. In essence we are trying to answer the question ***What are the consequences due to a particular flood event?*** To answer this question we have simplified it into the following steps:

- What is the likelihood of the 1% AEP storm generating the 1% AEP flood event?
- What is the performance of any flood mitigation works within the area of interest?
- How many people could be affected by the flood water? This is referred to as the Population at Risk (PAR) and may depend on several factors such as:
  - the time of year (especially holiday periods and the number of people who may be staying at a camping ground).
  - whether the event occurs in the daytime or during the night.
  - the amount of warning time available.
  - the nature of the area flooded such as residential homes, businesses, recreation areas, etc.

- What is the proportion of the PAR that may be killed, which results in Loss of Life (LOL)? The LOL may depend on the ability of people to understand any warnings issued and their capacity to physically respond to the warnings.
- What degree of damage to buildings and infrastructure likely as a result of the flooding?

In most cases consideration of such factors often requires subjective judgement. Therefore, strictly speaking the risk assessment will be only semi-quantitative, although professional judgement and experience are valid and accepted means of developing realistic models of complex natural or behavioral mechanisms and guidelines are available for the use of judgement in engineering risk assessments (refer Section A1.4).

A quantitative risk assessment framework can help the risk assessor focus on the key elements affecting the various processes involved in determining the sequence and impact of a particular hazard. The aspects with the most uncertainty can be identified, and selectively examined to estimate the influence these aspects may have on the outcome. This can have much benefit in assessing the most appropriate mitigation measures. QRA is also beneficial for:

- Comparison of the lives risk with available criteria.
- Prioritisation of risk sites to facilitate the development of a defensible and transparent risk management plan.
- Quantification of the financial benefits from the works for inclusion in an economic assessment such as benefit cost ratio.

A1.4 Guide to the Assignment of Subjective Probabilities

The estimation of probability figures may be carried out in a variety of ways. Depending on the amount and quality of existing data, such as documented records of historical slope failures including failure location, size and causes, a numerical analysis may be possible. However, for cases where there is little or no existing data a more subjective assessment of probability is necessary. A system using subjective judgements may also be useful as a check on other methods of frequency analysis.

As a guide, the following subjective judgement probabilities were developed in the United States for the nuclear industry (Barneich et al., 1996) to test the reasonableness of subjective probabilities.

Table A-1: Guide To Assigning Subjective Probabilities

Description	Annual Probability
Occurrence is virtually certain.	1
Occurrence of the condition or event is observed in the available database.	10^{-1}
The occurrence of the condition or event is not observed, or is observed in one instance, in the available database; several potential failure scenarios can be identified.	10^{-2}
The occurrence of the condition or event is not observed in the available database. It is difficult to think about any plausible failure scenario; however, a single scenario could be identified after considerable effort.	10^{-3}
The condition or event has not been observed, and no plausible scenario could be identified, even after considerable effort.	10^{-4}

A1.5 Limitations, Benefits and Defensibility of Risk Assessment

There are various inherent limitations when conducting and interpreting the results of a risk assessment. However, depending on the objectives and quality of output, a risk assessment can provide significant benefits to a facility owner and/or manager. The following points are adapted from the landslide risk assessment guidelines published by the Australian Geomechanics Society, March 2000, which are applicable in any risk assessment:

- *The judgement content of the inputs to any analysis may result in values of estimated risks with considerable inherent uncertainty.*
- *The variety of approaches that can reasonably be adopted to analyse [landslide] risk can result in significant difference in outcome for the same situation when considered separately by different practitioners.*
- *To complete a risk assessment, time and skills are required to make and interpret the field observations and develop the insight and understanding of the* issues *[slope process applicable]. Greater experience and understanding of the processes will improve the reliability of the analysis.*
- *Revisiting an analysis can lead to significant change due to increased data, a different method or changing circumstances.*
- *The consequences of an inability to recognise a significant hazard will lead to an underestimate of the risk.*
- *The results of an assessment are seldom verifiable, though peer review can be useful.*

- *The methodology is currently not widely accepted and thus there sometimes is an aversion to its application.*
- *It is possible that the cost of the analysis may outweigh the benefit of the technique in making a decision, especially where complex detailed sets of data are required. However, this is really an issue of matching the analysis method to the scale of problem and the resources available.*
- *There may be difficulty in completing a quantitative analysis due to the difficulty of obtaining sufficient data for reliable evaluation of the frequency of events.*
- *It is difficult to accurately analyse risk for low probability events.*
- *The risk assessment process is generally most useful because it encourages a systematic approach to a problem and enhances the understanding of the potential consequences.*

A1.6 Risk Criteria

A1.6.1 General

Current ways to present risk to life, which are discussed in the following sections, include:

- individual risk.
- expected value of life loss (which is also a form of societal risk). This can often be referred to as the annualised lives risk (ALR).
- societal risk (in terms of F-N curves).

At present, the types of risk where guidance on risk criteria can be found are individual risk (e.g. DUAP, 1990) and societal risk (e.g. Australian National Committee on Large Dams, ANCOLD, 1998 suggested limit lines presented as F-N curves). The societal risk guidelines currently published by ANCOLD are illustrated on Figure A-2 in this Appendix. The Australian Geomechanics Society (AGS) has published guidelines on the conduct of landslide risk management. This paper (AGS, March 2000) presents a summary of acceptable and tolerable risk criteria for individual and societal risk. ANCOLD (1998) has also published guidelines on individual risk criteria. A summary of published risk criteria is provided in Jonkman and van Gelder (2002).

One of the key aspects (and possibly one of the most controversial) of risk assessment is in deciding what are "acceptable" and "tolerable" risks. Prior to discussing examples of risk criteria, it may be useful to consider the following general principles in establishing risk criteria (quoted from IUGS, 1997):

> *"There are some common general principles that can be applied when considering tolerable risk criteria.*
>
> *a) The incremental risk from a hazard to an individual should not be significant compared to other risks to which a person is exposed in everyday life.*

b) The incremental risk from a hazard should, wherever reasonably practicable, be reduced, i.e. the As Low As Reasonably Practicable (ALARP) principle should apply.

c) If the possible loss of life from a landslide incident is high, the risk that the incident might actually occur should be low. This accounts for society's particular intolerance to incidents that cause many simultaneous casualties, and is embodied in societal tolerable risk criteria.

d) Persons in society will tolerate higher risks than they regard as acceptable, when they are unable to control or reduce the risk because of financial or other limitations.

e) Higher risks are likely to be tolerated for existing [natural] slopes than for planned projects, and for workers in industries with hazardous slopes, e.g. mines, than for society as a whole.

These principles are common with other hazards such as Potentially Hazardous Industries (PHI) and dams. There are considered to be other principles that are applicable to risk from slopes and landslides:

f) Tolerable risks are higher for naturally occurring landslides than those from engineered slopes.

g) Once a natural slope has been placed under monitoring, or risk mitigation measures have been executed, the tolerable risks approach those of engineered slopes.

h) Tolerable risks may vary from country to country, and within countries, depending on historic exposure to landslide hazard and the system of ownership and control of slopes and natural landslide hazards."

Informed people often tolerate risks that are considerably higher than published criteria or guidelines. For this reason, consultation with potentially affected parties can be beneficial when assessing the usefulness of published risk criteria.

Furthermore, several key issues relating to the use and application of risk evaluation and risk criteria are summarised below (adapted from IUGS, 1997):

- estimates of risk are approximate, and not absolute values.
- published risk criteria are themselves not absolute boundaries.
- it is advisable to use different types of criteria, as long as their applicability is carefully evaluated.
- in any decision making process, risk assessment is only one input and there will be others which need to be considered, such as political, societal and legal issues.
- the estimate of risk can change with time because of natural processes, such as removal of vegetation by fire, weathering of natural slopes, changing weather patterns.
- extreme events should be considered in the hazard analysis. However, it is often the smaller, more frequent events that contribute the most to the level of risk.

A1.6.2 Individual Risk Criteria

Published individual risk criteria are available for potentially hazardous industries (e.g. DUAP, 1992 and as discussed in HSE, 1988, 1989a, 1989b and 1992), however their interpretation and strict comparison across various industries can be problematic. Given the varying perception within the public domain of the danger or health risks due to different industries, such as the dams industry, chemical industry, and, say, the nuclear industry, the public perception of "acceptable" and "tolerable" risk levels may vary.

The difference between acceptable and tolerable risk levels is important when assessing appropriate criteria for evaluating the calculated risks. Definitions are provided in the Glossary.

Individual risk is the annual probability that an identifiable person or an individual from a specific group, may be killed because of the identified hazards. In general, individuals or specific groups that can be identified for this study include:

- Holiday camp users who may only be present in the inundation areas for short periods of time during any year.
- Homeowners who may live within a particular inundation zone either virtually continuously or for a large proportion of the year.
- People who may have a particular circumstance that means that they cannot evacuate an area as easily as others, e.g. some retirement home residents.

For hazardous industry, suggested individual risk criteria are available that consider the variability in exposure and vulnerability (DUAP, 1992), and include:

Land Use	Suggested Criteria (risk per year)
Hospitals, schools, child-care facilities, old age housing	5×10^{-7}
Residential, hotels, motels, tourist resorts	1×10^{-6}
Commercial developments including retail centres, offices and entertainment centres	5×10^{-6}
Sporting complexes and active open space	1×10^{-5}
Industrial	5×10^{-5}

These criteria were developed for use when planning the location of a new hazardous industry such as a chemical manufacturing plant, and represent acceptable limits on individual risk that may be imposed by the proposed facility. They may not necessarily be directly applicable to assessing the acceptability or otherwise of the individual risk imposed by naturally occurring flood events, but do provide some guidance.

Appendix A
Risk Assessment Details

Other suggested criteria have been put forward for the tolerable risk for loss of life due to constructed slopes (Australian Geomechanics Society, March 2000):

Situation	Suggested Tolerable Risk for Loss of Life
Existing slopes	10^{-4} person most at risk
	10^{-5} average of persons at risk
New slopes	10^{-5} person most at risk
	10^{-6} average of persons at risk

According to the above reference, acceptable risks may be one order of magnitude lower than the above tolerable risk criteria. ANCOLD (1998) suggests that for the individual most at risk the tolerable limit for existing facilities is 10^{-4} and for new facilities or major upgrades the tolerable limit is 10^{-5}. In the Netherlands a limit of between 1×10^{-3} and 1×10^{-6} has been suggested by the Dutch Technical Advisory Committee on Water Defences (TAW, 1988). The lower value is used in cases where the elements at risk (i.e. people) have no control over their exposure to the event or the hazard itself, which can be thought of as an imposed risk situation. The highest value is used in cases where the element at risk has complete control i.e. recreational activities such as sky diving or mountaineering.

These compare with examples of risks to individuals gathered from a number of sources, which are the additional increment of risk arising from the activity in question and listed below:

	Chances of fatality (per million person years)	Chances of fatality (per year)	Chance per person per year (approx.)
Voluntary Risks (average to those who take the risk)			
Rock climbing[3] (UK)	8,000	8×10^{-3}	1 in 125
Smoking[1] (20 cigarettes/day)			
all effects	5,000	5×10^{-3}	1 in 200
all cancers	2 000	2×10^{-3}	1 in 500
lung cancers	1,000	1×10^{-3}	1 in 1,000
Parachuting[2] (US)	1,900	1.9×10^{-3}	1 in 530
Hang Gliding[3] (UK)	1,500	1.5×10^{-3}	1 in 670
Mountineering[4]	600	6×10^{-4}	1 in 1,660
Drinking alcohol[5]	380	3.8×10^{-4}	1 in 2,600
Swimming[1]	50	5×10^{-5}	1 in 20,000
Playing rugby football[1]	30	3×10^{-5}	1 in 33,333
Owning firearms[1]	30	3×10^{-5}	1 in 33,333

Appendix A
Risk Assessment Details

	Chances of fatality (per million person years)	Chances of fatality (per year)	Chance per person per year (approx.)
Industry Risks			
Air Crew[6]	1,000	1×10^{-3}	1 in 1,000
Quarry workers[2]	290	2.9×10^{-4}	1 in 3,400
Coal mining[2] (US)	210	2.1×10^{-4}	1 in 4,800
Coal mining[3] (UK)	110	1.1×10^{-4}	1 in 9,500
Construction worker[3] (UK)	90	9×10^{-5}	1 in 10,800
Transportation Risks (average to travellers)			
Travelling by motor vehicle[1] (NSW)	145	1.45×10^{-4}	1 in 7,000
Travelling by train[1] (NSW)	30	3×10^{-5}	1 in 33,333
Travelling by aeroplane[1] (accidents)	10	1×10^{-5}	1 in 100,000
Risks Averaged over the Whole Population			
Road accidents[2] (US)	300	3×10^{-4}	1 in 3,300
Road accidents[1] (NSW)	200	2×10^{-4}	1 in 5,000
Road accidents[7] (NZ)	140	1.4×10^{-4}	1 in 7,100
Road accidents[3] (UK)	100	1×10^{-4}	1 in 10,000
Accidental falls[1]	60	6×10^{-5}	1 in 17,000
Drowning[2] (US)	30	3×10^{-5}	1 in 33,300
Homicide[1]	20	2×10^{-5}	1 in 50,000
Electrocution (non-industrial)[1]	3	3×10^{-6}	1 in 333,333
Cataclysmic storms and storm floods[1]	0.3	3×10^{-7}	1 in 3,333,333
Lightning strikes[1]	0.1	1×10^{-7}	1 in 10,000,000
Meteorite strikes[1]	0.001	1×10^{-9}	1 in 1,000,000,000

Sources:

1. Higson, D.J., Risk to Individuals in NSW and Australia as a Whole. Australian Nuclear Science and Technology Organisation, July 1989.
2. Reid, S.G., Practical Procedures for Setting Standards. Lecture 8, One Day Post-graduate Course on Engineering Risk Assessment, University of Sydney, 8th March 1991.
3. Health and Safety Executive (HSE), Risk Criteria for Land Use Planning in the Vicinity of Major Industrial Hazards. London, Her Majesty's Stationary Office, 1989.
4. Wilson, R. and Church, E.A.C., Risk Assessment and Comparisons: An Introduction. Science, Vol 236, April 1987.
5. Department of Planning, New South Wales. Risk Criteria for Land Use Safety Planning. Hazardous Industry Planning Advisory Paper No. 4, 1992.
6. Construction Industry Research and Information Association (CIRIA). Rationalisation of Safety and Serviceability Factors in Structural Codes, Report 63, London, July 1977.
7. Land Transport Safety Authority (LTSA). Road Safety Strategy 2010. National Road Safety Committee, Wellington, New Zealand, October 2000.

By comparing the suggested criteria published by DUAP with examples of individual risk exposure reported for NSW, it can be seen that the suggested criteria are considerably lower than many risks tolerated in society.

For the reasons outlined above, the use of individual risk criteria should be exercised with care, and their applicability carefully scrutinised in the context of the risk management process. In particular, the direct applicability of the DUAP guidelines to this situation is debatable given that they were developed to deal with safety planning for potentially hazardous industrial developments (DUAP, 1994 pp iii), not naturally occurring phenomena.

Using individual risk as the only measure of lives risk is not recommended and the risk should be assessed according to more than one method. In fact, ANCOLD require that for dams the assessment include evaluating individual and societal risk and that criteria for both are usually required to be satisfied.

A1.6.3 Societal Risk

Annualised Lives Risk

The expected value of life loss (also referred to as annualised lives risk, ALR) is a kind of societal risk in that the risk is represented as the likelihood of a single fatality but is calculated based on the total number of people that may be considered to be at risk. This is different to individual risk where the risk is calculated expressly for a particular individual or group of individuals. The ALR is probably the most difficult measure of risk to define because it can be calculated in many ways that may give rise to considerable variation in the level of risk for a given site.

For this risk assessment the ALR is presented for each community and hence the risk is the likelihood of a fatality from the entire population at risk due to the specified flooding event, averaged over the number of people exposed to the flooding during the year.

There are limited cases where criteria have been published for ALR. Within the dams industry the US Department of the Interior Bureau of Reclamation (USBR) suggest a limit of 0.01 fatalities per annum for ALR (USBR, 1997). This guideline is used in the dams industry where flooding is a major dam safety hazard. A major dam owner in British Columbia (BC Hydro) is reported to use a guideline of 0.001 for ALR (Jonkman & van Gelder, 2002 and Whitman, 2000).

The ALR is useful when comparing risk values within a particular study area, at various sites. In this QRA we have ranked the ALR for each community to enable a risk profile to be generated covering all sites. This is a valuable tool to aid the prioritisation of risk treatment measures.

It may also be used to compare risks at different sites, as long as the basis for calculating the risk values is comparable. For example, the QRA carried out by Pells Sullivan Meynink Pty Ltd (PSM, 1998) for Thredbo Village located along the Alpine Way in New South Wales estimated that the expected annual fatalities resulting from the road fill above Carinya lodge was 0.073 (pp 32). Although it is not clear from the report what is expressed by "expected annual fatalities", it may be analogous to the ALR. A value for the average annual expected loss of life was reported from a study of landslides carried out at Montrose in Victoria (Finlay, 1996). The Montrose study reported an average annual expected loss of life due to *all landslides* in that particular study area of 0.05 to 0.6 persons, which apparently local residents are willing to tolerate (Finlay and Fell, 1997).

The expected value of life loss expresses risk as a single number, which has some limitations. The following comment is repeated from the ANCOLD risk assessment guidelines (1998):

> *"expected value of life loss, [f. N], is a useful measure, especially for identifying the relative contributions of the various failure scenarios to the overall risk to life. However, ANCOLD does not favour the use of the overall expected loss of life as the single measure of Societal Risk. The reason is that the total expected value of life loss hides the various life loss scenarios that can occur. The total expected value is a single number and there are an indefinite number of combinations of life loss scenarios that can produce that figure. In other words, the single number of total expected value of life loss tells a decision maker nothing of the range of life loss that could occur. In contrast, an "F/N" plot does give information about the many life loss scenarios that can occur. It is for this reason that ANCOLD prefers F/N plots as the main measure of Societal Risk, notwithstanding their acknowledged problems. It should be noted that the overall expected life loss cannot be overlaid onto F/N graphs and there is no means of comparative plotting of the two measures (expected value and F/N plots).*

F-N Curves

Few organisations have provided published guidelines on societal risk. Due to the difficulty in determining and interpreting such criteria, some organisations deliberately avoid providing any quantitative guidelines (e.g. DUAP). ANCOLD has published recommended societal risk criteria for use in the dams industry, in the form of F-N curves (refer Figure A-2). It is important to note that the development of risk assessment guidelines by ANCOLD (including their recommended societal risk criteria) was intended as a tool to assist managers and planners in the planning and design of new structures, and the prioritisation of upgrade works on existing structures.

Estimated risks should be interpreted in the context of what people and society as a whole are prepared to accept and live with, and indeed are already living with. Figure A-2 provides a graphical summary of quantified risks to life compiled from sources in the US and UK. The data is presented as an F-N curve, which plots the cumulative frequency (F, or probability) of N or more deaths occurring per year against the number of deaths (N). An F-N curve can also be thought of as illustrating the incremental risk of death.

Within the F-N diagram ANCOLD define a threshold above which the level of annualised risk is generally regarded by society as unacceptable and measures should be put in place to reduce the risk. A lower threshold is also defined, below which the risk is generally regarded by society as acceptable. The intermediate zone, labeled "ALARP" (**A**s **L**ow **A**s **R**easonably **P**racticable), represents a risk level where the risk should be reduced where practical risk reduction measures are available, in consideration of such things as operational and financial constraints. The lower threshold is currently under review by

ANCOLD and it is proposed that the "acceptable" zone is removed and the entire area on the graph below the "unacceptable" threshold be referred to as ALARP (ANCOLD, 2001).

Although there is much debate at present regarding the use and interpretation of these F-N curves (e.g. Fell and Hartford, 1997), it is suggested (ANCOLD, 1998) that F-N curves are presently the best available method for quantifying societal risk. Societal risk criteria reflect society's aversion to disasters that involve multiple fatalities in that the greater the expected loss of life the lower the acceptable chance of failure.

Typically, F-N diagrams are used to demonstrate risks where there are potentially large numbers of fatalities involved.

Comparison of suggested societal lives risk criteria with other risks tolerated by society indicates that the suggested unacceptable threshold is lower than many societal risks reported for America and U.K. (DUAP, 1992, Morgan, 1992). This would be expected given that in general people expect to be exposed to significantly lesser levels of risk when the risk is imposed on them rather than when they choose to undertake an activity that exposes them to a risky situation. The unacceptable threshold is supported by internationally recognised experts in the fields of engineering geology and geotechnical engineering (Hoek, 2000). AGS (2000) and Riddolls & Grocott (1999b) provide further examples of risk criteria in the geotechnical engineering field. HSE (1992), HKGPD (1994) discuss risk criteria in relation to the citing of hazardous industry.

Appendix A
Risk Assessment Details

Figure A-1: Individual Risk (chance of fatality per year)

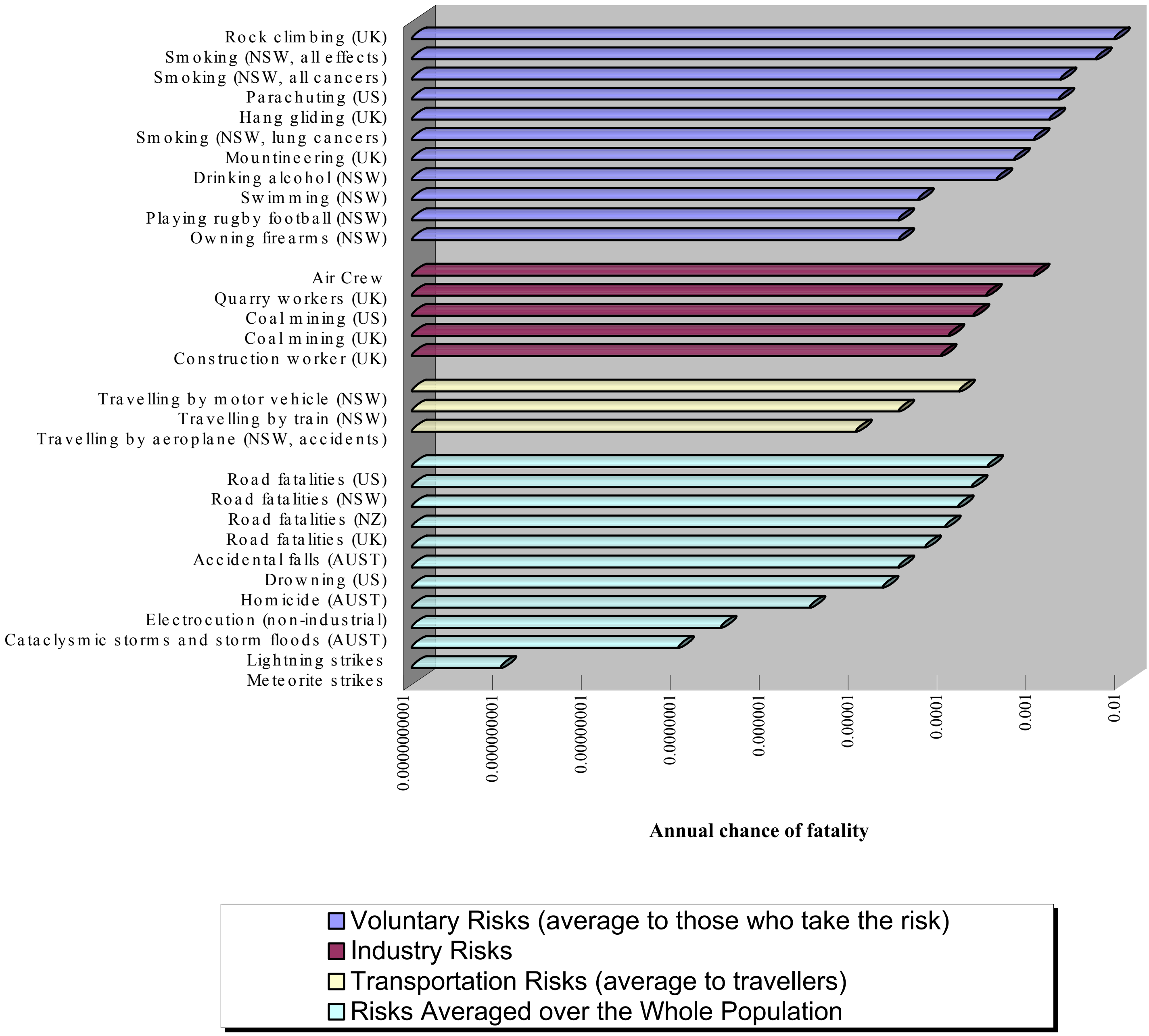
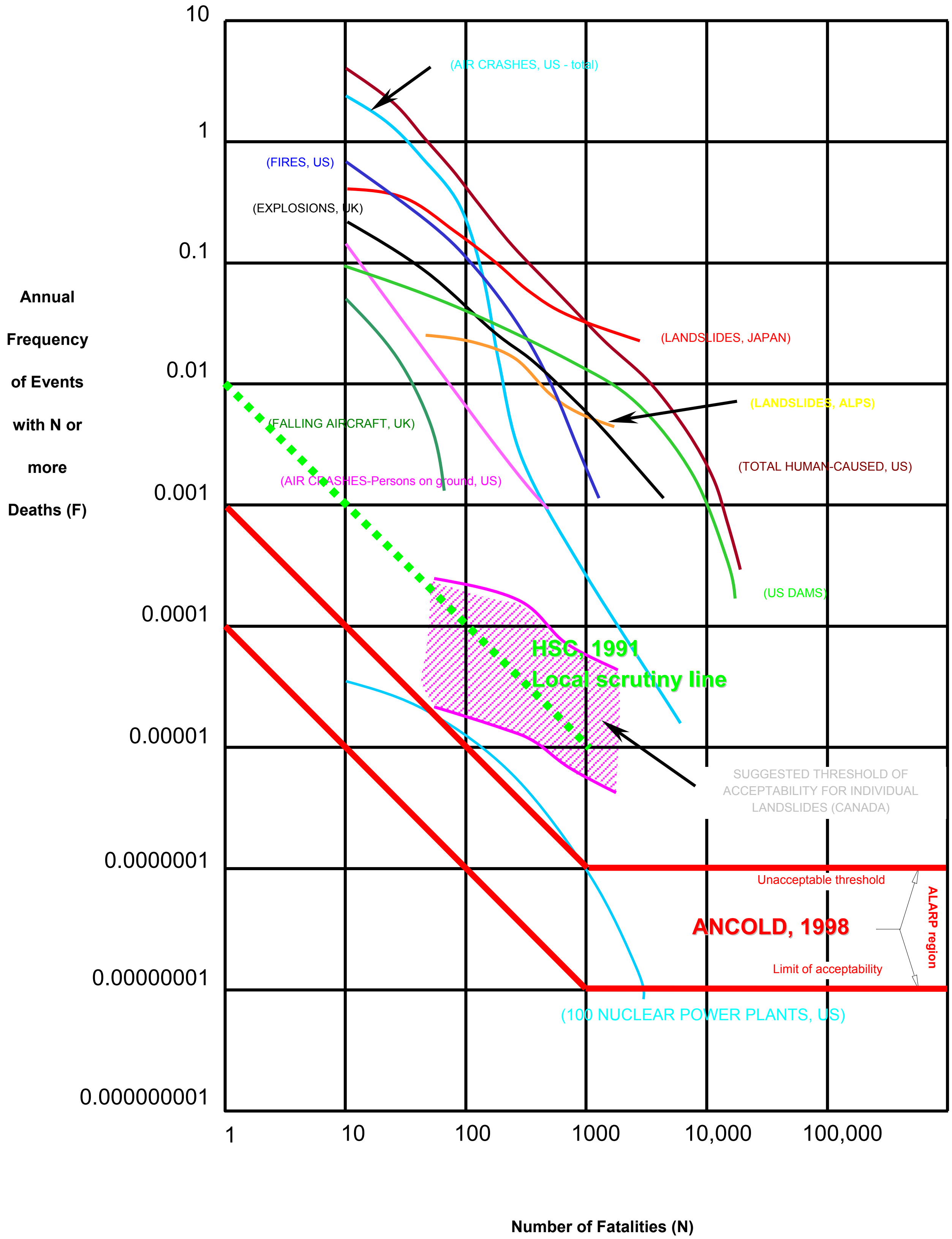


Figure A-2: Societal Risk Graph



Appendix B

Lives Risk Model Data

Appendix B
Lives Risk Model Data

Appendix B Lives Risk Model Data

B.1: ASSUMED DISTRIBUTION OF PEOPLE AND PROPERTY FOR EACH COMMUNITY

EW/TCDC ranking	USBR ranking	PRIVATE RESIDENTIAL	SCHOOLS	CAMPING			HOTEL/MOTEL		BUSINESSES		NOTES
		(houses)	(people)	(caravan spaces)	(cabins)	(people in tents)	(units)	(people)	(units)	(people)	
1. TARARU											**Residential: EW Med zones**: 21+3+6 = 30. **EW High zones**: 8+1 = 9. **Sunset Motel** 07 868 8573, Andrea McCartney. **7** units (1 to 4/5 in each) average max people **28**. Nov-Xmas 80% av occupancy. Mar-Apr 90% occupancy. Winter 45-65%. **Rest Home** rear part of grounds only (approx $62000m^2$). Not considered further.
Low	Very Low										
Med	Low	30					7	28			
High	Med	9									
	High										
2. TE PURU											**Residential: EW Low zones**: 27.5+15.5+1 = **44. EW Med zones**: 35+13+19.5 (includes holiday park manager's house) = 67.5**. EW High zones: 10** **Te Puru School** 07 868 2747. 7 classrooms total. Average 180 children, 12 staff, 6+ parent help. Approx 50% of buildings in **EW Low** zone (50% of 180+12+6 = **99**). Most of outside play area within **EW Low zone**. **Boomerang Holiday Park** 07 868 2879. 117 caravan sites, 113 rented all year. 24 trams (holds 2.5 people) tabulated as caravans, 2 cabins, 20 tent sites, rare to be all used (20x4people/tent = **80**). Estimated 400 max possible capacity, but probable peak estimated at 200-300 Xmas-Jan. Estimated 30 people on average during winter season. Unsure of exact figures as caravans mostly leased per year and people come and go as they please.
Low	Very Low	44	99	8							
Med	Low	69.5		121	2						
High	Med	10									
	High			12		80					
3. WAIOMU											**Residential: EW Low zones**: 16. **EW Med zones**: 1.5+9+1.5 = **12**. **EW High zones**: **1.5** **Waiomu Bay Holiday Park** 07 868 2777, Dianna and Alesta White. 70 (52.5=17.5) caravans max. Full between Xmas to mid Jan (school hols). Max 20 people tenting at same time. Weekends only for rest of year. Unsure of exact figures as caravans mostly leased per year and people come and go as they please.
Low	Very Low	16									
Med	Low	12		17.5							
High	Med	1.5									
	High			52.5		20					
4. POHUE											Single EW high zone only.
Low	Very Low										
Med	Low										
High	Med	7.5									
	High										
5. TAPU											**Residential: EW Med zones**: 0+0+17 = **17**. **EW High zones**: **2**. **Tapu Motor Camp** 07 868 4837, Ray Humphrey. Approx 90 caravans + 1 cabin (**2**). Approx 300-400 people max Xmas-Jan. 5-6 people winter. Tents approx 40 sites located on grass near stream, 100 people max (**50** in EW Med, **50** in EW High zone) Xmas-Jan, approx 20 after. Unsure of exact figures as caravans mostly leased per year and people come and go as they please. **Tapu School** has far corner of fields in EW Med zone (total area $600m^2$). Buildings out of flood zone, more than 50m from EW Med zone edge.
Low	Very Low	17									
Med	Low	2		90	2	50					
High	Med										
	High					50					
6. COROMANDEL											**EW Med zone** **Residential:** 18.5+1 = **19.5** **Motel - Anchorage Lodge** 07 866 7992. Recently developed, aerial photo not up-to-date. Buildings on poles, prob no flood threat= 1unit x 6p, 2 x 3p, 3 x 2p=18p. Buildings poss in med zone= 18p units + 37p backpackers + 2 (?) staff = 57. **Admirals Arms Hotel** 07 886 8623. www.admiralsarms.co.nz. Sleeps 12 people upstairs (safer) + 2(?) staff = 14. No answer. 14+57 = **71**. **Kohanga Reo** 07 886 8417. No answer. Contacted council, mother of child at kohanga (Margaret) said approx 15 children + approx 4 adults (8+4 = **12**) for same hours as regular school. ~8 shops incl: bakehouse, fish+chips, grocery, hairdresser, 2x craft shop. Half of recreation + swing area. Half of council buildings/information centre. Residential 'Units' = halfway house/flats. **EW High zone** incl BP service station + 2x tennis courts. Hauraki House venue for meeting etc. Info from police - John Morrisey 07 866 1190
Low	Very Low										
Med	Low	20.5	12				15	71	9	34	
High	Med	24.5							1	6	
	High										

Note: Grey shading denotes areas that cannot contain data under expected flood conditions

Thames Valley Combined District

EMERGENCY PLANNING UNIT
Thames Coromandel District Council
525 Mackay Street
Private Bag
THAMES

Phone: (07) 868-6025
Fax: (07) 868-9586
E-mail: cdthames.org.nz

12 May 2003

Gordon Ashby
URS New Zealand Limited
PO Box 4479
CHRISTCHURCH

Dear Gordon

Key Assumptions

Further to our conversation at Hamilton on 8 May 2003 I include my comments concerning assumptions in the URS Report relative to available warning.

Comments re 4.1.1, Is There Warning Available? Page 4.4. See attached schedule.

The following schedule seeks to illustrate the situation existing at June 2002 and possible potential for improvement. No attempt has been made to compensate for procedures inadequate at that date.

I feel that there is an imbalance in the risk assigned over the three (3) Camp Grounds. I question whether Te Puru is in fact the highest risk. A further study of the aerial photographs complete with inundation data will assist this process.

Further I suggest that Pohue is in fact part of the Waiomu community in the same way as the two streams, (Karaka and Whangarahi), are part of the Coromandel township. If Pohue is included in Waiomu I feel the values will change, probably better reflecting the overall community risk assessment. A similar situation exists in Thames where Tararu is being considered in isolation to the overall existing 'Flood Management Plan'. Note that this is my opinion and not that of council. I have forwarded a copy of this correspondence to CEO Steve Ruru and to Peter Wishart. They may wish to comment on this suggestion.

R H (Ron) White
Manager EPU

Risk Assessment – Available Warning – Key Assumptions

Ability to detect or anticipate the onset of flood conditions

Factors	Existing situation as at June 2002	Potential for Improvement
Is heavy rain forecast?	The June 21 event was forecast on 19.06.02. Metservice usually forecast severe weather events, *but not always.* The Coromandel flooding on 20 April 2003 was not forecast.	Weather forecasting is, again, not an exact science. Systems are constantly being reviewed and improved.
Are rain gauges and stream gauges installed?	Yes but not over all the streams. Tapu and Te Puru have level gauges. Rainfall gauges exist at a range of private sites.	Room for considerable improvement including more effective 'River Watch' Teams.
Are they an effective indicator of potential flooding?	Yes if they can be coordinated. Both require human monitoring and intervention.	An effective and reliable human river watch system is possible.
Are they telemetered and alarmed – how accessible is the information from them?	Nil telemetry.	Telemetry is possible but probably more useful as a record rather than a warning tool.
Catchment size and characteristics – how quickly does heavy rainfall lead to flood conditions?	Catchment areas are available from Environment Waikato. Short steep catchment characteristics mean little time between torrential downpours in the headwaters and flooding at community level.	Pest control and stream maintenance are considered viable mitigation measures.

The ability of the authorities to take action to warn people.

Factors	Existing Situation as at June 2002	Potential for Improvement
Is there an established Civil Defence network in the community and are people well trained?	An established network, moderately trained.	Potential for considerable improvement. Apathy a major issue and availability of the *right people*.
Is there an established plan of alert levels and response actions?	Yes at Te Puru (Written formal action plan) and to a lesser extent at Tapu. Gaps at Tararu, Waiomu and Coromandel.	Realistic action planning and camping ground evacuation procedures seen as a priority.
Are communications reliable in adverse weather?	Adequate. Alternate communications available but not used in June 2002.	There has been a considerable input to alternate communications with further enhancements planned.
How easy is it to communicate with people in locations at risk. (by phone, road etc?)	Each community subject to isolation during extreme weather. Phone and roads subject to damage. Have managed but with difficulty at times.	Room for improvement – but acceptance of risk by those living in high hazard zones is a key element .
Are there adequate resources to cover the area and contact everybody in the available time?	What is the available time? Metservice warnings not a problem. Unpredictable events like the June 2002 weather bomb - not possible.	Events such as the weather bomb are unpredictable. Certainly earlier evacuation is an obvious potential. Again a degree of self reliance and responsibility is a necessary key to improvement.

The ability to evacuate to a safe location in the available time

Factor	Existing Situation as at June 2002	Potential for Improvement
How far do people at risk have to move to get to a safe location?	Not far. In most cases only a few metres. Designated 'Safe Assembly Centres' are available within a short distance.	Confirmation of appropriate assembly points, escape routes and greater community awareness is necessary.
Are there physical barriers to negotiate eg. Steep slopes, or escape routes likely to be blocked?	Generally no. However I am not sure the escape routes have been disseminated as well as they might have been.	As above.
Are there established evacuation plans and safe locations identified, both for householders and facilities such as camping grounds?	Documented for Te Puru (seen as the area of highest risk) but left to CD and ES staff for other areas. Camping grounds included in overall community plan in each case.	Individual evacuation plans for each camping ground seen as a priority. Evaluation and documentation of community action plans will be a routine outcome.
Have these plans been exercised?	No. The real event happens often enough. Dissemination of MetService Warnings is an exercise in itself – several each year	Not sure how. A credible exercise would be easier to organise with more active CD participation at community level.
What level of awareness and preparation is there in the community in relation to the flood hazard?	Varies. Flooding is a well known and documented hazard in many parts of the Coromandel. The Thames Coast is no exception and few people would have been UNAWARE of the hazard.	Public awareness and preparation is an ongoing function of any civil defence organisation.

THAMES COAST FLOOD RISK ASSESSMENT

Risk model Rev F2 27-May-03

Lives risk model inputs

Input cells in red

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business		
TCDC/EW Hazard Zone		Low	Med	Hi	Low	Med	Hi	Low	Med	Hi	Med	Hi	Very Hi	Low	Med	Hi	Low	Med	Hi
USBR Flood Severity		Very low	Low	Med	Very low	Low	Med	Very low	Low	Med	Low	Med	Hi	Very low	Low	Med	V. low	Low	Med
USBR fatality rate	Susceptibility	1			1.2			1.5			1			1			1		
	Adequate																		
	Little warning		0.002	0.01		0.002	0.01		0.002	0.01	0.002	0.01	0.015		0.002	0.01		0.002	0.01
	No warning		0.005	0.03		0.005	0.03		0.005	0.03	0.005	0.03	0.15		0.005	0.03		0.005	0.03

Base PAR (max. case)

	Private residences Low	Private residences Med	Private residences Hi	Schools Low	Schools Med	Schools Hi	Retirement villages Low	Retirement villages Med	Retirement villages Hi	Camping grounds Med	Camping grounds Hi	Camping grounds Very Hi	Hotels and Motels Low	Hotels and Motels Med	Hotels and Motels Hi	Business Low	Business Med	Business Hi
Tararu		75	22.5											28				
Te Puru	110	173.75	25	99						8	246	104						
Waiomu-Pohue	40	30	22.5								35	125						
Pohue																		
Tapu	42.5	5									234	50						
Coromandel		51.25	61.25	12										71			34	6

Level of warning		Tararu	Te Puru	Waiomu-Pohue		Tapu	Coromandel
Day	Adequate	0.50	0.50	0.50		0.50	0.50
	Little warning	0.40	0.40	0.40		0.40	0.40
	No warning	0.10	0.10	0.10		0.10	0.10
Night	Adequate	0.40	0.40	0.40		0.40	0.40
	Little warning	0.40	0.40	0.40		0.40	0.40
	No warning	0.20	0.20	0.20		0.20	0.20

	Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business		
TCDC/EW Hazard Zone	Low	Med	Hi	Low	Med	Hi	Low	Med	Hi	Med	Hi	Very Hi	Low	Med	Hi	Low	Med	Hi
USBR Flood Severity	Very low	Low	Med	Very low	Low	Med	Very low	Low	Med	Low	Med	Hi	Very low	Low	Med	V. low	Low	Med
PAR with mitigation Option 2																		
Tararu	15	12.5	2.5										28					
Te Puru	282.5	25		99						262	24	80						
Waiomu-Pohue	70	7.5	15															
Tapu	25	22.5									26	8						
Coromandel		20	20	12												34	6	

IMPROVED WARNING SYSTEMS

Level of warning		Tararu	Te Puru	Waiomu-Pohue		Tapu	Coromandel
Day	Adequate	0.80	0.80	0.80		0.80	0.80
	Little warning	0.15	0.15	0.15		0.15	0.15
	No warning	0.05	0.05	0.05		0.05	0.05
Night	Adequate	0.60	0.60	0.60		0.60	0.60
	Little warning	0.30	0.30	0.30		0.30	0.30
	No warning	0.10	0.10	0.10		0.10	0.10

PAR with mitigation Option 3																		
Tararu		2.5																
Te Puru	2.5			99						24	80							
Waiomu-Pohue (Op. 2)	70	7.5	15															
Tapu										184	50	50						
Coromandel		15	7.5	12												34	6	

THAMES COAST FLOOD RISK ASSESSMENT

LOCATION: Tararu

People at risk by activity and location (Base Case)

Inputs in red

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business		
TCDC/EW Hazard Zone		Low	Med	Hi	Low	Med	Hi	Low	Med	Hi	Med	Hi	Very Hi	Low	Med	Hi	Low	Med	Hi
USBR Flood Severity		Very low	Low	Med	Very low	Low	Med	Very low	Low	Med	Low	Med	Hi	Very low	Low	Med	Very low	Low	Med
Base PAR (max. case)			75	22.5											28				
PAR adjustment factors (same across all hazard zones and all seasons)																			
Wkd or holiday	Day		0.9						0.9			0.9			0.9			0.6	
	Night		1						1			1			1				
Normal work & school	Day		0.5			1			0.8			0.5			0.5			1	
	Night		1						1			0.6			0.6				
School holidays	Day		0.8						0.8			0.7			0.7			1	
	Night		1						1			0.8			0.8				
Calculated PAR																			
Wkd or holiday	Day		67.5	20.3											25.2				
	Night		75.0	22.5											28				
Normal work & school	Day		37.5	11.3											14				
	Night		75.0	22.5											16.8				
School holidays	Day		60.0	18.0											19.6				
	Night		75.0	22.5											22.4				
	Min.		48.8												14.0				
	Max.		97.5												28.0				
PAR seasonal adjustment (applies only to camping grounds and hotels/motels)																			
High season as above																			
Low season	0.3																		
Wkd or holiday	Day														7.6				
	Night														8.4				
Normal work & school	Day														4.2				
	Night														5.0				
School holidays	Day														5.9				
	Night														6.7				
	Min.														4.2				
	Max.														8.4				
Mid season	0.6																		
Wkd or holiday	Day														15.1				
	Night														16.8				
Normal work & school	Day														8.4				
	Night														10.1				
School holidays	Day														11.8				
	Night														13.4				
	Min.														8.4				
	Max.														16.8				

THAMES COAST FLOOD RISK ASSESSMENT

LOCATION: Te Puru

People at risk by activity and location (Base Case)

Inputs in red

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business		
TCDC/EW Hazard Zone		Low	Med	Hi	Low	Med	Hi	Low	Med	Hi	Med	Hi	Very Hi	Low	Med	Hi	Low	Med	Hi
USBR Flood Severity		Very low	Low	Med	Very low	Low	Med	Very low	Low	Med	Low	Med	Hi	Very low	Low	Med	Very low	Low	Med
Base PAR (max. case)		110	173.75	25	99						8	246	104						

PAR adjustment factors (same across all hazard zones and all seasons)

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business		
Wkd or holiday	Day		0.9						0.9			0.9			0.9			0.6	
	Night		1						1			1			1				
Normal work & school	Day		0.5			1			0.8			0.5			0.5			1	
	Night		1						1			0.6			0.6				
School holidays	Day		0.8						0.8			0.7			0.7			1	
	Night		1						1			0.8			0.8				

Calculated PAR

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business		
Wkd or holiday	Day	99.0	156.4	22.5							7.2	221.4	93.6						
	Night	110.0	173.8	25.0							8	246	104						
Normal work & school	Day	55.0	86.9	12.5	99						4	123	52						
	Night	110.0	173.8	25.0							4.8	147.6	62.4						
School holidays	Day	88.0	139.0	20.0							5.6	172.2	72.8						
	Night	110.0	173.8	25.0							6.4	196.8	83.2						
	Min.		154.4									179.0							
	Max.		308.8			99.0						358.0							

PAR seasonal adjustment (applies only to camping grounds and hotels/motels)
High season as above

Low season 0.3

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business		
Wkd or holiday	Day										0.4	11.1	4.7						
	Night										0.4	12.3	5.2						
Normal work & school	Day										0.2	6.2	2.6						
	Night										0.2	7.4	3.1						
School holidays	Day										0.3	8.6	3.6						
	Night										0.3	9.8	4.2						
	Min.											9.0							
	Max.											17.9							

Mid season 0.6

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business		
Wkd or holiday	Day										2.2	66.4	28.1						
	Night										2.4	73.8	31.2						
Normal work & school	Day										1.2	36.9	15.6						
	Night										1.4	44.3	18.7						
School holidays	Day										1.7	51.7	21.8						
	Night										1.9	59.0	25.0						
	Min.											53.7							
	Max.											107.4							

THAMES COAST FLOOD RISK ASSESSMENT
LOCATION: Waiomu-Pohue
People at risk by activity and location (Base Case)

Inputs in red

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels		
TCDC/EW Hazard Zone		Low	Med	Hi	Low	Med	Hi	Low	Med	Hi	Med	Hi	Very Hi	Low	Med	Hi
USBR Flood Severity		Very low	Low	Med	Very low	Low	Med	Very low	Low	Med	Low	Med	Hi	Very low	Low	Med
Base PAR (max. case)		40	30	22.5								35	125			

PAR adjustment factors (same across all hazard zones and all seasons)

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels		
Wkd or holiday	Day		0.9						0.9			0.9			0.9	
	Night		1						1			1			1	
Normal work & school	Day		0.5			1			0.8			0.5			0.5	
	Night		1						1			0.6			0.6	
School holidays	Day		0.8						0.8			0.7			0.7	
	Night		1						1			0.8			0.8	

Calculated PAR

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels		
Wkd or holiday	Day	36.0	27.0	20.3								31.5	112.5			
	Night	40.0	30.0	22.5								35	125			
Normal work & school	Day	20.0	15.0	11.3								17.5	62.5			
	Night	40.0	30.0	22.5								21	75			
School holidays	Day	32.0	24.0	18.0								24.5	87.5			
	Night	40.0	30.0	22.5								28	100			
	Min.		46.3									80.0				
	Max.		92.5									160.0				

PAR seasonal adjustment (applies only to camping grounds and hotels/motels)
High season as above

Low season 0.3

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels		
Wkd or holiday	Day											1.6	5.6			
	Night											1.8	6.3			
Normal work & school	Day											0.9	3.1			
	Night											1.1	3.8			
School holidays	Day											1.2	4.4			
	Night											1.4	5.0			
	Min.											4.0				
	Max.											8.0				

Mid season 0.6

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels		
Wkd or holiday	Day											9.5	33.8			
	Night											10.5	37.5			
Normal work & school	Day											5.3	18.8			
	Night											6.3	22.5			
School holidays	Day											7.4	26.3			
	Night											8.4	30.0			
	Min.											24.0				
	Max.											48.0				

THAMES COAST FLOOD RISK ASSESSMENT
LOCATION: Tapu
People at risk by activity and location (Base Case)

Inputs in red

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business		
TCDC/EW Hazard Zone		Low	Med	Hi	Low	Med	Hi	Low	Med	Hi	Med	Hi	Very Hi	Low	Med	Hi	Low	Med	Hi
USBR Flood Severity		Very low	Low	Med	Very low	Low	Med	Very low	Low	Med	Low	Med	Hi	Very low	Low	Med	Very low	Low	Med
Base PAR (max. case)		42.5	5									234	50						

PAR adjustment factors (same across all hazard zones and all seasons)

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business		
Wkd or holiday	Day		0.9						0.9			0.9			0.9			0.6	
	Night		1						1			1			1				
Normal work & school	Day		0.5			1			0.8			0.5			0.5			1	
	Night		1						1			0.6			0.6				
School holidays	Day		0.8						0.8			0.7			0.7			1	
	Night		1						1			0.8			0.8				

Calculated PAR

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business		
Wkd or holiday	Day	38.3	4.5									210.6	45						
	Night	42.5	5.0									234	50						
Normal work & school	Day	21.3	2.5									117	25						
	Night	42.5	5.0									140.4	30						
School holidays	Day	34.0	4.0									163.8	35						
	Night	42.5	5.0									187.2	40						
	Min.		23.8									142.0							
	Max.		47.5									284.0							

PAR seasonal adjustment (applies only to camping grounds and hotels/motels)
High season as above

Low season 0.3

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business		
Wkd or holiday	Day											10.5	2.3						
	Night											11.7	2.5						
Normal work & school	Day											5.9	1.3						
	Night											7.0	1.5						
School holidays	Day											8.2	1.8						
	Night											9.4	2.0						
	Min.											7.1							
	Max.											14.2							

Mid season 0.6

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business		
Wkd or holiday	Day											63.2	13.5						
	Night											70.2	15.0						
Normal work & school	Day											35.1	7.5						
	Night											42.1	9.0						
School holidays	Day											49.1	10.5						
	Night											56.2	12.0						
	Min.											42.6							
	Max.											85.2							

THAMES COAST FLOOD RISK ASSESSMENT

LOCATION: Coromandel

People at risk by activity and location (Base Case)

Inputs in red

		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business		
TCDC/EW Hazard Zone		Low	Med	Hi	Low	Med	Hi	Low	Med	Hi	Med	Hi	Very Hi	Low	Med	Hi	Low	Med	Hi
USBR Flood Severity		Very low	Low	Med	Very low	Low	Med	Very low	Low	Med	Low	Med	Hi	Very low	Low	Med	Very low	Low	Med
Base PAR (max. case)			51.25	61.25	12										71			34	6

PAR adjustment factors (same across all hazard zones and all seasons)

Wkd or holiday	Day		0.9						0.9			0.9			0.9			0.6	
	Night		1						1			1			1				
Normal work & school	Day		0.5			1			0.8			0.5			0.5			1	
	Night		1						1			0.6			0.6				
School holidays	Day		0.8						0.8			0.7			0.7			1	
	Night		1						1			0.8			0.8				

Calculated PAR

Wkd or holiday	Day		46.1	55.1											63.9			20.4	3.6
	Night		51.3	61.3											71				
Normal work & school	Day		25.6	30.6	12										35.5			34	6
	Night		51.3	61.3											42.6				
School holidays	Day		41.0	49.0											49.7			34	6
	Night		51.3	61.3											56.8				
	Min.		56.3												35.5				
	Max.		112.5			12.0									71.0			40.0	

PAR seasonal adjustment (applies only to camping grounds and hotels/motels)
High season as above

Low season 0.3

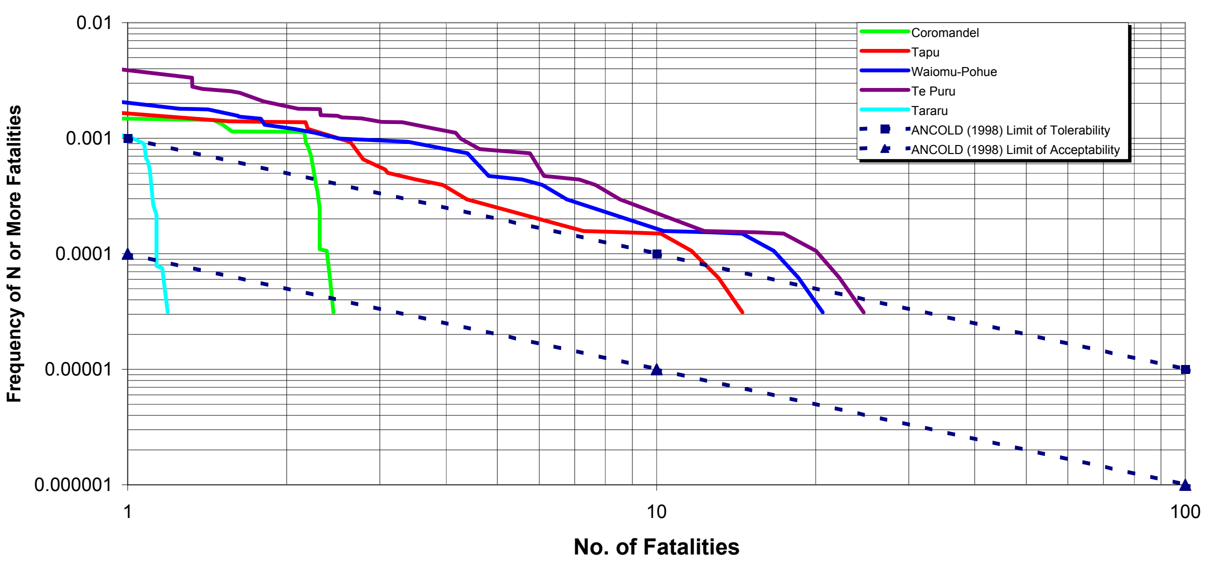
Wkd or holiday	Day														19.2				
	Night														21.3				
Normal work & school	Day														10.7				
	Night														12.8				
School holidays	Day														14.9				
	Night														17.0				
	Min.														10.7				
	Max.														21.3				

Mid season 0.6

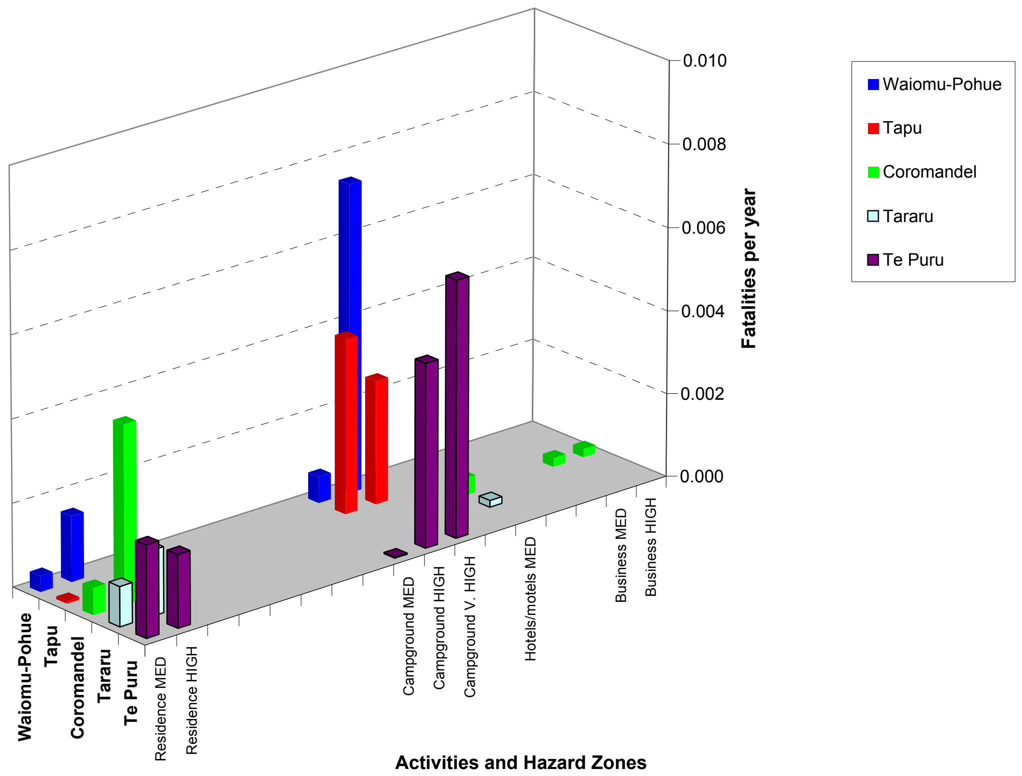
Wkd or holiday	Day														38.3				
	Night														42.6				
Normal work & school	Day														21.3				
	Night														25.6				
School holidays	Day														29.8				
	Night														34.1				
	Min.														21.3				
	Max.														42.6				

Location		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business			
	TCDC/EW Hazard Zone	Low	Med	Hi	Low	Med	Hi	Low	Med	Hi	Med	Hi	Very Hi	Low	Med	Hi	Low	Med	Hi	
	USBR Flood Severity	Very low	Low	Med	Very low	Low	Med	Very low	Low	Med	Low	Med	Hi	Very low	Low	Med	Very low	Low	Med	
			Residence MED	Residence HIGH							Campground MED	Campground HIGH	Campground V. HIGH		Hotels/motels MED			Business MED	Business HIGH	TOTAL ALR
Te Puru			2.22E-03	1.75E-03							2.63E-05	4.43E-03	6.18E-03							**0.0146**
Waiomu-Pohue			3.83E-04	1.58E-03								6.30E-04	7.43E-03							**0.0100**
Tapu			6.39E-05									4.21E-03	2.97E-03							**0.0072**
Coromandel			6.55E-04	4.30E-03											4.19E-04			2.18E-04	2.07E-04	**0.0058**
Tararu			9.59E-04	1.58E-03											1.65E-04					**0.0027**

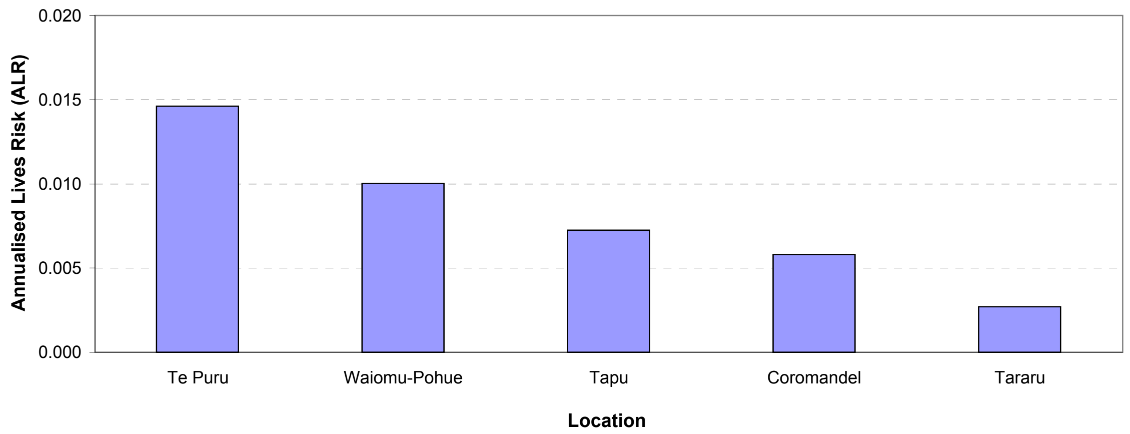
F-N Chart



Fatalities per Year by Activity for Each Community



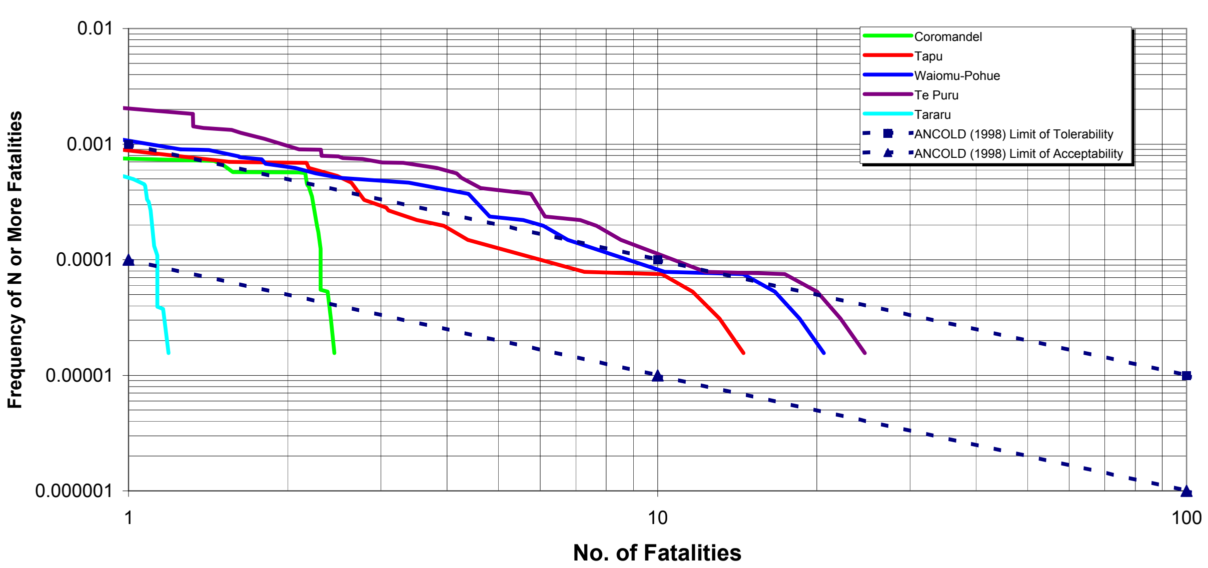
Lives Risk Profile

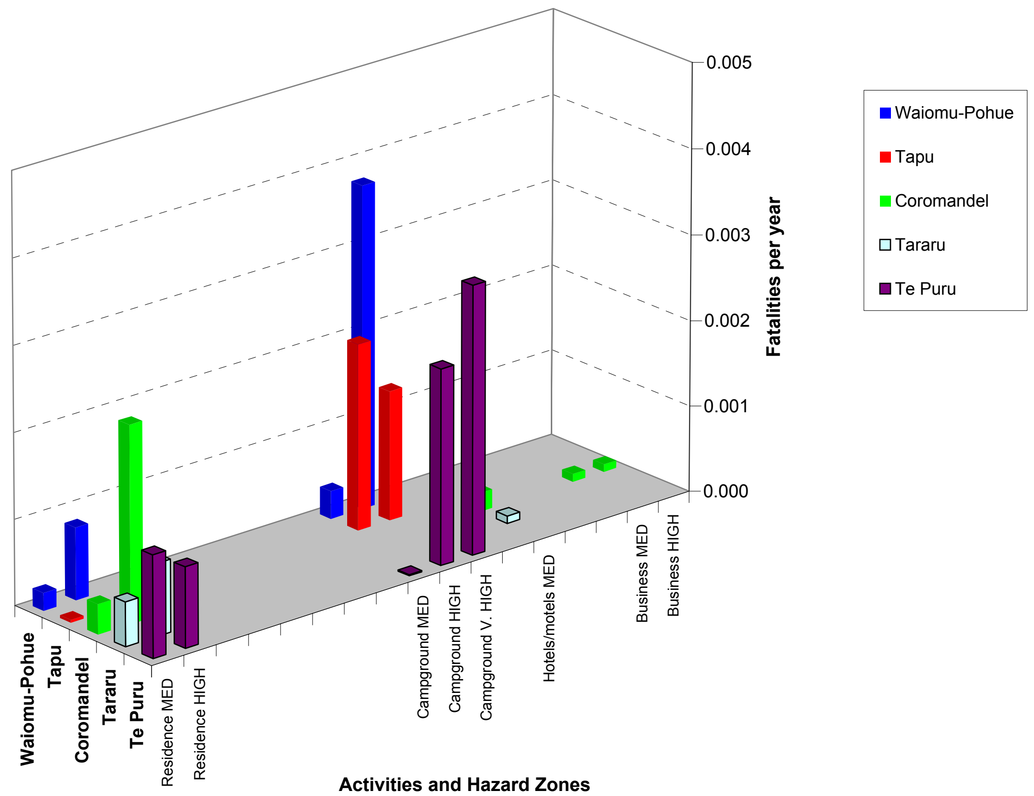


SUMMARY OF LIVES RISK - BASE CASE

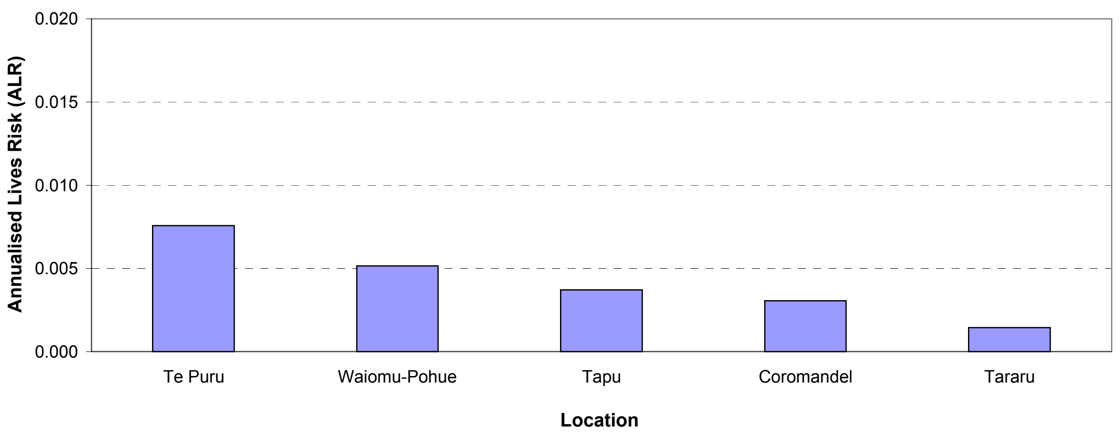
Location		Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business			
	TCDC/EW Hazard Zone	Low	Med	Hi	Low	Med	Hi	Low	Med	Hi	Med	Hi	Very Hi	Low	Med	Hi	Low	Med	Hi	
	USBR Flood Severity	Very low	Low	Med	Very low	Low	Med	Very low	Low	Med	Low	Med	Hi	Very low	Low	Med	Very low	Low	Med	
			Residence MED	Residence HIGH							Campground MED	Campground HIGH	Campground V. HIGH		Hotels/motels MED			Business MED	Business HIGH	TOTAL ALR
Te Puru			1.20E-03	9.38E-04							1.36E-05	2.28E-03	3.13E-03							**0.0076**
Waiomu-Pohue			2.06E-04	8.44E-04								3.25E-04	3.77E-03							**0.0051**
Tapu			3.44E-05									2.17E-03	1.51E-03							**0.0037**
Coromandel			3.53E-04	2.30E-03											2.19E-04			9.23E-05	8.88E-05	**0.0031**
Tararu			5.16E-04	8.44E-04											8.63E-05					**0.0014**

F-N Chart





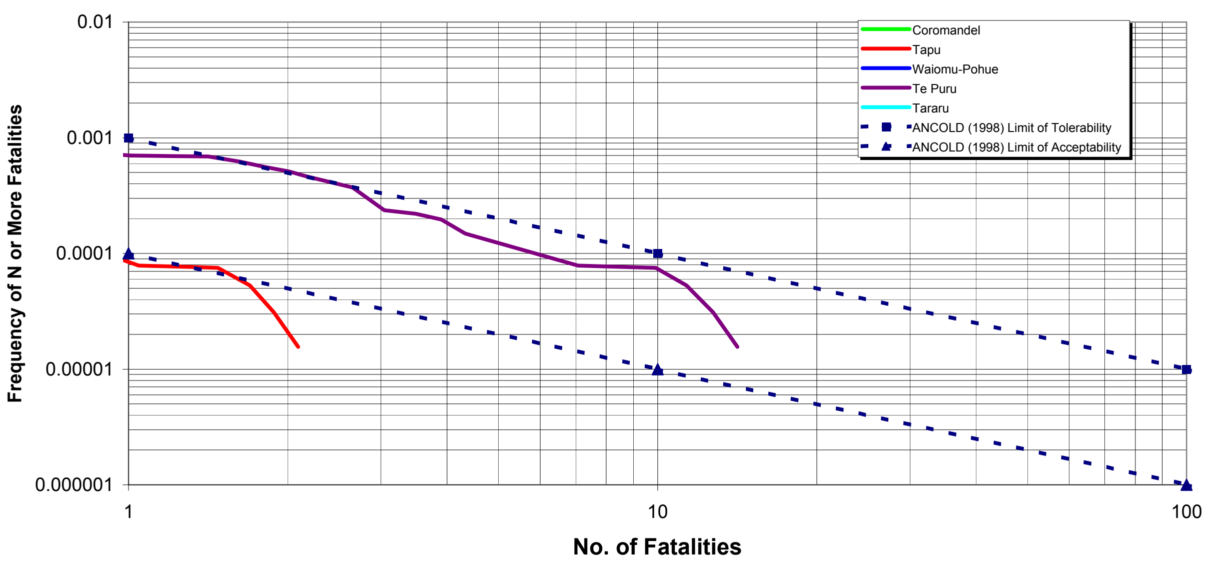
Lives Risk Profile



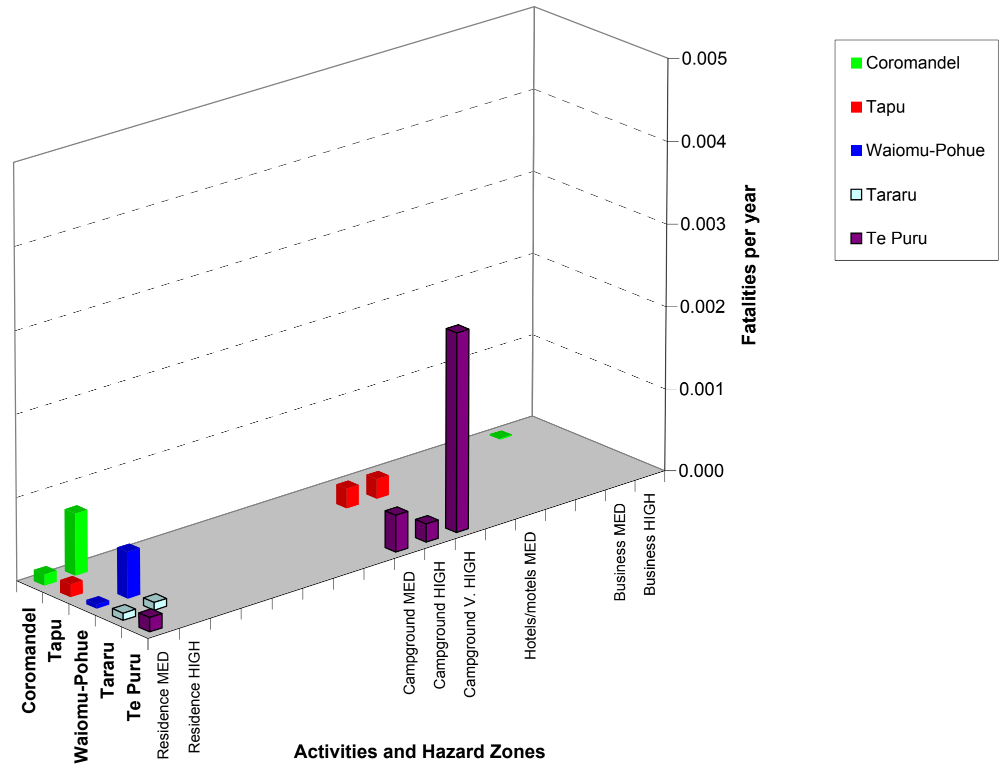
SUMMARY OF LIVES RISK - WARNING SYSTEMS UPGRADE ONLY

Location	Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business			
TCDC/EW Hazard Zone	Low	Med	Hi	Low	Med	Hi	Low	Med	Hi	Med	Hi	Very Hi	Low	Med	Hi	Low	Med	Hi	
USBR Flood Severity	Very low	Low	Med	Very low	Low	Med	Very low	Low	Med	Low	Med	Hi	Very low	Low	Med	Very low	Low	Med	
		Residence MED	Residence HIGH							Campground MED	Campground HIGH	Campground V. HIGH		Hotels/motels MED			Business MED	Business HIGH	**TOTAL ALR**
Te Puru		1.72E-04								4.45E-04	2.23E-04	2.41E-03							**0.0033**
Coromandel		1.38E-04	7.51E-04														1.63E-05		**0.0009**
Tapu		1.55E-04									2.41E-04	2.41E-04							**0.0006**
Waiomu-Pohue		5.16E-05	5.63E-04																**0.0006**
Tararu		8.60E-05	9.38E-05																**0.0002**

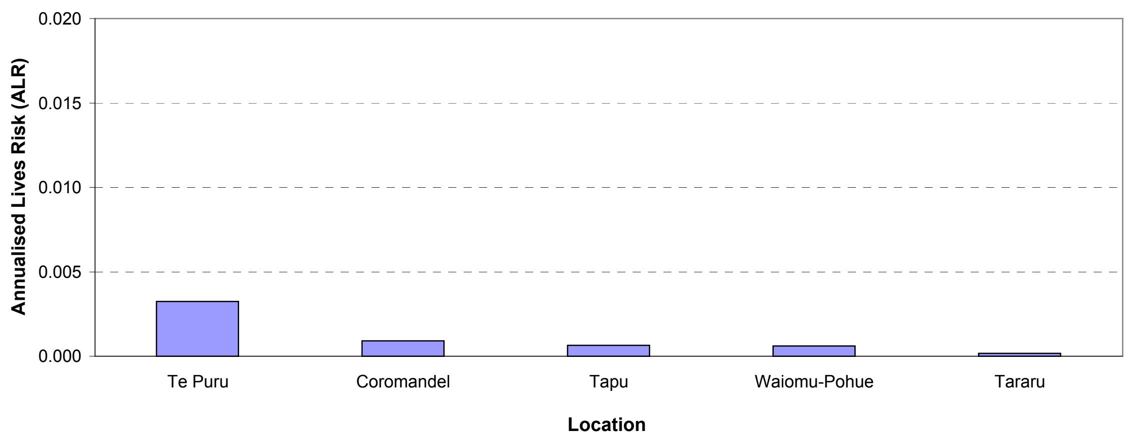
F-N Chart



Fatalities per Year by Activity Following Risk Treatment (Option 2)



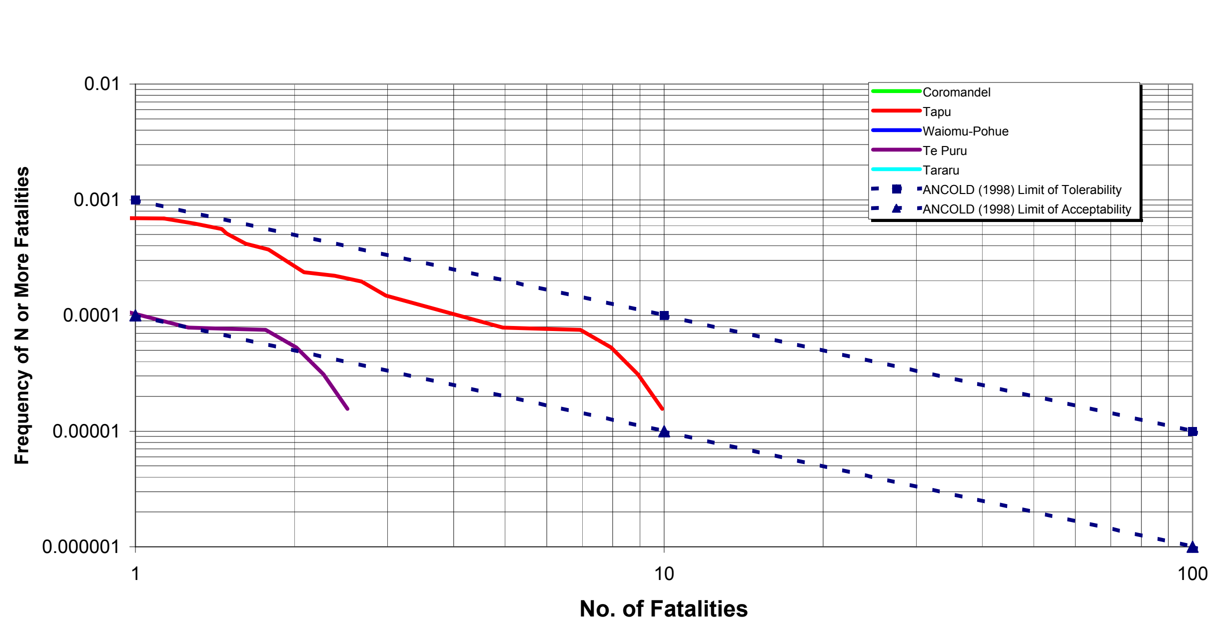
Lives Risk Profile



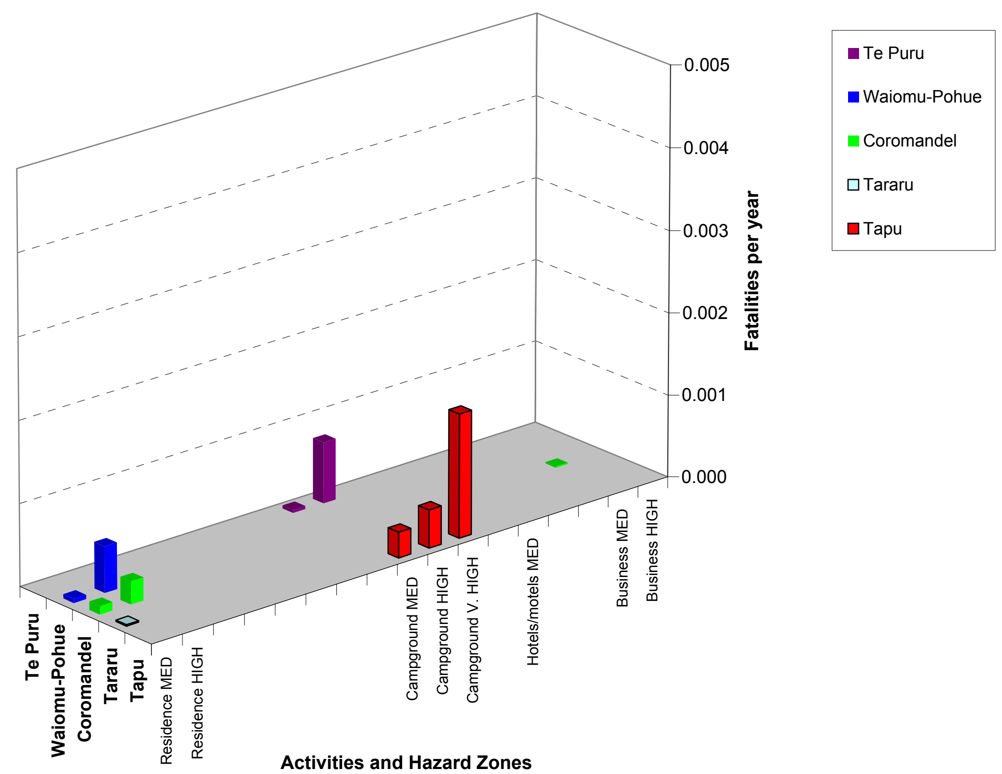
SUMMARY OF LIVES RISK - CAPITAL WORKS OPTION 2 + WARNING SYSTEMS UPGRADE

Location	Private residences			Schools			Retirement villages			Camping grounds			Hotels and Motels			Business			
TCDC/EW Hazard Zone	Low	Med	Hi	Low	Med	Hi	Low	Med	Hi	Med	Hi	Very Hi	Low	Med	Hi	Low	Med	Hi	
USBR Flood Severity	Very low	Low	Med	Very low	Low	Med	Very low	Low	Med	Low	Med	Hi	Very low	Low	Med	Very low	Low	Med	
		Residence MED	Residence HIGH							Campground MED	Campground HIGH	Campground V. HIGH		Hotels/motels MED			Business MED	Business HIGH	**TOTAL ALR**
Tapu										3.13E-04	4.64E-04	1.51E-03							**0.0023**
Te Puru										4.08E-05	7.42E-04								**0.0008**
Waiomu-Pohue		5.16E-05	5.63E-04																**0.0006**
Coromandel		1.03E-04	2.81E-04														1.63E-05		**0.0004**
Tararu		1.72E-05																	**0.00002**

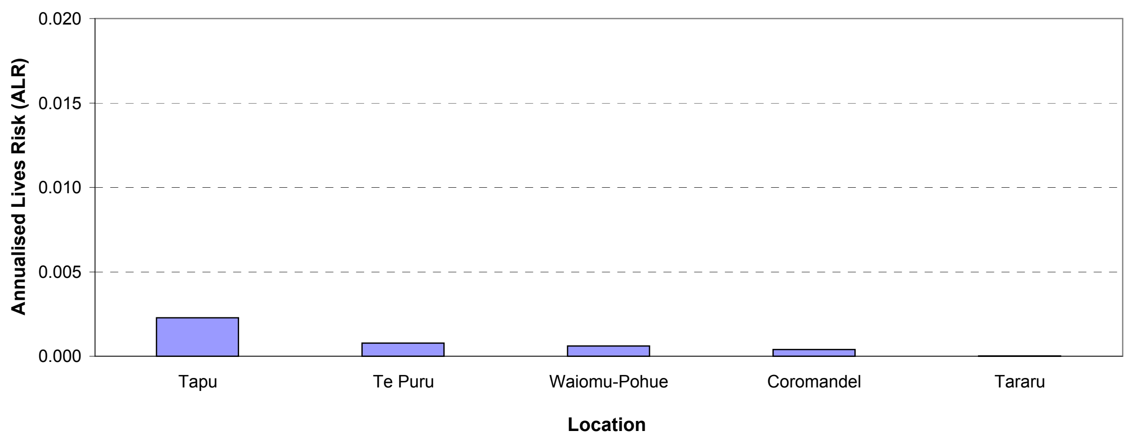
F-N Chart



Fatalities per Year by Activity



Lives Risk Profile



SUMMARY OF LIVES RISK - CAPITAL WORKS OPTION 3 + WARNING SYSTEMS UPGRADE