THE IMPACT OF VOLCANIC HAZARDS AT RABAUL PAPUA NEW GUINEA

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THE IMPACT OF VOLCANIC HAZARDS AT RABAUL PAPUA NEW GUINEA

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Foreword

This study was commissioned by those members of the Insurance Underwriters' Association of Papua New Guinea appearing below -

American Home Assurance Company
General Accident Insurance Company PNG Limited
GRE Pacific Insurance Pty. Ltd.
New Zealand Insurance Company Limited
Niugini Insurance Corporation
Queensland Insurance (PNG) Limited
Southern Pacific Insurance Company (PNG) Limited
Taisho Marine & Fire Insurance Company Limited.

The Institute of National Affairs (I.N.A.) is pleased to have undertaken the task for them. The terms of reference were drawn by I.N.A. in consultation with the client. I.N.A. chose the researchers and was given a completely free hand in executing the work.

The authors, Russell Blong and Colin Aislabie, bring a very useful combination of disciplines to the task. Dr. Blong is Associate Professor in Earth Sciences at Macquarie University while Dr. Aislabie is Senior Lecturer in Economics at the University of Newcastle, Australia.

This study reflects a harmony of these particular approaches - the physical geographer and the economist. Their collaboration has resulted in something new in the field of natural-disaster management. The I.N.A. expresses its appreciation to Dr. Aislabie and Dr. Blong for this important contribution to the field generally and to understanding Rabaul in particular.

The role of the Insurance Underwriters' Association deserves special mention. Under political pressure themselves to change their policies, they did not pass to the research project any of that pressure. By limiting their involvement to funding, the Underwriters ensured an impartial report, one that may therefore enjoy the confidence of policy-makers in evaluating its conclusions and recommendations for public policy.

John Millett
Institute of National Affairs
12 April 1988

Preface

In preparing this report we have become indebted to many people and organisations who provided data and assisted in our enquiries. A list of many of these individuals and organisations is provided elsewhere in this report but we wish to acknowledge here our greater debt to a few individuals.

In particular we would like to thank Richard Joycey and Jo Brady, respectively President and Executive Officer of the Papua New Guinea Planters' Association at the time we undertook field work in Rabaul, for their assistance in providing office accommodation and in dealing with numerous administrative matters.

All of the staff of the Rabaul Volcanological Observatory helped with our enquiries on numerous occasions. In particular we would like to thank Dr. Peter Lowenstein, Principal Volcanologist, and Chris McKee, Senior Volcanologist, for their efforts not only in providing information but also in commenting on early drafts of several of the chapters.

Numerous people in government also provided vast quantities of information and valuable contacts. In particular we would like to thank Nason Paulias (Secretary), John Brown (Assistant Secretary, Community Government), Ellison Kaivovo (First Assistant Secretary, Economic Services) in the East New Britain Provincial Government; and Jim Power (Valuer-General's Office) and Wayne Lindsay (Regional Supervising Draftsman) in the Department of Lands and Physical Planning.

A large number of people in the private sector gave their time and information and provided assistance in many ways. We would like to single out four people for special thanks: Mike Manning (Managing Director, New Guinea Islands Produce), Michael Mayberry (President, Rabaul Chamber of Commerce), Hugh Coulter (Economist, Cocoa Industry Company), and Donald Dunbar-Reid (Senior Vice-President, Papua New Guinea Planters' Association).

In Australia the staff of Toplis and Harding (Loss Assessors) in Brisbane provided enormous help. Our particular thanks also go to John Cleasby (Macquarie University) for his cartographic skills, and to Sue Morsby (Macquarie University) for her remarkable skills in word processing several of the chapters.

We would also like to record our thanks to the staff of the Institute of National Affairs in Port Moresby. Brian Brogan (now at the National Centre for Development Studies at the Australian National University), organised the project and provided valuable assistance throughout the lengthy gestation period. Our warmest thanks go to Jocelyn and John Millett who pushed us along when they could and encouraged us when we proved tardy.

We wish also to acknowledge our debt to the Insurance Underwriters' Association of Papua New Guinea for providing the financial support for this project and for their interest in our efforts to provide a comprehensive account of the 1983-85 crisis and the effects of future eruptions on Rabaul and the Gazelle Peninsula.

C. Aislabie
R. Blong

Executive Summary

There was no eruption during the 1983-85 seismic crisis at Rabaul. Nevertheless, the crisis damaged the Rabaul economy and has left the continuing problem of coping with the expectation that an eruption will occur in the future.

It is inevitable that any consideration of the volcano hazard at Rabaul must place considerable emphasis on what has happened in the past. Chapters 2 to 5 of this study provide a history of volcanism at Rabaul, the recent history of the economy of the study area (Rabaul and its immediate hinterland) and a history of the 1983-85 seismic crisis. These chapters provide perspective as well as an assessment of how Rabaul coped with the crisis.

Among the more significant findings from our historical chapters we particularly note the following:

- There is insufficient evidence available to define precisely the periodicity of volcanic eruption, but it is possible to model the likely magnitude and character of future eruptions.

- The economy is driven by agricultural production for domestic consumption and export. There is a real sense in which the impact on the economy of, and its ability to bounce back from, an eruption depends much more on the damage to this sector than any damage to the town of Rabaul.

- Almost no attention was paid during the seismic crisis to either the possibility of a large-scale eruption or, more importantly, to planning for the rehabilitation period following any eruption.

One conclusion derived from a consideration of the 1983-85 crisis was that there appeared to be only a limited understanding of what was likely to happen during an eruption and of its more immediate consequences. In Chapters 6 to 8 we try to remedy this situation by examining a number of different eruption scenarios. While we believe these scenarios are realistic, an actual eruption could follow any one of an almost infinite number of possible outcomes. However, we believe it useful to first examine eruption scenarios (two are needed because the direction of the prevailing wind considerably influences the impact of the eruption) of a magnitude comparable to the 1937 eruption. It is very likely that an actual eruption would be of comparable, or lesser, magnitude. Then, we briefly sketch out the impact of a devastating eruption. Although such an outcome is not likely, examining it does allow consideration of the trade-offs that need to be made between the expense of taking account of such outcomes in pre-eruption planning and the risk that is being taken.

While the quality of any prediction as to the outcome of an eruption depends on the appropriateness of the assumptions incorporated in the modelling, our analysis highlights a number of important aspects of likely eruptions. Attention is particularly drawn to the following:

- Injury and loss of life are likely to result primarily from pyroclastic flows and falls of volcanic ash.

- Injury and loss of life will be reduced and the ability to cope with the eruption considerably enhanced if the populace will respond to the emergency along the lines indicated in the disaster plan. However, some deaths and injuries can be expected outside the declared disaster zones.

- It is to be expected that the total damage bill (for other than cataclysmic eruptions) for insured (commercial) buildings in Rabaul by category of risk is apportioned unevenly between insurance companies because of the different spatial distribution of policies.

- There will be some initial deleterious impact (from an other than cataclysmic eruption) on agricultural production although the long-term impact may be beneficial. On balance, we would be reluctant to describe the damage to the provincial wealth-generating mechanism as "serious" let alone "irreparable".

The final chapter, Chapter 9, considers some of the implications of the study. In it we concentrate on four main issues. These are as follows:

- The quality of volcanic hazard assessment in Rabaul is extremely important. It is our belief that more research needs to be done.

- Response to the threat of, reaction to, and recovery from, an eruption depends on the appropriate drafting and implementation of a disaster plan. Suggestions for improvement to the existing plan are considered.

- There is an investment stalemate in urban Rabaul where insurers have restrictions on the provision of seismic risk cover and credit providers will not make funds available for investment while these restrictions are in force. This problem is addressed.

- One response to the eruption threat, and particularly to the investment stalemate it has produced, is to shift the location of Rabaul township. The desirability of this course of action is considered.

The major recommendations which arise from our study are summarized below -

1. Several more carefully selected eruption scenarios should be constructed in order to better define the range of possible effects of eruptions on human health, residential and commercial buildings, government services and agricultural production.

2. More information on the possible effects of an eruption on public utilities should be undertaken in order to further improve the disaster plan and to guide future investment strategies in East New Britain.

3. Further attention must be given in the disaster plan to the evacuation processes necessary in the event that a large-scale eruption follows from a relatively small one. Further consideration should also be given to definition of the extended safe zone in the light of the recent stratigraphic work on the distribution of ignimbrite deposits and the estimated damage and danger to life presented in Chapter 8.

4. In view of the fact that considerable equipment damage will result from an eruption, urgent consideration must be given to backup facilities for Rabaul Volcanological Observatory that will allow monitoring of the immediate threat from possible further eruptions to continue.

5. Urgent consideration must be given to the design and construction of a major road towards Open Bay in order to facilitate the evacuation of large numbers of people in the event of a large-scale eruption.

6. Some aspects of the disaster plan relating to the location of evacuee camps and definition of areas at risk need to be modified in order to reflect the ash fallout patterns presented in the available (and additional) scenarios.

7. Consideration should be given in the disaster plan to organisational aspects relevant to the clean-up and recovery period in the aftermath of an eruption.

8. We recommend that at least one disaster exercise involving all of the relevant organisations be held each year, with full public participation.

9. Consideration should also be given to raising and maintaining the general level of volcano hazard awareness in the communities on the Gazelle Peninsula by the introduction of regular radio programs, and a newsletter, perhaps produced by desktop publishing means, and the re-introduction of the volcano bulletin boards. Consideration should also be given to the introduction of regular instruction on the volcanic hazard and the disaster plan in both primary and secondary schools.

10. Before further consideration is given to the relocation of many of Rabaul's functions to the Kokopo area, a careful analysis must be made of the relative risks posed by volcanic and other hazards to the two areas. The insurability of structures at any new site and the willingness of governments to provide meaningful incentives for relocation should be major considerations.

11. In setting eligibility criteria and rates for potential business in Rabaul and its immediate hinterland, lending institutions and the insurance industry should take full account of volcanic and other hazards in this area relative to other parts of the country rather than focussing on the Rabaul situation narrowly. Government assistance may be necessary in this regard by way of guarantees or other incentives in order that such institutions can continue to implement national priorities in the region.

12. We urge that Rabaul's possible relocation be seen as a national problem and that regional as well as provincial factors be taken account of in any proposed solution.

13. Until recommendations 10 and 11 have been accepted, no government restrictions should be imposed on new building or reconstruction in Rabaul.

14. Due weight in regional economic planning should be placed on the need for the provincial economy to continue to function in the aftermath of any eruption. Thus, agricultural and transport developments in the province should not unduly emphasise the involvement of Rabaul and its immediate hinterland.

15. The national government should be willing to accept its due responsibilities in the planning process, not simply confine its attention to narrowly targetted disaster planning and relief activities in the event of an actual eruption.

The volcanological hazard at Rabaul cannot be eliminated by implementing the findings of any report. However, the situation can be ameliorated if it is viewed in true perspective. Providing such a perspective is what we have sought to do in this report.

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Abbreviations

B.P.	Before Present
DCA	Department of Civil Aviation
DPI	Department of Primary Industry (now Department of Agriculture and Livestock)
DPPE	Department of Physical Planning and Environment
DWS	Department of Works and Supply
ENBP	East New Britain Province
ENBPDC	East New Britain Provincial Disaster Committee
ENBPDP	East New Britain Provincial Disaster Plan
Elcom	Electricity Commission of Papua New Guinea
IUA	Insurance Underwriters' Association of Papua New Guinea Inc.
K	Kina
LAES	Lowlands Agricultural Experiment Station
MM	Modified Mercalli
NDC	National Disaster Committee
NEC	National Executive Council
PDC	Provincial Disaster Committee
PNG	Papua New Guinea
PNGDF	Papua New Guinea Defence Force
RDP	Rabaul Disaster Plan
RVO	Rabaul Volcanological Observatory
VEI	Volcano Explosivity Index

Chapter 1

Assessing the significance of hazards at Rabaul Volcano

Introduction

The purpose of this study is to assess the physical and economic impact of volcanic hazards in the Rabaul area. The study assesses the impacts using a variety of hazard-analysis and economic techniques. It approaches the problem from a number of perspectives, mainly those of our major disciplines - physical geography and economics.

In several ways this study appears to be unique. Although historical and geological records of volcanic eruptions are commonly analysed to provide estimates of the magnitude and frequency of future activity, we know of no comparable studies which aim to utilise such data to model in detail a range of hazards induced by volcanic activity and their effects, in both physical and economic terms. At the same time, we have provided a detailed investigation of the 1983-85 seismo-deformational crisis (hereafter called the seismic crisis). From a natural hazards point of view this event is fascinating as it resulted in enormous efforts in preparation for the anticipated eruption and produced profound economic effects which lasted far beyond the end of the crisis period even though no eruption took place. Our investigation of the seismic crisis may have important lessons for the future, as "failed" eruptions such as this one could occur again in Rabaul before an actual eruption takes place.

This study provides not only a worthwhile assessment of the impact of failed eruptions and of future eruptions on the Rabaul area but also an innovative approach to natural-hazards risk analysis. We believe the methodology presented here can be transferred to hazard analysis in a variety of situations.

The study also breaks new ground in trying to shape the regionally dis-aggregated statistics, despite their paucity, into a meaningful picture of the provincial economic wealth generation and transmission mechanism. This provides a background to the first attempt to place a volcanic eruption (or possibility of an eruption) into an economic framework. While it is more usual to study the economic impact of a natural disaster, this work looks beyond such a narrow focus to view a potential disaster in proper economic perspective.

The study area

The area that would be affected by an eruption would, of course, depend on the scale of an eruption. In general, the term "study area" is used in this report to indicate all of that area which is within 50 kilometres from Rabaul in a direct line (Figures 1.1 and 1.2). The reasons for this are twofold. The area is that which could be affected directly by an eruption and which is primarily affected by the work of the East New Britain Disaster Committee (ENBDC). Furthermore, it is almost impossible to reach any point by road which is more than 50 kilometres from Rabaul in a direct line. Consequently, most of the significant economic activity within East New Britain Province (ENBP) occurs within this area; although Rabaul engages also in major entrepôt trade, particularly with other provinces in the Islands Region.

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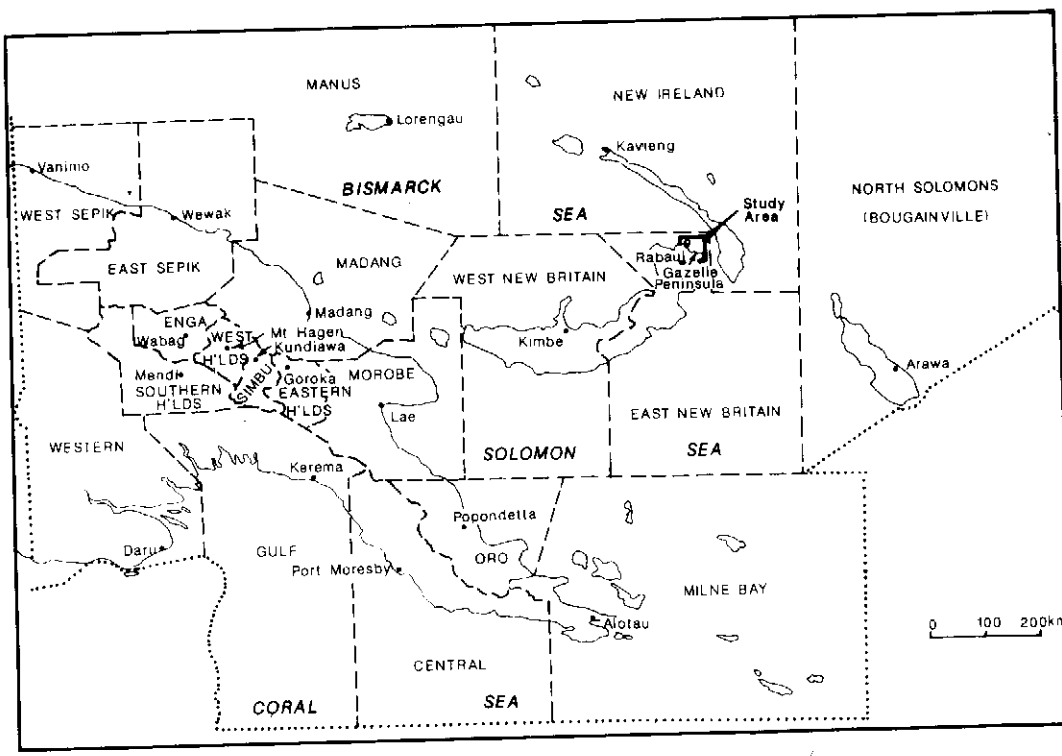
Figure 1.1

Provinces of Papua New Guinea and the study area



The methodology

In order to assess the impact of future eruptions it is necessary to understand the likely magnitude of such events and the location of possible vents. The standard technique involves an analysis of the historical record of eruptions, perhaps with an additional consideration of prehistorical eruptions where suitable geologic or stratigraphic information is available. We have used both approaches here but recognise that the historical record (about 200 years) is too short for an accurate determination of eruptive magnitude and frequency. Furthermore, the stratigraphic record of past eruptions in the Rabaul area is only partially known and poorly dated.

One of the major effects of volcanic eruptions results from the widespread deposition of volcanic ash (tephra). Because the size of the area affected is largely determined by eruptive magnitude and wind direction, different areas are likely to be affected depending on the month of the year in which volcanic activity occurs.

Because the Rabaul caldera is large and exhibits a number of past eruptive centres (or individual volcanoes) such as Vulcan, Tavurvur and Rabalanakaia, it is not possible to identify precisely the source of the next (or any future) eruption. This difficulty is compounded by the fact that the eruptions in 1878 and 1937 occurred more or less simultaneously from both Tavurvur and Vulcan.

Despite these inherent difficulties, monitoring carried out by the Rabaul Volcano Observatory (RVO) suggests that some limits can be placed on both the sources and the magnitude of the next eruption, assuming that it occurs in the next few years. Chapter 2 provides an introduction to the physical setting of Rabaul and outlines the reasoning which has led us to provide analyses of four separate events or scenarios:

- the 1983-85 seismic crisis;
- a 1937-magnitude eruption with the surface winds blowing from the southeast;
- a 1937-magnitude eruption but with the surface winds blowing from the northwest; and
- an eruption similar in magnitude to the very large eruption which occurred about 1,400 years ago and which was responsible for the formation of part of the Rabaul caldera.

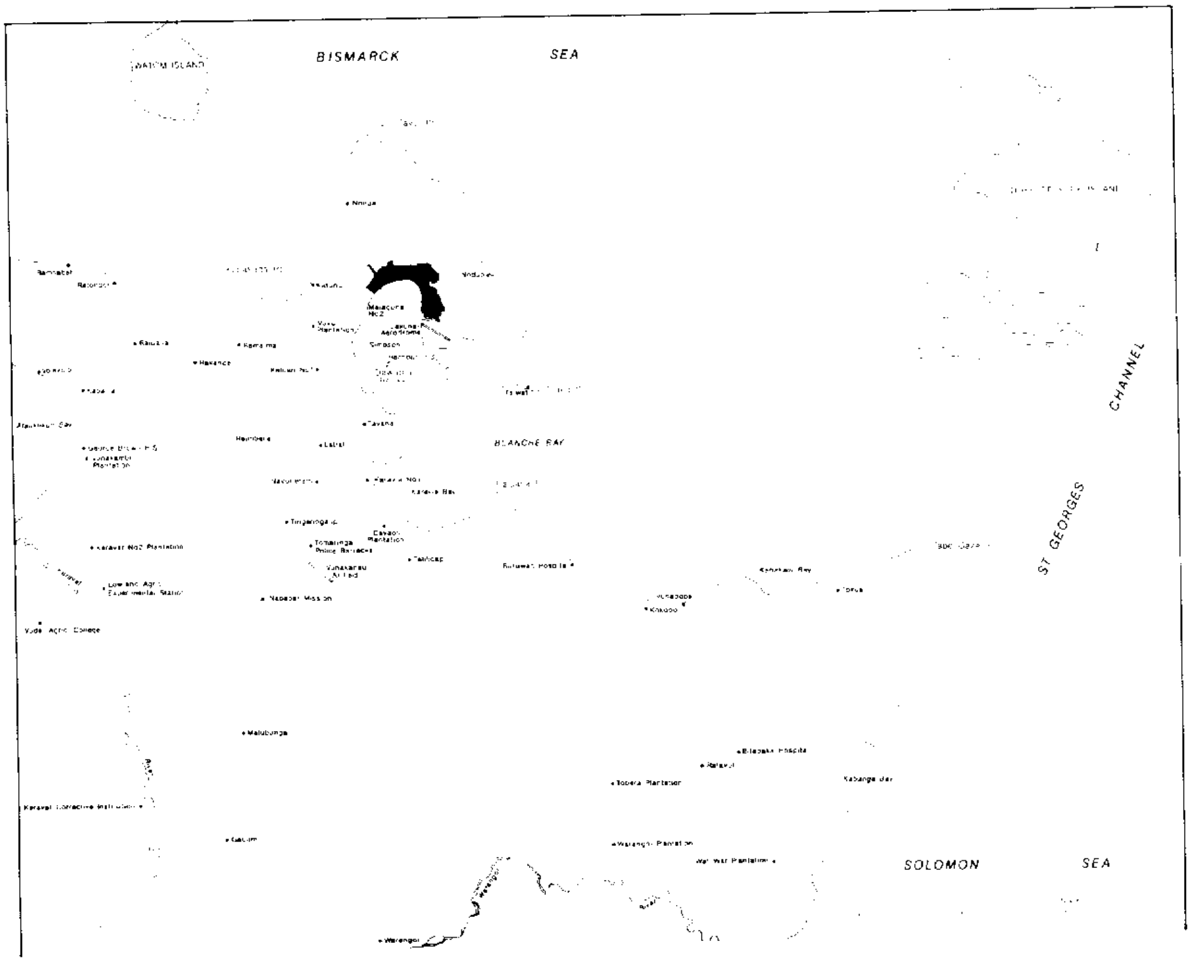
Analyses of these scenarios allow reasonably precise statements to be made about possible future events in Rabaul.

After selection of the eruptive magnitude, vent location and time of the year in which the eruption occurs, we have identified the range of hazards produced by each eruption and the areas likely to be affected. For each eruptive scenario we have considered up to seven separate types of volcanic hazard (earthquakes, ballistic projectiles, ash-falls with a range of thicknesses, pyroclastic flows and surges, tsunamis, toxic gases, and mudflows) and the likely effects of each on:

- humans;
- domestic buildings;
- commercial buildings; and
- agriculture, particularly the production of cocoa and copra.

Figure 1.2

The study area



Economic studies of natural-hazard impacts usually require more data and a greater investment in research than has been feasible in the present study. Nevertheless, sufficient information is available to assess the economic significance of the Rabaul volcanic hazard and to justify the view taken here that Melanesian economies possess considerable ability to adjust to change.

Essentially the economic contribution involves making a detailed case study of the regional economy paying particular attention to the provincial economic wealth generation and transmission mechanisms. Where possible, information was obtained on regional wealth in both the public and private sectors and attempts were made to gauge specific losses that were incurred during the 1983-85 seismic crisis and which were anticipated to occur during an eruption.

The research methodology employed included the administration of a survey to business persons, interviews, perusal of Disaster Committee memoranda, and literature searches. The literature search and extraction of information from official publications involved recourse to national and provincial budgets, census material, national input-output publications and tables, reports prepared for the national and provincial governments and official correspondence. In the literature search and extraction of information from non-official publications, the emphasis was more on academic publications relating to economic development and economic anthropology in the study area and ENBP and Papua New Guinea generally, although access to correspondence and reports also proved to be very useful.

Interviews were conducted in the Rabaul area during November and December 1986. Part of the field work involved the preparation and distribution of a questionnaire, visits to plantations, and the physical inspection of economic wealth generation and transmission facilities.

Economic wealth generation and transmission mechanisms within the study area are primarily concerned with the production of agricultural commodities, the further processing of agricultural commodities, the export of agricultural commodities including production from elsewhere in ENBP and from other provinces, and the production and distribution of goods and services in secondary and tertiary sectors and with the estimation of the replacement or compensation values of previous investment in the public and private sectors.

A basic economic model has been constructed, but the lack of data precluded the use of a more sophisticated approach to regional modelling, employing input-output analysis or regression techniques.

While the need to specify the economic wealth generation and transmission mechanisms within the study area makes this, to the best of our knowledge, the first economic and social study of the modern Rabaul economy, it should be appreciated that this has not been our primary goal. Indeed, it should be stressed that the approach to the Rabaul economy has been selective in order to concentrate attention on those features of it regarded as most relevant to the present study.

Outline of the study

Chapter 2 outlines the volcanic setting of Rabaul. This history provides a background within which the eruptions which have occurred during the period of European history can be appreciated. Together with the brief section on the monitoring activity undertaken by the Rabaul Volcano Observatory (RVO), this background provides the rationale for the selection of the scenarios for detailed study mentioned earlier.

Chapter 3 sets out the main features of the economic situation of Rabaul in the early 1980s and provides the bulk of the social and cultural information necessary to understand the impact of the 1983-85 seismic crisis.

The history of the seismic crisis is outlined in Chapter 4, largely as it is presented in official and unofficial documents that were made available to us in Rabaul and Port Moresby. This material describes the nature of the seismic and deformation data which suggested that an eruption was likely to take place and the response of the ENBP and Papua New Guinea governments to the crisis. The chapter details the legislative response, the formation of sub-committees and the efforts made to ensure that the population at risk could be safely evacuated when it became necessary. Considerable attention is devoted to perspectives on the insurance problems stemming from the crisis.

A major emphasis in Chapter 5 lies in a consideration of the economic arrangements made during the crisis and the costs and benefits to the Rabaul and ENBP economies. Attention is focused on business reactions to the crisis and the role and activities of the national government.

Chapter 6 provides a scenario of an eruption equal in magnitude and style to the May 1937 eruption in Rabaul but set in the late 1980s. The chapter begins with a scenario (an hypothetical construct) setting out a possible future for Rabaul based on levels of preparedness existing in Rabaul in late 1986. Clearly the scenario presented is but one of an infinite number of possible futures; but it serves to emphasise the relationships between the physical character of an eruption, the social and economic background of the town and its hinterland, and the effects of the eruption itself. The chapter continues by emphasising the types of hazard that would be experienced during a repeat of the 1937 eruption, the real extent of each hazard, the severity of the effects in terms of deaths and injuries, and the likely consequences on residential and commercial buildings, and on agricultural production. Considerable emphasis is given in this chapter to the costs of an eruption to the insurance industry, as the setting of insurance rates during and after the seismic crisis of 1983-85 has had profound effects on the recent development of the town.

In Chapter 7 a scenario is considered based on precepts similar to those used in Chapter 6 but occurring in the month of November in the late 1980s. Although equal in magnitude to the scenario presented in Chapter 6, the different wind direction produces effects significantly less than for the May eruption.

Chapter 8 attempts to model a very large eruption similar in style and magnitude to the 6th century eruption which formed part of the Rabaul caldera. Although the probability of an eruption of this size is very low (much less than 5 per cent), the consequences of such an event for Rabaul and the surrounding areas are particularly severe.

Finally, Chapter 9 generalises some aspects of the physical and economic effects so that a range of other possible eruptive scenarios can be considered and examines the implications of the information presented in the earlier chapters. Attention is focused on volcanological aspects, the disaster plan, the significance of the seismic crisis of 1983-85, the investment stalemate that resulted from the crisis, and the question of the relocation of Rabaul.

Chapter 2

The volcanic setting of Rabaul and future eruptions

Introduction

The information presented in this chapter provides the background data on which the scenarios of possible future eruptions are based.

This chapter sets out the volcanic history of the Rabaul area. Little attention is paid to the geochemistry or petrology of the eruptions. Instead, the emphasis is on eruption size and eruption style. Because most of this information comes from an interpretation of the stratigraphy (the record of volcanic deposits), the available information becomes progressively more detailed towards the present day.

The survey of volcanic history is followed by a short section on monitoring of the volcano carried out by the RVO. The information derived from monitoring provides a great deal of background about the likely source areas for eruptions and suggests limits on the size and character of any eruption which might occur in the next few years.

As it is not possible to model all possible future eruptions that might occur in Rabaul, data from the stratigraphic record and the current monitoring program are used to construct three scenarios which we believe provide realistic models of three possible futures. These models provide the basis of much of the substance of Chapters 6, 7, and 8.

Volcanic history

The Rabaul caldera measures 14 kilometres from north to south and nine kilometres from east to west. In the southeast the caldera wall has been breached, leading to the formation of Blanche Bay. Figure 2.1 outlines the caldera rim and indicates the known volcanoes in the Rabaul area. Three volcanoes - Watom Island, Varzin and Wairiki (four kilometres southeast of Varzin) - lie outside the caldera rim.

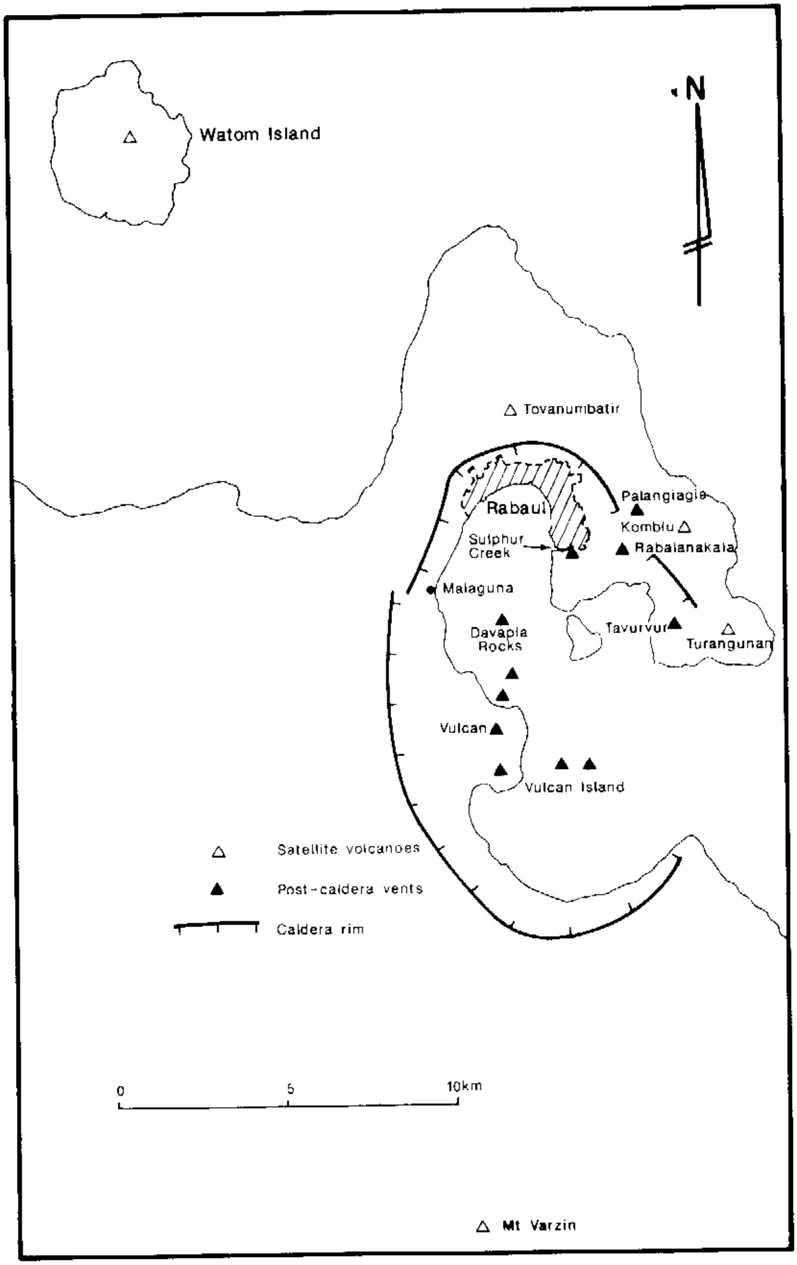
Satellite volcanic cones include Tovanumbatir (North Daughter), Kombiu (The Mother), Palangiagia (including Rabalanakaia), and Turangunan (South Daughter). Davapia Rocks (The Beehives) are probably also part of an old volcanic cone, now much eroded.

Other eruptive centres (vents) in the caldera include Tavurvur, Sulphur Creek, Vulcan Island and Vulcan. Eruptions have occurred from all of these centres in the last few hundred years. Some submarine centres also occur (Figure 2.1).

Prehistoric eruptions. A stratigraphic record of volcanic eruptions is nearly always incomplete. Small eruptions frequently leave relatively few deposits and these are rapidly eroded so that after a few years little stratigraphic record remains. Very large eruptions produce thick and widespread deposits which deeply bury the record of older volcanic history. In such cases only a few very deep exposures (and, sometimes, bore hole records) are available to allow interpretation of the volcanic history. Thus, a stratigraphic record is frequently biased toward relatively large and relatively recent (in a geologic sense) eruptions.

Figure 2.1

Volcanoes of the Rabaul area and the caldera rim



The available stratigraphic record of volcanic eruptions from the Rabaul caldera has been presented by Walker et al. (1981) and Heming (1974). Further detailed stratigraphic work on the early major eruptions will shortly be published by Nairn et al. (in prep.).

Many of the younger volcanic cones shown on Figure 2.1 are located on major (regional) northwest-trending or eastwest fractures. Eruptive activity in the Rabaul area extends back at least half a million years. The stratigraphic work by Nairn et al. has revealed at least 50 significant eruptive episodes in the history of the Rabaul caldera. Many of these eruptions were relatively small-scale events, similar in style and magnitude to the 1937 eruption, or involved the eruption of lavas from vents such as Kombiu and Rabalanakaia. However, at least nine major ignimbrite-producing eruptions[1] are known to have occurred; although the timing of all but the last two of these large eruptions is poorly known. Although McKee et al. (1985) and earlier workers believed that the major eruption which occurred about 3,500 years ago was the third-to-last major eruption from the Rabaul area, the more recent investigation of Nairn et al. suggests that the 3,500 year B.P. (= Before Present) event was the penultimate one. Ignimbrite deposits from this eruption extended at least as far as Arumbum, 40 kilometres south of Rabaul. This eruption may have led to the formation of the Simpson Harbour, part of the Rabaul caldera (Nairn et al.).

Both the 3,500 year B.P. event and the subsequent caldera-forming event about 1,400 years B.P. were very large eruptions. The more recent one began with a deposit of airfall ash to the northwest. The eruption then became a plinian eruption, producing a deposit of pumice similar to that which buried Pompeii in A.D.79. Subsequent coarse ash deposits reached at least as far as Watom Island. These airfall deposits were followed by massive deposits of pyroclastic material (ignimbrite) produced by eruption column collapse. Figure 2.2 (Walker et al. 1981), indicates the mapped extent of this ignimbrite deposit. The total volume of the 1,400 B.P. year eruption was about 11 cubic kilometres. It seems likely that at least part of Rabaul Harbour was formed as a result of caldera collapse associated with this eruption. The vent for the eruption was probably near the centre of the caldera (Walker et al. 1981). Stothers (1984) has suggested that dry fogs, a haziness in the sky, and a dimming of the sun and moon observed in the Mediterranean in the years A.D.536 and 537 were the atmospheric effects of this eruption of Rabaul volcano.

Both the 3,500 year B.P. eruption and the 1,400 year B.P. event seem to have been more violent than earlier large eruptions from the Rabaul caldera. These two eruptions, and probably earlier ones of a similar magnitude, would have caused major damage, perhaps total devastation, even at distances of 30 to 50 kilometres from the vent.

The work of Nairn et al. suggests that at least 10 damaging pyroclastic eruptions have occurred in the period between the 3,500 year B.P. event and the beginning of the historical record. These eruptions are believed to have been smaller in magnitude than the 3,500 and 1,400-year B.P. eruptions, but equal to or larger than the 1937 eruption. Damage, except that resulting from airfall ash, would have been largely confined to sections of the area within the caldera rim.

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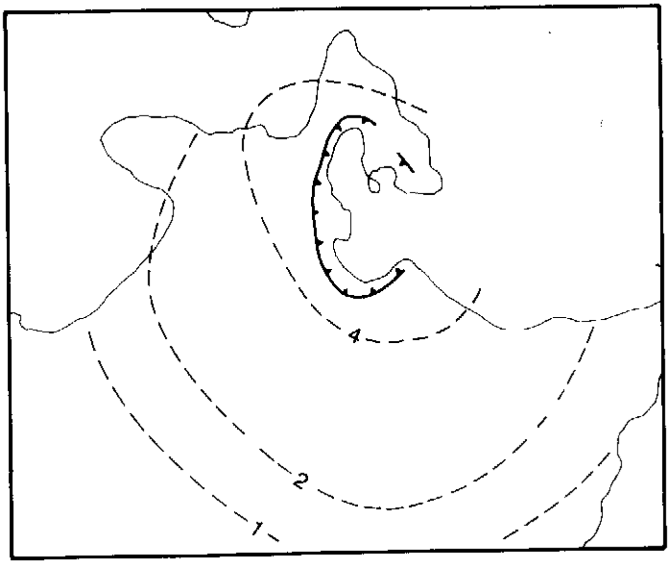
1. Ignimbrites are produced by the outward flow of hot (at least several hundred degrees Celsius) and fast-moving (more than 20 metres per second) pyroclastic flows - mixtures of gas, pumice and ash with a small proportion of dense rock fragments.

Figure 2.2

Approximate isopachs in metres of the ignimbrite deposits for the 1,400 year B.P. eruption (after Walker et al. 1981).



Historical eruptions. The first historical eruption at Rabaul was reported in 1767 by the navigator Philip Carteret. The source vent for this eruption is not known, but the work of Nairn et al. suggests that it may have been Tavurvur. The eruption was probably rather small. Similarly, little is known about the 1791 eruption reported by Captain John Hunter other than that it probably originated from a Tavurvur vent (Johnson and Threlfall 1985).

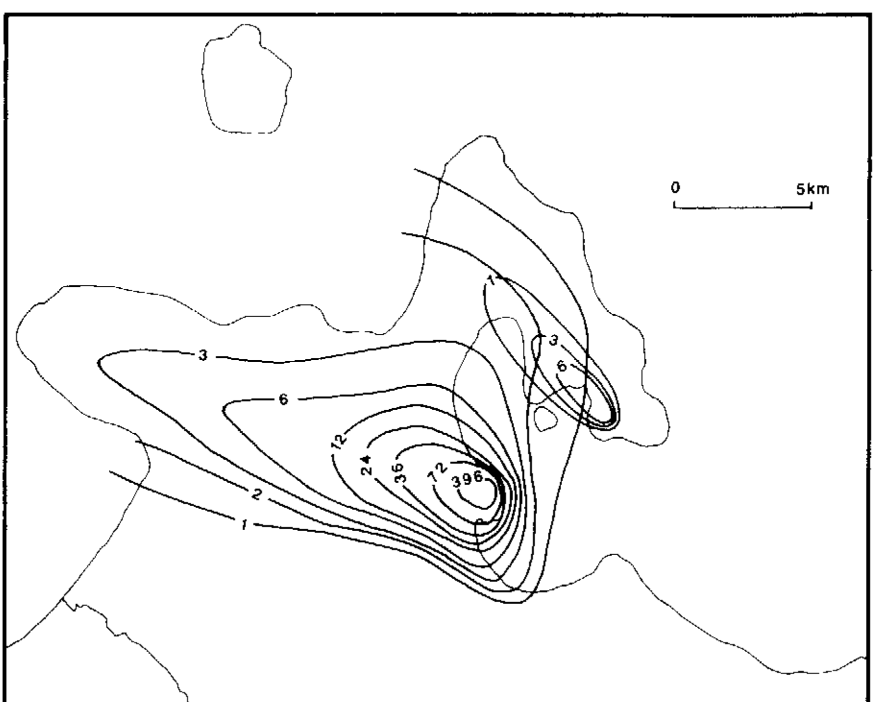
About 1850 an eruption occurred from the small craters near the head of Sulphur Creek on the eastern side of the harbour. Nairn et al. indicate that this eruption was phreatomagmatic - that is, ground water was converted to steam and erupted together with fresh rock material. Such eruptions are often characterised by the occurrence of surges in which rapidly moving clouds of steam and rock are blasted horizontally from the vent. According to Fisher (1939) many men were killed by the fall of huge blocks of pumice during this eruption.

The 1878 eruption was described by the Reverend George Brown (1908). He witnessed the eruption from the Duke of York Islands, and visited Rabaul a few days later. The eruption occurred from Tavurvur and from a new vent on the western side of the harbour, Vulcan Island. As was the case in 1937, the eruption from the Vulcan side of the harbour was by far the more voluminous. The eruption also seems to have been similar in style to the 1937 event. The magnitude of the 1878 eruption can be described as small-to-moderate (McKee et al. 1985). Brown (1908) was told that one woman was killed by the first ash-fall.

Excellent descriptions of the 1937 eruption and its effects have been compiled by Johnson and Threlfall (1985). This eruption produced about 0.3 cubic kilometres (300 million cubic metres) of volcanic ejecta (McKee et al. 1984). Nearly all of this was produced from Vulcan with only a small amount of ejecta issuing from Tavurvur. The eruption column at Vulcan reached a height of eight to 10 kilometres. The various hazards produced by this eruption will become evident later; however, Figure 2.3 indicates the extent of one of the most significant hazards - volcanic ash (tephra) fall - and emphasises that tephra was ejected from both Vulcan and Tavurvur during the 1937 eruption. The eruption killed about 500 people, mainly on the western side of the caldera. Damage to the town of Rabaul was relatively minor (Johnson and Threlfall 1985).

Figure 2.3

Distribution of the airfall ash deposits produced from Vulcan and Tavurvur during the 1937 eruption. Isopachs are in inches. (after Fisher 1939, and Johnson and Threlfall 1985).



The latest eruption at Rabaul occurred from June 1941 to about March 1942 and in December 1943 (Fisher 1976, Johnson and Threlfall 1985; McKee et al. 1985). This eruption was relatively small, although the occasional fall of volcanic ash on settled areas including the town made life unpleasant on several occasions.

In 1983 and 1984 data derived from geophysical monitoring of the volcano suggested that magma was moving toward the ground surface and that an eruption was likely to occur (see Chapter 4). A stage 2 alert was declared at the end of October 1983, but subsequently reduced to a stage 1 alert in November 1984. To date (January 1988) no eruption has eventuated and it is unclear whether such seismic activity and ground deformation are typical of the Rabaul caldera. Perhaps the seismic crisis represents a "failed eruption".

Eruption magnitude

The international scale used by volcanologists to describe the size of an eruption is called the Volcano Explosivity Index (VEI) (Newhall and Self 1982). The VEI scale ranges from 0 to 8. It is a logarithmic scale based on the volume of material ejected from the volcano, eruption column height and eruption character.

Consideration of the 1937 eruption of Vulcan illustrates the concept of the VEI.

According to one authority, the 1937 Vulcan eruption was VEI 4? (Simkin et al. 1981). The question mark indicates some doubt about the assigned value, but on the VEI scale, the 1937 eruption can be described as "large".

The volumes of ejecta associated with a VEI 4 eruption range from 100 to 1,000 million cubic metres so that the Rabaul eruption was towards the low end of this scale. As the eruption column height was only 8 to 10 kilometres this measure suggests that the VEI was only 3, a view supported by RVO staff (P. L. Lowenstein, C. O. McKee, personal comment, July 1987). For comparative purposes, the 1883 eruption of Krakatau was VEI 6 (10 - 100 cubic kilometres of ejecta, eruption column height more than 25 kilometres), and the 1941 eruption of Tavurvur was VEI 1 (10,000 to one million cubic metres, eruption column height 0.1 to 1.0 kilometres) (Simkin et al. 1984, p7).

The magnitudes of other historical eruptions at Rabaul are not well known but the values assigned by Simkin et al. (1981, 1984) and RVO staff are presented in Table 2.1.

Table 2.1
VEI for historical eruptions at Rabaul

Date	Vent	VEI
1767	Tavurvur?	2
1791	Tavurvur	1-2?
1850?	Sulphur Creek	2
1878	Vulcan Island and Tavurvur	3
1937	Vulcan and Tavurvur	3-4?
1941-43	Tavurvur	1-2?

Despite the evidence in this international record it should be noted that McKee et al. (1985, p201) believe the 1878 eruption of Vulcan Island to have been similar in magnitude to the 1937 event, describe the 1937 and 1878 eruptions as "small to moderate", and note that the magnitudes of earlier historical eruptions are unknown but are believed to be smaller than that of 1937.

On the VEI scale the 1,400 year B.P. eruption ranks as 6 (Simkin et al. 1981); that is, the eruption was of the same order of magnitude as the 1883 eruption of Krakatau. The eruption 3,500 years B.P. was probably of a similar magnitude.

The current monitoring program

The most pertinent evidence of the magnitude of the next Rabaul eruption derives from the current monitoring program of the RVO. Using seismic, gravity and tiltmeter surveys it has been possible to estimate the volume of magma that has been injected to shallow depths beneath the floor of the caldera.

Seismic data collected since 1985 indicate an elliptical pattern of seismicity (Figure 2.4) which may define the ring fault of the 1,400 year B.P. caldera-forming eruption. Although this elliptical block may be moving upwards in response to increased magma pressure beneath, most deformation is caused by elastic response to one or more pressure sources at depths of 1 to 3 kilometres within the central part of the fault-bounded block, suggesting the upward migration of relatively small volumes of magma (Mori and McKee 1986; Mori et al. 1986).

Deformation data suggest that two shallow reservoirs have received, since the commencement of the most recent phase of caldera unrest in 1971, a total volume of about 100 million cubic metres of magma. On the reasonable assumption that the expanded ejecta has a volume about 2.5 times that of dense rock (i.e. magma), the volume of erupted products from these reservoirs could be about 250 million cubic metres (0.25 cubic kilometres) (McKee et al. 1984; McKee et al. 1985). While there are a number of uncertainties, eruption of this volume of material would produce an eruption equivalent in magnitude to the 1937 event.

In summary, the evidence from the historical record and from the current monitoring program indicates that in terms of magnitude, the next eruption of the Rabaul volcano is likely to be equal to, or slightly smaller than, the 1937 eruption (cf. McKee et al. 1985, p196). However, it is also possible that a small-to-moderate eruption could initiate a large-scale eruption similar in magnitude to the 1,400 year B.P. event.

Eruption frequency

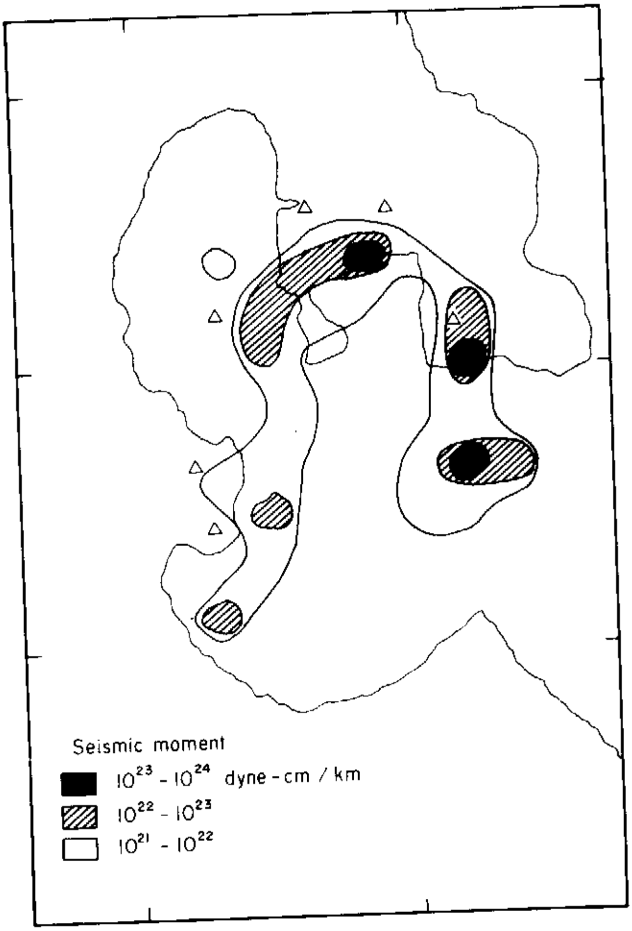
If it is assumed that the activity at Rabaul between 1937 and 1943 were all part of the one eruptive episode, then five eruptions have occurred during the last 220 years (Table 2.1). These very limited data suggest that the frequency of historical eruptions at Rabaul (on average) is of the order of once every forty-four years (McKee et al. 1985).

However, it is quite possible that some small eruptions occurred in the historical period between 1767 and 1878 but have not been recorded. If this was the case the eruptive frequency would be more than once in forty-four years. If an eruption occurs in the next few years, the average eruptive frequency would increase to about once in thirty-seven years.

It is clear that there are real dangers in generalising from such a short (and possibly incomplete) historical record, but the available evidence indicates that the average frequency of eruption in the last few hundred years is of the order of once every forty years or so.[2]

Figure 2.4

Seismic data for the period 1983-85 defines an elliptical pattern within the Rabaul caldera (Mori et al. 1986)



2. As Latter and Hurst (1987) point out, the 1941 and 1943 events can be regarded as eruptions independent from that in 1937 - this interpretation suggests an eruption frequency of 29 +/- 27 years. It should also be recognised that there is a possibility that eruption frequency in the past will provide no guide at all to eruption frequency in the future.

These limited data also suggest that the 1937 eruption was the largest during the historical period. Thus, the historical record strongly suggests that the next eruption of Rabaul will be smaller than or equal in magnitude to the 1937 event.

Two VEI 6 eruptions have occurred in the last 3,500 years. While this sample is far too small for adequate generalisations to be made it would appear that the frequency of major eruptions is of the order of once in 1,750 years or so. Another large eruption in the near future would alter this frequency to about once in 1,200 years, but both estimates suggest that on average one large eruption will occur for every thirty to forty-five small-to-moderate eruptions. That is, the probability of the next eruption being a large eruption is of the order of 2 to 3 per cent. Conversely, the probability that the next eruption will be equal to or smaller than the 1937 eruption is 97-98 per cent.

It is clear that the evidence on which these "calculations" are based is remarkably slender. However, it is interesting to compare these results with the summary of eruptive frequency-magnitude relationships presented in Figure 2.5. Figure 2.5 indicates that 99 per cent of the eruptions that have occurred around the world in the last 10,000 years and for which data exist have been equal to or smaller than the Rabaul 1937 eruption. Similarly, more than 80 per cent of the eruptions were VEI 2 or less. However, it should be noted that a large number of eruptions that were known to be explosive have been assigned a VEI of 2 by default, as no other descriptive information is available.

There may well be other problems with the data set on which Figure 2.5 is based (see discussion in Simkin et al. 1981, p22-26), and problems in regarding Rabaul as an "average" volcano by world standards but, in general, it is the smaller magnitude eruptions which are under-represented in the data file. Thus, although the Rabaul 1937 eruption was a large eruption compared with most known eruptions, the probability that the next eruption in Rabaul will be equal to or smaller than the 1937 eruption is of the order of 97 to 99 per cent.

Eruption models

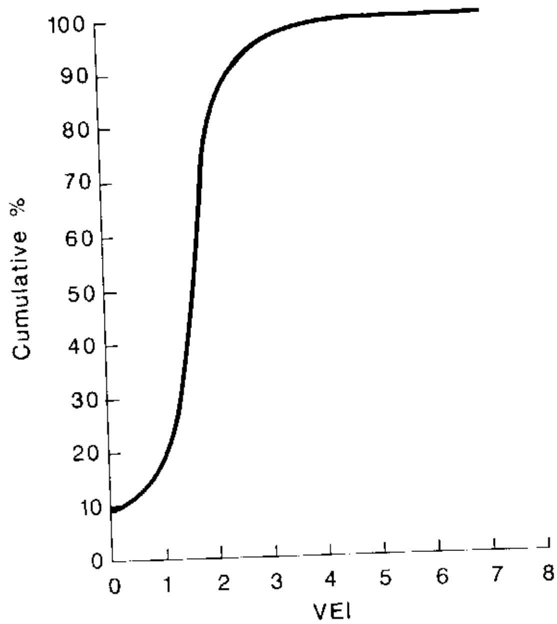
The information available about magnitude and frequency relationships for the Rabaul volcano suggests that it is necessary to model two separate eruptive magnitudes in order to assess the likely effects of future eruptions: (i) a small-to-moderate eruption similar in character to the 1937 eruption; and (ii) a large eruption similar to the event 1,400 years ago. Other eruptive magnitudes have certainly occurred at Rabaul but insufficient information is available at present to construct convincing models of such activity. As the smaller eruption is clearly the more likely, most attention is devoted here to such an occurrence. For a relatively small eruption, two factors additional to magnitude need to be taken into account - vent location within the caldera, and timing of eruptions in relation to wind directions which influence the spread of volcanic ash. For large eruptions these two factors are essentially irrelevant.

Vent location

The 1937 eruption involved the ejection of magma from the new vent at Vulcan and from the old vent at Tavurvur. Similarly, the 1878 eruption produced volcanic materials from two vents, Tavurvur and a new vent which produced Vulcan Island. The earlier historical eruptions are not well known but probably only involved one vent, or a group of closely related vents. Thus, recent eruptions have issued both from newly created vents and from long-established eruptive centres. The present problem is to choose the most realistic vent or vents for the next eruption.

Figure 2.5

Cumulative frequency curve of the Volcano Explosivity Index (VEI) date presented by Simkin et al. (1981)



The seismic evidence for the period September 1983 to June 1985 (Mori and McKee 1986), summarised in Figure 2.4 indicates two areas of concentration of seismicity within the ellipse which may mark the 1,400 year B.P. area of caldera collapse. One pronounced area is a zone northeast of Vulcan and extending east of the airport; the second concentration occupies a zone south of Tavurvur. If seismic data from the period February 1977 to June 1982 are considered, the pattern of seismicity focuses on two points further south on each limb of the ellipse (McKee et al. 1984). Thus the total pattern may indicate a northward migration of concentrations of seismic energy.

Areas of concentration of seismic energy presumably indicate areas where rock is being fractured by rising magma or where stress relief occurs as a result of magma injection. Although the relationship between concentration of seismic energy and eruptive centre is by no means certain, these data suggest two possible centres, one northeast of Vulcan, the other centred at Tavurvur. This evidence reaffirms the pattern of the 1937 and 1878 eruptions in which new vents were established on the western side of the harbour. The two possible vent locations discussed above are shown as 1 and 2 respectively on Figure 2.6.

However, ground deformation data indicate that the areas of maximum ground deformation are not located on the seismic ellipse but in two discrete areas, one about one kilometre east of the Vulcan Island (1878) eruptive centre (i.e. about two kilometres southeast of Vulcan itself), and the other two kilometres southwest of Tavurvur (i.e. nearly one kilometre southeast of the southeastern point on Matupit Island) (McKee et al. 1984). These two possible vent locations are shown on Figure 2.6 as 3 and 4 respectively.

While it is likely that the deformation centres better define future eruptive centres than do areas of seismic concentration it may be incorrect to assume that vents will form directly over the areas of maximum ground deformation. Rising magma will move along those conduits which offer the least resistance, possibly reaching the surface a kilometre or more distant from the deformed area. Thus, it is possible that the areas of maximum seismicity and maximum ground deformation on the eastern side of the Rabaul caldera both presage an eruption from Tavurvur.

It is clear that the selection of eruptive centres for the next eruption scenario is a matter of individual choice with only limited constraints provided by the monitoring evidence. We have chosen to locate one vent at the centre of maximum ground deformation southeast of Matupit Island (point 4 on Figure 2.6).

In the 1937 eruption the bulk of the ejecta came from the Vulcan vent, the vent which initiated the eruption and which "played" alone for 21 hours before Tavurvur erupted (Fisher 1976). The deformation data available in 1986 suggest that rising volumes of magma on each side of the harbour both have volumes of about 50 million cubic metres. Thus it seems likely that, in contrast to the 1937 situation, an eruption from point 4 is likely to be equal to rather than smaller than that from point 3. However, there are a number of assumptions in this assertion that cannot be tested. In order to simplify modelling, it is assumed here that an eruption equivalent to the 1937 Vulcan eruption occurs from point 4, and that an eruption equivalent to the 1937 Tavurvur eruption issues from the eastern side of Vulcan Island (point 5 on Figure 2.6). Some of the consequences of these assumptions will become evident in the following sections.

Eruption style

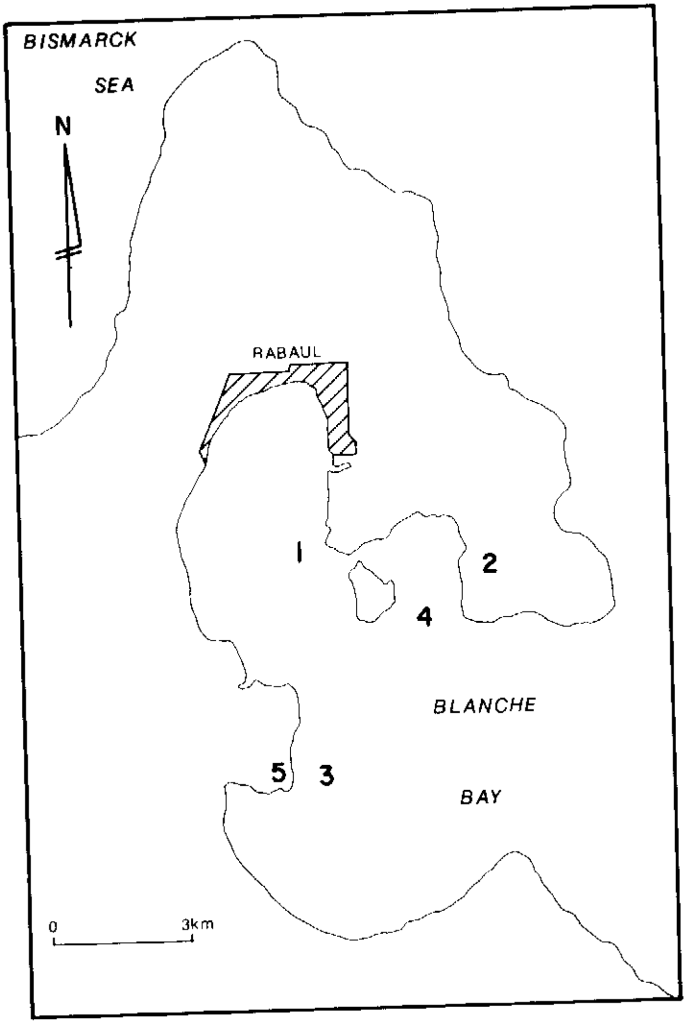
The change in vent locations considered above has certain consequences for eruption style. The Vulcan eruption of 1937 is best described as phreatomagmatic. This means that the hot volcanic products, erupted from an initially submarine vent, were quickly chilled by contact with seawater, and fragmented by the stresses involved. Much of the ejecta was fine-grained. The Vulcan eruption built a cone above water very rapidly (McKee et al. 1985), thus changing the character of the eruption towards that of a plinian eruption in which both coarse and fine ejecta rose vertically to heights of up to eight to 10 kilometres with ash drifting downwind to the northwest, thinning away from the vent. Pyroclastic flows and surges were produced from the vent and from collapsing portions of the eruption column with devastating consequences for adjacent areas.

The assumption of a submarine vent at point 4 for a Vulcan-style eruption poses no problems; an almost identical eruption mode can be assumed.

The 1937 Tavurvur eruption can also be modelled directly by assuming that the vent occurs on land at point 5 (Figure 2.6) rather than in the sea at point 3. However, minor (probably inconsequential) differences will result as the new vent will be built at sea level whereas the Tavurvur vent is more than 200 metres above sea level.

Figure 2.6

Possible vent locations. Point 2 is Tavurvur.



Timing of the eruptions

The month in which a relatively small eruption occurs is of major importance as the wind speeds and directions in the atmospheric column vary from month to month (Figure 2.7). Although it is possible to model the tephra fallout from a volcanic eruption where suitable wind data are available (Blong 1981b; McKee et al. 1985), the theoretical model has not yet been tested against real data. It is, therefore, simplest and most sensible to use the real tephra fallout data from the 1937 eruption. Figure 2.3 shows the two tephra depositional ellipses that resulted from the Vulcan and Tavurvur eruptions of 1937. These ellipses will be used directly in modelling an eruption except that the Vulcan ellipse will have its source at point 4 and the Tavurvur ellipse will be centered on point 5 (Figure 2.6). While there are inherent errors in these assumptions regarding local wind speeds and directions on each side of the harbour and resulting from the changed elevation of the point 5 vent compared with Tavurvur, these errors are likely to be insignificant compared with those introduced by any alternative assumptions. In utilising the 1937 eruption as a model the implicit assumption is also made that the 1937 maximum eruption column height of 8 to 10 kilometres (McKee et al., 1985), and the four day duration of the Vulcan eruption also refer to the modelled future small-to-moderate eruptions.

The southeast surface wind season normally lasts from April-May to October-November. The northwest season occurs for the rest of the year (Figure 2.7). Data presented by McAlpine et al. (1975) and summarised by McKee et al. (1985) indicate that surface winds (up to about 4 kilometres elevation) blow towards the west and northwest about 60 per cent of the time and towards the east-southeast the remaining time. Winds blowing toward the northwest sector also have higher mean and maximum velocities than those blowing toward the southeast. However, at elevations above about 4 kilometres winds blow toward the west and southwest more than 90 per cent of the time. Clearly, the distribution of airfall volcanic ash around Rabaul from small-to-moderate eruptions is influenced markedly not only by the location of the vent but also by the time of the year.

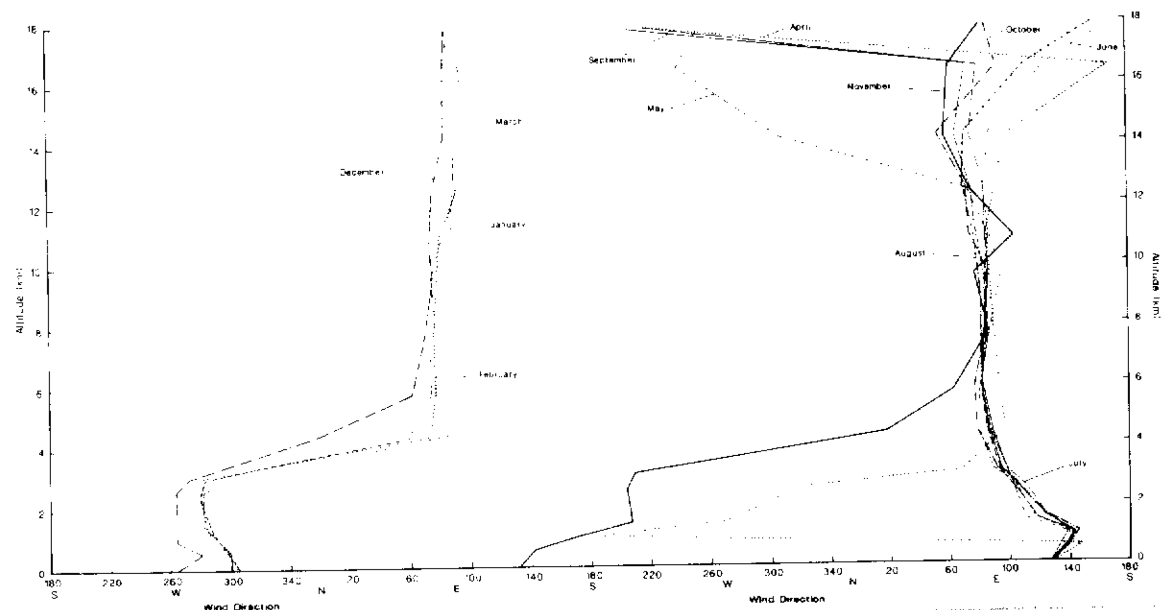
As the May 1937 eruption investigations by Fisher (1939) produced a detailed map of ash-fall distribution (Figure 2.3) and other descriptions of eruption character it seems sensible to produce a model based on a repeat of this event. This selection (scenario 1) not only simplifies and improves the accuracy of the model but also utilises the most probable (about 60 per cent) pattern for ash fallout. The likely consequences of such an eruption are examined in Chapter 5.

However, selection of the above model, in which the surface winds blow toward the northwest and west, overemphasises the consequences for Rabaul town and ignores the 40 per cent probability that an eruption will occur during the northwest season. Therefore, a second model (scenario 2), for an eruption of the same magnitude as the 1937 event but occurring in November when surface winds blow toward the southeast and east, is utilised in Chapter 6 to provide a comparison with scenario 1.

As mentioned earlier, surface wind direction is essentially irrelevant in modelling a large eruption equivalent to the 1,400 year B.P. event. Although the initial fallout pattern of the ash (tephra) is strongly influenced by wind directions these effects are soon overwhelmed by the massive plinian fall of pumice and the even more devastating emplacement of widespread pyroclastic flow (ignimbrite) deposits. While deposition of

Figure 2.7

Mean monthly wind directions for elevations up to 18 kilometres
(after data in McAlpine et al. 1975)



tephra hundreds of kilometres distant from the source is certainly influenced by upper-level winds, the discussion of the consequences of a repeat of the 1,400 year B.P. eruption (scenario 3) presented in Chapter 8 is limited to the effects of ignimbrite deposition likely to be experienced in ENBP.

While the months of May and November have been chosen for the scenario for good volcanological reasons, the late 1980s have been selected primarily for sociological and economic motives. The 1983-85 seismo-deformational crisis, as demonstrated in Chapter 4, produced a state of expectation and emergency preparation in Rabaul. After the volcano alert returned to stage 1 in 1985, the level of preparation deteriorated as some of those involved in contingency planning moved away from the area and as new people unfamiliar with the emergency arrived. Although emergency exercises have been held in the interval the level of preparedness has gradually declined and will continue to do so over the years until the evidence of volcanic activity increases again.

Although the level of human preparedness is likely to have only limited influence on the degree of physical damage resulting from an eruption, it may affect dramatically the degree of social disruption and the number of deaths and injuries. While such considerations have relatively limited effect on the economic models considered later it is most appropriate to build, as far as possible, on the state of preparation extant at the time of our investigations. Similar arguments apply to the level of economic activity. Thus, all three scenarios are set in the late 1980s.

While it is believed that the three eruption models and the consequences presented in subsequent chapters are reasonably accurate portrayals of likely events in the future of Rabaul caldera, it must be emphasised that an infinite number of other possible futures could occur. The three scenarios chosen represent eruptions that are likely to occur, but any future eruptions are extremely unlikely to follow exactly the models presented here. For example, future small-to-moderate eruptions are unlikely to occur with the exact magnitude or from the precise vent locations used in our models. For a May eruption, a vent closer to Rabaul town than those shown on Figure 2.6 would be likely to cause more damage than that presented in scenario 1.

Conversely, vents more distant from Rabaul would probably result in less damage. Scenarios 1 and 2 model events towards the extremes of the distribution of possible effects for a small-to-moderate eruption, but it should be clear that both more damaging and less damaging events are possible. Similarly, eruptive magnitudes larger and smaller than those depicted in the three scenarios are possible. We believe that the three scenarios chosen provide realistic models of likely events. Given the quality of the available information, it should be clear that numerous other equally likely events could have been modelled.

Chapter 3

The physical, cultural and economic setting

Introduction

The purpose of this chapter is to provide details of the physical, cultural and economic setting of the volcano problem at Rabaul. The emphasis will be on the economic setting, with remarks on the other topics being confined to those aspects of direct economic relevance.

Rabaul plays a number of varied roles in the ENBP economy. Nevertheless, the main driving force behind economic wealth generation in the Rabaul area is cash crop agriculture for export markets. The main crops are cocoa and copra and, to a lesser extent, cardamom. The factors which influence the level of production of these crops - world prices and the uncertainty caused by the granting of independence - had a major influence on how Rabaul coped with the 1983-85 seismic crisis.

The production of these crops is divided between the plantation and the smallholder/subsistence sectors. An examination of the plantation sector brings out the importance of supply-side influences on the level of production of these crops which are little influenced by seismic considerations or their aftermath. But this is not the whole of the story since plantations tend to be worked by non-Tolai nationals with the Tolai input into agriculture coming from a significant presence in the smallholder/subsistence sector. How this presence should be interpreted has been a matter of debate because of the controversy over the response by nationals in the agricultural sector to economic incentives.

Looking beyond agriculture, attention is focused in turn on other production, the distribution system, investment and the role of government in the provincial economy. While the seismic crisis cannot be completely ignored in this chapter its impact is considered in detail in Chapters 4 and 5. The chapter concludes with a consideration of estimates of the size of the provincial economy.

Physical

The existence of the volcano at Rabaul has placed the town upon a deep harbour formed when the ocean invaded the caldera, surrounding it with the steep walls of the caldera composed of pumice which may be easily tunnelled. The volcano also accounts for the relative fertility of the Gazelle Pensinula, particularly its northeast portion. Beyond the caldera rim (Figure 2.1) the slope of the land is gentle. The existence of a good harbour, combined with a fertile hinterland, gave this part of the Gazelle an early start in the process of development. The pre-independence era has left it with a relatively good road system, especially in the vicinity of Rabaul, and more generally in the Rabaul-Kokopo-Kerevat triangle. By way of contrast, while coastal plains have developed along the section from Cape Gazelle to Raluana Point, elsewhere in the Gazelle the mountains typically descend almost to the shoreline.

The physical setting not only explains the favoured position of Rabaul within ENBP but also accounts for the Tolai familiarity with the concept of trade at the time of first European contact. Epstein (1963) points out that the inland Tolai sold taro and other food crops in exchange for fish, salt water, wild fowl eggs and lime (used as a spice with betel nuts). While a state of continual petty warfare made long distance travel unsafe, a chain of markets flourished at which intermediaries bought and sold goods for tambu (indigenous shell money made from shell obtained during a return canoe voyage of more than 600 kilometres along the north coast of New Britain). This not only served as a medium of exchange but also as a medium of storage of value, accustoming the Tolai to saving, the concepts of debits and credits and to interest on borrowed funds. The ecology encouraged the development of social relationships in which diligence, industry and commercial sense were highly regarded.

The tropical climate, with its distinct wet season, makes the development of an infrastructure to assist transport and communication important since export commodity production is an all-year activity and the distribution system depends on ready access to Rabaul. It also provides a physical environment where constant maintenance is needed to keep up the standards of facilities and the level of output.

While Rabaul may not appear to be isolated when compared to many other places in Papua New Guinea, the influence of this factor cannot be ignored. It is on an island, rather than on the mainland. Although it has a good harbour it is over one hour's flying time from an international airport.[1] Most commodity production in ENBP takes place in the area defined by its road system and this area contains the bulk of the population. It is almost impossible to reach any point by road which is more than 50 kilometres from Rabaul in a direct line. A considerable amount of the goods trans-shipped through Rabaul have been brought there by coastal vessels, both from the adjacent islands and from elsewhere on New Britain. A brief description of the port facilities is to be found in Gilman (1983).

Clearly, Rabaul is what it is because of the port but, at a cost. Most goods brought into Rabaul by road for onward shipment could be sent from some other location to another international port by coastal shipping. It can be noted, in passing, that a somewhat more negative view of the "isolation" of Rabaul, which is regarded as a major factor in the economic stagnation in the mid-1970s, is taken by Varpiam and Jackson (1976).

Cultural

The factors referred to above have had a considerable cultural impact. The Tolai - the dominant ethnic group in the vicinity of Rabaul - have had over a century of contact with Europeans, leading to relatively better education and "development awareness". Within ENBP the distribution of "development", and the advantages perceived to flow from it, is uneven. However, "development" has not been without its problems. For example, there is a pronounced imbalance of the sexes in parts of the province as males seek employment in the towns, on the plantations and elsewhere.

While a number of sources point to the substantial growth in population since the first European contact and a shortage of land, a problem aggravated by extensive alienations of traditional land, it is still not clear whether the Tolai involvement with the urban economy reflects more the "push" of land shortages or the "pull" of the attractions of non-traditional activities. There is a "drift to the towns" from elsewhere in the province and, to a lesser extent, other provinces of Papua New Guinea resulting in unsightly "squatter" shanties on the fringe of Rabaul. Blamed on this, and on the process of "development" generally (through a retreat from adherence

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1. National Planning Office (1983) notes that in 1976/77 and in each of 1979, 1980 and 1981 Rabaul had the third largest number of air passenger movements (excluding passengers in transit) of any airport in Papua New Guinea ranging between 102,093 to 128,301 (compared to a range of 1,141,201 to 1,337,453 for the country as a whole).

to traditional custom and a perceived problem of exaggerated expectations among the educated young) is a claimed decline in the "law and order" situation (Grosart 1982).

The advent of self-government in 1973 and independence in 1975 has hastened the "localisation" of positions in the public service and has encouraged the increasing use of nationals in responsible posts by the missions and the private sector.[2] Desirable as this process has been, it has not been without its costs.

Three problems, in particular, can be identified. Many long-term employees have left. Their replacements, where expatriates, have come on short fixed-term contracts. Many of the more able nationals earn promotion that takes them to other postings, including ones outside the province. A constant change in personnel makes for neither continuity nor efficiency and, of particular relevance to this study, it means that many institutions are now almost solely administered by nationals who did not have experience of the problems of dealing with the 1983-85 crisis. However, there is no need to necessarily assume, as do the pessimists, that the current institutional apparatus will not respond well to some future emergency. Certainly, despite problems that are by no means unique to Rabaul, to Papua New Guinea or even to less developed countries, both the national and the provincial government function effectively in Rabaul and its hinterland.

One important consequence of the isolation of Rabaul is that the population within the town and its hinterland is limited. The 1980 census (see Figure 3.1) determined that the population of ENBP is 133,197 of which 98,375 live in the study area.[3] Of these 14,954 live in Rabaul, 2,167 in Kokopo and 894 in Kerevat.[4] Because this population implies a limited market, the potential sale of media (and advertising) is limited. This means that there is limited media coverage of local problems, with only a few matters being deemed newsworthy for media centred in Port Moresby or abroad. There are not only considerable doubts about the balance of the media coverage of the 1983-85 Rabaul seismic crisis but also some suspicion that, despite the production and free distribution of a small "newspaper" in Rabaul during the crisis, the situation was exacerbated by the circulation of exaggerated and ill-founded rumours as to the precise nature of the problem. A non-representative survey of public attitudes to the emergency (Kuester and Forsyth, 1985) found that of those who responded to the question "When did you last read a newspaper?" 24.1 per cent said that they could not read, 23.8 per cent had read their last newspaper a week ago, 26.1 per cent had read their last newspaper more than a week ago and only 12.6 per cent read a newspaper daily (and of these almost half had been interviewed in English).

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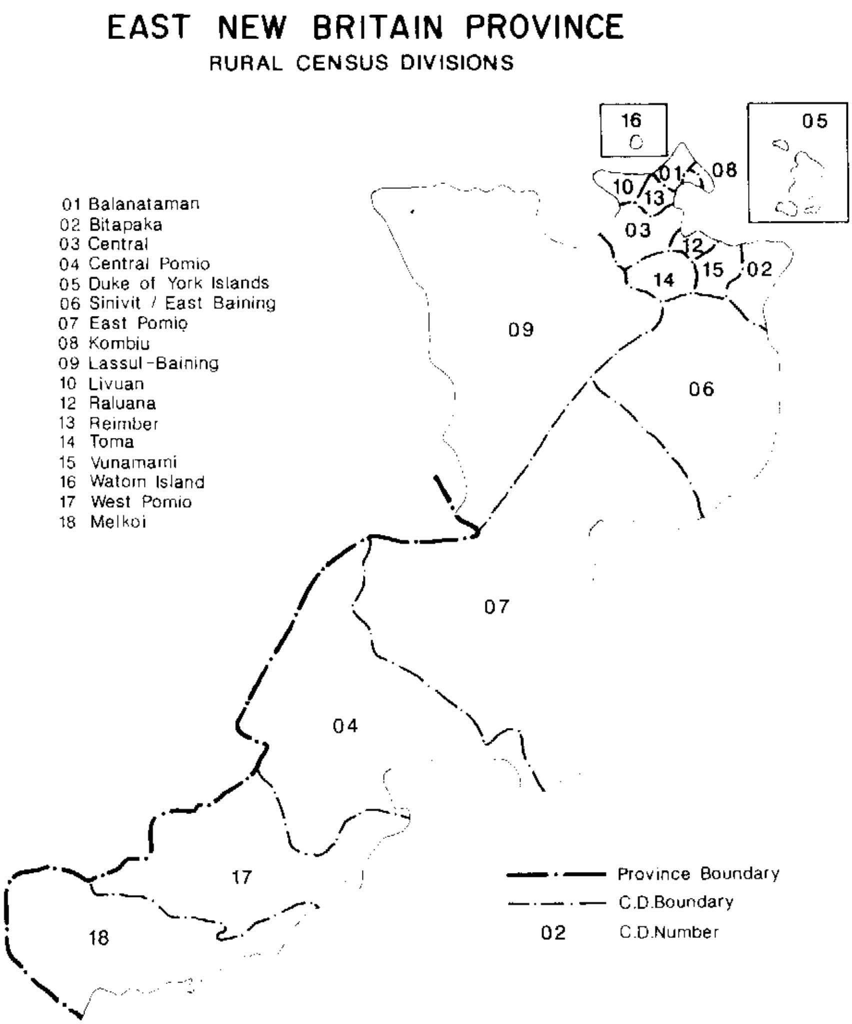
2. Citing various official sources, the World Bank (1982, p144) showed that nationals in ENBP had 11.2 per cent of Papua New Guinea's formal employment in 1975 and 11.8 per cent in 1977. The province had 6.7 per cent of all public servants in 1980 while it only had 4.4 per cent of Papua New Guinea's population in that year. Furthermore, the province had 15.2 per cent of national wage and salary employment on foreign operated large-holdings in 1978.

3. As in Table 3.3 the assumption is made that the study area comprises the whole of ENBP, less 46 per cent of the population of the Lassul-Baining census division (less 66 per cent of the population of the Sinivit/East Baining census division, and less 100 per cent of the East Pomio, Central Pomio, West Pomio and Melkoi census divisions) (Figure 3.1).

4. But note that Axline (1986), taking into account the provisional growth rates for each province, estimates the number of nationals in the province as 130,730, 132,952, 135,213, 137,511 and 139,849 in each of the years 1980 to 1984 respectively.

Figure 3.1

Rural census divisions, ENB Province



The answers to this survey can be placed in better perspective by examining some employment and education statistics. Firstly, consider some labour market statistics taken from McGavin (1986) but sourced from the 1980 National Census (the percentage the ENBP data is of data for Papua New Guinea as a whole is given in brackets).

The wage employment of citizens is 16,568 (8.3 per cent). This is 18.2 per cent (9.6 per cent) of the population; but the labour force, which takes into account those actively seeking wage employment, is 21 per cent (11.5 per cent) of the population. This means that measured labour market unemployment is 13.4 per cent (15.9 per cent) of the market labour force. At the Census 12.7 per cent (9.1 per cent) of those born in ENBP were enumerated outside the province. As far as education is concerned, 11.2 per cent (11.4 per cent) of males and 9.6 per cent (7.7 per cent) of females had grades 6 or 7 as the highest grade completed, 2.7 per cent (2.7 per cent) of males and 1.7 per cent (1.4 per cent) of females had grades 8 or 9 as the highest grade completed and 8.6 per cent (3.9 per cent) of males and 2.2 per cent (1.3 per cent) of females had completed grade 10 or over. Rabaul, by itself, had a population of 14,954 with 34.5 per cent in wage employment.

Secondly, the National Statistical Office placed the number of factories in ENBP in 1983 at 71 with most of these assumed to be in Rabaul. These factories employed 1,593 persons of a total formal sector employment in ENBP of 6,582, earning K5,753,000 (National Statistical Office, Secondary Industries, 1983).

It is difficult to determine the extent to which the communication problem is exacerbated by the language problem. While the language of government and administration is English, some provision is made for non-English speakers especially through recourse to Tok Pisin ("pidgin") which is regarded as a "lingua franca" in this part of Papua New Guinea. It is certainly effective in communicating with many who, coming from other parts of Papua New Guinea, do not speak the local language, called Kuanua (or Gunantuna). It is also possible that the language problem makes it difficult for the expatriate community to accurately assess the Tolai attitude to the volcano problem. It is claimed that many of the Tolai appear to take a relaxed attitude to this problem; but the evidence suggests that this falls considerably short of an indifference to the possibility of harm from a danger once it is clearly perceived. Certainly, there was a range of attitudes towards the seriousness of the crisis among nationals with whom the authors discussed the matter; but it is not possible to definitely state that the "typical" Tolai (or national) attitude differs from that of the expatriate community.

The linguistic homogeneity of the Tolai has been perceived as one of their big advantages in early economic development (Epstein 1964). The fact that the Tolai also speak Tok Pisin and a considerable number can, at least, follow spoken or written English has also been of considerable economic advantage to them.

The isolation of Rabaul, the "localisation" programme, the attempts to increase national participation in the agricultural sector during the 1970s, the volcano crisis and the consequent decline in the size of the expatriate community from all these causes have all raised fears that a future eruption will reduce expatriate involvement in the Rabaul economy below what some see as a level that is already too low from an economic efficiency point of view. However, the matter is by no means clear cut. Most of the problems instanced are not confined to Rabaul.

Indeed, the indigenous population may well consider that the costs of increased "localisation", which may well be incurred only in the short to medium term, are ones that should be borne in order to obtain the long-term benefits of greater local control over the regional economy.

Commodity production

Modifying Bawdekar, King and Olaba (1984) slightly, the role of Rabaul can be described in the following terms:

- A trans-shipment point for the import and export of goods by air and coastal and international shipping;
- A centre for the delivery of those services which cannot be provided economically at smaller centres;
- A centre at which various government services are provided to the region as a whole. This includes the other four provinces in the region (Manus, New Ireland, West New Britain and North Solomons);
- A manufacturing centre for certain products mainly destined for local markets in the Islands Region;
- An urban centre for the densely populated north-east Gazelle.

Despite these varied roles the main driving force behind economic wealth generation in the Rabaul area is cash crop agriculture for export markets.[5]

The main crops are cocoa and copra and, to a lesser extent, cardamom. Table 3.1 shows total production and national market share for ENBP by "plantation" and "others" for the cocoa years (October-September) 1976/77 to 1985/86. Notice that total tonnage for ENBP fluctuated between 7,243 tonnes and 10,329 tonnes with a tendency for production to decline during the earlier years and for production to recover over the latter period.

The price to producers also varied, not only from year to year but also from month to month, e.g. from October 1983 to September 1984 from a low of K1,593 to a high of K2,123. After taking into account the operations of the Cocoa Stabilisation Scheme, the average value of cocoa production to producers (in kina per tonne) for each of the cocoa years 1980/81 to 1984/85 was 1,474, 1,566, 1,660, 1,890 and 1,963 respectively, indicating that the total value of the crop in nominal terms for ENBP has been increasing.[6] By way of comparison, the Export Tree Crop Study[7] found that the total

5. Whether this is a "good thing" has been a matter of debate - for a decidedly negative view see Allen (1983).

6. Note that because of the operation of stabilisation schemes statistics of the export values of cocoa or copra crops (or statistics which incorporate the export values of cocoa or copra crops) provide an imprecise measure of the impact of these crops on the incentives open to cash-crop growers and on the economy of the study area.

7. Currently being funded by the Australian Centre for International Agricultural Research (ACIAR).

cost of plantation production in the early to mid 1980s was K1,371 in ENBP compared to K1,563 in the North Solomons, K2,490 in New Ireland and K1,755 in Madang Province.

Table 3.1
Cocoa production within ENBP and national share by category of producer and cocoa year, 1976/77 to 1985/86

	Production			**National share**		
	Plantation	Others (tonnes)	Total	Plantation	Others (per cent)	Total
1976/77	5,196	5,133	10,329	38	40	39
1977/78	5,061	4,697	9,758	33	32	33
1978/79	4,956	4,808	9,764	37	29	32
1979/80	4,613	4,480	9,093	33	27	30
1980/81	3,794	3,449	7,243	31	21	26
1981/82	3,793	4,617	8,410	32	26	28
1982/83	3,061	4,647	7,708	33	23	26
1983/84	3,448	5,315	8,763	40	28	32
1984/85	3,513	4,909	8,422	37	23	27
1985/86	3,695	6,185	9,880	37	27	31

Source: Amos Warekey, Cocoa Board; Planters Association (1976-78 data).

The statistical position for coconuts and copra is a little less generous. Table 3.2 indicates copra receivals 1975 to 1985 for ENBP and national market share.

Table 3.2
Copra receivals for ENBP, national market share and average Copra Marketing Board depot buying price

Year	Receivals (tonnes)	National share (per cent)	Buying Price (kina per tonne)
1975	52,570	38	149
1976	43,771	36	149
1977	48,084	36	208
1978	53,472	37	231
1979	57,315	36	266
1980	53,226	37	228
1981	53,522	38	208
1982	54,071	39	170
1983	51,904	38	240
1984	58,597	37	*
1985	58,923	34	311

* Data supplied by the National Statistical Office suggests a figure of 390 - the National Statistical Office estimate for 1985 is 313.

Source: H. Coulter, Copra Marketing Board of Papua New Guinea.

It is not known precisely what proportion of ENBP production of cocoa and copra is grown in the study area. Table 3.3 shows households growing cocoa and coconuts. Another source is used to determine, for the plantation sector, the extent to which the census divisions are in the study area. The information is used to prepare Table 3.4. This table indicates the number and estimated population of plantations in ENBP which are, and are not, in the study area. Since 87 per cent of the households growing coconuts, 88 per cent of the households growing cocoa and 90 per cent of the plantations about which information is available are in the study area and 52 per cent of the 1980/81 production of cocoa is from plantations, it is assumed that 89 per cent of ENBP cocoa and copra production can be attributed to the study area.

Table 3.3
Number and percentage of total households growing cocoa and coconuts, East New Britain Province

District	Census division	Coconuts h/holds	Coconuts per cent	Cocoa h/holds	Cocoa per cent	Total population
Kokopo	*Bitapaka	992	90	943	86	5,418
	#Sinivit/E.Baining	199	38	379	73	1,984
	*Raluana	972	83	966	82	6,060
	*Vunanami	867	83	887	85	5,252
Pomio	Central Pomio	384	35	160	14	5,339
	East Pomio	777	44	595	34	7,755
	West Pomio	254	17	69	5	6,713
	Melkio	469	50	102	11	4,474
Rabaul	*Balanataman	1,080	82	1,101	83	6,545
	*Central	898	62	1,033	71	6,974
	*Duke of York Is.	1,125	91	334	27	5,954
	*Kombiu	637	75	524	62	4,909
	@Lassul-Baining	142	13	889	79	5,119
	*Livuan	861	79	903	83	4,761
	*Reimber	1,152	83	1,194	86	6,160
	*Toma	1,493	79	1,675	89	9,671
	*Watom Island	276	88	274	87	1,546
Total		12,578	64	12,028	61	94,634
Outside study area		1,613		1,483		23,469
Inside study area		10,965		10,545		77,165

* in study area
\# estimated 34 per cent of resident village population is in study area
@ estimated 54 per cent of resident village population is in study area.

Source: 1980 National Census as shown in H. Coulter (n.d.) cocoa and copra boards.

Table 3.4
Number and total resident population of plantations in ENBP by census division#

District	Census division	Plantation number and resident population In study area		Elsewhere	
Kokopo	Bitapaka	20	2,535	0	0
	*Sinivit/E.Baining	5	570	1	100
	*Raluana		no information		
	Vunanami	19	1,872	0	0
Pomio	Central Pomio	0	0	2	130
	East Pomio	0	0	2	50
	West Pomio	0	0	2	105
Rabaul	Balanataman	1	100	0	0
	Central	8	655	0	0
	Duke of York Is.	4	619	0	0
	Kombiu	0	0	0	0
	Lassul-Baining	17	1,135	2	154
	Livuan	2	200	0	0
	Reimber	0	0	0	0
	*Toma	4	?	0	0
	*Watom Island	3	?	0	0

\# But note that National Statistical Office (1985) gives an estimate of 130 largeholdings covering 59,961 hectares. This source gives the production of copra in these three districts as 13,335, 1,165 and 3,687 tonnes respectively and for cocoa 2,304, 33 and 678 tonnes respectively.

* The source does not locate the plantations in this statistical division and it has only been able to locate a limited number from other sources. The use of numbers that have been rounded up in the source reflect the fact that for non-village establishments the data has been taken from the 1980 National Census.

Source: National Statistical Office 1983.

To put the relative contribution of cocoa and copra production into broader perspective, Tables 3.5 and 3.6 provide information on commodity exports through Rabaul and for Papua New Guinea as a whole. As can be seen from these tables, cardamom plays a relatively minor role in the agriculture of the study area. Its importance for the study derives from the fact that most of its production, and potential for future expansion, occurs in an area on the fringe of the study area,[8] thereby providing an incentive for an expansion of the road system and, consequently, adding to the range of options available at times of seismic crisis. An idea of the rate at which cardamom production has been increasing in the Malasait-Raunsepna area can be seen from Table 3.7.

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8. As pointed out in World Bank Country Study (1982, p239) cardamom can be grown in areas with altitude from about 600 metres upwards and, because of its high value per unit weight, can be grown commercially in areas which lack cheap transport.

Table 3.5 can be misleading in several respects. The information available suggests that, in general, forestry in ENBP is carried on outside the study area. Furthermore, because it only considers commodity exports, it provides no indication of the extent to which the indigenous population can support themselves from their "gardens" or through the purchase of, primarily, fruit and vegetables from local markets and road-side stalls.

Table 3.5
Commodity exports through Rabaul, 1981-86

Commodity	1981	1982	1983	1984	1985	1986
			(K'000s)			
Cardamom	0	40	204	829	426	411
Cocoa beans	14,751	13,969	14,691	31,363	32,408	27,336
Cocoa residue	320	297	377	470	816	623
Copra	3,122	578	966	2,070	1,086	37
Copra cake/pellets	689	831	1,433	1,389	938	888
Copra oil	12,508	12,110	20,038	40,421	22,706	10,887
Paints	84	100	96	136	187	157
Shell	211	269	232	210	161	18
Timber logs	23,163	24,728	19,445	33,791	24,392	30,028
Timber lumber	114	100	119	99	44	168
Tuna	0	0	279	0	217	0
Other domestic produce	267	63	0	383	17	21
Re-export	1,444	1,374	1,803	1,308	4,771	2,749
Total*	**56,673**	**54,459**	**59,696**	**112,409**	**88,171**	**73,318**

* The data in the columns may not exactly sum to these totals because of rounding errors.

Table 3.6
Commodity exports through Rabaul as national share, 1981-86

Commodity	1981	1982	1983	1984	1985	1986
			(percentage)			
Cardamom	0	18	41	43	18	23
Cocoa beans	43	44	36	47	53	49
Cocoa residue	98	98	96	99	98	100
Copra	16	4	4	4	3	0
Copra cake/pellets	100	100	100	100	100	100
Copra oil	100	100	100	100	100	100
Paints	37	74	83	73	83	85
Shell	58	70	52	50	30	2
Timber logs	73	50	45	55	44	100
Timber lumber	3	3	5	4	2	100
Tuna	0	0	97	0	5	0
Other domestic produce	0	0	0	0	0	0
Re-export	7	6	9	6	18	100
Total	**10**	**11**	**9**	**14**	**10**	**7**

Source: Tables 3.5 and 3.6, National Statistical Office, unpublished.

Table 3.7
Cardamom production Malasait-Raunsepna 1980-84

Year	Production Wet	Dry equivalent (tonnes)	Notes
1980	2.53	0.60	March - December
1981	4.30	1.00	
1982	28.28	6.60	January - October
1983	52.81	12.28	Nov. 1982 - Nov. 1983
1984		58.40	January - December (data scaled up to 12 months)

Source: W. S. Atkins International and Touche Ross Services (1985, vol.2). The statistic for 1984 is an estimate.

The plantation sector

While the various tables point to a recovery in production in recent years,[9] it has already been noted that Tables 3.1 and 3.2 indicate some earlier decline in copra and cocoa production, particularly from the plantation sector.[10] Plantation agriculture in particular, and cash-cropping more generally, requires continual careful husbandry. Old coconut palms need to be replaced. Cocoa plants need appropriate shade trees (coconut palms or otherwise) which must be pruned to facilitate harvesting. Fertilisers, herbicides, insecticides and fungicides are regarded as essential for optimal production. A regular procedure must be followed so that harvesting is continuous and field processing of the cocoa beans and coconut meat is carrried out so that the product is acceptable on receival at depots. To maintain production, constant application is needed in the short to medium term and re-investment in the long term.

Plantation agriculture also requires that attention be paid to costs and output, especially since Papua New Guinea is a high-cost country compared to some of its international competitors. Shepherd (1981) points out that minimum wage legislation requires planters to pay this wage even though the worker may produce virtually nothing. In practice this has led to the introduction of incentive schemes and to a "weeding out" of those who do not meet minimum production standards, with some

9. The National Statistical Office (1985) reports for largeholdings in 1982 that 7,174 coconut palms being grown on an additional 62 hectares and 6,708 replacement coconut palms being planted on existing areas in ENBP (with the corresponding data for cocoa trees being 307,349 and 414,837 respectively).

10. This statement has to be put in perspective. World Bank Country Study (1982, p205) cites official statistics that show that in 1975/76 of 29,868 hectares of smallholder cocoa 11,916 were not bearing while in 1978 of 23,431 hectares of plantation cocoa 2,961 were not bearing. Elsewhere (p.209) this report suggests that smallholders are not replanting because they are unwilling to cut down stands of trees still producing. It notes that most smallholders would find difficulty in obtaining access to necessary credit and suffer from difficulty in obtaining high quality planting material and extension service advice on controlling pests and diseases.

planters indicating that they cannot employ enough acceptable workers. In any case, cost pressures and productivity declines have placed management under pressure since the granting of independence when it was very probable that the average quality of management was declining.

Unfortunately, uncertainties associated with the granting of independence led to the abandonment of many plantations. Goldthorpe (1985, p78) cites a 1984 source that estimates the number of abandoned plantations in ENBP at 70.[11] Uncertainty also leads to an unwillingness to maintain appropriate levels of re-investment in many plantations which were not abandoned. Shepherd (1981) found that the main reason copra planters gave, in response to an end-1978 survey question, for not replanting was the uncertainty they felt about security of tenure. But confidence about the future appears to be returning; Coulter (1983) found in a mid-1983 survey that of the 26 reasons given by the twenty-two respondents (out of a total of 137 replies, a 43 per cent response rate) for not carrying out redevelopment or new development, only four mentioned uncertainty of tenure and only one uncertainty about the future. While production increased outside the plantation sector,[12] attempts to encourage greater national participation in agriculture on plantation sector land had limited success.

It has also been noted that, whether because of uncertainty or other reasons discussed elsewhere in this chapter, production appears to be well below what is technically feasible. For example, Bridgland (1981) points out that the 1980 estimates of 14,000 tonnes of cocoa from 54,550 hectares implies an approximate mean yield of 0.25 tonnes per hectare when, depending on the seed used, yields of 1.0 at least or 1.5 tonnes per hectare might be expected. Subramaniam (1981) in the same volume claims that yields in pensinsula Malaysia of about 1,000 lbs of dry beans per acre (1.1 tonne per hectare) per annum are achieved compared with less than 300 lbs of dry beans per acre (0.33 tonne per hectare) per annum in Papua New Guinea. He also claims that in Sabah, where the soils are of volcanic origin and similiar nutrient status to those of Papua New Guinea, yields exceeding one tonne per acre (2.47 tonne per hectare) per annum are not uncommon. He points to the small size of the Papua New Guinean plantation and the deterioration in the quality of management. Elsewhere, Coulter (1983) estimated that the opportunity cost[13] in constant 1982 values of not maintaining cocoa production in ENBP at 1975 levels was K33.25 million.

The recovery of confidence in the plantation sector occurred at a time when new better-yielding hybrid cocoa trees became available; but taking advantage of these advances required, in effect, new investment in cocoa trees, if not in shade trees as well. Of long term consequence for the copra sector, many plantation owners

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11. Since agricultural output is generally related to inputs and agricultural investment requires security of tenure, in general abandonment does not imply any reversion to non-plantation forms of agriculture. This explains why the estimates of the number of plantations for one purpose may differ considerably from estimates for some other purpose. In addition, estimates appear to be based on the results of surveys of "local knowledge" rather than on any "on the ground" plantation-by-plantation inspection.

12. But World Bank Country Study (1982, p213) estimated that the cocoa smallholder sector in ENBP would benefit from a ten year programme involving 50,000 hectares, requiring credit of the order of K58 million (1981 costs) and producing 40,000 million metric tonnes worth K60 million at peak yield.

13. This concept takes into account the difference between the economically most appropriate use of resources and their actual use.

considered it uneconomic to wait for new coconut palms to grow and chose other, faster-growing shade trees instead.

Production in the plantation sector is important not only for the further processing and the export income that it generates but also for the pattern of use of inputs that it dictates. Table 3.8 provides a summary of production costs on the assumption that no costs are involved in establishing and maintaining shade trees. Each cost element has a different pattern of impacts on the economy of the study area. In particular, it may be noted that imports from outside the study area account for much of the amount spent under many cost items and that some expenses are transmitted through the more developed sectors of the economy while others are transmitted through the less developed sectors. The former transmission paths tend to have a more immediate direct impact on the Rabaul economy.

Table 3.8
Summary of costs of production for plantation sector

	Cocoa (kina/tonne)	Copra
Seedlings	25.75	0.00
Labour[14] (to harvesting stage)	194.45	3.15
(subsequent stages)	172.18	70.80
Fertilizer	42.44	0.00
Weedicides	23.94	0.00
Insecticides	10.91	0.00
Fungicides	83.86	0.00
Fuel, oil, lubricants, husk/shell, firewood	89.37	18.80
Repairs/maintenance		
(to harvesting stage)	42.83	4.59
(subsequent stages)	27.12	3.28
Packaging	25.54	1.74
Marketing (freight)	20.00	10.00
Depreciation (to harvesting stage)	115.71	17.10
(subsequent stages)	159.71	25.66
Interest on working capital	29.31	0.24
Management costs	245.51	26.29
Administration costs	62.10	6.65
Total	**1370.74**	**188.30**

Source: Department of Agriculture and Livestock Export Tree Crop Study.

14. Note, in passing, that there is a debate as to whether plantation labour is expensive. Goldthorpe (1985) maintains that it is, and has always been, expensive although he gives four references (p. 17) to contrary positions.

Smallholder and subsistence production

Table 3.1 makes it clear that production is not confined to the plantation sector and that, indeed, production from this sector has become over-shadowed by production from other sources. Data exactly comparable to that contained in Table 3.8 is not available but Table 3.9 shows farm budgets for various smallholder development scenarios.[15]

Table 3.9
Small farm expenditure budgets for five years' operation, cocoa and copra (plus preliminary establishment costs where appropriate, in kina)*

Cost item	New settlement 4 hectares	Rehabilitation 4 hectares	2 hectares	Village module 4 hectares
House	1,600	800	800	1,600
Lease/rent	485	450	225	0
Felling/clearing expenses	270	210	75	270
Removal expenses	50	0	0	0
Loan/legal fees	51	51	51	0
Survey fees	150	0	0	0
Tools/equipment	205	205	180	205
Subsistence/living allowance	960	945	525	0
Seedlings	1,680	1,680	840	1,646
Shade cuttings	50	50	25	0
Seedling transport	167	167	84	163
Fertiliser	391	391	197	0
Insecticide/fungicide	1,391	1,391	696	816
Copra drier	600	600	600	0
Interest/repayments	3,872	2,986	2,206	927
Total	**11,922**	**9,926**	**6,504**	**5,627**

* Only the "no cocoa fermentary" option is considered.

Source: Asian Development Bank 1985.

The scale factor has an influence on the impacts on the economy of commodity production in the study area. It should also be noted that it is generally believed that largeholders obtain higher yields per hectare than smallholders. For example, Goldthorpe (1985) cites a 1973 source which contrasts (for Papua New Guinea as a whole) 900 kilogramme per hectare for coconuts from estates against 500 kilogramme per hectare from smallholders and 440 kilogramme per hectare for cocoa from estates against 330 kilogramme per hectare from smallholders. Goldthorpe also cites a 1974 study which provides cost data for cocoa production (for Papua New Guinea as a whole), disaggregated by three size categories, which indicates a clear inverse

15. This source is also of interest in that it does provide in Table 1, Appendix 14 some information on the foreign exchange cost of certain items (in this case those involved in tenders for public works).

relationship between size of plantation and cost of production with yield per hectare increasing with size of plantation and costs of production being higher on cocoa-only plantations as compared to multi-crop plantations. He also observes that larger plantations have been able to employ better qualified staff.

This case for the advantages of size in agriculture has been disputed (McKillop 1981). One problem in evaluating this issue is that there appears to be more than one way of organising non-plantation alternatives to subsistence agriculture. The extent of the economic incentive to engage in smallholder production can be gauged from Table 3.10.

Table 3.10
Potential smallholder returns, new tree crop projects

Commodity prices at		Kina per 44 hour week equivalent Copra	Cocoa	Rural minimum wage
1977	June	15.53	62.23	9.90
	December	13.20	62.23	10.23
1978	June	9.49	45.57	10.73
	December	13.77	47.58	10.98
1979	June	18.10	45.51	11.45
	December	17.85	41.30	11.73
1980	June	10.18	37.09	12.40
	December	9.30	21.43	13.00
1981	June	9.27	27.72	13.72
	December	7.54	36.96	14.01

Source: Colclough and Daniel (1982) and sources cited therein.

While the information available does not allow the impact on the urban economy of agricultural production to be quantified, the broad picture appears to be clear. The urban economy benefits from the expenditure on inputs (including labour and financial inputs), the expenditure on inputs for new investment, the expenditure from the return to the public sector and non-investment expenditure from profits.

The subsistence sector is reputed to provide a good living to those engaged in it within the study area (Bourke 1976; Rangai 1982, a,b,). As evidence, it is pointed out that the Tolai have shown little enthusiasm for working on plantations. Epstein (1963) indicates that it was during the affluent period before 1930 that the Tolai decided that he could be selective about the job he worked at. Epstein also notes a strong Tolai preference for investment in the service sector as opposed to manufacturing.

These Tolai attitudes do not mean that their investment in agriculture is insignificant. Epstein reports estimates that the Tolai planted 4,150,000 coconut and almost 2,941,000 cocoa trees during the post-war period up to 1960. It may also be noted that Goodman, Lepani and Morawetz (1985) report a Department of Primary Industry estimate for about 1980 of agricultural cash income (including own earnings and agricultural employment) of K16,746,000 for an ENBP rural population of 114,000 (average K144.53 per head) compared to a national agricultural cash income of K135,752,000 shared by 2,542,000 (average K53.40 per head).

Many of the Tolai commute to work, especially into Rabaul in order to obtain non-rural employment. It is shown in Table 3.11 that the rural primary industry minimum wage is substantially below that for urban general labourers in Level One centres (of which Rabaul is one). Furthermore, Rabaul is a relatively inexpensive place in which to shop (Minimum Wages Board 1983). For example, the "lowest cost food budget" for a family of man, wife and four children, based on a fortnightly minimum wage of K78.56 ranges from 20 per cent in Rabaul to 40 per cent in Port Moresby.

Table 3.9 may be misleading in one respect. While not insignificant amounts of investment are necessary for smallholder production of cash crops, Epstein (1964) has pointed out that the Tolai are particularly fortunate in that only a modest investment is needed in tools and equipment for work in their vegetable gardens.

Table 3.11
Ratio of urban general labourer's minimum wage to rural primary industry minimum wage 1972-82

Date 30th June each year	(1) Urban general labourer (Level One centres) kina per week	(2) Rural primary industry minimum kina per week	Ratio (1)/(2)
1972	8.00	5.90	1.36
1973	11.50	5.90	1.95
1974	13.80	5.90	2.34
1975	22.50	8.50	2.65
1976	27.18*	8.90	3.05
1977	28.08	9.90	2.84
1978	29.71	10.73	2.77
1979	30.82	11.45	2.69
1980	33.24	12.40	2.68
1981	36.78	13.72	2.68
1982	38.82	14.48	2.68

* The source also gives 28.18 in another place.

Source: Colclough and Daniel 1982.

The precise contribution of subsistence agriculture to the economy of the study area is unknown but Shaw (1985) reports that a major study of subsistence food production for Papua New Guinea as a whole found that non-marketed production (which does not equal total subsistence production) has been around 15 per cent of the value of the gross domestic product for some years. He cites a source which estimates that in 1977 21,352 tonnes of fruit and vegetables were sold in the Rabaul market (22.5 per cent of the total for urban Papua New Guinea and 8.8 per cent of the Papua New Guinea total) for K2,989,000 (17 per cent and 9.6 per cent respectively). He notes that those with familiarity with this area believe that for Papua New Guinea as a whole production for sale in these kinds of markets has been growing in recent years and he estimates the rate of growth at about 6 per cent per annum. Shaw also points out that while Papua New Guinea is fortunate in that its root and tree crop system of agriculture is relatively more efficient in terms of labour input per unit of food output, is not strongly seasonal and is a very dynamic system (all in comparison with, say, rice production), there is little processing of domestically produced food crops since, except for sago, no storable foods are produced. Another interesting point to note is that rice, substantial quantities of which are imported through Rabaul, has only one fifth the transportable weight of Papua New Guinea staples for the same consumable food energy.

The distinction should be noted between subsistence production in the strict sense where the villagers are able to grow all their own food and subsistence production used to augment an income from cash cropping (or, if you will, cash cropping used to augment an income from subsistence production). As pointed out by Macewan (1979) cash cropping is intrinsically no different from other ways of earning cash. The possession of cash considerably improves the range of options open to subsistence food producers and these range far beyond merely replacing (on a regular basis) purchased food which could have been grown locally.

Economic incentives

One objection that might be taken to the picture of the ENBP economy that is being built up is that it does not recognise the local response to economic incentives. This would imply, for example, that smallholder production is more affected by institutional considerations than by changes in commodity prices.

The precise nature of the response by smallholders to economic incentives in the agricultural sector is a matter for debate. Hugh Coulter, in the report from which Table 3.2 is sourced, argues that smallholders show a supply response to copra prices with copra production declining while prices were below K200 per tonne for all of 1982 and the first half of 1983 but with production picking up once prices approached K250 in August 1983. This would appear to accord with the following finding in Shaw (1985):

> "The continued viability of subsistence agriculture also means that villagers can move in and out of cash production as their cash returns change with price variations without large falls in living standards. Village smallholders show a high price elasticity of supply: when prices are high, they work harder at cash crops and supply more, when they fall supply drops, and for some farmers may cease."

Shaw's thesis is disputed by Gerritsen (1985). Like Milne Bay, much of the study area can be described as an area of "subsistence affluence". Gerritsen hypothesises that smallholders seek a set level of cash income by appropriately harvesting their cash crops. He claims that this hypothesis provides a better explanation than that afforded by Shaw for the phenomenon of Milne Bay's copra smallholders' increasing output in the face of a downward real price trend. Of course, Gerritsen's hypothesis does not necessarily contradict Coulter's claim in that Coulter is discussing a minimum acceptable price. Furthermore, although Shaw is discussing a short-term time allocation, the statistics used by Gerritsen to support his case cover five and a half and eleven years. Earlier, Fisk and Shand (1970) argued that the supply response will be inelastic in the short-term and more elastic in the long, that is, it will take producers time to respond to price signals. While cocoa or copra, and remembering that the Tolai would see the advantages of growing cocoa under copra, would tend to be planted provided there is a perception that this is a feasible path to economic advancement (see Table 3.10) it is difficult to believe that the Tolai would be unaware of other ways of profitably using their time when the income from cash crops is unattractive (Schoeffel 1983).

This problem in delineating the operable pattern of incentives has bedevilled government attempts to localize the plantation sector (Walter 1981). It should also be noted that different groups of nationals may have different motives for economic activity. Densley (1979) cites three studies by Epstein which distinguish five categories of village growers and sellers of produce. Besides "target operators" and "profiteers", who correspond to the pair of motives under discussion, there are "trippers" (sell for social reasons), "marginalists" (who sell to take advantage of a surplus produced unintentionally) and "buyers-sellers" (who sell in order to buy other produce which they do not themselves produce).

It is also relevant to note that to the extent that the villagers look to the government and "development" to improve their lot, their ambitions and training may not be pointing them in the direction of plantation ownership and management. Indeed, as pointed out by Manning (1987), lending agents insist on the involvement of a managing agent before they will lend to a group or individual unless proven management capability has been shown. The view of Pomponio and Lancy (1986) is of some interest here:

> "The government wants villagers to be 'self-sufficient'; the villagers want government financial aids and management. The quality of the education system has diminished since the heady days of the 1960s. The localization program is at a standstill. Given the current reduction of resources committed to schools, the system is unable to produce competent technocrats and managers to replace the remaining expatriates. On the other hand, rural development is also at a standstill...Output per acre ...has declined steadily as the government made a shift from a plantation economy in which workers were paid wages, to a self-employment system in a society that lacks the concepts and experience to plan, execute, and maintain independent businesses in the Western sense of the term".

Although their case studies do not include the study area, they do suggest that groups which got an early start in educational development, like the Tolai, send much more money to their villages than those who were late in the education race. Of course, the Tolai village has the additional advantage that so many villagers return from paid employment to their village each evening.

Other production

Reference has already been made above, and in the tables, to the fact that initial processing of both cocoa beans and coconut meat begins on the plantations or near to the smallholder's growing area. A governmental inspection system is used to ensure that receivals at depots maintain a high standard and Coconut Products Limited maintains a major processing facility for copra at Toboi just outside Rabaul.

It has also been noted above that there is a considerable export trade in commodities through Rabaul. However, keeping in mind the fluctuating value of this trade, it is difficult to predict what it might amount to in any year. Nevertheless, the estimates of future export trade through Rabaul that the authors have sighted do assume that this trade will increase.

Given the impetus from the agricultural sector it is to be expected that there would be a certain amount of secondary and tertiary industry in the urban sector. Nevertheless, it is limited for a number of reasons. Perhaps the most obvious of these, to which reference has already been made, is that of scale. The population of the study area, accounting for the bulk of the population in ENBP, is nevertheless quite small. Even allowing that other ports in "the islands" have close economic ties with Rabaul the market for goods and services produced in the urban sector of the study area must be limited. Consequently, it is useful to regard firms that do establish themselves in this area as fulfilling some particular niche that is not adequately catered for by imports or established firms.

If firms check to determine whether there is an appropriate niche for themselves before establishing in the study area, they would not be surprised to note that complaints have been made that competition in many areas in the study area is limited, leading to "excessive" costs and profit margins. Complaints of this nature, based as they are on casual empiricism, are difficult to substantiate although it is clear that some of them are being made by well-informed persons. Official comparison of average retail prices of selected items at representative outlets in Port Moresby, Goroka, Lae, Madang, Rabaul and Kieta/Arawa/Panguna cannot be said to reveal a pattern of Rabaul prices being set at a higher level than elsewhere (National Statistical Office 1985). In any case, the profitability of business in the study area as well as the "sunk" (that is, not recoverable) nature of much business investment are the usual reasons advanced as to why businesses in Rabaul, and close by, have shown such little interest in re-locating. However, as shall be discussed below, this does not necessarily mean that some, or indeed all, businesses in the study area did not suffer losses, and even substantial losses, on account of the volcano crisis.

The cost structure of the study area is relevant not only to a discussion of the profitability of businesses in the study area but also to decisions made in relation to primary production. There has been considerable new investment in this sector in recent years but the incentive offered to bring unused or under-utilised land back into production clearly depends on expected profitability. This is particularly important, as shall be shown below, when much new investment is financed on a "cash flow" basis. Of course, the relationships between agriculture and the other sectors of the economy of the study area are more mutually supporting than mutually antagonistic. While it is always open for large and smallholders to import direct, either on an individual or co-operative basis, the market structure has developed along the lines above. Cocoa and copra exports are controlled by statutory boards.

The distribution system

Attention should be drawn to a number of features of the distribution system. Firstly, some extent of its size can be gauged from data for retail sales in ENBP and Papua New Guinea as a whole given in Table 3.12. Secondly, the growing use of containers allows economies of scale to be achieved in importing. One importer suggested that containers also have a use as emergency storage during times of crisis, offering strengthened storage facilities at close proximity to where they are required. Thirdly, the need to import tends to make effective wholesaling and retailing rather capital intensive because of the need to maintain adequate stock levels. Statistics on importing and exporting through Rabaul are given in Table 3.13. In Table 3.14 statistics are given on the volume of coastal shipping by route. Fourthly, there is a distinctive hierarchy in the retail distribution system with every village and plantation boasting at least some form of trade store. This is a system which, of course, offers advantages to those conveniently placed or adequately serviced by the road system in relation to the main shopping areas in Rabaul (and to a lesser extent, Kokopo). The contribution of aviation and telecommunications in making this all come about should be mentioned in passing.

In trying to obtain some insight into exactly what is distributed it can be noted that the only detailed analysis of household expenditure in the study area known to us provides analyses on the basis of a sample of 89 households' purchases of goods in Rabaul by type of outlet and type of expenditure.[16] The marginal totals show the following expenditure pattern in kina per fortnight: food 40.64 (cereals 11.69, meat and fish 13.17, fruit, vegetables, nuts and roots 7.02 and miscellaneous food 8.76); drink, tobacco and betel nut 22.34 (soft drinks 1.99, alcoholic drinks 10.53, cigarettes and tobacco 7.01 and betel nuts and accompaniments 2.81); and other subgroups 18.22 (clothing and footwear 6.19, household and entertainment durables 7.87 and other goods 4.16). It should be noted that the survey did not cover expenditures on services, utilities and transport goods. The K81.20 was spread among the following kinds of outlets: listed outlets 5.68, trade stores 54.14, market and street sellers 13.75, restaurants, stalls, hotels, bars and clubs 4.82, specialist shops 2.12 and other 0.69.

Finally, on distribution, to bring together what has been noted in a number of places above, a good port, containerisation and economies of scale generally have given Rabaul trans-shipment exports to counter-balance the trans-shipment commodity imports. Suggestions that the town of Rabaul be moved to what are deemed to be safer locations will always run up against the problem that the town is part of a "system" based on close proximity to the port. It is not only that substantial investments have been made in Rabaul - the problem is that there are good reasons why these investments have been made there and not elsewhere.

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16. National Statistical Office Bulletin No. 8 - Household Expenditure Survey 1975/76. The source indicates that non-citizens and persons living in institutions are virtually excluded from the survey.

Table 3.12
Retail sales and selected services in ENBP, values and national shares, 1981-85

Year	Values: Retail sales (K'000)	Values: Selected services (K'000)	Shares: Retail sales (per cent)	Shares: Selected services (per cent)
1981	43,880	4,675	9.2	9.1
1982	39,560	5,093	8.5	10.4
1983	35,612	4,427	7.4	8.9
1984	39,119	3,645	7.1	6.7
1985	41,885	3,954	6.9	6.8

Notes:

1. Sales by co-operative societies, government enterprises, indigenously-owned rural trade stores, urban and rural markets (where mainly agricultural produce is sold), businesses which do not sell from fixed premises are excluded. Sales by all retail stores, motor vehicle and accessories dealers, hotels, boarding and other accommodation, and restaurants, personal and household services and recreational services (from fixed premises) and clubs are specifically included.

2. The retail sales of goods comprise sales of goods to households for final consumption while other retail sales cover sales of services to households for final consumption.

Source: National Statistical Office, Census of Retail Sales and Selected Services.

Table 3.13
Imports and exports through Rabaul and national shares, by month 1980-86

Month	Imports: Value (K'000)	Imports: Share (per cent)	Exports: Value (K'000)	Exports: Share (per cent)
1980				
January	5,904	9.3	11,133	17.2
February	6,614	13.7	4,348	24.7
March	6,303	12.6	5,856	8.8
April	4,497	9.1	8,307	13.7
May	5,881	11.0	5,801	7.7
June	5,662	10.2	5,986	10.0
July	7,370	12.7	10,737	14.1
August	7,714	12.2	6,572	7.2
September	5,873	10.6	3,206	7.4
October	8,028	10.5	6,370	11.7
November	4,585	8.0	3,967	13.8
December	7,378	13.8	6,781	12.8
Total*	**75,810**	**11.1**	**79,064**	**11.4**

Table 3.13 (continued)
Imports and exports through Rabaul and national shares, by month 1980-86

Month	Imports Value (K'000)	Imports Share (per cent)	Exports Value (K'000)	Exports Share (per cent)
1981				
January	3,571	5.5	5,103	10.7
February	3,030	5.7	4,443	10.8
March	7,499	13.1	5,333	10.5
April	5,564	8.4	5,828	11.1
May	5,581	9.3	4,246	8.8
June	3,816	7.3	4,598	10.3
July	4,602	7.6	7,290	13.4
August	7,136	9.3	4,606	11.2
September	11,907	17.4	7,410	13.5
October	6,563	10.5	4,314	7.5
November	5,023	8.2	6,885	15.9
December	4,085	7.3	5,032	11.7
Total*	**68,377**	**9.3**	**65,089**	**11.5**
1982				
January	5,861	12.2	4,318	10.6
February	4,461	9.3	6,670	16.7
March	6,515	9.8	2,810	12.3
April	4,335	6.4	4,594	8.3
May	5,836	7.4	4,352	12.3
June	4,631	7.3	3,466	7.8
July	6,642	10.7	6,743	8.7
August	5,769	9.9	4,420	7.7
September	7,607	14.2	4,654	12.9
October	3,019	4.5	3,730	6.6
November	6,876	8.4	6,046	11.6
December	3,686	6.7	4,096	7.8
Total*	**65,238**	**8.7**	**55,898**	**9.8**
1983				
January	5,912	8.6	3,895	10.8
February	3,780	8.2	2,337	4.8
March	5,136	6.5	3,778	6.7
April	3,865	5.8	4,070	8.5
May	6,422	10.4	4,610	7.2
June	4,154	5.8	5,184	10.1
July	4,490	7.1	3,498	3.8
August	4,577	5.7	7,302	12.7
September	3,724	5.3	6,627	10.1
October	5,453	7.2	2,442	5.0
November	7,022	8.3	9,205	16.1
December	4,718	8.9	6,749	11.6
Total*	**59,253**	**7.2**	**59,696**	**8.8**

Table 3.13 (continued)
Imports and exports through Rabaul and national shares, by month 1980-86

Month	Imports Value (K'000)	Imports Share (per cent)	Exports Value (K'000)	Exports Share (per cent)
1984				
January	3,966	4.9	5,915	11.1
February	2,613	3.7	12,297	19.5
March	4,698	6.9	5,302	8.8
April	3,784	6.0	9,454	15.0
May	2,996	4.3	8,187	13.2
June	6,411	9.0	10,663	12.0
July	4,122	6.7	9,903	16.7
August	6,766	7.7	10,167	14.4
September	6,817	9.3	9,001	12.7
October	5,248	6.4	11,219	12.9
November	6,270	8.6	10,272	17.7
December	7,416	11.2	10,030	15.2
Total*	**61,107**	**7.0**	**112,409**	**14.0**
1985				
January	5,834	7.1	6,761	9.5
February	3,045	4.1	6,098	10.8
March	5,646	7.6	9,621	16.2
April	4,081	6.5	3,364	4.8
May	5,937	7.6	11,319	15.1
June	4,793	7.0	8,938	10.8
July	6,225	8.6	6,367	8.2
August	7,742	9.3	8,750	9.1
September	3,198	6.0	5,643	7.7
October	6,753	7.2	7,636	7.8
November	4,140	7.1	6,055	8.9
December	5,359	7.4	7,802	9.4
Total*	**62,751**	**7.2**	**88,171**	**9.7**
1986				
January	6,517	8.0	6,475	9.7
February	2,826	4.8	6,971	7.7
March	3,216	4.9	5,072	7.5
April	4,039	5.3	8,410	8.6
May	4,890	6.8	6,128	8.5
June	4,826	6.5	4,484	5.2
July	3,858	4.7	7,711	7.4
August	4,624	5.5	5,223	5.7
September			4,945	5.4
October			6,389	7.2
November			3,965	6.1
December			3,965	9.2
Total*			**73,332**	**7.3**

* The data in the columns may not exactly sum to these totals because of rounding errors; import data unavailable beyond August 1986.

Source: National Statistical Office, Abstract of Statistics, various issues.

Table 3.14
Coastal shipping by selected routes, 1978-1982

To Rabaul from	1978 T	1978 F	1979 T	1979 F	1980 T	1980 F	1981 T	1981 F	1982 T	1982 F
	(in thousand tonnes)									
Lae	22.9	6.5	27.7	4.4	28.9	7.7	27.1	6.2	22.8	8.7
Port Moresby	6.3	5.9	7.0	5.0	7.0	5.2	6.2	2.5	4.6	2.5
Kimbe	0.9	7.4	1.6	7.9	2.7	10.4	2.1	8.1	1.8	14.7
Kieta	3.6	5.4	2.9	4.0	1.7	4.5	1.8	7.9	2.7	2.7
Kavieng	2.9	10.1	2.0	9.4	2.4	12.6	1.5	6.7	3.1	13.1
Lorengau	0.5	2.3	1.2	2.1	0.9	2.3	0.6	3.1	0.7	4.9
Total	**37.1**	**37.6**	**42.4**	**32.8**	**43.6**	**42.7**	**39.3**	**34.5**	**35.7**	**51.1**

By way of comparison the total (T+F) coastal shipping tonnages in these years for the whole of Papua New Guinea are:

1978	320.3
1979	294.0
1980	334.2
1981	267.3
1982	330.7

Notes: T To Rabaul from .... F From Rabaul to.....

Source: Bawdekar, King and Olaba (1984) and sources cited therein.

Investment

The specific impact of the crisis on investment will be discussed below. Indeed, some of the more obvious signs of dilapidation in Rabaul reflect more the continuing aftermath of the crisis of confidence in 1976 at the time of the granting of independence rather than more recent events. Table 3.15 provides information as to the value of new houses and flats commenced and completed over a number of relevant quarters. This table is supported by Table 3.16 which uses the same source to aggregate over the financial year (and extend the period over which the observations are taken) as well as providing annual data on the value of new houses and flats under construction at the end of the year.

The next question to be considered is that of incentives to invest. This is more than a matter of the impetus given by a recovery in both agricultural production and tourism since continual new investment is necessary to make good the effects of depreciation. Certainly, as already mentioned above, the maintenance backlog is being caught up. Furthermore, it is possible to note a hardening in the latter part of 1986 in the market for rental accommodation. But the "niche" nature of business opportunities makes it difficult to assess whether expressions of confidence that new investments would occur outside the agricultural sector, once problems peculiar to the seismic crisis are sorted out, are fully warranted, especially since these problems mean that the assertions made are unlikely, for the moment, to be put to any test. Nevertheless, in the light of what has been said above about the profitability of business, it is reasonable to believe that, subject to settling these problems, established businesses would find buyers as well as there being new investment.

However, since many established businesses are in a position to cater for the flow-on effects of increased agricultural production it would be prudent not to exaggerate the possibilities of new investment were crisis-related problems to be sorted out.

Table 3.15
New houses and flats commenced, completed and under construction, ENPB, by value and national share, quarterly March 1980 to December 1986

Date	Commencements Value (K'000)	Commencements Share (per cent)	Completions Value (K'000)	Completions Share (per cent)	Under Construction Value (K'000)	Under Construction Share (per cent)
1980						
March	103	1.7	66	1.2	151	0.1
June	133	3.3	67	2.4	217	1.3
September	194	3.0	148	2.9	263	1.5
December	361	4.9	123	2.4	501	2.5
1981						
March	275	2.6	132	1.2	644	3.3
June	288	2.2	347	5.2	585	2.3
September	271	4.1	487	7.1	369	1.4
December	472	4.5	0	0.0	841	3.1
1982						
March	0	0.0	576	6.8	265	1.2
June	63	1.6	103	0.9	225	1.5
September	58	1.0	226	2.3	57	0.5
December	25	0.5	0	0.0	82	0.8
1983						
March	0	0.0	82	0.2	0	0.0
June	0	0.0	0	0.0	0	0.0
September	0	0.0	0	0.0	0	0.0
December	8	0.1	8	0.2	0	0.0
1984						
March	77	1.9	0	0.0	77	0.3
June	4	0.1	0	0.0	81	0.3
September	4	0.1	4	0.0	81	0.4
December	231	3.7	81	1.0	231	2.1
1985						
March	0	0.0	0	0.0	231	1.5
June	0	0.0	59	1.0	172	1.3
September	40	0.4	0	0.0	212	1.2
December	0	0.0	172	3.9	40	0.2
1986						
March	13	0.4	40	1.2	13	0.1
June	305	0.1	13	0.0	305	2.9
September	22	0.3	172	3.8	140	0.9
December	106	0.9	155	3.6	91	0.4

Source: National Statistical office, Building Statistics, various issues, Table 11.

Table 3.16
Buildings other than houses and flats commenced, completed and under construction, ENBP, by value and national share, quarterly March 1980 to December 1986

Date	Commencements Value (K'000)	Commencements Share (per cent)	Completions Value (K'000)	Completions Share (per cent)	Under Construction Value (K'000)	Under Construction Share (per cent)
1980						
March	325	3.1	242	0.4	635	2.4
June	802	15.8	153	4.5	1,284	4.6
September	160	3.5	563	4.5	881	4.4
December	1,046	9.4	235	4.2	1,693	6.6
1981						
March	416	4.7	680	10.8	1,429	5.1
June	229	0.2	11	0.1	1,647	5.2
September	82	1.2	77	0.7	1,652	5.9
December	82	1.4	0	0.0	1,734	7.1
1982						
March	99	2.3	1,177	21.9	656	3.2
June	1,150	13.3	578	6.6	1,228	6.0
September	385	4.8	0	0.0	1,613	7.8
December	314	2.5	1,413	15.5	514	1.3
1983						
March	43	0.7	205	2.0	352	1.0
June	50	0.6	50	0.6	250	0.7
September	0	0.0	250	3.1	0	0.0
December	0	0.0	0	0.0	0	0.0
1984						
March	0	0.0	0	0.0	0	0.0
June	109	0.9	14	0.1	0	0.0
September	0	0.0	95	1.4	95	0.5
December	0	0.0	0	0.0	0	0.0
1985						
March	0	0.0	0	0.0	0	0.0
June	0	0.0	0	0.0	0	0.0
September	0	0.0	0	0.0	0	0.0
December	0	0.0	0	0.0	0	0.0
1986						
March	0	0.0	0	0.0	0	0.0
June	361	4.3	0	0.0	361	1.3
September	0	0.0	0	0.0	0	0.0
December	131	2.2	100	0.8	392	1.8

Source: National Statistical Office, Building Statistics, various issues, Table 11.

The government and the economy

The role of government in the provincial economy can now be examined. Although attention is concentrated on budgetary provisions, the national and provincial governments themselves are major providers of services and utilities.[17]

This government role is apportioned between the ENBP government in Rabaul and the national government in Port Moresby. However, both the provincial and the central government can have responsibility for the function of government. Bonney (1984) points out that, while primary education has been declared an area of "primarily provincial competence", 41 per cent of the Community Education Sectoral Program expenditure is apportioned to the national Department of Education. This means that it is not possible to develop a precise picture of all governmental activity in ENBP without considering in detail decisions made in Port Moresby. Nevertheless, it is possible to sketch out the main outlines of how government affects the workings of the ENBP economy.

The first thing to note is that governmental expenditure broadens the supply and demand base of the provincial economy. While employees in both the public and private sectors may have similar consumption patterns, government as such in Papua New Guinea engages in many activities that are not likely to be generated by market signals. Next it may be noted that, whatever else is happening in the ENBP economy of a cyclical nature, it does not appear to be substantially reflected in the provincial government estimates to be found in Table 3.17. Another way of looking at this "stabilizing" influence of the provincial budget is to note that changes in it are of a minor order of magnitude compared to changes in the value of imports and, particularly, exports through Rabaul port as recorded in Table 3.13.

Information on national government expenditure in ENBP is more sketchy because it has not been possible to locate a source which allocates all national government expenditure on a provincial basis. Bonney (1984) notes that of a national budget of K751 million in 1982, 45 per cent was allocated to the national government, 18.9 per cent to provincial governments, 13.5 per cent to loan charges while the balance went to the National Public Expenditure Plan (now the Public Investment Programme) which enables Port Moresby to maintain firm control over the growth elements of national expenditure. While it is only possible to determine how 75 per cent of this expenditure has been allocated on a provincial basis, ENPB benefited to the extent of K40 per capita (compared to a median provincial allocation of K31 per capita), say approximately K5.3 million (and approximately K7.1 million if the unallocated portion had been allocated pro-rata).

This estimate differs from that obtained from other sources, although it is possible that these differences reflect differences in precisely what is being calculated and the specific assumptions each author makes. For example, Axline (1986) estimates that the funding of Plan provincial projects and national projects in ENBP in each of the years 1980 to 1984 was K3,875,000, K4,734,000, K10,051,000, K7,044,000 and K826,000 respectively.[18]

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17. For example, Department of Education Planning Branch (1985) reports a staffing of 103 in ENBP "government agency" provincial high schools as compared to 50 in ENBP "church agency" provincial high schools.

18. There is a sense in which it can be said that national spending on disaster-related projects in the study area helped make up for the fact that 1984 was a particularly lean year for ENBP expenditure from this source (see Chapter 5).

Table 3.17
Budget estimates of the ENBP government, 1982-1985

	1982	1983	1984	1985
		(K'000)		
Revenue				
Grants	9,909	9,934	10,408	10,740
Internal revenue	1,692	2,180	2,280	2,276
	11,601	12,114	12,688	13,016
Expenditure				
Premier's office	198	207	244	301
Secretary's office	301	202	235	358
Rural development*	462	720	744	715
Forests	243	232	242	244
Education	3,996	4,186	4,511	4,543
Community development	138	142	169	166
Commerce & tourism	147	134	138	158
Health	555	675	651	746
Communication services	146	164	110	131
Planning & technical services	0	178	131	234
Community government	402	385	361	340
Finance & administration	692	790	760	735
General overheads	931	780	839	960
Capital works, services and maintenance	2,158	2,605	2,972	2,694
Financial transactions	445	520	524	531
Secretary's advance	787	194	59	167
Total**	**11,601**	**12,114**	**12,688**	**13,017**

Notes: Estimated total expenditures in 1986 and 1987 are K13,579,700 and K14,649,300 respectively, with internal revenue in the two years being estimated at K2,856,000 and K3,412,000 respectively.

* Also known as Primary Industry.

** The data in the columns may not exactly sum to these totals because of rounding errors.

Source: ENBP Budget Estimates, various years.

An overview of national government expenditures in ENBP outside the Plan has not been found although it is clear that these expenditures are substantial in some areas. For example, Budget Document No. 1 shows that in the 1985 National Health Budget ENBP received an allocation of K1,125,400 for primary health as well as a K1,526,000 hospital allocation. It may be noted that in 1984 ENBP had a police force of 292 officers and Kerevat Corrective Institution had 75 staff and an average of 289 detainees. In other words, if it is assumed that a high proportion of the national government's own spending is in the Port Moresby area and the balance is distributed evenly across the country on a per capita basis, then, taking into account expenditure under the Plan, the total government expenditure (provincial and national) in ENBP is likely to vary between two and three times the provincial government budget, depending on the year in question. By way of comparison, information on estimated domestic factor income attributable to ENBP is to be found in Table 3.18.

Table 3.18
Domestic factor incomes ENBP total, national share, and per capita, 1980 and 1983

Year	Compensation of employees	**Operating surplus** Market (Km)	Non-market	**Domestic Factor Incomes** Value (Km)	National share (per cent)	Per capita (Kina)
1980	50.0	48.3	11.8	110.0	7.3	829
1983	47.2	52.3	7.2	106.7	6.4	770

Source: National Statistical Office Bulletin No. 24.

The size of the provincial economy

Turning to the last major question to be discussed in this chapter, it is necessary to consider the size of the ENBP economy and, by inference, the size of the economy within the study area. This will allow the determination of assets and productive capacity put at risk as the result of an eruption and the scale of local resources available to deal with its aftermath. The evidence relating to this comes from various sources briefly surveyed in turn.[19]

First, there is the evidence from the transmission mechanisms discussed above. Wealth is primarily created by cash crop production with important supplements from a variety of sources: subsistence agriculture, the entrepot trade through the port, the further processing of agricultural products, manufacture and the provision of services in both the public and private sectors. While insufficient accurate information is available on each of these components, it is known that in 1980 and 1983, the only years for which information is available (see Table 3.18), domestic factor incomes for ENBP were K110 million and K106.7 million respectively. If other items in the national accounts are apportioned across provinces in the same ratio as domestic factor incomes are distributed across provinces, this would yield a provincial gross domestic product of K127.6 million and K126.9 million respectively for these years. Since 89 per cent of ENBP cocoa and copra production is attributed to the study (see page 29) and it is doubtful whether 11 per cent of ENBP non-cocoa and copra production occurs outside the study area, it can be estimated that its gross domestic product in both years is about K113 million.

19. Although it is not referred to explicitly in the text, a brief summary of information influencing the size of the ENBP is given in Table 3.19.

Even if it is accepted that K113 million is a very rough estimate and if it is acknowledged that estimating the value of the capital stock necessary to generate such a level of gross domestic product is fraught with conceptual and practical difficulties, it would be reasonable to assume that the value of all that is being put at risk by an eruption at Rabaul is nearer to the higher "ballpark" estimates that have been mooted (say K500 million rather than K200 million). It will be noted in Chapter 6 that the figure that has been obtained for total sum insured in the study area is K108 million which would not cover most of the agricultural and indigenous sectors of the economy nor much public investment (a striking example is the Warangoi hydro-electric scheme which cost K38.3 million when commissioned in 1983).

Of course, what policy or other conclusions might be drawn from estimates of this kind can be a matter of debate; but one point that can be made is that though the damage caused by anything less than an eruption that is cataclysmic, (the total destruction of life and economic production in the study area), may be severe, as has happened with other disasters, recovery will occur - and frequently much more speedily than is at first thought possible.

Table 3.19
Summary of information on factors influencing size of ENBP economy

Factor	Year 1982	1983 (K'000)	1984	1985
Returns from cocoa for cocoa years@	12,795	16,562	16,532	-
Returns from copra for copra years@	9,192	33,006	-	18,235
Commodity exports through Rabaul*	54,763	-	112,409	-
Exports through Rabaul*	55,898	59,686	112,409	-
Imports through Rabaul*	65,238	59,253	61,170	-
Retail sales and selected services	39,560	35,612	39,119	-
Provincial budget	11,601	12,114	12,688	13,017
Domestic factor income	-	106,700	-	-

@ These estimates are approximate in that they make use of the average price for the year rather than take into account production and prices for individual months.

* As explained in the text statistics of the export values of cocoa or copra crops (or statistics which incorporate the export values of cocoa or copra crops) provide an imprecise measure of the impact of these crops on the incentives open to cash crop growers and on the economy of the study area.

Because information on ENBP and the study area is so fragmentary it is important not only to realise that estimates are very imprecise but also to make whatever test is possible on their plausibility. To do this the procedure adopted above is followed and relevant items in the national account statistics are apportioned across provinces in the same ratio as domestic factor incomes are distributed across provinces. If this is done, the ENBP market component of private final consumption expenditure would be appoximately K50 million in 1983 which can be compared to an estimate of approximately K40 million for retail sales and selected services (see Table 3.12). Applying the same procedure to "exports of goods and services" the national accounts suggest these should total to approximately K41.4 million in 1983.

Table 3.5 reveals that the timber logs exported in 1983 through Rabaul would be approximately K19.4 million but the December 1983 issue of the Papua New Guinea Timber Digest reveals that ENBP companies only exported K6.2 million suggesting that K13.2 million is the produce of other provinces exported through Rabaul. This would suggest that of the ENBP commodity exports through Rabaul in 1982 of no more than K46.5 million which would not represent an unacceptable order of magnitude since other produce of other provinces exported through Rabaul has not been taken into account. Consequently, these tests, crude as they are, do not suggest that the argument is grossly astray.

Other statistics that might provide some insight into the size of the ENBP economy are those concerned with valuations of land and of structure and contents for insurance purposes (mentioned above). Valuations are, of course, affected by the difficulties of disposing of properties in the current circumstances for reasons discussed elsewhere in this report. One informant has suggested that at current market values (late 1986) the land within the Rabaul town boundary (which includes Nonga) and on Matupit Island would fetch about K13 million while its capital value (that is, land plus buildings) would be about K60 million. However, it may be noted that the 1986 provincial budget set the land tax, which apparently only applies to the Rabaul area, at 3 per cent of valuation and expected it to raise K320,000 implying a formal valuation base of approximately K106.7 million in late 1985. On the liabilities side, bank debt is estimated to be in the region of K40 million to K50 million with approximately 30 per cent being town-based.

As has been already indicated, K500 million is not an impossible estimate for the wealth put at risk by any eruption with up to half of it being insured properties and the land on which these properties stand. The bulk would be non-insured properties and the land on which these properties stand (in particular agriculture and village properties and land) and the remainder government and community facilities not taken into account elsewhere. This figure allows the estimates of property damage from an eruption to be seen in broader perspective, although it is the income generated by this property that provides the province with the possibility that it will be able to recover (back to present levels) from all but a cataclysmic eruption.

Chapter 4

The seismic crisis in Rabaul, 1983-85

Introduction

Geophysical monitoring of the Rabaul volcano began shortly after the 1937 eruption. A period of increased seismic activity began in 1971. In August 1983 the number of earthquakes per month increased from 30-80 to more than 200. This trend accelerated in the next few months with more than 13,000 earthquakes being recorded in April 1984. Deformation in the Matupit Island area may have begun as early as 1971 with the southern end of the island rising about 1 metre between 1973 and the end of 1982. Between November 1983 and May 1984 the uplift of the southern end of Matupit Island averaged 50 millimetres per month, compared with the earlier rate of about 8 millimetres per month. The seismo-deformational crisis (hereafter called the seismic crisis) which began in August 1983 and lasted until late 1984 led to the declaration of a stage 2 alert (see below) on 29 October 1983 and produced profound effects on life in Rabaul and on the economy of the Gazelle region.

This chapter is concerned with the reaction to the seismic crisis; the impact of the crisis is considered in Chapter 5. We have been quite selective in presenting the available information and only a few aspects of the crisis are considered here. In being selective, this study dwells on those aspects which had particular significance to the progress of the crisis and its effects, those which had important social or economic ramifications, those which aid in understanding the likely course of future seismic crises or eruptions, and those which provide insights for natural-hazards studies in general.

Accordingly, in this chapter, the following aspects are considered: the seismic crisis, the legislation passed, the stages of alert and their declaration, the organisation of the East New Britain Provincial Disaster Committee (ENBPDC) and its sub-committees, the evacuation plan, some of the legal aspects, and the role of the insurance industry.

In this chapter few sources of information are cited. During the course of our investigations numerous correspondence files including some that are confidential were made available to us. Almost all of the statements produced here are based on written correspondence but the confidentiality of our "informants" has been protected in all cases.

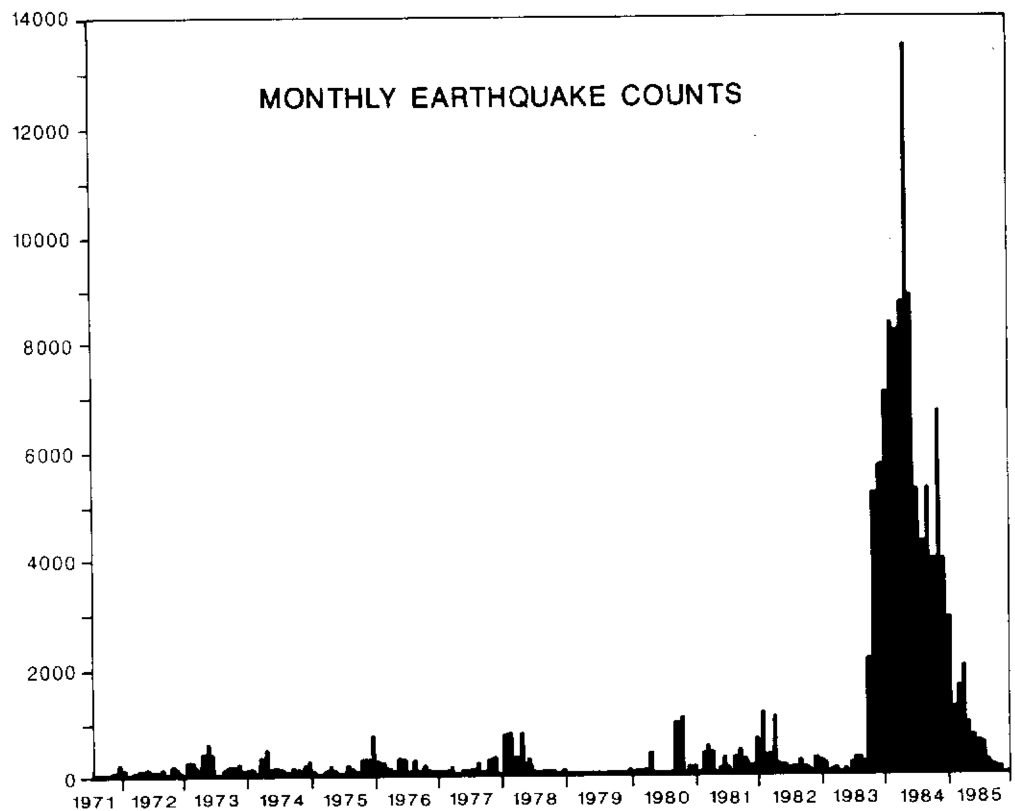
The seismic crisis

Molten rock (magma) rises toward the ground surface from depths of many tens of kilometres. As the magma forces its way toward the surface, the overlying rock is fractured, producing earthquakes. Some of the earthquakes may be "felt" but many are detected only by instruments. The ground surface may also be deformed by the accumulation of molten rock and gas at depths of only a few kilometres.

The pattern of instrumentally detected earthquakes for the period late-1971 to the end of 1986 is shown in Figure 4.1. As McKee et al. (1984, p399) note:

Figure 4.1

Monthly earthquake counts for the Rabaul area, 1971-85
(after Mori et al., 1986)



"Background levels of seismicity (our detectability limit is about ML -1) rose more or less steadily from a "normal" level of about 10 events per day in August 1983 to about 50 per day before the first seismic crisis on 19 September 1983. Background seismicity reached a peak of about 350 events per day in late-April 1984, but declined to about 160 events per day in May 1984. From September 1983 to May 1984, 15 major seismic crises occurred, at intervals of 1 to 47 days, and a large number of minor crises or swarms took place. Major crises typically involved hundreds of earthquakes in the space of less than one hour. ...Usually the strongest events were felt at MM III-V[1] in Rabaul town and took place at or near the beginning of a crisis."

The seismic crisis which occurred on 23 March 1984, for example, included several felt earthquakes, the strongest having a Richter magnitude ML = 5.1. Some of the felt earthquakes were very shallow and were accompanied by underground rumbling and explosive noises with waterspouts 3 to 5 metres high along part of the shoreline to the northwest of Vulcan Point.

Since measurements began in 1973 the area with the strongest rate of deformation has been the southern end of Matupit Island. Up to August 1983 the average monthly rate of uplift was about 8 millimetres. From November 1983 to May 1984 uplift in this area averaged 50 millimetres per month. Deformation crises accompanied the seismic crises with the largest uplift in a single crisis totalling 60 millimetres.

Over 94,000 earthquakes and 0.63 metres of uplift on Matupit Island occurred during the 14 months of the crisis period. By December 1984 seismicity was back to about 60 events per day and rates of ground deformation had fallen to about one to two times the pre-August 1983 level (McKee at al. 1984).

A stage 2[2] alert was declared on 29 October 1983.

Dr Peter Lowenstein, Principal Government Volcanologist at the RVO advised the ENBPDC that as of 26 March 1984 there was a 50 per cent chance of an eruption as well as a 50 per cent chance of the declaration of stage 3 before the end of the year. He considered that the probability of stage 3 being declared during a particular month would rise from 27 per cent in April to 44 per cent in September and the probability of proceeding to stage 4 without going through stage 3 during a particular month would rise from 21 per cent in April to 42 per cent in September. In the event of an eruption occurring the probability of people surviving would be 90 per cent if they were in the red zone (see Figure 4.2)[3] but only 50 per cent in the purple zone. The probability of widespread damage during the northwest season was estimated to be 10 per cent in the red zone, 70 per cent in the purple zone and 30 per cent in Rabaul town. These probabilities would be 20 per cent, 70 per cent and 60 per cent respectively during the southeast season. It was estimated that there was a 50 per cent chance that the eruption would last up to a week and a 50 per cent chance that it would last up to three weeks.

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1. A summary of the Modified Mercalli scale of earthquake intensities is presented in Appendix 1.

2. The various stages are defined in a later section of this chapter.

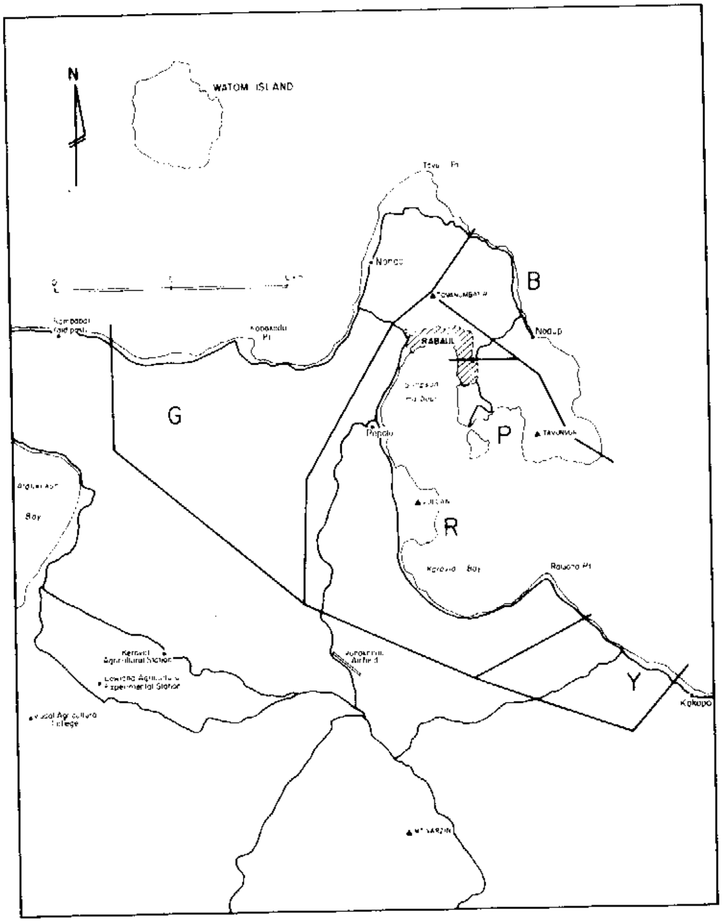
3. In Figure 4.2, B = blue; G = green; P = purple; R = red; y = yellow.

Figure 4.2

The five zones of the danger area

BASE MAP MAP 1

ZONES MAP 1



Legislation

As a response to the declaration of stage 2 and the developing crisis in Rabaul eight acts of parliament were passed in the first two weeks of March 1984. Brief descriptions of each of these acts follow.

1. **Disaster Management Act.** This act defines disaster to mean "an earthquake, volcanic eruption, storm, tempest, flood, fire or outbreak of pestilence or infectious disease, or any other natural calamity whether similar to any such occurrence or not, on such an extensive scale as to be likely to endanger the public safety or to deprive the community or any substantial proportion of the community of supplies or services essential to life."

This act also established the National Disaster Committee (NDC) and defined its membership as the Secretary to the Department of the Prime Minister, the Commander of the Defence Force, the Commissioner of Police, and the heads of departments responsible for financial matters, defence matters, works and supply matters, health matters, foreign affairs and trade matters.

The functions of the NDC were set out:

- to supervise the national state of preparedness for emergencies and to report on it to the National Executive Council (NEC);
- to maintain the National Emergency Plan of the NEC;
- to assign responsibilities for disaster-related activities to departments and other bodies;
- to co-ordinate departmental relief actions and collate national relief requirements;
- to advise the NEC if an appeal for international assistance is required;
- to lay down guidelines for the preparation and format of provincial disaster plans;
- to examine and where necessary approve all grants from national funds for emergency relief;
- to foster public awareness of the effects of natural phenomena and measures which can be taken to prevent or mitigate them;
- to supervise the establishment of stockpiles of relief supplies; and
- in the case of a disaster, to advise the NEC of all the circumstances and on the advisability of declaring a National Emergency under the act.

This act also established provincial disaster committees for each province and set out the membership and functions of the committees. Financial arrangements for disaster relief operations were set such that in any financial year the first K15,000 of disaster-related expenditure are paid for by the provincial government, the next K15 - 100,000 are shared by provincial and national governments and the the rest is taken care of by the national government.

2. **Emergency (General Powers) Act.** This act makes "provision for the control of the national emergency to be declared in relation to the volcanic eruption expected in the Rabaul area of ENBP during 1984."[4] This act provides for the appointment of the controller and deputy controller and sets out the very wide-ranging powers available to them to requisition aircraft, ships, installations, to regulate transport and the use of roads; to enter or search lands and buildings by force; and to order persons to perform labour. In addition, neither the controller nor anyone authorised by him is liable for anything done or omitted to be done.

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4. It would be interesting to know whether this act and each of the other acts referred to below applies in 1988!

3. **Emergency (Defence Force) Act.** This act provides for the defence force to provide assistance to civilian authorities subject to the orders of the controller. Under this act the defence forces can give assistance of a civilian nature only. If assistance is required to help restore law and order a separate call out is necessary by the Head of State acting on the advice of the NEC under Section 204 of the Constitution.

4. **Emergency (Registration of Evacuees) Act.** This act provides for a system of registration of evacuees so that their whereabouts during an emergency can be known. The act also details the offences and penalties for persons who fail to register under the act.

5. **Emergency (Requisition) Act.** This act provides for the requisition during the expected national emergency at Rabaul in 1984 (and for related purposes) of animals, aircraft, vehicles, ships, machinery, installations, buildings, land, accommodation (including accommodation on aircraft, vehicles and ships), goods and things. Requisition may take place immediately or at some time in the future. While a value of a requisitioned item must be stated, no account is to be taken of any appreciation in the value of the article due to the national emergency.

6. **Emergency (Requisition Compensation) Act.** This act sets out principles of compensation for requisition of items. Vehicle hiring rates are generally set at K10/day except for larger PMV's which range from K15-20/day. Barge hire rates are set at K1,250/day while aircraft hire rates range from K400/hr for a 4-6 seat helicopter to K3,000/hr for an F28.

7. **Emergency (Motor Vehicle Third Party Insurance) Act.** This act "disapplys" (sic) various third party insurance provisions under the conditions of a national emergency.

8. **Emergency (Workers' Compensation) Act.** This act makes provision for workers' compensation for authorised disaster and emergency workers.

These eight acts illustrate the wide-ranging effects of a disaster, or in this case just the preparation for it, and the complexity of disaster management. Further aspects of this complexity are explored in a later section (Legal Aspects - see below).

The disaster plan

A Rabaul Disaster Plan was completed in June 1983 by a consultant expert from the office of the United Nations Disaster Relief Co-ordinator before the onset of the August 1983 seismic crisis and before the passage of the 1984 Disaster Management Act which made it mandatory for emergency plans to be prepared. In the 1985 edition of the East New Britian Provincial Disaster Plan (ENBPDC) chapters deal with the concept of the plan, national arrangements, organisation in ENBP, alert stages and volcanic hazards, disaster control centre arrangements, general disaster response (other than for Rabaul Volcano), the Rabaul eruption response, a larger eruption and extended evacuation, and supporting plans. The four ALERT stages are defined:

Stage 1: There is a risk but no immediate cause for alarm. The Provincial Disaster Committee (PDC) reviews plans and arrangements, enhances training, public awareness and general activities. The public is normally advised.

Stage 2: The risk has increased, and a hazard situation is possible. The PDC initiates preliminary manning of the Disaster Control Centre and resource deployments. Regular public reports are provided.

Stage 3: The risk is serious and a hazard situation is probable. Disaster organisation is activated on a continuous basis. Initial response teams and support resources are deployed.

Stage 4: The situation is critical and a hazard situation is imminent or has occurred. The Disaster Plan is fully activated. There is full deployment of personnel and resources. Evacuation of the danger area is hastened. Regular public information and advice is provided.

"It is the responsibility of the Chairman PDC, in concert with the Committee to urgently consider advice on hazard warnings and declare as necessary ALERT STAGES, activate the Plan, inform the National and Provincial Governments and the Public" (ENBPDC, 1985).

On 22 February 1984, in response to the situation in Rabaul but some four months after the declaration of stage 2, the NEC: (1) approved the establishment of a National Disaster Committee (NDC); (2) approved the establishment of a National Disaster Centre at Murray Barracks; and (3) authorised and designated the Commander of the Papua New Guinea Defence Force (PNGDF) to be appointed as Controller during the declaration of a National Emergency.

Under the Emergency (General Powers) Act both controller and deputy controller could be appointed before the actual declaration of an emergency. Brigadier General K. K. Noga as Commander of the PNG Defence Force was appointed as controller with Nason Paulias, chairman of the ENBPDC as the deputy controller. The latter appointment was not clarified until June 1984.

The Disaster Management Act 1984 established the core members of the PDC as the Provincial Secretary of the Department of East New Britain, the Provincial Police Commander, the Provincial Health Officer, the Assistant Secretary Community Government and the Provincial Works Manager. Co-opted members included assistant secretaries of the departments of Primary Industry, Commerce, Finance, and Administration and Communication Services.

As early as February 1984 a request came from the Rabaul Chamber of Commerce to the PDC for representation on the Committee, particularly as the policy of self-reliance during and after evacuation of Rabaul town emphasised the efforts of private businesses. This request was evidently not granted although the Chamber was represented on the food and transport sub-committees, providing access to decision-making in areas where business expertise could assist the government in planning for the volcanic emergency. It is also noteworthy that no church organisations are represented on the PDC although the Disaster Management Act 1984 specifically mentions that the PDC can co-opt to the Committee, "a member of a mission or voluntary organization".

Sub-committees

Much of the work of the PDC in planning for an eruption and the evacuation of Rabaul was carried out by sub-committees. The briefs and activities of these sub-committees are set out in Appendix 2. The sub-committees named here have a variety of different names in different documents. The ones used here appear in ENBPDC (1984). The work involved indicates some of the magnitude of the task in planning for the eruption.

Evacuation

The main thrust of the ENBPDP is to save lives. In fact the 1984 Disaster Unit Planning Report states: "This government with positive assistance from the National Government tried to take care of everything possible and is adamant that no life will be lost if and when an eruption takes place".

The danger area. With this emphasis on the preservation of life in mind the Disaster Plan (1985, Chapter 7.8) defines the DANGER AREA as that area in which there is considered to be a likely risk to life and property from the effects of an eruption. With an eruption equivalent to a 1937 eruption in mind "the area adjacent to the danger area is established as the SAFE AREA, and for a larger eruption, the INITIAL SAFE AREA pending reclassification of the DANGER AREA and a secondary and more distant evacuation".

The Initial Safe Area for the initial evacuation, pending resolution of the magnitude of the eruption, was defined as that area on the northwest coast, west of Ratongor and south to Kabaira Bay and thence southeast through Tingenagalip to Ulagunan and north to Kokopo High School (Figure 4.3). In the event of a more catastrophic eruption the extended safe area for planning purposes was defined as outside a radius of 23 kilometres from the summit of Tovanumbatir.

The danger area was divided into five zones (Figure 4.2):

Purple area. Area of highest risk for an eruption in or adjacent to the Matupit (Greet) Harbour area, and includes the area south of Namanula Street, Malay Town, Sulphur Creek, Matupit, Rapindik and Taliwat. This area would be varied with refinement of the probable eruption centre. Eventually this zone was abandoned because of the administrative problems it caused. The dividing line between the red and purple zones was the middle of Namanula Road. For example, the court house (on the south side of the road) was closed and relocated to Vunadidir but the post office, in the red zone on the northern side of the road, was open for business as usual!

Red area. A high risk area which includes the remaining parts of Rabaul town and the area bordered by the coast south to Raluana and inland from Tunnel Hill, south to Rakunai, Tingenagalip, Taliligap and to Raluana.

Blue area. An area along the northeast coast of Crater Peninsula extending north from Praed Point to the summit of North Daughter (Tovanumbatir) which will always be at risk due to its proximity to the caldera and the likelihood of isolation due to closure of roads by earthquakes and landslides.

Green area. An area to the west of Rabaul, adjoining the red and blue areas and extending along the north coast from Laweo Point to Ratongor and subject to ash-falls and mud flow during an eruption in the southeast season (April-November). Whilst Watom Island may experience some ash-falls it is not included in the danger areas for a smaller eruption.

Yellow area. An area to the southeast of the red area extending from Raluana to the Kokopo High School and subject to ash-falls and mud flows during an eruption in the northwest season (November-April).

The Evacuation Plan involved two major parts:

1. The preparation for orderly evacuation of approximately 60,000 people from within the danger zone areas to the safe areas.

2. The provision of information to the public within and outside the province and the country with an emphasis on self reliance and safety procedures.

Pre-evacuation. Although the evacuation plan made it clear that the authorities saw no need to evacuate any areas until a stage 3 alert had been declared, the declaration of stage 2 in late 1983 and the seismic crises early in 1984 prompted many people to voluntarily evacuate the purple and red zones. In late May 1984 it was reported that approximately 5,000 people from the Matupit, Latlat, Rapolo and other areas in the purple and red zones had moved and resettled in settlements outside of the danger zones. Most of these people were living in the Kerevat and Vudal areas. Many of the settlements were composed of people from the same area or village. For example the Matupit people moved to the Napapar, Navunaram, Butuwin, and Vunamami areas while the Malaguna people shifted to the Kereeba area; and people from Talwat relocated to Napapar No 3 and 4. No doubt a large number of those moving to the safe zone went to live with wantoks or moved onto the blocks awarded by the Administration in the 1950s to reduce the mounting land pressure in the Rabaul area (Epstein 1969). A number of mixed race people from Rabaul town had moved out to Mandres and various companies established areas in the safe zone for their employees. A large number of Sepiks and Highlanders went to live with wantoks around Kerevat township.

Although most people had moved back to their villages by mid-year, preparations had been made in the pre-evacuation areas and many Tolai intended to return to these areas when stage 3 was declared. The water supply was the main problem in these areas - a survey recommended the construction of water points at Vudal, Vunapalading, Vunairima, and Napapar No 3. Kegs normally used for beer were distributed to Kerevat, Takubar, and Vunapit areas. Some locations were to be tested for bore water wells.

Apart from the movement of thousands of people to designated safe areas, some of the expatriate wives and children returned to Australia or went to stay with friends elsewhere in Papua New Guinea. At one stage it was suggested that it might be possible to voluntarily repatriate nationals from other provinces and the PNG Defence Force undertook a survey of this population with registration on a voluntary basis. At 13 March 1984 a total of 2,243 people had been identified from the following provinces: East Sepik (1,098), Morobe (335), Eastern Highlands (333), Madang (142), West New Britain (107), National Capital (89), West Sepik (51), Western Highlands (42), Southern Highlands (18), Chimbu (15), and other provinces (13).

The registration of these nationals evidently followed a request from the New Zealand High Commissioner to the Papua New Guinean government for backloads on a Hercules on its second trip to Rabaul from New Zealand via Port Moresby. However, no repatriations were made. The controller advised that registration should continue as the government would find other means of airlifting these people from Rabaul but eventually it was decided that repatriation to other provinces would not be possible because of the high costs involved.

The movement of large numbers of people from the southern end of Rabaul, particularly from the purple zone, created a number of problems. While the Disaster Plan envisaged that normal school education would continue during stage 2 it was inevitable that student numbers would fluctuate as parents moved in and out of the danger areas or otherwise reacted to the emergency. Table 4.1 shows fluctuations in enrolments for purple and red zone schools during the period when the crisis was perceived to be at its worst. In addition the Malaguna Technical and Rabaul Secretarial colleges which between them catered for approximately 400 boarders from all provinces of Papua New Guinea were shut. The Vunakanua Teachers College was also shut.

Table 4.1
Enrolment in purple and red zone schools

School	**Enrolments at nominated dates**		
	20/2/84	29/2/84	30/3/84
Talwat Community	106	-	-
Matupit Community	145	-	-
St Michael's Matupit	96	66	76
Matupit Seventh Day Adventist	24	-	-
Rabaul Vocational Training College	64	46	52
Police Barracks Pre-School	35	-	-
Mater Dei Pre-School	30	-	-
Matupit Farm Pre-School	37	20	-
Rabaul International Primary	130	78	-
Waiau Ahnon Commercial	563	199	225
Rabaul Provincial High	400	547	512
Torchbearer Community	379	276	229
St Martin's Community	560	297	356
Sacred Heart International Primary	162	109	117
Vocational Training College	80	80	77
Malaguna Community	108	56	33
Malagunan Community	235	57	-
Rakunai Community	310	-	310
Navunaram Community	213	224	289
Latlat Community	110	70	39
Tavui-Liu Community	225	-	225
Nangananga Community	220	225	-
Raburua Community	119	86	79
Raluana Community	312	332	311
Woolnough Vocational Training College	77	77	-

Source: From Ministry of Education data, 1984.

Because many of the schools in the purple zone had few pupils during February and March 1984, a number of teachers were transferred to schools in the safe zones. These transfers were necessary as some schools in safe areas experienced an increase in numbers. Some school property, such as desks and blackboards, was also transferred. One effect of these transfers was that teachers and staff had no gardens of their own and required money for the purchase of food.

Concern was expressed during April 1984 at the number of break-and-enters in Malay Town, Sulphur Creek and Rapindik areas in properties where occupants had voluntarily evacuated. Residents who had left the purple zone had evidently been assured that police would safeguard properties but, at least according to absent residents, this appeared to be not the case.

Evacuation centres. The main preparation for evacuation at stages 3 and 4 was the establishment of seven major government evacuation centres with accommodation for approximately 10,000 people at Kerevat, Nganalaka, Vudal, George Brown, Kokopo, Gaulim/Malabunga, and Bitapaka (Figure 4.3). It was decided that it would be easier to control and manage large groups of people than small numbers of people spread over the many plantations and schools. However some smaller evacuation centres were also established. The preparations made at each of the seven centres are outlined in Appendix 3.

Food. Much of the early emphasis in the evacuation plan concerned "self-reliance" and every evacuee was expected to be self-sufficient for at least the first few days after evacuation. As it became evident that food would be provided for many evacuees by their employers, this policy broke down to some extent and was officially abandoned even though much of the rhetoric remained. In October 1984 Doyne Hunt, an Australian disaster consultant who had been involved in formulation of many aspects of the 1984 revised version of the Disaster Plan, wrote a very critical review of the Food Plan. The main problem seemed to lie in the plan to feed some but not all of the evacuees, and the lack of organisation for each evacuation centre, particularly for components such as health, welfare, food, shelter and hygiene. Hunt emphasised the need to treat evacuees as normally as possible, and for the command at the evacuation centres to lie in the hands of those who lived there - in most cases school teachers and administrators.

By late October the basic food plan had been altered; the strategy now was to feed 60,000 people for seven days. In the Plan staple foods such as rice or root crop (kaukau, taro or yams) were given Priority 1, protein-rich food such as tin fish or meat, Priority 2, and vegetables and energy rich foods (fats or oils - most people use coconut), Priority 3. The estimated daily costs of feeding 10,000 people are presented in Table 4.2. Alternatively, an Electricity Commission document gives the needs of a family for one week as 5 kilograms of rice, 4 tins of fish, 4 tins of meat, 2 kilograms of sugar, 1 tin of milo, 1 bottle of coffee, 500 grams of tinned milk, 1 packet of tea, and 500 grams of salt. The total quantities of food required to feed 60,000 people for seven days and the costs involved according to PDC estimates are presented in Table 4.3.

Figure 4.3

Distribution of facilities and projects undertaken during the seismic crisis

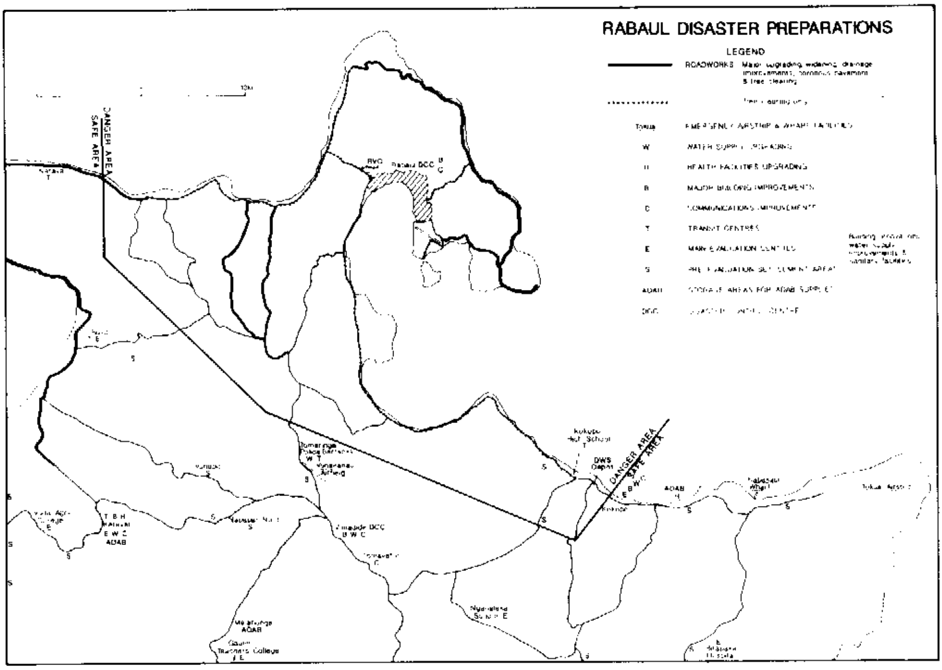


Table 4.2
Costs of feeding 10,000 people per day (November 1984 prices)

Item	Quantity (tonnes)	Cost per tonne (kina)	Total cost (kina)
Rice	4.0	510	2,040
Fats/oils	0.4	1,510	604
Tin meat/fish	1.0	3,240	3,240
Total	-	-	**5,884**

Table 4.3
Quantities and costs of storing food for 60,000 people
for seven days (November 1984 prices)

Item	Location	Quantity (tonnes)	Cost per tonne (kina)	Total cost (kina)
Rice	Kokopo	28.0	510	14,280
Rice	Kerevat	112.0	510	57,120
Fats/oils	Kokopo	2.8	1,510	4,228
Fats/oils	Kerevat	11.2	1,510	16,912
Tin meat/fish	Kokopo	4.0	3,240	12,960
Tin meat/fish	Kerevat	28.0	3,240	90,720
Total				**196,220**

Source: Tables 4.2 and 4.3, ENBDC 1984.

All food stored in the safe areas by the wholesalers was to be sold at retail prices as this would create financial incentives. The government was to provide transport subsidies for the movement of food. The departments of Primary Industry and Commerce were to purchase food from the wholesalers on request from evacuation centre co-ordinators and to deliver it to the evacuation centres.

One of the basic problems with the food plan involved the storage of rice at Kokopo and at Kerevat, as rice does not last for any length of time, particularly in containers which are not covered. Eventually, most wholesalers had to transport the rice they had stored in safe areas back to Rabaul again.

Accommodation. The Plan also allocated office accommodation for government departments, statutory bodies and many private organisations. Most of this accommodation was in the Kokopo and Kerevat areas but it was also spread around a little. A list is provided in Table 4.4. Some attention was also paid to the problem of informing the population as to the whereabouts of each organisation so "that they will know exactly where they can get the services during the emergency and rehabilitation periods".

Table 4.4
Location of temporary accommodation

Organisation	Locations
Government offices	
Provincial Secretary	Kalamanagunan School
Division of Health	Vunapope - Kerevat Health Centre
Division of Rural Development	District Office - Kokopo Transit Centre - Kerevat High
Division of Community Development	District Office - Kokopo Transit Centre - Kerevat High
Division of Commerce	District Office - Kokopo Transit Centre - Kerevat High
Liquor Licensing Inspector	Kalamanagunan School
Regional Public Service Inspector	Kalamanagunan School
Department of Finance	Kokopo Pre-School
Rabaul Town Community Government	Kokopo Pre-School
Division of Lands	Kenabot Plantation
DPI Produce Inspectors	Kenabot Plantation
Division of Education	Livuan (North Coast)
Division of Forest	Forestry Office - Kerevat
Bureau Management Services	Cash Office - Vudal Agricultural College
Red Cross	Kokopo Show Ground - Kerevat National High School
P.T.C.	Post Office Kokopo
Works and Supply	D.W.S. Depot - Kokopo D.W.S. Depot - Kerevat
National Planning Office	Rakunai
Elcom	Warangoi Township Kerevat
Marine and Harbours Board	Vunadidir
Customs	Vunadidir
Police	Police Station Kokopo Police Station Kerevat
Magisterial Services	Court House (Kokopo) Vunadidir Police Station Kerevat
Bureau of Consumer Affairs	?
Office of Civil Aviation	Vunakanau
Cocoa Industry Board	Lowlands Agricultural Experiment Station (LAES)
Electoral Commission	?
Fire Fighting Services	Kokopo Police Station Vunakanau
Labour	Vunabakut (Kokopo)
Department of Urban Development	?
Ombudsman Commission	Channel College
PNG Development Bank	Vunamami Vocational
National Provident Fund	?
International School	Kokopo Golf Club Vunakabi, Mandras, Ulaveo

Table 4.4
Location of temporary accommodation
(continued)

Wholesalers	
Anderson Foodland	Gelagela Plantation - Kokopo
Burns Philp	Kokopo - Raulavat North Coast
Chin Cheu	Vunamami - Kokopo
Freddy Chan	Tapo - Kokopo
James Cheung	Kokopo
Steamships	Ulaveo - Kokopo
Seeto Hung & Sons	Kokopo
M & R Seeto	Vunamami - Kokopo
	Kerevat, North Coast
Paradise Bakery	Kokopo
Rice Industry	Talina - Kokopo
Other companies and Industries	
New Guinea Cocoa	Watta Plantation - Kokopo
Angco	Takubar Plantation - Kokopo
Acquip	Kokopo
Rabaul Trading	Toma Cocoa Fermentary
R.M.I.	LAES Kerevat - North Coast
Barlow Industry	Vudal
	Lassul Baining
New Britain Engineering	Putput Plantation - Kokopo
New Guinea Motors	Vunapope - Kokopo
Morgan Equipment	Ramandu Plantation
	Lassul Baining
A.S.P.	Kerevat - North Coast
Darragh Pty. Ltd.	Vimi Plantation - Kokopo
NGIP	Tokiala Plantation - Tavilo
SP Brewery	LAES Kerevat
Cocoa Industry	LAES Tavilo
Bali Merchants	Ravalian Plantation
Gabriel Achun (Soft drinks factory)	No temporary arrangement - to be closed during the emergency period
Rabaul Bakery	Ulagunan
Meriba Construction	To be completely closed down
Rabaul Engineering	Sonoma - Kapkap Plantation - Kokopo
Shell Gazelle Autoport	?
New Britain Quarries	LAES - Kerevat
Boroko Motors	Tabuna - Kokopo
PNG Motors	Vunamami - Kokopo
West Electrics	Catholic Mission - Napapar
Martin Wong & Sons	Kabanga - Kokopo
Gazelle Motors	Tibu - Kokopo
David Seeto	Wongawonga
Raymond August	Will go different location
Gazelle Agencies	Putput Plantation - Kokopo

Table 4.4
Location of temporary accommodation
(continued)

Dawapia Construction	Gaulim
Ross Engineering	Kerevat
Tanubada Dairy Product	Kokopo
R.B.M.	Kokopo
Rabaul Tyre Service	Kokopo (Works & Supply shed)
Rabaul Welding & construction	Gazelle Sawmill - North Coast
Rabaul Battery Service	Pilapila/Natawa Plantation - North Coast
Rabaul Electrical Service	Gunanur - Kokopo/LAES - Kerevat
Rabaul Refrigeration	?

Source: ENBDC 1984.

The evacuation itself. There were several concerns about the evacuation. One of these involved the capacity of the road network and the trafficability of the roads themselves during the emergency. This problem was overcome (at least in part) by the expenditure of considerable sums of money on road improvements including tree removal, widening, straightening, upgrading, and sealing. The roads involved are shown on Figure 4.3. Details of the costs of these improvements are presented in Chapter 5.

A second problem concerned whether drivers would show up at the evacuation points or merely evacuate their wantoks without returning to the danger zone. The question of whether some of the key personnel involved in the evacuation would actually turn up when the time came certainly exercised the minds of some of those in charge of the whole operation. There was concern in June 1984 that it might not be possible to evacuate Nonga Base Hospital quickly if the Volcano Alert went straight from stage 2 to stage 4. The main problem appeared to be that it might be difficult to persuade some drivers to evacuate patients rather than wantoks and it would then be difficult to persuade staff to stay to evacuate patients when transport out of the danger zone could not be guaranteed. A purely practical problem was finding some of the personnel in a hurry as their addresses were not always known.

It has been suggested that one of the reasons that the Defence Force contingent was called in was to counter such potential problems. A Defence Force contingent of 301 men was present in Rabaul from late February 1984 but this was scaled down to 102 men in late April 1984. Before the scale-down most of the major tasks given to the Defence Forces had been completed or partly completed. These tasks included the establishment of the evacuation centres, water testing, accommodation area survey and population census, numbering and location of pickup points, establishment of the Malaguna evacuation route, tree clearing on the main escape routes, land surveys in Kerevat and on the North Coast, and plant operations to assist the Department of Works and Supply in resurfacing of the escape routes.

Evacuation exercises. One way of tackling problems and potential problems was to hold evacuation practices. These occurred on 20 June 1984, 26 September 1984, 20 February 1985, 23 October 1985, and 6 August 1986.

On the whole the exercises went fairly well. The emphasis here is on the problems identified as a result of these exercises; but there can be no doubt that these practices played an important role in establishing the likely success of any "real exercise" in defining the roles of those taking part, and in integrating the various complex parts of the evacuation process.

Problems identified during the 20 June 1984 exercise included: (1) the Vunadidir Operations Centre was locked; (2) the radio room had no power points; (3) there were radio interruptions from outstations to begin with and then the outstations switched off and so couldn't be contacted; (4) one convoy to Vunamami Training Centre got lost - Defence Force drivers were identified as the problem as they did not know the locations and evacuation routes; and (5) too many officials treated the exercise too casually.

Several potentially serious accidents nearly occurred during this exercise because of government officers speeding while taking part in the exercise. The worst offenders were identified as Defence Force drivers, DWS truck drivers, and Health ambulance drivers. This led to the promulgation of speed limits for evacuation convoy vehicles of 50 kilometres per hour on sealed roads and 40 kilometres per hour on unsealed roads.

In simulation exercise "Mauden Paia" on 20 February 1985, 6,360 people were evacuated to three transit centres in 4.5 hours utilising 50 vehicles and two barges. Some evacuees used walking tracks. As a result of this exercise it seemed necessary to use seventy-five vehicles rather than fifth, and to fully utilise sea transport as barges could carry 800 each, and trucks only twenty-five rather than thirty-five. It was also recommended that pick-up points in the blue zone (at Baai, Boisen, Korere) plus Talwat and the Nonga and Tavui areas should be evacuated by barge. In this exercise, in contrast to the June 1984 practice, radio operations worked well.

The "Punuongo na Kaia Exercise" (23 October 1985) was judged as successful and many aspects clearly went very satisfactorily but it seemed that radio operators still needed more familiarisation with radio usage - a further exercise was proposed for them. However, communications in general seem to have been successful, particularly with the pick-up points in the blue zone as a result of locating a relay on a vessel between the Duke of York Islands and Korere. Nonga Hospital was slow to evacuate. There was a certain level of complacency in some departments and divisions. It also became clear that the evacuation plan needed to be reviewed and simplified. As a result of this exercise it appears there might also have been some antagonism between at least some members of the Disaster Committee and Defence Force personnel.

Evacuation for a large eruption. It seems clear from the Disaster Plan, which is regarded internationally as a very good disaster plan, from the evidence of careful thought having gone into the preparations for evacuation, and from the attempts to grapple with problems through repeated evacuation exercises that, when an eruption occurs, a successful evacuation of the populace at risk will be undertaken. The likely success of the operation can be seen as a benefit of the extended 1983-85 seismic crisis.

However, one major doubt remains about the evacuation plan - that is, the action necessary should the eruption be a large one (a risk of less than 5 per cent as described in Chapter 2). Although Chapter 8 in the 1985 edition of the Disaster Plan deals with a Larger Eruption & Extended Evacuation, this section appears to be much less carefully thought out than the earlier sections. It is also based on the assumption that the limit of damage in a large eruption would be within a 23 kilometre radius of North Daughter. An examination of Figure 2.2 and the discussion in Chapter 6 below suggest that this view may be an optimistic one.

It is interesting to note that in all the minutes and correspondence sighted there is almost no discussion of the possibility of, or planning for, a large eruption. Although this might seem sensible given the probabilities involved, our view remains that a detailed contingency plan is necessary should this unlikely event occur. One prominent member of the NDC believed that sea or air evacuation would be impossible in the conditions prevailing after a first (small-moderate) eruption and that the only viable options were evacuation by road through the Bainings to Open Bay and through Warangoi to the Wide Bay area. Further comments on this difficult problem are made in Chapters 8 and 9.

Organisational preparations

It is clear from the details of the preparations for evacuation presented above that many governmental and private organisations devoted enormous amounts of energy (and money) in early 1984 to preparations for the temporary abandonment of Rabaul and the saving of lives in the event of an eruption. It is worthwhile considering the efforts made by two organisations, the PNG Electricity Commission (Elcom) and the Department of Civil Aviation (DCA), as they illustrate quite different responses to the problem, even though both organisations had large capital investments at risk. Neither organisation was represented on the PDC.

Elcom. By mid-March 1984 Elcom had prepared evacuation quarters for staff and families at Warangoi and Kerevat, including latrine pits, fuel, furniture, water tanks and showers etc. Eight two-room sheds were relocated from Vunamami to Kerevat. Evidently there was also an offer from Elcom to fly out families of staff to home provinces - five families were reported to be ready to do so in March.

In order to maintain supply during and after the emergency four Elcom mobile rescue teams were fitted out with oxy-acetylene cutting torches, portable welders, chain saws, axes, torches, water eskies, first aid kits, lights, radios, gas masks, safety goggles, protective gloves, A.B.S. handles, H.V. Testers, rubber gloves, link sticks and fuel containers. These mobile teams were to be located at Matalau - Nodup Community School, Toleap/Pila Community School, Navunaram Community School or Butuwin Health Centre with one team on standby at Kerevat. The four teams were rostered on 8 hour shifts, 24 hr/day.

At the declaration of stage 4 Elcom would abandon its Rabaul office and move to the Kerevat Power Station works office. Rabaul town power would then come from Warangoi via the Kerevat switchyard. If Warangoi power became unavailable for some reason Kerevat Power Station diesels would then supply power to Rabaul during stage 4. Elcom believed the main worry would be falling power poles and requested in the Rabaul Courier public assistance in reporting leaning poles and other problems.

The plan devised by Elcom - in particular the fact that the Rabaul office would not be abandoned until stage 4 was declared - rested on the principle that if the Rabaul diesel station was totally destroyed by an eruption it would not matter very much as some of the generators were more than thirty years old. The policy was to keep diesel stores low in Rabaul and high in Kerevat. As the Islands Region stores for Elcom were held in Rabaul there was no shortage of spares and no need to get in any extras. However, most of the stock of spare parts were moved out of Rabaul to Kerevat and Warangoi.

As there are no problems with deterioration of these stores they were still there in late 1986.

Civil Aviation. The Department of Civil Aviation (DCA) has three airports under its control in the Rabaul area - Lakunai (Rabaul), Vunakanau and Tokua (Figure 4.3). The latter two were upgraded as a result of the seismic crisis (see Project Details in Chapter 5). Although construction work was undertaken at Vunakanau it was designated as an emergency-only aerodrome because of its location in the hazard area. Rabaul was the Islands Region centre for civil aviation and thus responsible for Bougainville, New Britain and New Ireland.

Control over most of the Island Region airspace was transferred from Rabaul to Nadzab (near Lae) early on in the crisis. Only a thirty nautical mile zone remained under the control of Rabaul. The twenty or so DCA staff at Rabaul were reduced to about eleven and the T-Vasos Navaids system was removed from Lakunai. Early on in the crisis DCA moved the airport fire trucks from Rabaul to Lae. The Defence Force commander in Rabaul made a request to the PDC in April 1984 to ask for the return of the fire trucks on the basis that there would be a good deal of ash in the air during an eruption and aircraft would be exposed to situations in which fires occurred. He also pointed out that the DCA concern for the safety of its fire trucks could be satisfied by driving the trucks to safe areas if at any time they were found to be in a danger area. His request was evidently answered as a March 1985 official DCA document says "Rescue Fire Fighting Services will remain at Rabaul Airport until declared stage 3 when they will be deployed to Tokua."

On the declaration of stage 3 DCA would move to Tokua leaving Vunakanau and Rabaul airports for PNGDF operation and for security. As controlling authority, the Defence Force might allow some operations to continue. Services such as flight planning, aerodrome flight information service and search and rescue alerting services within the aerodrome flight information zone would move to Tokua and be available in limited form for Tokua, Rabaul and Vunakanau. At the declaration of stage 3 Rabaul airspace would be restricted to a 25 nautical mile radius and 20,000 feet. Civil aircraft would have to ask PNGDF permission to enter this airspace. DCA believed it would take perhaps a day to set up at Tokua with the biggest problem being atmospheric pressure readings for altimeter calibrations. In the interval, Nadzab air space and information could be used, particularly as it covers most of the area anyway. At stage 3 aircraft operators should move their aircraft from Rabaul Airport. Fuel supplies would be stockpiled at Tokua and Kavieng and search and rescue supply centres would be established at pre-selected aerodromes in ENBP and at Lae.

After an initial over-reaction to the seismic crisis and the declaration of the stage 2 alert DCA became well organised with the publication of an <u>Aeronautical Information Circular</u> on 14 March 1985 on Rabaul Volcanic Activity. While most of this document seems quite straightforward it does contain the following nonsensical comment about Rabaul Airport: "Depending on circumstances prevailing and <u>immediately prior</u> to stage THREE alert, it is intended that some navigation aids and <u>lighting facilities</u> will be decommissioned"!

<u>Legal aspects</u>

It is interesting to consider two aspects of the legislation concerned with disaster management in some detail as these examples indicate the breadth of planning undertaken for the anticipated emergency and some of the ramifications which can stem from emergency planning and legislation. The first aspect concerns the settlement of people in the pre-evacuation areas, and the second the legal ramifications of requisitioning transport for the evacuation.

Under the Disaster Management Act 1984 agreements could be signed between "owners" and "users" of land in pre-evacuation areas. These agreements allowed occupation for the emergency period only but the occupiers would be allowed to build temporary houses and plant food crops, but not cash crops. The users were liable for damage during occupancy and would vacate within fourteen days of notice being given.

Although some trouble was gone to to set up the legal basis of these agreements, most landowners stated that the people occupying their land were relatives and saw no problems relating to land usage.

Reference has already been made to the Emergency (Requisition) Act of 1984 which gives the controller wide powers in requisitioning vehicles, ships and machinery. This act was signed into law on 5 March 1984. Much of the detail provided here pre-dates the act but indicates the complexity of decision-making and the range of factors that had to be taken into account in framing this act and the supporting acts which are concerned with compensation and insurance.

The Office of Legislative Counsel advised the Prime Minister's Department on 21 February 1984 that the ENBDP provided for the requisitioning of vehicles and ships to assist in the evacuation of Rabaul and that it was normal for compensation to be paid in respect of items requisitioned. The requisitioning of vehicles was clearly essential to the evacuation programme and advance notice to, and the co-operation of, the public was necessary if only to ensure that the necessary vehicles were not removed far from Rabaul prior to requisition.

According to the Disaster Plan the vehicles likely to be requisitioned were 240 PMV's, 140 trucks, 130 private utilities, and 20 buses, a total of 530 vehicles. It was suggested that hire rates would range from K10 to K20 per day. It was proposed to supply free fuel with the estimated necessary amounts being 40,000 litres of petrol and 16,000 litres of diesel. It was also proposed to hire eight barges at rates varying from K1250 to K3000 per day and one tug at K300 per day. As the barges might be required for five days and the tug for seven days the total estimated cost was K44,200.

It was suggested that the usual principles of compensation in relation to requisitioned items were: (1) payment of a sum as hire charge or rental during the period for which the item is requisitioned; (2) payment of reasonable expenses incurred in connection with the requisition by the person from whom the item was requisitioned; (3) a sum equal to the cost of making good any damage caused to the requisitioned item during the period of requisition; (4) in the event of the total loss of the item requisitioned a sum equal to its value immediately before the time of loss; (5) indemnification against any claims made against the item or its owner or driver during the period of requisition; (6) no payments would be based on values inflated because of the existence of the emergency; and (7) the establishment of a tribunal to hear disputed claims. As requisitions could only be made under Emergency Regulations there would be a problem in trying to requisition vehicles before a national emergency had been declared.

It is evident that the Emergency (Registration) Act of 1984 was framed to cover most of these points but some interesting issues arose in relation to the insurance of requisitioned vehicles and ships.

In nearly all cases insurance policies provide that where an item insured is requisitioned the insurance cover is immediately withdrawn. There is also a general obligation on insured persons to minimise risk, an obligation which could reasonably be interpreted as requiring removal of the vehicle from a danger area to a safe area at the earliest opportunity.

The situation with regard to requisitioned ships was even more interesting. Burns Philp were advised by their insurers in February 1984 that neither their vessels nor the lives of those on board would be covered from the moment that they were requisitioned. In order to retain their existing cover, the vessels would have to leave the danger area as soon as stage 3 was declared. Other shipowners were evidently advised by their insurers that if, on the declaration of stage 4, their ships were not immediately removed at least 50 kilometres from Rabaul, the insurance cover would be withdrawn. Thus, it was clear that unless requisition and compensation intentions were made known in advance it was likely that the ships necessary for the evacuation of the town would be far from Rabaul when needed. The total value of the ships which might have to be requisitioned was over K7 million.

Perspectives on the insurance problem

Insurance premiums for volcano, tsunami and earthquake cover increased markedly during the seismic crisis. Acrimonious arguments between insured and insurers were not uncommon. One company had its premium increased by 129 per cent and reported the rate for fire insurance excluding volcano cover as K3.06/1000 and with volcano cover as K14.28/1000. The manager of the insurance company even wrote to the company's mortgagee indicating the possible non-payment of the premium, obviously endeavouring to get the bank to put pressure on the company to carry this insurance. Another company with a supermarket in Rabaul reported the following increases in insurance costs: 1983, K11,000; 1984, K18,100; 1985, K59,500; 1986 estimate K122, 000. In addition the insurers advised that they were withdrawing replacement coverage and would only insure for indemnity. The insurance companies estimated that their total exposure in Rabaul was about K120 million; as discussed in Chapter 3 the total value of Rabaul would seem to be about K500 million.

The discussion included in this section endeavours to present the viewpoints of both the insurers and the insured using where possible the actual words of those most involved and to outline the actions of the government.

Insurer and insured views. In June 1984 one insurance company manager wrote to the PDC to explain company policy:

> "When insuring property it is normal for the insured to purchase a basic fire or householders contract and select additional extraneous perils if required. Should a client require volcanic cover then his policy would be endorsed to include loss or damage arising from earthquake, volcanic eruption or subterranean fire. Earthquake extension excepted, most premiums have remained the same as last year with the exceptions being increases as a result of adverse claims experience, wages adjustments, government stamp duty and levy increases.
>
> "Insurance is usually a yearly contract and as such the risk is assessed from year to year dependent on current material facts and past experience by that office. Past results, experience, and trends are

considered when rating any proposal or renewal of insurance. Obviously the declaration at Rabaul of a stage 2 alert and the ENBP Premier, Mr. Ronald ToVue stating that an eruption could happen anywhere in the area within three months indicated to everyone that the behaviour of the Rabaul caldera had changed and naturally insurers and reinsurers had to reassess their premium rating for earthquake and volcanic cover.

"On 13th December 1983 the Insurance Underwriters Association of Papua New Guinea Inc. (I.U.A.) advised all members that the minimum rate applicable to cover for Earthquake, Volcanic eruption, Seismic Wave, Subterranean Fire and associated perils be 1.125 per cent in addition to existing rates and further more that this surcharge was to apply to renewals and increases in sums insured.

"Much background work concerning the rating for the earthquake extension was done well before stage 2 alert was declared. The Technical Reference Committee of the Underwriters Association first examined earthquake rates in PNG on the 16th June 1983 and both the writer and other local managers had dealings with the Rabaul Volcanological Observatory during 1983".

Extracts from a letter written by another manager in October 1985 are also of considerable interest:

"At the time apprehension in connection with this event was first raised just two years ago, my Company together with other Underwriters in Papua New Guinea, agreed to maintain in force, cover against the risks of earthquake and volcanic eruption. In the case of my own company and so far as I know, all other Underwriters, the agreement to do so was achieved only after considerable negotiation with Reinsurers subscribing to our Treaty and Facultative reinsurance agreements who were most anxious that we take the opportunity, as we were legally entitled to do, to allow current policies to lapse at expiry. Further, in the case of most of us, considerable pressure has been brought to bear by Directors who have demanded justification for our continuing to expose our Companies to an inevitable loss. Both the Reinsurers and our directors are aware that, in other parts of the world, in situations where there is threat of an inevitable eruption of an identified volcano, it is just not possible to obtain insurance of property in the immediate area.

"We examined very carefully, our exposure to loss at Rabaul and were able to distinguish between two very different types of client. On the one hand, we have substantial commitments to the insurance of the property of large trading companies and statutory corporations who have assets throughout the country and whose capital resources are unusually high. These clients are of such a type we believe they would have every chance of obtaining an alternative insurer. They have very substantial assets spread widely through out Papua New Guinea of which a relatively small amount ...... is located at Rabaul. They offer a large premium income and wide spread of risk and therefore, have some attraction to insurers, particularly to those insurers who, unlike ourselves, have no other meaningful commitment at Rabaul.

"The other class of client is the small trading company and private householder. We believe that such people would find it quite impossible to obtain alternative markets for their insurance. In the case of businessmen, were cover to be withdrawn they would have to close their businesses for most of them operate on overdraft facilities which would be withdrawn if the assets secured in relation to the credit line were not protected against volcanic risks.

"Accordingly, we have given notice to Brokers acting for clients who fall into the first group above, that we intend to lapse policies they hold upon expiry at 30th June, 1986. We believe that by giving nine months notice of our intention, their Brokers will have the opportunity to seek alternative markets at whatever terms may be available. The clients will also have time to consider whether there might be other methods of transferring the risks involved within the framework of their own substantial capital resources. ...

"What then the Company has chosen to do, is to continue to provide protection to the Papua New Guinean people and small scale industrial ventures established locally .... Whilst what we have chosen to do will obviously cause considerable inconvenience to the clients concerned, we believe it will not seriously disrupt the business activities of the township of Rabaul and its environs.

"In conclusion, I would like to record this Company's interest in assisting Government in any way that is possible, to prepare the community in ENB for the disaster it will surely sustain. We are very much in favour of supporting any measures designed to encourage the people and business houses of Rabaul to remove their assets to a safer location. In this connection, we are ready at all times to provide insurance cover against earthquake and volcanic risks at places further afield, such as, for example, Kokopo."

Another letter written in December 1985 makes some additional points of interest:

"The company has continued to carry high liabilities throughout the main period of the crisis but as general insurance normally caters for sudden and unexpected events, the more drawn out the Rabaul situation becomes there is continuing difficulty with regard to price and availability of reinsurance which must be renegotiated annually.

"Despite the current relaxation in the emergency we do believe that a new growth centre should be identified to encourage a move away from Rabaul to prevent the future loss of community property. We have some doubts that Kokopo being also in such close proximity to Rabaul with the attendant risks of ash fallout, seismic shock and seismic wave is not sufficiently clear of the danger area to provide the degree of separation required to encourage investment decisions to relocate. In addition the port facilities would be a compromise and therefore less than satisfactory to all concerned.

> "The development of an alternative township and port with significant reduction to loss from natural geophysical perils is in our view essential and would certainly be recognised by lower insurance rates."

The levies set in early 1986 for earthquake, volcanic eruption and tidal wave for the IUA and two companies are presented in Table 4.5. The three zones are shown on Figure 4.4. In some cases new policies with this cover would not be written in Zone 1 but policies would be assigned to a purchaser. More general comments which explain the reasons for rate escalation include:

> "All underwriters involved with risks at Rabaul are greatly dependent upon their reinsurers for excess of loss protection. Arrangements with the reinsurers are renegotiated annually at which time rates are struck and the scope of cover agreed for the following year. Because of the annual nature of reinsurance contracts we are not able to predict what restrictions, if any, may be imposed next year. Although we cannot therefore provide a firm assurance that insurance cover will be provided at Rabaul indefinitely, we do not at this time foresee any major difficulties".

The extracts included above indicate a number of important points and suggest that the insurers themselves were being squeezed by both reinsurers and company directors. These extracts also suggest that at least some companies worked hard to provide cover for their clients and, in some cases, probably exceeded their obligations to the insured. Nonetheless some equally compelling arguments were marshalled by the insured. As one businessman wrote to the Rabaul Chamber of Commerce in February 1985:

> "A move to Kokopo, or anywhere else for that matter, would substantially increase the insurance companies' exposure, as the new premises would have to be insured, and the abandoned premises would continue to be insured. This would effectively at least double exposure, and if as the I.U.A. representatives suggest the overseas insurance community takes the view that there will be a cataclysmic eruption, I cannot see that they would be happy to double or triple exposure. It would therefore seem to be somewhat ambiguous to be offering reduced rates for Kokopo and encouraging a move there.
>
> "If there is not going to be a cataclysmic eruption then the total exposure is far less than 120 million kina. Twenty-five per cent of the figure would probably be reasonable."

An IUA representative replied in March:

> "Certainly insurers are unwilling to double their exposure in the event of total relocation to Kokopo or elsewhere. In the event that this occurred cover would be gradually transferred from Rabaul risks to the new location during the construction period. The Association's members are unable to offer additional cover beyond the present exposure levels of K120,000,000."

Figure 4.4

The three insurance zones set in early 1986

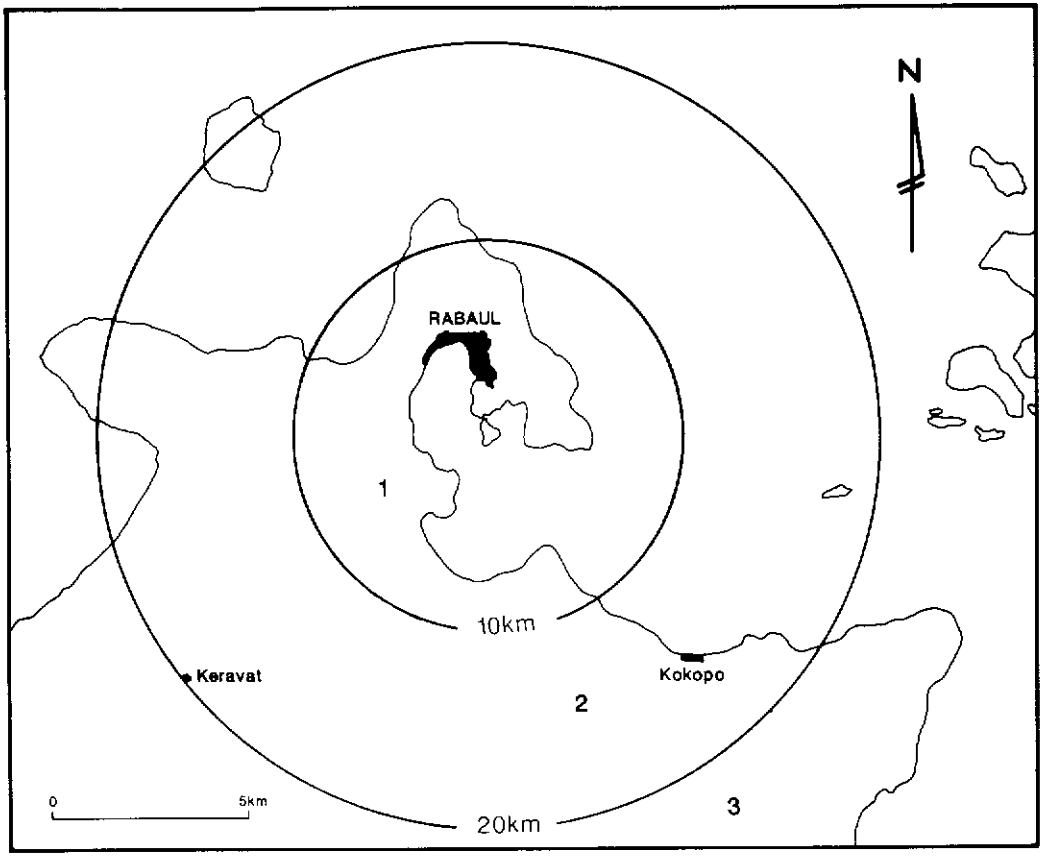


Table 4.5
Seismic risks premiums for Rabaul by insurance company and zone, 1986.

Company	Zone Inner 10 km	11-20 km	Remainder ENBP
	per cent of sum insured		
Underwriters Association (most companies)	3.5	3.125	1.10
Southern Pacific	1.625	1.35	1.10
G.R.E.	3.5	3.0	2.5

Notes:

1. GRE refused to renew any existing cover granted after 1 June 1983.

2. South Pacific refused to renew cover beyond 30 June 1986 for very large clients (mainly Carpenters and Steamships).

3. Since 1985 companies have been unwilling to grant new cover except Southern Pacific who will accept new clients outside the inner 10 kilometre ring.

Source: Insurance Underwriters" Association of PNG.

The reply to the Rabaul Chamber of Commerce also made some interesting but disconcerting comments about total loss:

> "World-wide experience dictates that a maximum probable loss of 100 per cent is always determined in respect of catastrophes. Report No. 83/17 prepared in November 1983 by the volcanologist team in Rabaul for Department of Minerals and Energy supports the view that in the event of an eruption equal to the 1937 eruption the township of Rabaul has a high risk of total destruction due to a combination of lava flows, mud-rain, flood, tsunami, and earthquake... We can only rely on the scientific data available which states that Rabaul remains on stage 1 alert but is on an irreversible course towards a volcanic eruption. In the event of an eruption seismologists advise that a 96 per cent chance exists that a likely eruption termed small-moderate is expected, which is in the range of the 1937 intensity. However, the likelihood of a catastrophic event occurring is 4 per cent so Insurers cannot discount this eventuality. Even so, the "small" 1937 eruption destroyed the town of Rabaul and killed 500 people."

The IUA's reply on this matter is disconcerting on two grounds. We do not have a copy of this declaration but a statement in the "Twelfth Information Bulletin" dated 16 January 1984 and issued to provincial and national government authorities provides some of the flavour:

"Evidence is accumulating to suggest that the volcano may on this occasion have embarked on an irreversible course towards the next eruption and that it is only a matter of time before this occurs. The length of time will depend on whether the seismic activity and ground deformation continues at current rates or increases, but in any event an eruption within a period of a few months is becoming more likely and the situation is progressing through stage-2".

As the principal government volcanologist wrote on another occasion and in a different context "I am sure you will agree that the meaning of (this) statement can be changed considerably simply by omitting the words "suggest", substituting "has" for "may have" and omitting "becoming more", which is regrettably what appears to have been done by most people when reporting on the situation". The IUA reply seems to be one of those cases.

Secondly, the IUA letter implies that the 1937 eruption destroyed the town of Rabaul. Nothing could be further from the truth; although it is difficult to estimate with accuracy the physical damage to the town, a careful reading of Johnson and Threlfall (1985) and the numerous earlier sources suggests that damage in the town was minor. Furthermore, although about 500 people were killed by the 1937 eruption, Fisher's (1939) map locates all the bodies that were recovered after the eruption. It is noteworthy that none of these was found in Rabaul, the area where almost all insured property is located; nearly all the bodies were found immediately west and northwest of Vulcan.

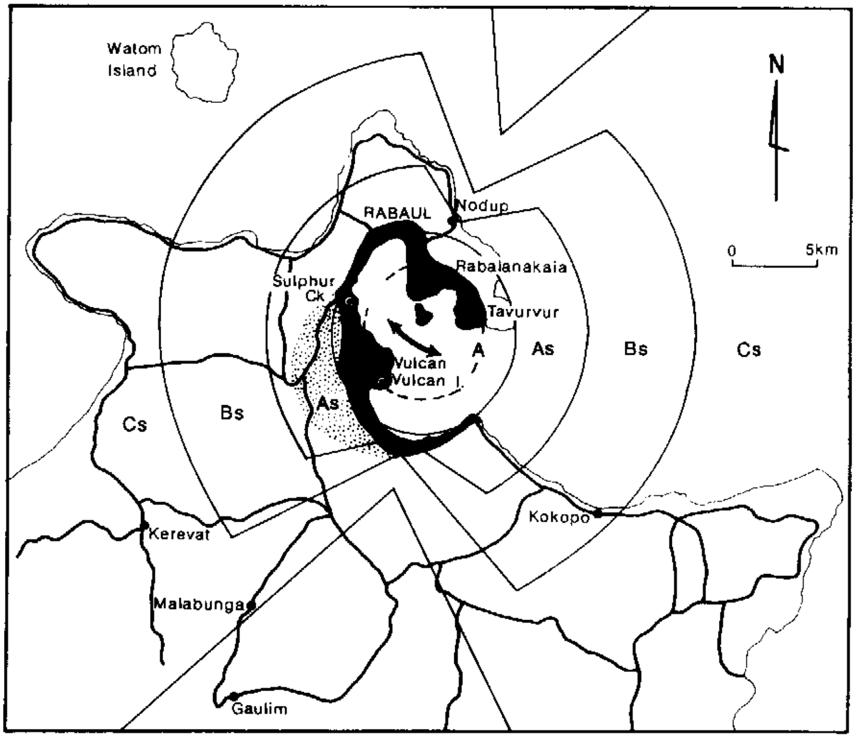
The IUA seems to have based some of its estimations of damage rates (and hence premiums) on the assumption that loss in the hazard zone 'As' (see Figure 4.5) will be 100 per cent and in 'Bs' 50 per cent. This assumption also ignores the fact that the prevailing wind will be in only one of two directions and that only half of each zone is likely to be severely affected. The earthquake loadings assumed are also too high - average earthquake intensities should have been used rather than the maxima. It appears that a typographic error also resulted in a serious overestimation of the rating.

The businessman who began this correspondence also commented astutely on the calculation of premium income:

"The method as explained is that premiums are calculated <u>worldwide</u> to cover actual losses plus contingencies. They have been taking premiums for volcanic eruption cover in Rabaul for many years. Are there no provisions in respect of Rabaul that would have been built into premiums in <u>past years, worldwide</u>? In short are we (in Rabaul only) paying more because there have been an exceptional number of catastrophes throughout the world that were above contingency levels. We are told that our premiums have been structured so that expected losses will be recovered over 50 - 60 years. Does this mean that we in Rabaul must fully bear our own losses? Are we no longer part of the worldwide pool arrangement? Is the cost of the cyclones borne solely in Fiji? Is the cost of the Darwin cyclone being borne solely in Darwin? Is this not in contradiction of the basic philosophy of insurance?".

Figure 4.5

Hazard zones described in McKee et al. (1985)



- Flowage hazard zone Fs1; dense pyroclastic flows, low-density surges, mud flows.
- Flowage hazard zone Fs2; low-density surges, mudflows.
- Flowage hazard zone Fs3; mudflows
- Historically active volcano
- Zone in which future eruptions likely to occur
- As,Bs,Cs — High, intermediate, and low risk windblown tephra hazard zones
- Seasonal winds; length of arrow signifies relative amount of time winds blow in indicated direction
- A — Zone subject to fall of heavy tephra on ballistic trajectories

Government involvement. At the same time that insurance rates were rising, the IUA was endeavouring to have some downward adjustments made. In April 1985 a letter to the Insurance Commissioner pointed out that Rabaul clients were penalised by having to pay 7.5 per cent stamp duty on their increased premiums and that the purchase of overseas reinsurance meant the payment of an additional 4.8 per cent withholding tax. In both cases, the IUA believed, the government was seen to make a windfall profit out of the misfortune of the people in Rabaul. In similar situations in Fiji the government had agreed to forgo these payments in relation to insurance against tropical cyclone damage.

The concern about insurance rates expressed by individual businessmen, the Chamber of Commerce and the Planters Association resulted in some government action. In June 1986 the government set out the view that earthquake and volcano levies in the inner zone (Zone 1) of 3.5 per cent were excessive and raised the question of use of the Prices Regulation Act to force the rates down. The government also appears to have believed that: (1) insurance companies had consistently misused and misinterpreted the scientific data provided with the use of worst case scenarios in setting rates; (2) considerable overestimation had occurred of the severity and extent of damage likely to be caused by a 1937 type eruption; (3) errors and false assumptions had been made in calculating rates; (4) there is considerable overloading in calculations both for earthquake and volcano cover, with levels probably two to three times too high in relation to the physical risks. It was suggested that a levy of 1.3 per cent for the inner zone might be appropriate. The government also believed that transfers of insurance to purchasers of property in nearly all cases should be allowed. The government also raised concerns about levels of cover, levels of reserves, cover for new businesses in Rabaul, dominance by three companies of the market in Rabaul, and the possibility of a special disaster insurance scheme.

In December 1985 a prominent firm of chartered accountants surveyed a number of business men and arrived at a general consensus: (1) insurance must be obtainable and transferable for the development of Rabaul; (2) the cost of insurance was secondary to the importance of actually having it; and (3) an increase in the excess was acceptable as long as it did not exceed 25 per cent and providing there was a corresponding decrease in the premium.

A final point which can be made in relation to premiums themselves is that while they rose markedly in response to the declaration of stage 2, with the return to a stage I alert in December 1984 there has been no corresponding fall in premiums. The effects of the increases in insurance premiums for volcano cover and the reduction in the availability of cover are considered in Chapter 5.

Chapter 5

The impact of the 1983-85 seismic crisis

Introduction

The time framework of the crisis was determined by action of the provincial government which was primarily involved in the day-to-day management of the crisis. In response to volcanological information the provincial government declared a stage 2 alert in October 1983 and returned the state of preparedness to stage 1 approximately 15 months later. Despite uncertainty, the provincial government decided that it had to proceed as if a major natural disaster could be imminent.

While governmental activity provided the framework in which the seismic crisis was played out, much of the perceived impact was felt by individuals (as individuals and as members of families and other social groups) and businesses (including agricultural production units). Their reaction depended on their specific situation and, consequently, cannot necessarily be determined without placing emphasis on strictly spatial factors.

The crisis induced many to change their residence, whether permanently or temporarily. In general, individuals received no compensation from the government or employers for the costs involved in this operation. A number of educational institutions were closed although most continued to operate with fluctuating levels of enrolment. Besides movement costs, losses would also arise from declines in property values, increased insurance charges, dislocation of economic activity and outlays on preparations to meet the impending disaster. Detail of individual reaction to the crisis can be perceived in the findings of the Kuester and Forsyth (1985) questionnaire which is discussed below.

A certain amount of information on business reaction to the crisis was obtained from copies of correspondence and other limited-circulation documentary sources. This was supplemented by interviews and the administration of a questionnaire.

Despite a disappointing response rate, the replies to the questionnaire provide a useful introduction to business reactions to the emergency. In general, the direct and indirect effects are seen as negative. Most firms estimated the amount necessary to compensate them for the past and continuing effects of the crisis at K800,000 or less. While most firms believed that their experience with the crisis indicated they could cope with a 1937 magnitude eruption a substantial minority believed that they could not. With considerable qualification, most firms expressed concern with a sense of complacency in December 1986. The questionnaire revealed that the three main areas of impact of the crisis were in its effects on costs, on the utilisation of resources, and on finance for investment.

While the measures the provincial and national governments took to cope with the crisis were described in the previous chapter, details of a number of major projects which would have an impact on the local economy are decribed below. However, the dependence of the regional economy on export commodity production prevents a quantification of the reflationary effect of this activity.

The crisis as a private event

The official perception of events is not the only possible one. Discussions with many of those involved with the events in the study area during this time indicate that many of them do not see the crisis necessarily beginning with the proclamation of stage 2 and necessarily ending with the reversion to stage 1.

Individual responses on the question of timing are part of the broader consideration that the impact of the crisis depends on the specific situations in which individuals find themselves and these situations can differ so much from person to person. Consequently, one aim of this study is to provide as much background as possible against which individual perceptions of the crisis may be appraised.

It needs to be stressed that even statements which are conventionally regarded as "factual" depend on the specific situation and circumstances of the individual. This is particularly so when trying to assess the impact of the crisis. It should be readily comprehensible that the impact, that is the balance of costs and benefits, of any event in the present depends upon the assessment made of its effect on the future and the extent of present concern about what happens in the future. While this may sound abstract and subjective it becomes concrete and objective enough if it affects the relationships between decision-makers in society, especially through the working of the market place. To give but one example, how a householder is affected by an event that affects the value of a house he owns depends on his circumstances. Subjectively, he probably places a different value on the house. Objectively, the market value may well have changed. Other factors, both subjective and objective, dictate the options open to him. In other words, the impact of the crisis depends vitally on how expectations have changed compared to what they might have been had no crisis occurred.

Of course, while individual differences have to be recognised, if only to account for the fact that common experiences are reported in different ways, many individual differences are not economically significant. Indeed, it makes sense to distinguish between those aspects of the impact of the crisis that, in general, are best understood in aggregate and those aspects where significant differences reveal themselves among the effects reported by some individuals, companies and government departments. Only some of the latter may be affected by the most economically significant advantages and disadvantages of the seismic crisis.

Individual reactions

It is known that some of the indigenous population moved out of the perceived danger areas. Some survey information from May 1984 is available in Kuester and Forsyth (1985). From a non-random sample of 273 (64 per cent males, 79 per cent persons with children, 67 per cent Tolai, 24 per cent other nationals, 41 per cent completed high school or higher education and 43 per cent in skilled employment), 61 per cent (of 252) had no family member who had moved out of Rabaul, 10 per cent had one living in a pre-evacuation centre and 2 per cent had one who had partly moved but had returned. Ignoring less significant answers, 43 per cent (of 256) had not moved any belongings out of Rabaul while 39 per cent had. Furthermore, 60 per cent (of 264) had not built a house or planted a food garden outside Rabaul, 27 per cent had done both while 6 per cent had only built a house and 7 per cent had only planted a garden.

Of course, the nature of this survey is such that it cannot include those who decided to leave the study area permanently. These would have included, in particular, expatriates who would have left for overseas (but, presumably, in many instances only earlier than they would have left in any case) and nationals (such as urban "squatters" living on the fringe of Rabaul and those working on plantations) who, again, may only have expedited an inevitable departure. In many cases there could be some mixing of private and business costs as recruitment and training costs might be expected to increase. This question is considered again when responses to the questionnaire are examined.

The responses to the survey reveal that many living in Rabaul had the option to shift residence, in whole or part, to areas outside Rabaul perceived to be at less risk. The likelihood of this option being taken up is increased by family ties with rural villages, rights of access to rural land and the good transport facilities for commuting into Rabaul for employment and shopping. It appears, also, that the Seventh Day Adventist Church was involved at this time in encouraging rural settlement by some of its adherents, many of whom are said to be still engaged in that project.

Perhaps the significant impact on individuals of the crisis is that it induced many to change their residence, whether permanently or temporarily. In general, individuals received no compensation from the government or employers for the costs involved in this operation. In some cases these were quite substantial especially where, in effect, households were being maintained simultaneously in both Papua New Guinea and Australia.

These financial losses from relocation costs were probably only substantial in money terms in the case of expatriates. Individuals would also suffer loss from an inability to sell residential property or, if they were lucky enough to find a buyer, from the reduced property values on offer. Insurance premiums from earthquake and volcano cover, if held, would rise. Beside the psychological losses associated with the impending disaster, there would be others which may also have involved some monetary losses from the dislocation to economic activity which is discussed below. There would also be costs involved in preparing to meet the disaster such as the purchase of emergency rations, torches and FM radio receivers (less liable to interference from atmospheric conditions during an eruption). Of course, it might be argued that this last kind of expenditure, while still a cost, is really part of a prudent life-style if one lives near a volcano and is not related to a particular emergency.

Business reactions

Response to the questionnaire. Information was obtained from businesses, and the private sector in general, through interviews and by means of the administration of a questionnaire. A number of firms generously allowed considerable amounts of information to be extracted from their correspondence files.

The Rabaul Chamber of Commerce permitted one of the authors (Colin Aislabie) to address a meeting and to describe the questionnaire as "The Rabaul Chamber of Commerce Member's Questionnaire". A copy of the questionnaire (see Table 5.1) was sent to every non-private post office letter box number in the study area found in the current Papua New Guinea telephone book (there is no street delivery of mail in Papua New Guinea) as well as to such other letter box numbers that could be obtained from other sources. A total of 457 questionnaires were distributed, of which 11 were returned as "not delivered" and it was known that at least eight involved businesses whose responses were included as part of a larger organisation. A total of thirty-two usable responses were received. These 32 respondents employed 2065 nationals and 106 expatriates whereas a Chamber of Commerce survey in the latter part of 1984 among "business houses" of Rabaul elicited 31 replies from "major" companies employing 1,306 nationals and 114 expatriates.

A number of factors contributed to this poor response rate. Given the limited amount of time available for field work in Rabaul it was decided that it was not feasible to develop a more useful and selective mailing list. The list used would have included organisations which were no longer in business, duplications, many who, while within the study area, would regard themselves as remote from events in Rabaul, many whose command of English would be inadequate and who were not familiar with questionnaires, and others who would regard themselves as outside the private sector or too small to be concerned with something that was in some way associated with the Chamber of Commerce. Of course, this was appreciated at the time but it was considered desirable to give as many people as possible an opportunity to contribute to the study. It should be stressed that without a local newspaper there is no way most people in Rabaul would learn of the study.[1] This also meant that the study in most cases was unfamiliar to those who received the questionnaire.[2] A final point to note is that the questionnaire (like the study in general) was circulated over a year after the return to stage 1 when many wanted to put the seismic crisis behind them. Consequently, the summary of answers to be found in Table 5.1 should only be regarded as typical of the kind of information that we obtained in interviews in Rabaul. Nevertheless, the picture these answers paint does not appear to be unrepresentative of information the authors have obtained from interviews, from perusing reports and correspondence, and from other sources.

The proclamation of stage 2 had a variety of major negative effects on business and private sector interests. Some negative effects reported in Table 5.1 (especially in Question 1, Section A Transport/Mobility) reflect costs incurred in falling in with the official policy of evacuation as the response to an expected eruption. Because of the merits of such a policy, other negative effects in this table reflect the desire of private sector businesses and individuals to protect themselves by removing some or all property and personnel from the areas of greatest volcanic hazard.

Such an "obvious" response to the seismic crisis has major indirect effects. Businesses and individuals left in Rabaul have to cope with reduced demand for goods and services and also with interruptions to supply. The former can reflect not only fewer residents but also changed patterns of expenditure.[3] The latter not only reflects departures from Rabaul but also a precautionary running down of stocks.[4]

With additional cost, lower demand and interruptions to supply, net income is likely to fall reducing the value of businesses as going concerns. The immediate effect is on cash flow because even if proprietors were going to react to reduced profitability, their likely reactions would be overshadowed by similar responses induced by concern

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1. This problem is by no means confined to this particular study. Schoeffel (1983) found considerable difficulty in contacting women's associations in the study area and was forced to make a radio plea for assistance which, unfortunately, was only taken up by United Church groups.

2. Indeed, those who were interviewed by or had attended the meeting addressed by one of the authors are disproportionally represented among the respondents.

3. For example, money is spent on emergency-related goods such as torches and tinned food and the number of shopping trips into Rabaul are reduced.

4. One of the immediate economic consequences of the crisis was that some businesses, especially in the distributive sectors, found themselves overstocked. The response to this is "not to get caught twice" and, as a result, inventory levels were kept low until confidence returned.

at the effects of a possible eruption. No-one would buy a going business or, in other ways, invest additional funds in Rabaul or its immediate hinterland.

Respondents found it much more difficult to discern any positive effects of the crisis. In general, those mentioned are incidental rather than figuring in the larger scheme of things, although mention was made of improvement to the road system and also of increased development in the Kokopo area.

While most respondents provided details of a hypothetical compensation figure to make good the effects of the crisis, a substantial minority did not. However, an examination of the completed forms revealed that in almost all cases this would have reflected uncertainty as to the appropriateness of an estimate as this group comprised "business" organisations with religious and government connections, or was a club or was located outside Rabaul, or the organisation had not been in Rabaul in 1984. In particular, the absence of an answer did not reflect an unwillingness to provide financial-style information.[5]

Of the other respondents one nominated a "nil" compensation figure and the majority of the remainder a figure under K500,000. Of these, seven nominated K100,000 or less and the others K300,000 or less. Of the six respondents not accounted for, four nominated K500,000 and another two K1,000,000 or less.

Of course, to some extent expectations as to a level of compensation would be related to size of firm. To some extent this possibility can be tested. Twenty-two of the respondents who answered the compensation question also provided information on the number of nationals and expatriates employed. Regression analysis using ordinary least squares established almost no relationship between the compensation figure nominated and either or both the number of nationals and the number of expatriates employed. Consequently, the hypothesis that expectations as to a level of compensation would be related to size of firm is rejected.

In Questions 4 and 5 other information on the effects of the crisis is sought. These answers only added to the picture being built up and suggested that this picture would not be changed by varying the precise question asked. The answers to Question 6 were more interesting. Of course, as a number of respondents commented, they were not around in 1937! The ability to cope with the consequences of a 1937 eruption is important as it is the largest historical eruption. The answers given mean that while most businesses believed (even if some qualification was expressed) that they could cope with the most likely outcome, a significant minority was not so confident. Question 7 was added because so many unsolicited expressions of concern about complacency were received. Those troubled in this respect pointed to evidence that the measures relating to information provision and a possible evacuation were not being maintained at the standard set during the emergency. It is interesting to note the extent of comment and qualification to the answers to this question. A check revealed that the answer given to this question did not depend on the answer given to the previous question. Some of the matters raised by respondents can now be examined in more detail.

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5. The only strictly commercial firm solely located in Rabaul which did not provide an estimate here did provide financial information in response to other questions. Only two organisations (one with religious, the other with commercial, connections) provided no financial information at all in its response. Both of these are located outside Rabaul and most likely did not consider that many questions were relevant to their circumstances.

Table 5.1
Response to Questionnaire

Question 1: What are the three major negative effects of the crisis as it directly affects your business?

	Answer	Number of mentions
A. Transport/mobility		
(i)	Transfer costs of equipment	2
(ii)	Decentralisation costs to ensure continuity	1
(iii)	Problem of storage out of danger zone	1
(iv)	Movement of business	1
(v)	Dislocation from movement of records	1
(vi)	Problems in arranging transport	1
B. Supply and demand		
(i)	Reduced demand	15
(ii)	Difficulties with supply	5
(iii)	Lack of development in town	4
(iv)	Reduced building demand	2
(v)	Reduced tourism demand	2
(vi)	Temporary close of business	1
(vii)	Delays in production schedule	1
C. Financial		
(i)	Decreased value of assets	4
(ii)	Uncertainty as to future	3
(iii)	Reduced rental income	2
(iv)	Inability to sell business	1
(v)	Bad media publicity	1
(vi)	Adverse impact on budget	2
(vii)	Loss of competitiveness	1
(viii)	Inability to obtain finance	1
D. Staff related		
(i)	Difficulty in attracting/retaining staff	5
(ii)	Staff uncertainty/morale	2
(iii)	Increased costs of staff repatriation	2
E. Insurance related		
(i)	Increased insurance costs	9
(ii)	No insurance for new developments	5
(iii)	No bank finance because of no insurance	1
F. Other		
(i)	Question not relevant	4
(ii)	Inconvenience/other minor side effects	2
(iii)	Security risks	2
(iv)	Structural damage/repairs	1

Table 5.1
Response to Questionnaire

Question 2: What approximate value in kina would you need to be given to adequately compensate for the entire crisis including its perceived continuing effects?

	Amount	Number of mentions
(i)	Nothing	1
(ii)	KI to under K500,000	12
(iii)	K500,000 to under K1,000,000	6
(iv)	K1,000,000 to under K1,500,000	1
(v)	K1,500,000 to under K2,000,000	-
(vi)	K2,000,000 to under K2,500,000	-
(vii)	K2,500,000 to under K3,000,000	-
(viii)	K3,000,000 to under K3,500,000	-
(vix)	K3,500,000 to under K4,000,000	-
(x)	K4,000,000 to under K4,500,000	2
(xi)	K4,500,000 to under K5,000,000	-
(xii)	No answer	10

Question 3: What are the three major positive effects (if any) of the crisis as it directly affected your business?

	Answer	Number of mentions
	A. Perceived positive effects	
(i)	Improved public awareness of adequate design for earthquake resistance	1
(ii)	Increased development in Kokopo area	1
(iii)	Improved airport/road system	2
(iv)	Evacuation planning	2
(v)	Greater financial commitment (to church)	1
(vi)	Better geographical distribution of (church) adherents	1
(vii)	Greater cost consciousness	1
(viii)	Accelerated diversification	1
(ix)	Better labour availability outside Rabaul	1
(x)	Satisfaction from being on fringe of danger area	1
(xi)	Planning for future	1
(xii)	Business adjustments	1
	B. No perceived positive effects	
(i)	Question not relevant	1
(ii)	None	18
(iii)	Additional negative effects listed	2
(iv)	Other comment	3

Table 5.1 (continued)
Response to Questionnaire

Question 4: Are there any major negative (or positive) effects of the crisis that you would regard as significant but which only indirectly affected your business?

	Answer*	Number of mentions
A. Negative indirect effects		
(i)	Evacuation costs	1
(ii)	No insurance for new developments	3
(iii)	Decline in Rabaul expatriate population	1
(iv)	Breakdown in service infrastructure	2
(v)	Reduced business confidence in Rabaul	1
(vi)	Adverse effects of damage to agriculture	1
(vii)	Increased insurance costs	1
(viii)	Decreased value of assets	1
(ix)	No prospect of further Rabaul development	1
(x)	Transport costs of equipment	1
(xi)	Long-term loss of population	2
(xii)	Changes in consumption patterns	1
(xiii)	Inability to obtain finance	1
(ix)	Lack of preparation	1
(x)	Attracting appropriate staff	1
B. Positive indirect effects		
(i)	Departure of some unemployed persons	1
(ii)	Tolerance of Tolai people	1
C. Other		
(i)	No answer to question	6
(ii)	No effects	8
(iii)	Other comment	2

Note:

* Only answers that provided information additional to that given in response to previous questions have been tabulated

Table 5.1 (continued)
Response to Questionnaire

Question 5: Information would be appreciated of any significant changes in your ability to conduct business in the area arising from changes in insurance and/or other services/facilities/attitudes, etc...

	Answer	Number of mentions
A. Negative changes		
(i)	Increased insurance costs	1
(ii)	Reduced budget for facilities, equipment and maintainance	1
(iii)	Reduced ability to borrow funds for expansion	2
(iv)	No bank finance because of no insurance	1
(v)	Inability to sell business	1
(vi)	Need to work harder	1
(vii)	Had to layoff staff	1
(viii)	Lack of confidence affects property investment	1
(ix)	Reduced insurance cover of properties	1
(x)	Reduced ability to expand	1
B. Other		
(i)	Business returned to normal	2
(ii)	Future secure provided port operable	1
(iii)	Other comment	3
(iv)	No changes	2

Question 6: On balance, do you think your business would have coped with an eruption no worse than that experienced in 1937?

	Answer	Number of mentions
A. Positive replies		
(i)	Yes (no qualification)	13
(ii)	Yes (with loss of income)	3
(iii)	Yes (with erraticity in supplies)	1
(iv)	Yes (with extra staff)	1
(v)	Yes (with compensation)	1
B Negative replies		
(i)	No (no qualification)	6
(ii)	No (because of law and order problem)	1
(iii)	No (subject to extent of damage to premises)	1
C. Other		
(i)	Unable to say	8
(ii)	No reply	2

Table 5.1 (continued)
Response to Questionnaire

Question 7: Are you concerned with any sense of present complacency as to the likelihood of a volcano eruption? (Give details if possible).

	Answer	Number of mentions
A. Positive Replies		
(i)	Yes	1
(ii)	Yes (but most would know how to cope with an emergency)	1
(iii)	Yes (but it is confidence-building)	1
(iv)	Yes (more government action needed)	3
(v)	Yes (decline in planning and readiness)	2
(vi)	Yes (decreased willingness of people to spend on preparations)	1
(vii)	Yes (because insurance money can be collected if an eruption occurs)	1
(viii)	Yes (regarding duration and magnitude of possible eruption)	1
(ix)	Yes (lack of official information)	4
B. Negative replies		
(i)	No	8
(ii)	No (we keep up emergency arrangements)	1
(iii)	No (it can actually be confidence-building)	1
(iv)	No (provided reliable information provided)	1
C. Other		
(i)	No reply	3
(ii)	Other comment	3

Assets and investment. An examination of the answers to Questions 1 and 4 in Table 5.1 reveals that besides insurance (discussed in the next section), the direct and indirect cost implications of the crisis particularly related to transport/mobility and staffing matters, without attention being focused on any particular item except the difficulty in attracting and retaining staff. As already noted in Chapter 3, many businesses have an income directly restricted by international prices (for commodities) while those that can operate on a cost-plus basis face a strictly limited size of market, part of which is considerably cost-conscious.

Mention has already been made of the reduced demand for goods and services. An extract from The Rabaul Courier dated 9 November 1984 gives one view of the problem:

"In September 1983 business around town was booming because of the high copra prices and companies were boasting of increased sales - even to the degree of as much as 30 to 40 per cent higher than other years. Stock had become a problem and the businessman rushed to the bank to secure a higher overdraft to purchase even more stock for his Christmas trade. Then stage 2 was declared with the evacuation of expatriate and nationals alike so the businessman found his extra stock sitting on the shelf with no buying public. The only thing he had was a very high overdraft with interest to match. The public did not begin to return to Rabaul until well into April and even then did not come back in the same force as previous....It is only in the last few months that Rabaul has settled to a comparatively better trading time."

It is interesting to note that the headline on the Gourier of 18 April 1984 was "Its Back to Business as USUAL".

Where the reduced demand for goods and services is sufficiently serious this would affect the extent to which the funds tied up in capital stock, such as buildings, could be employed. This was noticed, for example, in the market for rented accommodation. The crisis brought a considerable reduction in demand - it was particularly noteworthy that some firms replaced married employees with ones that were single.[6] Rental incomes from new leases more than halved. Houses became much more difficult to sell and it is claimed that some contracts negotiated at the time of the announcement of the crisis were not honoured. The position with commercial properties is a little more difficult to assess. It is clear that in late 1986 some properties were significantly run down, or at least, not used as originally intended. However, some signs of neglect appear to be more the long-term effect of independence - especially on the Chinese community - and it has been suggested to the authors that the more visible signs of the crisis itself resulted from a lack of maintenance which was being corrected in the latter part of 1986.

Although there were complaints that the capital stock was not fully utilised because of the crisis, some respondents complain of a lack of (bank) finance for new investment (resulting from the attitude of the insurance companies). Are these two points of view reconcilable? Indeed, is further investment allowed or desirable?

These questions touch on a number of interesting points. Some will be considered immediately and others in the next section where insurance is treated. Firstly, a majority of the four banks in Rabaul (Papua New Guinea Banking Corporation, Westpac, Bank of South Pacific, and Australian and New Zealand Bank (ANZ)) reported some slump in lending during 1983-84 but generally have experienced overall lending growth since 1980. Since 1984 all banks have experienced a good growth in lending. An early 1986 estimate put the total outstanding debt for the region in the order of K40 to K50 million with possibly 30 per cent totally town-based. As might be expected, much lending is in the agricultural sector with most lending being ultimately dependent on agricultural growth.[7]

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6. One estimate received by the authors was that at the height of the crisis 85 per cent of expatriate women and children had left.

7. Our impression is that the effect of an eruption on the rural economy would be less severe than on Rabaul. However, even short of a cataclysmic eruption, ash "fall-out" might affect large areas of the Gazelle Peninsula and cause temporary loss of most if not all food, copra and cocoa crops.

Another credit-granting body, specialising in vehicle and equipment leasing finance with a late-1985 portfolio of K1.75 million located on the Gazelle Peninsula, was also not willing to change its commitment to servicing its clients. While it recognised that the nature of its assets meant the risk of damage and destruction was unlikely to be significant, regular repayments of a portion of the equipment leases would probably have to be deferred in the event of an eruption. The company noted that prudent business should go on as usual as "to stand by negatively and wait for a disaster seems an unwarranted approach".

It is possible to point to evidence of an official attempt to encourage, or at least condone, increased investment. Premier ToVue wrote to the IUA in August 1985 saying that the owner of the Hamamas Hotel had been advised to go ahead and re-build the hotel because demand for accommodation was high and the service was needed by the community. In late 1985 and 1986 some building applications for Rabaul were made and some buildings opened again. Elcom was also advised to go ahead with the erection of powerlines to villages including some on Matupit Island because the services were needed while the eruption was awaited.

The growth in lending has taken place despite the fact that the other three banks have joined the ANZ Bank in requiring earthquake and volcano coverage for Rabaul-based assets offered as security. Consequently, borrowing for expansion or new investment within Rabaul requires the possession of non-Rabaul-based security. Of course, the opportunities for expansion have mainly occurred outside Rabaul in agriculture and, in particular, in cocoa redevelopment. Given the possibilities for successful investment in this area banks are prepared to take into account a proven track record since effective new investment improves the asset values of agricultural property.

Growth in the agricultural sector, plus the recovery in confidence following the non-arrival of the eruption, mean that there are opportunities for profitable business activity in Rabaul. Much of this would be enjoyed by organisations who had previously suffered from a decline in demand because of the seismic crisis. However, the very restricted availability of bank credit for urban purposes inhibits entrepreneurial activity. Those already there find it difficult to realise on their assets while those who might like to invest, or expand, in Rabaul are inhibited. Replies to the questionnaires, as well as information provided in interviews, suggest that three classes of businesses believe that they have been worst affected by the crisis. These are the more entrepreneurial-type organisations which sense opportunity for further profitable expansion in the post-crisis situation, those which stand to benefit from this expansion, and those trying to liquidate their assets.[8]

The reader might well believe that whether further investment is allowed or desirable is a much more pertinent question. However, it is more appropriate to take up this question elsewhere in this report (Chapter 9) when the options open to those with an interest in the future of the Rabaul economy are examined.

Insurance considerations. Following the declaration of a stage 2 alert, on 13 December 1983 the IUA advised its members that the minimum rate applicable to cover for earthquake, volcanic eruption, seismic wave, subterranean fire and associated perils, (hereafter called the "seismic risk levy"), would be 1.125 per cent in

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8. In regard to this latter group, it should be noted that this would include those reappraising their asset position as a normal course of business and expatriates seeking to return home.

in addition to existing rates in the highest risk inner 10 kilometre zone centred on Matupit Island (see Figure 4.4).[9] To put this in perspective, the fire policy without the cover for volcanic eruption and associated risks for one large Rabaul firm was 0.306 per cent of which 0.1 per cent would cover administration and the balance conventional risks. It should be noted that the seismic risk levy in itself was not new. It had averaged 1.0 per cent prior to the mid-1970s but had slipped under competitive pressure to approximately 0.5 per cent by late 1983. The firm referred to above indicated that their new rate of 1.428 per cent meant an increase of 129 per cent in their 1984 premium bill, implying that their levy had previously been 0.318 per cent.[10]

This initial increase was followed by a rise to 1.625 per cent in April 1984 and to 3.5 per cent in December 1986. However, the present situation is a little more complex than this suggests because of the different policies adopted by different companies. Most of the insurance business in Rabaul is shared by five companies. The rate position in 1986 is summarised in Table 4.5.

The increase in rates and, indeed, other costs, by themselves, do not necessarily represent reductions in personal and business incomes. Whether this occurs depends on the extent to which these increases in costs can be passed on. Nevertheless, given that the provincial economy as a whole has no control over the prices received for its commodity exports, the ultimate burden is likely to be borne within ENBP. Also note that the amount of coverage for the rate quoted may have declined because of the change from a replacement basis to an indemnity one,[11] which would considerably affect the actual cover on older buildings. Concern has also been expressed as to whether coverage has been affected by the decline in property values in recent years. The insurance companies also made arrangements for loss assessment in the aftermath of an eruption. In October 1984 the IUA wrote to the PDC regarding arrangements for settling claims as quickly as possible after an eruption. Arrangements including chartering of a boat, and the use of a four-wheel drive vehicle and six motor cycles, the latter to be stored in New Britain ready for use. The boat would be fully provisioned and totally self-sufficient. The Underwriters asked for co-operation to ensure that the boat, vehicles and equipment would not be requisitioned, and that access would be given to field staff (twenty in all) to differentiate between volcanic, fire, looting and other damage losses.

A firm of loss assessors was also retained to obtain copies of sale prices in Rabaul from the Department of Lands ranging over the last ten years. It was anticipated that where a contract provided for indemnity, rather than replacement, the average sale price prior to the declaration of stage 2 would be taken as a price by way of settlement. If only partial damage occurred, provided the sum insured on the property represented at least 90 per cent of the pre-October 1983 value, no contribution would be paid by the policy-holder.

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9. That is, the cover for volcanic eruption and associated risks was typically affected by way of a premium on the conventional policy applicable to householders for fire and related risks - it did not relate to other kinds of policies, for example, few firms carry "loss of profits" insurance (although when it is carried the amounts involved are usually substantial) and life insurance rates do not depend on residence.

10. The non-levy part of this account was 0.306 per cent.

11. Initial costs minus depreciation.

One problem in assessing the importance of earthquake and volcanic cover is that the crisis has affected economic activity and property values and this is independent of the policies of the insurance companies. Nevertheless, the insurance companies are perceived as bearing prime responsibility for the decline in property values as can be seen from the views of the Valuer-General's Department in Rabaul in January 1986. It suggested that increased volcano rates for businesses were likely to influence larger companies to pull out of Rabaul, and to encourage small businesses on slim profit margins to close down. As existing policies often could not be extended to new structures, plant or machinery or to improvements, investment was discouraged because financial institutions would not give mortgages or finance property development in Rabaul unless it had volcano cover. The Valuer-General's Department further commented:

> "Notwithstanding the volcano, the immediate effects of the above would be slight over the current and immediate years, but as buildings deteriorate or become outdated and uneconomical, it will eventually be necessary for some improvements and/or extensions to be made...Should the volcano not erupt in Rabaul for another 80 years, then the attitude of the insurance companies would seem to me to have just the same effect as if the volcano had erupted - their attitudes are stunting development and growth".

> "Property owners (including residences) have had to accept much reduced prices on houses in the town, whether their properties have volcanic insurance or not. Those without, have to find a purchaser with his own finance or properties in other areas which he is prepared to risk. Consequently, the demand is lower, the number of purchasers lower and the price obtained is lower. In some instances the decreases have been more than 50 per cent of what the property may have realized in 1983 before stage 2. Properties with volcanic cover are selling for at least 20 per cent less than their 1983 price, due to a sudden drop in demand".

This suggests a considerable impact of the policies of the insurance companies but note that very few transactions were actually taking place.[12] Note also the view that availability of cover not the cost is the key issue (p.81).

One point that is inclined to be overlooked is that there are disincentives in the present system for commercial self-insurers. For example, if a large organisation with a widespread net of facilities in Papua New Guinea decides to self-insure (that is, meet the costs that would normally be met by insurance cover), it would find that if it placed the monies previously used to pay insurance premiums into its reserves it would no longer be able to claim tax relief on the foregone expenditures even though it is, in effect, paying itself to insure itself. The existence of this problem has been recognised at the official level.[13]

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12. Another factor that should be mentioned is that where a property was already covered it would not be possible always to transfer the cover with the property.

13. There are other areas in the insurance field where the national government was receiving additional revenue to partly offset its additional outlays directly as a result of the crisis. For example, in early 1985 additional insurance premiums would have to pay a 7.5 per cent stamp duty and the transfer of additional funds to overseas reinsurers would be liable to a 4.8 per cent withholding tax.

Among instances of loss because of these factors can be included the case of one company which, because of a refusal to renew its earthquake cover, in February 1986 reported the loss of funding for the purchase of shares resulting in a substantial foregone opportunity. The Indosuez Niugini Bank had intended to open a branch in Rabaul but decided to open one in the Highlands instead because "the potential disaster situation connected with the Rabaul volcano led us to reassess the long-term viability of such an investment".

The crisis and the national government

Much of the direct involvement of the national government was in the provision of funds for emergency-related public works. Details of a number of these are to be found in Table 5.2 but adjusted in some cases as explained below.[14] At that stage K2,288,661 had been authorised by the National Disaster Committee (NDC) for 29 projects,[15] K1,762,330 had been committed and K1,181,212 had been spent. Because of the haste engendered by the emergency many initial estimates had to be made before any adequate investigation of what was involved was carried out. Consequently, later, the authorised vote was changed to reflect the actual expenditure by being "written up" as amounts were transferred from under-spendings to over-spendings.

Some details in Table 5.2 have been altered to reflect the recommended "written up" authorisation as at the beginning of October.[16] The figures in Table 5.2 total to K3,900,256. The attachment to the source document for this table gave a total of K4,568,710 for anticipated costs of approved works, proposed works awaiting funding and the other allocations mentioned in the table. Therefore, the content of the table can be regarded as being consistent with estimates of the cost of the emergency to the national government as being in the vicinity of K4,500,000. Since costs absorbed into departmental budgets are not taken into account, this figure should be increased by some amount to take into account the hidden subsidy to the emergency costs. A "guesstimate" might be that this subsidy is of the order of one-third of the formal costs. This would provide a "ball park" figure of, say, K6 million which may not be an unreasonable estimate for the direct cost to the national government of the emergency with almost all this money being spent in ENBP.

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14. The document used to prepare Table 5.2 is dated 16 May 1984. Attached to the copy the authors inspected was a single sheet of paper dated 30 May 1984 entitled "Financial Summary of Rabaul Disaster Preparations". Information in this document is consistent with the Progress Report but it also contained other information reflecting anticipated costs of other approved works. This information was used to provide the Additional Items and Other Allocations at the end of Table 5.2.

15. An additional project, the Warning Siren, had also been proceeded with prior to authorisation being obtained. This project was subsequently abandoned.

16. This explains why some "expenditure" amounts have obviously been "rounded up" arithmetically.

Table 5.2
Some national government financial commitments
in the study area 1983-85

Item	Amounts (kina)
Airstrips	
Vunakanau	122,536
Tokua	702,236
Wharves	
Kabakaul Wharf	156,000
Roads	
Nonga-Matalua 8 km	85,571
Matalua-Baii-Talwat 8 km	94,054
Talwat-Rapindik 8 km	40,766
Kurakakaul-Rakunai 8 km	94,878
Davaon-Nangananga 3 km	26,342
Vunavutung-Kavavar 11 km	99,109
North Coast 88 km	196,235
Burma Road 0.6 km	45,500
Utilities	
Kokopo water supply	125,596
DWS water and sewerage supplies	7,642
Reception areas	
PDC stockpile evacuation centre stores	23,076
Government stores, Kokopo and Kerevat	13,021
Kerevat Health Centre	68,800
Upgrade evacuation and transit centres	22,400
Administration	
DWS departmental costs	26,500
Disaster control centres, Rabaul & Vunadidir	44,000
Upgrade DWS depots, Kokopo & Kerevat	32,299
Evacuation preparation	
Warning siren	3,335
Tree clearing	43,000
Standby evacuation fleet	37,000
Emergency issues - rescue teams	15,143

Table 5.2 (continued)
Some national government financial commitments
in the study area 1983-85

Item	Amounts (kina)
Sundry	
DWS building supplies	33,445
DWS mobile plant spare parts	132,000
Upgrade health facilities	3,790
Volcanological Observatory works	15,572
Additional Items	
Additional road maintenance	92,000
PTC communication improvements	225,000
Administrative costs (ENBP)	60,000
Other allocations	
National Disaster Committee Standby Fund	250,000
National Executive Committee grant for police & defence force operations	207,000
Land acquisition for Tokua airstrip	912,410

Source: ENBPDC (1984).

National government project details

The purpose of this section is to provide more detail in a narrative form of projects funded by the national government. Since it draws on a wider range of sources than those used to prepare Table 5.2 it contains additional financial information to that found in that table.

Projects

Declaration of the stage 2 alert and the concerns about evacuation of Rabaul resulted in a number of projects being implemented to aid in the evacuation, to assist with accommodation of the evacuees and to provide for the eruption aftermath. Some of these projects were funded by foreign aid assistance but most were a cost on the national government. Some of the major projects are listed below with brief descriptions of their purpose and the costs involved. The costs listed generally do not include costs absorbed into departmental budgets for salaries, administration, transport or utilities. Furthermore, the costs listed do not include the NDC standby fund of K250,000, the NEC grant for police and defence force operations of K207,000, or the K32,000 allocated to the Disaster Unit by the ENBP Government.

DWS Rabaul Office Capital Works Programme including Rabaul Disaster Plan projects (RDP) totalled K2,281,000 representing a fourfold increase in capital works workload. Despite this increased load, which was undertaken without any increase in staff or other resources, 78 per cent of the expenditure was completed in the first five months of 1984.

Volcanological projects. Alterations to the Rabaul Volcanological Observatory (RVO) were completed for K18,196. The DWS Schedule gives completion date as February 1984 and cost as K23,000. Total funds committed at 10 May 1984 were given as K15,572. A separate project involving airconditioning of the observatory at a cost of K9,500 was authorised but the funds were not received before the end of 1984.

A plan was also devised for a temporary volcanological observatory at Tomavatur. This was costed at K137,500 and funding was approved by NEC but the project was cancelled. A plan to move RVO to Tokua was incorrectly reported as underway in the Post-Courier (30 January 1985) but had not advanced further by late 1987.

Another volcanological project was the Australian International Development Assistance Bureau (AIDAB)-funded installation expenses for two high precision mercury tiltmeters and a network of four magnetic stations (magnetometers) around the caldera. All instruments were loaned by the University of Queensland. AIDAB was also to fund the costs of processing the results. The tiltmeters were installed in the Sulphur Creek vault next to the Rabaul Golf Club. These instruments were so sensitive that they could detect the movement of cars in the golf club car park! Results were telemetered to RVO and then transmitted by satellite to the United States of America and then to the University of Queensland. The new magnetometers were installed at Vulcan, Matupit Island and Tavurvur to supplement an earlier one located at Rabaul Airport. Each magnetometer cost A$25,000 and provided a major improvement in the ability of RVO to monitor changes in the magnetic field and stress variations caused by magma forcing its way toward the surface.

Monitoring efforts were also improved by electronic tilt measuring equiment provided by New Zealand, the installation of this equipment and the setting up of an electronic distance measuring network by the United States Office of Foreign Disaster Assistance, and the provision of a mobile seismic array by Japan. Monitoring was also to be enhanced by the installation of three tide gauges on piles in Blanche Bay, one at Rabaul main wharf and one at Kabakaul Bay. These five gauges would allow ground deformation in the caldera to be monitored. The estimated cost of the tide gauges was K18,000, but the instruments themselves worth about K25,000 were not installed until September 1987.

A request from the Government of Papua New Guinea to the United States Office of Foreign Disaster Assistance for provision of a mobile volcano observatory was rejected. This means that RVO has no emergency monitoring facilities to fall back on if the observatory is disabled by a small to moderate eruption. In effect, RVO would then be unable to give any warning of the possible escalation of a small-scale eruption to a large-scale caldera collapse.

In all, RVO benefited to the extent of more than K0.5 million during the period 1983-87 as a result of the seismic crisis. However, it is interesting to note that despite this considerable expenditure on upgrading RVO equipment, in 1985 RVO faced equipment maintenance problems as a result of a lack of funding and staffing shortages.

Airport projects. Vunakanau airstrip was upgraded, made operational and capable of accepting Hercules C-130 aircraft in March 1984. Cones and windsocks were to be provided later. The project was completed at a cost of K119,324 but in September 1984 DCA and DWS recommended that Vunakanau be closed.

Land acquisition for Tokua Airstrip cost K912,410. The major construction at Tokua was completed during September 1984. Expenditure to the end of 1984 was K779,437. Additional costs were incurred at Tokua because of the delay in debris disposal and minor improvements required to the approach road. An additional amount of K65,000 was required at end of 1984. Upgrading of the Tokua access road would also cost about K500,000 at a cost of K50,000/km over flat country. The DWS were to establish a labour line at the airstrip to maintain it and to provide security.

Wharves projects. By the end of 1984 expenditure on Kabakaul wharf had been K135,259. Work was stopped on the wharf at the end of March 1984 pending a hydrographic survey to ensure that coastal barges could access the site. As a result of this survey, the scope of the project was increased and work recommenced in June 1984 on extension, dredging and piling. Work continued at the end of 1984 to repair damage by heavy seas and to install navigational aids including front and rear leads on the wharf and marker piles on the reef.

Although not a volcano-related project, in the last few years about K1 million has been spent on the Rabaul wharf in order to upgrade its seismic resistance.

Road projects. The 8 kilometre Nonga-Matalau Road project (Figure 4.3) was completed by the end of March 1984. Actual expenditure was given as K71,695 and the final commitment was estimated at K85,571. The Matalau-Baai-Talwat Road project (8 kilometres) was completed by the end of April 1984 with an actual expenditure of K60,551 and final commitment given as K94,054. Upgrading of 3 kilometres of the Talwat-Rapindik Road was completed by the end of February 1984. Actual expenditure was K40,222. The Vunavutung-Kavavar Road project of 11 kilometres was completed by the end of April 1984. The actual expenditure was K90,690.

Expenditure on the upgrading of the 33 kilometre Kurakakaul-Rakunai Road to the end of 1984 totalled K122,126 plus an additional expenditure of K28,840 on a reinforced box culvert at the junction with the North Coast Road to solve the flooding problem. A one kilometre re-alignment at the northern end was delayed by land negotiations.

Although it was intended to upgrade 3 kilometres of the Davaon-Nangananga Road this turned out to be not feasible and it was decided to use it as a walking track (and possibly four-wheel drive) escape route. Actual expenditure at the end of January 1984 was K14,078; final commitment K26,342.

The upgrading of 33 kilometres of the North Coast Road was completed by the end of 1984 with an actual expenditure of K196,235. This work had a lower priority than other road improvements as the road was in a reasonable condition. Coronus stockpiling and tree clearing progressed but earthworks did not commence until all other road projects were financially completed and the remaining funds identified. Maintenance for 1985 was estimated at K4,000 per kilometre for 43 kilometres, i.e. K172,000 per year.

The Burma Road diversion of 0.6 kilometres was also completed by the end of 1984 with an actual expenditure of K45,500. The provision of a footpath 0.6 metres wide on Tunnel Hill was to cater for evacuees from Rabaul moving on foot up Tunnel Hill and to reduce congestion on the two-lane road. The estimated cost at the end of 1984 was K34,000. One of the arguments for the need for this footpath was that there was a possibility that Burma Road would be closed thus producing heavy foot traffic.

These extensive and expensive road works have created a problem for the provincial government in that it now has to maintain upgraded roads to better than normal condition until an eruption occurs. The extra maintenance cost was estimated at K92,000 (46 kilometres of road at K2,000/kilometre) for the remainder of 1984.

Utilities projects. When the Defence Force checked early in 1984, all the water supplies in the safe areas were found to be contaminated. DWS proposed to improve and install water supplies at the transit (registration) centres, the major evacuation centres and in the pre-evacuation settlement areas. It was hoped that funding could be obtained from foreign non-government organisations. This was largely unsuccessful.

At the end of 1984 the erection of a fence and surfacing of the access road completed the Kokopo Water Supply Project. Actual expenditure to the end of 1984 was K126,000. This work involved the completion of Bore No 3, pipe work, and the construction of a pump house and storage tanks. A temporary public watering point had been provided in January 1984. Other DWS water and sewerage supply projects were suspended after an expenditure in 1984 of K8,998.

At Tomaringa the upgrading of water supply and sewerage works at the Police Depot cost K6,000 to the end of 1984. Other water supply improvements had a total estimated cost at the end of 1984 of K76,262 of which K10,000 was provided by a Canadian organisation, and K8,442 by the Human Assistance Program. There may be some double-counting in these estimates. The actual expenditure at the end of 1984 was K19,500.

Reception area projects. The PDC stockpile of Evacuation Centre Stores was completed by the end of March 1984 with an actual expenditure of K23,076. The provision of shelving and security for government stores provided by AIDAB at Kokopo and Kerevat was completed in June 1984 at a cost of K13,087. At the Kerevat Health Centre, construction of a ward and a maternity wing cost K65,800. The upgrading of evacuation and transit centres was completed in April 1984 at a cost of K28,476 although at that date the digging of pit latrines by institution students and Corrective Institutions Service inmates had not been completed.

Administration projects. Departmental costs incurred by DWS on a new mobile radio network cost K22,579 to the end of 1984 but further expenditure in 1985 was anticipated pending the outcome of a NDC communication working group report. Upgrading of the DWS depots at Kokopo and Kerevat incurred an expense of K32,655 in the first half of 1984.

Upgrading of the alternate PDC at Vunadidir cost K41,037 to the end of 1984, although most of the work except for the installation of a standby generator was completed by March of that year. Later, Doyne Hunt recommended additional work on the radio/communication rooms.

Evacuation preparation projects. A warning siren arrived from the United Kingdom at the end of May 1984 and underwent coverage tests in mid-June. This high-power (S150) siren cost K4,567 but still left a major deficiency in the overall warning system. FEMA (the United States Federal Emergency Management Agency) reported that with the largest siren available (at a possible cost of K150-200,000) the topography would still leave blind spots at Nonga and Talwat which could be covered by radio or gas-operated sirens. It was agreed in September 1984 that more information and survey was required before going ahead with a siren warning system. One view was that it was unnecessary anyway.

Trees were cleared from along the edges of all the main evacuation routes to prevent the roads being blocked by falling limbs, a very common occurrence during the ash-fall (and earthquakes) of 1937. The expenditure in 1984 totalled K43,000 and there was an additional need for minor clearing in 1985 around the evacuation pick-up points.

The cost of maintaining and running the twenty vehicle evacuation fleet during 1984 was K36,744 and it was estimated that maintenance of a fleet of twenty-six trucks in 1985 would cost K83,000. At the end of 1984 the PDC was still waiting for Chamber of Commerce reaction to the proposal that the private sector provide approximately twenty-four trucks to supplement the DWS fleet. Later in 1985 the problem of maintaining the evacuation fleet was resolved by placing nineteen vehicles in the government auction with the hope that if the situation changed the fleet would be restored again. Breathing apparatus units were purchased for the rescue teams together with some other supplies at a cost of K16,500 but there was a delay in the supply of some items and the project was suspended before the end of 1984.

Sundry projects. In 1984, K28,253 was spent on DWS building supplies but the project was suspended before the end of the year. Another K1,000 was spent by DWS for the printing of forms. An additional amount between K67,000 and K144,000 was spent before May 1984 on DWS mobile plant spare parts. In November 1985 the PDC decided to sell these spare parts which had been purchased for the Kokopo and Kerevat DWS depots as the parts were becoming obsolete and had depreciated in value since purchase. Funds from the sale were to be kept in a trust account until needed.

An expenditure on evacuation centre stores of between K5,565 and K18,000 was made in the first half of 1984. In June the stock was described as 90 per cent complete but awaiting the supply of minor items currently out of stock in government stores and private suppliers. Eventually requirements were revised downwards due to a reduction in the number of evacuation centres and the non-availability of some items. Nearly K10,000 was spent upgrading health facilities at Vunapope. The facilities provided included a mortuary and a casualty clearing station.

The impact of governmental activity

Because this report is concerned with the impact of the crisis on the study area it is not appropriate to provide a detailed analysis of all government-related crisis activity including its financial ramifications. It is quite clear that whatever the impact of this activity it was concentrated in the first part of 1984 when most of the adjustment to the crisis situation took place.[17]

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17. After about July 1984 there was a tendency to defer even authorised expenditure on the grounds that the situation had stabilised. For example, there were no more orders placed for the building supplies mentioned in Table 5.2.

The effect of this additional spending in ENBP was to mitigate partly the deflationary impact of other factors which were inducing a fall in demand. There appears to be no doubt that some businesses, at least, did suffer significant falls in demand. It is difficult to determine the extent to which the private sector benefited from this increased government expenditure but the benefits would have been concentrated on firms doing work relevant to the emergency. For example, the funds discussed in Table 5.2 would be expended by the government but suppliers and contractors would receive some benefit. In addition, there would be the usual multiplier effects from these expenditures. In examining tables in Chapter 3, such as Tables 3.13, 3.15 and 3.16, it must be recognised that the level of economic activity would fluctuate for reasons other than the seismic crisis (commodity prices for example) so that it would be imprudent to point to anything in these tables as evidence of the impact of increased government expenditure.

Conclusion

The 1983-85 seismic crisis undoubtedly had a major impact on the economy of the study area. But, for reasons discussed in Chapter 3, the limited impact of the crisis on commodity production restricted the immediate and continuing impact of the crisis. While the crisis cast a considerable gloom over the present and future outlook for Rabaul, it would take an eruption considerably more serious than the largest historical event (in 1937) to eliminate, or even significantly affect, the rural sector in the study area. Indeed, as touched upon in Chapter 3, among the problems of this sector - the recovery of production in the plantation sector, the improvement of production in the smallholder sector and more development in a considerable part of the province - the threat of an eruption needs to be put in perspective. There is a sense in which the impact of the crisis reinforced conclusions that are obvious about the physical reality of the situation - Rabaul is located in both the best and worst of positions.

Chapter 6
Scenario One

Introduction

The scenario presented in this chapter is based on the hypothetical occurrence of an eruption in the late 1980s equal in magnitude, and similar in style, to the 1937 eruption at Rabaul. The reasons for the selection of this eruption as one of three models of a future eruption have been presented in Chapter 2.

The chapter begins with a brief review of the 1983-85 seismic crisis pertinent to the development of the scenario. This is followed with a description of the sort of precursor phenomena which might be expected and an outline of the hypothetical eruption. The latter is based, in part at least, on the historical accounts of the 1937 event contained in Johnson and Threlfall (1985). This scenario also forms the basis for the early stages of the eruptions modelled in Chapters 7 and 8. The emphasis here is on the types of volcanic hazards experienced and the areas affected by them.

The following section provides estimates of deaths and injuries in each hazard zone. These estimates have been compiled in a spreadsheet using census data on the population resident in each area with adjustments for the success of the evacuation prior to the start of the eruption and the likely death and injury rates for each hazard for those remaining at risk. A range of estimates is provided. The census data are also used to estimate the number of houses at risk in each area. A similar approach, using different damage and destruction factors for each type of volcanic hazard, is then used to estimate the effects of the model eruption on dwellings. Again, a range of estimates is provided.

In the next section the effects of the eruption on commercial buildings is estimated using a similar approach. Our emphasis is on insured buildings in Rabaul as it is these structures about which we had available the most information. In a final section we examine the effects of a 1937-style eruption on the most important agricultural crops cocoa and copra.

Rabaul in 1986

As described in Chapter 5, the 1983-85 seismic crisis had profound effects on Rabaul. Some people left never to return. Many nationals moved out to bush blocks around Kerevat and Vudal to re-establish gardens on the government land that had been leased to local government councils in the 1950s.

The PDC met on a weekly basis. Purple, red, green, blue and yellow evacuation zones (Figure 4.2) were declared, the colours indicating priorities in evacuation and, in the case of blue and yellow, a dependence on the wind seasons. A disaster plan which focused on evacuation in the event of a 1937-size eruption and the associated emergency was formulated, modified, tested (in part) and updated. A number of disaster subcommittees were set up to work on the continuation of government services, education, law and order, operations, evacuation transport, health, public utilities, and the voluntary evacuation centres.

Defence Force personnel were deployed to Rabaul with a wide range of tasks associated with evacuation centres and evacuation routes. A major disaster centre was established at Vunadidir, complete with desks, status boards, telephones, telexes and ceiling fans, so that emergency efforts could be properly co-ordinated after Rabaul was abandoned. A free weekly newspaper, the Rabaul Gourier was started in May 1984 with a circulation of 5,000 in an effort to control rumours and to provide accurate information and background material for residents of the district. A new airstrip was built at Tokua. Aviation services at Rabaul were downgraded to the extent that it was no longer the main Islands Region airport but just a local strip with control over only a 30 nautical mile radius airspace, regional control passing to Nadzab. A new wharf was built at Kabakaul. Several roads were widened, provided with a coronus pavement or sealed, and cleared of overhanging trees so that the evacuation would not be slowed. Water supplies and toilet and health facilities at evacuation centres were improved. Stockpiles of tarpaulins and other goods were made.

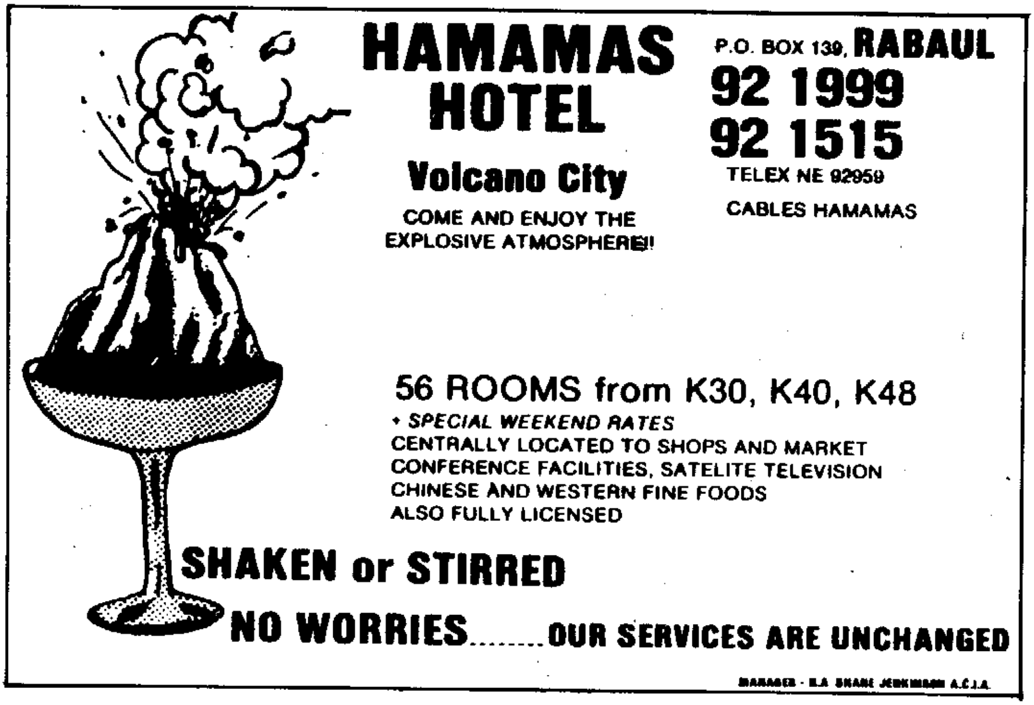
Nationals from provinces other than New Britain and New Ireland were surveyed with a view to repatriating them. The Volcano Observatory benefited from grants of aid and personnel which allowed upgrading of some of the instrumental network and analytical facilities. Public utilities made plans for the provision of electricity, radio broadcasting, and postal and telephone services. Commercial enterprises considered relocation, particularly to Kokopo; a few moved but most stayed put in Rabaul; two-thirds of the businesses surveyed by the Rabaul Chamber of Commerce in January 1985 said they would only consider moving after an eruption. However, there was considerable uncertainty engendered in the commercial world by difficulties in obtaining adequate insurance and finance. The Hamamas Hotel which had provided confident advertisements during the crisis (Figure 6.1) burnt down and (reportedly) could not be rebuilt because finance institutions were reluctant to lend against a structure on which insurance companies would not provide earthquake, volcano and tsunami cover. Property values fell. Government agencies pondered the move and some planning was done for a new urban centre at Kokopo-Vunapope, encouraged by the earlier recognition that Rabaul town was running out of suitable land anyway.

By late 1986, the level of awareness of the risk presented by the volcano had declined considerably. At the end of 1984 the volcano had gone back to a stage 1 alert which signalled that a possible eruption was considered to be years to months away. The Rabaul Gourier ceased publication in late 1984. The much-investigated warning siren system never had been installed because of limited effectiveness and the cost (and it would not survive an eruption anyway) and because it probably wasn't necessary. By the end of 1985 moves were afoot to sell off the spare parts that had been stockpiled for the emergency.

The PDC had moved to monthly meetings because there wasn't really that much to do and the full-time executive officer specified in the Plan (ENBDC, 1984) spent most of his time on more pressing government business. Although a limited exercise had been held in August 1986, there hadn't been a disaster practice for almost a year. Some of the citizens who had taken a leading role in formulation of the evacuation plan had left the town and it seems doubtful that some of the replacement staff had even read let alone understood The Plan. School enrolments which had declined dramatically during the emergency, particularly in the purple zone, returned to normal. The citizens of Rabaul were still interested in the volcano and trusted the judgement of those at the Observatory. Correctly, they felt confident that there would be ample

Figure 6.1

Hamamas Hotel advertisement which appeared in newspapers
at time of seismic crisis



warning time if it became necessary to leave the area. The yellow volcano information boards scattered through the town and district remained empty. The Rabaul Chamber of Commerce and the Planters' Association still pressed for insurance and financial justice but believed that commercial expansion of the town at its present site should not be encouraged. However, some of the buildings that had been closed for lack of tenants reopened and the Town Planning Division received a few applications for extensions to business premises.

The scenario

> Several maps and other documents in this section of the text indicate boundaries between various levels of hazard. It is important to note that these maps refer only to this scenario. In this scenario we are dealing with a specific situation, a replay of the 1937 eruption. Even though the scenario has been made as realistic as possible, the situations presented here are most unlikely to occur during the next eruption exactly as portrayed here - no two eruptions are ever the same. The scenario in no way supercedes information produced by the RVO or the ENBPDC.

Precursory activity. On one morning in early November in the late 1980s the RVO reported that the heavy ground shaking felt on the previous evening had resulted from an earthquake of Richter magnitude 7.9 at shallow depth in the Solomon Sea 150 kilometres southeast of Rabaul. RVO reported that the quake was tectonic in origin rather than volcanic. In Rabaul itself Modified Mercalli intensities (see Appendix 1) had reached as high as MM8 in some of the low-lying parts of the town built on recent sediments and reclaimed land and on steep slopes to the north of the town, but damage was limited to cracking of some masonry walls, and minor damage in a few stores and a score of houses where bottles fell from shelves. Small landslides occurred in roadcuttings on the western side of the caldera, and a number of water tanks failed.

Rabaul people had learnt in 1984 that earthquakes that produced slow horizontal shaking were centred a long way away. It was the ones with a vertical motion that set people to thinking about the volcano, so there was little concern about the early November "guria". Whatever the connection between tectonic earthquakes and volcanic activity, and there seems to be little agreement amongst volcanologists on the subject, some argued later that the early November event marked the onset of increasing seismicity around the Rabaul volcano.

There were only a few minor tremors (few of them felt) during the next six weeks but after that seismicity increased irregularly both in total shocks, felt shocks, and in terms of total energy. By February of the next year instrumentally detected quakes had reached 50 per day, nearly all located on the elipse believed to mark the edge of the collapsed floor produced during the large eruption about 1,400 years ago. Other monitoring of the volcano suggested magma was again moving toward the surface. Tiltmeters around the caldera showed inflation of the area southeast of Matupit. After that, in early March, seismicity and inflation virtually ceased. RVO issued a bulletin which said in part:

> Another few weeks of observation may be required to determine whether the present lull is just temporary or whether activity will increase again and possibly result in a seismic crisis or an eruption.

In March the number of instrumentally detected earthquakes totalled only 160, as low as for many months before things had become complicated back in 1983. But in the second week of April an earthquake swarm occurred, including three sharp felt earthquakes that made loose objects jump up and down. Scientists at the University of Queensland telexed to say that their analysis of data relayed by satellite from the magnetometer array around the harbour showed marked changes in the local magnetic field. The new tideguage network, despite teething problems, also showed that deformation had increased to a surprising rate. A stage 2 alert was posted in the third week of April, indicating that an eruption might occur in only weeks to months.

As there had long been a feeling amongst some members of the PDC that stage 3 might be very short or even non-existent because of all the preparatory rock fracturing and magma movement that had occurred during the 1983-85 seismic crisis, the PDC got things moving fairly quickly. The disaster centre at Vunadidir was cleaned out and spruced up. Similar activity at the office in Rabaul made it clear that nobody had paid much attention to the two centres for months. All over the Gazelle, people in responsible positions dusted off their copies of the 1985 edition of the East New Britain Provincial Disaster Plan (ENBDP). Those who read the second page wondered where the 1986 edition promised by July of that year was, and hoped that the assumption in the Plan that stage 2 would last at least a month was correct. Each of the sub-committees was reactivated, with new personnel where necessary.

During the remainder of April seismicity increased in an irregular fashion. During two of the more than MM 4.5 earthquakes, felt by nearly everyone in the town, waterspouts were noticed from the foreshore on Matupit Island. On several occasions seiches up to 400 millimetres occurred but did no damage except to grind a couple of ships against the upgraded wharf which had been designed to take seismic loads. In the last week of April, on two days the number of detected earthquakes exceeded 1,500. Dead fish were found floating near the shore on several occasions.

On the southern end of Matupit Island the surveyed lines showed a total uplift for the whole of April of 250 millimetres with nearly half of this total occurring in the last six days. Some quick calculations suggested that the addition of magma to the reservoir believed to be southeast of Matupit Island since 1983 was about 65 million cubic metres. There were unconfirmed reports of some very warm patches of ground and sulphurous smells on the southwest slopes of Tavurvur.

At the PDC meeting in the first week of May, following the Volcanologist's report, two chief concerns were raised: should stage 3 be declared?; and, was there a possibility that a very large eruption might occur when all the planning was so obviously geared toward an event similar in magnitude to that experienced in 1937?

By the end of the second week in May it seemed clear that the volcano was heading toward an eruption.

Ground deformation in the Matupit Island area continued, but irregularly. Cracks appeared in the airstrip and golfers complained increasingly about minor changes in the course. The felt earthquakes increased both in number and intensity; some of the populace became nervous. The Kokopo Road and the Burma Road were both blocked briefly by landslides, the former on two occasions. A rockfall occurred one night onto the Talwat-Baai Road. Numerous cracks and a couple of hummocks had also appeared in the Kokopo Road where it ran along the edge of Karavia Bay.

Stage 3 was declared early on the morning of May 11. This put all the disaster-relevant organisations on standby, although many of them had been acting that way since the beginning of the month anyway. This declaration meant that an eruption was now deemed to be only weeks to days away. Public radio broadcasts were made every few hours (though it wasn't clear to everyone that they should be listening to the FM station) and new information was posted at the volcano information bulletin boards twice a day. Vandals axed the cable of the seismic array at Malaguna again (it had happened previously in 1984) but the rest of the instrumental network performed well. The police did not have the resources to search for the perpetrators - there were so many other things to do, especially as only two-thirds of the PNG Defence Force contingent had so far reached Rabaul. The RVO staff had been almost continually harassed by the media, especially those with home telephone numbers listed in the book, but things had been better since a Papua New Guinea Geological Survey geologist had arrived from Port Moresby to work with the Public Information Unit, providing professional liaison with the media.

Declaration of stage 3 meant that selective evacuation of those areas most at risk might begin. In large part this was hardly necessary. Although the old purple zone which had stretched northward as far as Namanula Street had been abolished because it had provided such a strong but arbitrary division, this area had largely been deserted before the declaration was made public. Many Matupit Island residents had left a week or more before and most of the families of expatriates in the southern part of town had departed on early leave or gone to visit friends on distant plantations or in other parts of Papua New Guinea. Schools in this area had already closed as many of the pupils had left. A similar but more selective evacuation had occurred in the red, blue and green zones.

Despite the relatively low level of preparations and awareness at the time of declaration of stage 2, the necessary activities had moved along well when the stage 3 notice was posted. Documents for the Declaration of Emergency and Requisition Orders had been prepared. Many excess stores, items of equipment, provisions, health requirements and other materials necessary to maintain the large evacuated population were in position in the designated safe areas. Many of the stores in Rabaul had either set up branch offices or moved their entire operations to Kerevat, Kokopo, Vunapope or adjacent plantations. While some staff remained in Rabaul or made daytime return trips to the town, their families were already residing in the designated safe areas. Similarly, many of the non-essential government workers and their families had already moved to evacuation centres.

The preparations made during the 1983-85 seismic crisis played a significant role in the high level of preparedness attained when stage 3 was declared. The long lead time had been invaluable. It was now obvious to some that the parts of the Disaster Plan that called for "enhanced training of disaster personnel" and "clearing of likely obstructions ..." were largely unworkable in the short time that stage 2 had lasted. It was the earlier preparations and training that allowed the key personnel to be reasonably confident that the evacuation plan would work; that, and the fact that an even larger percentage of the populace had pre-evacuated from the red zone than had been generously allowed in the Plan.

Within six hours of the declaration of stage 3, nearly all the remaining people in the so-called purple zone had been evacuated although not all of these had gone further than the red zone. Final evacuations of non-essential workers and their families were also under way from the red zone. Many of the self-sufficient had voluntarily evacuated. The registration desks at the evacuation centres opened but they were too late for the first several thousand evacuees. Hardly any of those who left bothered to disconnect the pipes from the house roof gutters at the point where they led into the water tanks but in most cases evacuees remembered to take with them the TC-21C small particle face masks with which they had been issued. The three rescue teams had been deployed to their bases with most of their earthmoving and other equipment except for a dozer and a grader that were awaiting major repair in DWS workshops. Government offices commenced the evacuation to "safe" area locations but were hampered by a lack of transport - many vehicles were busy on other official tasks associated with the whole emergency and others had gone missing, long overdue on return journeys to the safe areas or "commandeered" by wantoks to lift families and possessions from the town. It was difficult to find fuel for vehicles. The few stores in town still selling provisions did a roaring trade but many items were in short supply.

Six hours into the stage 3 period, the airport was closed. In many ways this was little more than a formality. Although Talair and Pacific Helicopters had still used the Lakunai strip during stage 2, Air Niugini had cancelled flights as soon as cracks had appeared in the runway and had ceased overnighting planes in Rabaul two weeks before that. The reduced fire-fighting facilities had moved days before to Tokua. Local airspace was now under the control of the Papua New Guinea Defence Force.

At the port, ships had quickly prepared to leave, their masters mindful of insurance difficulties if they remained within a 50 nautical mile zone during an eruption. Within five hours of the declaration the harbour was virtually empty except for one coastal ship that was having boiler problems. While the ship's engineers struggled valiantly with repairs half the crew left by road. Departing ships noted bubbles rising to the surface south of Matupit. As arranged, several of the ships steamed toward the evacuation points around the north coast.

At Elcom the few remaining tonnes of diesel were pumped back into a tanker and the Rabaul generating plant was abandoned to its fate. Few contingencies were made for this plant as it was regarded as surplus to the generating requirements of the Gazelle area and was more than thirty years old anyway.

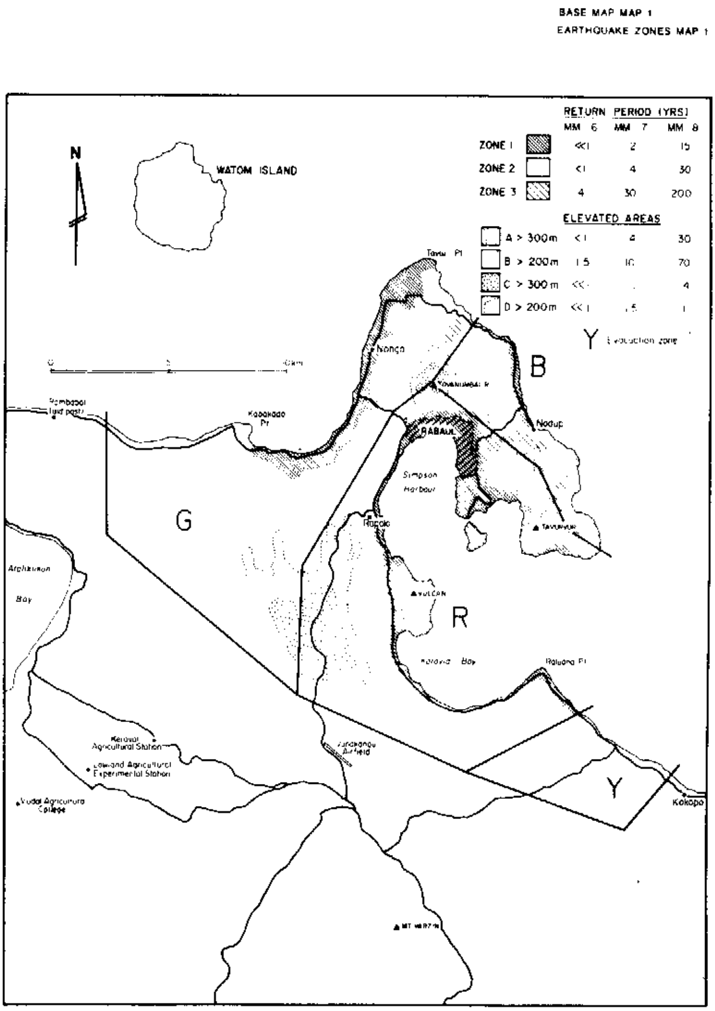
Six hours after the start of stage 3, volcanologists noted on the seismographs the beginning of harmonic tremor, indicating that an eruption was imminent. Stage 4 was declared immediately. The National Broadcasting Commission broadcast the declaration of stage 4 on both AM and FM stations and police vehicles broadcast the warning with loud hailers. The remaining people in town hurriedly left, generally with the available vehicles full. Those who made for the designated pick-up points found an inadequate number of vehicles for those waiting and many continued walking towards Tunnel Hill or Namanula Hill. Despite the continued pleas that people must help themselves and be self-sufficient with supplies for three days, many of the evacuees had inadequate rations.

The eruption began at 4.10 p.m. on the same day, May 11.

The eruption. In the last hour before the eruption began, ground shaking was almost incessant with felt earthquakes occurring every few minutes. Intensities reached as high as MM 8, causing a few frame houses to fall off their piles. Many water tanks

Figure 6.2

Zones of earthquake risk at Rabaul (after Gaull, 1979)



were damaged. Damage was concentrated at the southern end of the town but minor damage occurred on both sides of the harbour and, to a lesser extent, along the northcoast. Zones of earthquake risk (after Gaull 1979) are indicated on Figure 6.2. More than 1.1 metres of uplift occurred at the southern end of Matupit Island with 0.45 metres occurring along the shore at Rapindik. In both areas this ground deformation caused some damage to buildings. Two landslides occurred from the caldera wall onto the Kokopo Road. Rockfall from Davapia Rocks created a small tsunami which swept across Simpson Harbour inundating the western shore near the slipway to a depth of about one metre.

The eruption began at 4.10 p.m. with an area of disturbed, then boiling, water about one kilometre southeast of Matupit Island. Within minutes almost continuous explosions were heard and a column of steam and then pulverised rock and ash rose skywards to a height of several hundred, then several thousand, metres. Within minutes ash began falling on Matupit Number 1 village. By 4.30 p.m. ash began falling at the airport terminal - by this time the eruption column reached to 4,500 metres and the cloud began to fan out covering an ever-widening area within which day had turned into impenetrable blackness except for the brief illumination provided by increasingly frequent lightning.

The noise of the explosions was like the barrage of a hundred guns, except in a few areas where the explosions from the volcano were not heard. The air smelt strongly of sulphur as wet ash fell to the ground. The initial eruption was phreatomagmatic in character and most of the ejecta were fine-grained. Later, from Karavia Bay it was possible to identify a few individual blocks, more than one metre in diameter, arching out of the rapidly rising eruption column and falling toward the ground as ballistic projectiles. Such bombs fell as far as 2.5 kilometres from the vent (Figure 6.3).

By 4.45 p.m. fine wet ash began falling around the Rabaul market area and a few minutes later ash-fall began around Toboi wharf and Malaguna Number 2 as the rising eruption column penetrated into the higher level more westerly winds and the ash fanned out to the west and northwest.

By 6 p.m., two hours after the start of the eruption, the rising column of gas, ash and entrained air had reached a height of 9 kilometres. Ash-fall-induced darkness extended across more than 400 square kilometres. Watom Island was shrouded in impenetrable darkness. Nearly all areas that received more than 5 millimetres of ash-fall experienced a darkness more total than that found on the darkest night with no moon.

Figure 6.4 indicates the area on the Gazelle Peninsula that received more than 25 millimetres (one inch) of ash. A dusting of ash even occurred more than 200 kilometres to the northwest. The darkness was alleviated only by the incessant lightning flashes, the noise and echo of explosions from the vent and thunder within the atmosphere. Nearly everywhere that ash-fall occurred it was wet, occasionally with the stench of sulphur, sometimes with a salty taste. The ash-fall stripped leaves and branches and, in some cases, brought trees crashing to the ground. Repeated lightning strikes occurred even more than 15 kilometres from the vent - some trees caught fire, others were felled. In a few areas the ash fell as mud, accompanied by torrential rains which cut gullies up to 4 metres deep along the western shore of Simpson Harbour and over 8 metres deep along the north coast.

Figure 6.3

Ballistic projectiles,
1937-magnitude, May eruption

BASE MAP MAP 2
BALLISTICS MAP 2

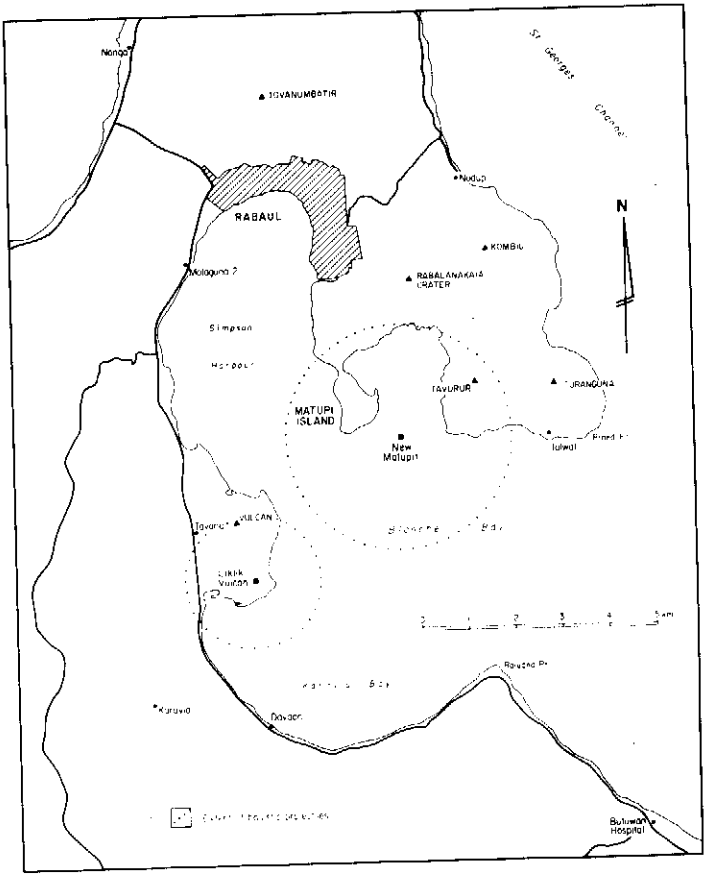
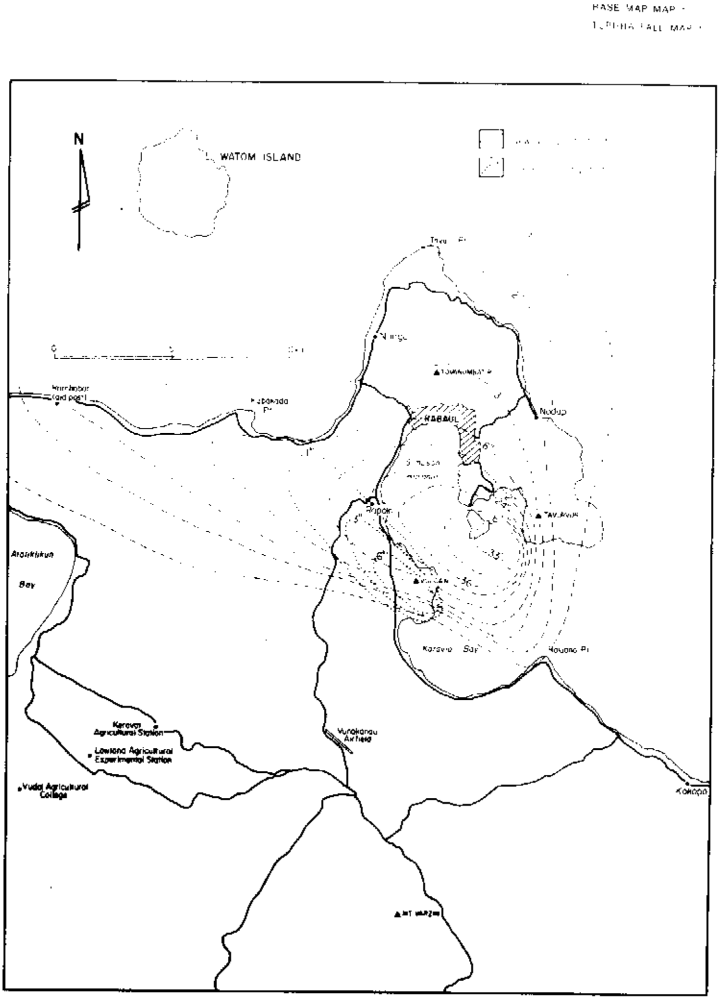


Figure 6.4

Isopach map of tephra (ash) fall, 1937-magnitude, May eruption



Around the vent itself during the next few hours pyroclastic surges (horizontally-moving turbulent clouds of rock, gas and water) radiated out from the still-submarine vent. The surges reached speeds of up to 80 kilometres per hour and distances of 4 to 5 kilometres from the vent. These were not true surges but developed where the dense fall of ash from the drifting eruption column pushed the lower part of the cloud out laterally. They were best-developed towards the northwest, reaching 4 kilometres from the New Matupit vent. In other directions they extended only 2 kilometres (Figure 6.5). These surges were cold.

However, pyroclastic flows were generated as portions of the rising eruption column collapsed, and reached speeds of more than 100 kilometres per hour. These flows were given enhanced mobility across water by the growing rafts of pumice. These flows reached as much as 2 kilometres from the vent (Figure 6.5) and attained temperatures of more than 200 degrees Celsius.

It is not clear whether the tsunami that formed in Greet-Matupit harbour were generated by the pyroclastic flows, the surges, or coupling of atmospheric shock waves with the harbour surface, but small tsunami spread out, racing onto the Rapindik shore to a height of more than 5 metres and to lesser heights in Karavia Bay and on the western side of Simpson Harbour. All but the westernmost part of the town were sheltered from the full force of these tsunami by Matupit Island which was almost half-covered by the two largest waves which came ashore between 5 and 6 p.m. Figure 6.6 shows the extent of the inundation by tsunami. The pattern of inundation was extremely complex as a result of refraction and protection by reefs. In most cases the rising water was slack water (that is, the water level rose and fell fairly gently without onshore sweeping of large waves).

The vent had begun building in more than 50 metres of water but the rate of eruption was so rapid that the vent had built above the harbour surface by 7 p.m. At 9 p.m. the cone, later to be called New Matupit, stood more than 120 metres above its base. Pyroclastic flows still moved as turbulent incandescent clouds down portions of the flank.

The eruption from this New Matupit vent lasted 27 hours but the eruption peaked in intensity during the first twelve hours. The New Matupit vent reached a height of 195 metres with a diameter at sea level of 1.3 kilometres. The cone was joined to Matupit Island but a narrow passage to Matupit Harbour remained on the eastern side (Figure 6.7).

The next morning a hazy light appeared over the northern part of Blanche Bay as the eruption decreased in intensity and much of the ash was washed from the atmosphere by heavy rains. The eruption column now rose only to 4 or 5 kilometres and there was more steam than ash though Blanche Bay was still rocked by occasional explosions and black rolling clouds were hurled kilometres into the air to the accompaniment of lightning displays and renewed ash-fall a few kilometres to the northwest, downwind from the vent. By the Tuesday morning a sheet of pumice more than a metre thick extended from Praed Point to Raluana Point, covering most of Simpson Harbour and the western part of Blanche Bay (Figure 6.8).

On the western side of the harbour, late in the morning a small column of steam arose from a point near the 1878 Vulcan Island vent. The vent began only 200 metres from the shore and about 20 metres above sea level. This vent which became known as Liklik Vulcan produced only a minor eruption by comparison with that which had

Figure 6.5

Pyroclastic flows and surges,
1937-magnitude, May eruption

BASE MAP MAP 2
SURGES & PYROCLASTIC FLOWS MAP 2

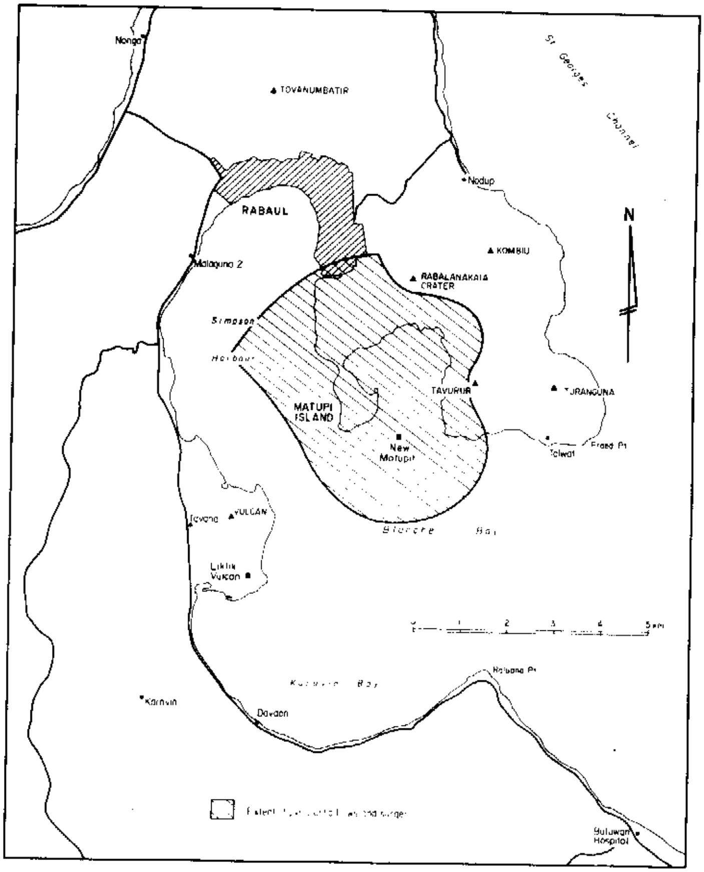


Figure 6.6

Tsunami,
1937-magnitude, May eruption

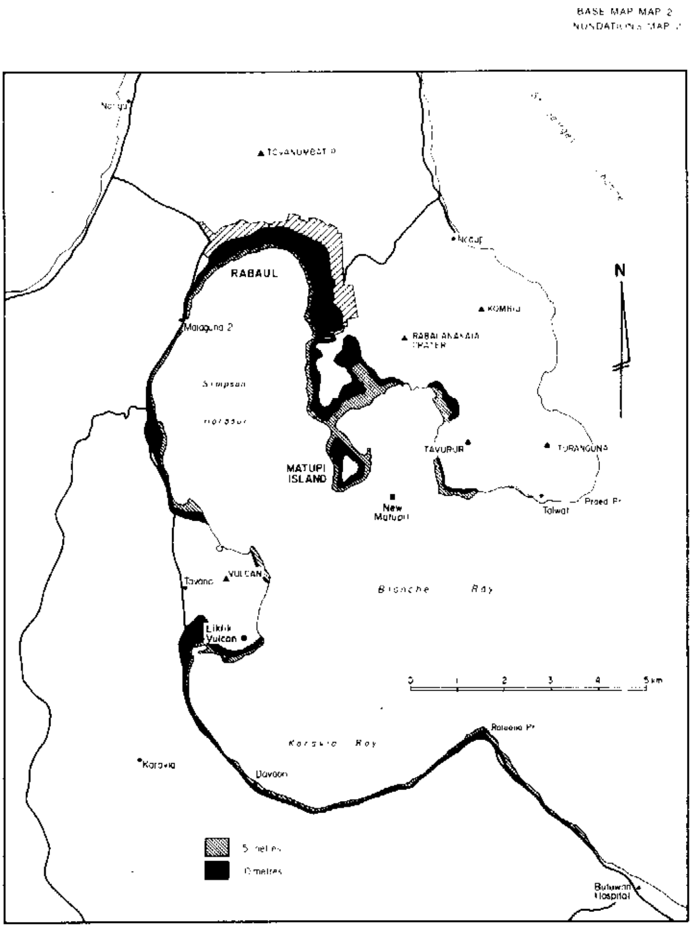


Figure 6.7

Volcanic cone growth,
1937-magnitude, May eruption

BASE MAP MAP 2
VENTS MAP 3

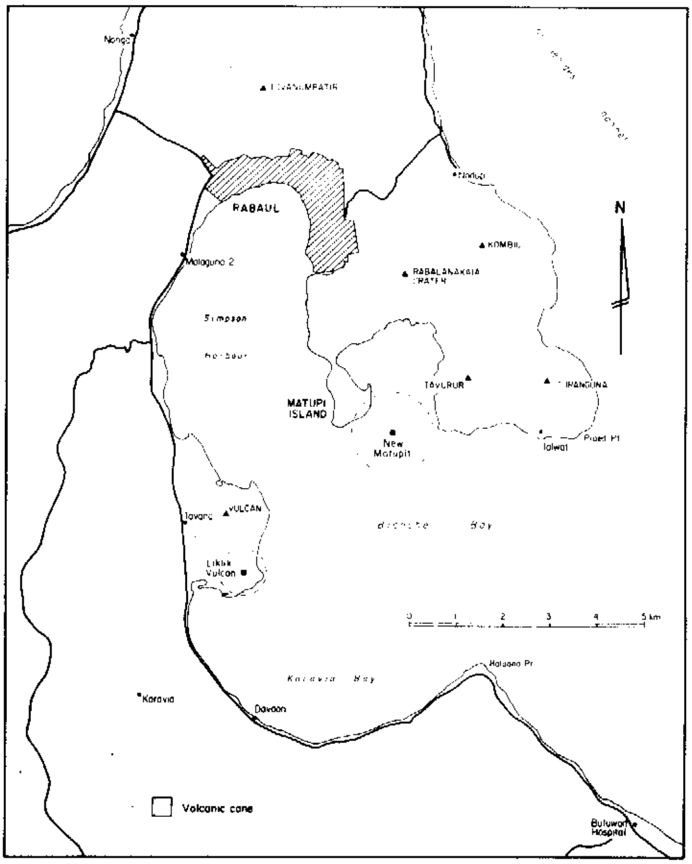
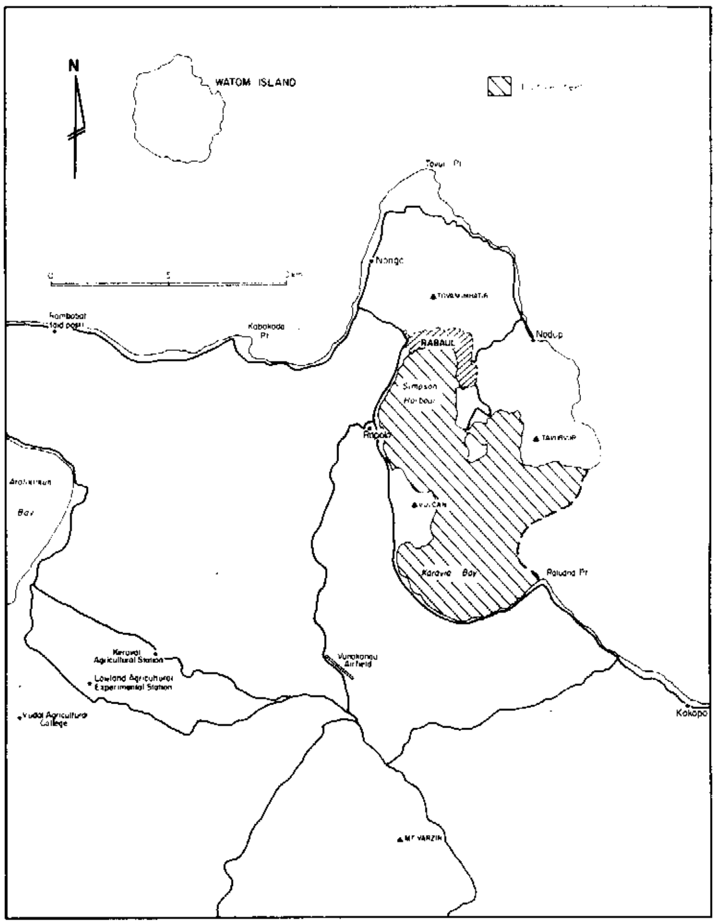


Figure 6.8

Pumice sheets,
1937-magnitude, May eruption

BASE MAP MAP 1
PUMICE SHEET MAP 1



occurred on the other side of the harbour, although the eruption was to last much longer. The eruption column rarely reached more than 2,500 metres in height although some large ballistic blocks were thrown out to land more than 1,500 metres from the source (Figure 6.3). Most of the time a dirty steam column rose from the vent interspersed with some short periods of vulcanian activity with a cloud of ash drifting downwind during this intermittent explosive activity. On some occasions during the next few days when activity was at a low ebb, toxic gases, particularly CO_2 (carbon dioxide), came from the vent filling low-lying pockets until dispersed by relatively strong onshore breezes. At the end of the first week of activity this vent stood more than 60 metres above the previous ground surface and the cone had a basal diameter of more than 900 metres. The extent of tephra fall, limited when compared with that from New Matupit, is shown on Figure 6.4.

Deaths and injuries

Before the eruption. The scenario presented earlier envisages that a large proportion of the population evacuated the purple and red zones early on in the warning process. Our present concern is not with the success of this evacuation but with the number of casualties produced by the evacuation process itself.

It is reasonable to expect that the number of deaths and injuries resulting from road accidents would increase during a time when many more people than usual were travelling the roads. This seems to be a characteristic of evacuations everywhere.

In this scenario, a few (two to five) people were killed and perhaps 30 to 40 people were injured in road accidents during the evacuation period. Most of these casualties occurred during the stage 3 and stage 4 periods resulting from increased traffic to and from the main evacuation centres and the Disaster Centre at Vunadidir. Although lower speed limits had been promulgated they had proved difficult to enforce.

The rescue teams and the medical services established at Vunapope were able to deal fairly readily with most of the casualties. While the road accident rate had risen sharply because of the emergency, industrial accidents and sports-related injuries had fallen in the previous week, and the total number of hospital admissions remained at about the normal level.

Thus, for the pre-eruption period, total eruption-related casualties were two to five dead and thirty to forty injured and hospitalised.

During the eruption. The brief eruption scenario presented above indicates that a number of different volcanic hazards offered risks during the 198? eruptions from New Matupit and Liklik Vulcan. Table 6.1 indicates the range of volcanic hazards that will be experienced in the Blanche Bay area DURING the next eruption. Secondly, the table estimates the area (in square kilometres) likely to be affected by the next eruption. These data emphasise the magnitude of the New Matupit eruption in comparison with that of Liklik Vulcan. This information merely summarises the data presented in Figures 6.2 to 6.6.

The degrees of risk presented in Table 6.1 as death rates (per thousand) are based on judgement, largely founded on the sorts of evidence presented by Blong (1984). In fact, while there is a considerable amount of information about the number of deaths in volcanic eruptions and some of this is hazard-specific, little evidence is available in the literature as to the proportion of deaths amongst those at risk. Thus the numbers presented in the table are only expert opinions, based on the little information at hand, and taking due cognisance of special factors which may operate at Rabaul. For example, the 40 per cent death rate estimated for pyroclastic flows and surges is very low compared with those previously published (e.g. Blong 1984, p131). However, there is considerable evidence from the 1937 Vulcan eruption (on which the present scenario is modelled) that numerous people survived the surges that were experienced at Malaguna No. 3 and at Rakunai and that no burns or asphyxiation were reported (Johnson and Threlfall 1985, p45; McKee et al. 1985, p212). Similarly, the 5 per cent death rate suggested for those at risk from tsunamis around Blanche Bay is low by comparison with that produced by, say, Krakatau (1883) tsunamis. In the present case, however, the water is described as slack water.

Table 6.1
Areas affected* and hazard risks

Hazard	Areas affected (square km) New Matupit	Liklik Vulcan	Death rate (per thousand)	Injury/ death ratio	Most common injury types
Earthquakes					head injuries
MM6	30	-	1	4	fractures, soft tissue injuries
Ballistic projectiles	17	6	10	2	head injuries
Tephra falls					
more than 183 cm	8	-	50	20	head injuries, burns,
183 - 61 cm	18	-	25	40	fractures,
61 - 15 cm	47	4	10	50	respiratory
15 - 2.5 cm	500+	18	1	100	problems
Pyroclastic flows and surges	21	-	400	1.5	burns, fractures
Tsunami	15	-	50	3	fractures
Toxic gases	-	6	100	5	respiratory problems

Note: * Areas affected are calculated from relevant areas on maps presented in Figures 6.2 to 6.6. The area defined as affected by earthquakes is roughly equivalent to Zone 1 on Gaull's (1979) microzonation map reproduced here as Figure 6.2.

Estimates of the ratio of injury to death are also based on scant data, but they do at least suggest relative magnitudes. It is assumed that the injuries referred to require at least medical, if not hospital, treatment. The important point is that estimates of the ratio of injury to death vary by two orders of magnitude. They indicate, in conjunction with the death rate data that virtually everyone at risk from a heavy tephra fall (more than 61 centimetres), pyroclastic flow or surge will be killed or injured and that, at the other extreme, relatively few people will be seriously injured or killed by earthquakes or by tephra falls of less than 15 centimetres.

Figure 6.9 illustrates the distribution of population in the Rabaul area by census units. Population estimates are based on the 1983 census data from the Rural Community Register for ENBP.

Each of the figures illustrating the extent of areas at risk from specific hazards associated with the model eruption (Figure 6.2 - 6.8) has been overlain on Figure 6.9 to determine the population resident in each hazard area. These data are summarised in Table 6.2.

Table 6.2
Residents at risk

Hazard	No. of residents at risk New Matupit	Liklik Vulcan
Earthquakes		
greater than MM6	24,240	-
Ballistic projectiles	2,800	150
Tephra falls		
more than 183 cm	2,000	-
183-61 cm	890	-
61-15 cm	11,380	332
15-2.5 cm	24,455	1,631
Total	38,725	1,963
Pyroclastic flows & surges	6,530	-
Tsunami	1,650	-
Toxic gases	-	300

Note: Totals are not provided in this table as double counting would be involved in a simple summation. That is, some residents are at risk from more than one volcanic hazard.

However, the figures in Table 6.2 are no more than intelligent guesstimates; the information available to the authors is not sufficiently detailed to predict the number of residents in the tsunami zone, for example, without a great deal of further work. The estimates of those resident in the ash-fall zones are, on the other hand, more likely to be reasonably accurate as they cover larger areas and encompass a number of census units, rather than fractions of them.

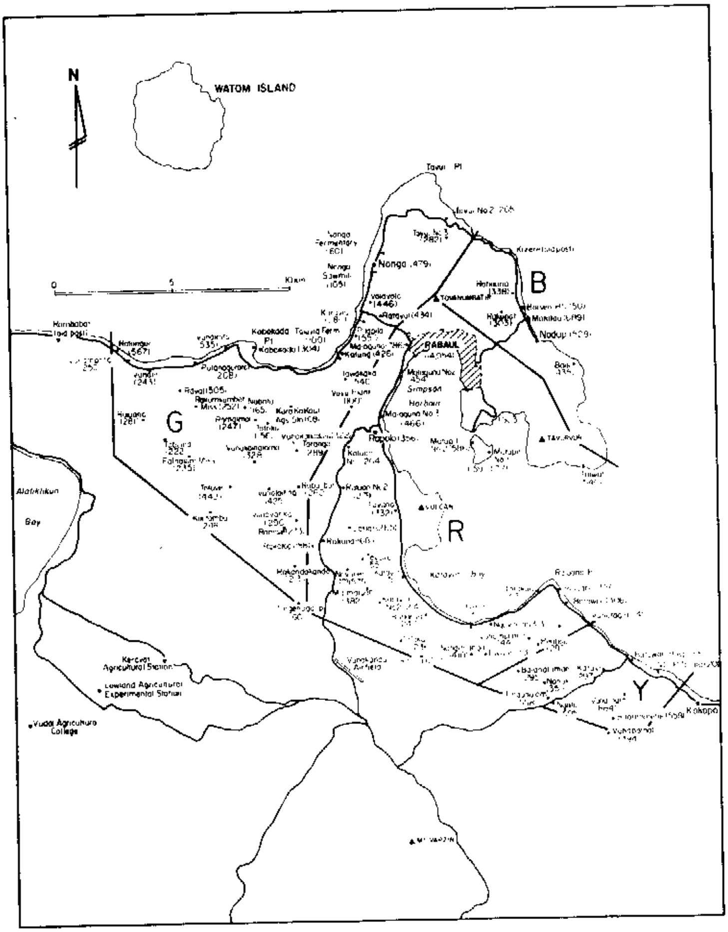
It is clear from Table 6.2 that the greatest number of residents are at risk from earthquakes and tephra falls. Also the number of people likely to be affected by the New Matupit eruption is much greater than for the Liklik Vulcan eruption.

In Table 6.2 the number of residents at risk is the population normally resident in the area. Clearly, for the scenario presented here, a large proportion of the population will have successfully evacuated before the start of the eruption.

Figure 6.9

Distribution of population in the Rabaul area
by census units

BASE MAP MAP 1
POPULATIONS 1983 MAP 1



For the present scenario five models have been run, varying evacuation rates and death rates to estimate the likely deaths and injuries which might result from a 1937 magnitude eruption in the late 1980s. The "average" model assumes the deaths per 1,000 at risk shown in Table 6.1 and the evacuation rates listed in Table 6.3.

The evacuation rates in Table 6.3 recognise that evacuation rates will be highest where risk is perceived to be greatest but that it is doubtful that there has ever been a 100 per cent evacuation of a risk zone. Accurate figures are rarely available but Perry (1985, p54-55) presents North American case studies where 11 per cent and 49 per cent of the populace failed to evacuate in the face of natural hazard impacts and notes: "In general, particularly in natural disasters, getting people to evacuate is a difficult problem. Many people refuse to leave even when ordered to do so". The greatest proportion of the population evacuated where: (1) sources advising evacuation were the most credible; (2) the family was together as a unit at the time evacuation was announced; and (3) personal risk was perceived to be great.

These three factors are likely to operate (together with other factors such as a memory of the 1937 eruption) to encourage evacuation in the Rabaul area. There may be variations between ethnic groups as factors such as degree of community involvement and fatalistic attitudes will also affect willingness to evacuate.

Table 6.3
Anticipated evacuation rates

Zone	Evacuation rate (per cent)
Purple	99
Red	97
Blue	95
Green	90
Yellow	10
Other areas	1

The expected deaths and injuries based on the evacuation rates listed in Table 6.3 and the death rates in Table 6.1, are set out in Tables 6.4 and 6.5. It is possible using the model to assign deaths and injuries to specific hazards and to individual census units. The "average" model (model 1) in Tables 6.4 and 6.5 refer to the rates specified in Tables 6.3 and 6.1. The four other models use different rates of evacuation and deaths per 1,000 in order to examine the effects of such variations. The following combinations were utilized: (1) evacuation rate plus 10 per cent; death rate minus 10 per cent (model 2); (2) evacuation rate plus 20 per cent; death rate minus 20 per cent (model 3); (3) evacuation rate minus 10 per.cent; death rate plus 10 per cent (model 4); and (4) evacuation rate minus 20 per cent; death rate plus 20 per cent (model 5). Table 6.4 and Figure 6.10 summarise the deaths anticipated for each of the five models.

Table 6.4
Estimated deaths

Evacuation rate Death rate per 1000	+ 20% - 20%	+ 10% - 10%	Average Average	- 10% + 10%	- 20% + 20%
Model No.	3	2	1	4	5
Total at risk	2,607	2,759	5,517	12,476	19,426
Hazard					
Earthquakes	-	-	1	4	7
Ballistic projectiles	-	-	-	3	7
Tephra falls					
more than 183 cm	-	-	1	12	25
183 - 61 cm	-	-	1	3	6
61 - 15 cm	-	-	4	16	31
15 - 2.5 cm	2	2	4	7	10
Pyroclastic flows	-	-	25	304	632
Tsunamis	-	-	1	5	9
LV projectiles	-	-	-	-	-
LV tephra fall (more than 15 cm)	-	-	-	-	1
LV tephra fall (15 - 2.5 cm)	-	-	-	-	-
Toxic gas	-	-	1	4	8
Grand total	**2**	**2**	**38**	**358**	**736**

The mean evacuation rate for the whole area at risk varies from 74 per cent to 97 per cent, (Figure 6.10), the low rates resulting from the substantial populations west of the green zone and on Watom Island who are not perceived to be at risk in the Disaster Plan. The assumptions presented here suggest that these populations experience a low (1/1,000) risk from ash-falls of a few centimetres thickness.

On the basis of these assumptions, Table 6.4 indicates that the total number of people at risk after evacuation (that is, still in the hazardous zones) will vary by almost an order of magnitude from about 2,500 to about 20,000. However, the anticipated death toll varies by 2.5 orders of magnitude from a few people to more than 700. It is evident from the other data in the table that this larger variation is principally a function of the number of deaths resulting from pyroclastic flows and surges which is, in turn, a function of the number of people remaining in the purple zone (see Figure 6.5). The death tolls for models 2 and 3 are low largely because both models assume 100 per cent evacuation of the area likely to be affected by pyroclastic flows and surges. The converse is true for models 4 and 5.

Table 6.4 also indicates that the next most important "cause" of death is tephra falls more than 15 centimetres in thickness. Comparing Figures 6.4 and 6.9 indicates that evacuation rates in the red zone influence these death tolls; in models 1 and 2 evacuation rates in these zones are also assumed to be 100 per cent.

Figure 6.10

Expected deaths and injuries versus mean evacuation rate, 1937-magnitude, May eruption

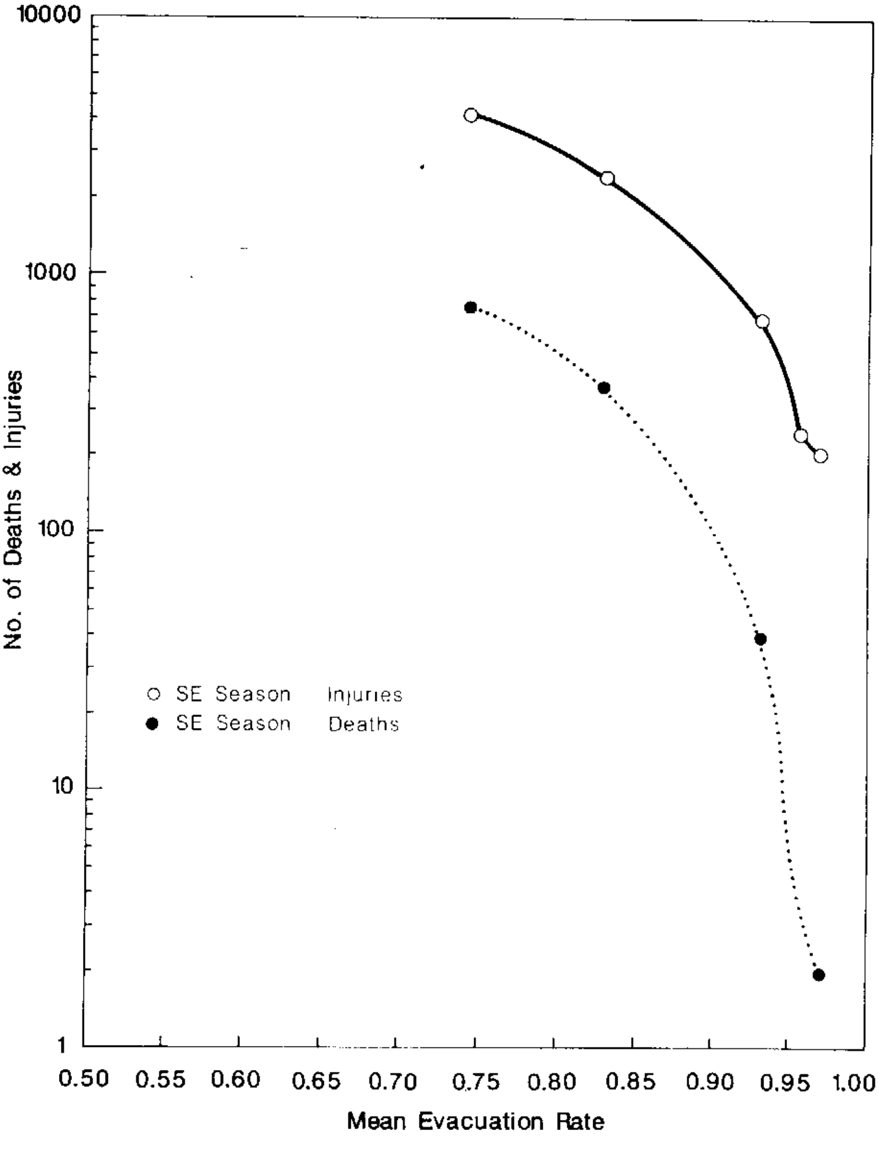


Table 6.5 and Figure 6.10 indicate that the total number of injured can be expected to vary between 200 and more than 4,000. When evacuation rates in the purple and red zones are 100 per cent injuries will usually be slight - mainly respiratory and eye problems associated with tephra fall. However, when the evacuation rate in the purple zone falls below 90 per cent, hundreds of serious injuries, mainly burns and fractures, are likely to result from pyroclastic flows and surges.

Table 6.5
Estimated injuries

Evacuation rate	+ 20%	+ 10%	Average	- 10%	- 20%
Death rate per 1000	- 20%	- 10%	Average	+ 10%	+ 20%
Model	3	2	1	4	5
Total at risk	2,607	2,759	5,517	12,470	19,416
Hazard					
Earthquakes	-	-	4	14	27
Ballistic projectiles	-	-	-	7	14
Tephra falls					
more than 183 cm	-	-	20	213	395
183 - 61 cm	-	-	25	111	196
61 - 15 cm	-	7	189	812	1546
15 - 2.5 cm	209	244	401	665	969
Pyroclastic flows	-	-	38	457	948
Tsunamis	-	-	3	15	28
LV projectiles	-	-	-	-	1
LV tephra fall (more than 15 cm)	-	-	5	22	43
LV tephra fall (15 - 2.5 cm)	-	-	7	24	45
Toxic gas	-	-	4	21	-
Grand Total	**209**	**251**	**696**	**2,361**	**4,251**

After the eruption. Within a few days of the eruption some people had begun to move back into the red zone and the other areas most affected. Many of these people were members of the hastily assembled teams designated to assess the extent of damage, particularly in the Rabaul town area. However, many others had also moved into the area to check out their own property and businesses, to recover possessions they had left behind, or just to look. Some of these non-official people in the "disaster" area had used their influence to get into the area; others had easily bypassed the official control points.

The ash-fall which blanketed tens of square kilometres to a thickness of more than 10 centimetres had stripped leaves from the vegetation, and the fine ash deposits which had marked the closing phases of the eruption set hard on the ground, forming an impervious crust. Although it had rained hard in some areas during the eruption, there was no further rain for a week in the area where the ash lay thickest.

When the rain did come, the lack of vegetation and the crusted ground surface meant that a tremendous amount of runoff occurred, causing gullying and mudflows (secondary lahars) where the crust was breached. Although the rate of erosion was very variable it was influenced most by ash thickness and slope gradient.

The areas most affected by mudflows are shown on Figure 6.11. The most critical areas were on the western slopes of Tavurvur and Rabalanakaia where tephra thicknesses totalled more than 15 to 50 centimetres. On the western side of Simpson Harbour numerous mudflows occurred in the area west and northwest of Vulcan where 25-75 centimetres of ash had fallen.

Crusting of the ash and the lack of leaves and organic matter to absorb the occasional afternoon rainfalls also produced sudden and spectacular flooding in many areas on a number of occasions. These events occurred even where only four to five centimetres of ash had fallen. Even weeks after the eruption, flash floods still occurred whenever and wherever more than 20 millimetres of rain fell at a rate of more than 10 millimetres per hour.

It is assumed that six to ten people will be killed and up to a score injured by mudflows and flash floods in the weeks after the eruption. These incidents would be more common in the squatter settlements in the southeast area of the town, on the steep lower slopes of Rabalanakaia and in the Tavana area on the western side of Simpson Harbour.

Overview of deaths and injuries

Tables 6.4 and 6.5 summarise the best estimates of anticipated deaths and injuries which would result from an eruption in Rabaul in the late 1980s equal in magnitude to the 1937 event. Clearly, the number of deaths and injuries is very dependent on evacuation rates (Figure 6.10). When the evacuation process is very successful, a significant proportion of total deaths (up to 80 per cent) occurs during the evacuation period and as a result of mudflows and flash floods in the eruption aftermath. When evacuation, particularly in the purple and red zones, is less successful the proportion of total deaths resulting from pyroclastic flows and surges varies from more than 50 per cent to 85 per cent.

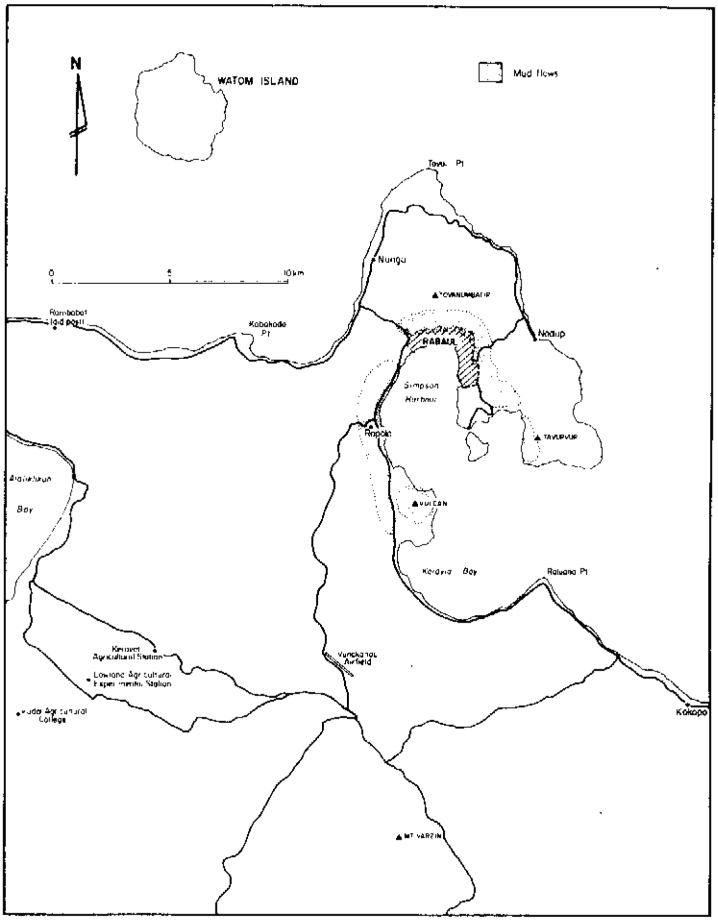
Similarly, when evacuation rates are high the total number of injured is expected to be only 200-250 people and nearly all of the injuries will be of a relatively minor nature. With low evacuation rates, serious fractures and burn injuries resulting from the collapse of buildings in heavy tephra falls and from pyroclastic flows are likely to form a significant proportion (more than 25 per cent) of the total injuries. Thus, it is important to note that not only the number of casualties varies (inversely) with the evacuation rate but also that the type of injuries, and the treatments required, change.

Since the population data is some years old and the scenario is a little in the future the estimates of deaths and injuries are inclined to be on the low side, perhaps by 15 - 20 per cent.

Figure 6.11

Mudflows,
1937-magnitude, May eruption

BASE MAP MAP 1
MUD FLOWS MAP 1



Damage to dwellings

The buildings at risk in the New Matupit and Liklik Vulcan eruptions occur in the same hazard zones as those shown on Figures 6.2 to 6.11. However, the degree to which buildings are at risk is not necessarily the same as for the humans who occupy them. The sorts of damage that buildings are likely to suffer have been presented with a good deal of case study material by Blong (1984).

A brief survey of building styles was made in part of southern Rabaul town (in the area south of Namanula Street and including Turanguna Street, part of the road to the airport, and the squatter area to the east of the police barracks). Houses were classified according to the pitch of the roof (steep or gentle), wall cladding material (fibro, concrete block, wood, steel sheeting, native materials), and whether the house was low set (usually a concrete slab foundation), medium set (about one metre above the ground), or high set (usually on concrete pillars or steel posts with laundry and car port underneath). Squatter houses were classified in the same way.

Each of the classified characteristics has relevance to one or other type of volcanic hazard. For example, steeply pitched roofs probably encourage the sliding of accumulated tephra, either clearing the roof or creating unbalanced loads. Fibro wall cladding has little resistance to ballistic projectiles or pyroclastic flow impacts compared with metal cladding (Blong 1981a). High-set houses may allow mudflows and tsunamis to pass beneath them with little structural damage providing the foundation piers remain intact. The information gained from classifying this small portion of the town has been used in estimating risk factors specific to Rabaul as presented in Table 6.6.

Table 6.6 sets out the expected number of dwellings in each of the volcanic hazard risk areas as portrayed on Figures 6.2 to 6.11. The expected number of dwellings has been reached by dividing the number of residents in each census unit by household size. The number of dwellings for each area is only approximate and based on 1980 Census data and on 1977 data on household size. Average household size for Rabaul is given as 4.4 residents per dwelling for urban areas, 6.0 for villages, and 4.8 for planned and unplanned settlements (Morauta 1982, p188). Clearly, using average occupancies hides much of the variation but as the other available data on dwellings, such as structural strength, are of limited quality there is little point in utilising more sophisticated analyses.

Dwellings are also divided into two kinds - (1) Type 1, those that have been designed, and the construction supervised, by appropriately qualified personnel; and (2) Type 2, those that have been built without the assistance of qualified persons. The problem with this division is that we have little information about housing types in the areas at risk. With the available data it is assumed that 95 per cent of the village dwellings, 70 per cent of the settlement buildings, and 40 per cent of the urban dwellings are of Type 2 construction. The high proportion of less well constructed buildings in the urban area of Rabaul exemplifies the large number of buildings built by squatters on the town margins but included in the urban population figures and the "boi" houses found at the rear of many of the high covenant houses. Using the above data the numbers of Type 1 and Type 2 buildings in each census unit was then aggregated to produce totals for each volcanic hazard type as shown in Table 6.6. It is important to note that only dwellings are considered in Table 6.6. Business and industrial premises are considered later.

Three categories of dwelling damage are presented in Table 6.7. A building regarded as destroyed has been damaged to the extent that the cost of repairs would exceed the cost of replacement. Badly damaged buildings require repairs costing more than 40 per cent of the replacement value. Slightly damaged buildings are assumed to require repairs costing less than 40 per cent of the replacement cost.

Table 6.6
Dwellings at risk

Hazard	New Matupit Type 1 dwellings	New Matupit Type 2 dwellings	Liklik Vulcan Type 1 dwellings	Liklik Vulcan Type 2 dwellings
Earthquakes				
more than MM6	2,040	2,600	-	-
Ballistic projectiles	130	420	1	20
Tephra falls				
more than 183 cm	130	290	-	-
183 - 61 cm	20	140	-	-
61 - 15 cm	1,050	1,300	5	50
15 - 2.5 cm	1,170	3,360	15	250
Pyroclastic				
flows and surges	610	770	-	-
Tsunamis	90	250	-	-
Toxic gases	-	-	2	50
Mudflows and floods	20	240	2	50
Totals	**5,260**	**9,370**	**25**	**420**

Note: Dwellings at risk from both earthquakes and tsunamis are assigned solely to the New Matupit eruption.

The risk factors (number of houses per hundred damaged or destroyed) that appear under these three headings in Table 6.7 are based very largely on intuition, backed by the sorts of evidence presented in Blong (1984, Chapter 5). In each case the degree of risk relating to the less-well constructed houses (Type 2) is greater than that applied to the dwellings erected with the assistance of qualified personnel (Type 1). All of these figures must be regarded as first approximations, and the results that depend on them must be treated with caution, if not suspicion. The risk factors apply particularly to the situation in ENBP and take account of housing style as well as the magnitude of the eruption modelled in this scenario; the factors cannot be directly applied to any other situation.

The risk factors presented here provide estimates towards the maximum risk. In other words, it is probable that for the eruption modelled here the actual number of houses destroyed and damaged is more likely to be less than, rather than more than, the specified numbers.

For the eruption modelled here it appears that heavy tephra falls would provide the greatest risk, virtually all dwellings being damaged or destroyed by more than 150 centimetres of tephra. In making this assessment it is assumed that the tephra fall is relatively compact and that it is wet, both factors that occurred in the 1937 eruption.

Tephra falls of 60 - 180 centimetres and pyroclastic flows and surges are judged to provide roughly equal risks to houses, although the latter would damage virtually all houses in the area at risk whereas tephra falls of the specified magnitude would probably only cause damage to 65-85 per cent of those structures at risk (and much of this damage would be slight).

Table 6.7
Total dwellings at risk and risk factors

Hazard	No. of Dwellings at risk*	Dwelling damage (per cent)					
		Destroyed		Badly damaged		Slightly damaged	
		(1)#	(2)	(1)	(2)	(1)	(2)
Earthquakes							
more than MM6	4,640	1	2	1	2	2	4
Ballistic projectiles	570	1	1	3	5	5	10
Tephra falls							
more than 183 cm	420	30	50	50	40	20	10
183 - 61 cm	160	15	30	30	30	20	25
61 - 15 cm	2,400	5	15	10	20	20	30
15 - 2.5 cm	4,800	1	10	3	15	10	20
Pyroclastic flows & surges	1,380	20	30	30	40	50	30
Tsunamis	340	5	10	10	15	15	20
Toxic gases	50	-	-	1	2	5	10
Mudflows@	310	5	10	10	15	15	20

Notes:
(1) and (2): House Types 1 and 2. See text for explanation.
@ Dwellings at risk from mudflows were derived by making an approximate count of actual structures in Rabaul town on 1:2000 maps and estimating the number of dwellings in the other areas shown at risk on Figure 6.11.
* Total of dwellings at risk from both New Matupit and Liklik Vulcan eruptions. The numbers of dwellings at risk are taken from spreadsheet calculations but rounded.

However, the degree of risk needs to be multiplied by the number of dwellings at risk. These results are presented in Table 6.8. The number of houses at risk at New Matupit and at Liklik Vulcan have been combined for this table.

Table 6.8 sets out the estimated number of houses of Types 1 and 2 likely to be destroyed or damaged by each type of volcanic hazard.

Table 6.8 suggests that the greatest number of dwellings will be affected by falls of volcanic ash of less than 15 centimetres. Falls of ash up to 60 centimetres and pyroclastic flows and surges will each affect about the same number of dwellings, with average damage being rather higher in the latter case. The heavy tephra falls (more than 183 centimetres) and earthquakes with intensities more than MM6 will each damage 300 to 450 houses but the degree of damage is much greater in the case of the heavy tephra falls. Each of the other volcanic hazards will affect only 100 or so houses (or in the case of toxic gases only a very small number of houses).

Table 6.8
The number of dwellings damaged or destroyed*

Hazard	Number of dwellings: Destroyed (1)#	(2)	Badly damaged (1)	(2)	Slightly damaged (1)	(2)	Totals
Earthquakes more than MM6	15	70	10	70	30	130	325
Ballistic projectiles	1	5	5	20	10	40	80
Tephra falls							
more than 183 cm	40	150	60	120	30	30	430
183 - 61 cm	1	50	5	50	2	40	150
61 - 15 cm	50	210	110	270	210	410	1,260
15 - 2.5 cm	10	370	40	540	120	730	1,810
Pyroclastic flows & surges	120	230	180	310	310	230	1,380
Tsunamis	5	30	10	40	10	50	145
Toxic gases	-	-	-	1	-	5	5
Mudflows	5	10	10	20	15	20	80
Totals	**250**	**1,130**	**430**	**1,440**	**740**	**1,690**	**5,670**
	1,380		**1,870**		**2,430**		

Notes:
* All numbers, including totals, have been rounded. The totals in this table have not been discounted for damage that has already occurred to houses, inflicted by hazards that occurred earlier in the eruption.
\# (1) and (2): House Types 1 and 2. See text for explanation.

The data in Table 6.8 also suggest that less than 1,400 houses will be destroyed or at least damaged to the extent that replacement is cheaper than rebuilding. Similarly, more than 40 per cent of the 5,700 houses shown as damaged or destroyed will be damaged to less than 40 per cent of the replacement cost.

As the data presented in Table 6.8 are of doubtful quality it is worth considering variations in the rates of destruction and damage to dwellings. Table 6.9 allows for variations of plus or minus 10 and plus or minus 20 per cent in these rates and indicates the number of houses in each category. Figure 6.12 presents these data in terms of the percentage of housing stock in each category. This diagram suggests that of a total housing stock of about 15,000 dwellings at risk between 7 and 11 per cent of houses are likely to be destroyed, 10-15 per cent badly damaged, and 13-19 per cent slightly damaged.

Table 6.9
Estimated destruction and damage to dwellings

Damage rate	+ 20%	+ 10%	Average*	- 10%	- 20%
Hazard					
Type 1					
Destruction	299	274	249	224	199
Badly damaged	510	467	425	382	340
Slightly damaged	866	794	722	649	577
Type 2					
Destruction	1,316	1,206	1,097	987	877
Badly damaged	1,717	1,574	1,431	1,288	1,145
Slightly damaged	2,024	1,855	1,686	1,518	1,349

Note: * Average factors are those presented in Table 6.7, except the numbers have not been rounded here.

More significantly, it should be recognised that only 25 per cent of the destroyed houses are Type 1 houses and only 25 per cent of the total damaged and destroyed dwellings are of this type. Comparison between Tables 6.8, 6.9 and Table 6.6 indicates that the per cent destroyed represents about 5 per cent of the Type 1 houses of this type that were considered to be at risk. On the other hand, about 11 per cent of the Type 2 houses are considered to have been damaged beyond repair or destroyed. This comparison suggests that the risk of destruction to a Type 2 house is twice that of the risk to a Type 1 house, the risk in this case being a function of the structural soundness of the dwellings and location.

In the badly damaged category, the average risk to Type 1 houses is about 8 per cent, and to Type 2 houses more than 14 per cent suggesting that the latter is 1.9 times more vulnerable. In the slightly damaged category the comparative figures are 13 per cent (Type 1), 17 per cent (Type 2), and relative vulnerability, 1.3 times.

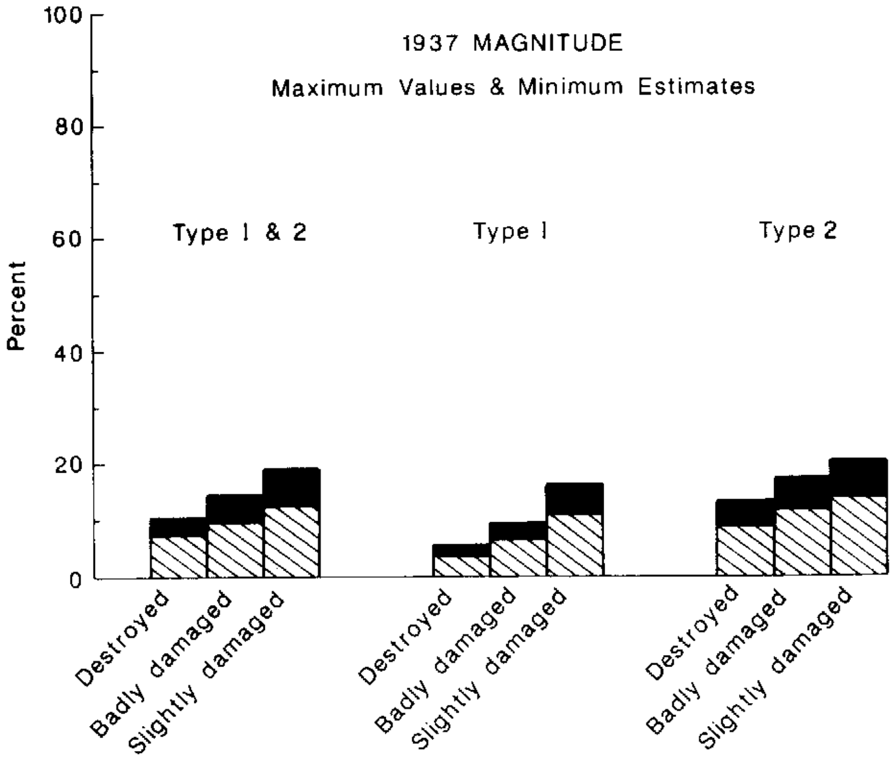
Finally, it should be recognized that these figures are percentages of the housing stock at risk in this eruption, not percentages of the total housing stock in the Rabaul area. Clearly, percentages of total dwellings are significantly lower than those shown here on Figure 6.12.

Damage to commercial buildings

The most useful source of information available to the authors as to the value of commercial buildings at risk is contained in insurance records. It is considered that such buildings would be comparable to Type 1 dwellings and that, as a first approximation, probabilities of damage for appropriate hazards could be taken from Table 6.7. However, these probabilities relate to all domestic dwellings. Therefore it is necessary to outline the rationale for using insurance company data on the nature of risks insured and the amount of cover for each class of risk. This involves considering two matters - the differences between commercial and domestic property valuation and the information provided by insurance policies on the anticipated maximum loss from a specified hazard.

Figure 6.12

Destruction and damage to dwellings,
1937-magnitude, May eruption



Domestic dwellings are usually valued by adding together the value of the "structure" and the value of the "contents". With non-domestic buildings the position is a little more complicated. To begin with, the determinants of domestic dwelling value are relatively simpler. Consequently, it is more meaningful to value a number of domestic dwellings in terms of multiples of mean values. The non-domestic building, on the other hand, is likely to have a current value that is more closely tied to its precise specifications and use history. Furthermore, while the value of the "contents" of the domestic dwelling are, on average, likely to be related to the value of the "structure", this is much less likely with the non-domestic building. At one extreme it can be an inexpensive shelter for very expensive "contents". Part of this difference in value comes from the fact that the ratio of "plant" to "stock" in the non-domestic building can reflect a wider range of variability in end-use than is likely to be encountered with the typical domestic dwelling. Finally, a non-domestic building and its contents can be part and parcel of a firm's ability to earn profits so that loss of profit and other kinds of insurance may be taken out to reflect this aspect of property valuation whereas this kind of problem usually does not arise in the insurance of domestic dwellings.

These differences between methods of commercial and domestic property valuation mean that while domestic properties are essentially valued objectively - that is, in relation to some notion of market value - it is harder to apply this concept to non-domestic properties. What the insurance policy does is to place a maximum value on what is at risk from particular hazards. This means that while the domestic and the non-domestic property might be covered by an identical policy and, while the insurance company in both cases will only make payouts recommended by the loss assessors, there is more information content in non-domestic property insurance because it reveals what the insurer believes his maximum (insurable) loss is likely to be whereas in the domestic case property values are likely to be more readily establishable from other sources.

The data. The Insurance Underwriters' Association of Papua New Guinea (IUA) commissioned Toplis and Harding (Queensland) to be responsible for loss assessment in the event of an eruption at Rabaul. As part of this exercise, Toplis and Harding were provided by the individual underwriters with information on property risks underwritten in the vicinity of Rabaul. This information is used by Toplis and Harding to maintain a data base on these risks.

At the request of the IUA, Toplis and Harding made available to the authors a print out of this entire data base. While the information provided differs from company to company typically the following data is given for each policy:

- Surname/company name and address usually a post office box number;
- Classification of coverage - for example, householders, marine cargo, fire-commercial, etc.;
- Location of property insured - usually a section and lot number;
- Due date;
- Insurance type for example, contents/domestic, buildings-commercial, stock-finished goods, etc.;
- Sum insured and endorsements[1].

Since the location of the property insured is usually expressed as a section and lot number 1:4000 maps (Department of Lands, Surveys and Environment) were used to determine the street(s) upon which the property fronts and the nearest cross-streets.

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1. The latter is usually an indication that seismic risks have been covered.

Since non-domestic buildings are considered here to be comparable to Type 1 dwellings probabilities of damage for appropriate hazards are taken from Table 6.7. To express the concepts of "destroyed", "badly damaged" and "slightly damaged" it is assumed that a building in each of these categories would suffer, on average, damage equal to 100 per cent, 70 per cent and 20 per cent respectively of the total insurance[2] on the property at that site.

The individual spreadsheets. Separate computer print-outs were provided by Toplis and Harding for each insurance company. A computer spreadsheet was then prepared for each company. The following information was then transferred to the spreadsheet from the data provided by Toplis and Harding.

- Surname/company name;
- Section and lot number;
- Insurance type;
- Sum insured.

The survey maps were then used to provide, where possible, the street address of each insured location and the two nearest cross-streets. An examination of the location information revealed that the amount of commercial property at risk in several hazard categories identified above and used in Table 6.7 was so small that these categories could safely be ignored. Three categories are involved. These are -

- Ballistic projectiles;
- Toxic gases;
- Mudflows.

In addition nothing would be lost by making the simplifying assumption that any building affected by 15 centimetres (6 inches) or more of tephra could be treated as if it lay within the 61-15 centimetres category while any building affected by less than 15 centimetres of tephra or less could be treated as if it lay within the 15-2.5 centimetres category.

Unfortunately, the information on location provided by two insurance companies[3] was so sketchy that it was decided to apportion their business across the various risk categories on the summary sheet (see below) in proportion to the aggregate amount at risk of the remaining companies. Even where the quality of information provided by companies was much better there were cases where it was not possible to determine within which risk categories particular policies lay. It was decided to apportion these policies across the various risk categories on the spreadsheet for the particular companies concerned in proportion to the aggregate amount at risk of that company in each of the various risk categories. However, if the information that was provided indicated that the property did not lie in the study area then the policy was ignored.

The information was transcribed to the spreadsheets by policy, or part of a policy, and then aggregated over all policies for a particular company.[4] After the totalling was

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2. That is, regard is not had to the particular category of insurance but to the sum of the nominated maximum possible payouts under such policies as may be held.

3. One of which has almost no business in the study area.

4. To avoid any confusion it is pointed out that aggregation was not carried out by client - the various policies that clients might have (often reflecting different locations) - were treated as if they were quite separate from other policies.

carried out the amounts that could not be allocated to appropriate risk categories were apportioned along the lines indicated above. The process of apportioning produced a property value at risk within risk categories for each insurance company. The data on damage probabilities and degree of damage discussed above were then used to determine estimates of damage (that is, by total destruction, by substantial damage, by minor damage) within each risk category. An estimate of total damage within each risk category was then obtained by simple addition. The reader will appreciate that it is not possible to add these totals together[5] to provide what would appear to be a grand total of eruption damage. Double counting must be avoided - a building, say, totally destroyed by pyroclastic flow should not be regarded as also substantially damaged by earthquake in any accurate count of the grand total of eruption damage.

The summary sheet. The property value at risk, the estimates of damage and the estimate of total damage within each risk category for each insurance company were then transferred to a summary sheet (Table 6.10). It was then possible to sum across companies within risk categories to obtain an initial total for property value at risk and for damage within each risk category. This information was used to apportion the data from the two companies for which individual spreadsheets could not be prepared. After apportionment the final totals for property value at risk and for damage within each risk category were calculated.

The total sum insured is K108,211,901 of which K91,691,563 is accounted for by the five insurance companies for which there is sufficient information to prepare spreadsheets. For these companies (after rounding up) the total amounts at risk for the five hazards being considered are K88.0 million (earthquake), K30.6 million (tephra falls of less than 15 centimetres), K57.4 million (tephra falls of more than 15 centimetres), K14.0 million (pyroclastic flows) and K35.6 million (tsunamis). The effect of apportioning is to raise these amounts to K103.9 million, K36.1 million, K67.8 million, K16.5 million and K42.1 million respectively. The damages incurred from each kind of risk within this scenario, after apportionment,are K2.2 million (earthquake), K1.8 million (tephra falls less than 15 centimetres), K10.8 million (tephra falls more than 15 centimetres), K8.4 million (pyroclastic flows), and K6.3 million (tsunamis)[6]. Since the second and third amounts can legitimately be added together for the reason outlined above, it is possible to claim that tephra fall (K12.7 million) is likely to be the single most serious source of damage within this scenario, costing approximately 11.7 per cent of the value of the property (for which the sum insured is a surrogate).

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5. Except in the case of tephra falls where distinct geographical zones are being treated.

6. That is, the (unrounded) total earthquake damage of K2,181,214 is 0.021 per cent of the total K103,867,337 at risk, comprising 100 per cent of one per cent for total destruction, 70 per cent of one per cent for badly damaged and 20 per cent of 2 per cent for slightly damaged. The K103,867,337 was obtained from the spreadsheet (the original data from the insurance companies), the one per cent, one per cent and 2 per cent from Table 6.7 (for dwelling type 1) and the 100 per cent, 70 per cent and 20 per cent are assumptions made by the authors to quantify the concepts of "destroyed", "badly damaged" and "slightly damaged". Similar reasoning will explain the damage estimates by hazard category and insurance company in Table 6.10.

An examination of Table 6.10 suggests that the total damage bill by category of risk is apportioned unevenly among insurance companies because of the different spatial distribution of policies. This variation is summarised in Tables 6.11 and 6.12. Obviously, the concentration of risk from tsunamis reflects relative strengths in those parts of the insurance market which have maritime connections. The concentration of risk from pyroclastic flows reflects, on the other hand, the fact that the company concerned has a small number of very large policies, the addresses given for which are, in a majority of cases, in the area under risk from pyroclastic flows according to the scenario that is being explored.

Table 6.10
Damage estimates by risk category and insurance company

Name	Earth-quake risk	<15cm tephra risk	>15cm tephra risk	Pyroclastic risk	Tsunami risk
Company A					
Sum insured K13,014,708					
Property value at risk	12,814,708	2,218,491	10,787,217	445,247	9,164,831
Damage estimates					
by total destruction	128,147	22,185	539,361	89,049	458,242
by substantial damage	89,703	46,588	755,105	93,502	641,538
by minor damage	51,259	44,370	431,489	44,525	274,945
Total damage	269,109	113,143	1,725,955	227,076	1,374,725
Company B					
Sum insured K18,337,850					
Property value at risk	18,108,350	15,056,500	3,051,100	12,500,000	0
Damage estimates					
by total destruction	181,084	150,565	152,555	2,500,000	0
by substantial damage	126,758	316,187	213,577	2,625,000	0
by minor damage	72,433	301,130	122,044	1,250,000	0
Total damage	380,275	767,882	488,176	6,375,000	0
Company C					
Sum insured K7,702,320					
Property value at risk	7,472,576	3,354,187	4,118,389	180,605	58,743
Damages estimate					
by total destruction	74,726	33,542	205,919	36,121	2,937
by substantial damage	52,308	70,438	288,287	37,927	4,112
by minor damage	29,890	67,084	164,736	18,061	1,762
Total damage	156,924	171,064	658,942	92,109	8,811
Company D					
Sum insured K30,472,280					
Duplicate final total	27,500,230	2,061,389	25,434,841	518,088	22,786,867
Damages estimate					
by total destruction	275,002	20,614	1,271,742	103,618	1,139,343
by substantial damage	192,502	43,289	1,780,439	108,798	1,595,081
by minor damage	110,001	41,228	1,017,394	51,809	683,606
Total damage	577,505	105,131	4,069,575	264,225	3,418,030
Total amount at risk c/f	65,895,864	22,690,567	43,391,547	13,643,940	32,010,441
Overall damage c/f	1,383,813	1,157,219	6,942,648	6,958,409	4,801,566

Table 6.10 (continued)
Damage estimates by risk category and insurance company

Name	Earth-quake risk	<15cm tephra risk	>15cm tephra risk	Pyroclastic risk	Tsunami risk
Total amount at risk b/f	65,895,864	22,690,567	43,391,547	13,643,940	32,010,441
Overall damage b/f	1,383,813	1,157,219	6,942,648	6,958,409	4,801,566
Company E					
Sum insured K22,164,405					
Duplicate final total	22,114,405	7,885,719	14,037,206	350,972	3,621,344
Damages estimate					
by total destruction	221,144	78,857	701,860	70,194	181,067
by substantial damage	154,801	165,600	982,604	73,704	253,494
by minor damage	88,458	157,714	561,488	35,097	108,640
Total damage	164,403	402,172	2,245,953	178,996	543,202
Total amount at risk	88,010,269	30,576,286	57,428,753	13,994,912	35,631,785
Overall damage	1,848,216	1,559,391	9,188,600	7,137,405	5,344,768
Apportion K16,520,338					
amount at risk	15,857,068	6,509,019	10,347,107	2,521,504	6,419,883
Damage	332,998	280,960	1,655,537	1,285,967	962,982
Final figures					
amount at risk	103,867,337	36,085,305	67,775,860	16,516,416	42,051,668
Damage	2,181,214	1,840,351	10,844,138	8,423,372	6,307,750

Table 6.11
Company percentages of total damage bill

Company	Earth-quake risk	<15 cm tephra risk	>15 cm tephra risk	Pyro-clastic flow risk	Tsumami risk
A	12	6	16	3	22
B	17	42	5	76	0
C	7	9	6	1	0
D	26	6	38	3	54
E	21	22	21	2	9
Apportioned	15	15	15	15	15
Total	**100**	**100**	**100**	**100**	**100**

Table 6.12
Company percentages of total damage bill

Company	Earthquake risk	Tephra risk	Pyroclastic flow risk	Tsunami risk
A	12	14	3	22
B	17	10	76	0
C	7	7	1	0
D	26	33	3	54
E	21	21	2	9
Apportioned	15	15	15	15
Total	**100**	**100**	**100**	**100**

The probabilities taken from Table 6.7 are reflected in the ratio of value of damage from a particular risk category to the amount at risk in that category. These are earthquake - 2 per cent, tephra fall less than 15 centimetres - 5 per cent, tephra fall more than 15 centimetres - 16 per cent, pyroclastic flow - 51 per cent and tsunami risk - 15 per cent.

Effects on agriculture

A very wide range of effects on agricultural activity can be anticipated as a result of a replay of the 1937 eruption during the latter part of the 1980s. Although these effects would include death and injury to animals and plants, both domestic and commercial as outlined in Blong (1984, Chapter 7), the emphasis here is solely on the effects on copra and cocoa production as these are the major cash crops in ENBP and the mainstays of the agricultural economy.

Cocoa production. The model of the effects of the eruption on cocoa and copra is similar in construction to those for deaths and injuries and damage to dwellings. The method in respect of cocoa production is set out below.

Current cocoa and copra production figures have been estimated for each census division using monthly production figures produced by the Produce Inspection Division in Rabaul. For cocoa production, complete figures were available only for 1985 with partial sets for 1984 and 1986. Production is very variable from month to month as might be expected as flowering flushes occur every six to eight weeks with a main flush in November to January. As well, in general there is a biennial peak in production but some years may have only "one and a half" flushes. Table 6.13 sets out estimated mean annual cocoa production based on 1984-86 figures for each census division that would be affected. The table refers only to export standard cocoa, but non-export standard beans amount to only one to 2 per cent of total production. Figures refer to bags of cocoa; there are about 16 bags to the tonne. The ten census divisions (out of nineteen) produce between 50 and 75 per cent of total ENBP cocoa. It is evident from the table that Balanataman, Kokopo and Central divisions produce approximately 50 per cent of the total.

Table 6.13
Estimated annual cocoa production (bags)

Census division	Bags/year (x 1,000)	Percent of ENBP production
Balanataman	39.3	24
Central	8.2	5
Kokopo	34.4	21
Kombiu	1.6	1
Livuan	3.3	2
Reimber	1.6	1
Raluana	6.6	4
Rabaul town	0.1	-
Vunadidir	3.3	2
Watom	1.6	1
Total	**100.0***	**61**

Note: * The monthly production for the 30 months of available data is 8,273 plus or minus 4,064 bags.

Each of the volcanic hazards is likely to have differing effects on cocoa production. These effects may also be experienced for differing periods of time. Not surprisingly, there is little information in the literature on the specific effects of volcanic eruptions on cocoa production. Three lines of evidence have been used here in estimating the effects suggested in Table 6.14: (1) the general lines of evidence provided by Blong (1984, Chapter 7); (2) the expert opinions of agricultural consultants familiar with the many aspects of cocoa production; and (3) the detail in the Australian Archives for claims for assistance from two cocoa plantation owners in the aftermath of the 1937 Rabaul eruption (Australian Archives GRS A518 item Z836/4). Greater weight has been given to this third source of information in compiling Table 6.14. It should be noted that this emphasis has produced longer lasting and more deleterious effects than those suggested by the other sources.

The estimates in the table take into account that cocoa trees take five to six years to produce, but that mere flower loss is unlikely to be very serious as only one in a thousand flowers becomes a pod and flowers stripped from a tree are replaced within a few days. In areas of pyroclastic flows, some trees will be affected by blasts, heat or lightning strikes. In areas of tephra fall effects will include acid rains and aerosols, defoliation, lightning strike, leaf, limb and pod removal, burial and retention of ash on photosynthetic surfaces. The estimates also assume that variations will occur in the effects of ash-fall on parasites and pollinators, for example, that harvesting will be more difficult in some areas, that erosion will progressively and differentially remove accumulated ash and that planters will take some steps to improve yields. With such a variety of effects it is clear that the actual consequences of the eruption may be significantly different from those presented here.

Table 6.14
Estimated effects (per cent) on cocoa production
(all values are negative)

Hazard	Time after eruption 1 month	 1 year	 2 years
Earthquakes	10	-	-
Ballistic projectiles	80	60	20
Tephra			
more than 183 cm	100	70	30
183 - 61 cm	60	30	30
61 - 15 cm	40	20	10
15 - 2.5 cm	30	20	10
Pyroclastic flows	100	50	20
Tsunamis	50	30	10
Toxic gases	20	-	-
Mudflows	70	50	20

Clearly, the effects of each eruption hazard are not constant across each census division. Figures 6.2 - 6.11 show the distribution of eruption hazards. Equally, it is doubtful that cocoa production is distributed evenly within each census division. While precise information on cocoa areas is not available the 1:100,000 and 1:50,000 maps indicate plantation areas. On the assumption that cocoa and coconuts are usually grown together, Table 6.15 indicates the estimated proportion of each census division that will be affected by each eruption hazard.

Figure 6.13 sets out estimates of the effects of a 1937 magnitude eruption on cocoa production. In effect, this figure has been produced by multiplying elements in the tables (Tables 6.13 - 6.15) together. The central curve shows the effects on cocoa production over the two year period based on the values produced in Tables 6.14 and 6.15. The upper and lower limits assume that the effects (Table 6.14) and the proportions varied by plus or minus 20 per cent. The range of values shown in Figure 6.13 thus allows for the inherent problems in making reliable estimates.

Nonetheless, the figure suggests that an initial brief decline in cocoa production of the order of 20-35 per cent is likely to be reduced within two years to about 10 per cent. Although the greatest effect on production is in Balantaman census division, about 80 per cent of the total decrease in production being recorded in this division (Table 6.16), the most dramatic effect is in Kombui census division where the table suggests the entire cocoa production is wiped out. The table indicates that the most serious effects are in Kombui and Rabaul town census divisions but production from these areas is very minor. On the assumption that all earlier estimates are correct, this figure still produces a slight exaggeration as no allowances have been made for double counting.

Table 6.15
Proportions of census divisions affected by eruption hazards
(per cent)

Census division	Earth-quakes	Ballistic projectiles	Hazard: Tephra falls in cm >183	183-61	61-15	15-2.5	Pyroclastic flows	Tsunamis	Toxic gases	Mudflows
Balantaman	50	-	-	10	30	65	-	2	-	10
Central	10	1	-	5	10	5	-	1	5	5
Kokopo	-	-	-	-	-	-	-	-	-	-
Kombiu	70	20	10	20	10	60	30	20	-	10
Livuan	-	-	-	-	-	80	-	-	-	-
Reimber	10	-	-	10	30	60	-	5	-	10
Raluana	5	-	-	-	-	-	-	5	-	-
Rabaul town	100	-	-	-	60	40	30	20	-	30
Vunadidir	-	-	-	-	-	-	-	-	-	-
Watom	-	-	-	-	-	100	-	-	-	-

Figure 6.13

Estimated effects of eruption on cocoa production over two year period, 1937-magnitude, May eruption

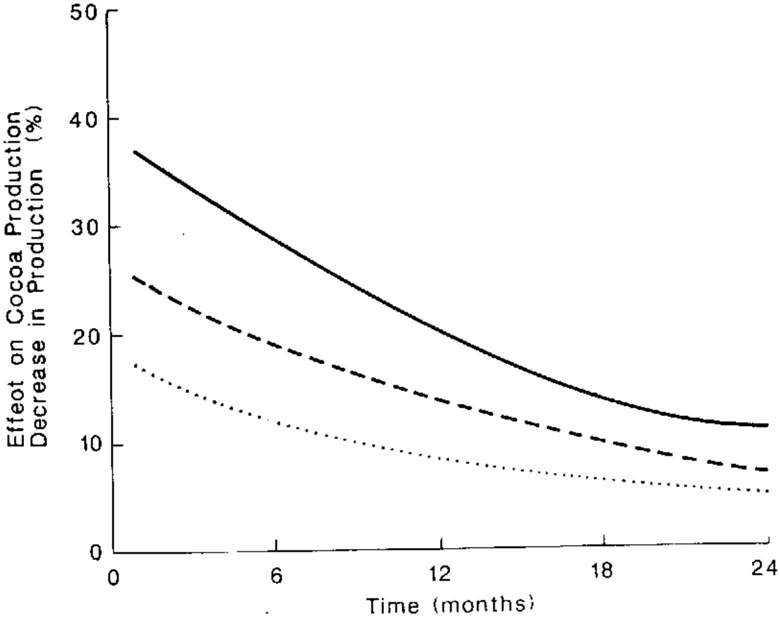


Table 6.16
Changes in cocoa production by census division

Census division	Initial production/year (x 1,000 bags)	Per cent change 1 month	1 year	2 years
Balanataman	39.3	-51	-28	-15
Central	8.2	-15	-8	-4
Kokopo	34.4	0	0	0
Kombui	1.6	-100	-65	-30
Livuan	3.3	-24	-16	-8
Reimber	1.6	-46	-28	-15
Raluana	6.6	-3	-2	-1
Rabaul town	0.1	-97	-56	-24
Vunadidir	3.3	0	0	0
Watom	1.6	-30	-20	-10
Totals	**99.6**	**-25**	**-14**	-7

Coconut/copra production. The model of the effects of the eruption on copra production has been constructed in exactly the same way as the one for cocoa production. Table 6.17 sets out the estimated annual copra production for each census division based on available monthly data during 1985-86. Although Balanataman and Kokopo are again the largest producers they do not dominate to the extent that they do in relation to cocoa production.

Table 6.17
Estimated annual copra production (bags)

Census division	Bags/year (x 1,000)	Percent of ENBP production
Balanataman	42.5	11.8
Central	28.5	7.9
Kokopo	40.3	11.2
Kombiu	18.9	5.3
Livuan	19.6	5.4
Reimber	19.5	5.4
Raluana	26.9	7.5
Rabaul town	-	-
Vunadidir	22.2	6.2
Watom	10.5	2.9
Totals	**228.9**	**63.6**

Table 6.18 sets out the estimated effects of the eruption on copra production at three time periods - one month, one year and two years after the event. The values are based on information contained in Blong (1984) and on the details contained in the Australian Archives pertaining to the aftermath of the 1937 eruption (GRS A518 item Z836/4). For the more severe forms of damage (e.g. pyroclastic flows and thick tephra falls) many of the estimates are the same as for cocoa production. For areas affected only by relatively thin tephra falls estimates of lost production are rather higher than might be anticipated largely because of an unusual incidence of lightning strike to coconut palms and subsequent insect attack (Promotheca species?).

Table 6.18
Estimated effects on copra production
(all values are negative)

Hazard	1 month	Time 1 year (per cent)	2 years
Earthquakes	5	-	-
Ballistic projectiles	80	60	20
Tephra			
more than 183 cm	100	70	20
183 - 61 cm	60	30	20
61 - 15 cm	40	30	10
15 - 2.5 cm	30	20	-
Pyroclastic flows	100	50	20
Tsunamis	40	20	10
Toxic gases	10	-	-
Mudflows	20	10	-

Table 6.19 outlines changes in copra production by census division over the two year period. Comparison with Table 6.16 indicates that changes are less marked than in the case of cocoa production and that recovery is likely to be more complete in the two year period. Figure 6.14 illustrates the closely parallel curves which result when allowances are made for plus or minus 20 per cent changes in both the effects and the proportions of census divisions affected.

Summary of effects on agriculture

Although the data which can be utilised to model the effects of the eruption on cocoa and copra production leave much to be desired, we can be reasonably confident that actual declines in production will be within the bounds illustrated on Figures 6.13 and 6.14. In both cases the magnitudes of the eruption effects appear to be greater than those recorded in the literature on eruption effects on agriculture but rather less than those documented for some plantations in the Rabaul area in 1937-39. The differences between the two sets of information probably reflect the extraordinary incidence of lightning strikes, torrential floods and mudflows in the area west and north of Simpson Harbour in 1937 compared with many eruptions.

Figure 6.14

Estimated effects of eruption on copra production over two year period, 1937-magnitude, May eruption

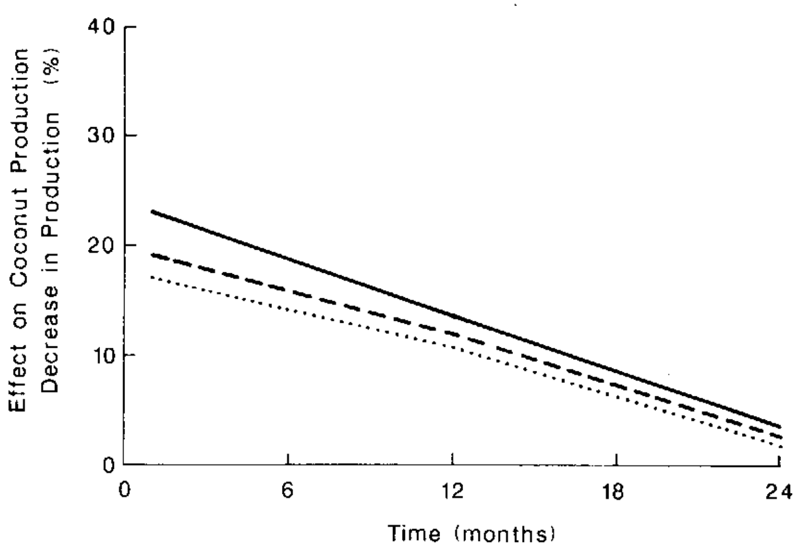


Table 6.19
Changes in copra production by census division

Census division	Initial production/year (x 1,000 bags)	Per cent change 1 month	1 year	2 years
Balanataman	46.9	-43	-26	-5
Central	27.7	-12	-7	-2
Kokopo	48.9	-	-	-
Kombiu	25.5	-100	-6	-19
Livuan	22.0	-24	-16	-
Reimber	27.1	-40	-26	-6
Raluana	30.9	-2	-1	-1
Rabaul town	-	-	-	-
Vunadidir	27.0	-	-	-
Watom	11.4	-30	-20	-
Totals	**267.4**	**-19**	**-12**	**-3**

After this initial period, production is likely to increase, the fertilizing effects of the ash outweighing the earlier problems. It seems likely from considerations of the effects of ash-fall on agriculture elsewhere (see Blong 1984, Chapter 7.7) that recovery of the industry will be relatively rapid, with the benefits outweighing the losses within a few years.

As would be expected the effects on cocoa and copra production are not evenly distributed. While Kombiu census division is the most drastically affected area it is the impact on Balantaman which is likely to have the greatest influence on economic recovery in the Rabaul area.

Although the only effects on agriculture considered here are those concerned with cocoa and copra production, it must be realised that all agricultural endeavour, whether commercial or subsistence, will be adversely affected by the eruption in the short-term. As a general rule it can be assumed that animals will be affected in similar ways and in similar proportions to humans. Birds, including domestic fowls, are likely to be more seriously affected, with higher death rates. Bananas are likely to be seriously affected as the fronds are very susceptible to damage. Root crops such as taro are likely to be only marginally affected in the very short term (weeks) and to benefit positively in the ensuing months and years. Market supplies are likely to be drastically reduced in the weeks and even months following an eruption. The effects of the eruption on subsistence food crops may be much greater than on plantation agriculture - further investigation of this possibility is required.

Economic and social impact of the eruption

According to this scenario an eruption would lead to insurable losses of, say, 10 to 20 per cent of the total value of (non-domestic) insured property. An upper estimate for total[7] property loss within the area affected by the eruption would be 20 per cent of value although much lower estimates, of say 10 to 15 per cent, could not be regarded as unreasonable.

7. Insured and non-insured, domestic and non-domestic, indigenously owned and non-indigenously owned.

Serious as this cost is and even taking into account the toll in terms of dead and injured and the impact on domestic dwellings it is doubtful that the provincial wealth generating mechanism could be said to have suffered "serious" let alone "irreparable" damage. The main reason for this is that, as explained in Chapter 3, the Rabaul-based economy depends on a wealth-generating mechanism that involves commodity production, the entrepôt trade and government expenditures.

Estimates of declines in commodity production suggest an initial brief reduction in cocoa production of the order of 20-30 per cent. Lost production would likely to be reduced to about 10 per cent within two years. Copra production would not be affected as severely and recovery should be complete within a two year period. It is anticipated that the Rabaul-based economy can cope with damage of this order of magnitude. However, this wealth-generating side of the story has to be placed in broader perspective and this will be attempted below.

While the overall verdict may be favourable there is no doubt that major problems will arise in a number of sectors even if this is only for a limited period of time. A number of these will be examined in turn, beginning with the impact on communications.

In some ways the most serious blow to communications will be from probable damage to Rabaul airport, particularly by pyroclastic flows and surges (Figure 6.5). This is recognised of course in that new facilities have been constructed at Vanakanau airstrip, and Tokua airstrip has been built since the beginning of the 1983-85 seismic crisis. However, neither is in the position to replace Rabaul airport immediately and fully and it must be expected that passenger and air cargo arrangements will be more expensive and less satisfactory until facilities and road connections are upgraded. Whether it would be prudent to repair Rabaul airport is a matter beyond the scope of this report and is bound up with questions of future provincial development strategies.

Obstruction to the harbour itself by sheets of floating pumice is likely to last only a few weeks. Most damage to harbourside facilities by tsunamis and ash would be repairable and, in any case, alternative arrangements can be made to maintain the reduced levels of commodity exports through Kabakaul wharf and other facilities. There appears to be little doubt that the case for restoring damaged harbourside facilities is stronger than that for repairing the airport although this should not be taken to imply that no case exists for developing alternative port facilities elsewhere in ENBP.

It is to be anticipated that there will also be significant damage to some roads caused by landslides, debris from pyroclastic flows, tsunamis, and ash-fall, and as a result of torrential rainfall, gullying and mudflows. However, such damage should be repairable in a matter of weeks and it is not anticipated that damage will be on such a scale as to seriously affect wealth generation in the province. Another problem, with short-run implications, is the expected damage to the volcano monitoring equipment, much of which is very susceptible to damage by highly magnetic ash. Without the availability of a mobile laboratory, it is likely to be some weeks after the eruption before adequate monitoring can be re-established. Thus, some delay to the recovery process can be anticipated because of the inability of the experts to provide firm re-assurances about the nature of further volcanic activity.

Interruptions to communications will affect commercial life because of the importance of imported goods in the province's economic life. This will aggravate the loss of "contents" and "plant and machinery" directly due to the eruption. In particular, the loss of agricultural production may be more serious as a consequence of interruptions to supplies of fertilisers, herbicides, insecticides and fungicides than from tephra fall on crops. However, evidence from the aftermath of other eruptions suggests that both agriculture and commerce will be able to cope with both direct damage and consequent disruptions. It should be noted that some enterprises and individuals are likely, on balance, to benefit from the eruption because of the extra demand generated by restoration work for repairs, clean-up equipment, overtime and the creation of new business opportunities. Furthermore, it is likely that the feeling that the eruption is over will lead to an improvement in business confidence.

This brief discussion suggests that the financial sector will cope reasonably well with an eruption. One obvious point of uncertainty relates to the financial consequences of uninsured losses. However, there is no reason to expect them to be unsupportable. In general, the financial sector will benefit from the fact that it has had a considerable period of time to adjust to the eruption possibility. Furthermore, in this context, by "financial sector" is really meant the longer-term consequences on the study area of the eruption since credit and insurance providers have, in general, national, and even international, financial bases so that immediate financial and insurance losses are not principally borne within the study area. It is likely that an eruption will attract some national and international financial aid but this is better treated in the context of the impact of an eruption on the broader community and this is the next subject discussed.

Elsewhere in this report the variability of impact of the seismic crisis on those in the study area has been stressed. The same point can be made about the variability of impact of any eruption. To some individuals and organisations it will most likely be at most an inconvenience. To others it could well be a disaster. Most individuals and organisations will suffer an impact that will lie somewhere between these extremes. Part of the differences in outcomes will depend on the precise nature of the volcanic events but part will depend on just how the individuals and organisations are positioned in relation to them at the precise time they occur.

Part of the variability in outcome will depend on resources, both human and material, available to meet the consequences of the eruption. Those lacking these resources will be particularly disadvantaged. To some extent this kind of problem is alleviated by the indigenous social system. Nevertheless, with the eruption expected to lead to deaths, injuries, the destruction of, and damage to, dwellings, and damage and loss to the business, government and agricultural sectors, the impact on the community can only be described as a major one. While it is difficult to speculate on the flow of any national or international aid which would help the study area recover, there is no reason why this should be expected to be of a minor order of magnitude compared to the scale of the disaster. For example, a governmental committee noted that Hurricane Iwa which struck the islands of Kauai and Oahu in November 1982 "will result in gains to the Hawaiian economy that are greater than the losses it caused" (Honolulu Star Bulletin, 18 January 1983, p193).

Governmental role

The only part of the role of the government considered here is that of the government as a victim of the disaster. Of course, some governmental bodies carry insurance but much damage would have to be made good out of current budgets and any vote of assistance from the national government. Despite protestations to the contrary, the provincial and national governments will probably have a greater involvement in the provision of food and shelter beyond the limited period of time incorporated in current planning. The restoration of communications will be an immediate and expensive priority. Given all the uncertainties associated with predicting the timing and scale of the eruption it is almost inconceivable that the course of actual events will follow those laid down in the Disaster Plan (ENBPDP, 1985). Nevertheless, it would be very surprising indeed if the work of the ENBPDC did not lead to a return to "normalcy" and then to a start on the "road to recovery" much more quickly than if the committee had never embarked on its labours.

In addition to the immediate restoration of communications the ENBPDC (as the arm of government) will be faced with a variety of urgent (and expensive) tasks including the restoration of public utilities (electricity, water and sewerage, street cleaning and garbage disposal) and the removal of ash and debris from the town and other affected areas.

Besides the more obvious tasks of cleaning-up after a natural disaster, the committee will face the need to make a variety of important decisions, each with major financial and economic implications. Recovery can be impeded if speedy decisions that command business and public confidence are not reached on the post-eruption strategy. Numerous "signals" will indicate a return to "normalcy" and an increase in public and business confidence. Schooling, as has been seen above, is a particularly important problem. While the requisitioning of schools and the dispersal of teachers and pupils is a necessity dictated by the emergency a return to normal schooling arrangements is not only a powerful signal that "normalcy" has returned but, for many, a pre-requisite for a return to pre-eruption routines. Other signals include the return of garbage collections, the re-opening of public buildings such as the post office and the court house and supplies at the market. It is likely, however, that the first decision that will need to be made, in the light of pressures from the insurance and financial industries (see Chapters 4 and 5) is whether Rabaul should be re-occupied at all as a site for continued investment. This question is considered in Chapter 9.

Chapter 7
Scenario Two

Introduction

For four to five months of the year, near-surface winds in the Rabaul area blow from the northwest. As Figure 2.7 indicates winds above about 4 kilometres altitude continue to blow year round from the east-southeast. The strengths (velocities) of the winds also vary through the year. Thus, for an eruption occurring in the opposite season, ash will fall in different areas to those affected by the May 1937 eruption. It is necessary to evaluate an eruption during this season as it has about 40 per cent probability of occurrence.

The eruption modelled here is equal in magnitude to the 1937 eruption but occurring in November. As we have no actual occurrence on which to base our model there are a number of uncertainties involved. The volcanic ash distribution shown on Figure 7.1 is based on the theoretical tephra fallout model presented by Blong (1981b) and McKee et al. (1985). It is assumed that the fallout is integrated from 10 kilometres to the surface, so that two lobes form - one produced by the low-level winds blowing to the southeast and one produced by all the winds to give a southwestern lobe.

The southwestern lobe extends more than 25 kilometres. The outline shown on Figure 7.1 is believed to approximate the 25 millimetre isopach. Approximations of 150 millimetre, 610 millimetre and 1,800 millimetre isopachs are shown on Figure 7.2. The uncertainties in this technique must be emphasised.

Other hazards associated with the eruption are largely unchanged. However, as it appears that some of the 1937 pyroclastic flows were sandwiched between the wind-driven tephra cloud and the ground it appears that some pyroclastic flows would extend more, in this scenario, toward the southeast (Figure 7.3). The distribution of earthquakes and ballistic projectiles will be unaffected by the change of season; the areas influenced remain the same as those shown on Figures 6.2 and 6.3. As the cause of possible tsunamis are not known with certainty, it is difficult to predict the effects on tsunami generation. Tsunamis may be generated by pyroclastic flows striking the water thus tsunamis may be more extensive towards the south in this scenario. However, the additional vulnerable coast, around Butuwin, is protected by a reef so the areas affected by tsunamis remain essentially the same as in Figure 6.6. Clearly the distribution of toxic gases from the Liklik Vulcan vent will also change with wind direction.

Figure 7.4 indicates the areas most likely to be affected by mudflows. As with Figure 6.11 those areas with steep slopes and ash thicknesses greater than 150 millimetres are judged to be most vulnerable.

Figure 7.1

Outline of area likely to receive 25 millimetre or more ash-fall
1937-magnitude, November eruption

BASE MAP MAP
TEPHRA FALLS MAP

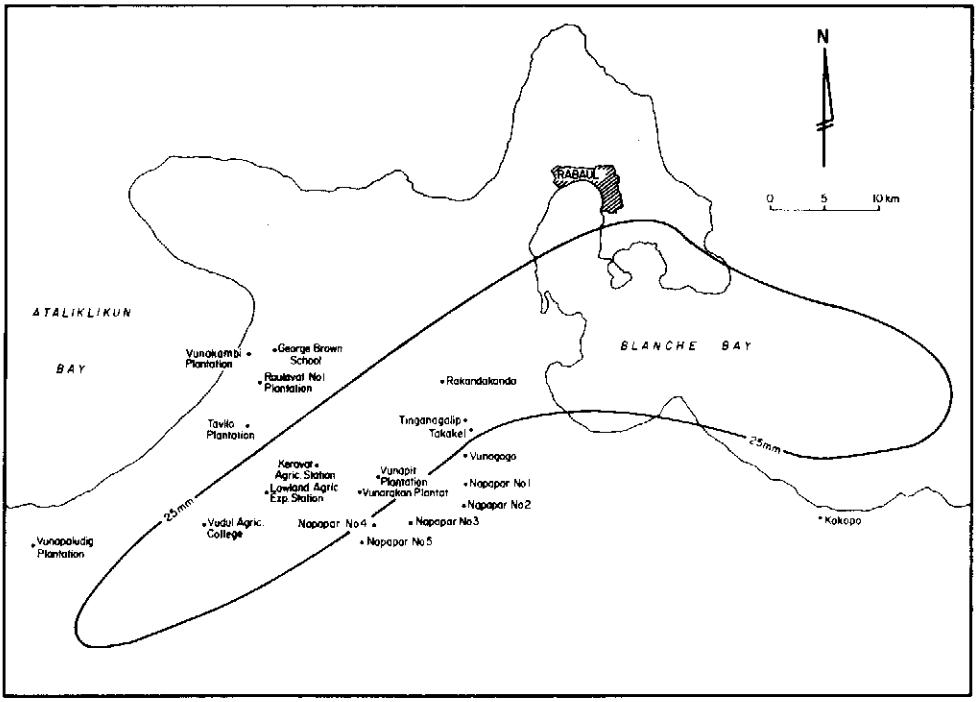


Figure 7.2

Expected ash-fall isopachs for 1937-magnitude, November eruption

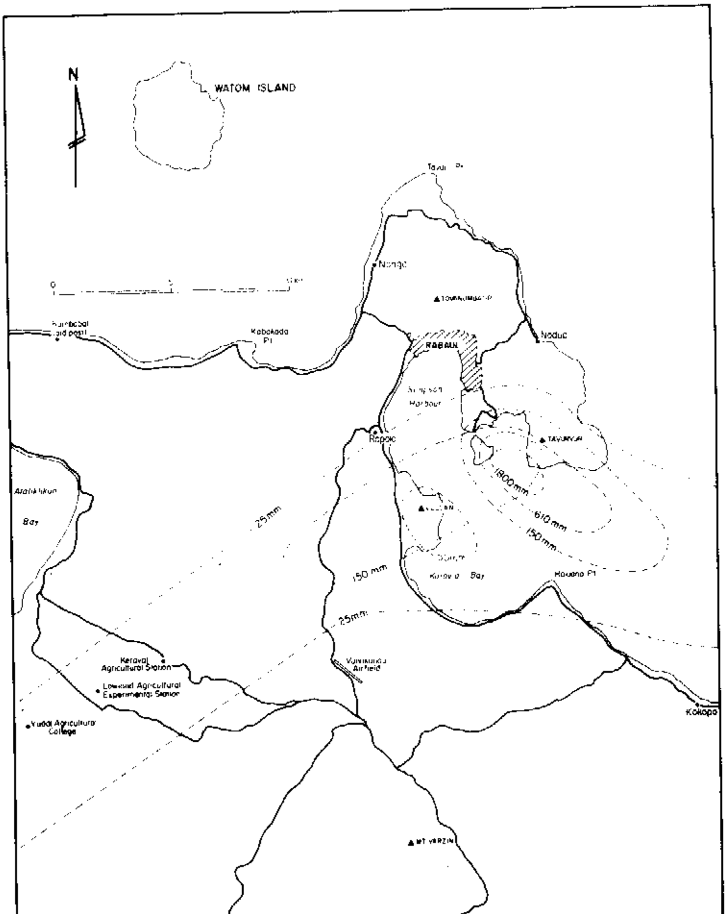


Figure 7.3

Anticipated distribution of pyroclastic flows
1937-magnitude, November eruption

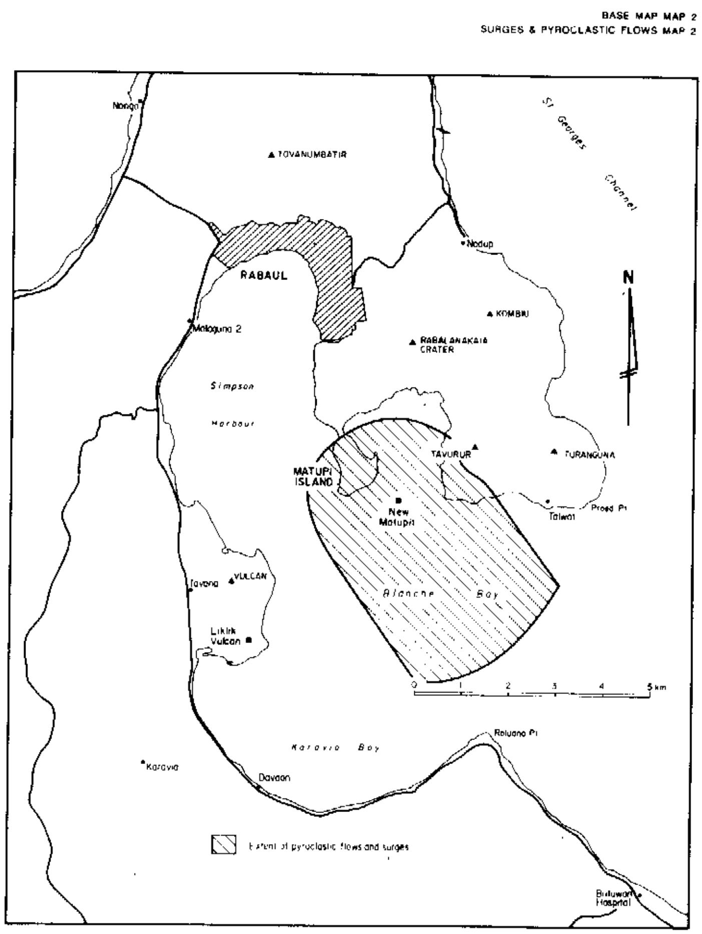
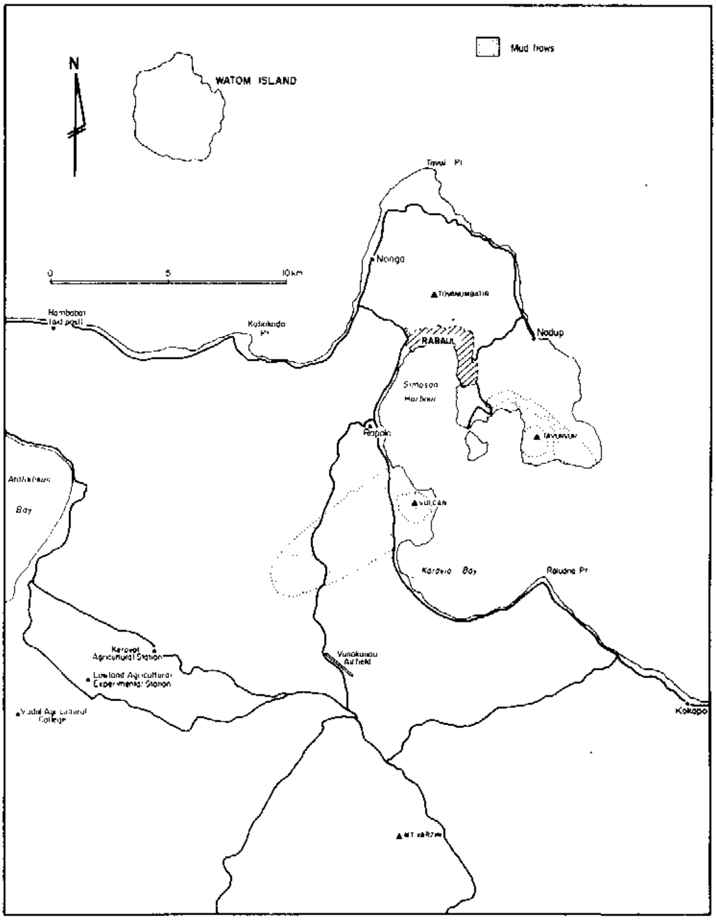


Figure 7.4

Mudflows,
1937-magnitude, November eruption

BASE MAP MAP 1
MUDFLOWS MAP 1



Deaths and injuries

Table 7.1 has been compiled in the same way as Table 6.2 - that is, by overlaying the hazard maps on the population distribution map (Figure 6.9). Comparing these two tables indicates that many fewer residents can be judged to be at risk during a November eruption.

Table 7.2 indicates anticipated evacuation rates. These are identical to those for the May eruption (Table 6.3) except that the rates for the yellow and green zones are reversed.

Table 7.3 sets out in considerable detail the totals at risk (after evacuation) and anticipated deaths. For the "average" state (i.e. evacuation rates as in Table 7.2 and death rates as in Table 6.1) the projected death toll is less than half that of a May eruption (Figure 7.5). For the most severe case modelled, the death toll is little more than a third of that suggested for a May eruption. The major reason for the lower death toll lies in the fact that only small areas of land are threatened by pyroclastic flows in a November eruption. Similarly, heavy tephra falls affect fewer residents.

Table 7.1
Residents at risk

Hazard	No. of residents at risk New Matupit	Liklik Vulcan
Earthquakes		
more than MM6	24,240	
Ballistic projectiles	2,800	150
Tephra falls		
more than 183 cm	2,000	-
183 - 61 cm	1,200	-
61 - 15 cm	1,740	332
15 - 2.5 cm	4,460	-
Pyroclastic flows and surges	2,200	-
Tsunamis	1,650	-
Toxic gases	80	-

Table 7.2
Anticipated evacuation rates

Zone	Evacuation rate (per cent)
Purple	99
Red	97
Blue	95
Green	10
Yellow	90
Other areas	1

Table 7.3
Estimated deaths

Evacuation rate	+ 20%	+ 10%	Average	- 10%	- 20%
Death rate per 1000	- 20%	- 10%	Average	+ 10%	+ 20%
Model	5	4	1	2	3
Total at risk	6,059	6,105	6,857	10,039	13,220
Mean evacuation rate	(0.89)	(0.89)	(0.87)	(0.79)	(0.70)
Hazard					
Earthquakes	2	3	3	6	9
Ballistic projectiles	-	-	-	3	7
Tephra falls					
more than 183 cm	-	-	-	-	1
183 - 61 cm	-	-	-	4	7
61 - 15 cm	-	-	1	3	5
15 - 2.5 cm	3	3	3	4	4
Pyroclastic flows	-	-	9	103	214
Tsunamis	-	-	1	6	12
LV projectiles	-	-	-	-	-
LV tephra fall (more than 15 cm)	-	-	-	-	-
Toxic gas	-	-	-	1	2
Grand total	**5**	**6**	**17**	**130**	**261**

Table 7.4 sets out anticipated injuries during a November eruption. The numbers of injured are also less than those expected in a May eruption (Figures 7.5 and 6.10).

Two provisos need to be noted in relation to these data. Firstly, it is clear that although the Rabaul Volcano Disaster Plan calls for the evacuation of the yellow zone for a November eruption, the model presented here suggests that this is hardly necessary (cf. Figures 6.9 and 7.2) except perhaps in the northernmost area around Raluana Point. Secondly, many of those at risk from minor tephra falls in the area southwest of Karavia Bay will not be evacuated, at least according to the Plan. In fact, this area is likely to be one in which the population at risk increases as a result of the influx of evacuees from other areas. This influx has not been allowed for in the spreadsheet calculations summarised in Tables 7.3 and 7.4 - it can be anticipated that actual casualties will be higher than those shown. This is an important point as a significant proportion of the (minor) injuries and a few deaths can be anticipated in this area.

As with a May eruption some deaths are likely to occur as a result of mudflows and flash floods in the aftermath. Although the total areas likely to be affected by mudflows after the two eruptions are similar (Figures 6.11 and 7.4) the November mudflows will occur in less densely settled areas. It is presumed, therefore, that deaths and injuries will be fewer than in the aftermath of the May eruption.

Figure 7.5

Projected numbers of dead and injured for November eruption versus May eruption

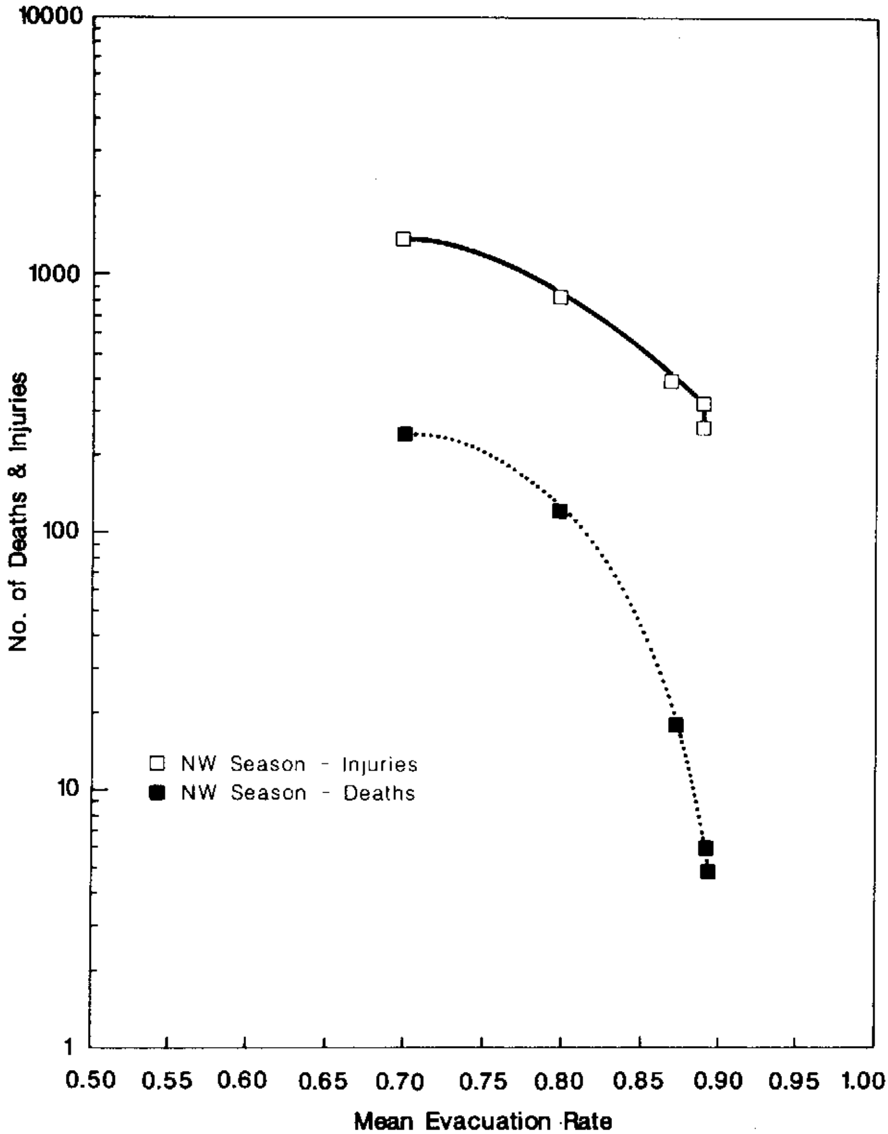


Table 7.4
Estimated injuries

Evacuation rate	+ 20%	+ 10%	Average	- 10%	- 20%
Death rate per 1000	- 20%	- 10%	Average	+ 10%	+ 20%
Model	5	4	1	2	3
Total at risk	6,059	6,105	6,857	10,039	13,220
Hazard					
Earthquakes	9	10	14	24	36
Ballistic projectiles	-	-	1	7	14
Tephra falls					
more than 183 cm	-	-	1	8	15
183 - 61 cm	-	-	12	129	247
61 - 15 cm	22	24	36	133	248
15 - 2.5 cm	258	292	323	381	438
Pyroclastic flows	-	-	13	155	321
Tsunamis	-	-	4	19	37
LV projectiles	-	-	-	-	1
LV tephra fall (more than 15 cm)	-	-	1	5	9
Toxic gas	-	-	-	6	11
Grand total	**289**	**326**	**405**	**867**	**1,377**

Damage to buildings

Estimates of the number of dwellings at risk during a northwest season eruption have been constructed from the estimates of population at risk and in the same way as detailed in Chapter 6. The total number of dwellings at risk is approximately 8,500 of which nearly 75 per cent are judged to be of Type 2 construction. Table 7.5 indicates that the greatest number of dwellings are judged to be at risk from earthquakes and, secondly, thin tephra falls. Clearly, the number of dwellings at risk from earthquakes, ballistic projectiles and tsunamis are virtually the same as in scenario 1. Despite the similarities in the two models and despite the fact that the two eruptions are of equal magnitude only 55 per cent of the number of buildings at risk in scenario 1 are now in areas judged to be hazardous.

The risk factors presented in Table 6.7 were used in a spreadsheet model to estimate the number of buildings that might be destroyed, badly damaged, and slightly damaged. Table 7.6 presents estimates of the numbers of buildings in each of these three categories. Thin tephra falls, earthquakes, ballistic projectiles and pyroclastic flows again produce damage to the greatest number of buildings but it is clear that the majority of buildings that suffer damage will be only slightly damaged.

The estimates presented in Table 7.6 must be treated with a great deal of caution. Figure 7.6 indicates reasonable variations (the shaded areas indicate plus or minus 20 per cent) in the proportions of buildings of each type and each damage category. The significant point is that serious damage (or destruction) is always less than 12 per cent of the buildings at risk and slight damage is always less than 15 per cent of building stock. In the case of Type 1 buildings the proportion is always much lower.

Table 7.6
Estimates of building damage

	No. of buildings						
	Type 1			**Type 2**			
	Destroyed	Badly damaged	Slightly damaged	Destroyed	Badly damaged	Slightly damaged	Total
Earthquakes	13	13	26	67	67	133	319
Ballistic projectiles	1	4	7	4	21	44	81
Tephra falls							
more than 183 cm	2	3	1	7	6	2	21
183 - 61 cm	10	19	13	53	53	44	192
61 - 15 cm	4	8	17	84	113	168	394
15- 2.5 cm	3	7	25	99	150	198	482
Pyroclastic flows	25	38	63	97	130	97	450
Tsunamis	4	8	12	27	40	54	145
Toxic gases	-	-	-	-	-	1	1
Mudflows	3	5	8	9	14	18	57
Totals	**65**	**105**	**172**	**447**	**594**	**759**	**2142**

It is also interesting to compare the effects on buildings of the two eruptions modelled, remembering that the two eruptions are of equal magnitude. Table 7.7 provides such a summary comparison of the effects of each hazard. Table 7.8 presents a summary based on building types and damage types.

Table 7.5
Dwellings at risk

Hazard	No. of dwellings
Earthquakes greater than MM6	4,650
Ballistic projectiles	575
Tephra falls	
more than 183 cm	20
183 - 61 cm	240
61 - 15 cm	640
15 - 2.5 cm	1,240
Pyroclastic flows and surges	450
Tsunamis	350
Toxic gases	10
Mudflows	350
Total	**8,525**

Table 7.7
Ratios of damage - scenario 1/scenario 2*

Hazard	Damage ratio
Earthquakes	
greater than MM6	1.0
Ballistic projectiles	1.0
Tephra falls	
more than 183 cm	22.0
183 - 61 cm	1.0
61 - 15 cm	3.0
15 - 2.5 cm	4.0
Pyroclastic flows	3.0
Tsunamis	1.0
Toxic gases	5.0
Mudflows	1.5
Total	**2.6**

Note: * Scenario 1 refers to an eruption during May (southeast season) equal in magnitude to the 1937 eruption. Scenario 2 refers to an eruption during November (northwest season) equal in magnitude to the 1937 eruption.

Figure 7.6

Proportions of buildings likely to be destroyed or damaged
1937-magnitude, November eruption

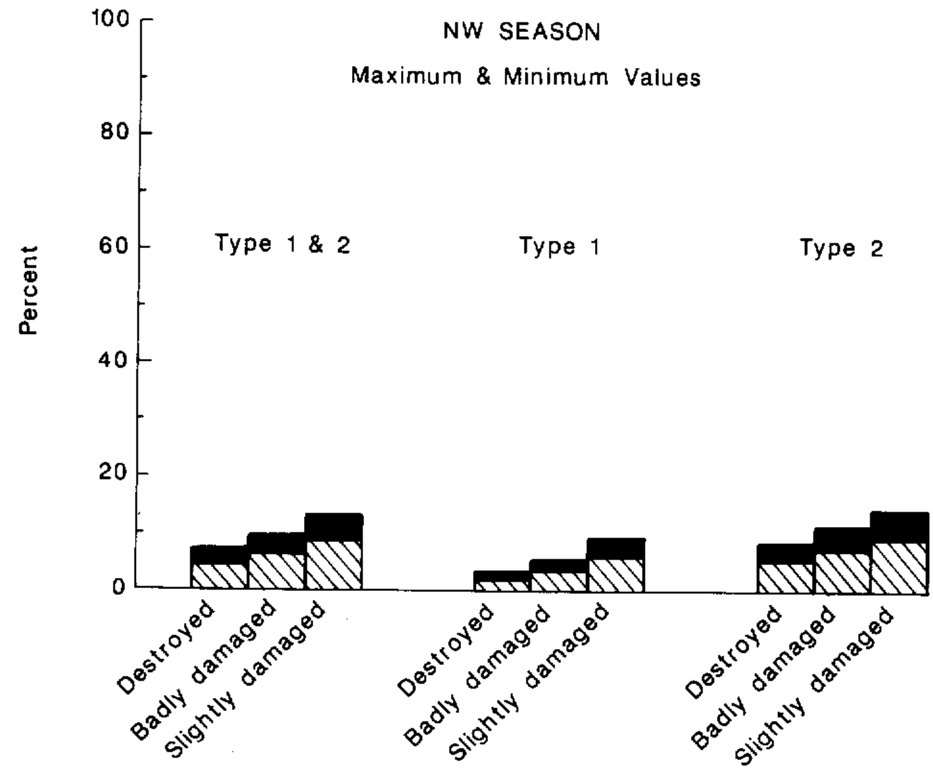


Table 7.8
Ratios of damage - scenario 1/scenario 2

Building type	Damage	Ratio
Type 1		
	Destroyed	4.0
	Badly damaged	4.0
	Slightly damaged	4.0
Type 2		
	Destroyed	2.5
	Badly damaged	2.5
	Slightly damaged	2.5

These results emphasise the importance of modelling at least two differing eruptions even though they are of the same magnitude and from the same eruptive centres. While it cannot be guaranteed without further work that these two eruptions represent the end members of a continuum they certainly lie towards the ends of the distribution. Further comment along these lines is left until Chapter 9.

Damage to insured commercial premises

Much of the discussion in Chapter 6 relating to the first scenario is immediately applicable to the treatment of this scenario. In particular, there is no need to repeat what has already been written about damage probabilities and property valuation and the data. In general, the discussion above relating to the individual spreadsheets is still applicable although, of course, adjustments must be made to take account of the substantial differences in the two scenarios.

Since the earthquake and tsunami risks have not been changed by the change in scenarios, the relevant columns in Table 7.9 are identical to the comparable columns in Table 6.10. Since the pyroclastic risk does not affect insured buildings in this scenario, this column has no non-zero entries. There is some tephra risk in the less than 15 centimetre category, the details being given in the note to Table 7.9.

It should be stressed again that the damage figures in Tables 6.10 and 7.9 are not cumulative. Consequently, there is a danger that the amount of property damage that could result from an eruption according to this scenario might be played down. Nevertheless, Table 7.9, when compared to Table 6.10, reflects the picture obtained in comparing the maps associated with these two scenarios. There is less damage because the wind is blowing in a different direction. Table 7.10 summarises the differences in damage to insured commercial premises for the two scenarios.

Table 7.9
Damage estimates by risk category and insurance company

Name	Earth-quake risk	<15cm tephra risk*	>15cm tephra risk	Pyroclastic risk	Tsunami risk
Company A					
Sum insured K13,014,708					
Property value at risk	12,814,708	0	0	0	9,164,831
Damage estimates					
by total destruction	128,147	0	0	0	458,242
by substantial damage	89,703	0	0	0	641,538
by minor damage	51,259	0	0	0	274,945
Total damage	269,109	0	0	0	1,374,725
Company B					
Sum insured K18,337,850					
Property value at risk	18,108,350	0	0	0	0
Damages estimate					
by total destruction	181,084	0	0	0	0
by substantial damage	126,758	0	0	0	0
by minor damage	72,433	0	0	0	0
Total damage	380,275	0	0	0	0
Company C					
Sum insured K7,702,320					
Property value at risk	7,472,576	0	0	0	58,743
Damages estimate					
by total destruction	74,726	0	0	0	2,937
by substantial damage	52,308	0	0	0	4,112
by minor damage	29,890	0	0	0	1,762
Total damage	156,924	0	0	0	8,811
Company D					
Sum insured K30,472,280					
Property value at risk	27,500,230	0	0	0	22,786,867
Damages estimate					
by total destruction	275,002	0	0	0	1,139,343
by substantial damage	192,502	0	0	0	1,595,081
by minor damage	110,001	0	0	0	683,606
Total damage	577,505	0	0	0	3,418,030
Total amount at risk c/f	65,895,864	0	0	0	32,010,441
Overall damage c/f	1,383,813	0	0	0	4,801,566

Table 7.9 (continued)
Damage estimates by risk category and insurance company

Name	Earth-quake risk	<15cm tephra risk*	>15cm tephra risk	Pyroclastic risk	Tsunami risk
Total amount at risk b/f	65,895,864	0	0	0	32,010,441
Overall damage b/f	1,383,813	0	0	0	4,801,566
Company E					
Sum insured K22,164,405					
Property value at risk	22,114,405	0	0	0	3,621,344
Damages estimate					
by total destruction	221,144	0	0	0	181,067
by substantial damage	154,801	0	0	0	253,494
by minor damage	88,458	0	0	0	108,640
Total damage	464,403	0	0	0	543,202
Total amount at risk	88,010,269	2,024,500	0	0	35,631,785
Overall damage	1,848,216	0	0	0	5,344,768
Apportion K16,520,338 amount at risk	15,857,068	0	0	0	6,419,883
Damage	332,998	0	0	0	962,982
Final figures amount at risk	103,867,337	2,024,500	0	0	42,051,668
Damage	2,181,214	42,515	0	0	6,307,750

* Since the <15 cm tephra risk only involved ten properties covered by four insurance companies with most of the risk relating to one policy, it was decided not to disaggregate for this particular risk.

Table 7.10
Ratios of estimated damages - scenario 1/scenario 2

Hazard	Scenario 1/scenario 2
Earthquake	1
less than 15 cm tephra risk	43
more than 15 cm tephra risk	no damage in scenario 2
Pyroclastic flow risk	no damage in scenario 2
Tsunami risk	1

Effects on agriculture

The method for estimating the effects of the November eruption on agriculture is identical to that outlined in Chapter 6 for the May eruption. Estimated annual cocoa production is as set out in Table 6.13. The differences in distribution of tephra fall, pyroclastic flows and surges, and mudflows for the November event as shown in Figures 7.2 to 7.4 (cf. Figures 6.4, 6.5, and 6.11) produce some differences in the proportions of census divisions affected by these hazards (Table 7.11, (see page 171) cf. Table 6.15). The boundaries of the census divisions are shown on Figure 3.1. As the estimated negative effects on cocoa production of each volcanic hazard are the same as those used in the last chapter the estimated effects of a November eruption can be determined by multiplying together the appropriate elements of Tables 6.13, 6.14 and 7.11. A comparison of Tables 6.16 and 7.12 indicates that the main reason only minor adverse effects occur from a November eruption is the reduction in effects in Balanataman census district, countered to a lesser extent by an increase in the Central census unit. Exact comparison of the effects of the two eruptions is difficult, but Figures 7.7 and 6.13 suggest that the effects in November are only about one-third those resulting from a May eruption. This comparison assumes, of course, that the effects of ash-fall and other volcanic hazards on plant pollination, insect predators and so forth are similar for the two eruptions. Clearly, this assumption may prove to be seriously in error.

Table 7.12
Changes in cocoa production by census division

Census division	Initial production/year (x 1,000 bags)	Per cent change 1 month	1 year	2 years
Balanataman	39.3	-6	-1	0
Central	8.2	-40	-23	-12
Kokopo	34.4	0	0	0
Kombui	1.6	-73	-42	-18
Livuan	3.3	0	-	0
Reimber	1.6	-10	-6	-3
Raluana	6.6	-8	-5	-2
Rabaul town	0.1	-51	-25	-11
Vunadidir	3.3	-5	-3	-2
Watom	1.6	0	0	0
Totals	**99.6**	**-8**	**-3**	**-2**

The effects on coconut and copra production can be described in a similar fashion. The available information on copra production in the mid-1980's is presented in Table 6.17. The proportions of census divisions affected by a November eruption are shown in Table 7.11 and the likely changes in production following an eruption, hazard by hazard, are given in Table 7.13. The estimated reduction in production for the two year period following an eruption is illustrated in Figure 7.8.

Figure 7.7

Estimated effects on cocoa production over a two year period, 1937-magnitude, November eruption

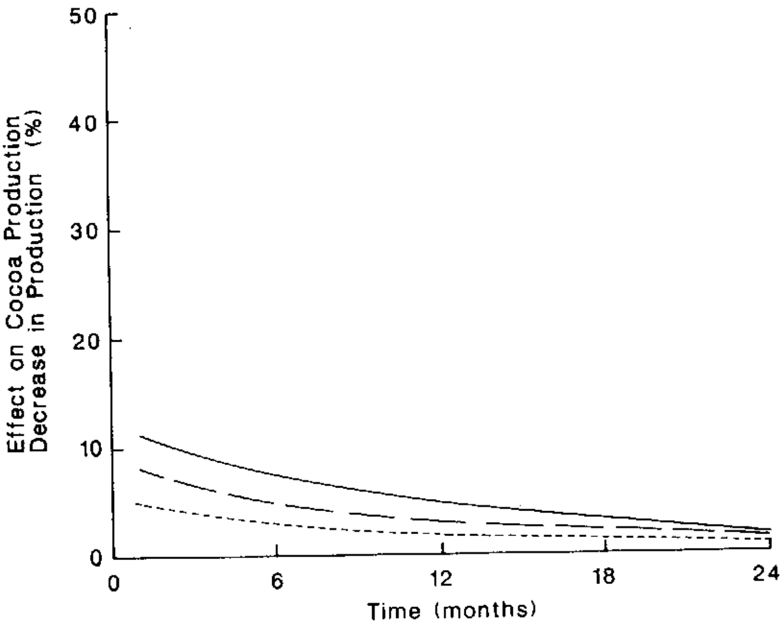


Figure 7.8

Estimated effects on coconut (copra) production over a two year period, 1937-magnitude, November eruption

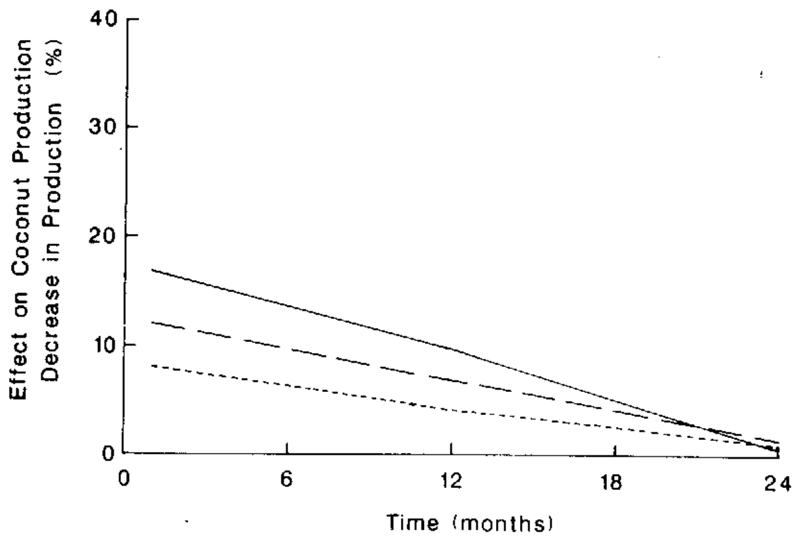


Table 7.11
Proportions of census divisions affected by eruption hazards
(per cent)

Census divisions	Hazard									
	Earth-quakes	Ballistic projectiles	Tephra falls >183cm	183-61cm	61-15cm	15-2.5cm	Pyroclastic flows	Tsunamis	Toxic gases	Mudflows
Balantaman	50	-	-	-	-	-	-	2	-	-
Central	10	1	-	5	25	50	-	1	5	12
Kokopo	-	-	-	-	-	-	-	-	-	-
Kombiu	70	20	5	10	10	15	10	20	-	15
Livuan	-	-	-	-	-	-	-	-	-	-
Reimber	10	-	-	-	-	20	-	5	-	-
Raluana	5	-	-	-	-	15	-	5	-	-
Rabaul town	100	10	1	5	5	20	10	20	-	2
Vunadidir	-	-	-	-	-	15	-	-	-	-
Watom	-	-	-	-	-	-	-	-	-	-

Table 7.13
Changes in copra production by census division

Census division	Initial production/year (x 1,000 bags)	Per cent change		
		1 month	1 year	2 years
Balanatan	46.9	-3	0	0
Central	27.7	-33	-21	-4
Kokopo	48.9	0	0	0
Kombui	25.5	-60	-35	-12
Livuan	22.0	0	0	0
Reimber	27.1	-9	-5	-1
Raluana	30.9	-7	-4	-1
Rabaul town	-	0	0	0
Vunadidir	27.0	-5	-3	0
Watom	11.4	0	0	0
Totals	**267.4**	**-12**	**-7**	**-2**

Although these estimates indicate that a November eruption will produce significantly less serious effects for cash crop production than a May eruption, it must be remembered that subsistence agriculture will also be adversely affected. These effects may be particularly serious in the first few weeks after an eruption as food crop production will be reduced in the area of one of the main concentrations of evacuees. In this area residents as well as evacuees may require some assistance.

Overview

Several important points emerge from this brief review of the effects of a November eruption equal in magnitude to the 1937 eruption. Firstly, the effects of a November eruption are much less than those of a May eruption. Estimated deaths are about half those anticipated for a May eruption. Similarly, damage and destruction of building stock in November would probably be only 25-40 per cent of that in May. In the case of agriculture the effects are estimated to be reduced to about one-third of those expected with a May eruption.

Secondly, these comparative data raise questions about the likely effects of eruptions occurring in other months of the year. Unfortunately, the answers are not known as insufficient modelling has been undertaken. Although it is believed that the May and November eruptions of 1937 magnitude represent the spectrum of possible effects, it is unlikely that the end members of the distribution have yet been analysed. Further work along these lines should be undertaken.

The need for further work is emphasized by the conclusion that during a November eruption, evacuation into the area at risk from relatively minor tephra falls seems likely to occur. This conclusion should be checked by further analysis, if possible utilizing additional atmospheric fallout models. Fallout patterns for each month of the year should be analysed to determine the likely extent of evacuation into potential ash-fall areas. Although minor ash-falls are likely to cause only short-lived problems related particularly to health, transport and agriculture, such potential problems require consideration in the Disaster Plan.

Chapter 8
Scenario Three

Introduction

In this chapter the effects of a large-scale eruption in the Rabaul caldera are considered. The basic model for this scenario is the 1,400 year B.P. eruption the deposits from which have been described by Walker et al. (1981) and briefly outlined in Chapter 2 (see Figure 2.2). In terms of the Volcano Explosivity Index this eruption was very large (VEI 6), producing more than 10 cubic kilometres of ignimbrite and airfall ash deposits.

In Chapter 2 it was emphasised that although there are a number of difficulties in estimating the frequency of occurrence of such a large-scale eruption, it seems certain that the probability of an eruption of this magnitude is considerably less than 5 per cent. In fact, it is likely that the frequency of occurrence of such eruptions is significantly less than once in twenty eruptions - perhaps of the order of only once in every one hundred eruptions. So far as it is possible to tell from the stratigraphic evidence the frequency of such large eruptions in the Rabaul area in geologically recent times is of the order of, on average, once in every 1,700 to 2,000 years. In the terms presented by Latter and Hurst (1987) the mean recurrence interval of such large eruptions is about once in 2,800 years.

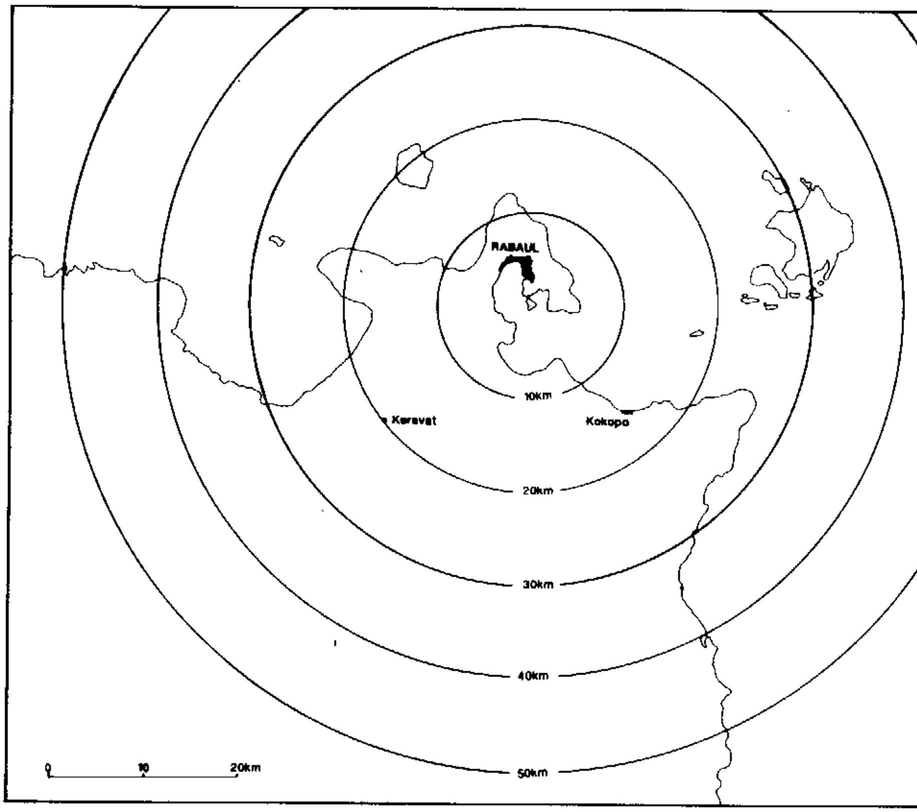
On a world scale, the relative infrequency of such large-scale eruptions is emphasised in Figure 2.5. Consequently, there are no good historical comparisons available in the literature. The only large-scale eruption of roughly similar style to have occurred this century was the 1912 Katmai-Novarupta eruption in Alaska. Although this eruption killed no one (at least not directly), because of the scarcity of population, smaller eruptions involving fast-moving pyroclastic flows, for example the 1902 eruption of Pelee on Martinique, have produced death tolls of up to 30,000. The rather similar eruption of Mount Lamington in Papua New Guinea in 1951 killed about 3,000 people.

In this report only the effects of the pyroclastic flows (ignimbrite deposits) are considered. As with the eruptions considered in the earlier scenarios a multiplicity of hazards can be expected to be associated with a large-scale eruption in Rabaul. Earthquakes, ballistic projectiles and toxic gases are likely to produce damage and casualties within a few kilometres of the vent but the effects of all these hazards would soon be overwhelmed by the effects of ignimbrite deposition. Tsunamis generated during the eruption could affect shorelines tens and even hundreds of kilometres from Rabaul. Coastal areas of southern New Ireland are likely to be most at risk from tsunamis. Ash-falls are also likely to be very widespread perhaps producing deposits several centimetres thick even on portions of the Papua New Guinea mainland. It is not inconceivable that minor climatic deterioration could also occur on a world-wide scale as the result of the injection of enormous volumes of fine particulates and sulphuric aerosols into the upper atmosphere.

Given all the uncertainties in estimating the effects of ignimbrite emplacement - the best known aspect of early large-scale eruptions in Rabaul - we have focused our attention solely on the effects of this aspect of a VEI 6 eruption. The basic framework for consideration of large-scale ignimbrite eruptions is presented in Figure 8.1. Rather than consider just one eruption, four possibilities are considered with the limits of thick (more than 0.5 to one metre) ignimbrites reaching 20, 30, 40 or 50 kilometres from the centre of the caldera.

Figure 8.1

Gazelle Peninsula with circles of radii 10, 20, 30, 40, and 50 km to show possible areas affected by a large ignimbrite eruption.



Although the deposition of pyroclastic flows at distances of 40 and 50 kilometres from the vent might seem quite improbable, it should be noted that Walker et al. (1981) believe the pyroclastic flows generated by the 1,400 year B.P. event completely devastated the entire area surrounding Rabaul out to a distance of at least 50 kilometres. Similarly, the 3,500 year event emplaced pyroclastic flow deposits at Arumbum, 40 kilometres south of the vent. Some volcanologists doubt that pyroclastic flows can travel over water but such deposits from the 1,400 year B.P. event have been identified on Watom Island. Over-water travel is probably made possible by the earlier eruption of a thick mantle of pumice which floats on the surface.

Some pyroclastic flows, and hence ignimbrite deposits, can be expected even beyond the margin set for each case, particularly in relatively low-lying areas. On the other hand there may be limited areas, sheltered by topographic highs within the limits shown on Figure 8.1, which are unaffected by pyroclastic flows.

The margins of deposition shown on Figure 8.1 are circular. Such a margin is improbable in reality, but there is little point in attempting a more sophisticated model.

In the discussion of the effects of a large ignimbrite eruption set out below, attention is focused on the same aspects as those considered in earlier scenarios; that is, the effects on people, dwellings, commercial structures and agriculture.

Effects on people

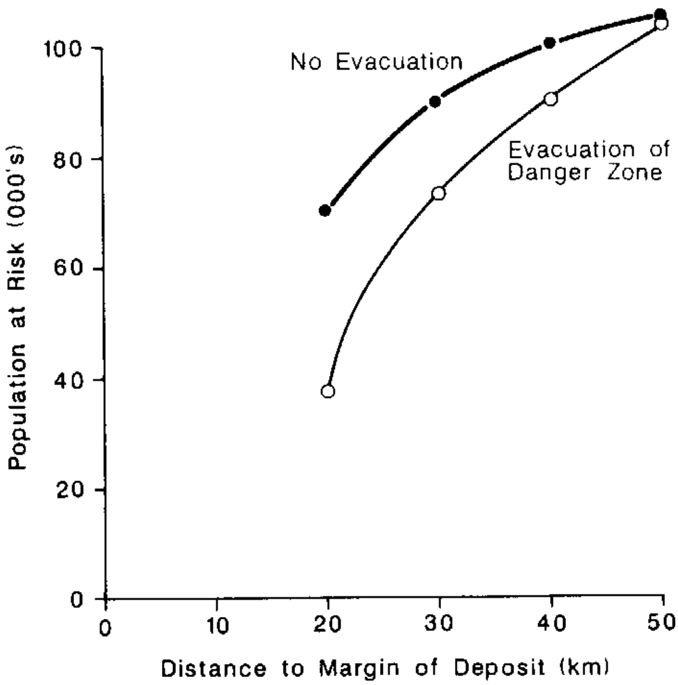
Although there are no direct observations of the effects of large-scale ignimbrite eruptions on people it is clear that the chances of human survival in areas with as little as half a metre of pyroclastic flow deposit are negligible. It must be remembered that pyroclastic flows are composed of a mixture of fragmented rock and gas moving at speeds of more than 100 kilometres per hour at temperatures of at least several hundred degrees Celsius.

The model constructed here is based on each of two considerations - no evacuation, and evacuation as for a small-moderate eruption such as that presented in Chapter 6. Figure 8.2 presents the results. The total population at risk for an eruption producing pyroclastic flows which extend to the 50 kilometres radius is estimated to be about 105,000. The proportion of the population in each census division living in the area at risk has been estimated for the 50, 40, 30 and 20 kilometres radii assuming that no evacuation took place. For the second curve, it has been assumed that the red, blue, green and yellow zones were evacuated as planned for a small to moderate eruption. The evacuees in this case were assumed to be distributed to other census divisions in the same proportions as they are in the official evacuation camps at Gaulim, Kerevat, LAES, Vudal, Vunamami, Kokopo, and Bitapaka (see Appendix 4.3).

Although there are a number of assumptions (with significant error terms) in the construction of Figure 8.2, it is important to note that after evacuation from the danger zone there would still be more than 35,000 people in the area affected by ignimbrite deposition even for an eruption which extended only to the 20 kilometres radius. It is also important to note that the number of people at risk climbs rapidly as the radius of ignimbrite deposition increases.

Figure 8.2

Relationship between extent of ignimbrite deposits
and population at risk



Obviously the curves in Figure 8.2 are based on the assumption that people evacuated from the danger zone do not move very far beyond the areas of the evacuation camps. This assumption would be in error if it were not for two factors which probably need to be taken into account. Firstly, if a large eruption follows from a relatively small eruption it will be difficult to predict as much of the monitoring capability of RVO is likely to be damaged or destroyed by the initial eruption. Secondly, for an eruption that extends toward the 50 kilometres radius from the caldera, there are very few evacuation routes beyond this zone, and none suitable for large numbers of people. It is also worth pointing out that a secondary evacuation beyond the initial safe zone has not been practised and is, in fact, not clearly formulated in the Disaster Plan.

Effects on buildings

As no detailed information has been compiled on the number, type and distribution of dwellings at risk in a large eruption, the numbers presented here are rounded estimates based on the population figures used earlier in the chapter and household size information derived from that presented by Morauta (1982). For Rabaul town it is assumed that average household size is 4.6 persons and for the rest of the area, 5.6 persons. All estimates have been rounded.

In this section no distinction is drawn between Type 1 and Type 2 houses. Most of the Type 1 houses are located in the Kerevat - Kokopo - Rabaul triangle. Figure 8.1 suggests that virtually all of the houses in this area would be destroyed or damaged beyond repair by the smallest of the eruptions considered here (20 kilometres radius), with the possible exception of some dwellings located in protected spots on the lee sides of topographic highs near the margins of the pyroclastic flows.

Figure 8.3 suggests a relationship between eruption size and the number of dwellings destroyed or seriously damaged. For the largest eruption about 20,000 dwellings would be destroyed or seriously damaged. This number would seem to be reduced by only 5 to 10 per cent for an ignimbrite eruption reaching only to 40 kilometres from the vent. Even for an eruption with pyroclastic flow deposits extending to only 20 kilometres from the vent, it is estimated that about 13,000 dwellings would be destroyed or seriously damaged.

The vast majority of the commercial buildings on the Gazelle Peninsula are located in Rabaul, Kokopo and Kerevat. It seems likely that nearly all of these structures would also be destroyed or seriously damaged by an ignimbrite eruption extending to 20 kilometres from the vent. It also seems certain that the great majority of schools and other public buildings in this area would be demolished.

It must also be remembered that numerous other dwellings, public and commercial buildings elsewhere in the Islands Region (and possibly on mainland Papua New Guinea) would be damaged by tsunamis and by tephra falls of several centimetres or more.

Effects on agriculture

Details of cocoa and copra production for the community government areas affected by the eruptions considered in scenarios 1 and 2 have been presented in Tables 6.13 and 6.17. Data for the additional community government areas likely to be affected by a large-scale eruption are summarised in Tables 8.1 and 8.2. Addition of the two sets of tables indicates that the census divisions considered produce about 95 per cent of ENBP cocoa and about 97 per cent of ENBP copra.

Figure 8.3

Relationship between extent of ignimbrite deposits and number of dwellings likely to be damaged or seriously destroyed

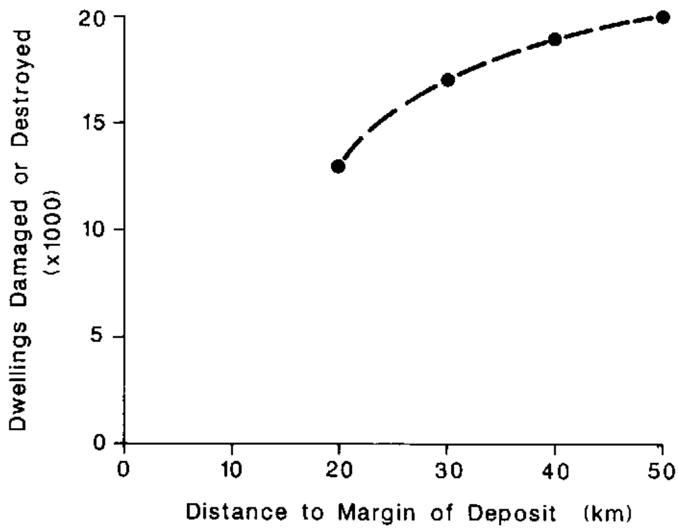


Table 8.1
Estimated annual cocoa production (bags)
by selected census division, ENBP

Census division	Bags/year (x 1,000)	Per cent of ENBP production
Bitapaka	9.7	6
Sinivit	8.7	5
Duke of York Is.	1.0	1
Lassul	23.9	15
Toma		12.07

Table 8.2
Estimated annual copra production (bags)
by selected census division, ENBP

Census division	Bags/year (x 1,000)	Per cent of ENBP production
Bitapaka	30.7	9.6
Sinivit	17.8	3.5
Duke of York Is.	20.4	5.6
Lassul	23.3	6.2
Toma	35.2	8.2

Figure 8.4 has been constructed to show the proportion of ENBP cocoa and copra production that would be destroyed by eruptions producing ignimbrites which extended to 20 to 50 kilometres from the vent area. Similar assumptions to those outlined in Chapter 6 have been used to estimate the proportions of the plantation areas at risk from each eruption.

The proportion of the cocoa and copra crops destroyed by the four eruptions considered here is set out for each census division in Table 8.3. The effect on total copra and cocoa production of ENBP is shown in Figure 8.4. Only one damage curve is presented as it is assumed that the two crops grow in the same areas and that the proportion suffering destruction is the same in each case.

Figure 8.4 indicates the dramatic effects that a large-scale eruption would have on agricultural production in ENBP. For the eruption reaching to 50 kilometres from Rabaul Harbour about 90 per cent of the crops would be destroyed. An eruption producing ignimbrite deposits which extended to 30 kilometres would still destroy an estimated 80 per cent of the two crops.

It should be remembered that not only export crops but also crops for domestic consumption would be devastated in the areas shown on Figure 8.1. Furthermore, considerable damage would occur in areas of ash-fall and tsunamis, far beyond the area considered on Figure 8.1.

Figure 8.4

Effect on agricultural production
of large-scale eruptions

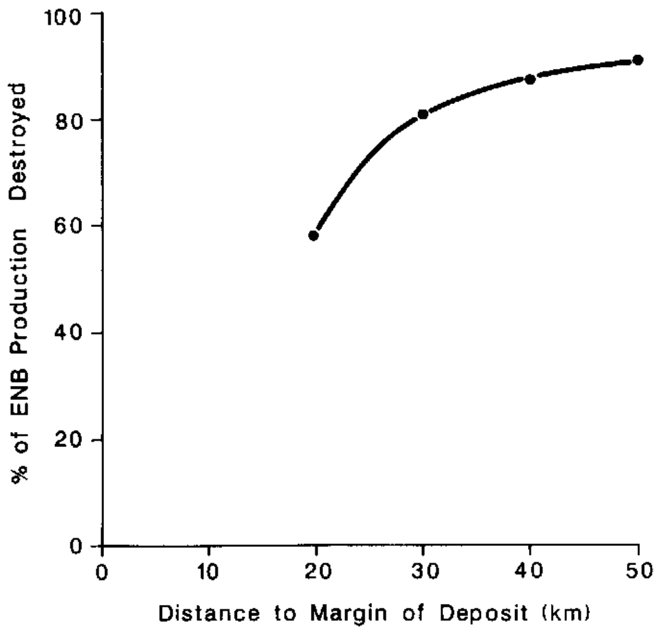


Table 8.3
Damage estimates for cocoa and copra production

Census division	Extent of ignimbrite deposit 50 km	40 km	30 km	20 km
	per cent destroyed			
Bitapaka	100	100	90	10
Sinivit	50	40	20	-
Raluana	100	100	100	100
Vunamami/Kokopo	100	100	100	70
Balanataman	100	100	100	100
Central	100	100	100	90
Duke of York Islands	100	100	40	-
Kombiu	100	100	100	100
Lassul	90	70	40	-
Livuan	100	100	100	80
Reimber	100	100	100	100
Toma	100	100	100	60
Watom	100	100	100	60
Vunadidir	100	100	100	70
Rabaul town	100	100	100	100

While it seems clear that agricultural production in ENBP would be decimated by a large-scale eruption, the period of time that such effects would remain seems less certain. For all but the marginal parts of the ignimbrite the area would remain uninhabitable for at least some months (if not years) - initially temperatures in the deposit would be high, and would cool only slowly over a period of months. Furthermore, erosion of the deposit would make the area dangerous for humans as considerable reworking by mudflows and new streams would occur.

However, erosion of the deposit would also expose the original ground surface and, in many cases, surviving root stocks. Many of these can be expected to propagate quickly. In areas totally devastated by hot pyroclastic flows during the eruption of Lamington in 1951, taro plants penetrated 230 millimetres of deposit within 17 days of the eruption. Similar rapid recovery of selected species in favoured areas can be expected in the devastated area around Rabaul. Nonetheless, it would be some years before cash crop production began in the devastated area, and some tens of years before production reached pre-eruption levels.

Overview

Figures 8.2 to 8.4 indicate that a large-scale eruption from the Rabaul caldera would have an absolutely devastating effect on the population, building stock, agriculture and economy of ENBP. Although it has been emphasised that the chance that such a large-scale eruption will occur in the next few years is very remote, with an average annual probability of occurrence of less than 0.0005 (less than once in about 2,000 years on average), some planning for this remote possibility should be undertaken. In particular, backup instrumentation for RVO needs to be made available so that monitoring of the volcano can continue after any initial eruption. Availability of such monitoring capability would at least allow the possibility of a second evacuation if required. Secondly, a great deal more thought needs to be put into the mechanics of a second evacuation to areas safe from a large-scale eruption. In particular, a further examination should be made of the feasibility of constructing a suitable road for evacuation to Open Bay.

Chapter 9
Implications of the study

Introduction

The volcanological, economic and risk assessment studies reported in this monograph contain a number of important implications. Several of the chapters contain overviews or concluding sections which indicate some of the more significant findings. Rather than merely repeat those conclusions, this chapter considers five major aspects of our investigation - hazard assessment, the disaster plan, the significance of the seismic crisis, the question of the relocation of Rabaul, and the investment stalemate.

Hazard assessment

To the best of our knowledge this study is the only one of its kind in the field of volcanic hazard assessment. Certainly, numerous maps of hazardous areas around volcanoes have been produced - in effect the work of McKee et al. (1985) provides a volcanic hazard map of the Rabaul area (see Figure 4.5) based on the evidence adduced from past eruptions and a model of the atmospheric fallout of volcanic ash. Somewhat similar maps have been produced for numerous volcanoes around the world, including others in Papua New Guinea such as Manam.

The next step in volcanic hazard assessment is to utilise the evidence of historical and prehistoric eruptions, together with data from the current monitoring program in the caldera, to produce best estimates of the character, magnitude, and location of the next eruption. Despite the obvious difficulties of making sound judgements in the absence of complete (or in many cases, adequate) data, this type of analysis is a relatively common practice in hazard assessment.

The present study takes volcanic hazard assessment a step further by attempting to judge in some detail the effects of specific eruptions on the people, the infrastructure and the economy of Rabaul and ENBP. Although some studies which utilise a similar methodology have been used in earthquake risk assessment (eg. Martin 1986), previous attempts at volcanic risk analysis have evidently not proceeded this far.

For the present study, volcanic hazard has been subdivided into component hazards which have differing effects in identifiable areas. Such subdivision allows identification of the individual hazards that have the most significant impacts on the population, buildings, and agriculture of the area. For example, the analysis in Chapter 6 makes it clear that it is pyroclastic flows that are likely to have the greatest impact on human life, but that relatively large numbers of people are likely to be injured (albeit slightly) by minor falls of volcanic ash. Such findings have clear implications for the Disaster Plan (see below).

The final aspect which makes this study unique is that the assessment of risk has been placed firmly in an economic framework, particularly in terms of assessing the impact of an eruption on the regional economy. This analysis indicates the extent to which the economy of ENBP is likely to be affected, the aspects of the economy which bear the brunt of the impact, and the resilience of the agricultural sector which is the mainstay of the local economic base.

Although the type of analysis presented for the three scenarios seems to be a step forward in the art of volcanic risk assessment, it is clear that the study presented here has a number of important limitations which need to be kept in mind when evaluating the results. Firstly, only three model eruptions are considered. While these three eruptions have been carefully selected as representative of the possible eruptive magnitudes and styles, numerous other eruption styles and magnitudes are possible.

Scenario 1 represents a May eruption of 1937 magnitude that would have a large impact on ENBP and Rabaul. The November eruption (scenario 2), of identical magnitude, clearly has much less effect. While the two eruptions seem to lie toward the endpoints of the spectrum of consequences stemming from a 1937 magnitude eruption, it is important to note that other eruptions of this magnitude have not been modelled; for example, the effects of a June or March eruption from the same vents are not known. Similarly, the magnitude of the effects of an eruption from the Sulphur Creek area or from southeast of Vulcan Island are not known. Furthermore, studies of relatively small eruptions of differing magnitudes are also needed. Clearly, such analyses need to be undertaken before volcanic risk assessment in the Rabaul area can be considered to be complete.

Another weakness of this study lies in the relative lack of attention devoted to an analysis of the effects of eruptions on the operation of public utilities responsible for telecommunications, radio, water supply, the port etc. This deficiency stems not only from a shortage of time for such a study but also from the fact that it is much more difficult to model the effects of an eruption on such entities. Nonetheless, such studies should be undertaken, perhaps using the event tree and decision tree-type analyses that are common in the consideration of the probabilities of technological hazard impact.

Another volcanological aspect which the situation at Rabaul has highlighted is that volcanoes do not always erupt even when it appears that an eruption is almost certain to occur. Studies of such "failed eruptions" have not been prominent in the volcanological literature. One of the few failed eruptions that has been studied in any detail was that at Campi Flegrei (west of Naples) in 1970. This area experienced considerable ground deformation, the destruction of numerous dwellings as a result, and the evacuation of part of the town of Pozzuoli. The seismic crisis at Rabaul in 1983-85, and similar seismo-deformational disturbances at Long Valley (California) and again at Campi Flegrei at the same time, none of which have yet led to an eruption, are likely to direct the attention of the volcanological community toward the difficult task of distinguishing between precursor phenomena that lead to an eruption and those that do not. In this sense at least the events at Rabaul are likely to have ramifications far beyond Papua New Guinea.

The Disaster Plan

Although the Disaster Plan is clearly a good one, improved significantly by the various practice evacuations conducted during 1984-86, the assessment of risk carried out here suggests several points that require further consideration.

The most significant point concerns the slight possibility that a large eruption will occur, probably following a relatively small initial eruption. If ignimbrite deposits extend as far as 50 kilometres from the vent a very large proportion of the population of ENBP would be at risk. As indicated in Chapter 8, the death toll would probably still be large if pyroclastic flows reached a radius of 20 kilometres from the vent, and even if evacuation had already taken place from the designated danger zones.

At the present time the official reaction to a large-scale eruption has been but poorly formulated. The Disaster Plan defines the extended safe area as outside a radius of 23 kilometres but the logic of this choice is not made clear. Although a chapter is devoted to the issue of a large-scale eruption in the Disaster Plan, the mechanics of the operation have not been thought through carefully and the feasibility of the plan has not been tested. Two points indicate the magnitude of the problem.

The population at risk can be reduced if (i) RVO is capable of forecasting the probability of a large eruption; and (ii) suitable escape routes are available. In relation to the first point it must be noted that electronic equipment is extremely susceptible to damage by even very minor amounts of volcanic ash, as ash is almost invariably magnetic. Computing equipment can be made reasonably safe in sealed rooms with positive pressure air-conditioning but the field sensors are likely to have a high failure rate following an initial eruption. If there is to be any warning in Rabaul of the possible escalation from a small to a large eruption then backup equipment such as a mobile laboratory must be made available to RVO.

It then follows that if warning is provided that a large-scale eruption is likely, opportunities must be available for evacuation to areas beyond the initial safe zones. In these circumstances evacuation by sea for large numbers of people does not seem feasible as most of the official and unofficial evacuation areas are located some distance inland; it is also not unlikely that there would be marked unwillingness amongst shipowners to risk their vessels. As the bulk of the evacuees would already have moved some distance inland, evacuation by road seems sensible. Unfortunately, at the present time there are no suitable escape roads capable of allowing the movement of large numbers of people beyond the 50 kilometres radius. The economic feasibility of constructing such a road with adequate capacity towards Open Bay as part of a general development strategy for the <u>whole</u> of New Britain should be considered as a matter of urgency.

Scenarios 1 and 2 also highlight some other points which suggest modification of the Disaster Plan. In scenario 2 it seems clear that minor but significant amounts of tephra fall are likely to occur in the area west of Vunakanau and including Kerevat, LAES, and Vudal (Figures 7.1 and 7.2). The Disaster Plan, of course, positively encourages the movement of large numbers of evacuees into this area as several of the official evacuee camps are located here. Furthermore, during the seismic crisis many people from Rabaul went to live with wantoks in this area. Given the scarcity of resources which can be utilised for the accommodation of evacuees it may well be that there is no alternative to the movement of people into this area.

Several points need to be addressed. Firstly, the atmospheric fallout model needs to be re-run and combined with other more sophisticated models to check the likelihood that ash-fall will occur in this area. With the present state of analysis it is not clear whether this problem is peculiar to the month of November or whether similar fallout patterns can be expected during other months of the northwest season.

Secondly, the consequences of evacuation into an area of ash-fall need to be considered in the Disaster Plan. Relatively minor amounts of ash-fall are readily survived by the vast majority of the populace, but some health consequences can be expected (see, for example, Table 6.1). Plans need to be made for dealing with the increase in minor nose, throat and bronchial injuries. Similarly, transport in an area of volcanic ash fallout is likely to be severely curtailed, or repairs to motor vehicles and accidents are likely to increase. Food gardens may also be damaged in these areas so that residents as well as evacuees would need to be fed for at least short periods. Water supplies, particularly for residents, are likely to be polluted by ash-fall.

The possible problems stemming from evacuation into this area are also likely to be identified in several other areas which are not considered by the Disaster Plan. For example, Watom Island is likely to receive minor amounts of ash-fall from an eruption during the southeast season. This possibility was recognised in the definition of danger zones (see Chapter 4). However, we have no evidence that this recognition indicates that some disaster assistance will be necessary. Similarly, some areas along the north coast to the west of the green zone are likely to experience identical problems which need to be addressed as part of the Disaster Plan.

A further aspect which receives little attention in the Disaster Plan is organisation in the aftermath of the eruption. In the material made available to us there are few references to the aftermath other than to the identification of those personnel who will be allowed first access to the impact area. To our knowledge, the tasks of such personnel have not been specified although it seems likely that, in the case of some public utilities at least, relevant recovery tasks have been identified and assigned.

Given that a workable disaster plan exists, the PDC could now profitably address the major issues of the aftermath and recovery phases and evacuation to an extended safe zone for use in the event of a large-scale eruption.

Significance of the seismic crisis

The seismic crisis of 1983-85 was of major significance in a number of ways. Two of the most important results of the crisis and the resulting insurance question - the investment stalemate and the discussion about the possible relocation of Rabaul - are considered separately.

Firstly, the seismic crisis paved the way for the development at a national level of emergency plans and legislation applicable to a wide variety of national emergency situations but focused particularly on the anticipated eruption in Rabaul. Thus, the seismic crisis provided a firm basis for action on the part of the national government in relation to future national emergencies.

Secondly, the seismic crisis resulted in the influx to ENBP of aid from both national and international sources. The financial contribution of the national government via the funding of disaster-related projects has been set out in Chapter 5. The amount of K6 million may be compared to the Chapter 3 estimates from Axline (1986) that the national funding of provincial projects and national projects in ENBP varied between K826,000 and K10,051,000 over the years 1980 to 1984 and with the Table 3.17 expenditure estimates of the ENBP Government which varied between K11,601,000 and K13,017,000 over the years 1982 to 1985.

Other aid from overseas designed to alleviate problems associated with probable volcanic hazard in fact has contributed to the longer-term development of the province by upgrading water supplies in some of the evacuation areas and by contributing toward the enhanced capability of the Volcanological Observatory. It is interesting to note that had the seismic crisis been short-lived and culminated in an eruption, say early in 1984, most of the expenditure on projects would not have been possible. In this case, development aid would probably have been replaced (even exceeded) by disaster aid.

The crisis provided time for the Disaster Plan to be upgraded into a thorough document that laid the organisational basis for an evacuation that would work, at least for an initial evacuation. There can be little doubt that had an eruption occurred in late 1985 or 1986, similar in style to that outlined in scenario 1 or scenario 2, Rabaul would have been successfully evacuated with little loss of life and few unmanageable problems arising in the immediate aftermath.

However, it seems almost certain that, with time, there has been a decline in readiness, a problem faced by disaster managers everywhere. One complaint about the evacuation exercise held late in 1985 was that some personnel failed to take it seriously. The problem in Rabaul is compounded by the fact that some of the key personnel, instrumental in the design of the plan and its testing by various exercises, had already left Rabaul before the end of 1986 and more have departed since. This problem occurs not only with the Disaster Plan itself but also with the contingency plans developed by private companies, government departments, and statutory bodies. A major problem faced everywhere by disaster managers is the difficulty of maintaining the level of preparedness in the community, and in particular amongst those who occupy key positions. In this Rabaul is no exception.

Relocation of Rabaul

By far the most significant effect of the crisis produced by the insurance problem was the urgent re-consideration of the question of the relocation of the town of Rabaul. This issue had also been raised (and indeed relocation recommended) following the 1937 eruption.

In February 1984 the NEC authorised the chairman of the National Disaster Committee to find suitable government land to relocate all Matupit Island people and directed that all fuel depots in Rabaul be moved to a suitable site in Kokopo. The government also purchased Kenabot plantation near Kokopo as well as substantially more land than was necessary for the airport at Tokua. Later a hold was placed on all civil works in Rabaul.

In April 1984 a report prepared by the Department of Physical Planning and Environment (DPPE) paid considerable attention to the possibility, or necessity, of relocating Rabaul township. The study also took account of the fact that "the existing town of Rabaul is fully developed and there are limited prospects for expansion, even if these were regarded as desirable given the threat of the volcano" (Bawdekar et al. 1984).

The report noted the significance and growing importance of the port of Rabaul both as a provincial and as a regional centre and suggested two alternatives: (i) to disperse the regional functions of Rabaul to other provincial centres, notably Kimbe and

Kavieng and to develop at the same time in the northeast Gazelle an urban centre which could take over the provincial role of Rabaul; or (ii) to develop within the north east Gazelle an urban centre which could take over both regional and provincial roles.

Various options in ENBP were considered in this report including Kokopo - Vunapope, Tokua - Reiven, Bitapaka, Warangoi, Vunakanau, and Kerevat including LAES, Tavilo and Raulavat Plantations. As an area of about 750 hectares would be needed to duplicate Rabaul's functions, one of the major limitations for some of these sites was the availability of suitable land. The preliminary conclusion was reached that only the Kokopo - Vunapope and Tokua areas appeared to be suitable. At least some of the discussion seems to be based on the mistaken premise that the hazard zoning for Rabaul takes into account the possibility of a catastrophic eruption (see Chapter 8), and thus suggests that Kokopo is suitable! The report recommends that detailed planning should start in the Kokopo - Vunapope area to establish its suitability for urban development.

A range of comments were made on this report by a number of other government departments. The Department of Health suggested that Bitapaka could be a regional training centre for aid post orderlies and it is better placed than Nonga as a referral hospital. DPPE in response noted that this reinforced the choice of Kokopo - Vunapope as the urban site as they are only 10 kilometres from Bitapaka and connected by a good sealed road.

DWS raised a number of points including: the need for identification of an alternative SAFE development centre as soon as possible to encourage investment; the need for major upgrading of the Kokopo road and other roads because of substandard pavement and poor horizontal alignment; that the Kerevat bore field was being developed for water supply and could be expanded to cater for future development of the Kokopo area; the need to take into account the possibility of tsunami damage in any areas less than 10 metres above sea level; and that money should be spent on upgrading of services at Kokopo rather than on existing offices in Rabaul. DWS also asked the question whether much land was available for further development at Kimbe.

RVO personnel commented: "Taking into consideration all the other factors that will influence the choice of the alternative site we feel that the recommendation to select Kokopo-Vunapope as the alternative administration centre of East New Britain and as the urban centre for the North East Gazelle is the correct one".

After considering recommendations from other departments DPPE added the recommendation that Vunakanau would appear to deserve some further consideration as a second string option in the event of major problems at Kokopo, the latter resulting from the unwillingness of the church to sell viable plantation land. The option seems to stem from a recommendation made by the ENBP Town Planning Committee because the Vunakanau-Tomaringa-Vunadidir area was central and had available substantial areas of alienated land. Further consideration of the area would need to establish that the area was a safe location where insurance companies were prepared to carry volcanic and earthquake risks.

As early as March 1983 (that is, before the DPPE report was released) it was understood that NEC had accepted the draft urban planning study and allocated K40,000 in 1985 for engineering studies. Government departments were believed to have been told that they must establish at Kokopo unless they have compelling reasons to be in Rabaul. The ENBP Executive Council endorsed the draft proposal for the development of Kokopo as an alternative town to Rabaul within the next ten years (November 1984).

At the end of January 1985 it was reported in the Post-Courier that an insurance company spokesman said: "Insurers would welcome the relocation of Rabaul. The Insurance Underwriters Association has recently revised its premium rates for earthquakes, volcanic eruption and tsunami in East New Britain. A property at Kokopo, for example, would cost less to insure than a similar property in Rabaul because the potential loss by volcanic eruption or tsunami is assessed to be less than Rabaul" (see Figure 4.4).

The Chamber of Commerce felt strongly "that positive moves towards rezoning of land and the making available of leasehold land at Kokopo should not be allowed to be forgotten with our return to Stage 1. We have enthusiastically supported initiatives by the Departments of Housing and Lands for the necessary national government approval and funding to enable work to continue. We are pleased to report that the National Executive Council have been relatively quick to recognise the high priority required of the situation and that we should see considerable progress in 1986. ...It has been the aim of the Chamber to encourage government to make the necessary preparations to allow for limited expansion and reorganization at Kokopo and two of our members have already established premises and are trading sucessfully".

A prominent firm of chartered accountants suggested that an application be made to the World Bank or the Asian Development Bank for funds for Kokopo resettlement. Businesses could be encouraged to relocate by making land and finance available, by taxation benefits such as a double deduction for trucking costs, area allowances, and exemptions from land tax.

A businessman proposed that a four lane highway be built from Rabaul to Gaulim and connected to Bialla and Kimbe with the development of dormitory towns and new industrial sites and plantation nucleus estates built on the highway outside the danger zone. This notion seems to have received no further consideration.

By late 1985 concern was being expressed in some quarters that nothing much was being done about relocating Rabaul. Complacency had set in. Concerns about the possibility of a large eruption which would have profound effects on the Kokopo area as well as on Rabaul seemed forgotten. As with the evacuation plan itself, attention was focused almost entirely on the effects of a relatively small eruption. The analysis carried out here, even with the provisos expressed early in this chapter, suggest that if a relatively small-scale eruption is considered, there is little need to relocate Rabaul. On the other hand, if a large-scale eruption is anticipated, relocation of Rabaul's infrastructure to Kokopo would seem to provide no benefits.

The investment stalemate

The events of 1983-85 led to an investment stalemate in Rabaul and the rest of the study area which continues to the present day. Limits to the growth of Rabaul, in particular, and to the study area in general, are not only those which arise from the policies of insurance companies and credit providers and the perceived shortage of land. The continuing threat of an eruption engenders a loss of confidence and the possibility of government policy measures to regulate (or divert elsewhere) growth that might otherwise be expected to take place in or near Rabaul.

A variety of options have been discussed as being appropriate to the present circumstances. In general, these involve one or more of the following: shift all activities centred on Rabaul elsewhere; shift selected activities centred on Rabaul elsewhere; shift (additional) growth that might have centered on Rabaul elsewhere; allow such growth as can be financed occur in Rabaul with other growth finding the best available alternative site; or, without explicitly considering Rabaul (and the rest of the study area), encourage growth elsewhere in ENBP.

Government policy, in practice, if not on paper, has tended to change with perceptions of the nature of the crisis, and possibly with shifting perceptions of the role of governments as administrations have changed. Despite the purchase of land by the government at Tokua and near Kokopo, by early 1986 a government document claimed that no government restrictions exist on new building or expansion in Rabaul. In fact, a number of relatively significant building projects have been recently undertaken in Rabaul.

However, a number of major studies (e.g. Bawdekar et al. 1984; Asian Development Bank, 1985; Atkins International, 1985), not necessarily directly related to the volcano crisis, have been carried out; these could have some bearing on the future development of the study area. Two different thrusts can be identified in future development proposals. Firstly, ENBP offers opportunities for future rural development which is ultimately going to encourage port and urban growth. Secondly, while the desirability of fostering urban growth outside Rabaul is recognised, there are considerable doubts about the likelihood of that happening, given the absence of adequate alternative port facilities to Rabaul, the low probability that an eruption will actually close the port for more than a few weeks, and the unwillingness of businesses with investments in Rabaul or with future plans for investments in Rabaul to accept some alternative site. Whatever the impetus these reports give to thinking about the future of Rabaul, they fall a long way short of facing up to the long-term problem of the investment stalemate in Rabaul.

The essence of the problem is that while at the margin there is development going on, or being projected, which would provide some counterbalance to the pattern of development encouraged by the ENBP developmental process outlined in Chapter 3, the pressure of events give every sign of merely reinforcing the established process. There appears to be no co-ordinated plan within which a strong growth pole outside Rabaul would be developed.

While it may do no more than state the obvious, thinking about the future of Rabaul needs to begin with a detailed assessment of what are the alternative port possibilities, given that Rabaul (Simpson Harbour) was either unusuable or that its future use was deemed to be imprudent. This is the emergency-related subject on which there appears to be the widest divergence of opinions. This lack of any consensus is partly due to an unwillingness to recognise that "an alternative port to Rabaul" can mean different things under different circumstances. The arrangements that might suffice during an evacuation, or while Simpson Harbour was temporarily choked with floating pumice, are completely different from those that would be sought if Rabaul was either unusable, or its future use was deemed to be imprudent. More generally, each of the options noted above may imply different long-term port arrangements. What alternative port arrangements might be made is a matter beyond our competence to determine; but what we can point out is that the examination of meaningful scenarios incorporating answers to the investment stalemate depends on finding an answer (or more likely, a range of answers) to this particular question.

There is a sense in which each of the options noted above implies a choice of port arrangements. However, what we have here is more than a technical question, because any alternative port arrangement implies a possible need to develop additional road connections and will throw light on the most appropriate development of new urban centres. But the location of the alternative port arrangements affects the cost of road connections and urban centres and it is the whole package that has to be judged for its feasibility as a means of breaking the investment stalemate.

The extent of investment in and near Rabaul is such as to lead to suggestions that Rabaul would never be abandoned unless an eruption made it inoperable as a port and urban centre. This is why only one of the five options noted above implies an abandonment of the town. While this is understandable, any unwillingness to consider the implications of the abandonment strategy means that the opportunity for taking into account in development decisions some possible (future) need to move the town site will be lost.

One reason for an unwillingness to consider the abandonment of Rabaul is that sites near Rabaul, and indeed within the study area, appear quite unacceptable as port sites as well as not being sufficiently distanced from a possible eruption vent. Present development strategy appears to favour the Pomio-Bainings area, recognised as among the most undeveloped in Papua New Guinea, on the south side of New Britain with new roads proceeding from this area rather than initially being extensions of the road system in the study area. However, something of the same effect is being achieved on the north side of the island through the development of forestry. As indicated above, what appears to be missing from this course of events is any assessment of the role of this development in breaking the investment stalemate in Rabaul, or in providing the site for a future major port and town if the creation of one should become necessary.

The costs of developing a new major port and town site in ENBP would be considerable, assuming that such an option is meaningful in a technical sense. However, this barrier to change will appear less formidable if the process of development of a new facility was envisaged as taking place over time. Furthermore, the nature of the problem is such that some investment could be regarded as investment which would have to take place elsewhere in any case. Indeed, much of the cost of a major new development would arise not so much from the need to make new investments as from the fact that the whole orientation of development in ENBP has been towards the northeast tip of the Gazelle Peninsula. The overwhelming bulk of the ENBP population would probably find themselves seriously inconvenienced if, say as a result of an eruption, it was not possible to maintain government and commercial activity at Rabaul.

Despite the cost of the development of a new facility it would probably not be without some major advantages. Properly sited, it would ease the problems that will be encountered in the next seismic crisis or eruption at Rabaul. Investment that could only take place in a more secure environment could be accommodated. The process of decentralisation would be aided.

As we have indicated, we do not know if a major new port and town site in ENBP (or for that matter, at the eastern end of West New Britain) is technically feasible. Consequently, it is not possible to compare the expected costs and benefits of such an option. But until this option is seriously examined, we doubt whether it will be possible to fully appraise the other specified options.

One point that might be made, and one implicit in several of the suggestions made as to how the investment stalemate might be overcome, is that since the "ideal" solution (that is, finding a new major port and town) is likely to be expensive, even if technically feasible, it might be desirable to consider some alternative approach which might otherwise have been dismissed out of hand as too expensive and unpalatable. Most of such approaches would involve major upgradings of the provincial transport system to encourage commuting and the re-location of as much as possible of the residential, governmental and commercial development away from Rabaul so that the role of the port is maintained while the role of the urban centre is downplayed. However, it must be noted that if a major alternative port site does exist, splitting the town and port sites may prove to be more expensive in the long term. This strategy would also probably not provide a satisfactory solution in the event of a major eruption. Further investigations and risk analysis are necessary to determine the feasibility of this strategy.

Regardless of which option is adopted, there are some things that the national and provincial governments can achieve by announcing their intentions and by regulation. But no effective strategy is likely to be developed without the commitment of funds. While some funds will be, in effect, the diversion of monies which would otherwise have been spent in Rabaul there will be a need for additional budget outlays. To some extent these will be made more manageable because they can be spread over a period of time but inevitably attention will have to be focused on likely sources of funds.

The division of financial responsibility between the national and provincial governments makes it inevitable that little is likely to be achieved without some level of national government financial support. It is possible that some infrastructure can be developed in conjunction with, or for, rural projects, especially in the forestry area. It may also be possible to obtain some funds from aid donors. But inevitably, attempts to overcome the investment stalemate by means other than "muddling along" will involve a consideration of the national government's scale of priorities in the light of perceived needs elsewhere in the country.

Appendix 1
Modified Mercalli Intensity Scale - after Steinbrugge (1982)

I Not felt except by a very few under especially favourable circumstances.

II Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III Felt noticeably indoors, especially on upper floors of buildings, but many people do not recognise it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck.

IV During the day felt by many, felt outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V Felt by nearly everyone; many awakened. Some dishes, windows, etc. broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

VI Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

VIII Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimney, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbs persons driving motor cars.

IX Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; damage great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

Appendix 2
Sub-committees of the ENBDP Disaster Committee

The sub-committees named here have a variety of names in different documents. The ones used here appear in ENBDC (1984).

Command, Control and Communications (Operations)

The role of this sub-committee was to ensure that physical and procedural arrangements exist for the rapid collection, display, consideration and dissemination of operational information at the Disaster Control Operation Centres at Rabaul and Vunadidir and between operational support groups/centres remote from the Operation Centres.

Voluntary Evacuation Centres

The terms of reference included: evaluation of the present (May 1984) situation regarding pre-evacuation areas and to ascertain what assistance if any is required to continue with the updating of evacuation centres; and to prepare evacuation centres to a state of readiness for a possible evacuation.

Evacuation

The terms of reference for the Evacuation sub-committee included the broad objective of ensuring that physical and procedural arrangements exist for: (i) the rapid evacuation of people from the danger areas; and (ii) the rapid movement of stores and supplies from the danger areas. More specific tasks included a re-assessment of the number of people to be moved by the government, the establishment of priorities for the various categories of evacuees, organisation of the government evacuation fleet, organisation of drivers, finalisation of traffic routes for evacuation to and from safe areas, organisation of traffic control, re-assessment of the policy on sea evacuation, formulation of a policy on air evacuation, and the organisation of transport for the movement of government and private sector supplies.

Continuation of Government and Economic Services

The broad objectives of this Committee included the maintenance of food supplies to the public. This involved the relocation of the major wholesalers operating in Rabaul. The committee also aimed to guarantee the supply of fresh food and local meat, to ensure that no unnecessary price increases occurred, and to determine that commerce and industry throughout the Gazelle were not badly interrupted by the disaster. The emphasis on food supplies and the importance of cash crops to the local economy was also strengthened by the subsidiary aims which included ensuring the safe and immediate evacuation of DPI and Commerce officers and their families to pre-arranged locations, and the relocation and re-establishment of cocoa inspection for export crops.

Health

The terms of reference for this sub-committee for the pre-eruptive phase were to ensure that primary health care services were being maintained and strengthened in evacuation areas; to monitor water supplies, sanitation facilities, and malaria control measures in the evacuation areas; to monitor disease patterns; and to provide guidance to non-government organisations as to anticipated requirements.

During the eruptive phase this committee was to ensure that the provincial disaster plan was being implemented and to assess its adequacy to meet the demands created by the events; to notify the chairman if national or international health personnel or resources should be called on; and to promptly provide a report on the number of deaths and major injuries resulting from the eruption.

During the post-eruptive phase the terms of reference were to monitor disease patterns in the evacuation areas and report epidemics; to intercede with appropriate preventative measures for the maintenance of services such as adequate water supplies, sanitation facilities, and malaria control measures; to ensure that curative services were maintained at an adequate level through adequate staffing, supplying and equipping of the hospital, health centres and aid posts.

Law and Order

The terms of reference for this committee included the provision of security to evacuation centres and installations, the continuity of justice, recommendation of curfews where necessary, the provision of direction and assistance to evacuees, the restriction of unauthorized personnel, and the maintenance of general law and order in the declared emergency area.

The restricted areas from which unauthorised personnel were to be excluded were identified as Matupit cone, the volcanological instrument sites, the Rabaul Volcanological Observatory (RVO), and the Provincial Disaster Centres at both Rabaul and Vunadidir.

In May 1984, the committee meeting endorsed a proposal for village security whereby four or five people would be responsible for Law and Order in each Ward. These people would be issued with arm bands and would be the first people allowed into their respective areas after the eruption period.

Education

The main term of reference of this committee was "to monitor and assess the welfare and educational needs of all students during the disaster period". This committee was also required to determine locations in safe areas which could be used as temporary schools.

Public Utilities

The main objectives of this committee were to maintain services, before, during and after the eruption, to re-assess existing services and to take steps to up-grade them if necessary, and to forecast, if possible, the needs after the eruption.

Appendix 3
Details of evacuation centres

Preparations for accommodation at each of the seven centres included -

Gaulim playing field - 378 tarpaulins, 1,890 persons; 50,000 gallons water in 5 x 10,000 gallon tanks plus nearby Tobutin River; one or two tanks used to store creek water for toilets and washing; evacuees to go through transit centre (for Registration) at Vunadidir Junction.

Kerevat National High School - 369 tarpaulins, 1,845 persons plus 418 in dormitory accommodation; water okay (50,000 gallons plus 5,000 gallon reserve for fire hydrants) plus SP beer kegs if necessary; evacuees to pass through Kerevat transit centre.

Kerevat Lowlands - area near the golf course on oil palm and forestry blocks - 200 tarpaulins; 1,000 persons; Water from SP Well and bore water from Lowlands Centre. Evacuees to come from transit centres at Livuan and George Brown High School.

Vudal Playing Fields - 502 tarpaulins, 2,450 persons; 25,000 gallon storage tank plus treatment plant and pumps for water from creek; evacuees to pass through Kerevat transit centre.

Vunamami Vocational School - 200 tarpaulins, 1,000 persons; 20,000 gallon rainwater tank plus various 1,000 gallon tanks around school; the water supply was to be investigated as the pump might not be able to cope with extra load; evacuees to pass through transit centre located at Warangoi Junction.

Bitapaka Hospital - 200 tarpaulins, 1,000 persons; plus 600 accommodated in old hospital wards including NWS, DPI families and Health staff. Water available 12,000 gallons. Evacuees to pass through Kokopo transit centre.

Kokopo Sports Ground - 160 tarpaulins, 800 persons; plus permanent shelter at the grounds. Water supply adequate for Kokopo population plus evacuees; evacuees to pass through Kokopo transit centre.

Government stores were to move food, blankets, plates, knives, forks, spoons etc. to Kerevat and Kokopo during Stage 2. All other tools and equipment were stored at Vunapope, Kokopo National Works Depot, Kerevat National High School, Rabaul Base Medical stores and the Rabaul Government Stores. Defence Force personnel collected bamboo for tarpaulins and stored it at the Kokopo Showgrounds and at Kerevat Corrective Institution. Students at George Brown High School cut bamboo for that evacuation centre.

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MT. HAGEN

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