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LANDSLIP AND FLOODING HAZARDS IN EASTBOURNE BOROUGH

a guide for planning

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Landslip and flooding hazards in Eastbourne Borough; a guide for planning

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ABSTRACT

The extent and magnitude of landslip and flooding hazards in Eastbourne Borough are assessed, first by identification of landslips that occurred during the particularly wet winter of 1977, and by an assessment of stormwater systems. Eight hazardous situations are identified using criteria such as rock jointing, depth of weathering, stability, slope steepness and length, position on or relative to a slope, relationship of the slope to the movement of water, and the type, condition, and stature of vegetation.

From this information, a threefold urban suitability classification is derived, based on the presence and severity of those factors which represent physical constraints to subdivisional and building developments.

Preventive measures and a suggested use of the suitability classification are presented.

The manner in which the Eastbourne Borough Council has used the suitability classification in its district planning scheme to require more detailed information on specific hazards before subdivision, building, excavation, and removal of vegetation is outlined.

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Contents

Foreword

This report was first published in August 1978 by Wellington District Office, Water and Soil Division, Ministry of Works and Development.

As demand has exceeded original estimates it is now reprinted in the Water & Soil Miscellaneous Publication Series with the addition of a postscript outlining the manner in which the Eastbourne Borough Council has used the original report in its district planning scheme.

Acknowledgements

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Mr R. G. Brickell, Days Bay, for additional information on some landslips.

Introduction

The material presented in this report was collected following a request from the Wellington Regional Water Board (now Wellington Regional Council) to the District Office, Water and Soil Division of the Ministry of Works and Development, for assistance in identifying the extent and magnitude of the landslip and flooding hazard within Eastbourne Borough. Information was required that would aid the preparation of a pre-review statement for the Eastbourne Borough Council's District Planning Scheme.

Staff of the Water and Soil Division, Ministry of Works and Development, and the Geography Department of Victoria University collected the information and prepared the report.

For an assessment of landslip and flooding hazard to be useful for planning, a two-stage study was necessary.

The extent and magnitude of physical hazards were first identified through measurement of landslips that occurred during 1977, and an inspection of stormwater systems.

A number of factors emerged which could be used as criteria at the second stage to identify and evaluate potential physical hazards for future urban development. Areas are delineated on a map according to the degree of hazard and the type of information that will be necessary before subdivision or building can proceed.

Rainfall conditions

A comparison of rainfall conditions in Wellington and Eastbourne during 1974 and 1977 illustrates the slip inducing rainfall conditions that can occur in Eastbourne.

1977 was the wettest year ever recorded at a number of stations in the Wellington region (e.g. Table 1).

Table 1—Rainfall totals in mm for the three wettest years recorded at the longest running stations in the Wellington area.

Stations	1941	1974	1977	Length of Record (years)
Kelburn	1611	1706	1742	50
Karori Reservoir ...	1637	1713	1715	99
Wainuiomata ...	2816	2641	2841	89

The rugged topography of the Wellington area, as well as its location adjacent to Cook Strait, causes localised turbulence patterns to develop in storm airflow over the region. These in turn contribute to extremely localised patterns of heavy rainfall distribution as instanced in the Hutt Valley storm on 20 December 1976 (Tomlinson, 1977). A given year can therefore be much wetter in one part of the region than another as was the case in both 1974 and 1977. Figure 1 shows 1974 rainfall departures expressed as percentages above the 1941 to 1970 normals (averages). Rainfall exceeded the normals by 10 to 15 percent at Titahi Bay and north of Upper Hutt to over 45 percent near the harbour entrance. Highest departures occurred on the hills of the Wellington Peninsula between Makara and Johnsonville, and the south-eastern suburbs of Rongotai, Strathmore, Seatoun and Miramar in Wellington City. The 1977 departure map (Figure 2) shows a different pattern: the range increased from 15 percent at Paekakariki and Kaitoke to over 65 percent with highest departures occurring in a corridor running north-west to south-east from Titahi Bay across Petone to Eastbourne and Wainuiomata. Within this high departure corridor there were two maxima; one centred on Porirua with departures up to 65 percent and another centred around Eastbourne and Wainuiomata with departures of 50 percent. The whole corridor had annual totals exceeding the normal by 45 percent or more. So, although 1974 and 1977 were both very wet years in the Wellington area the distribution of the high departures from normal was markedly different: in 1974 the main concentration was over the Wellington Peninsula whereas 1977 it was a corridor running from Titahi Bay in the north to Eastbourne and Wainuiomata.

The reason for the differing nature of the 2 years lies in the synoptic storm producing systems that traversed the area; 1974 was a year of major southerly storms while in 1977 most major storms came from the south-east or north-west directions. Table 2 gives examples of rainfalls during large storms in certain selected localities.

As can be seen the storms gave widely varying rainfall depths over the Wellington area. Figure 3 shows a southerly storm on 2–4 July 1974. Maximum rainfall occurred on the hills of the Wellington Peninsula and at the southern end of the Rimutaka Range. Rainfall then decreased progressively to the north. Analysis of data from the large storms in 1974 and 1977 shows that southerly storms all give essentially similar rainfall concentration patterns. An example of a south-easterly storm is shown in Figure 4 with the highest rainfall depths in the Rimutaka and Wanuiomata areas. This concentration maximum covered Eastbourne Borough and extended a lobe through Alicetown in Lower Hutt to Linden and Porirua. Falls in Wellington City amounted to about half that in Eastbourne and in Upper Hutt to only a quarter. Other south-easterly

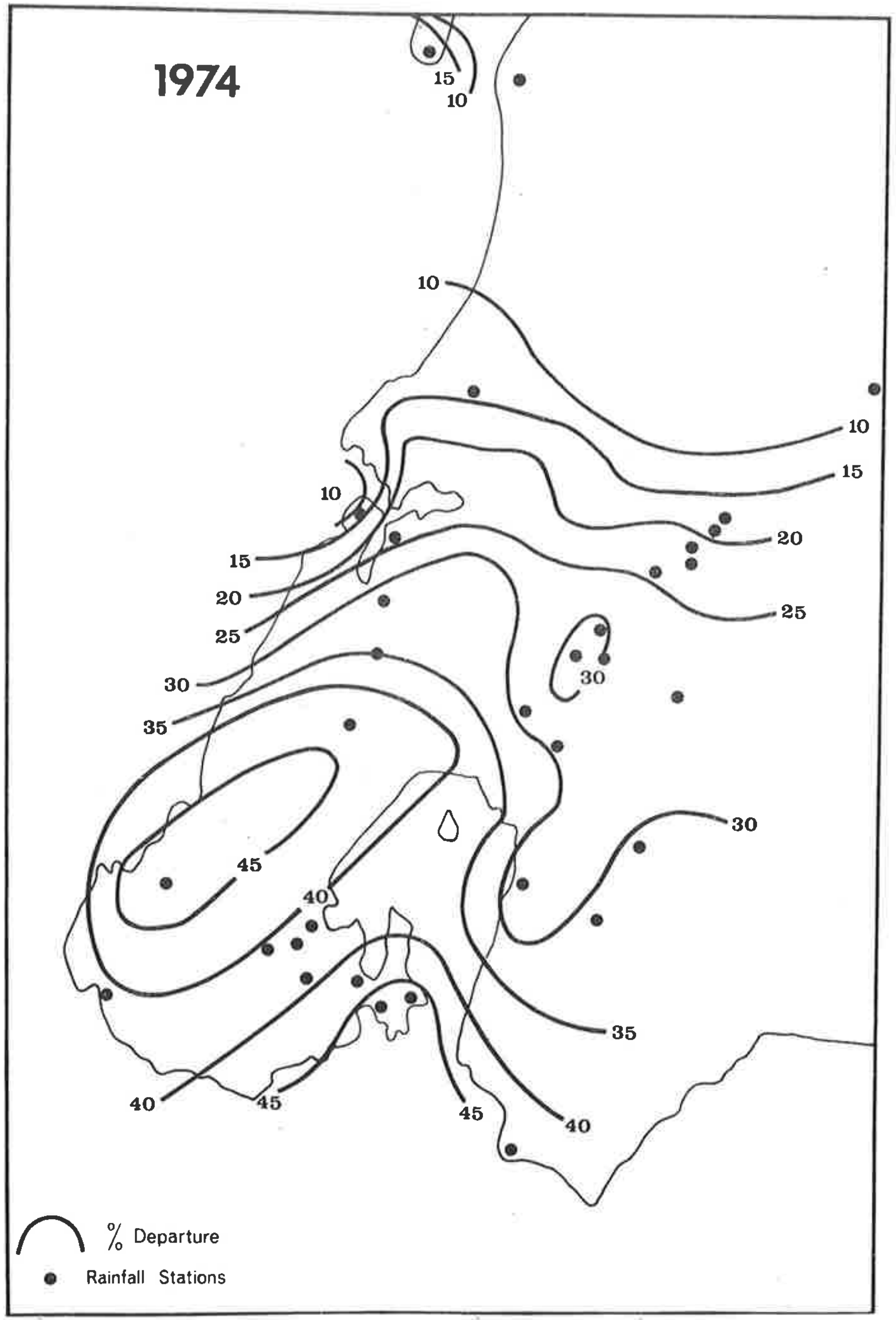


Figure 1—1974 rainfalls for the Wellington district expressed as percentages above 1941 to 1970 averages.

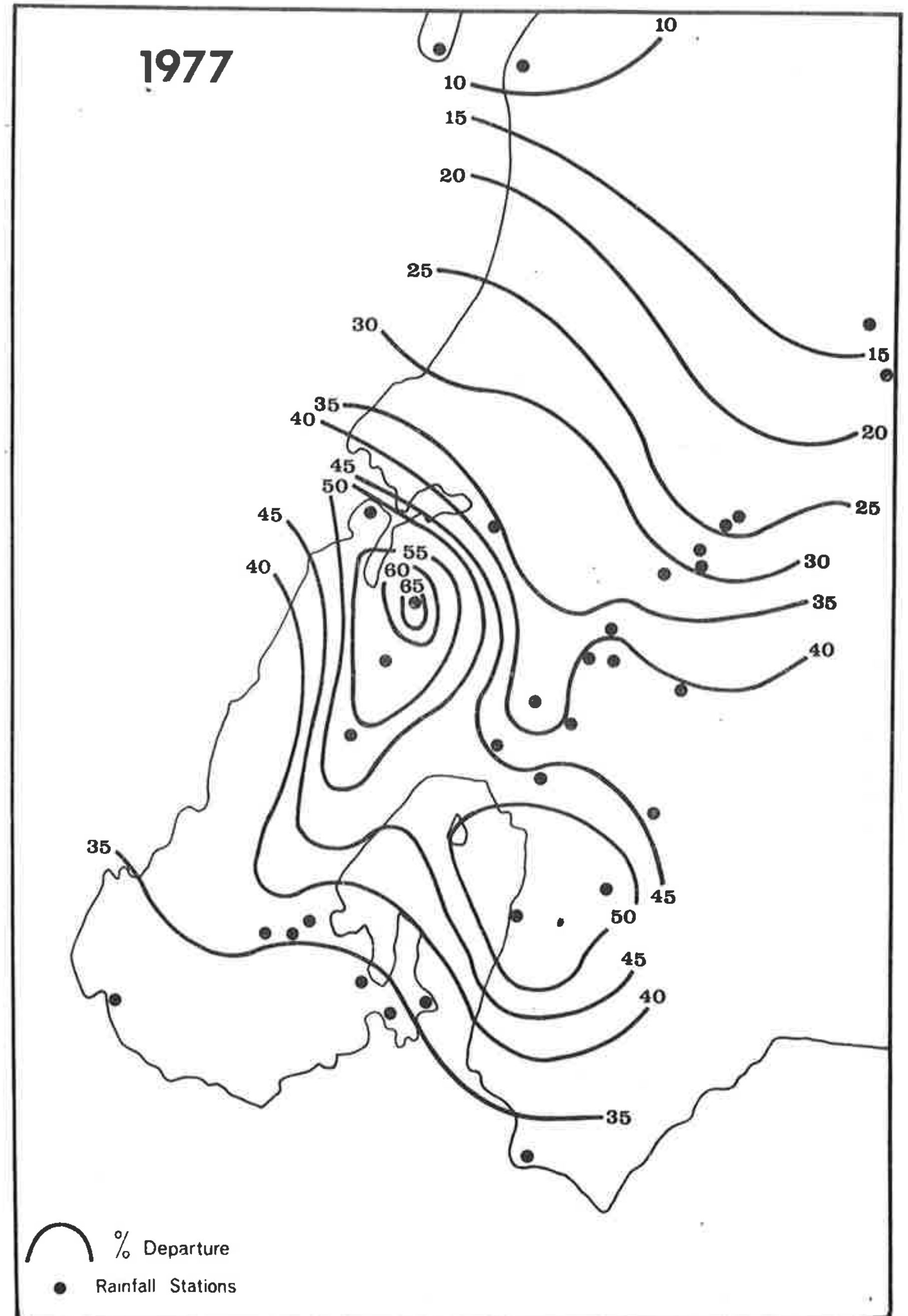


Figure 2—1977 rainfalls for the Wellington district expressed as percentages above 1941–1970 averages.

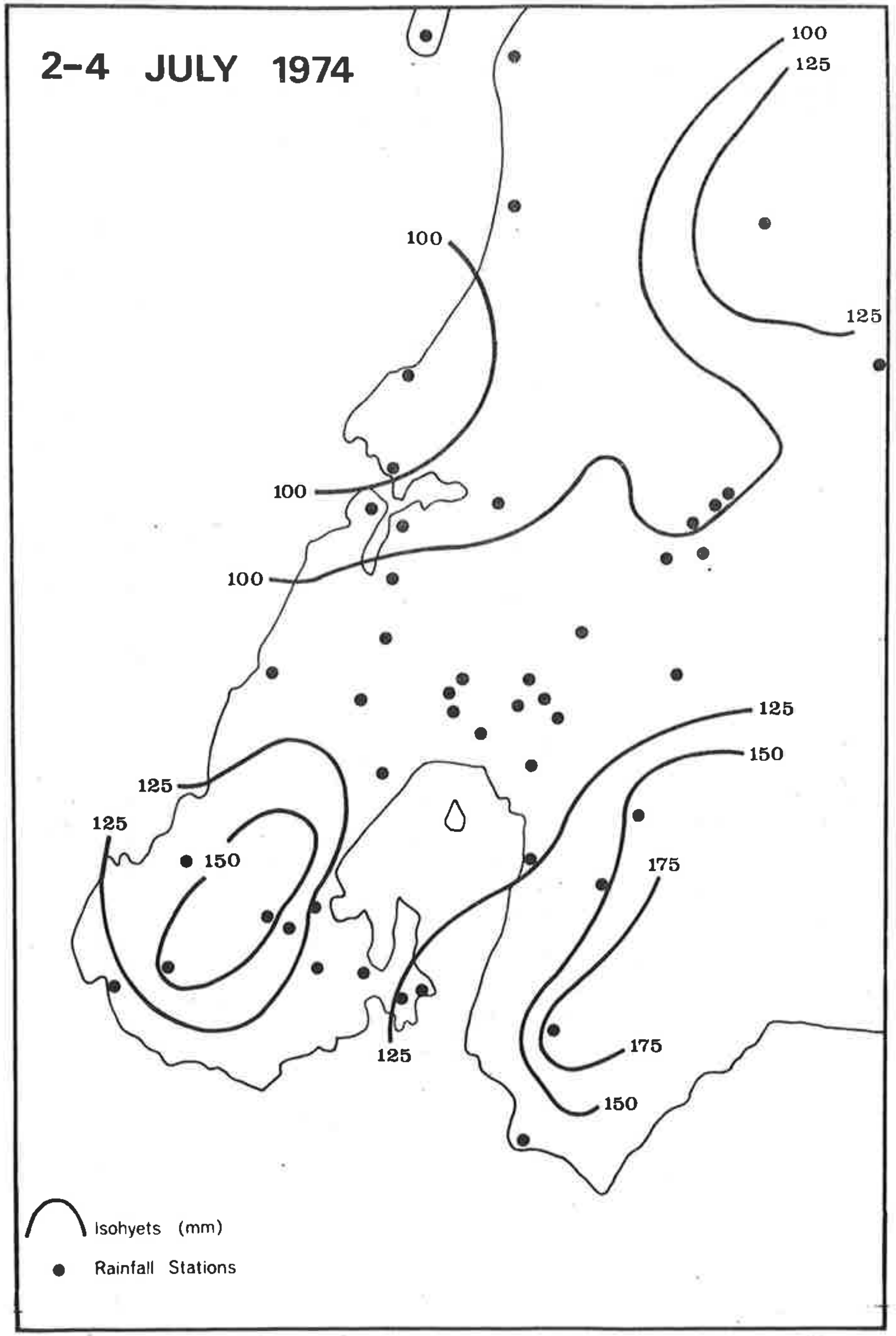


Figure 3—Distribution of precipitation from a southerly storm, 2–4 July 1974.

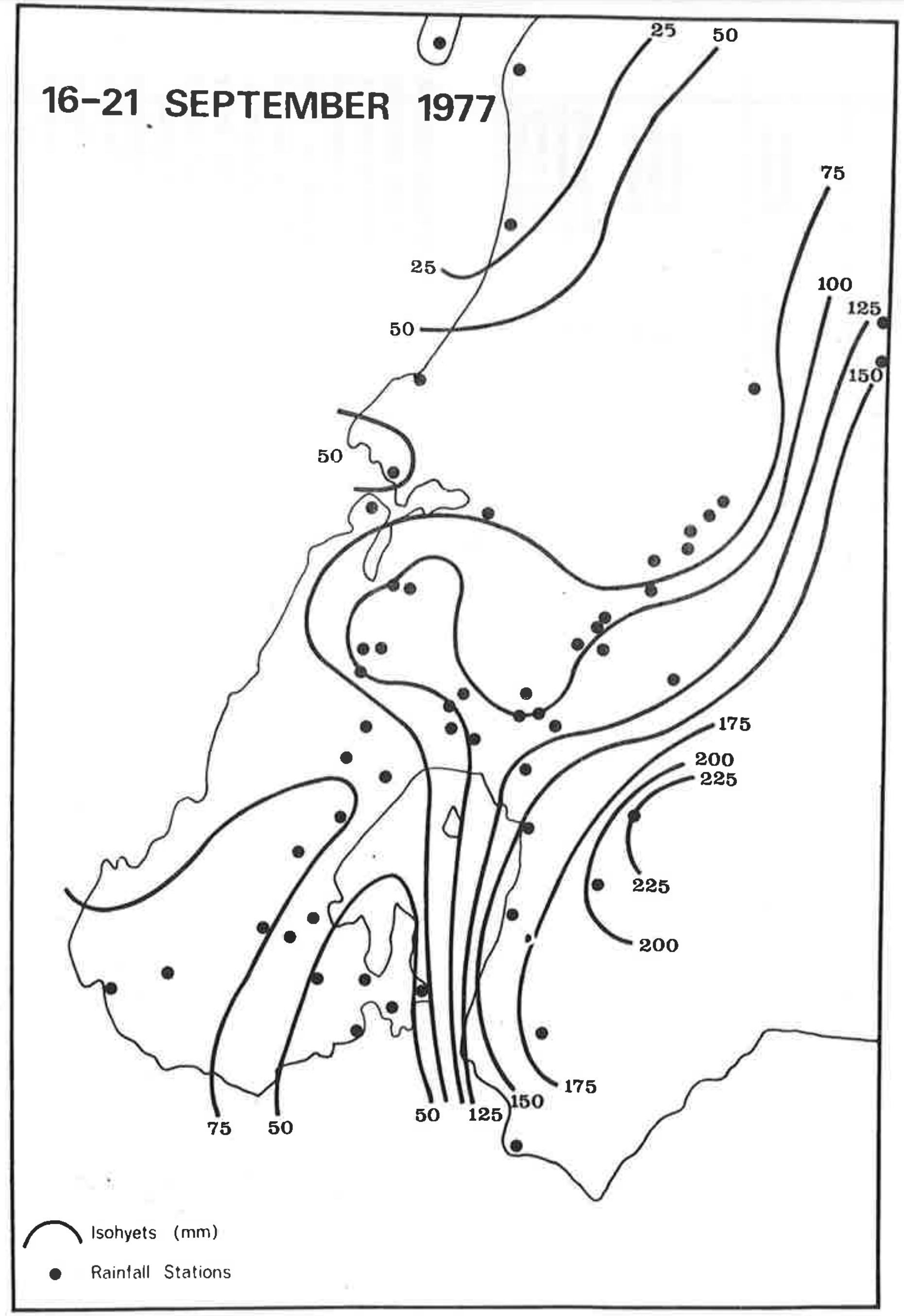


Figure 4—Distribution of precipitation from a south-easterly storm, 16–21 September 1977.

Table 2—Selected large storms in 1974 and 1977, rainfall in mm.

Locality	Porirua	Karori	Kelburn	Wellington Airport	Eastbourne (1977) Mahina Bay (1974)	Wainuiomata	Synoptic Direction
Date							
1974							
27–29 May	85	128	118	104	112	115	Southerly
2–4 July	106	150	124	128	124	149	Southerly
7–9 October ...	77	120	109	95	83	104	Southerly
1977							
10–11 February ...	90	91	84	51	163	174	South-easterly
10–11 April	110	61	57	51	97	95	North-westerly
26–30 August ...	84	70	53	34	192	271	South-easterly
16–21 September ...	120	80	58	41	173	222	South-easterly

storms gave a similar pattern. The north-westerly storm in April gave maximum falls from Titahi Bay through Porirua and Tawa and into Alicetown in Lower Hutt. Figure 5 shows storm localisation envelopes for the three types of storm just described.

Slip inducing rainfall

The large storms listed in Table 2, as well as the storm of 20 December 1976, all caused mass movements which have been documented in a number of publications (Bishop, 1977; Eyles, Crozier and Wheeler, 1974, 1978; Riddolls, 1977; Taylor, Hawley and Riddolls, 1977). Damage was very localised in all storms and was related to slope steepness, land use (in particular, to the presence of 'cut and fill' slopes), and the rainfall distribution.

Field surveys during 1974 and 1976 and a review of the historical evidence allowed values of rainfall to be postulated as thresholds above which serious slipping seemed to occur in Wellington City. These values were.

(a) A 4-month rainfall of between 750 and 800 mm, with susceptibility increasing towards the end of the wet period;

(b) With relatively dry antecedent conditions typical of summer and autumn, a 24-hour rainstorm above about 120 mm;

(c) On 'natural' slopes under grass, scrub, or forest (in dry antecedent conditions) a 24-hour fall of 200 to 250 mm (Eyles, Crozier, and Wheeler, 1978).

The concept of a 24-hour threshold, or 'triggering' storm has been refined in Figure 6. The graphs represent a Penman water balance model and were compiled from a computer printout supplied by the Meteorological Office. Inputs for the computer programme include daily rainfall, long-term 5-day mean evapotranspiration rates, and an available soil moisture capacity of 120 mm. This latter figure is a mean value for the water that can be held in the top 76 cm of soil or regolith between tensions representing field capacity and permanent wilting point for Korokoro silt loam and Judgeford silt loam (Gradwell, 1974) which are taken to represent Eastbourne soils. Zero on the soil moisture storage scale signifies field capacity and a deficit of 120 mm implies that the soil has dried out to wilting point. It is assumed that no further drying out takes place as soil moisture tension is too great for plants to extract water. When a rainfall event occurs it is assumed that soil moisture storage is recharged to field capacity; any additional precipitation is termed 'excess' and is shown as a vertical line on the graph. Excesses are plotted on a daily basis. This water either percolates downward through the soil under the action of gravity or runs off the ground surface.

Most mass movement during 1974 in Wellington City occurred in 4 storms in each of which a 24-hour 'excess' of 60 mm or more was experienced (Figure 6A). Similarly in Eastbourne during 1977 most mass movements occurred on the 4 days (11 February, 26, 29 August, 18 September) in which 'excess' was more than 60 mm (Figure 6C). Wellington City in 1977, while receiving a higher total rainfall than in 1974, suffered from very few mass movements. The maximum daily 'excess' of rainfall recorded at Kelburn (Figure 6B) was 48 mm.

It is postulated, therefore, that a 24-hour rainfall producing an 'excess' of 60 mm above soil field capacity, is a threshold rainfall above which serious slipping will occur on suburban hillslopes in the Wellington area. The notion of 'serious slipping' is somewhat subjective being based on the closure of more than one street or road and the use of such terms 'large' and 'numerous' in mass media reports of mass movements.

The slip-triggering threshold defined in terms of a water balance model is a valuable concept in that at any point in time, soil moisture deficit can be quickly calculated, and the magnitude of storm event needed to induce slipping determined. This is particularly important in the case of isolated summer storms such as the 20 December 1976 and 11 Feburary 1977 storms. The latter produced a rainfall of 135 mm at Eastbourne, 54 mm of which recharged soil moisture storage giving an 'excess' of 81 mm which triggered a number of mass movements. During severe drought conditions when soil moisture deficit is at 120 mm, a 24-hour rainfall of 180 mm would be necessary to cause serious slipping—i.e., a storm of the magnitude of the 20 December 1976 storm. It is clear from Figure 6 that the risk of slope failure is greatest during the winter months when, because of higher rainfall, and evapotranspiration rates of 1 mm or less per day, soil moisture is at or near field capacity.

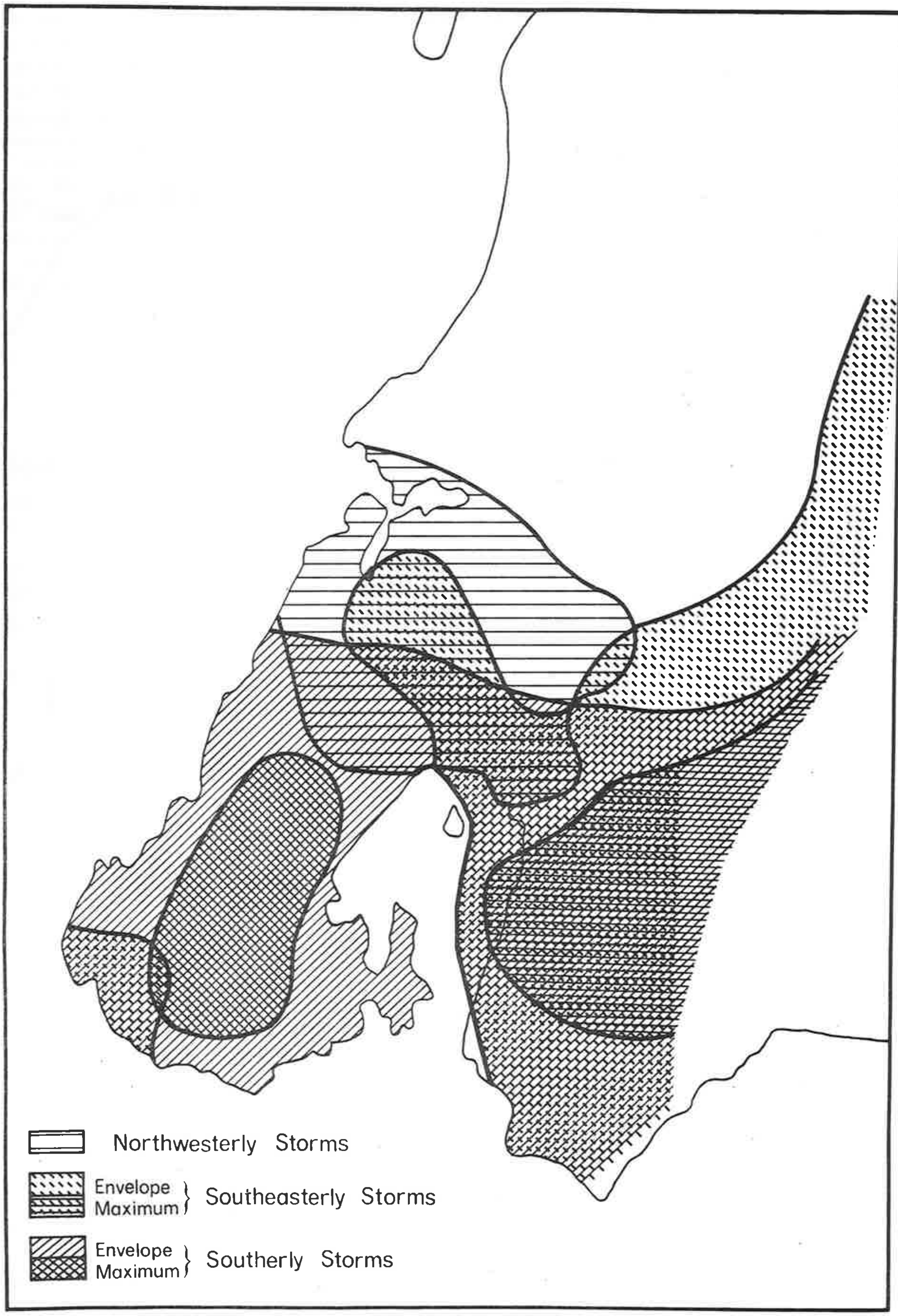
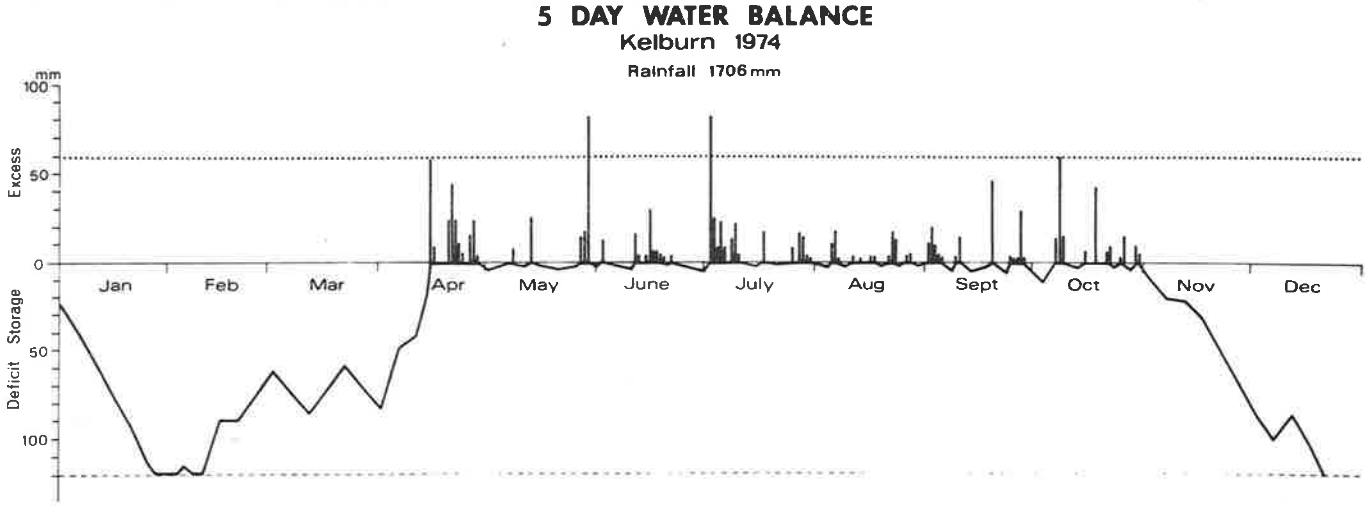


Figure 5—Approximate storm localisation areas.

A



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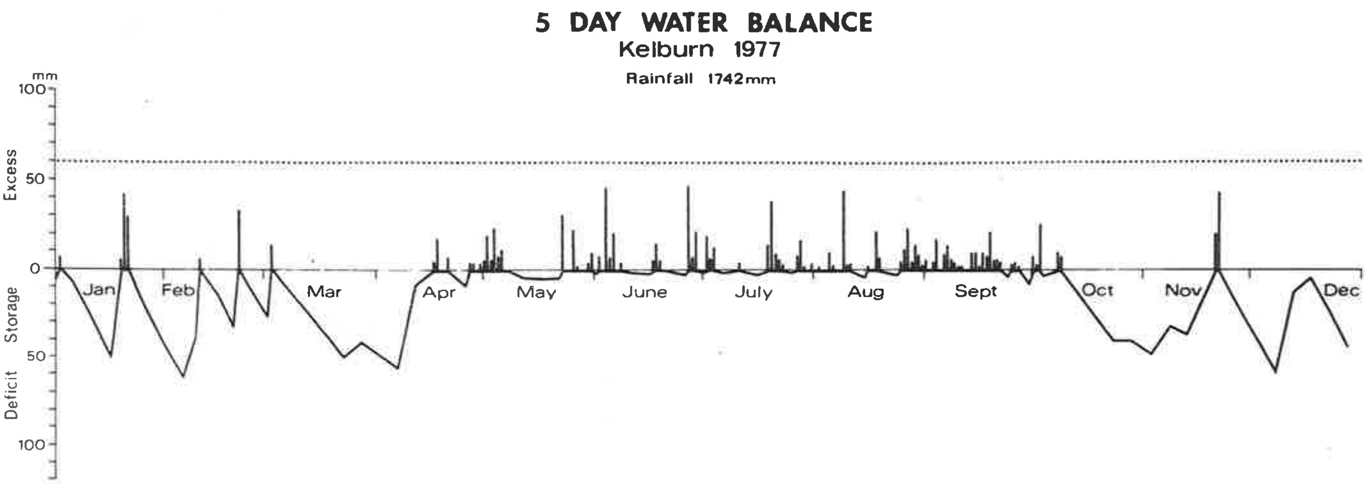

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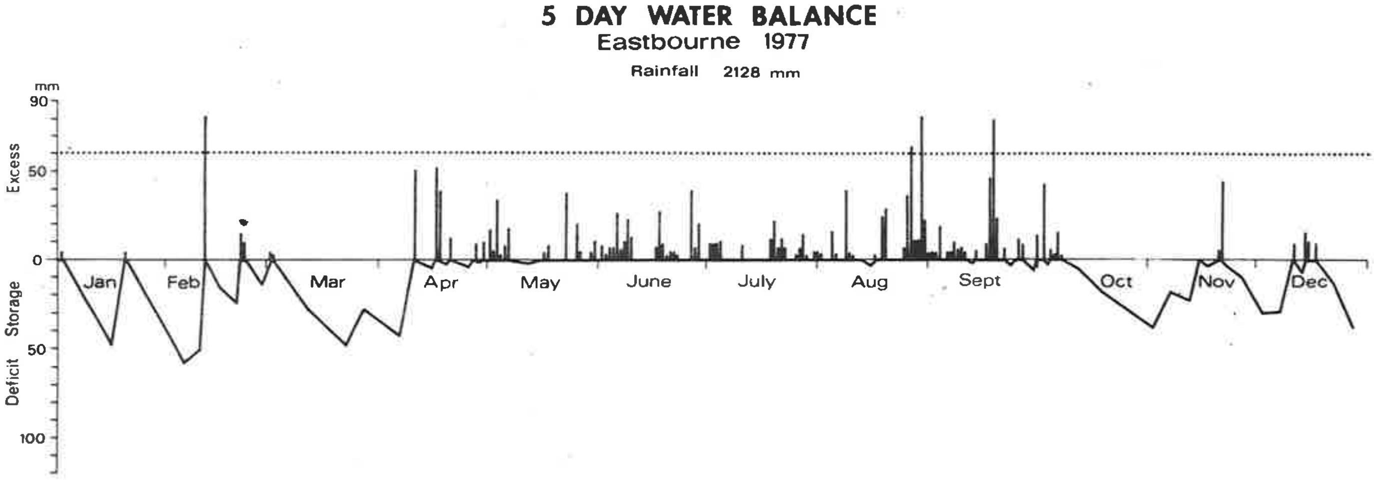

Figure 6—Water balance graphs based on Meteorological Office data and using a total soil moisture capacity of 120 mm. Evapotranspiration values from Gracefield are used in Figure 6C. The "threshold" value of 60 mm for 24 hour rainfall 'excess' is marked (- - - -).

Published return periods for 60 mm, 24-hour rainfalls in Lower Hutt and Petone are both less than 2 years (Robertson, 1963). Figures are not available for a return period calculation of 60 mm, 24-hours 'excess' rainfall. The historical record for Wellington City contains evidence (Eyles, Crozier and Wheeler, 1978) of serious mass movement damage in 1941, 1943, 1955, 1974, and 1976; that is in 5 of the last 36 years. The number of occurrences is insufficient for the 60 mm 'excess' threshold to be rigorously tested, but it is probably safe to conclude that any year experiencing several storms producing a 24-hour rainfall 'excess' of 60 mm or more will be a year of serious mass movement erosion.

Rainfall records show an increased variation about the mean since the late 1960s. There has also been a trend toward more easterly airflow on to New Zealand (Trenberth, 1976), a situation which would give more south-easterly storms. If this is true the frequency of slip-triggering storms may have increased for Eastbourne. The Borough Council would therefore be well advised to consider periodic repetition of conditions experienced during 1977 when planning for future subdivisional and building developments.

Assessment of Slope Stability

Methods

Most slips greater than 1 cubic metre in volume that occurred during 1977 were located (Map 1) and visited.

At each slip the following measurements and observations were made (Appendix 1):

Slip material—weathering grade (Appendix 2)
—presence of any major joint planes*

Site morphology—convergent, divergent, planar with respect to likely direction of water movement

Aspect of slip—orientation of slip

Slope angle of, shear plane,* and adjacent undisturbed slope or cut

Vegetation cover—species, size, degree of ground cover

Slip dimensions—length, width, depth, volume

Position of slope—top, mid or foot slope

Status of slope—cut, fill, traversed by path, localised water entry

The information collected and presented below gives a general description of slope failures that occurred in Eastbourne Borough during 1977 and which are likely to recur in the future given similar rainfall conditions.

Distribution of slips: 1977

One hundred and twenty slips were measured (Map 1), the majority being located on slopes with a westerly aspect as was expected considering the general orientation of the borough (see Photo 8).

Slopes in Eastbourne are very long and steep even for the Wellington area (Map 1), so a relatively high frequency of slips on natural ground can therefore be expected.

In fact, 31 of the recorded slips (26 percent) occurred on natural slopes (Photo 1) with a marked concentration in the 2 catchments at the top of Kaitawa Road, York Bay.

Thirteen slips occurred on the coastal cliff (2 of which involved rubbish and fill, Photo 2) which is very steep as a result of marine erosion and road widening and is subject to fires, high weathering rates from salt spray, exposure to wetting and drying, and wedging through root growth and root leverage in strong winds.

Sixty-one slips occurred on artificially cut slopes; 10 on fill slopes and 5 on a combination of cut and fill slopes.

The mean slope angle for all the slopes that failed was 49° with a higher mean slope angle for cut slopes that failed (55°) and lower for natural slopes that failed (44°). However, the gentlest slope that failed was 22°—the range reflecting the type of material involved and other contributory factors such as position on the slope, vegetation, and drainage.

Material involved

The majority of slips occurred in regolith—the weathered material between bedrock and the ground surface. In many cases the shear plane was along the bedrock/regolith contact.

There were several different types of material involved. The majority comprised weathered greywacke and colluvial material,* very loose in nature and deeply weathered. The most weathered material was found on the partly dissected interglacial marine terraces at Point Howard York Bay, and Windy Point.

Twenty-six slips involved the displacement of bedrock and weathering grade (Martin and Millar 1974) was recorded for bedrock involved in 46 slips—i.e., both displaced material, and at the slip plane. Weathering grades III and IV (Appendix 2) were most common. However, weathering grade is not a particularly useful index of bedrock susceptibility to failure in this locality as failure was usually along joint planes (Photo 3). There was also extreme variability in rock hardness at each site associated with alternating sandstone and argillite strata and the presence of old fault shatter zones in many exposures.

*Glossary.

Photo 1—Natural slip in gully head situation with shear plane along contact between bedrock and regolith.

Photo 2—Slip on coastal cliff involving colluvial material and vegetation.

Photo 3—Bedrock failure among joint planes in a cut slope—note range of jointing.

Photo 4—Slip face showing fill material on original soil surface (marked by hammer).

Photos 5 a and b—Slips associated with uprooting of dead beech trees on slopes in excess of 50°.

Fossil gully material* was involved in 6 slips all of which occurred in cut slopes. Three slips comprised exceptionally deeply weathered material (class V) which was crushable to light-brown sandy silt under finger pressure.

Twenty-two slips comprised a variety of fill material, e.g., old car parts, household rubbish, timber, bricks, and iron in a soil medium.

In the face of several slips old buried soils (see Photo 4) were found, in some cases indicating prior movement. This was confirmed by the presence of bent trees that had previously been moved to a horizontal position and then grown upright again.

Some material from 15 of the natural slips reached a watercourse but most of the slip debris (regolith material and vegetation) is still perched on the slopes, trapped by vegetation. Some is in a position where it could be washed down at a later date but most will probably revegetate. This has recurred in the past, evidenced by old revegetated slip scars and debris on the slopes. In a few situations where material did reach a watercourse it is still in the channel and could be reworked during future high rainfall events, but a great deal of sediment was transported by flood flows and contributed to blockages of watercourses and stormwater systems during 1977.

Site morphology and position on slope

The majority of slips (106) occurred in situations where surface water would not naturally concentrate.

Only 13 slips occurred in convergent locations, these being either seepage points or in valley head positions.

Seventy slips occurred near the base of slopes most of which had been cut. The 40 slips in mid slope position occurred mainly on natural slopes including the coastal cliff, while the 11 slips in top slope position occurred mainly in fill material. Most of the slips that occurred in mid slope positions on natural slopes were related to some form of vegetation disturbance, either the death of beech trees or to cleared gorse.

Vegetation influence

Twenty-seven slips were associated with vegetation disturbance in the previous 5 years or so. Disturbance was either natural (storm damage, or drought) or man-induced (felling of large trees, clearing of scrub vegetation, or fire).

Seventeen slips on natural slopes were associated with old dead beech trees. (Photo 5). These trees had been burnt, damaged in the Wahine storm of 1968, or had succumbed in the 1972–73 drought.

The effect of vegetation disturbance is demonstrated well by a cluster of slips, including one particularly large one (60 m long by 15 m wide and 450 cubic metres in volume) associated with an isolated area of beech forest which was burnt in 1973. Slipping began at the bottom of the slope in the following year and in subsequent years, particularly during the winter of 1977, dead beech trees and regolith avalanched down the slope and the slip surfaces were scoured by raindrop impact, slope wash, and rill erosion. Since the large slip occurred, several other parts of the burnt area have failed and there is every indication that a large proportion of the burnt area may slip away.

Eight slips occurred after pine trees had been felled. In 6 of these cases, trees were left on the ground adding weight to the slope and enabling water to collect on it. (Photo 6).

Twenty-nine slips were associated with gorse, the primary successional species after fire or clearing. In 2 cases slips occurred in a dense cover of gorse which had been cleared of tall manuka (2–3 m in height) 2 years previously.

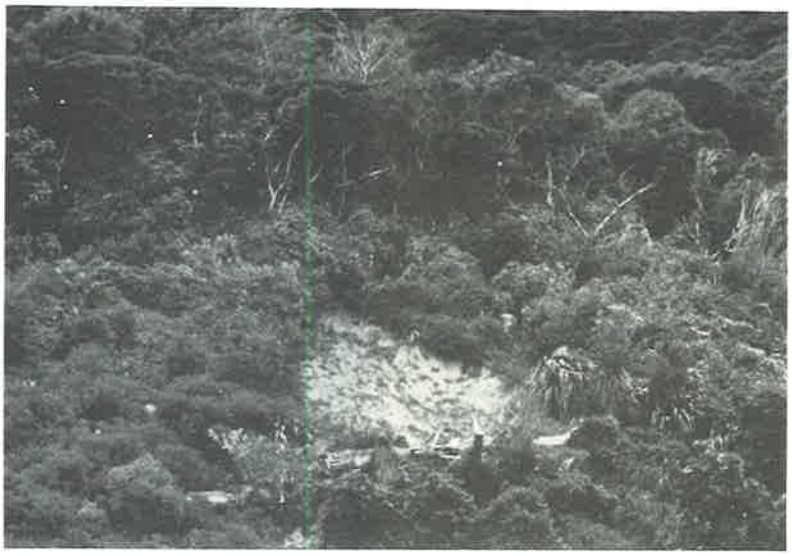

Photo 6—Trees left on slope after felling adding weight to slope, and enabling water to collect on it.

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*Glossary

Causes of slope failure

Natural slopes

Slope failures on natural ground were caused by a number of factors. High intensity rainfall (Figure 2) was the triggering mechanism causing saturation (Figure 6) of the unconsolidated deeply weathered material at high (>45°) slope angles.

The location of the 31 slips appears to have been controlled by channelling of subsurface water on to deeper parts of the bedrock/regolith interface such as fossil gullies, or where variations of permeability of the regolith material caused temporary perched water tables in the ground.

The cases described above indicate that naturally disturbed vegetation also tended to reduce slope stability by concentrating water into areas with reduced shear strength. There are several possible reasons for this.

Living trees have several beneficial effects on slope stability which are reduced if vegetation cover is removed.

Plant roots increase soil shearing resistance,* both directly by mechanical reinforcement (binding the soil mass together in and around the margins of areas occupied by trees, and by anchoring the regolith of the bedrock) and indirectly through water removal by transpiration (Gray, 1970). The combined effect of transpiration depleting soil moisture to some depth, and interception of rainfall is to reduce the rate of soil saturation while the tree roots provide pathways for the rapid movement of water.

In the case of large dead beech trees and the pines that had been cut, water could have been channelled along the stem of the tree into the regolith and around the dead and contracted roots. This would give rise to localised high pore water pressures* thus reducing the effective shear strength* of the soil. Trees which have fallen to the ground, and are left in a position where water can collect on the slope, and weight to the slope and also increase local pore water pressures.

Bishop and Stevens (1964), Gray (1970), O'Loughlin (1974), Brown (1975), and Parker (1978) provide evidence of the effect of tree root decay on slope stability. There appears to be a lag period between tree removal and the incidence of slipping which may be attributable to the decay time of roots.

O'Loughlin (1974) found in Canada that 3–5 years after tree felling, small tree roots had lost over half their original tensile strength (Photo 7).

In a study on shallow greywacke-derived soils on steep natural slopes in the Hapuakohe Range, South Auckland, Parker (1978) found that shear strength values were reduced by up to 40 percent in 4 years after forest felling due to root decay.

The evidence in Eastbourne suggests that there is a lag period before slipping occurs after vegetation disturbance.

For example, 8 of the slips associated with dead beech trees were concentrated in one catchment in York Bay which was particularly affected by strong winds and salt spray during the Wahine storm of 1968 and a succeeding storm. This area is typical of other even-age mature stands of beech in the borough which are underlain by a regolith of fairly uniform weathering history. A cyclic process may therefore affect other catchments in the borough in the future as even-age stands of beech die followed by slipping and then replacement by a new stand of beech.

Another contributory factor is slope angle. As many of the slopes affected are steeper than 45° the downslope component of surcharge (weight) is greater than the normal component (see Photo 5). This means that slipping may naturally be prevalent especially where tall trees are able to blow about in the wind adding to the shear stresses on the slope.

Vegetation which recolonises slips comprises dense native shrub species which, when saturated, have a considerable biomass. This may well be significant at times of marginal stability during storms, when water tables are at or near the surface. The rise in water tables which follows the drop in evapotranspiration with the removal of large trees, has been found to increase the rate of soil creep and thus decrease stability (Brown, 1975).

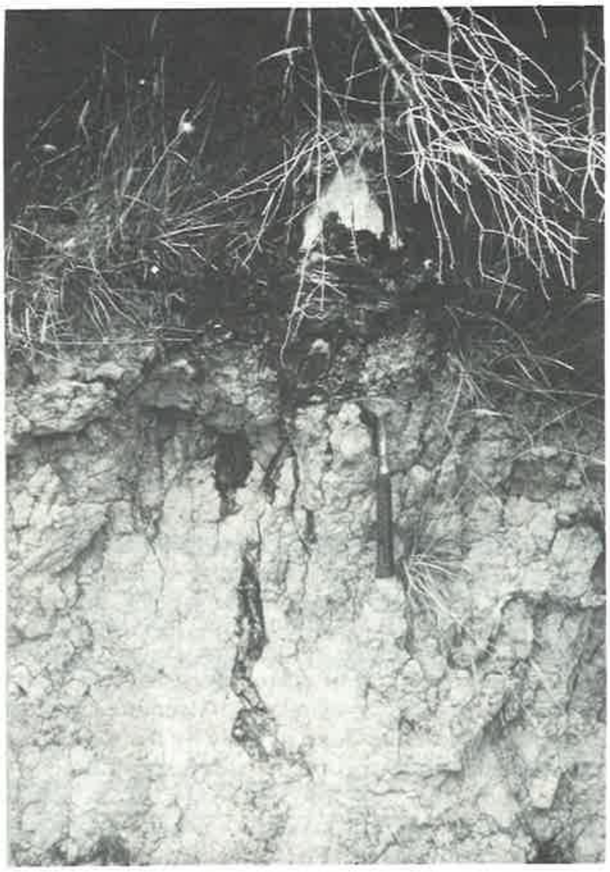


Photo 7—Old pine root from felled tree showing decay. Note root shrinkage which would allow water penetration to some depth into the ground.

*Glossary

Disturbed slopes

The majority of slope failures (74 percent) occurred on artificially disturbed slopes in the urban area of Eastbourne. The following factors contributed to slope failure:

Drainage

Inadequate or uncontrolled ground surface drainage was the most important contributory factor. Thirty-three slips showed clear evidence of triggering by localised entry of stormwater on to a slope. This occurred in a number of ways.

Stormwater collected from roofs and paved areas on one property was often channelled and discharged on to a lower elevated part of the section or on to an adjacent property in an uncontrolled manner.

There was evidence that broken 'wet' service pipes, perhaps by root wedging action, allowed localised concentrations of water causing failure.

Poor drainage, found on nearly all of the walking tracks in the borough, contributed to 19 slope failures. The absence or lack of maintenance of channels at the inside edge of tracks, allowed water to flow uncontrolled into the failed areas. These usually occurred at track corners where fill from the cut path was saturated and became unstable.

Oversteepened slopes

Too steeply battered banks contributed to 61 slope failures. The removal of toe support of a slope is a common cause of instability. This occurred where deeply weathered material, sometimes overlying rock, was exposed or where rock faces with inherent structural weaknesses were involved.

Three failures were associated with inadequate support structures which included inadequate foundations and poor or absent drainage measures behind the retention structure.

Overburden

Unnecessary overburden on steep slopes, such as felled trees, general rubbish (old car parts, timber, bricks, scrap iron, etc.) and soil was a contributory factor in 24 slope failures (see Photos 4 and 6).

All these factors can be controlled by various preventive measures as outlined below.

Preventive measures

Where urban land is limited, as it is in Eastbourne, a certain amount of instability of a shallow or superficial nature can be tolerated if precautions are taken to ensure personal safety and to ensure that costly damage to structures can be avoided. This can be done initially by restricting the building site on a section to a safe position, i.e., away from the toe or the edge of a slope. Additionally or alternatively other protective methods can be used. These include deflectors or catch nets to divert rockfalls, and alternative foundation designs, such as poles or stepped levels incorporating retention walls. It should be stressed that these measures can only be considered where minor instability of surface material is anticipated. As a general rule it is easier from an economic and safety viewpoint to avoid locations where risks are known to exist.

Earthworks associated with subdivisional development such as building platforms, access tracks and even garden landscaping all need care in their execution. The 3 basic problems are in deciding at what angle to cut rock or soil faces, how to place and compact fill material and how to construct retaining structures where these are deemed necessary. Professional advice from people with experience in slope stability and ground engineering problems, should always be sought on these aspects. In particular the recognition of adverse conditions in a rock or soil face are not usually appreciated by the layman. The presence of fault joint or bedding planes and seepage points are often not recognised and can lead to failures of cut slopes such as those recorded in the survey.

Excavated material and other general rubbish and waste should not be pushed on to existing slopes. This unconsolidated mass adds weight to the slope, interrupts percolation of water, and can fail readily or contribute to the failure of the material beneath.

Where fill is used to form a building platform, to create a pedestrian or vehicle access or a garden terrace, this should be placed in layers and adequately compacted. Underlying vegetation and soil should be removed and benches formed on underlying material if 'keying' is required. Adequate drainage should be incorporated in these earthworks. The New Zealand Standard Code of Practice NZS 4431 (1978) describes the engineering requirements of 'Earth Fill for Residential Development' and professional advice and workmanship is required when carrying out such an operation.

Where retention structures are considered necessary care should be given to their design. This should be carried out by experienced engineers and will usually require a building permit. Care should be given to the foundation conditions. The ground beneath must have adequate strength to carry the structure which should be capable of maintaining lateral support in the long term. Above all, adequate drainage measures must be incorporated in the design. Permeable retaining structures such as crib walls usually need a backfill of sandy or gravelly material with lateral drains incorporated. Any impermeable structure such as mass concrete should also have a backfill of permeable material and should have some outlets such as weep holes through the face.

Some rock faces and slopes in soil of silt or larger grain size can be stabilised by the use of horizontal drains. These are perforated pipes inserted at a slight angle into holes bored into the slope and are used where the source of seepage water is unkown or cannot be controlled. Shallow slides can also be controlled by the use of drains consisting of fabric-lined trenches filled with free-draining stone and sometimes draincoil.

Where the problem is not the control of siginificant earth pressure but merely the normal weathering and eroding processes of a slope, sprayed concrete (gunite or shot-crete) can be applied. Care should be taken to avoid ponding water behind the surface and weep holes should always be incorporated.

Alternatively, vegetative methods can be used, such as hydroseeding, grassing, or the planting of low-growing mat-rooting shrubs. As a general rule, where slopes are over 45° on intensely jointed weathered greywacke, vegetation should be kept low in stature.

The problem of drainage should be stressed in that it accounts for a high proportion of failures on developed ground. Particularly on steep slopes, total control of stormwater, both at the initial subdivisional and building stage and throughout the life of a dwelling, is essential if instability is to be avoided. Water collected from roofs, paved areas, drives and gardens should be channelled and directed into a competent stormwater system. Broken gutterings, downpipes, 'wet' service pipes, blocked gratings, drains, and open channels can direct water on to slopes which can become unstable when saturated. Maintenance by cleaning and clearing should be carried out regularly to avoid such problems.

Further comments and advice on the causes and remedies of slope failures can be found in chapters 2 and 3 of the DSIR Information Series 122 *Slope Stability in Urban Development.*

Assessment and causes of flooding

The survey of slope instability in the borough indicated that during periods of heavy rainfall in 1977, river channels and stormwater systems were unable to cope. Developed areas in central gully situations and adjacent to channels and piped culverts experienced flooding of sections, roads, and other paved areas, and in some cases buildings.

It has proved impossible to separate the flooding hazard entirely from the effect of soil and rock slips. Sediment and debris in the flows caused a reduction in the capacity of the waterways, blockages of channels and culvert entrances and temporary dams along watercourses, resulting in increased flow rates when these were breached.

Some consideration, however, has been given to the drainage system of the borough from existing information and limited field observations. Map 1 shows the natural channels of the 18 major catchments. An estimate of the 10-year and 50-year peak flood discharges likely to occur where the streams enter the urbanised area (derived from the TM61 method) are also shown.

Some stormwater systems within the developed flatter area have been mapped by the borough's engineers and these are also marked on the map.

From observation, watercourses emerging from the underveloped natural catchments are often diverted into formed channels or piped culverts across private sections before entering the borough-controlled stormwater system. This situation has resulted in arbitrarily sized and often inadequate channels frequently deviating in direction and having limited access for maintenance.

Subsequent visits to the borough revealed cases of flooding due to blocked gratings and diversion of flow from inadequate or blocked waterways.

Many of the stormwater problems can be coped with by simple preventive measures.

Preventive measures

The most effective flooding preventive measure is by flood plain regulation through zoning ordinances, subdivisional regulations and building codes. By these means houses can be sited away from areas of risk or if this is not possible be designed to aviod serious damage to the structure or its contents.

Alternative corrective measures can be applied to the waterway. The carrying capacity of stormwater systems can be increased by:

Straightening to remove undesirable bends.
Deepening or widening of open channels.
Replacement of undersized culverts.
Removal of obstructions.
Prevention of blockages by debris traps, or dams, and by regular maintenance.

In Eastbourne there is obviously a need to rationalise the urbanised section of the waterways.

Pipe sizes (diameters) required to carry peak flows of the magnitude that can be expected from the Eastbourne catchments are given in Table 3.

This table and the discharge figures on Map 1, show that it would be beneficial to upgrade some sections of the system to improve pipe sizes, alignments, and accessibility. Ideally the whole system should be brought under the control and responsibility of the borough council.

The problems associated with sediment and debris from slips in the upper reaches of the catchments need alternative remedies. The bedload and detritus must be halted or diverted before it enters and

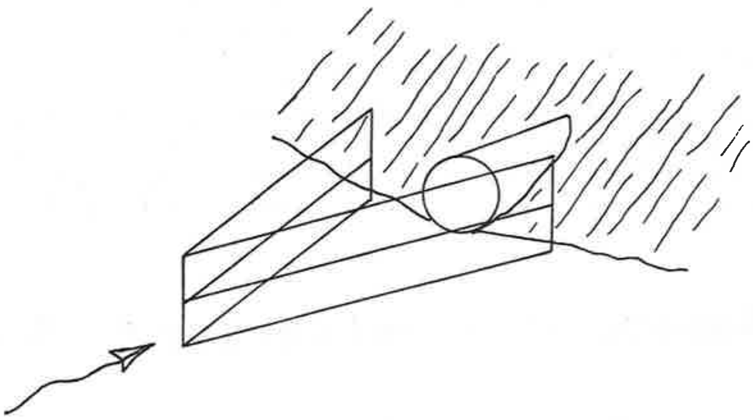
Table 3—Culvert Sizes—Circular concrete pipes (with socket entrance).

Discharge = Qm^3/sec.	0.6	0.8	1.0	1.2	1.4	2.0	2.5	3.0	4.0
Suggested diameter (mm)	600	650	750	800	900	900	1050	1200	1500

N.B. Assumed slope 1:10 (range 1:5 to 1:20).
Assumed length 300 m (range 50 m to 500 m).
Allowable headwater Q $\leq$1 m^3/sec. = 1 m. Q $>$ 1 m^3/sec. = 1.5 m.

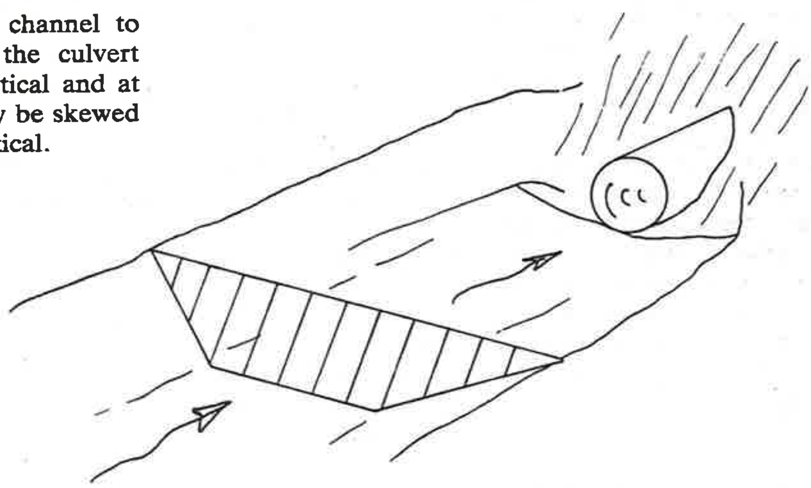
Debris Deflector

A structure placed at the culvert inlet to deflect the major portion of the debris away from the culvert entrance. Normally "V" shaped in plan, with the apex upstream.



Debris Rack

Structure placed across the stream channel to collect the debris before it reaches the culvert entrance. A debris rack is usually vertical and at right angles to the streamflow, but may be skewed with the flow or inclined with the vertical.



Detritus Crib

An open crib-type structure placed vertically over the culvert inlet in log-cabin fashion to prevent inflow of coarse bedload and light floating debris.

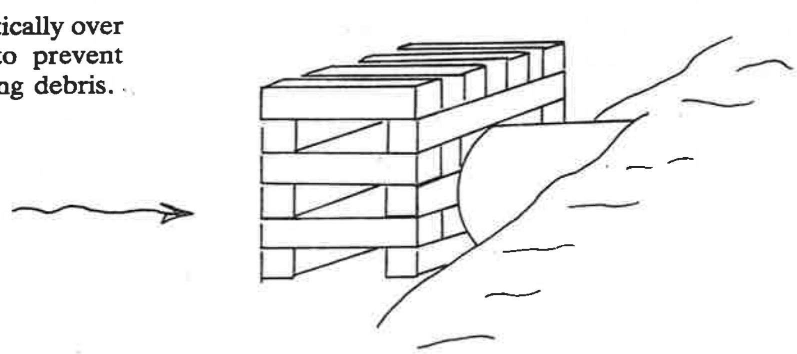


Figure 7—Debris control structures.

blocks the urbanised waterways. There are a variety of debris control structures which can be used in the Eastbourne catchments. Based on the type and quantity of debris expected, the 3 main types of structure suggested are the debris rack, the debris deflector, and the detritus crib. These are illustrated in Figure 7. Futher details on materials and construction can be obtained from Wellington Regional Council or from the Ministry of Works and Development Culvert Manual (CDP 706/A) which has a section on these structures. Whatever structure is envisaged there will always be a maintenance problem. Easy access to remove accumulated material will be required.

Indentification of Physical Hazards for Planning

Introduction

The popularity of Eastbourne as a residential area is related to its proximity to sea and bush and the many views across the harbour. The narrow, flat, coastal strip is now largely developed and new subdivisional and building developments are occurring on the bushclad hills. Buildings are already located below the coastal cliff, on flatter spurs above the cliff, on most valley floors, and even on the steeper hillsides. Consequently almost all areas available for further residential development include one or more potential hazards. If development takes place incorrectly in these areas slipping and flooding may occur.

There are many areas in and adjacent to possible future housing sites which contain dead or dying vegetation on steep slopes. These are areas of high risk.

Areas also exist adjacent to streams where flooding constitutes a risk, and in footslope positions where inflow of debris from the failure of natural slopes must be considered a possible hazard. These factors are quite unconnected with the more usual hazards associated with 'cut and fill' slopes.

Other factors that must be considered before subdivision or building is contemplated are the position and type of material on the slope—depth of regolith, depth of weathering, permeability of the regolith, and weathering grade of both regolith and bedrock.

It should also be remembered that in areas of very close jointing or very deep weathering, instability is likely to occur on relatively gentle slopes and low cut batters.

Such hazardous situations have been taken into account when classifying the borough in Map 2.

Urban suitability map

An urban suitability map showing areas with physical limitations to urban use has been prepared (Map 2), using the information from the slip and stormwater survey to develop a set of risk criteria.

The map is based on a subjective inspection of those areas with reasonable access. Much of the bush covered area within the eastern part of the borough has not been mapped, and throughout, lack of basic data on geology, soils and slopes as well as shortage of available time were major problems to mapping.

For this exercise, information was required for planning purposes to give a broad indication of areas where physical hazards may be encountered during development. More detailed information on specific risk factors will be required in the high risk areas before subdivision or building proceeds.

Map classification

The following criteria were used to identify areas of risk:

Geology: Distribution and character of rock and regolith—jointing, depth of weathering, stability.

Geomorphology: Slope steepness and length, position on or relative to a slope.

Hydrology and Hydrogeology: Relationship of the slope to the movement of water.

Vegetation: Type, condition and stature.

From these criteria, a three-fold classification was derived, based on the presence and severity of those factors which represent physical constraints to subdivisional and building developments.

For this exercise, the following situations were regarded as restrictive; that is, any subdivisional development or building proposal at such a location would have to include some form of precautionary measure to deal with the particular hazard, or would have to present evidence that no hazard exists.

Hazardous Situations	Hazards
Base of steep slope (>15°)	—Landslips, rock falls, or tree fall on to section from above —Slips in deep colluvium —Stormwater from above —Removal of toe of slope for building platform, garden, etc.
On steep slope (>15°)	—Failure of cut and fill slopes necessary to create building platform —Failure of natural slopes from above or below —Any access roads or tracks —Uncontrolled stormwater —Tree fall
Top of steep slope (>15°)	—Slips beneath foundations —Uncontrolled stormwater causing instability on site or below —Any access roads or tracks —Failure of fill slope

Centre of gullies	—Flooding from blocked culverts or channels or inadequate capacity of channels or culverts —Debris flows
Flood plains and areas adjacent to watercourses	—Flooding —Diversion of flow —Poor drainage conditions —Marshy foundation conditions
Poor foundation materials	—Thick (>2 m) unconsolidated material (colluvium, weathered rock, loess) overlying sloping basement rock —Areas with poor drainage
Large dead or dying trees on steep slopes (>15°)	—Related slipping and tree and debris avalanche —Root wedging in rock
Coastal strip (The extent of the area at risk should be studied further. See Gibb, 1981)	—Flooding —Erosion by the sea

It should be noted that all hazards are not of equal severity nor do they necessarily constitute a threat purely to the section of land in question; there may be offsite effects.

Owing to limited data, the map shows only 3 classes. It must be realised that within each class, subclasses could be identified according to the type of hazard if a more detailed survey was carried out.

Suitability classes

F Favourable: No hazards to further development other than those normally catered for in good subdivisional and building practice.

R1 Restricted suitability 1: Only 1 hazard or a combination of minor hazards.

R2 Restricted suitability 2: One severe hazard or a combination of 2 or more hazards. (The latter case is the more common.)

(See Photos 8 and 9.)

Use of the map

The map shows in general terms, by means of a graded restriction system, where hazardous areas exist. It should be noted that no reference has been made to totally restricted areas. With sufficient care and capital, most sites can be made safe for residential purposes.

The map and accompanying report is designed merely to present a synthesis of cautionary information for land use planning and initially will serve as a guide to the preparation of the Eastbourne Borough's reviewed district planning scheme. There are many other considerations to be taken into account when zoning land for suitable uses; this map will only be one of the many inputs.

When using the map where a residential zoning exists or is being considered, the area should be compared with the hazard classification presented on the map, and any necessary conditions or boundary alterations then incorporated into the ordinances or planning maps of the district scheme.

The map can also assist the council in deciding on approval of subdivisional scheme plans and building permits.

The Earthquake and War Damages Commission has in the past few years been faced with increasing demands on its funds allocated to landslip damage. In an attempt to reduce the incidence of instability problems, the Commission wrote in August 1976 to all local bodies with a "Suggested Council Policy Re Land Stability" (Appendix 3). Subsequently a joint subcommittee working on behalf of the Territorial Local Government Council produced a revised list of recommendations which included suggested formats for engineers' opinions on land stability for residential subdivision and building (Appendix 4).

The restricted suitability classification of the map was carried out with this information in mind.

In particular, it is suggested that both R1 and R2 classified land should require Format 1 to be produced by a subdivider as part of a scheme plan application. For R2 classified land Format 3 should be required in addition, for any building permit applications.

In other words, the map should be used to decide on the nature and extent of professional opinion required before building is allowed in potentially hazardous areas.

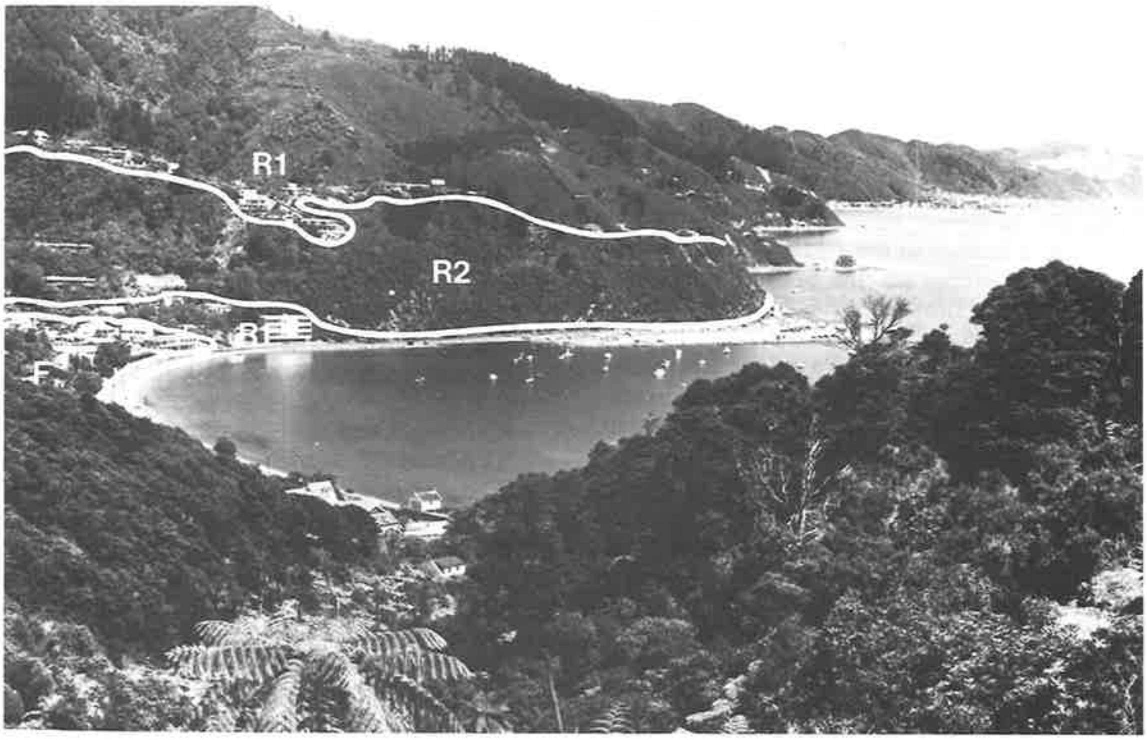


Photo 8—View of Eastbourne looking south from Point Howard, showing the coastal cliff, interglacial marine terraces, steep natural slopes, beech forest, gorse, and pine plantation. Also showing urban suitability classes.

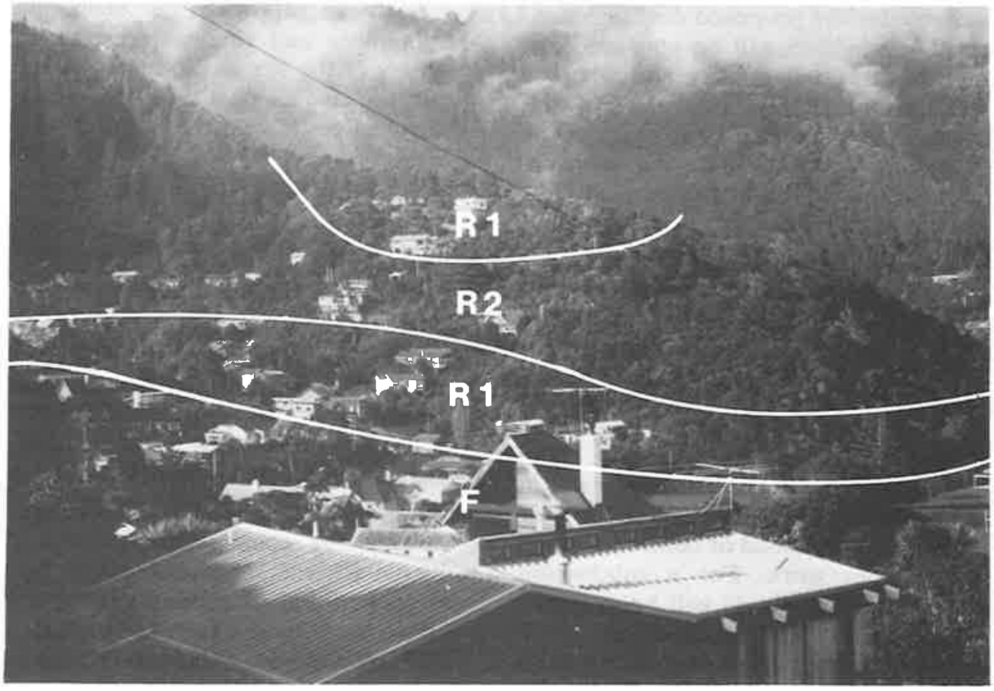


Photo 9—Urban suitability classes in part of Days Bay.

Postscript

Change to Eastbourne Borough District Planning Scheme

In May 1979 a change to the Eastbourne Borough Council district planning scheme became operative, to control land uses subject to the physical hazards identified in this report, and to control subdivision and building activities that are likely to cause landslip or flooding on site or to other sites. Provisions include the requirement to obtain council consent for:

- The destruction or irreparable damage to native vegetation higher than 3 m and exotic vegetation higher than 10 m and in both cases with a trunk circumference greater than 0.5 m.
- The clearing of areas of trees, bush or scrub in excess of 500 m^2 or 35 percent of the site which ever is the lesser.
- The removal of top soil.
- The excavation and/or depositing by powered vehicles or machinery of spoil, soil or other materials or the excavation or depositing by hand tools of more than 20 m^3 of spoil, soil or other materials.
- The formation of paths, vehicular access ways, parking areas, or any paved or sealed area in excess of 40 m^2.

There are several provisos to exclude trimming and pruning of trees, and to avoid conflict with other relevant legislation, e.g., Soil Conservation and Rivers Control Act and Noxious Weeds Act.

These ordinances apply to all suitability areas as defined on the maps. However, constraints will not apply to land which after detailed examination is found to be suitable for the proposed development.

No scheme of subdivision will be approved nor will any work be permitted on any site where a reasonable doubt as to stability, erosion, land slip, or flooding is indicated by council's engineers or the Wellington Regional Council *unless the applicant* satisfies the borough council that the possibility of such problems is unlikely to occur. The hazardous situations identified in the survey are referred to as likely problem areas where precautionary measures must be included in the subdivision and building proposals or evidence must be shown that no hazard exists.

To do this, the applicant may be required to obtain a professional opinion from a registered engineer experienced in soils engineering, land slope, and foundation stability, before approval in principle is given to a scheme of subdivision or before a building permit is issued or before approval is given to any other work. For a subdivision approval Format 1 (Appendix 4) will be required along with a certificate of completion of a subdivision. For a building permit Format 3 will be required. These formats give council the opportunity to set conditions on the advice of a suitably qualified engineer.

Before any scheme of subdivision is considered by council, the applicant must provide sufficient additional information to show the proposed uses of the site including:

- Topographical features including native trees higher than 3 m and exotics higher than 10 m in both cases with trunk circumference greater than 0.5 m.
- Existing levels and contours.
- The location of any watercourse and open drain.
- The location, area and depth of excavated and filled areas for building sites, pedestrian and vehicular access ways, parking areas, and new levels and contours.
- The location and grade of pedestrian and vehicular access ways.
- The means, location, and direction of sewage and stormwater disposal.
- The suitability of the site for subdivision and development, considering the location of hazards.
- Identification of sites on which buildings could be erected considering the location of hazards.
- Any other information that council may require.

The council may also refuse to approve a subdivision or building application if stormwater drainage or disposal of sewage is not adequate and could cause erosion, instability of land, land slip, or flooding.

The landslip and flooding hazard survey is indicative only; the onus is on the applicant to demonstrate that subdivision and building will not cause erosion, instability, land slip, or flooding.

Such an approach is economic in terms of manpower and financial resources, as a detailed survey of the whole borough suitable for site design purposes would be a time consuming exercise and a waste of resources; the majority of sites may never be developed anyway.

The district scheme provisions outlined above have been operative for 2 years and have now been incorporated in their entirety into the borough's recently publicly notified review scheme.

The necessity to identify hazardous situations and avoid them through the planning process has been emphasised by a 1981 Amendment to the Local Government Act which in part removes the obligation on councils to refuse all building permits in areas subject to erosion, subsidence, and slippage.

A policy of prevention rather than cure has been adopted by council through this change to the district scheme, which safeguards both the interests of council and of residents by attempting to avoid future landslip and flooding problems which during 1977 resulted in unnecessary physical, emotional, and financial costs to both parties.

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Glossary

Colluvial material: Loose, unconsolidated deposits which have accumulated on slopes under gravity.

Fossil gully material: Colluvial deposits of variable composition, perhaps inherited from the last ice age, which fill old gullies.

Joint plane: Crack in a mass of rock formed along a surface of weakness.

Natural slopes: Slopes which have not been artificially disturbed.

Overburden: Materials such as fill, spoil, and topsoil placed over natural ground.

Pore water pressure: Pressure applied through water contained in the spaces between soil and rock particles.

Shear plane: The surface of slope failure.

Shear strength: The resistance of a material to downslope forces along a surface under lateral stress (also shear resistance and shear stress).

Tensile strength: The resistance of a material when stretched.

Appendix 1 Landslip Data

Slip number	Length (m)	Width (m)	Depth (m)	Volume (m^3)	Aspect	Shear plane angle	Original angle	Vegetation	Material	Site morphology State of slope Position on slope
1	10	32	0.8	256	269°	60°	50°	Gorse, mahoe, matipo, flax 1 metre high Sparse to medium cover	Colluvium and weathered greywacke bedrock WG III (Weathering grade)	Convergent, coastal cliff, mid-lower slope
2	6	4	0.2	5	296°	38°	38°	Broom, gorse, honeysuckle 1 metre high Dense cover	Colluvium to weathered greywacke	Planar, cut slope, midslope, water from pipe
3	26	13	0.4	135	30°	43°	46°	Manuka, mahoe, rangiora, tree fern 2–3 metres high, 15 cm diam. Dense cover and undergrowth	Colluvium to weathered greywacke bedrock WG III–IV at shear plane	Planar, natural slope, footslope
4	7	4	0.8	22	35°	54°	52°	Manuka, mahoe, rangiora, tree fern 2–3 metres high, 15 cm diam. Dense cover and undergrowth	Colluvium to weathered greywacke bedrock WG III–IV at shear	Covergent, natural slope, footslope, valley head location
5	3	4	0.4	5	295°	46°	46°	Manuka, mahoe, rangiora, tree fern 2–3 metres high, 15 cm diam. Dense cover and undergrowth	Weathered greywacke to bedrock WG III–IV	Planar, natural slope, footslope
6	5	6	0.5	18	288°	40°	–	Grass, flax, garden shrubs Shrubs 0.6 metre Sparse cover	Fine colluvium and deeply weathered greywacke WG III–IV	Planar, cut slope, footslope Water from path
7	14	9	0.8	101	275°	42°	40°	Mahoe, matipo, flax 1–2 metres high Pines removed 5 years ago Dense shrub cover	Colluvium and weathered greywacke to bedrock WG III	Planar, cut slope, midslope, pines cut 5 years ago—some still on slope
8	6	5	0.6	18	275°	44°	39°	Mahoe, matipo shrubs 1 metre high Pines removed 7 years ago Dense shrub cover	Colluvium and weathered greywacke to bedrock—V-jointed WG III–IV	Planar, cut slope, footslope, pines cut 7 years ago
9	5	8	0.6	24	40°	46°	43°	Dead and dying beech since 1972 drought 1 metre high dense shrub regrowth beneath Mahoe, macropiper, rangiora, flax	Colluvium and weathered greywacke and argillite	Planar, natural, midslope Beech dying since 1972
10	10	6	0.6	36	275°	41°	35°	Weeds, rangiora, taupata 0.5–1 metre high Dense cover	Colluvium and weathered greywacke	Planar, cut slope, footslope
11	14	8	0.6	67	225°	39°	38°	Ngaio, mahoe, shrubs 3 metres high, 15 cm diam. Medium cover	Fill material	Planar, fill slope, footslope Runoff over bank
12	14	5	1.2	84	240°	29°	29°	Manuka, mahoe, matipo, tree fern 2–3 metres high Dense cover	Weathered greywacke and loess	Planar, natural slope, midslope
13	7	4	0.4	11	288°	34°	43°	Weeds, mahoe, macropiper 1 metre high Dense cover	Fill material	Planar, cut slope, footslope Water from roof and path
14	6	5	0.4	12	205°	43°	43°	Weeds, macropiper, rangiora 1 metre high Medium cover	Fill material and colluvium	Planar, cut slope, footslope Water and compaction from path
15	3	5	0.3	5	205°	58°	–	Weeds, macropiper, rangiora, mahoe 1 metre high Dense cover	Fill material	Planar, cut slope, footslope Reactivated 1956 slip
16	10	3	1.0	30	205°	58°	58°	Lupins 2 metres high Sparse cover	Weathered sandstone massive jointing WG III and IV	Planar, cut slope
17	4	4	1.0	16	205°	63°	58°	Lupins 2 metres high Sparse cover	Colluvial gully material	Convergent, cut slope, footslope Cut 1960–61

Slip number	Length (m)	Width (m)	Depth (m)	Volume (m³)	Aspect	Shear plane angle	Original angle	Vegetation	Material	Site morphology State of slope Position on slope
18	13	10	0.4	52	230°	42°	43°	Broom, taupata, ivy, fennel 2 metres high Dense cover	Colluvium and weathered greywacke	Planar, natural slope, midslope Water from track
19	7	3	0.3	6	230°	45°	45°	Broom, taupata, ivy fennel 2 metres high Dense cover	Colluvium and weathered greywacke	Planar, cut slope below, midslope
20	14	6	1.6	109	250°	33°	39°	Tree fern, manuka, mahoe 2–3 metres, 20 cm diam. Dense cover	Fill material—clay rubbish, pine branches, colluvium, and loess	Planar, fill slope, footslope Trees left on slope above
21	7	6	1.3	55	35°	42°	44°	Tree fern, manuka, mahoe 2–3 metres high, 20 cm diam. Dense cover	Fine colluvium	Convergent, natural slope, footslope Old movement Valley head location
22	14	8	0.4	45	245°	44°	43°	Manuka, ngaio 1 metre high Dense cover	Loose colluvium and weathered greywacke—old soil	Planar, cut slope, footslope Old slip Water off path and rubbish at top
23	8	5	0.6	24	180°	80°	80° cut	Manuka, ngaio, mahoe 1–2 metres high Dense cover	Massive weathered greywacke bedrock—jointed WG III	Planar, cut slope, footslope Cut, cleared of veg. and increase in height of cut
24	6	5	0.3	9	255°	36°	45°	Ngaio, mahoe, pine trees cut 1 metre high Dense cover	Colluvium and weathered greywacke	Planar, cut slope, footslope Trees cut above and left on slope
25	10	6	0.4	24	125°	35°	35°	Mahoe, rangiora, macropiper 1 metre high Sparse cover	Fill material	Planar, cut slope (top and bottom), fill slopes, footslope
26	4	6	0.3	7	250°	37°	39°	Weeds, lupin 0.5–1 metre high Medium cover	Fill material to weathered greywacke bedrock	Planar, fill slope, topslope Water from path above
27	6	5	0.2	6	260°	49°	46°	Gorse, akeake, manuka 1 metre high Dense cover	Weathered greywacke WG III	Planar, cut slope, footslope
28	6	7	0.3	13	175°	46°	67°	Tree fern, five finger, mahoe 0.5 metre Medium cover	Weathered greywacke—jointed	Planar, cut slope, footslope
29	100	12	0.3	360	300°	41°	46°	Gorse 1 metre high Dense cover	Colluvium weathered greywacke and fill	Convergent, fill slope, top to foot of slope Wall collapse and water over edge
30	6	8	1.0	48	265°	58°	53°	Manuka, taupata 3 metres high, 40 cm diam. Dense cover	Deeply weathered coarse sandstone and loose colluvial gully deposits WG IV	Convergent, natural slope, footslope, old movement, toe of slope undercut by water
31	7	4	1.0	28	315°	58°	51°	Manuka, taupata 3 metres high, 40 cm diam. Dense cover	Fine angular colluvial material	Convergent (niche point) natural slope, footslope Incised to bedrock
32	3	3	0.3	3	300°	58°	45°	Akeake, lupins, wattles 1 metre high Dense cover	Colluvium	Planar, cut slope, footslope Track and steps on slope
33	5	8	0.6	24	10°	50°	35°	Manuka, coprosma 2 metres high Dense cover	Colluvium and argillite WG III	Planar, cut slope, footslope Water off path
34	4	5	0.4	8	187°	55°	50°	Tree fern, five finger, gorse 3 metres high Dense cover	Colluvium to bedrock	Planar, cut slope, footslope
35	3	2	0.8	5	187°	54°	45°	Tree ferns, five finger, gorse 3 metres high Dense cover	Deeply weathered material and loess	Planar, cut slope, footslope
36	15 est	8 est	1.0 est	120 est	280°	60°	spur	Gorse 1 metre high Medium cover	Weathered greywacke rock WG III and IV	Divergent, coastal cliff, footslope
37	4	2	0.3	2	280°	50°	50°	Gorse 1 metre high Medium cover	Weathered greywacke rocks and colluvium	Planar, coastal cliff, midslope
38	4	3	0.2	24	310°	46°	46°	Gorse 1 metre high Medium cover	Colluvium over greywacke rock outcrop	Planar, coastal cliff, midslope
39	11	5	0.3	17	310°	41°	39°	Lupins, beech trees died and cut after 1968 Sparse cover	Coarse colluvium	Planar, cut slope, footslope

Slip number	Length (m)	Width (m)	Depth (m)	Volume (m³)	Aspect	Shear plane angle	Original angle	Vegetation	Material	Site morphology State of slope Position on slope
40	5	5	0.8	20	360°	65°	65° cut	No vegetation—rock face	Deeply weathered greywacke rock WG III–IV	Planar, cut slope, footslope 7 m high cut
41	–	–	–	47 est	37°	–	–	Five finger, tree fern, beech 3 metres high Medium cover	V. deeply weathered greywacke WG VI	Planar, cut slope, footslope
42	13	9	0.4	47	37°	41°	38°	Mahoe, tree fern, five finger, beech 1–3 metres high Dense cover	Colluvium with 4 cm argillite boulders WG III	Planar, cut slope, midslope Old track on slope and localised seepage
43	4	4	0.6	10	166°	41°	57°	Macropiper, tree fern, coprosma 2 metres high Medium cover	Fill and colluvium	Planar, cut slope, midslope Water from track
44	5	7	3.0	11	137°	39°	55°	Macropiper, tree fern, coprosma 2 metres high Medium cover	Fill and colluvium	Planar, cut slope, footslope Water from pipe at edge of track
45	8	3	0.2	5	245°	49°	49°	Hinau, manuka, mahoe 1 metre high Medium cover	Skin of weathered greywacke WG III	Planar, cut slope, midslope Tracks on slope
46	10	11	1.5	165	140°	38°	45°	Rangiora, mahoe, macropiper 1 metre high Dense cover	Weathered greywacke WG III–IV	Planar, cut slope, footslope Water from roof and drive
47	4	5	0.4	8	160°	55°	80° cut	Overhanging weeds 1 metre high Dense cover	Deeply weathered sandstone, V-jointed—wedge failure WG IV	Planar, cut slope, footslope
48	5	6	0.2	7	150°	66°	–	No vegetation—rock cut	Weathered sandstone with argillite bands—jointed WG V	Planar, cut slope, footslope Root wedging, water from path
49	3	4	0.3	4	172°	55°	80° cut	Grass, ferns 0.2 metres high Sparse vegetation	Weathered greywacke/sand stone WG IV	Planar, cut slope, footslope, water from path and pipe
50	2	4	0.2	2	172°	62°	80 cut	Grass, ferns 0.2 metres high Sparse vegetation	Colluvium and 1.5 m depth of weathered greywacke WG IV	Planar, cut slope, footslope.
51	8	4	0.2	6	208°	52°	52°	Gorse 1 metre Dense cover	Weathered greywacke to fine grained argillite bedrock	Planar, cut slope, footslope
52	15	20	1.5	450 est	305°	–	26°	Grass—garden	Colluvium—very deep (slump)	Planar, cut slope, midslope Possibly stormwater and tracking for garden
53	2	3	0.2	1	280°	55°	63° cut	Weeds 0.5 metres high Dense cover	Fill and fine alluvium	Planar, cut and fill footslope Dry stone wall collapse—no drainage
54	2	4	0.2	2	2°	52°	62° cut	Grass, broom 0.5 metres high Sparse cover	Weathered greywacke rock WG III	Planar, cut slope, footslope
55	3	5	1.0	15	187°	52°	51°	Mahoe, broom, rangiora 2 metres high Dense cover	Argillite and sandstone. Distinct bedding at right angles to slope—jointing WG III	Planar, cut slope, footslope 3 m high rock cut
56	3	4	0.2	2	180°	59°	79° cut	Garden plants, mahoe, coprosma 1 metre high Medium cover	Fill material	Planar, cut and fill slope, footslope
57	4	3	0.3	4	186°	48°	46°	Tree fern, rangiora 2–3 metres, 5 cm diam. Dense cover	Colluvium to bedrock WG III	Planar, natural slope, footslope—undercut by stream
58	6	5	0.2	6	214°	55°	55°	Tree fern, mahoe, dead beech Up to 4 metres high Sparse cover	Sandstone rockfall 1 m diam. boulders—coarse jointing WG III	Planar, natural slope, midslope Dead beech uprooted
59	3	3	0.4	4	320°	50°	33°	Manuka, beech (windfall) 4 metres high Sparse cover	Colluvium and weathered greywacke WG III	Planar, natural slope, midslope Dead beech, windfall area
60	60	15	0.5	450	316°	43°	41°	Dead beech (old burn 1972), manuka, coprosma, beech regrowth—1 metre Sparse cover	Sandstone and argillite bedrock avalanche WG III	Planar, natural slope, midslope Burn area on slope

Slip number	Length (m)	Width (m)	Depth (m)	Volume (m^3)	Aspect	Shear plane angle	Original angle	Vegetation	Material	Site morphology State of slope Position on slope
61	8	7	0.5	28	304°	36°	38°	Dead beech (old burn 1972), manuka, coprosma, beech regrowth—1 metre Sparse cover	Deeply weathered fine grade material—reworked loess	Planar, natural slope, midslope Burn area on slope
62	6	2	0.3	4	315°	52°	45°	Dead beech (old burn 1972), manuka, coprosma, beech regrowth—1 metre Sparse cover	Coarse weathered colluvium	Planar, natural slope, midslope Burn area on slope
63	3	8	0.4	10	100°	48°	34°	Bracken, mahoe 1 metre high Medium cover	Deeply weathered greywacke—silty with mottling	Planar, cut slope, top slope
64	16	7	0.6	67	300°	48°	48°	Tree fern, dead beech 5–10 metres Dense cover	Colluvium to argillite bedrock	Convergent, natural slope, footslope Niche point above
65	18	6	0.3	32	292°	49°	49°	Lupin, gorse, manuka 2 metres Medium	Weathered greywacke	Planar, coastal cliff, footslope
66	6	5	1.0	30	290°	29°	36°	Gorse, manuka (3 m) cut 2 years ago Dense cover	Sandstone and argillite WG III	Planar, cut slope, midslope Vegetation cut
67	8	4	0.8	26	340°	34°	36°	Gorse, manuka (3 m) cut 2 years ago Dense cover	Sandstone with natural pipe at base—to bedrock	Convergent, cut slope, midslope Path cut across slope
68	7	5	0.6	21	325°	44°	31°	Grass Sparse cover	Fine colluvium to bedrock	Convergent, cut slope, midslope Path cut across slope
69	7	22	0.6	92	205°	42°	36°	Broom, gorse 1 metre high Sparse cover	Fill material	Planar, fill slope, top slope Water from drive, wall collapsed
70	4	6	0.4	10	10°	65°	70° cut	No vegetation. Cut face	Weathered sandstone and colluvium WG III	Planar, cut slope, footslope
71	8	7	1.5	84	320°	38°	25°	No vegetation. Large pines cut 15, 3 and 1 year ago	Fossil gully material	Planar, cut slope, footslope Water from above
72	8	8	0.6	38	265°	48°	74° cut	Gorse, gums 1 metre and 4 metres Sparse cover	fine colluvium—fossil gully material	Planar, cut slope, footslope Cut 5–6 m high
73	6	7	0.6	25	255°	28°	60° cut	Five finger, rangiora 1 metre high Dense cover	V. fine clay colluvium, pockets of loess	Planar, cut slope, footslope 2–3 m high cut
74	6	9	1.0	54	340°	39°	70° cut	Gorse, five finger, manuka 2 metres high Medium cover	Colluvium to bedrock	Planar, cut slope, footslope
75	18	10	0.4	72	320°	43°	39°	Mahoe, rangiora, shrubs, Pine fell 1973 1 m diam. Medium cover	Fill material and colluvium	Planar, fill slope, midslope Water from drive Vegetation uprooted
76	7	7	0.2	10	320°	40°	39°	Mahoe, rangiora, shrubs, Pine fell 1973 1 m diam. Medium cover	Fill material and colluvium	Planar, fill slope, midslope Water from drive Vegetation uprooted
77	3	4	1.0	12	320°	–	–	Tree fern, coprosma, broom 1 metre high Sparse cover	Coarse colluvium	Planar, cut slope, footslope 3 m high—end of spur
78	3	3	0.12	1	240°	41°	41°	Gorse, broom, pine 1 metre–20 metres Sparse cover	Weathered greywacke	Planar, coastal cliff, footslope
79	5	4	0.2	4	240°	48°	52°	Gorse, boom, pine 1 metre–20 metres Sparse cover	Fine colluvium	Planar, cut slope, footslope
80	2	4	0.4	3	240°	53°	53°	Gorse, broom, pine 1 metre–20 metres Sparse cover	Weathered greywacke	Planar, cut slope, midslope Cut 10 m high
81	2	4	0.4	3	240°	41°	72° cut	Gorse, broom pine 1 metre–20 metres Sparse cover	Fill material and colluvium above massive sandstone WG III	Planar, cut and fill slope, midslope 2 m high cut
82	14	5	0.4	3	250°	50°	46°	Gorse, broom, pine 1 metre–20 metres Sparse cover	Fill material 1 m deep to bedrock	Planar, cut slope, top slope Cut 8 m Water from drive
83	5	5	0.8	20	250°	48°	33°	Mahoe, creeper 0.5 metres high Dense cover	Fine colluvium	Planar, cut slope, footslope Burst water pipe
84	4	3	0.2	24	285°	45°	45°	Gorse 0.2 metres high Sparse cover	Weathered greywacke rockfall—jointed WG III	Planar, coastal cliff, midslope

Slip number	Length (m)	Width (m)	Depth (m)	Volume (m³)	Aspect	Shear plane angle	Original angle	Vegetation	Material	Site morphology State of slope Position on slope
85	12	18	1.5	324	240°	41°	27°	Blackberry, tree fern, mahoe 0.1 metre-2 metres Dense cover	Deeply weathered material possibly loess Old buried soil	Convergent, cut slope, footslope seepage
86	8	4	0.3	10	265°	45°	38°	Dead beech, rangiora, hange hange, tree fern 1-2 metres high Medium cover	Colluvium	Planar, natural slope, midslope
87	25	8	0.3	60	235°	44°	43°	Dead beech, rangiora, hange hange, tree fern 1–2 metres high Medium cover	Weathered greywacke	Planar, natural slope, midslope
88	3	4	0.2	2	280°	61°	65°	Wattle, gorse 1–2 metres high Sparse cover	Colluvium and weathered greywacke	Planar, cut slope, footslope 3 m high cut
89	7	7	0.3	15	195°	56°	65° cut	Rangiora, five finger 1 metre high Sparse cover	Colluvium and weathered greywacke	Planar, cut slope, footslope 4 m high cut
90	20	15	0.5	150	235°	48°	35°	Mahoe, matipo, tree fern 2 metres high Medium cover	Fine fill material and weathered greywacke	Planar, fill slope, top slope Water into slope
91	2	6	0.3	4	235°	52°	75° cut	No vegetation. Cut face	Weathered greywacke	Planar, cut slope, footslope 2 m high cut
92	5	3	0.4	6	260°	38°	38°	Gorse 1 metre high Sparse cover	Fill material and colluvium	Planar, fill over coastal cliff, top slope
93	3	3	0.12	1	260°	65°	65°	Gorse 0.5 metres high Sparse cover	Weathered greywacke rock fall—jointed	Planar, coastal cliff, midslope
94	7	6	0.2	8	45°	50°	48°	Dead beech, mahoe, copromsa, rangiora 1.5 metres high Dense cover	Colluvium	Planar, natural slope, footslope
95	3	2	0.2	1	45°	48°	48°	Tree fern, hange hange 1.5 metres high Dense cover	Angular colluvium—clay material beneath	Planar, natural slope, footslope to creek
96	18	7	0.2	25	265°	44°	55°	Dead beech, mahoe, coprosma, rangiora 1.5 metres high Dense cover	Colluvium to bedrock	Planar, natural slope, footslope to creek
97	16	4	0.7	45	45°	54°	43°	Dead beech, mahoe, coprosma, rangiora 2 metres high Dense cover	Angular colluvium	Planar, natural slope, midslope
98	16	8	0.4	51	45°	47°	48°	Tree fern, mahoe, rangiora 2 metres high Dense cover	Argillite bedrock—V-jointed	Planar, natural slope, footslope
99	13	4	0.5	26	20°	47°	–	Gorse 1 metre high Dense cover	Deeply weathered greywacke removed by stream WG IV	Convergent, natural slope, footslope Valley head location
100	30	3	0.2	18	240°	50°	50°	Dead beech, mahoe, rangiora 1.5 metres high Dense cover	Loose colluvium over rock WG III	Planar, natural slope, top slope to creek
101	16	10	0.4	64	220°	50°	41°	Dead beech, mahoe, rangiora, coprosma 1.5 metres high Medium	Colluvium, sandstone, and argillite rockfall	Planar, natural slope, midslope
102	30	8	0.8	192	350°	36°	38°	Bracken, lemonwood 2 metres high Sparse cover	Very deeply weathered greywacke, possibly fossil gully material	Planar, cut and fill slope, top slope Fill and water over edge
103	3	6	1.0	18 est	210°	68°	22°	Tree fern, five finger, broom 2 metres high Dense cover	Colluvium over deeply weathered greywacke	Convergent, cut slope, footslope Water on to slope
104	7	5	0.4	14	270°	39°	39°	Tree fern, five finger, rhododendron 1 metre high Medium cover	Colluvium over mottled white clay. Greywacke rocks WG II–IV	Planar, cut slope, footslope Track across slope
105	5	7	0.4	14	159°	38°	46° est.	No vegetation. Cut face	Fossil gully material WG III–IV	Planar, cut slope, footslope.
106	7	7	0.3	15	159°	33°	46°	No vegetation. Cut face	Fossil gully material WG III–IV	Planar, cut slope, footslope
107	7	4	0.6	17	110°	slump		Dead beech, little undergrowth Sparse cover	Fill material and weathered greywacke in a deep clay matrix WG IV	Planar, fill slope, top slope Water from drive and roof

Slip number	Length (m)	Width (m)	Depth (m)	Volume (m³)	Aspect	Shear plane angle	Original angle	Vegetation	Material	Site morphology State of slope Position on slope
108	40	15	1.0	600	120°	36	30°	Dead beech, beech, rangiora, manuka, mahoe, five finger 2 metres high Dense cover	V. deeply weathered greywacke, almost red weathered WG IV–V	Planar, natural slope, midslope to creek Possibly old slip
109	6	4	0.2	5	120°	28°	37°	Flax, rangiora 1 metre high Dense cover	Loose colluvium and argillite Possibly fossil gully	Planar, cut slope, footslope Cut 3 m high. Pipe discharging on to slope
110	4	5	0.1	2	75°	32°	56° cut	No vegetation. Cut face	Weathered greywacke, argillite shear plane at joints WG III	Planar, cut slope, footslope Water from roof
111	12	2	0.1	2	285°	46°	46°	Gorse 1 metre high Sparse cover	Fill, rubbish colluvium, and sandstone rockfall WG III	Planar, fill and rubbish over coastal cliff, top slope
112	4	3	0.1	1	285°	46°	46°	Gorse 1 metre high Sparse cover	Weathered greywacke rockfall WG III	Planar, coastal cliff, midslope
113	5	6	0.1	3	315°	46°	46°	Gorse 1 metre high Sparse cover	Greywacke rockfall and colluvium WG III	Planar, coastal cliff, midslope
114	5	3	0.1	2	185°	46°	56°	Broom, gorse, mahoe 0.8 metres high Sparse cover	Greywacke rockfall and colluvium WG III	Planar, coastal cliff, midslope
115	6	4	0.2	5	159°	50°	51°	Mahoe, rangiora 1 metre high Dense cover	Greywacke joint blocks failed with colluvium WG III	Planar, cut slope, footslope Path across slope
116	40	12	0.3	144	290°	49°	49°	Dead beech uprooted, tree fern, mahoe, rangiora, supplejack 1–2 metres Dense cover	V. loose colluvium and greywacke rock WG III	Planar, natural slope, midslope Seepage point
117	18	9	0.2	32	20°	56°	56°	Dead beech uprooted, tree fern, mahoe, rangiora 1–2 metres Dense cover	Colluvium and argillite rock WG III	Planar, natural slope, midslope
118	7	4	0.2	6	360°	56°	56°	Dead beech uprooted, tree fern, mahoe, rangiora 1–2 metres Dense cover	Colluvium to bedrock WG III	Planar, natural slope, midslope
119	15	18	0.8	216 est	340°	33°	36°	Garden, fruit trees Sparse cover	A slump of soil and fine colluvium	Planar, fill slope, midslope Garden paths and water over slope
120	5	6	0.3	9	310°	42°	41°	Gorse 1 metre high Dense cover	Colluvium to bedrock	Planar, natural slope, midslope

Appendix 2 Classification Scheme for Weathered Greywacke

Term		Grade	Description
True residual soil	...	VI	Original rock fabric completely destroyed. Rock completely changed to soil, generally light or yellow-brown sandy clay.
Completely weathered	...	V	Original rock structure completely weathered—crushable to light brown sandy silts under finger pressure. Original rock fabric still visible, with joint patterns marked by iron or black manganese dioxide stains.
Highly...	... ...	IV	Original rock structure retained but generally weathered to light brown colour right through. Most of material can be crushed to silt and sand sizes under finger pressure, but harder lumps remain. Rock structure generally open and closely jointed.
Moderately weathered	...	III	Original rock structure retained. Brown weathering extends part way through rock fragments, leaving grey unweathered central core. Rock structure tighter. Rock fragments easily broken with hammer blow.
Slightly weathered	...	II	Hard jointed rock. Brown colour extends inwards a slight distance on joint planes. Interior has colour and texture of unweathered greywacke. Separate pieces require moderate hammer blow to break.
Fresh rock	... ...	I	Unweathered greywacke. Shows no discoloration, loss of strength, or any other effects due to weathering.

Modified from Fookes and Horswill 1970—(Martin and Millar, 1974).

Appendix 3 Earthquake and War Damages Commission: Suggested Council Policy Re land Stability

1 Council shall maintain a map of the borough/city showing areas of known, suspected, or potential land instability.

2 Council shall seek the advice of a civil engineer specialising in the field of soils engineering and more particularly land stability for the purpose of reviewing the above map and providing such additional guidelines (e.g., surface slope) as are necessary to help identify potential land instability problems.

3 When approvals for subdivisions are sought in any area of known, suspected, or potential land instability or where indicated by the special guidelines, council shall obtain Statement A[1] herein prior to giving approval of a scheme plan.

4 Where special restrictions or requirements for building site preparation and/or foundations and/or site drainage which apply to individual site works are contained in a report, council shall hold a copy of such report available for inspection by the public and shall ensure that the existence of such report is known to an engineer preparing Statement B[1] for a building permit application.

5 Where building permit applications for new houses are sought in any area of known, suspected, or potential land instability or where indicated by the special guidelines, council shall obtain Statement B herein prior to the issue of the permit.

6 Where inspection by a professional engineer during construction is indicated, council shall require such inspection to be carried out as a condition of the approval of permit.

(NOTE: Any fees incurred for preparation of statements under 3 and 4 and for professional inspection during construction under 6 payable by the applicant.)

[1]See Appendix 4, Formats 1 and 3.

Appendix 4 Recommendations of Territorial Local Government Council Subcommittee

The committee recommends that local authorities with any involvement in residential development:

1. Read *DSIR Information Series No. 122*—Slope Stability in Urban Development.
2. Take care with planning in relation to land stability and indicate on the relevant town planning data map the areas where instability is known, potential, or suspected. (Note: Be careful not to give a spurious air of accuracy or certainty to the information.)
3. Whenever development is proposed in such areas insist on a proper opinion in Format 1 from a suitably qualified person before granting provisional approval and laying down the necessary conditions.
4. When approving such proposals reserve the right to amend the conditions of, or withdraw, such approval should information brought to light during construction make such action desirable.
5. Before accepting the subdivision as complete require a further proper opinion in Format 2, if appropriate, and make such further conditions as may be necessary relating to individual sections. (Every effort should be made at the Format 1 stage to avoid such further conditions. When it does happen, become a little more determined to do better next time.)
6. Take all practicable steps to ensure that purchasers are made aware of any and all conditions relating to the use of each individual section.
7. Where appropriate require a proper opinion in Format 3 before the issuing of a building permit.
8. Take every practicable step to prevent actions which are beyond the control of council but may well place persons or property at risk.
9. At every step involving any technical issue make full use of the qualified professional advice of the council's own staff or consultants to evaluate all opinions, proposals, and recommendations made.
10. Do not call for the use of the formats unless there is a genuine reason for them. This can lead to them being treated in a perfunctory manner on both sides. Remember the boy that cried "Wolf!"
11. Get a copy of *Slope Stability Considerations in Residential Subdivision Planning*, a paper presented by David E. Hollands at the 1977 Conference of the New Zealand Institute of Surveyors.

Format 1 (6/77)

FORMAT FOR ENGINEER'S OPINION ON LAND STABILITY FOR RESIDENTIAL SUBDIVISION

Explanatory Note:

The professional opinion provided for in the following format deals with an aspect of the suitability of land for subdivision for building purposes and may be submitted to Council with the Scheme Plan pursuant to specific provisions of the District Scheme required by Regulation 16 (3) of the Town and Country Planning Act 1953. Alternatively, the opinion may be required as a condition at the time of Scheme Plan approval pursuant to the Municipal Corporations Act 1954 or the Counties Amendment Act 1961. Because of the cost of obtaining such opinion, it should normally only be required in an area previously defined as having problems of known, potential or suspected landslope or foundation instability and where there is no reason to expect that the subdivision will not be approved on other grounds. Modifications to this format should only be made to the extent that they are appropriate to the specific opinion and are drawn to the attention of the local authority engineer accordingly.

To The Borough/City/County Engineer,

....

Subdivision/Land Description *(insert)*

I .... *(insert name)* of ....

.... *(insert firm name and address)*

hereby confirm that:

1. I am a Registered Engineer experienced in the field of soils engineering and more particularly landslope and foundation stability as applicable.
2. Site investigations have been carried out under my direction and are described in our report(s) dated .... The professional opinion given in para. 4 is based on the assumption that the data obtained from these investigations are representative over the whole subdivision.
3. I am aware of the details of the proposed subdivision and proposed engineering works as shown on the following drawings and specifications: ....

   ....

   (insert references to all drawings and specifications, including dates of latest amendments)
4. In my professional opinion, not to be construed as a guarantee, (the proposed works give due regard to landslope stability considerations and that) there is (will be when the work is completed in accordance with the drawings and specifications) *(delete as appropriate)* on each residential section a site suitable for a residential building not requiring specific design in terms of NZS 1900 and related documents, providing that:

   (a) ....

   (b) ....

   (c) ....

   (insert here details of any special conditions and/or special design criteria for building location and/or site grading and/or foundations and/or drainage, of which Council and future section owners should be made aware)

This professional opinion is furnished to the .... Council for its purposes alone, on the express condition that it will not be relied upon by any other person.

Signed .... Date ....

Note:

Where engineering works are to be undertaken before sites will be considered suitable for house construction, a condition of the Scheme Plan approval would normally require an "Engineer's Opinion after Works for Residential Subdivision" to be provided at the final plan stage. Such further opinion should afford the opportunity to vary the special conditions and/or special design criteria given in section 4, based on site conditions as exposed during construction and any changes in the proposed works. Variations, if significant, might in turn cause Council to reconsider its approval and/or conditions.

Format 3 (6/77)

FORMAT FOR ENGINEER'S OPINION ON LAND STABILITY FOR RESIDENTIAL BUILDING

Explanatory Notes:

The professional opinion provided for in the following format may be obtained in support of a building permit application. Because of the cost of obtaining such opinion, it should normally only be required for a site which is in an area previously defined as having problems of known, potential or suspected landslope or foundation instability, or for a section in a subdivision where final plans were approved subject to specific investigation and engineering design for that section. Modifications to this format should only be made to the extent that they are appropriate to the specific opinion and are drawn to the attention of the local authority engineer accordingly.

To: The Borough/City/County Engineer

....

Building/Site Description *(insert)*

I .... *(insert name)* of ....

.... *(insert firm name and address)*

hereby confirm that:

1. I am a Registered Engineer experienced in the field of soils engineering and more particularly landslope and foundation stability as applicable.
2. Based on my inspection of the site and knowledge of local conditions I am able to provide the following professional opinions:

   (Note: Where this opinion is also based on reliance on previous plans and reports by others, reference should be included here.)

or

2. Site investigations have been carried out under my direction and are described in our report(s) dated .... The following professional opinion is based on the assumption that the data obtained from these investigations are representative over the whole subdivision.
3. I am aware of the details of the proposed residential building and engineering works as shown on the following drawings and specifications ....

   ....

   (insert references to all drawings and specifications, including dates of latest amendments)
4. In my professional opinion, not to be construed as a guarantee, the drawings and specifications give due regard to landslope and foundation stability considerations, providing that:

   (a) ....

   (b) ....

   (Note here if the proposed engineering works and/or foundations involve requirements which should be subject to inspection during construction by a Registered Engineer or person acting under his direction. Also note any special conditions of which Council and future section owners should be made aware.)

This professional opinion is furnished to the .... Council for its purposes alone, on the express condition that it will not be relied upon by any other person.

Signed .... Date ....

Appendix 5 Data maps:

landslip, stormwater, and slope data.

NOTATION

STORMWATER SYSTEM

(Source : Brickell, Moss, Rankine & Hill data incomplete*)

Stream above-built up area		
Stream below-built up area		
Kerb & Channel		
Culvert Entrance		
Stormwater Pipes		
150 mm diameter		A
200 mm	"	B
225 mm	"	C
300 mm	"	D
375 mm	"	E
450 mm	"	F
600 mm	"	G
675 mm	"	H
800 mm	"	I
1200 mm	"	J

FLOOD DISCHARGES

Stream Nº	10 yr m³/s	50 yr m³/s
1	1·65	2·62
2	1·81	2·87
3	1·04	1·70
4	1·25	2·04
5	·78	1·27
6	·64	1·21
7	·90	1·70
8	1·19	2·25
9	2·28	4·31
10	·83	1·58
11	·56	1·12
12	2·06	3·78
13	·94	1·78
14	·47	·89
15	1·65	3·12
16	·45	·90
17	·45	·88
18	·42	·80

SLOPES

≤15°

15°–25°

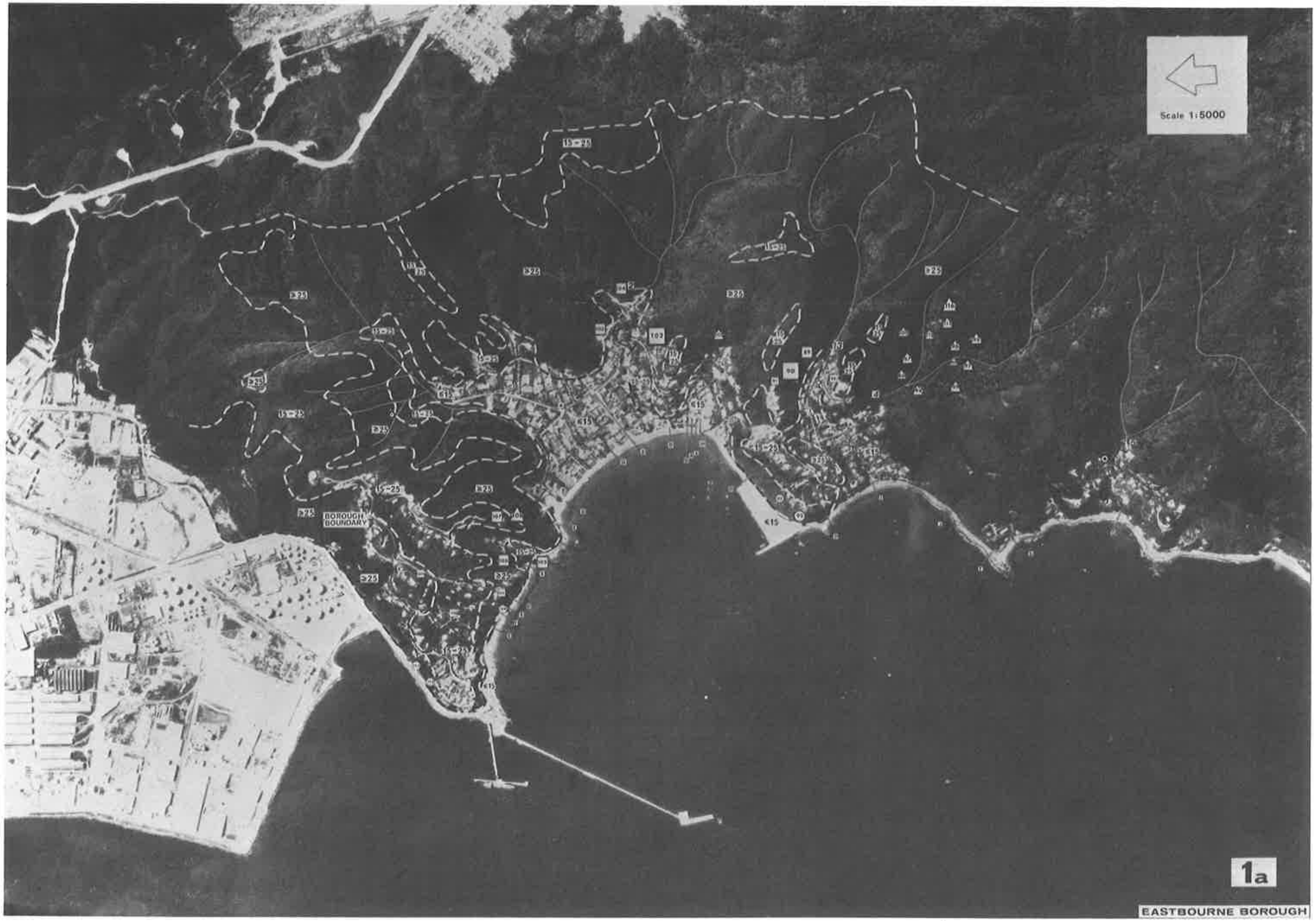
≥25°

Slope boundaries were determined graphically from the 50 foot contours on NZMS2 sheet 164/3 & transferred to the uncontrolled photo mosaic without field checking.

SLIPS

Type of Slope	Volume of Slip (Cubic metres)			
	1-5	6-19	20-99	>100
Disturbed	□	□	□	□
Natural	△	△	△	△
Coastal	○	○	○	○

EASTBOURNE BOROUGH

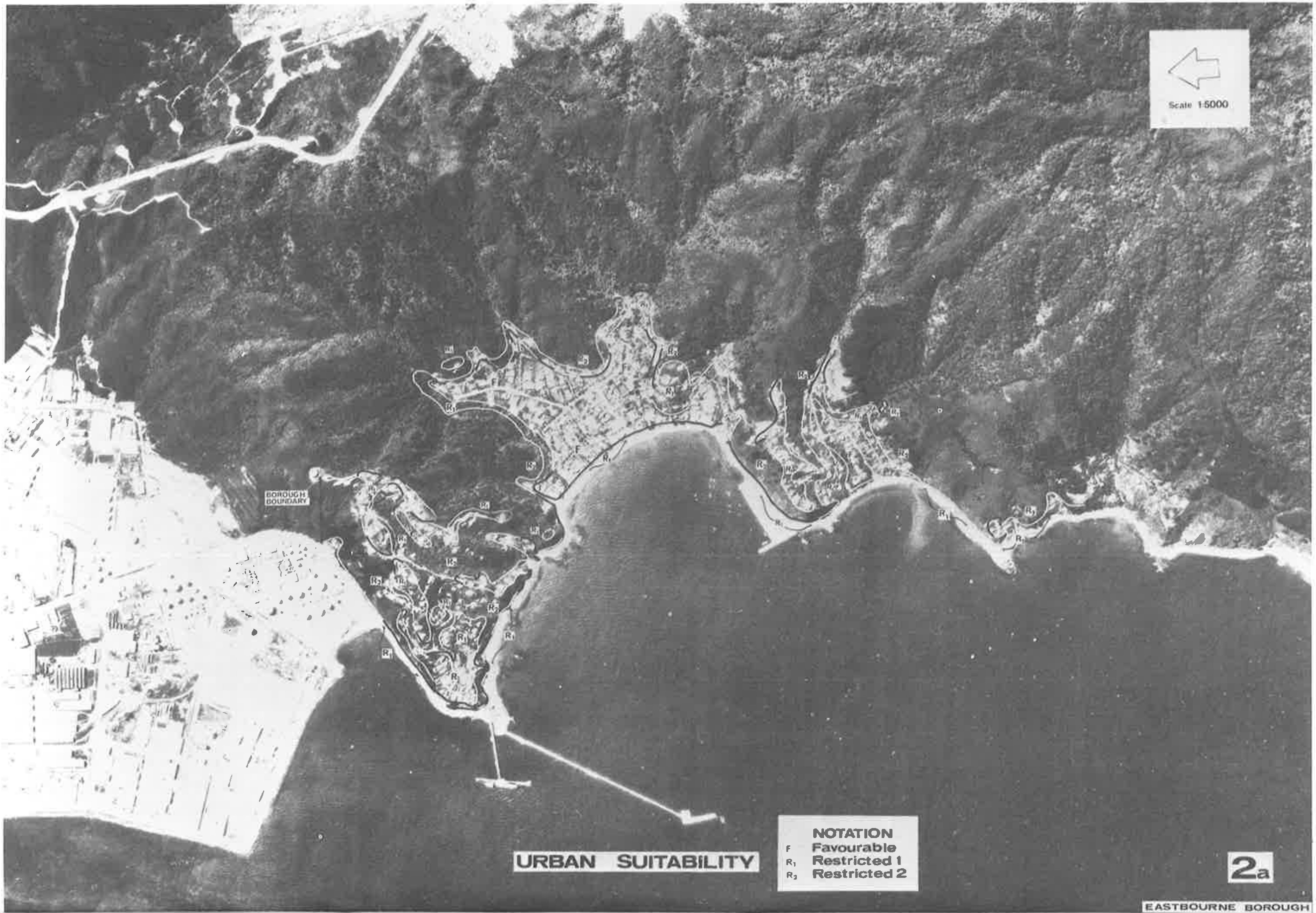

Scale 1:5000
BOROUGH BOUNDARY
1a
EASTBOURNE BOROUGH

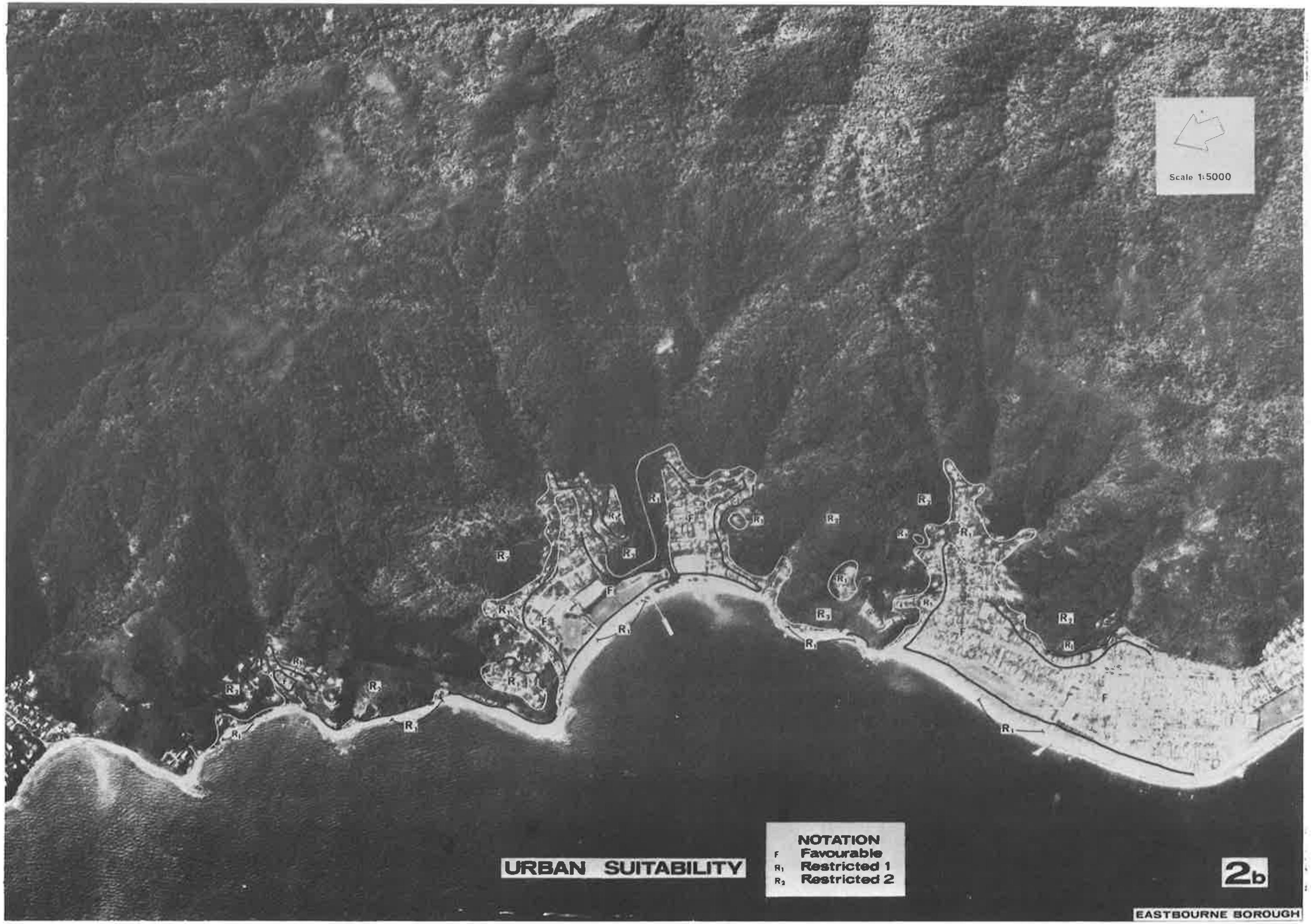
Scale 1:5000
1b
EASTBOURNE BOROUGH


Scale 1:5000
>25
15-25
<15
BOROUGH BOUNDARY
1c
EASTBOURNE BOROUGH

Appendix 6

Urban suitability maps.


Scale 1:5000
BOROUGH BOUNDARY
URBAN SUITABILITY
NOTATION
F Favourable
R_1 Restricted 1
R_2 Restricted 2
2a
EASTBOURNE BOROUGH


Scale 1:5000
URBAN SUITABILITY
NOTATION
F Favourable
R1 Restricted 1
R2 Restricted 2
2b
EASTBOURNE BOROUGH

P. D. HASSELBERG, GOVERNMENT PRINTER, WELLINGTON, NEW ZEALAND—1982
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31. Land and water resource surveys of NZ: map coverage and reference lists. C L Clark. $10.00 — 1982

32. A procedure for characterising river channels. M P Mosley. $8.00 — 1982

33. The United States Environmental Protection Agency's 1980 ambient water quality criteria: a compilation for use in NZ. D G Smith. $5.00 — 1982

34 Water Quality Research in NZ, 1981. J S Gifford. $5.00 — 1982

35 Liquid and waterborne wastes research in NZ, 1981. J S Gifford. $3.00 — 1982

36 New Zealand River Temperature Regimes. M P Mosley — 1982

37 Landslip and Flooding Hazards in Eastbourne Borough - a guide for planning. $8.00 — 1982

38 Physical and Chemical Methods for Water Quality Analysis. $5.00 — 1982

39 A Guide to the Common Freshwater Algae in New Zealand. $5.00 — 1982

40 Peat lands policy study; reports and recommendations. $5.00 — 1982

41 Index to hydrological recording stations in New Zealand 1982. $5.00 — 1982

42 A Draft for a National Inventory of Wild and Scenic Rivers: Part 1, Nationally Important Rivers (free) — 1982

43 A Review of Land Potential in the Bay of Plenty - Volcanic Plateau Region. $10.00 — 1982