Library

COOK COUNTY COUNCIL

Makorori Beach Township

Engineering Geology Report

Kingston Reynolds Thom and Allardice Limited
Engineers Architects Planners Quantity Surveyors
PO Box 4498 Auckland New Zealand Ph 795 700
71 Peel Street PO Box 1335 Gisborne Telephone 76 639

Proj. 2535 Dec.1983

C O N T E N T S

1.0 INTRODUCTION

1.1 This report presents the results of engineering geological mapping of the Makorori Beach Township Area carried out by KRTA Limited in December 1983.

1.2 The work was undertaken at the request of the Cook County Engineer, in his letter reference 57.1 130, in order that Council might assess the long term use of the area for continued residential development.

1.3 The purpose of the mapping was to identify the major engineering geological features related to the overall stability of the area.

2.0 CONCLUSIONS AND RECOMMENDATIONS

2.1 For ease of discussion the site has been split into four areas which are defined as follows:

Area 1 - to the west of fault 'A'	)	western half of the site
Area 2 - to the west of fault 'B'	)	
Area 3 - to the west of stream 'B'	)	
Area 4 - to the east of stream 'B'	))	eastern half of the site

The location of the faults, and streams referred to above are indicated on the Engineering Geology Maps Figs 4 to 7.

2.2 Area 1 consists of a series of old mudstone flowslides which have flowed from the north and north-west onto a flat area of old beach deposits. The ground is presently being eroded by stream action which is causing minor localised slip failures. The establishment of vegetation and good surface drainage is recommended to prevent the continued erosion and enlargement of the small slip scarps in the area. No major instabilities are envisaged here.

2.3 Area 2 has resulted from the erosion of a substantial fault bounded block of banded mudstone. A large old flowslide from the western side of this block marks the western boundary of Lot 1. State Highway 35 crosses the area, and the ground below the Highway consists of end-tipped embankment fill, overlying old slump debris from the slope above. The majority of the houses are located just off this slumped material. Lots 16 to 19 are however on a thin tongue which extends to the road edge whilst Lots 27 and 28 are well onto it. The risks to these properties may be summarised as follows:

(a) Failure of the slopes below State Highway 35 - Failure of these slopes is likely if the ground becomes saturated if heavy surcharge loads are applied or if excavations are left unsupported. Such failures would extend past the present limit of slump debris and cause damage to the houses beyond. It is essential, therefore, that drainage and earthworks are properly controlled in this area. It is recommended that the present drainage system for runoff from State Highway 35 be checked under heavy rainfall conditions, to ensure it is operating satisfactorily, and that regular checks should be made to ensure that blockage or leakage is not occurring. The properties located on old slump material dispose of their waste water by soakage into the ground. Failure of the soakage or rain and surface water collection systems will result in local saturation of the ground and slope failure. It is essential, therefore, that these systems are adequately operated and maintained to avoid stability problems. For these reasons these properties have a greater risk of failure and would benefit from properly designed drainage measures to reduce the water level in the slope.

(b) Failure of the old slumps above State Highway 35 - It is considered probable that unless extensive drainage measures are implemented, further slumping will occur, but that the debris from such failures would be largely confined to the Highway and not reach the houses below.

(c) Failure of the eroded knolls of soil/rock above State Highway 35 - The field inspection suggests that these knolls, whilst oversteep in places, are not in imminent danger of major failure. However, continuing erosion or further slumping of the ground below them will eventually lead to this. It is anticipated that whilst the bulk of the debris would be contained by the road, a small quantity will undoubtedly reach the houses below. The establishment of ground cover to slow the erosion process is recommended for the presently exposed areas of ground.

(d) Failure of the peak above State Highway 35 - Such a failure would cause considerable damage to the houses below. The possibility of this occurring, however, without failure of the lower slopes first, is remote. The situation should therefore be re-assessed following any such failures of the slopes below.

2.4 Area 3 has resulted from the long-term erosion of the main siltstone cliff ridge, the accummulation of unconsolidated slope debris at the base and the construction of State Highway 35 across the area. The ground below the Highway consists of end-tipped embankment fill, overlying unconsolidated debris from the slopes above. The houses in this area are all situated at the toe of, or on, the unconsolidated slope debris so the comments of section 2.3(a) concerning failure of the slopes below State Highway 35 apply equally here. The cuts above the Highway are large but the strata dip into the slope and they appear generally stable. No major potential rock slides were exposed in the cut faces and it is considered that the debris from any rock slides or from the erosion of the natural cliffs above would be contained on the Highway. It is unlikely, with the exception of isolated boulders which may with momentum roll across the road, that debris from these cuts would affect the houses below.

2.5 Area 4 has resulted from the long-term erosion of the main siltstone cliff ridge and the accummulation of unconsolidated slope debris at the base. The houses in this area are all situated on unconsolidated slope debris, however Lots 55 to 62 are situated immediately below stream 'C' and a number of other major drainage channels on an area of higher ground. The risks to these properties may be summarised as follows:

(a) Failure of the cliff face - The strata dip into the face and so major dip slope related failures of the cliff are unlikely. Active erosion of the cliff face is taking place by saturation and slumping of the weathered mantle during periods of heavy rainfall followed by removal of the slumped debris in the form of a debris flow down the major natural drainage channels to the slopes below. It is considered likely that following future periods of intense rainfall, further debris flows will occur down the major drainage channels and may damage properties in the area of Lots 55 to 62. This area has not been observed during periods of heavy rainfall, and so it has not been possible to determine the likely direction of such flows. It is recommended that such a survey be undertaken to define in more detail the properties most at risk, and to consider possible forms of protection which would reduce the risk of damage. The risk of damage to the remaining houses on the lower half of the slope by such a failure is considered small.

(b) Failure of the unconsolidated slope debris - Failure of these slopes is likely if the ground becomes saturated, if heavy surcharge loads are applied or if excavations are left unsupported. It is essential, therefore, that drainage and earthworks are properly controlled in this area. At the present moment each house has developed an independent soakage system for the disposal of waste water, and in some cases a drainage system to intercept and dispose of surface water runoff. Such systems may be appropriate in isolation or under conditions of light usage, but faced with continued heavy usage or during periods of heavy rainfall with the influx of large quantities of rainwater runoff from the cliffs above, the systems are likely to be inadequate and the ground soon become saturated and will then fail.

Such failures have already occurred and it is considered that unless a co-ordinated approach to drainage of the whole area is adopted, further failures are inevitable. It is recommended that detailed surveys be made of the scope and performance of the present soakage and drainage systems, the permeability characteristics of the slope debris and the natural drainage regime from the cliff faces during periods of high flow. This data would indicate the adequacy or otherwise of the existing soakage systems, and enable the design of a suitable overall drainage system. Should the soakage systems presently installed prove to be unsuitable, then consideration could be given to the use of alternative waste disposal systems.

3.0 SITE DESCRIPTION

3.1 As indicated on the Location Plan fig. 1, Makorori Beach Township is situated on the coast approximately 8 km to the north east of Gisborne. The town occupies a thin crescent-shaped area of less steeply sloping land, bounded to the north and north east by the ridge of siltstone cliffs which form Tatapouri Point, to the north west by State Highway 35 and to the south by the sea.

3.2 The access road to the town branches from State Highway 35 to the west of the town and runs along the foreshore. All the present development, consisting of some 49 houses, lies to the north of this road and has access from it.

3.3 The steep slopes above the houses are generally bush covered and there has obviously been a concerted attempt during recent years to establish a good growth of vegetation to reduce ground erosion and slips in these areas. This also applies to the slopes above State Highway 35.

3.4 The drainage pattern of the area is essentially directly down the cliffs to the sea. Where faults or other geological discontinuities are concentrated, stream runoff has exploited these inherent weaknesses and eroded more extensively. Such a stream has breached the cliff ridge towards the middle of the site, cascading as a waterfall down the eroded rock face and splitting the town in half. State Highway 35 is routed through this natural low point in the cliff ridge.

3.5 A similar situation but at a much earlier stage may be seen above the far eastern half of the town (beyond Lot 52) where a small catchment area collects and discharges over a possibly faulted section of the cliff, resulting in a greater erosion of the cliff and a thicker deposition of debris at the base of the cliffs below.

3.6 The natural drainage above the western half of the town has been changed by the drainage measures implemented along State Highway 35. A flume adjacent to Lot 16 now discharges much of the collected runoff to the beach below.

3.7 The western end of the town is bounded by a hummocky area of slightly higher ground which extends in a band about 60 to 100 metres wide and 400 metres long from the ridge above the town to the beach edge, and which has the form of a large old flowslide. A small stream flows down the western side of this feature and is referred to later in this report as stream A.

3.8 The items described above may be seen in more detail on the aerial photography figs 8 & 9 and on the Engineering Geology maps figs 4 to 7.

4.0 SITE GEOLOGY

4.1 The New Zealand Geological Survey Map, and published data of the area, indicate that the underlying strata consist of a considerable thickness of alternating brown-grey silty turbidite sandstones and blue-grey muddy siltstones of Lower to Mid Miocene age. Thicknesses of these strata vary from a few inches to many feet, however, this banding which is a notable feature of the rocks of the Lower Miocene becomes less pronounced in the more massive silty mudstones of the Middle Miocene. These strata first emerged during the Quarternary and subsequent erosion has shaped them to the present land form.

4.2 The strata presently dip gently northwards into the cliffs at between 13^{o} to 25^{o} and a major fault (fault A) is indicated which follows the general course of stream A. This fault juxtaposes the rocks of the Lower Miocene to the east with the rocks of the Middle Miocene in the west. The details of the geology are presented on the Geological Map Fig. 2.

4.3 A careful study of the aerial photographs and the field mapping confirm the published information, and in addition indicate two further minor faults or discontinuities shown as faults B & C on Figs 5 & 6. Evidence was also encountered, beyond both ends of the town, of higher level beaches formed during earlier periods of higher sea level.

5.0 DESCRIPTION OF WORK

5.1 Following an initial site visit a survey was made of published and unpublished information on the geology of the area. Stereoscopic aerial photographs of the site were then studied in detail. These were available over the period from 1942 to 1982 and provided much information which could not be obtained in the field due to steepness of terrain thickness of bush cover and other problems of access. Field mapping of the terrain was then carried out using the 1:1000 scale aerial photographs provided by Cook County Council as base maps. Further information was obtained at this time from discussion with local residents. This data has been combined to produce the Engineering Geology Maps Figs 4 to 7.

5.2 It should be noted that where development has taken place the natural slope of the ground has been altered to varying degrees; by regrading, retaining structures etc. Such man-made alterations, their effects on the stability of individual sections and the adequacy or otherwise of the foundations or soakaway systems of individual houses are beyond the scope of this report and are not dealt with herein.

5.3 In order to delineate the major natural features of the area which influence the overall ground stability, extensive use has been made of the 1942 aerial photographs which predate most of the present development.

6.0 DISCUSSION

6.1 For ease of discussion the site has been split into four areas which are defined as follows:

Area 1 - to the west of fault 'A'	western half of the site	
Area 2 - to the west of fault 'B'		
Area 3 - to the west of stream 'B'		
Area 4 - to the east of stream 'B'	eastern half of the site	

The location of the faults, and streams referred to above are indicated on the Engineering Geology Maps Figs 4 to 7.

6.2 Area 1

6.2.1 This area lies to the west of fault 'A' as shown on Fig. 4 and has been cleared and is in pasture. Fault 'A' has down thrown the more massive silty mudstones of the Middle Miocene against the banded sandstones and siltstones of the Lower Miocene in the east, resulting in the truncation of the cliff ridge which extends to Tatapouri Point and a generally more gentle topography.

6.2.2 A small flat area immediately to the north and south of State Highway 35 indicates that beaches were formed at higher levels in the past. During these earlier periods the natural erosive processes coupled with a probable high water table level caused the "papa" country to the north of the Highway to fail as a series of soil slumps and large flowslides. These flowslides came from the higher ground to the north and north west and appear to have reached a temporary equilibrium in their present location.

Ground water flow through this slip debris has and is leading to sub surface channel erosion with the subsequent collapse of areas of ground as these tunnels are enlarged. This, in conjunction with localised oversteepening of slopes by stream erosion and the passage of stock is leading to small scale localised shallow slip failures at present. Such features are small and well north and west of the Highway. They are, therefore, unlikely to have any affect there. It is additionally considered unlikely that the large old flowslides could become reactivated except in an extreme event such as a combination of prolonged periods of heavy rainfall and earth-quake action.

6.2.3 The continuing erosion and enlargement of the small scarps in this area may be considerably reduced by ensuring that good surface drainage exists and that vegetation is quickly re-established on the exposed areas. The successful application of such techniques may already been seen in areas alongside stream 'A'.

6.3 Area 2

6.3.1 This area lies between faults 'A' and 'B' as shown on Figs 4, 5 & 6, and is generally bush covered north of the houses. Much of this cover has been planted by the M.O.W. and local residents, for erosion control and stability reasons.

6.3.2 The cliff ridge which extends to Tatapouri Point is present further to the north of the area shown on the Engineering Geology Maps. A substantial block of banded mudstone remains against these cliffs between faults 'A' and 'B' and it is erosion of this block which has formed the present topography of the area.

6.3.3 The pattern of this erosion may be seen in the west of the area where a large flowslide is indicated. In the past as a result of erosion, oversteepening of the slopes and saturation of the ground following periods of wet weather, the ground has failed. Due to the high water content the failure has taken the form of a flowslide, where soil and rock debris is borne along on a viscous mix of soil and water. Upon reaching the old beach line the debris has flowed out unrestrained to form a characteristic bulging toe as indicated between stream 'A' and Lot 1. The present ground profile suggests that this failure may not have occurred as a single event, but rather as a series of nonetheless major failures; the toe of the slope slipping first followed by progressive slides as the ground immediately above became unstable, through lack of support or continuing soil erosion. The back scarp of this slide has retreated to the cliff ridge and so no more of the block here remains to fail. Over the remainder of the area, however, there is still a substantial quantity of this block which could fail in a similar fashion in the future.

6.3.4 At present the erosion process described in 6.3.3 has only reached an intermediate stage over the remaining area. Initial slumping of the toe of the slope has already taken place and this debris mantles the lower third of the slope from just north of State Highway 35 to just north of the lower houses (Lots 1 to 16). Above this, the middle third of the slope is being actively eroded by water runoff. The water courses have heavily dissected the face leaving four major knolls of soil/rock overhanging the Highway. Slopes of 48° have been recorded in this section. Above this yet again, beyond the area shown on the Engineering Geology Maps, the ground rises less steeply in grassed slopes to a peak along the cliff ridge. This area has only suffered minor surface slumping, aggravated by stock movement and surface drainage.

6.3.5 The picture has been further complicated by the construction of State Highway 35 across the area. Early photographs of the Highway indicate that it was constructed by cut and fill in the sidelong ground of the slumped toe of the slope.

The result of cutting on the upslope side has been that the pre-existing slumps have been reactivated following periods of very heavy rainfall and have moved into the road. To date this has been dealt with by either crib walling the toe or by regrading the slope and establishing good vegetation cover. The cause of the failures is the infiltration of surface runoff and it is felt that only extensive drainage, including bored and surface drains will positively prevent future movement.

6.3.6 The fill below the Highway was end-tipped, is unlikely to have received compaction and so is liable to flowslides and slumping when it becomes saturated. Flowslides have occurred in the last 10 years as a result of water runoff from the Highway. However, since the construction of the flumes, the kerb and channeling and other drainage measures the risk of a reoccurence has reduced. The growth established on these slopes has also aided in this respect.

6.3.7 As indicated on Figs 5 & 6 the bulk of the houses in this area are situated below the slopes described in 6.3.1 to 6.3.6 on gently sloping hillwash covered old beach deposits. Lots 16 to 19 sit on a thin tongue of old slump material which extends over these beach deposits to the road edge whilst Lots 27 and 28 are higher up on the slumped toe of the slope. The risks to these properties may be summarised as follows in Sections 6.3.8 to 6.3.11.

6.3.8 (a) Failure of the slopes below State Highway 35 - Failure of these slopes may be initiated if the ground becomes saturated if heavy surcharge loads are applied, or if excavations are left unsupported. Such failures would extend past the present limit of slump debris and cause damage to the houses beyond. It is essential, therefore, that drainage and earthworks are properly controlled in this area. As a result of earlier failures, measures have been taken to control runoff from State Highway 35. The efficacy of this drainage system under heavy rainfall conditions is not known, and it is recommended that this be checked to see if improvements are necessary. It is additionally recommended that this system be regularly checked to ensure that blockage or deterioration has not occurred. Many slope failures in the past have been caused by leaks from a storm water collection system. The properties located on old slump material dispose of their waste water by soakage into the ground. Local saturation and failure of the ground will occur where the waste water soakage field is overloaded or ceases to function properly, or where surface water runoff is allowed to enter the system. The inadequate collection and disposal of rain or surface water runoff will have similar consequences. For these reasons properties on the slump debris are more at risk from a failure than those beyond the limit of previous slump material and would benefit from properly designed drainage measures to reduce the water level in the slope.

6.3.9 (b) Failure of the old slumps above State Highway 35 - During periods of rain these slumps are constantly being supplied with water and debris from the runoff and erosion above. It is considered probable, therefore, that unless extensive drainage measures are implemented then further slumping will occur in the future. It is, however, anticipated that the debris from such failures would be largely confined to the Highway and not reach the houses below. Such failures would, however, have an immediate affect on the overall stability of the ground above, possibly promoting failure.

6.3.10 (c) Failure of the eroded knolls of soil/rock above State Highway 35 - The exposure of rock in this area was poor but it appears that the underlying rock is a banded mudstone which dips gently into the slope. A major dip slope failure is, therefore, unlikely. The field inspection suggests that these knolls whilst oversteep in places are not in imminent danger of major failure, however, continuing erosion or further slumping below them will eventually lead to this. The volumes of material involved are fairly substantial and whilst it is anticipated that the bulk of the debris would be contained by the road a small quantity will undoubtedly reach the houses below. Such a failure would have an immediate affect on the overall stability of the ground above. Whilst it is impossible to prevent erosion entirely, the establishment of ground cover does slow the process and this is recommended for the presently scarred rock exposed areas of ground.

6.3.11 (d) Failure of the peak above State Highway 35 - Failure of the peak would produce a debris pile of a size similar to the large flowslide to the west of the area. This would cause considerable damage to the houses below. The possibility of this occuring, however, without failure of the lower slopes first is remote. It follows, therefore, that the situation should be reassessed following any such failures of the slopes below. Whilst not of a major significance the establishment of ground cover on the incipient surface slumps here would be of benefit in slowing the erosion process.

6.4 Area 3

6.4.1 This area lies between fault 'B' and stream 'B' as shown on Fig. 6 and is generally bush covered north of the houses. As for Area 2, much of this cover has been planted by the MOW and local residents for erosion control and stability measures.

6.4.2 The cliff ridge which extends to Tatapouri Point is immediately above this area and the present topography is a result of the long term erosion of this cliff face as modified by the construction of State Highway 35.

6.4.3 The underlying rock is predominantly a muddy siltstone with occasional inter bedded silty sandstones which dips into the cliff face at about 15°. A major dip related failure is, therefore, unlikely and none were seen. The siltstones and mudstones are particularly prone to the weathering effects of wetting and drying cycles. Small cracks rapidly develop on drying and the fine debris mantle so formed either falls by gravity or is washed by rain down to the base of the cliff. During periods of heavy rain preferential drainage channels rapidly develop down the cliff face and once established tend to collect and transport the weathered debris in the form of a debris flow down to the base of the cliff. Here, with a high water content, the debris fans out unrestrained, to form an unconsolidated debris pile. Over a period of time where runoff is not high the debris mantle may remain on the face, forming a thin soil on which vegetation can develop. The establishment of vegetation does not, however, prevent continued erosion it merely tends to slow the process and in these cases the failures occur as shallow surface slumps or hillcreep following saturation of the soil. Following failure fresh rock is exposed and the process begins again. The size of debris pile depends, therefore, on the amount of surface runoff and the degree of weathering of the slope above. Prior to construction of State Highway 35 the natural slope here would have developed as described above to a form similar to that seen at present in Area 4 further east.

6.4.4 State Highway 35 extends across the area in sidelong cut and fill. The cuts above the Highway are large but with the strata dipping into the slope appear generally stable. No major potential rock slides were exposed in the cut faces although it is understood that one did develop in the past during road reconstruction. The size of this rock slide was, however, sufficiently small that the debris was contained on the Highway. Erosion of the natural cliff slopes above the cut faces is still continuing. The slopes, however, have grass and light scrub cover and the surface runoff flows are small so small amounts of flow debris are expected over the cut faces. Such material that does slump off the slope will accumulate on the road edge at the base of the cut and be cleared away during drainage maintenance. It is considered unlikely, therefore, with the exception of isolated boulders which may with momentum roll across the road, that debris from these cuts would affect the houses below.

6.4.5 Probably in view of the size of the cuts the extent of placed fill on the slopes below the Highway here is greater than in Area 2. This has emphasized the break in slope with the less steeply sloping section of accumulated slope debris below. The comments of section 6.3.6, therefore, apply equally here.

6.4.6 The houses in this area are situated either at the toe of, or on, the unconsolidated slope debris. The comments of section 6.3.8, therefore, apply equally here.

6.5. Area 4

6.5.1 This area lies east of stream 'B' as shown on Figs 6 & 7 and is generally bush covered north of the houses. Much of the cover immediately north of the houses has been planted by local residents for erosion control and stability reasons.

6.5.2 The cliff ridge which extends to Tatapouri Point is immediately above this area and the present topography is a result of the long term erosion of this cliff face.

6.5.3 The underlying rock type is the same as that encountered in Area 3 consisting predominantly of blue grey muddy siltstone with occasional more competent layers of silty sandstone. One such harder standstone layer extends along the face and because of its more resistant nature, may be identified as a zone of localised steepening. In the water courses down the cliff this layer has formed short steep waterfalls. Rock was generally only exposed in the water courses, the ridges between these drainage channels being covered with dense bush and scrub. The dip of the strata is generally about 19° into the slope and so major dip slope related failures of the cliff are unlikely.

6.5.4 The formation of the present topography has taken place by the process of erosion of the cliff face described earlier in section 6.4.3. The more gently sloping ground at the base of the cliffs consists, therefore, of an accumulation of unconsolidated slope debris. Where there is a greater concentration of surface runoff and more intense weathering of the cliff face then a greater quantity of such debris accumulates. In this area there are two concentrations of major natural drainage channels down the cliff face, north-east of Lot 43 and between Lots 55 & 62. In both these areas a greater quantity of slope debris has been deposited forming areas of higher ground.

6.5.5 The houses in this area are all situated on unconsolidated slope debris, but may be split into two groups dependent on their location on the slope. Lots 37 to 54 are on the lower half of the slope whilst Lots 55 to 62 are further up on the area of higher ground described in section 6.5.4. The risks to these properties may be summarised as follows:

(a) failure of the cliff face;

(b) failure of the unconsolidated slope debris.

6.5.6 (a) Failure of the cliff face - As discussed in section 6.5.3 and confirmed by examination of the aerial photographs taken since 1942, a major dip related rock slope failure is unlikely in this area. Active erosion of the cliff face is taking place at present, by the processes described earlier in section 5.4.3 viz saturation and slumping of the weathered mantle during periods of heavy rainfall followed by removal of the slumped debris in the form of a debris flow down the major natural drainage channels to the slopes below. Where a house is in the path of such a debris flow then the solid material accumulates and can cause considerable damage. This appears to have happened in the past as evidenced by the remains of the damaged house on the area of higher ground north east of Lot 43. No other homes are located in this area, however, Lots 55 to 62 are in a similar situation on the other major area of higher ground. It is considered likely that following future periods of intense rainfall further debris flows will occur and may damage properties in this area. This area has not been observed during periods of heavy rainfall and so it has not been possible to determine the likely direction of such flows. It is recommended, however, that such a survey be undertaken to define in more detail the properties most at risk and to consider possible forms of protection which would reduce the risk of damage. The risk of damage to the remaining houses on the lower half of the slope by such a failure is considered small.

6.5.7 (b) Failure of the unconsolidated slope debris - Failure of these slopes may be initiated if the ground becomes saturated, if heavy surcharge loads are applied or if excavations are left unsupported. It is essential, therefore, that drainage and earthworks are properly controlled in this area. At the present moment each house has developed an independent soakage system for disposal of waste water and in some cases a drainage system to intercept and dispose of surface water runoff. Such system may be appropriate in isolation or under conditions of light usage but faced with continued heavy usage or during periods of heavy rainfall with the influx of large quantities of rain water runoff from the cliffs above, the systems are likely to be inadequate and the ground soon becomes saturated and will then fail. This is particularly likely towards the toe of the slope or where the original ground profile has been altered and inadequate retaining structures constructed. Whilst it is the case that the areas of higher ground tend at present to receive more surface water runoff direct from the major natural drainage channels the chance of saturation of the ground is high throughout the area, being dependent on the intereaction of the various drainage and soakage systems installed. Failures due to saturation of the ground have occurred since development and it is considered that unless a co-ordinated approach to drainage of the whole area is adopted then further failures are inevitable.

It is recommended, therefore, that detailed surveys be made of the scope and performance of the present soakage and drainage systems, the permeability characteristics of the slope debris and the natural drainage regime from the cliff faces during periods of high flow. This data would indicate the adequacy or otherwise of the existing soakage systems and enable the design of a suitable overall drainage system. Should the soakage system presently installed prove to be unsuitable then consideration could be given to the use of alternative waste disposal systems.