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Landslide zoning at Beauty Point and St Helens

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Abstract

Two major Tasmanian landslide areas have been proscriptively zoned since 1977. Each area is underlain by unconsolidated Tertiary clay, sand and gravel. Where these sediments underlie steep foreshore slopes at Beauty Point in the north and St Helens on the East Coast, active and recently active landslides have occurred in small townships. Control of development has been necessary in these unstable and marginally stable regions, with landslip 'A' and 'B' areas being proclaimed by government. The methods used in landslide zoning rely on detailed morphological mapping.

INTRODUCTION

Slope instability is prevalent in many areas of Tasmania and two types of landslide zoning have been implemented (Stevenson and Sloane, 1980). One, a five-zone system, advisory in nature, has predominantly been applied to the Tertiary lacustrine clay sediments of the River Tamar Valley of the central north coast. It is largely descriptive in nature and the zones indicate the increasing potential for slope instability. Government bodies use the system to control development or to seek further advice before approving development. This more general descriptive zone system is therefore used to inform the public, government bodies and local authorities of the possible risks of landslide hazard.

The second zoning system is proscriptive and is used where advice alone is insufficient and the magnitude of the landslide hazard is such that compulsory control is required. Such control is proclaimed under the *Local Government Act 1973*, with 'A' and 'B' landslip areas being declared. No development is allowed in an 'A' area and special building regulations are imposed in a 'B' area under the *Building Regulations 1978*. These special regulations ensure sensible building practices in 'B' landslip areas and control such things as the siting of buildings, drainage, excavation and the removal of vegetation.

Two major landslide areas have been declared by government since 1978. This report describes the landslide problem in each area and presents the zoning assessment methodology in each case. Different types of mapping from those used elsewhere are described, with slight variations relating to the nature of the instability in each area. A great reliance is placed on detailed morphological mapping.

LANDSLIDES AT BEAUTY POINT, NORTHERN TASMANIA

Introduction

Beauty Point, a township of 1000 inhabitants, lies on the western shore of the River Tamar estuary in northern Tasmania. Primary industries, transport and shipping facilities are the dominant employers of the local population.

Early settlement centred around the steep slopes adjacent to the river. These foreshore slopes are bounded to the west by a low escarpment, forming the edge of an undulating plateau region. Plateau drainage is ill-defined and the steeply sloping (20–30°) escarpment at the plateau edge drops to a well-defined bench, about 30 m above sea level. The steep township slopes, from the bench to the foreshore, are prime building sites providing uninterrupted estuary views.

Average rainfall is 905 mm with a definite winter peak between June and October.

Geology

The plateau region is underlain by a thick sequence of Tertiary lacustrine sediments and basalt. Upper sand, gravel and clayey sand extend to depths of up to 10 m from the plateau surface. These in turn overlie up to 20 m of basalt, virtually un-jointed and massive, with low vesicularity. The basalt is variable in thickness and the upper and lower boundaries undulate. Below the basalt is a thick sequence of organic-rich clay and sandy clay with sand units, extending well below sea level (fig. 1). Abundant plant leaf and stem fragments and mica along bedding surfaces are characteristic of these sediments.

Auger and diamond drilling has determined that the mid-slope bench and the steep foreshore slopes are underlain by up to nine metres of high-plasticity clay, silty and sandy clay with gravel lenses. The gravel lenses frequently contain groundwater. Jennings (1964) suggested that these deposits are Quaternary in age. The slope mantle is undoubtedly colluvial, possibly Quaternary in age.

The upper escarpment slopes are mantled by gravel and sandy-gravel slope wash derived from the plateau surface sediments. Diamond drilling also determined that the escarpment basalt did not appear to supply the seepages at the foot of the escarpment, whereas elsewhere in Tasmania Tertiary basalts are reliable aquifers.

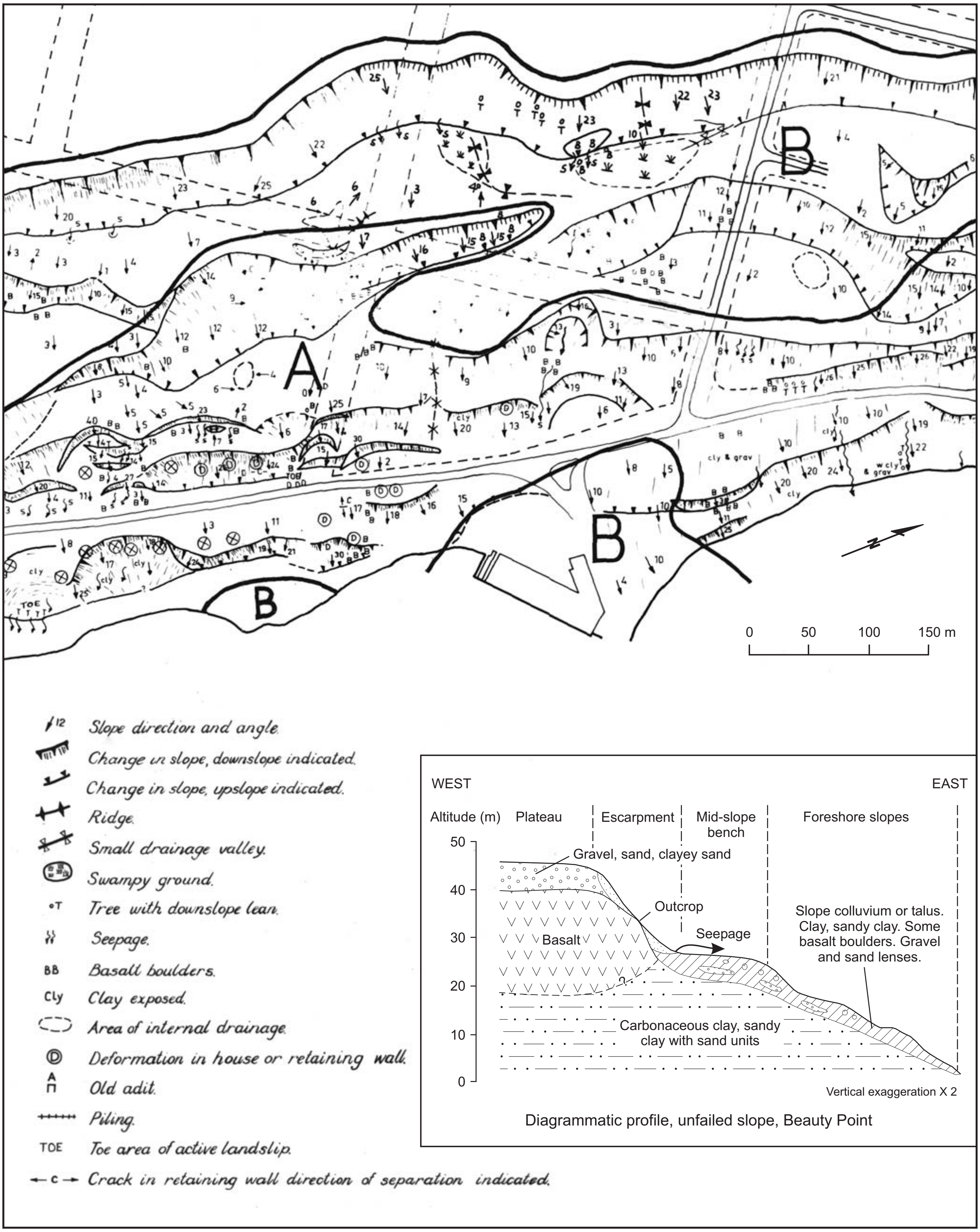

Figure 1

Part of the Beauty Point Landslip Zone Map.

The groundwater from the plateau region is considered to originate in the sand and gravel overlying the basalt as the surface sediments exhibit a high infiltration capacity. The seepage origin at the top of the basalt in the escarpment is masked by the sand and gravel slope-mantle and seepages first appear at the concave break of slope at the foot of the escarpment, where the clayey colluvial sediments of the mid-slope bench may inhibit further infiltration.

The landslide problem

Early reports of landslides at Beauty Point exist around the turn of the century when a large landslide either occurred or re-activated on the steep foreshore slopes. The headscarp extended back to the harbourmaster's house which was subsequently cut into three parts and dragged by bullock teams to its present location. The first oblique aerial photograph, taken by a light aircraft in 1934, showed that an arcuate grove of pine trees had been planted on this main landslide area and wooden piling had been driven in along the toe region. As the area developed during the 1940s and 1950s the trees were felled and houses built.

At some time during the late 1950s two large landslides occurred further to the north, again located on the steep foreshore slopes. The Crozier Street landslide, and another named Whites slip, both affected homes adjacent to the main road which traversed the slopes. Mr White's house was pulled back from the headscarp of one of the landslides, while a somewhat rotated and deformed house on the toe region still stands today. Blake (1961) reported on the activity of these landslides but no mention was made of the main landslide to the south. Rows of wooden piles were driven into each landslide adjacent to the main road and swampy depressions on the mid-slope bench were drained. A drainage adit was driven into the base of the Crozier Street failure but it was located too far below the landslide mass to be effective. Jennings (1964) reported on the landslide problem after a small drilling programme was conducted. He recommended that drainage should be improved and suggested a ban on building between the plateau escarpment and the waterfront. Individual septic tank sewerage systems were eventually replaced by a town scheme which reduced the amount of water entering the slope from households. In 1960 a large landslide occurred in Launceston, resulting in the destruction or eventual removal of 40 houses. Home owners were compensated by the government under the *Lawrence Vale Landslip Act 1961*.

The main landslide at Beauty Point reactivated in November 1969, resulting in the destruction of ten houses, with a final total of fifteen houses eventually destroyed or rendered uninhabitable. The government compensated homeowners under the *Beauty Point Landslip Act 1970* and also declared the *Beauty Point Landslip Act 1971* which prohibited building in the area suggested by Jennings (1964). The landslip declaration was, in effect, equivalent to an 'A' landslip zoning under the current proscriptive zoning scheme. The 'A' and 'B' landslip zoning system was developed during the mid 1970s and a reappraisal of the stability of the Beauty Point area began in 1978. A different approach was employed to that previously used for mapping areas of instability and for determining the location of the zone lines.

Investigations

Initially an assessment of the instability history of the area was made. A series of five detailed town maps at a scale of 1:2400 and a contour interval of five feet were readily available. These five base maps enabled morphological and other features to be accurately plotted. Slope angles, breaks of slope, seepages, depressions etc. were all plotted using a standard system of symbols. Additional features such as the occurrence of talus or colluvial boulders, deformed and destroyed houses, kinked or leaning trees, deformed and cracked retaining walls were also added to the map. The result was a detailed morphological map, at a scale where information could be seen on individual house lots. A section is shown (fig. 1) and the complex morphology of the slope in the vicinity of the main active landslide is immediately apparent. The morphology of undisturbed areas is considered to be similar to the slope profile at either end of the township (fig. 1).

To reiterate, the profile consists of an upper plateau bounded by a steep escarpment, a mid-slope bench and a steep slope segment from the edge of the bench to sea level. Where this simple morphology has become slope-complex the areas are considered to be actively unstable or previously unstable. Depressions on the mid-slope bench and drainage features exhibiting a major cross-slope component all tend to indicate slope disruption due to previous landslide movements.

In summary, the active landslides are of the semi-rotational earth flow type. Active soil-creep is evident at various locations. The instability is associated with up to nine metres of clayey colluvial or talus deposits, containing gravel aquifers. These slope deposits mantle the mid-slope bench and steep foreshore slopes. Gravel aquifers exist in the colluvial mantle. These aquifers are laterally and vertically variable in their occurrence and prediction of their location is difficult.

Zoning

Inspection of the steep upper escarpment slopes at Beauty Point indicates that the free draining sand and gravel show no evidence of instability, reflected by the simple slope morphology. No history of instability is known and there appears to be little reason for the previous 'A' landslip category, despite the steep slopes. A landslip 'B' category is therefore proposed, enabling control over development.

The steep foreshore slopes located at the edge of the mid-slope bench are underlain by geologically similar materials which may reflect a mass-movement origin. These steep slopes, well above the threshold slope-angle considered to be critical, have major active landslides and morphological features which indicate recent instability. The aquifers providing groundwater to the landslide areas are laterally variable and unpredictable at a scale of one or two house lots. The steeply sloping foreshore region is therefore considered to be unstable or only marginally stable and is therefore zoned as an 'A' landslip area, as further development may affect the delicate stability equilibrium, as has happened in the past.

The next area to be considered is the mid-slope bench. This is geologically similar to the foreshore slopes but has lower slope angles. Where the overall slope profile from plateau to the foreshore is still morphologically 'simple' the bench is zoned 'B' as no evidence of instability is apparent. Where areas of slope complexity occur and can be related to active or recently active landslides downslope, then these areas are also included in the 'A' zone category. Steep slope segments are visible in the slope-complex areas and the geological materials are considered to have residual strength properties (c'r ≅ 5–10 kPa, ϕ'r ≅ 12–18°). Slope complexity is an important criterion used in the zoning of the Beauty Point area and the 'A' zone boundary shows broad upslope embayments around such areas.

The 'A' and 'B' zone boundaries do not exactly follow the major morphological breaks of slope, but are set back inland from these features. This enables control of development in the case of the 'B' line, or building prohibition in the case of the 'A' line immediately above these major breaks of slope. The setback forms a buffer zone preventing either development or imprudent development which could directly influence the stability of the area immediately downslope. The width of the buffer zones is determined by considering the length and angle of slope, the slope materials and the instability features.

The landslide zoning can now be summarised. The steep, unstable foreshore slopes with sections of complex slope morphology, included as indicative of instability of the mid-slope bench, are zoned 'A' landslip areas. The remainder of the bench and adjacent escarpment slopes are zoned as 'B' landslip areas. There is still potential for instability in these areas or a potential influence on other areas, unless there are controls on development in these 'B' areas. By definition, the 'B' areas are subject to the *Building Regulations 1978*.

The 'A' and 'B' lines are drawn on the morphological map and overlaid on the town map. Where the line passes through a building minor adjustments may be made. For example it may be considered safe to develop a house further in one direction, but not in another, depending on its location in relation to the major break of slope.

LANDSLIDES AT ST HELENS

Introduction

The township of St Helens, population 1000, lies at the head of Georges Bay in north-eastern Tasmania. Forestry and fishing are dominant industries and the area is a popular holiday and retirement centre.

A three-kilometre section of steep slopes on the south-eastern side of Georges Bay is badly affected by landslides and marine erosion, threatening some 90 household properties and two roads. The steep bayside slopes occur at the edge of a small plateau region known as Aerodrome Hill. The plateau surface gently undulates and has an altitude of 35–45 metres. Plateau drainage is ill-defined, with broad swampy depressions carrying run-off during periods of peak rainfall. These are either relict drainage features or result from the high permeability of the sandy and gravelly surface sediments. The regional watershed follows St Helens Point Road, close to the edge of the plateau which is adjacent to the bay. A small road, Treloggens Track, traverses the steep slopes in the south-western half of the area. The steep slopes at the north-eastern end are known as Chimney Heights.

Average rainfall is 785 mm, with a slight winter maximum; high intensity falls often occur during summer.

Geology

The Aerodrome Hill plateau is underlain by gravel, sand and clay of Tertiary (Miocene–Oligocene) age, somewhat similar to the sediments found at Beauty Point. The sediments are generally unconsolidated, especially the sand and gravel units. These coarser sediments are largely granite-derived and contain varying amounts of clay. Sedimentary features such as current bedding, clay pellets and balls are noticeable in the gravels which lense and interdigitate with the clayey sediments. The sediments vary both laterally and vertically, and correlation between outcrops and drill holes is difficult.

The simplified sequence consists of up to five metres of sand and medium gravel below the plateau surface. This overlies a firm plastic clay up to four metres in thickness. Gravelly and clayey sand with gravel and sand lenses underlie the upper clay unit and in turn overlie another clay unit at about mid-slope level. This mid-slope plastic clay unit overlies the lower gravelly and clayey sand unit which is up to seven metres thick. At the base of the slope, exposed on the foreshore, is a grey plastic clay.

The coarser sediments suggest a moderately energetic depositional regime with channel fill deposits apparent. An alluvial fan or braided stream environment is suggested.

The upper surfaces of the clay units are sharply defined and undulatory. Lower margins of the units are often gradational. The clays contain montmorillonite and testing indicates c'r ≅ 5 kPa, ϕ'r ≅ 14–16°.

Exposures are generally poor, apart from the eroded slope sections. The slopes are mantled by up to three metres of Quaternary sand and gravel colluvium derived from the highly erodible Tertiary sediments.

A resistant band of iron-cemented gravel up to one metre in thickness is exposed at the top of the bayside slopes. The iron-pan is consistent over the upper plateau, at a depth of one to two metres from the ground surface, and is considered to be a soil profile feature (fig. 2).

The landslide problem

Instability was obviously present before the first reports by Mortimer (1970) and Jennings (1972). These reports concerned instability at the south-western end of the slopes, adjacent to the mid-slope Treloggens Track. The foundations of a house had been affected by a reactivated semi-rotational landslide and tension cracking of the ground was evident both above and below the track. A holiday home had been previously removed from the slide mass. Embankment failures had also occurred adjacent to the upper St Helens Point Road where it traversed the steep slopes below the plateau edge. The failures associated with the upper road were related to vegetation removal and the over-steepening of embankments by excavation. Marine erosion was considered a contributing factor to foreshore slumping by removing support from the base of the steep slopes. Instability was also attributed to above average

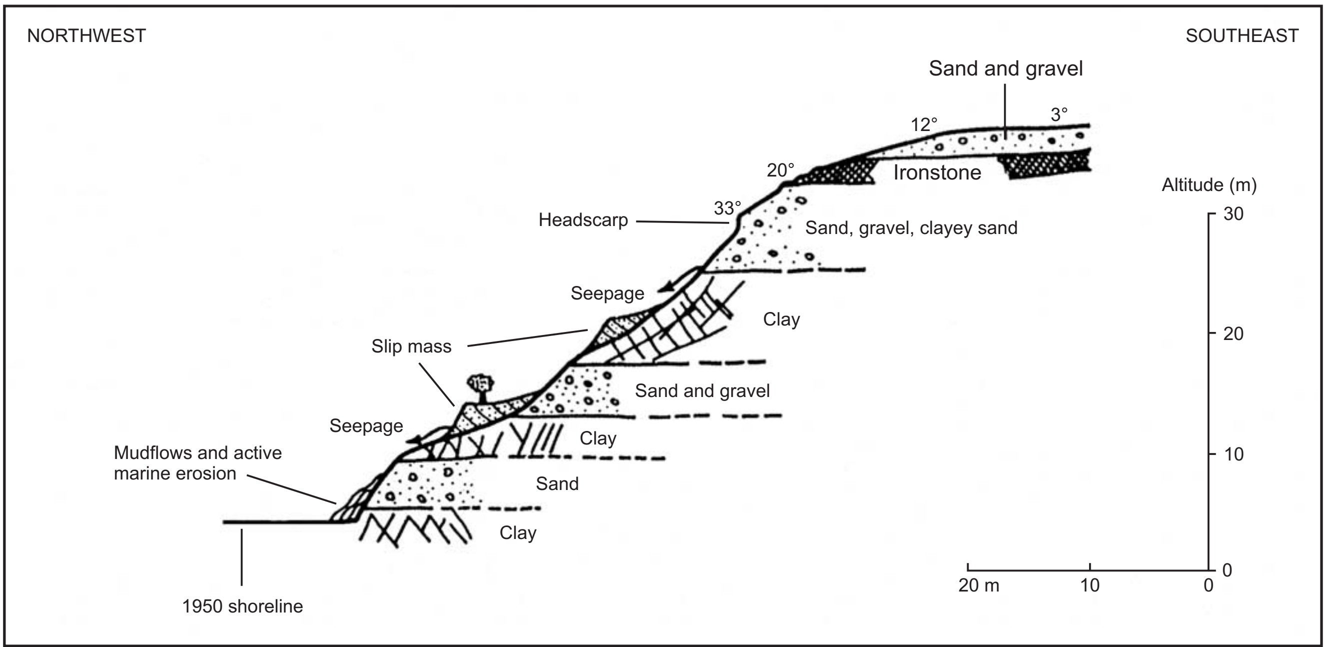

Figure 2

Slope profile, Chimney Heights, St Helens, showing simplified geology and slope failures in an area of active marine erosion.

rainfall in 1969 and 1970, after an eight-year period of well below average rainfall. In 1973 these south-western slopes, incorporating the first 27 building allotments and the upper road embankment, were proclaimed as the *Landslip Area – Aerodrome Hill, St Helens* in 1973, preventing further development. Effectively the area became equivalent to an 'A' landslip area under the current proscriptive zoning scheme.

Renewed instability occurred during 1975–1978 with reactivation of previous landslides and the acceleration of marine erosion. New landslides and tension cracking resulted along much of the three kilometre coastline. Above average rainfall was again a contributing factor during this period. The author's involvement began in 1978 when the magnitude of the instability problem necessitated control over the development of the area.

Investigations

The area was photographed obliquely from a light aircraft. Surface mapping of the geology and morphology was plotted on a transparent overlay of the photographs at a scale of approximately 1:850. All features associated with the failures were mapped, including tension cracks, head scarps and mud flows, together with leaning trees, deformed houses and seepages, as well as the major breaks of slope and slope angles. Geological information was plotted on a separate overlay. The photographs provided an ideal base for mapping, allowing accurate location of features and resulting in a pictorial representation of the failures, useful when consulting with local groups regarding the magnitude of the problem and the need for landslide zoning.

Problems arose when transferring the mapped features from the photographs to the 1:1200 scale subdivision plan of the area. The solution was to survey a series of easily distinguishable features, such as the headward extension of the slide scarps, at regular intervals along the slope and later extending these to a series of slope profiles. The known survey points were plotted and the mapped features transferred, together with the slope-map information.

Investigations determined that a series of factors was responsible for the instability problems. These include the removal of vegetation from the steep slopes to provide uninterrupted views and the introduction of water into the slope from households and road drainage. Recent development of the area has accelerated the effect of both these factors. Marine erosion of the foreshore is more dominant at the foot of the slopes to the north-east. This is related to slope aspect as the dominant storm direction is north-westerly or north-easterly. The gently sloping near-shore region is also a factor in wind-wave amplitude at this location.

Remedial measures in the landslide area have included improvements of road and house drainage, foreshore protection and revegetation of slopes.

Diamond drilling along the escarpment edge and along the mid-slope Treloggens Track was used to evaluate the stratigraphy and to locate possible aquifers. No major aquifers were discovered, but minor aquifers are being currently monitored. Some indications of an upper and lower aquifer were found, the two aquifers varying in salinity.

Landslide movements seem to occur soon after heavy rainfall and the source of groundwater feeding the landslides may only originate from the area between the watershed close to the plateau edge, and the foreshore. Rain falling on the rest of the plateau is likely to infiltrate to the impervious iron-pan and then be directed inland, away from the watershed, as the iron-pan has a regional slope in this direction. The lack of success of aquifer location may just be related to the spacing of drill holes, as groundwater may be

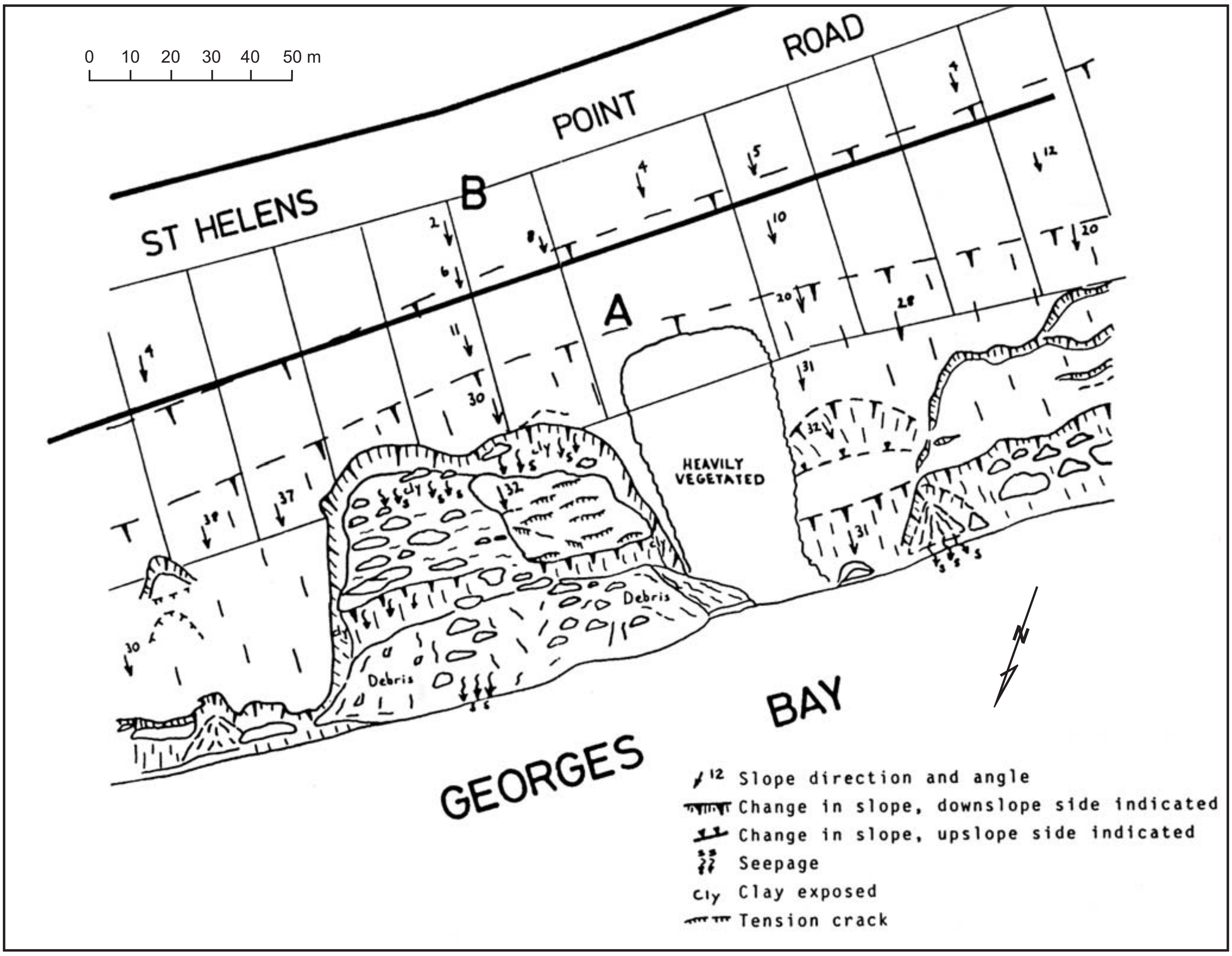

Figure 3

A section of the Landslip 'A' and 'B' Zone Map, Chimney Heights, St Helens.

quite localised in the high permeability gravel, following hollows in the upper surface of the clay layers below.

The active landslides can be divided into two distinct areas. The south-western or Treloggens Track area has either old or 'ancient' landslides of the semi-rotational slump type combined with foreshore slumping and associated tension cracks. 'Ancient' landslides may be of Quaternary age, possibly occurring at the end of the last Glaciation when reduced vegetation cover, freeze-thaw activity and generally saturated ground conditions probably existed. Also featured are recently active landslides occurring either through reactivation of older scarps or through parasitic failures on the toe region of the older slides. Marine erosion is an apparent factor, but is not as dominant as in the north-eastern or Chimney Heights area. This area is characterised by extensive marine erosion actively undercutting and cliffing the foot of the slopes. The subsequent removal of support at the toe of the slope has resulted in many small planar slab and debris slides involving the gravelly slope mantle (fig. 2, 3). Large vegetated rafts of the slope veneer have slid off the underlying clayey sediments. Mud flows are common and have also eroded the exposures of gravel and sand at the base of the slope.

Zoning

The most important criterion when considering the active failures was the most headward occurrence of landslide scarps or tension cracks. Any section of slope below this upper limit was considered unstable and therefore designated an 'A' landslip area. The steep slope sediments immediately above the failed sections were considered to be at risk, due to an inherent reduction in stability associated with the failures below.

The Chimney Heights area was relatively simple to zone as the upslope segments range from 28° to 38°. Above this is a small slope facet of 10° to 20° centred around the iron-pan outcrop before the major break of slope at the plateau edge. Only a relatively short unfailed slope segment is present below this point. The major break of slope was therefore considered to be a convenient boundary for the 'A' zone. A 15 m set-back from the plateau edge was included, to prevent development immediately on the break of slope. As the watershed is located along the upper road the area from here to the plateau edge was zoned a 'B' landslip area, in order to control development in this area, considered as influencing the stability of the steep slopes below (fig. 3).

The south-western area of failures has longer slopes, consistently between 18° and 26°, and the occurrence of semi-rotational landslides and extensive tension cracks indicates that slopes of this magnitude are potentially unstable, particularly when considering their long-term stability using residual strength parameters. Similar reasoning was used here to that employed in the Chimney Heights area and the upper major break of slope was considered a convenient boundary. Where little downslope failure had occurred, or where the 10° to 15° slope facet at the plateau edge is longer, the 'A' and 'B' zone boundaries were shifted downslope. This meant that the 'B' zone boundary coincided with the major break of slope at the edge of the plateau and the 'A' boundary coincided with the convex break of slope between the steeper foreshore slope segment and the upper 10° to 15° slope facet.

The zoning philosophy can be simply summarised. The overall consideration is the stability of a moderately uniform 20° to 30° slope at the plateau edge. The sections of slope which have already failed are likely to extend in a headward fashion and therefore sections of the same slope segment above are at risk. Similarly, adjacent sections of the same slope segments are at risk, depending on groundwater conditions and the amount of disturbance through development. The major break of slope at the edge of the plateau is a suitable instability boundary. Conditions on the flat or lower slope angle facet at the top of the steep slopes may have a direct influence on the downslope stability; control of development is required and the areas are zoned 'B' landslip.

CONCLUSION

The risk-zoning methods rely in both cases on detailed mapping of the landslides and associated features, as well as detailed slope-mapped information of the surrounding area. The geology and groundwater conditions are assessed by surface mapping and diamond and auger drilling, with piezometers installed at suitable locations for later monitoring. Some geomechanical testing and analysis is performed. Further analysis and testing is to be conducted.

A zoning decision is usually, by necessity, a rapid process, as the decision to zone particular areas is often political. Criticism may be levelled at the lack of geotechnical analysis. Although analysis is a useful tool to confirm deductions made from the field investigations it cannot supplant these direct observations.

We have adopted a relatively simple approach and our methodology can be summarised as follows. Slope failures, both active and recently active, are present in these areas. Slope segments with similar geology and similar slope angles, especially where they represent an upslope or sideslope continuation of the failed sections, must by analogy be considered to be of marginal stability. There is therefore a major reliance on detailed morphological mapping. The highly variable nature of the geology, with respect to the detection of aquifers providing groundwater and directly affecting pore pressure in the slope materials, renders further refinement of the assessment of the stability of these slopes extremely difficult. Further work is proceeding, especially with regards to stability and geotechnical investigation of the slope sediments.

The detailed morphological maps are very 'user friendly'; local residents and members of government instrumentalities can easily read the maps and understand most of the reasoning behind the zoning which has been imposed. In this respect the mapping detail and scale are important.

Although it may not necessarily apply in other areas this landslide zoning appears to be successful. No homes have been destroyed through landslides in Tasmania since 1971. Although climatic factors may be responsible it is felt that if zoning had not been applied in high risk areas, and development had continued unchecked, then some losses would have occurred.

The zoning described has resulted in the declaration of both landslide areas by the Tasmanian Government in 1981 (St Helens) and 1984 (Beauty Point).

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