Tasmanian Geological Survey
Record 2013/09

Parnella landslide area, St Helens

Geomorphological mapping and a review of past investigations and mitigation works

Mineral Resources Tasmania
Department of Infrastructure, Energy and Resources

Tasmania
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Cover: Eroding shoreline scarp in the Chimney Heights area in 2007 (prior to major failure in 2011), showing 1993–1994 shore protection works.

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by M. D. Stevenson

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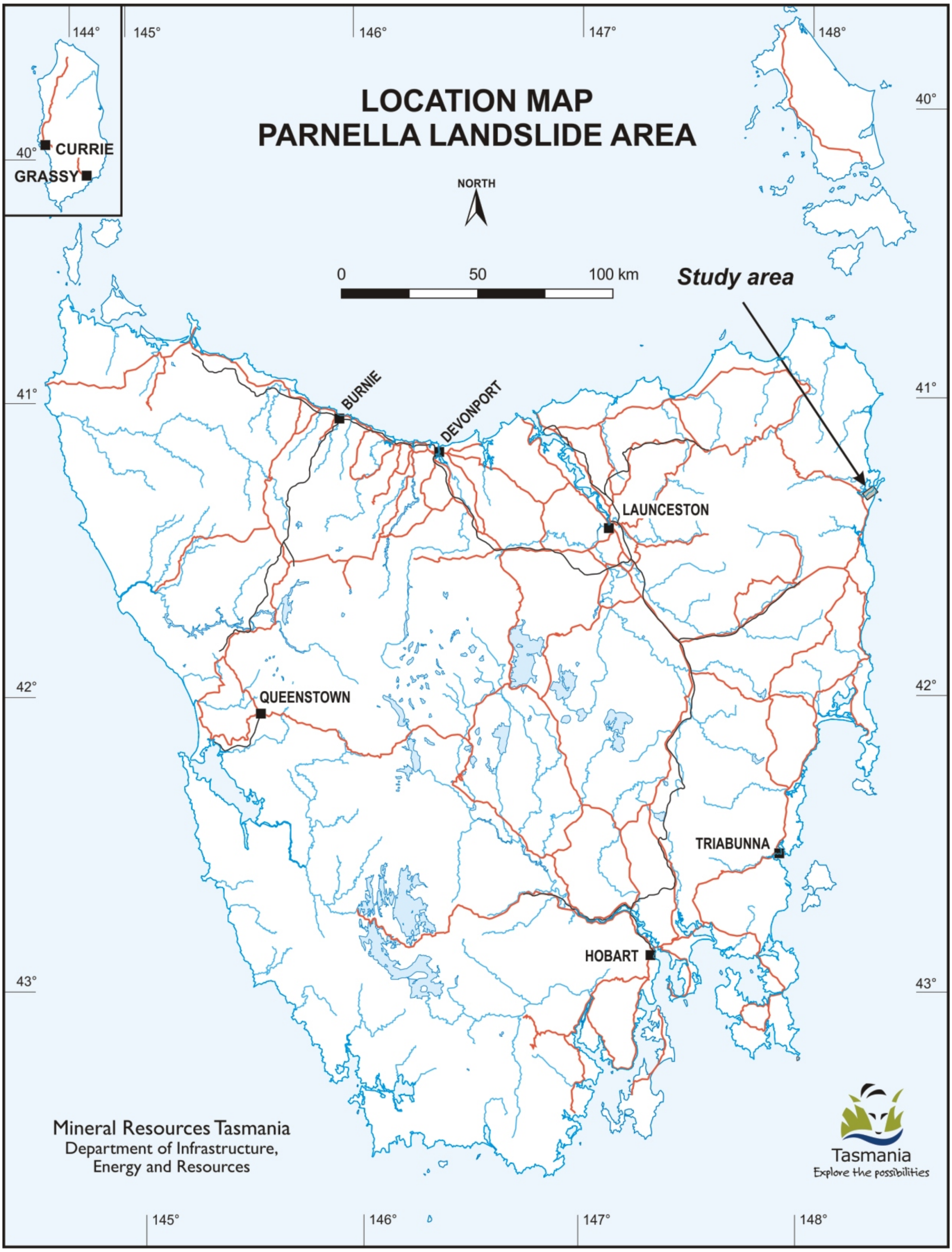

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Introduction

The Parnella landslide area on the southern shores of Georges Bay (fig. 1), near St Helens, is naturally prone to slope instability and landslides resulting from a range of natural factors. Some landslide activity can be discerned in the earliest available aerial photography dating from the 1950s, prior to any residential development or the construction of St Helens Point Road.

Road construction and residential development of this area has exacerbated the natural factors that drive slope instability. Consequently the level of landslide activity has increased since the earliest residential development of this area in the 1960s.

A number of investigations, landslide mitigation measures and development controls have been implemented in this area over many years, with varying degrees of success.

A thorough review by Mineral Resources Tasmania (MRT) has been undertaken of all the past work together with geomorphological mapping of the entire area. The mapping was undertaken with the aid of new mapping technology that has provided much greater detail and greater accuracy than was previously possible.

This report presents the findings of the recent MRT work and aims to provide the best available knowledge base for the future management of the area. The report will aid the stakeholders in developing a landslide risk management strategy and ensuring the long-term sustainability of development within the Parnella landslide area.

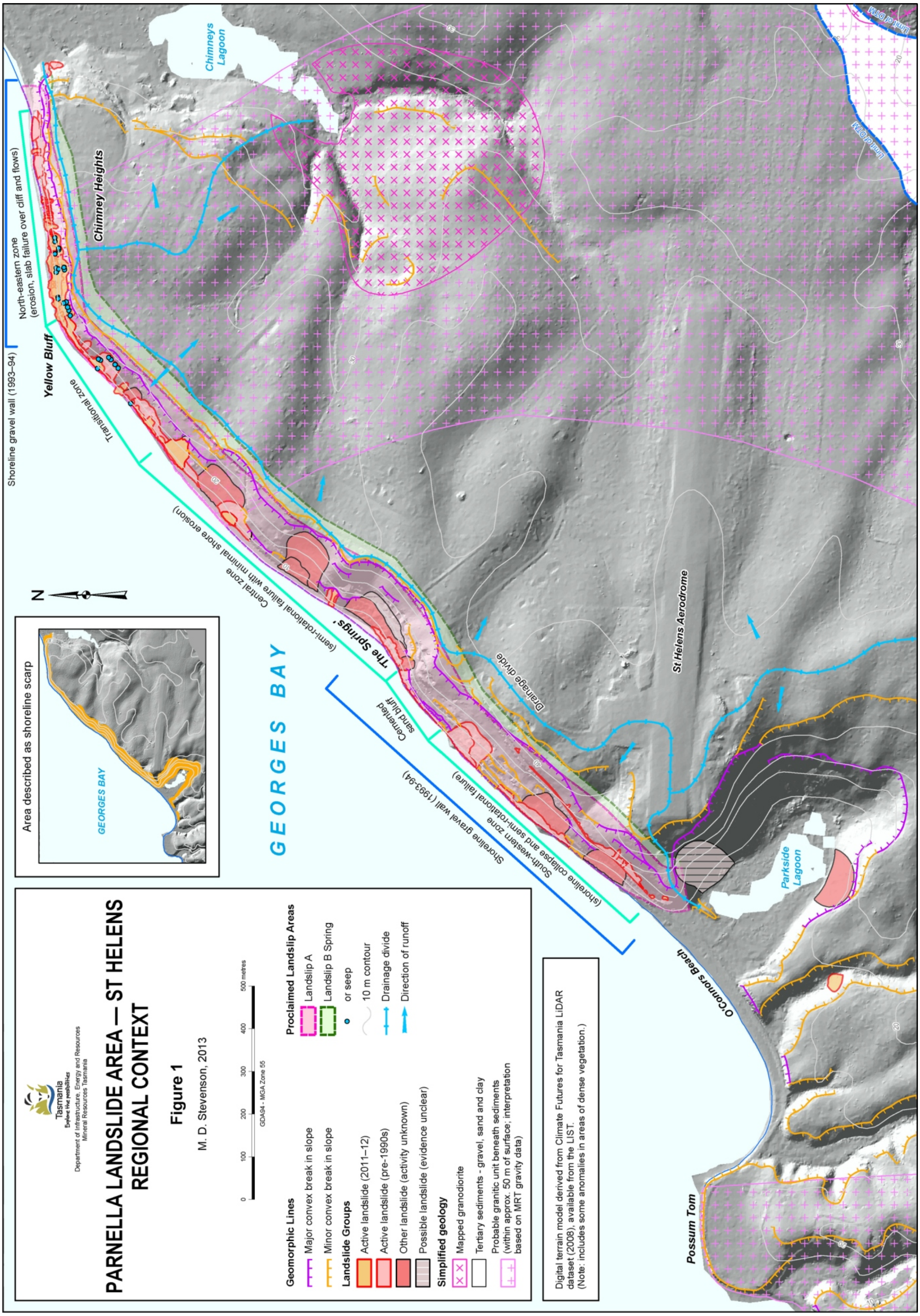
Geomorphological and landslide mapping

A program of detailed geomorphological mapping was undertaken by MRT utilising aerial photography spanning more than four decades — acquired on 26 February 1969 (1:6000 scale), 23 April 1981 (1:6000 scale), and 20 March 2012 (1:10 000 scale). In addition some other aerial photography has been consulted for comparative purposes (e.g. 16 March 1950 at 1:24 000 scale). This has allowed an accurate assessment of past landslide activity within the area and the evolution of landslide activity over time. The mapping was carried out digitally using an on-screen stereo projection tool (Stereo Analyst™) integrated with a Geographic Information System (GIS – ArcMap™). The high resolution imagery allows accurate and detailed mapping in a three-dimensional (stereographic) view, which is captured directly into the GIS environment. The accuracy of this method of mapping is dependent on a number of factors, but has been shown by field verification to be better than one to two metres horizontally.

In addition to the new mapping, thorough research into MRT's past investigation reports and correspondence files, dating back to the 1970s, was also conducted to identify past landslide activity. Landslide mapping was conducted across the Parnella area in 1979 by Sloane (1979, 1985*a,b*) for the Tasmania Department of Mines (the predecessor of Mineral Resources Tasmania), prior to the subsequent 1981 Landslip Area proclamation (see *Proscriptive zonation — proclaimed Landslip Areas*). This mapping was never published and only exists in a rudimentary draft form at 1:1200 scale, with some small parts drafted for specific reports (Sloane 1985*a,b*, 1992*b*). An attempt was made to capture this earlier landslide mapping, but it was found to have significant spatial inaccuracy, with errors of 8–14 m horizontally being common, but up to 25 m in places. The reason for this inaccuracy appears to be the poor topographic base available at the time; as there were no topographic contours available the base consisted of a number of surveyed landscape features and a few surveyed slope traverses (Benn, 1979). Sloane (1979, 1985*a,b*) states that the mapping was derived from oblique aerial photographs and transferred onto a plan showing the surveyed points. It also appears that further spatial error has been introduced in projecting the oblique view onto a plan view, with the mapped shoreline being displaced up to 20 m from the shoreline that is visible in the 1981 aerial photographs. Despite the spatial inaccuracy, this earlier mapping has been very useful in documenting the state of activity of the landslides across the area in 1979, and in revealing some internal landslide features not visible in the regular aerial photographs, as well as showing the location of the springs active at this time.

All of the landslides recorded in the new mapping program have been recorded in the MRT *Geohazards (Landslides)* database, along with full documentation of their movement history and past investigations. The public are able to view the mapped landslides with basic summary information on MRT's online web map viewer (see *Bibliography*).

Three new map sheets have been produced that should be used in conjunction with this report. A small (prepared at 1:7500 scale) map summarising the *Regional context* is included with this report as Figure 1. Two detailed, large-format 1:1250 scale map sheets cover the entire length of the Parnella landslide area (Maps 1 and 2), with each map sheet comprising a *Geomorphology and landslide map* and an *Infrastructure and topographic map*.



PARNELLA LANDSLIDE AREA — ST HELENS REGIONAL CONTEXT
Figure 1
M. D. Stevenson, 2013
Tasmania
Explore the possibilities
Department of Infrastructure, Energy and Resources
Mineral Resources Tasmania
0 100 200 300 400 500 metres
GDA94 - MGA Zone 55
Geomorphic Lines
Major convex break in slope
Minor convex break in slope
Landslide Groups
Active landslide (2011–12)
Active landslide (pre-1990s)
Other landslide (activity unknown)
Possible landslide (evidence unclear)
Simplified geology
Mapped granodiorite
Tertiary sediments - gravel, sand and clay
Probable granitic unit beneath sediments (within approx. 50 m of surface; interpretation based on MRT gravity data)
Proclaimed Landslip Areas
Landslip A
Landslip B
Spring or seep
10 m contour
Drainage divide
Direction of runoff
Digital terrain model derived from Climate Futures for Tasmania LiDAR dataset (2008), available from the LIST.
(Note: includes some anomalies in areas of dense vegetation.)
Area described as shoreline scarp
GEORGES BAY
N
G E O R G E S B A Y
Chimneys Lagoon
Chimney Heights
Yellow Bluff
Shoreline gravel wall (1993–94)
North-eastern zone (erosion, slab failure over cliff and flows)
Transitional zone
Central zone (semi-rotational failure with minimal shore erosion)
'The Springs'
Cemented sand bluff
South-western zone (shoreline collapse and semi-rotational failure)
Shoreline gravel wall (1993-94)
Drainage divide
St Helens Aerodrome
Parkside Lagoon
O'Connors Beach
Possum Tom
Limit of DTM

Topography, geology, material properties and groundwater

Topography

The Parnella landslide area is situated on the generally northeast–southwest orientated southern shore of Georges Bay (fig. 1). The ground along the shore slopes down to the bay for a distance of just over 2.5 km from Parkside Lagoon to Chimneys Lagoon, and is referred to here as the *shoreline scarp*. The northeastern end of the shoreline scarp in the Chimney Heights area, approximately 600 m in length, differs in being orientated in an almost east–west direction. The scarp rises up to an undulating plateau at approximately 48 m above sea level (mASL) in the southwest and approximately 35 mASL in the northeast. At both ends of the shoreline scarp the slopes turn away from the bay and continue southwards, alongside Parkside and Chimneys lagoons (fig. 1).

The shoreline scarp has variable topography along its length, and is generally steeper at the northeastern end, in the Chimney Heights area. Sloane (1985*a,b*) found that the main scarp slope, below the major break in slope, had a slope of 28–38°, with a small slope facet above this, below the minor break in slope, with a slope of 10–20° (fig. 2). Southwest from Yellow Bluff the shoreline scarp changes orientation and transitions over about 300 m to longer, less steep, slopes. On this part of the scarp Sloane (1985*a,b*) found that the main scarp slope, below the major break in slope, had a slope of 18–26°, with a small slope facet above this that is similar to that in the Chimney Heights area (fig. 3). The slope segment at the far southwestern end of the shoreline scarp, below the western end of the St Helens aerodrome, is a little steeper, with natural slopes up to about 30° (Map 1).

Prior to human modification of the shoreline there was a steeper slope segment, the *shoreline cliff*, developed at the foot of the slope along much of the shoreline scarp. This shoreline cliff is formed by undercutting of the slope by wave erosion and was generally only 1–2 m in height and near vertical in many places. There are two sections of the shoreline scarp where the shoreline cliff has developed to greater heights. Below Treloggens Track (at 32–47 St Helens Point Road) the shoreline cliff reaches 4–10 mASL over a length of about 160 m and forms a bluff capped by partly cemented coarse sand and gravel (fig. 1, see *Geology*). In the Chimney Heights area, the northeastern end of the shoreline scarp is steeper overall, but there is still a distinct steeper lower slope segment (shoreline cliff) that reaches 6–12 mASL with slopes generally in excess of 50° (fig. 2) over a length of about 600 metres.

The plateau above the foreshore scarp is dissected by a number of small watercourses that drain to the southeast and east, with the great majority of runoff flowing into Chimneys Lagoon (fig. 1). This has led to an overall slope on the plateau towards the east, away from the shoreline scarp, and the development of a drainage divide that in most places is within 10–100 m of the major break in slope at the top of the shoreline scarp. The drainage divide is similarly close to the top of the scarp adjacent to Parkside Lagoon, to the southwest, but the slopes down to Chimneys Lagoon, to the east, are much gentler and the drainage divide is located well back from the steeper slopes (fig. 1).

Geology

The broad geology of this area is reasonably well understood (Walker, 1957; Harris, 1968; Cocker, 1977; Forsyth, 1989; McClenaghan *et al*., 1987; McClenaghan *et al*., 1992; McClenaghan, 2002). Significant additional investigations focussed on the Parnella area were conducted by Sloane (1979, 1985*a,b*). This work included a number of drill holes and sample analyses (see *Material Properties*), in addition to the landslide mapping mentioned above.

The dominant geology of the Parnella area is mid-Tertiary age (Miocene–Oligocene) sediments originally deposited in an alluvial environment, probably an alluvial fan or braided stream system (Sloane, 1985*a,b*). Microflora within the Tertiary sediments have been studied by Forsyth (1989) and a sample from Parnella was found to be of Oligocene age. The sediments consist of relatively unconsolidated gravel, sand and clay with the coarser sediments largely derived from granitic rocks, which form much of the basement geology in the region (Sloane, 1979, 1985*a,b*). The plateau is covered with coarse quartz sand and gravel lag derived from the Tertiary sediments. The slopes around the plateau are largely mantled with the same material to a depth of up to three metres (Sloane, 1979), thus masking the underlying geology on these slopes in most places.

Various investigations and drilling (including Sloane, 1979, 1985*a,b*, 1986) have shown that inland from the top of the shoreline scarp an iron-cemented layer of sand and gravel ('ironstone'), generally up to one metre in thickness, occurs beneath the surface sand and gravel at a variable depth of 0.5 to four metres. Sloane (1985*a,b*) found that this subsurface, iron-cemented layer had a general slope that reflected the surface of the plateau and was considered to be a soil profile (diagenetic) feature, i.e. an iron pan. However it appears that in detail the upper surface of this iron pan does not have a consistent slope and is laterally variable in its development. In some places the sand and gravel is only weakly cemented by iron and does not form an impervious layer. Investigations show that beneath the iron-pan layer the geology is dominated by sand and gravel to a depth of around 5–6 m (in the northeastern parts of the area at least). In some cases it has been found that the iron pan is situated directly on top of a gravelly clay layer (Sloane, 1986), probably where the upper sand layer has largely been removed by long-term erosion, e.g. the far northeastern end of the area.

Investigations by Sloane (1979, 1985*a,b*), including drilling through the plateau to below modern sea level, found that there is a repeated sequence of sand and gravel beds overlying clay beds, which tend to vary both laterally and vertically (fig. 2). Beneath the upper sand and gravel dominated unit, which contains the iron pan, there is a sub-horizontal bed of firm, plastic, yellow-brown clay, sometimes containing sand and gravel lenses; this clay layer is up to about four metres thick. Gravelly and clayey sands underlie the upper clay unit, at 10–15 m above sea level, and in turn overlie another plastic clay unit. This middle clay unit overlies a lower gravelly and clayey sand unit that can be up

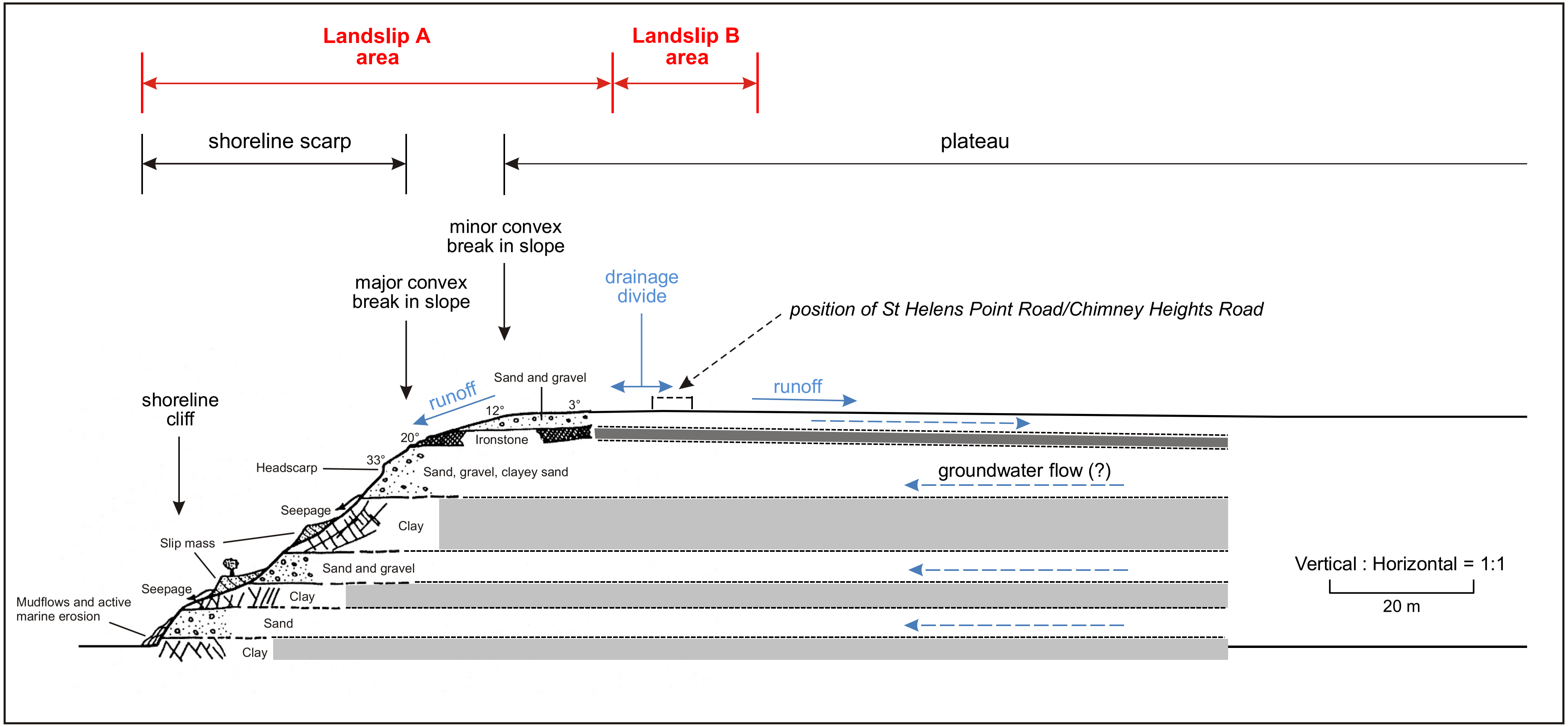


Figure 2

Typical slope profile with simplified geology and hydrology for the northeastern zone, Chimney Heights area (modified from Sloane, 1985a,b). Landslides on the shoreline scarp within this area are typically planar slab failures, debris slides and earth flows, most of which fall over the steeper lower slope segment (the shoreline cliff) and the landslide debris is then carried away by wave action. Note: the detailed stratigraphy is not well understood. Sloane (1985a,b) found that the subsurface iron pan ('ironstone') has a general dip inland and the upper surfaces of the sub-horizontal clay units are sharply defined and undulating. However both appear to have significant lateral and vertical variability.

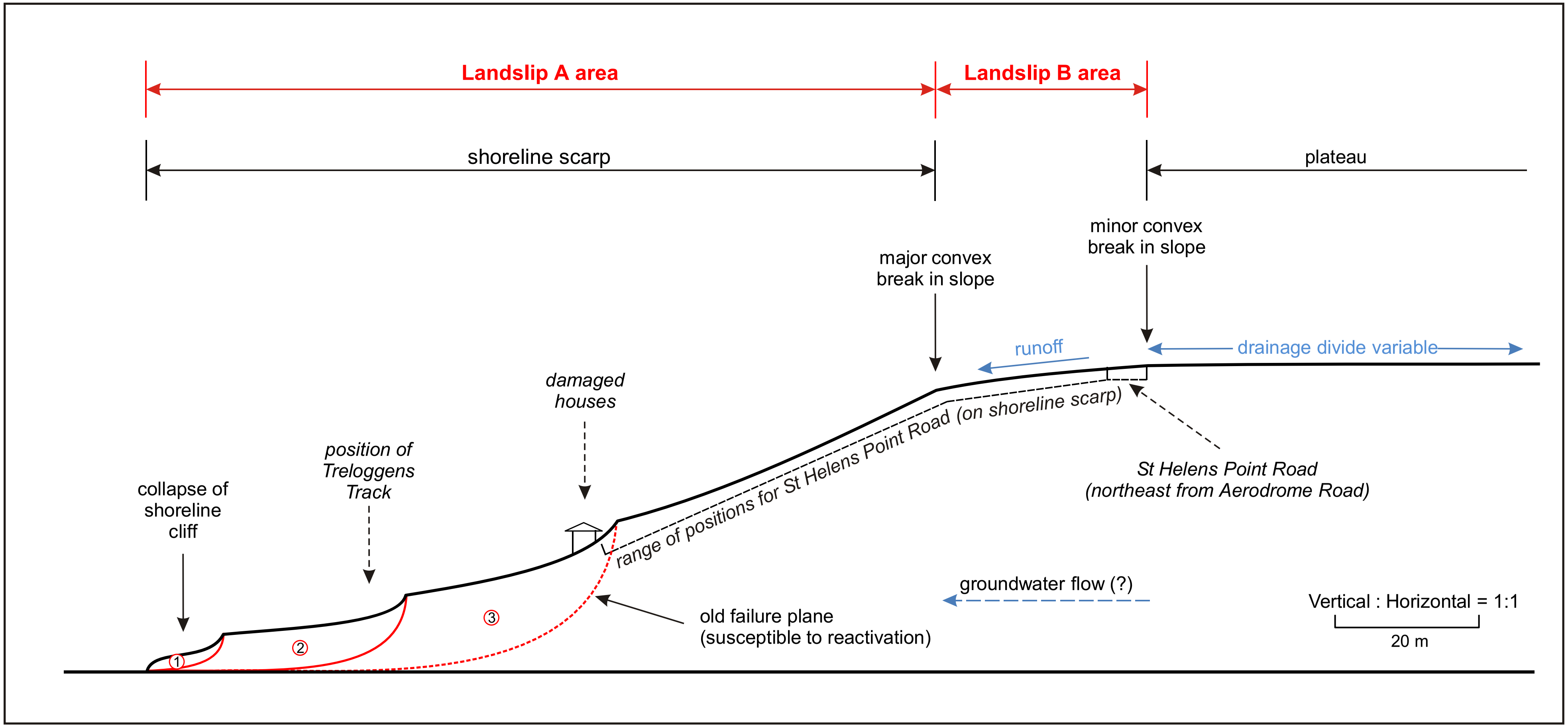


Figure 3

Typical slope profile with simplified hydrology for southwestern and central zones, southwest of Yellow Bluff. Landslides on the shoreline scarp within this area are typically semi-rotational slides. Typically there are failures observed in three slope positions of increasing size: ① — common landslides at the shoreline cliff are driven by shore erosion; ② — subsequent progressive failure advancing inland (southwestern zone), or long-lived active failures (central zone) with little shore erosion; and ③ — pre-existing old landslides that are susceptible to reactivation. The geological sequence here is not well understood as most outcrop is covered in slope deposits, but Tertiary clay does outcrop at the shoreline.

to seven metres thick. Below this is a grey, plastic clay that is exposed at the shore in many places, at the base of the shoreline scarp (fig. 2). Sloane (1985*a,b*) found that the upper margins of the clay units are sharply defined with an undulating surface, while the lower margins are often gradational. Unfortunately the drilling work upon which Sloane based these observations was not documented and no drill logs have been retained. No drill core and samples from over twenty drill holes has been retained, except for two cored holes for which MRT does not have any location information.

There are abundant sedimentary features seen throughout the area where the underlying gravel, sand and clay units are exposed at the surface. Sloane (1979, 1985*a,b*) observed channel fill deposits, large-scale current bedding, and clay pellets and balls within gravel lenses.

Detailed mapping of the slope morphology has revealed the presence of discontinuous convex breaks in slope along the length of the shoreline scarp at various elevations (fig. 1, Maps 1 and 2). There are major and minor convex breaks in slope that appear to show a correlation with the upper boundaries of exposed sand and gravel units, which may be significantly cemented in some cases. The shoreline scarp at the northeastern end (Chimney Heights area), where it is orientated in an east–west direction, shows a distinct steeper, lower slope segment (the shoreline cliff). The top of this shoreline cliff appears to broadly correlate with the top of the sand unit beneath the middle clay unit (fig. 2).

The George River Granodiorite, a coarse-grained, sparsely porphyritic biotite-hornblende granodiorite, outcrops on the eroded plateau about 600 m inland from the shoreline scarp (fig. 1), at the back of Chimneys Lagoon (Cocker, 1977; McClenaghan *et al*., 1987; McClenaghan *et al*., 1992; McClenaghan, 2002). There are a few other scattered outcrops of this granitic rock further to the south, suggesting that a larger granitic body is buried beneath the Tertiary sediments. Compiled gravity data held by MRT supports the presence of an elongate, subsurface, north–south body of granitic rock through this area. The probable granitic body extends northwards beneath the shoreline in the Yellow Bluff area with a maximum width of approximately 800 m and centred just west of Yellow Bluff (fig. 1), although this is based on only a few sparse gravity measurements.

The gravity data also suggest that this probable granitic body is within approximately 50 m of the surface of the plateau (M. Duffett, MRT senior geophysicist, pers. comm.). Given that the shoreline scarp rises to about 35 m in the Yellow Bluff area, the granitic body would be expected to be relatively close to the surface at the base of the shoreline scarp. Bowen *et al.* (1989) suggested that the underlying geology of the entire Parnella area is weathered *in situ* granitic geology, and that it is this material which is involved in the landslides. The abundant evidence of Tertiary sediments and sedimentary structures at the surface and in drilling, as discussed above, shows that this is clearly not the case; it is revealing that Bowen *et al.* (1989) make no reference to any earlier geological or landslide investigation reports. However the presence of a granitic unit outcropping somewhere on the shoreline scarp in the Yellow Bluff area is not entirely ruled out, as large parts of the shoreline scarp are obscured by slope deposits, including landslide deposits.

A detailed inspection was conducted on four sandy samples from the Parnella area (samples 148052, 148054, 148055, 148060; Table 1); a sedimentary petrology report is included as Appendix 2. This report provides descriptions based on observations under the microscope and makes conclusions about the likely origin of these samples. It is concluded that two of the samples, one each from the southwestern (148055) and northeastern (148060) parts of the shoreline scarp, are probably fluviatile (river borne), while another from the southwestern area (148052) is probably a beach or dune sand. It is also concluded that these sediments were originally derived from granitic geology. The fourth sample (148054) appears to be a decomposed granite, with very little or no transport or mixing with other material. This sample was also collected towards the southwestern end of the shoreline scarp in a road cutting along St Helens Point Road. Stratified, sedimentary sands are well exposed along this cutting (e.g. samples 148052 and 148055), including the site at which this sample was collected. Given that the gravity survey suggests that a near-surface granitic unit does not occur in the vicinity of this part of the shoreline scarp, it is possible that sample 148054 is derived from a transported cobble or boulder of granite within the sedimentary sequence.

Material properties

The Tertiary-age sediments of the Parnella area consist of a variable sequence of relatively unconsolidated gravel, sand and clay, with the coarser sediments being largely derived from granitic rocks (Sloane, 1979, 1985*a,b*). The plateau and the surrounding slopes are mantled with a lag deposit of coarse quartz sand and gravel. The variability of the sediments reflects the environment of deposition, i.e. probably an alluvial fan or braided stream system (Sloane, 1985*a,b*). Bowen *et al*. (1989) carried out sizing analyses on three sandy samples from the northeastern end of the shoreline scarp (Chimney Heights area) and found a variable clay fraction (about 5–20%), very little silt, and coarser grains ranging up to gravel size, with a median grainsize of medium sand.

The clay beds within the Tertiary sedimentary sequence have properties that make them highly susceptible to landslide failure at varying scales. Table 2 shows the results of laboratory analyses carried out on the clays at Parnella by Mineral Resources Tasmania and the former Tasmania Department of Mines.

Sloane (1985*a,b*) observed that the clay in all of the clay beds intersected by drilling is plastic in nature. The analyses in Table 2 show that these clays are highly plastic and that the dominant clay mineral present is kaolinite, with variable amounts of quartz and minor mica (including illite). The dominance of kaolinite clays, as opposed to montmorillonite clays, is consistent with the Tertiary sediments being derived from the granitic rocks in the region. The linear shrinkage results show these clays to be slightly to moderately expansive, while the shear strength analyses reveal that the clays have a consistently low residual shear strength. Three samples collected from sandy clay horizons (134380, 148059 and 148061) were also analysed and had higher shear strengths. Sample 134380 was collected from a roadside cutting near 64 St Helens Point Road and with samples 148059 and 148061 being collected from the shoreline scarp at Chimney Heights. The higher shear strengths of these samples is related to their greater quartz content (Table 2), which would increase their frictional resistance to shearing.

Table 2 includes four samples collected for analysis during the Sloane (1985*a,b*) investigations. Only a broad summary of these results was reported at the time, and it was mistakenly reported that the clays contained montmorillonite, rather than kaolinite. Three of Sloane's samples were collected from the two unlocated drill hole cores now stored in the MRT Core Library, which were drilled in about 1983.

The general high plasticity and low shear strength of the clays at Parnella explains their high susceptibility to landslide failure once they become wet. Potential large-scale failure and movement occurring within these Tertiary-age clay beds, which may be at considerable depth, will then affect the stability of the overlying sand and gravel beds, regardless of their own particular material properties. In this circumstance, a geotechnical assessment of stability that only considers the material properties of the near-surface materials (i.e. less than about six metres depth) will not properly address the potential for landslide failure.

It appears that the clay may also have an inherent susceptibility to erosion, at least on some parts of the foreshore scarp. Bowen *et al.* (1989) reported that clay sampled from the northeastern end of the shoreline scarp (Chimney Heights area) had a high sodium content, making it dispersive, a result confirmed by a field test for dispersivity. Dispersive clays dissolve into a slurry when in contact with fresh water and so are highly prone to erosion. MRT has conducted laboratory tests for dispersion on six samples (clay and fine sandy clay) from various locations along the shoreline scarp (Table 2). All of these particular samples were found to have a low level of dispersion, with an Emerson class number of 6; however it was also found that all six had a moderate to high degree of slaking during testing. The degree of erodibility is possibly quite variable across the Parnella area and dependent on the particular chemical and mineralogical characteristics of the clays. Much of the shoreline cliff in the Chimney Heights area is deeply rilled (photo 9) and so reflects an increased erodibility within this area at least.

Groundwater

The hydrology and groundwater of this area was investigated by Sloane (1979, 1985*a,b*). This work included a number of drill holes and piezometer monitoring; unfortunately the drilling work upon which Sloane based his observations was not documented, and no drill logs nor piezometric monitoring data have been retained. From this work a general understanding of the hydrology and groundwater for this area has been derived, but further detailed studies would be required to fully understand what is likely to be a complex system.

The average rainfall for St Helens is 775 mm with only a slight winter maximum, but high intensity falls related to east coast storms can occur at any time during the year. Jennings (1972) found that short bursts of high-intensity rainfall interspersed with dry periods are typical for this area. Sloane (1979) ascertained that about 25% of the rainfall on the area infiltrates to the water table or the impermeable clay layer at the base of the upper sand and gravel unit. Sloane (1985*a,b*) also found that the subsurface iron pan had a general slope inland away from the shoreline scarp, so that the water that infiltrates should tend to be directed away from the shoreline scarp (fig. 2). However, as noted previously, the lateral continuity and development of the iron pan is not well understood.

For the water that infiltrates further down to the impermeable clay layers (fig. 2), the direction of flow will be dependent on the form of the upper surface of the clay unit encountered. As noted above this surface is undulating, but groundwater is commonly seen issuing from the base of the upper sand and gravel unit on the slopes of the shoreline scarp in the northeastern part of the area, and seems to be the main source of groundwater seepages in this area (Sloane, 1979). This suggests that a significant portion of the water reaching the clay-gravel interface is directed towards Georges Bay, and therefore suggests an overall dip in the bedding in that direction, although it may only be a slight dip. It is likely that the undulating upper surface of the clay units exerts a significant control on the location of groundwater seepages at the shoreline scarp.

The sand and gravel horizon overlying the middle clay unit, at about 10–15 m above sea level, and the lower sand and gravel overlying the clay unit just above sea level (fig. 2), also act as aquifers in some areas, with seepages occurring at these levels on the shoreline scarp (Sloane, 1979). 'The Springs' area in the central part of the shoreline scarp is a large zone of seepage, with extensive swampy ground occurring immediately below Treloggens Track (fig. 1).

In general, the subsurface iron pan directs groundwater inland, while the underlying stratigraphy directs the groundwater towards Georges Bay, at least in some areas (fig. 2). This suggests that groundwater issuing from springs on the shoreline scarp could potentially be sourced from infiltration much further inland. It appears that the natural groundwater flow in the Parnella area is likely to be complicated by local variations in geology and stratigraphy, with lateral discontinuities and undulating upper surfaces. Extensive drilling and detailed study are required to delineate the groundwater flows.

The natural drainage has now been complicated by drainage from houses, roads and pathways or tracks on or above the shoreline scarp (Sloane, 1979). Household stormwater disposal systems, and any remaining septic tank soakage trenches, will be allowing water to infiltrate into the aquifers. In addition, drainage from St Helens Point Road will also be adding to the groundwater if it is not directed all the way down to Georges Bay in lined drains. If the springs on the shoreline scarp are also fed by infiltration occurring well inland, then the housing subdivisions constructed on the plateau in recent years could also be influencing the groundwater flow.

Table 1

Results of analyses carried out on the sand samples at Parnella by Mineral Resources Tasmania.

MRT Sample ID (Reg. No.)	Location	Easting (MGA)	Northing (MGA)	Collected by	Grainsize analysis (% passing each sieve – µm sizes)										X-Ray Diffraction (XRD) analysis
					63	90	125	180	250	500	1000	2000	4000	8000	
148052 (E202419)	Cutting, St Helens Point Road (stratified, coarse sand)	607203	5423403	C. Mazengarb	3.0	3.1	3.4	6.5	9.4	26.5	39.5	51.6	82.4	100	Quartz >80% K-feldspar 5–10% Kaolinite <2% Gibbsite <2%
148053 (E202420)	Cutting, St Helens Point Road (fine sand)	607196	5423398	C. Mazengarb	6.4	6.7	12.3	43.2	62.1	96.4	99.8	100	100	100	Quartz >80% K-feldspar 5–10% Kaolinite <2% Gibbsite <2%
148054 (E202421)	Cutting, St Helens Point Road (pale, silty, fine–medium sand)	607150	5423368	C. Mazengarb	35.6	37.7	40.2	44.1	50.2	69.6	86.4	97.3	100	100	Quartz 35–50% K-feldspar <2% Kaolinite 25–35% Halloysite (hydrated) 15–25% Gibbsite <2% Mica <2% (may include illite)
148055 (E202422)	Cutting, St Helens Point Road (gravelly sand)	607102	5423332	C. Mazengarb	17.3	18.6	20.2	22.1	23.7	26.8	35.9	51.4	70.4	88.6	Quartz 65–80% Kaolinite 15–25% Mica <2% (may include illite)
148059 (E202426)	Shoreline scarp, Chimney Heights (fine sandy clay)	608290	5424428	C. Mazengarb	47.5	50.8	57.5	69.3	83.4	98.2	99.5	99.7	99.7	100	Quartz 35–50% K-feldspar 2–5% Kaolinite 35–50% Mica <2% (may include illite) Tourmaline 2–5%
148060 (E202424)	Shoreline scarp, Chimney Heights (stratified sand)	608462	5424462	C. Mazengarb	11.5	12.2	13.1	14.1	15.5	21.0	34.1	71.3	99.3	100	
148061 (E202425)	Shoreline scarp, Chimney Heights (fine sandy clay)	608449	5424459	C. Mazengarb	51.2	58.9	74.6	90.6	98.0	99.6	99.7	99.8	100	100	Quartz 35–50% K-feldspar 2–5% Kaolinite 35–50% Mica <2% (may include illite) Tourmaline 2–5%

Analyses by R. N. Woolley, Mineral Resources Tasmania.

Notes for Table 1:

1. These analyses were carried out using standard methods. The grain sizes were determined by a wet sieve analysis.
2. The samples collected by C. Mazengarb were sampled from outcrop and analysed in 2013.

Table 2

Results of analyses carried out on the clays at Parnella by Mineral Resources Tasmania and Tasmania Department of Mines

MRT Sample ID (Reg. No)	Location	Easting (MGA)	Northing (MGA)	Collected by	Atterberg Limits: Plastic Limit (% wt H_2O)	Atterberg Limits: Liquid Limit (% wt H_2O)	Linear Shrinkage (%)	Effective Residual Shear Strength: Angle of internal friction ($'_r$°)	Effective Residual Shear Strength: Cohesion (c'_r kPa)	Dispersion (Emerson Class No.)	X-Ray Diffraction (XRD) analysis
131652	Hole 6, depth 9 m	unknown	unknown	D. J. Sloane	32	95	19	–	–	–	–
131653	Hole 6, depth 18 m	unknown	unknown	D. J. Sloane	33	92	18	15	4	–	–
131654	Hole 7, depth 6 m	unknown	unknown	D. J. Sloane	34	141	23	16	7	6	Kaolinite 65–80% Mica 2–5% (may include illite) Quartz 15–25%
131655	Shoreline	unknown	unknown	D. J. Sloane	30	104	19	13	5	–	–
134380 (E202415)	Cutting, near 64 St Helens Point Road	606781	5423029	C. Mazengarb	27	74	16	23	4	6	Kaolinite 35–50% Mixed layer clay 2–5% (probably smectite illite) Mica 10–15% (may include illite) Quartz 35–50%
134381 (E202416)	Shoreline, below 101 Treloggens Track	607652	5424018	C. Mazengarb	30	106	21	14	7	6	Kaolinite 65-80% Mica 5–10% (possibly illite) K-feldspar <2%, Quartz 15–25% Halite <2%
148050 (E202418)	Shoreline, Possum Tom (soft, grey clay)	605977	5422909	C. Mazengarb	23	61	14	23	1.5	6	Kaolinite 25–35% Mixed layer clay 2–5% (probably smectite illite) Mica 10–15% (may include illite) Quartz 35–50%, Halite <2%
148056 (E202423)	Shoreline scarp, Chimney Heights	608515	5424466	C. Mazengarb	30	119	24	17	6	6	Kaolinite 65–80%, Smectite <2% Mica 5–10% (may include illite) Quartz 15–25%, Tourmaline <2% Rutile <2%
148059 (E202426)	Shoreline scarp, Chimney Heights (fine sandy clay)	608290	5424428	C. Mazengarb	21	53	13	33	2	6	Quartz 35–50%, K-feldspar 2–5% Kaolinite 35–50% Mica 2–5% (may include illite) Tourmaline 2–5%
148061 (E202425)	Shoreline scarp, Chimney Heights (fine sandy clay)	608449	5424459	C. Mazengarb	22	58	14	29	4	6	Quartz 35–50%, K-feldspar 2–5% Kaolinite 35–50% Mica 2–5% (may include illite) Tourmaline 2–5%

Analyses by R.N. Woolley, Mineral Resources Tasmania.

Notes for Table 2:

1. These analyses were carried out using standard methods. The direct shear strength analyses were carried out with a standard small shear box.
2. The first three samples collected by D. J. Sloane are taken from the core for two drill holes that were drilled in about 1983, and are now stored in the MRT Core Library. Only a brief summary of the results for the Sloane samples were provided in Sloane (1985*a*,*b*), where it was mistakenly reported that the clays contain montmorillonite, rather than kaolinite.
3. The XRD results for Sloane's sample 131654 are a 2009 re-analysis using modern techniques and so are directly comparable with the other, more recent, samples.
4. Sample 131654, and the Mazengarb samples, were also recently analysed for dispersivity. Although the dispersivity was low, there was a moderate to high degree of slaking.
5. Sample 148050 had some coarse fragments (>500 µm) removed during Atterberg testing.
6. The samples collected by C. Mazengarb were sampled from outcrop and analysed in 2012–2013.

There is evidence of early landslide activity, of unknown age, that has been overlain by four major phases of recent landslide activity in the Parnella landslide area (fig. 1):

- old landslides (probably formed pre-European settlement);
- pre-development landslide activity (isolated areas of failure along the scarp);
- 1960s to mid-1970s (major failures begin, concentrated in southwestern two-thirds);
- late 1970s to early 1990s (major failure in northeast area plus increased activity in the southwest);
- post-shoreline gravel wall, 1993–1994 (ongoing minor failures, then major failures in 2011).

The style of the landslide activity varies across different zones along the shoreline scarp, as does the form of the shoreline scarp itself. These zones are indicated on Figure 1.

Old landslide activity ('Other landslides' and 'Possible landslides' on maps)

There is clear geomorphological evidence for old, large-scale landslide activity in several places along the length of the Parnella landslide area. Landslide activity similar to that observed in recent history, both small and large-scale, has probably been occurring intermittently in this area for a very long time, and almost certainly prior to European settlement of the area.

As described above, the slopes are largely mantled with coarse sand and gravel from the plateau to a depth of up to three metres (Sloane, 1979). These slope deposits have masked much of the slope morphology and probably obscure evidence for old landslide activity, so that only the largest old landslide features are now evident in the landscape. The morphology of these large, old landslides suggests that they have developed by a semi-rotational failure mechanism (fig. 3). Human modifications can also make landslides difficult to identify. The upper parts of one old landslide feature (landslide ID 5022), in the southwest, has been heavily modified by the construction of St Helens Point Road and Treloggens Track. The original form of this landslide is evident in the 1950 aerial photography and a careful study of remaining natural slope morphology.

The morphology of old landslides will degrade with time and erosion, especially in the soft Tertiary sediments. There are some large morphological features in the Parnella landslide area that are suggestive of old landslide features, but due to slope deposits and degradation it is difficult to be certain of their origin; these features have been mapped as 'possible landslides' (landslides 5023, 5060).

A large amphitheatre-like structure (280 m across) forms a prominent hollow in the middle of the shoreline scarp (fig. 1) in the area of 47–73 St Helens Point Road, which is intersected by Treloggens Track in a mid-slope position. This feature extends up to St Helens Point Road and is known locally as 'The Springs', because of the significant groundwater discharge in the area. Much of the area below Treloggens Track here is now very thickly covered in vegetation and landforms are not obvious, but the 1969 aerial photographs clearly show landslide morphology (landslide 1092). There are also some possible landslide features extending a little further upslope, up to 30 m above Treloggens Track (landslide 5060). However other than the arcuate shape of the larger 'amphitheatre' and the undoubted past landslide activity on the lower slopes, there is little evidence that the entire structure represents an old landslide. The significant spring activity in this area has probably caused long-term incision of this section of the shoreline scarp.

Note: 'Other landslides' are referred to here as 'old landslides' because they have a very long history, but it should not be assumed that they are now stable. In fact some of these landslides at Parnella have been reactivated in recent history (see below).

Pre-development landslides

Landslide activity and shore erosion is evident in the Parnella area prior to the major development of St Helens Point Road and the subsequent residential development beginning in the 1960s. Mortimore (1970) states that a study of old charts of Georges Bay showed that the shoreline in the Parnella area had changed considerably over the previous 60 years. Investigations at the time were focussed in the southwestern zone, so this is presumably where shoreline recession was observed.

The 1950 aerial photography shows an open forest of trees and shrubs across the plateau and along the slopes, with a grassy understorey and marshy vegetation along the watercourses on the plateau. The grassy understorey suggests this area was being used for grazing at the time. In 1950 St Helens Point Road was a rough, narrow track on essentially the same alignment as the modern road. This track ascended onto the plateau across the southwestern end of the shoreline scarp, as does the modern road, but at that stage there were no significant cuttings.

Landslide activity is evident in a number of places along the shoreline scarp in the 1950 aerial photography, but there does not appear to be widespread, large-scale landslide activity. The observed active landslides are generally located within the broader areas that subsequently saw the greatest activity following development. The scale of the 1950 aerial photography (approximately 1:24 000) does not allow for detailed mapping of these landslides.

1960s to mid-1970s landslide activity

Major, widespread landslide activity in the Parnella area appears to have started in the 1960s and is evident throughout the Parnella area by 1969. By the late 1960s the landslides had become a threat to housing and infrastructure. Jennings (1972) noted that the years 1969 to 1970 had above average rainfall, following three years of very much below average rainfall.

Detailed aerial photography is available from 1969 (1:6000 scale) and shows significant housing development in the Parnella area. St Helens Point Road had been upgraded to a major road with a significant cutting where the road ascends on to the plateau in the southwest, while Aerodrome Road, Chimney Heights Road and the St Helens aerodrome had already been constructed on the plateau. Treloggens Track had also been constructed along the face of the shoreline scarp by 1969. This track provides access to many of the properties below St Helens Point Road, but was never an official road, having been constructed illegally (Bowen *et al.*, 1989; Steane, 1989). In 1969 the only sealed road was that part of St Helens Point Road where it ascended the shoreline scarp in the southwest, although it appears that the whole of this road was sealed by late 1970 (Jennings, 1972). In 1969 there were 29 houses or shacks built, or being built, on the face of the shoreline scarp, largely along Treloggens Track; a further 22 houses or shacks were built, or were being built, within 50 m of the top of the shoreline scarp.

Southwestern zone (approximately 700 m in length) — southern Treloggens Track

Very active collapse at the shoreline and semi-rotational failure of the slope immediately behind was occurring along the shoreline downslope of Treloggens Track (fig. 3), below 1–15 St Helens Point Road (landslide 1089) and 21–47 St Helens Point Road (landslides 1091, 5020) (Stevenson, 1973). These landslides were driven by erosion and undercutting of the 1–2 m high shoreline cliff in these areas, which removes the support at the base of the slope (photo 1). The shore erosion within this zone appears to have been quite active in the 1969 aerial photography with many large trees having fallen onto the beach.

Below 25–31 St Helens Point Road one semi-rotational landslide (5020) has advanced 14 m inland by progressive failure above Treloggens Track, with the track cracking and failing by 1970 (Mortimore, 1970; Jennings, 1972). By 1973 about 60 m of the track had dropped one to 1.5 metres (Stevenson, 1973) (refer to Map 1). In the early 1970s the activity of this landslide resulted in the reactivation of the pre-existing large, old landslide (1090) that surrounds it; this included the properties at 21 to 31 St Helens Point Road. This reactivation seems to have involved relatively small movements across the width of the old landslide feature (about 90 m across) by a large-scale semi-rotational mechanism (fig. 3).

On the southwest end of the shoreline scarp, Jennings (1972) noted in 1970 that there were a series of small slips or embankment failures along the cuttings on St Helens Point Road, mainly on the steeper parts of the shoreline scarp. Stevenson (1973) stated that there were small falls of sand and underlying clay in the road cuttings upslope of 1 to 19 St Helens Point Road (landslides 4919, 5048). In the 1969 aerial photography it is evident that directly above the largest part of the cutting on St Helens Point Road, on the steepest slopes, significant failures were in the early stages of development (landslide 4920). These significant failures are below the western end of the St Helens aerodrome.

Cemented sand bluff (approximately 160 m in length) — southwest of 'The Springs'

At the shore downslope of Treloggens Track, below 32 to 47 St Helens Point Road, the shoreline cliff reaches 4–10 mASL, increasing in height towards the northeast, and is capped by partly cemented coarse sand and gravel. The 1969 aerial photography shows significant failure occurring along this bluff (landslide 1091) with blocks of cemented sand and gravel, and a number of large fallen trees, lying on the beach below the bluff. Stevenson (1973) noted very large (8 m^3) blocks of soft conglomerate that had recently fallen onto the beach and were being destroyed by wave action.

Central zone (approximately 800 m in length) — 'The Springs' to Yellow Bluff

To the northeast the zones of active failure, in the 1969 aerial photographs, become a little more discontinuous in extent. Several of these active landslides are situated at the toe of pre-existing large, old landslides, and both the active and old landslides appear to have formed dominantly by semi-rotational mechanisms (fig. 3). There were active failures at the shoreline below Treloggens Track in the following locations:

- 'The Springs' area (below 49–61 St Helens Point Road – landslide 5062);
- below 75–77 St Helens Point Road (landslide 5063);
- below 101–105 St Helens Point Road (at the northern end of Treloggens Track – landslide 5082).

Further to the northeast there were significant failures (landslides 5085, 5087) occurring at the shoreline and extending into the adjacent transitional zone, below 117–133 St Helens Point Road, with a number of large trees having fallen onto the beach. One large active landslide extended up to 50 m inland and up to 18 m into the properties at 117–119 St Helens Point Road (landslide 5085). A possible incipient failure extends a further 10 m into the backyards of these properties in the form of a shallow depression about 17 m across with a broadly hummocky surface.

Transitional zone (approximately 300 m in length) — southwest from Yellow Bluff

The form of the shoreline scarp and the style of landslides transition over about 300 m towards the northeast, from about 121 St Helens Point Road to the point at Yellow Bluff. The mechanism of movement for the landslides changes towards the northeast, with shallower slab failures progressively becoming more dominant than semi-rotational failures. By the time of the 1969 aerial photography one landslide zone (5087) in particular, below 121–131 St Helens Point Road, was undergoing major failure, with associated collapse at the shoreline and a number of large fallen trees lying on the beach.

Northeastern zone (approximately 600 m in length) — Chimney Heights area

The final 600 m of the shoreline scarp, in the Chimney Heights area, is orientated in an east–west direction, is generally steeper, and is characterised by a different style of landslide failure. The landslides in the Chimney Heights area typically involve the failure of slabs of material from above the steeper lower slope segment (the shoreline cliff), which then fall down onto the beach, where the material is subsequently carried away by wave action. Sloane (1979) described the landslides in the Chimney Heights area as "mudflows, debris slides and planar slab failures exposing the clay and gravel in the slope face". He also noted that "the base of the slope has been undercut by wave erosion". The earth (or mud) flows commonly form on the exposed Tertiary sediments with their headscarps at or above the top of the shoreline cliff, and are often associated with a deeply rilled cliff face.

At the time of the 1969 aerial photography major failure was occurring at several locations (landslides 5098, 5120, 5123, 5128, 5130, 5133, 5134) in the Chimney Heights area, and there were associated fallen trees lying on the beach. In many places the upper slopes in the 1969 aerial photography, which were not yet in active failure, show features suggestive of older landslide failures.

Vegetation

The vegetation on the sites with houses or shacks in 1969, and also on many of the vacant sites along St Helens Point Road and Chimney Heights Road, had largely been cleared. Vegetation had also been cleared around the St Helens aerodrome, including most of the slopes below the western end of the runway, which is directly above the significant cutting on St Helens Point Road. It is likely that this widespread vegetation removal contributed to the subsequent landslide activity. Another contributing factor is likely to have been the modification of the natural drainage by the housing and road development, as well as the additional domestic drainage issuing from individual building sites.

Late 1970s–early 1990s landslide activity

From the late 1970s there was a marked increase in the ongoing landslide activity and an increase in the areas affected. Sloane (1985*a,b*) states that the renewal of activity occurred during 1975–1978 with the reactivation of existing landslides, occurrence of new landslides and the acceleration of the shore erosion. The most dramatic expansion of landslide activity occurred in the Chimney Heights area, in the northeastern zone, where the exposed soils on the steep shoreline scarp made the failures quite obvious. Sloane (1979) stated that the majority of failures in this area became more obvious within the preceding three years (1976–1979).

Sloane (1979) observed that the preceding ten years at St Helens were dominated by above average annual rainfall, while there had been a noticeable peak in annual rainfall in the preceding five years (1974–1979). The decade prior to this (1959–1969) had been dominated by below average annual rainfall. Sloane (1979) concluded that the heavier rainfall, especially in the preceding five years, must have contributed considerably to the increased landslide activity.

Detailed aerial photography is also available from 1981 (1:6000 scale). The only change in the road infrastructure between 1969 and 1981 was that all the roads, except Treloggens Track, had been sealed. Some of the large hollows in Treloggens Track, e.g. in 'The Springs' area, had also been filled. By 1981 an extra three houses or shacks had been built on the face of the shoreline scarp, all along Treloggens Track; and an extra 22 houses or shacks had been built, or were being built, within 50 m of the top of the shoreline scarp.

Southwestern zone (approximately 700 m in length) — southern Treloggens Track

Very active failure continued along the shoreline downslope of Treloggens Track, below 1 to 15 St Helens Point Road (landslide 1089) and 21 to 47 St Helens Point Road (landslides 1091, 5020), with associated erosion of the low shoreline cliff. One part of Treloggens Track, below 25–31 St Helens Point Road, has suffered continuing damage and has to be periodically repaired (Sloane, 1979; refer to Map 1).

The pre-existing large, old landslide (including properties at 21 to 31 St Helens Point Road; landslide 1090) that was reactivated in the early 1970s appears to have continued to move slowly. This ongoing slow movement was shown by the development of tension cracks in the ground at the head of the old landslide feature and damage to buildings in the area (Map 1). Sloane (1979) observed 50 mm vertical displacement on these cracks in mid 1979. Extensive damage had occurred to the holiday house at 25 St Helens Point Road and as a consequence the house was removed in the late 1970s (photo 2; Sloane, 1979, 1985*a,b*). The foundations of the house at 21–23 St Helens Point Road were also damaged (Sloane, 1979, 1985*a,b*).

It was found that between 1969 and 1981 the low shoreline cliff in the southwestern zone of the shoreline scarp had generally receded inland by one to four metres where landslides were not active. However where landslides were active the outward push of the landslides seemed to be keeping pace with the shore erosion with little net change in the position of the shoreline scarp.

Where St Helens Point Road rises onto the plateau, below the western end of the St Helens aerodrome, the cut slopes above the road were in major failure by 1979 (Sloane, 1985*a,b*), which is clearly evident in the 1981 aerial photography. This zone of failure (landslide 4920) is characterised by planar slab failures, with two large earth flows (landslides 5046, 5047) in the middle, and is similar in style to the landslides occurring in the Chimney Heights area. The zone is about 160 m in length and caused serious problems with repeated collapse onto the road and roadside drainage. These failures are clearly related to the over-steepening of the embankments in the cutting with a contribution from earlier vegetation removal (Sloane, 1985*a,b*).

Cemented sand bluff (approximately 160 m in length) — southwest of 'The Springs'

The 1981 aerial photography shows that major failure (landslide 1091) occurred below this bluff between 1969 and 1981, increasing in scale towards the taller northeastern end of the bluff. The inland retreat of the cliff line was confined to the southwestern, and lower, half of the bluff, with up to seven metres retreat since 1969.

Central zone (approximately 800 m in length) — 'The Springs' to Yellow Bluff

There was a general increase in the landslide activity and extent within this zone between 1969 and 1981. In one case the increased activity led to the reactivation of a surrounding pre-existing large, old landslide (Sloane, 1979). By 1979 tension cracks had developed 50 m inland around the head of this old landslide (4923), which is situated just below the northern end of Treloggens Track at 97–105 St Helens Point Road. This large reactivated landslide is surrounded on its northeastern side by an even larger old landslide (5083) that is not known to have reactivated recently.

All of the active landslides observed in 1969, which extended up to 50 m inland at 117–119 St Helens Point Road (landslide 5085), continued to move, and by 1981 most had pushed out over the beach by up to five to eight metres. Some of these had expanded laterally but not extended any further inland. Those parts of the shore not affected by active landslides in this central zone showed very little change between 1969 and 1981, with only relatively minor erosion. Hence, where landslides were active the outward push of the landslides onto the beach outpaced any erosion.

Transitional zone (approximately 300 m in length) — southwest from Yellow Bluff

As stated above, the form of the shoreline scarp, and the style of landslides, transitions over about 300 m in this area. Collapse at the shoreline is common along the length of this zone and the failures become less rotational in style towards the northeast. By the time of the 1981 aerial photographs, major failure had progressed dramatically throughout this transitional zone and continued into the northeastern zone.

At the time of the 1981 aerial photography major failure had progressed on the large active landslide zone (5087). The toe of this landslide zone had pushed out over the beach by up to four metres in the central part of the landslide. The headscarp was largely unchanged from 1969 but the central section, below 123–127 St Helens Point Road, had advanced inland by up to eight metres and had reached the upslope property boundary. Another large landslide (5094) within this area was now particularly active (photo 3) and appears to have been a reactivation of a pre-existing landslide, which was not active in 1969. The headscarp extended six to twelve metres beyond the property boundaries of 141–143 St Helens Point Road, and the landslide toe pushed out three to seven metres over the beach.

Northeastern zone (approximately 600 m in length) — Chimney Heights area

By 1981 there had been a substantial expansion of the major failures within this zone and they were now largely continuous up to within about 80 m of the eastern end of the shoreline scarp (fig. 1). The headscarps along this zone had generally advanced inland by four to twelve metres, but the position of the base of the shoreline scarp had changed relatively little since 1969. There was a large number of fallen trees lying on the beach in 1981 as a consequence of this landslide activity.

The northeastern zone is characterised by a steeper lower slope segment (the shoreline cliff). The landslides here are dominated by planar slab failures over the cliff and earth flows, some of which are quite large. The landslide debris deposited on the beach appears to be carried away quite quickly by wave action, and thus there is little apparent change in the toe position of the landslides between 1969 and 1981. The position of the base of the exposed shoreline cliff itself also appears to have changed little over this time.

Figure 2 of Sloane (1985*a,b* — on which Figure 2 of this report is based), as well as Sloane's draft mapping (held by MRT), shows eight metres of retreat since 1950 at the base of the shoreline cliff in the northeastern zone. The new detailed mapping shows that there has been very little retreat here, if any, from 1969 to 1981. A careful comparison of this mapping with the 1950 aerial photography also suggests little change from 1950 to 1969 in this area — although the scale of the 1950 photography (1:24 000) and the white cliff adjacent to a white beach make the exact position a little uncertain. If there had been any retreat from 1950 to 1969 it would have been much less than eight metres. The retreat measured by Sloane probably resulted from the spatial inaccuracies inherent in the mapping methodology used in 1979 (see *Geomorphological and Landslide Mapping*). Sloane's observations led him to the conclusion that shoreline erosion "is more dominant at the foot of the slopes to the north-east" (Sloane, 1985*a,b*), but this is not supported by the new mapping.

Vegetation

Apart from additional house sites being developed, the aerial photography shows a significant increase in vegetation density and tree size from 1969 to 1981, both on the plateau and on the shoreline scarp. This is possibly due to a change in land use from grazing to residential development. Despite this, there has also been a significant increase in landslide activity over this time. Much of the vegetation on the shoreline scarp that was involved in landslide movements probably died as result of the disturbance.

Ongoing landslide activity

The existing active landslides along the shoreline scarp continued to be active to varying degrees throughout the 1980s, without any significant expansion, fluctuating season by season, up until major shore protection works were implemented in 1993–1994 (see *Mitigation works*). There are no detailed reports on landslide activity occurring in the 1980s and early 1990s, but earlier correspondence between the former Department of Mines and the Parks and Wildlife Service reveals ongoing instability, particularly in the southwestern and northeastern zones. Unfortunately Bowen *et al.* (1989), in investigating the options for shore protection works, made several significant incorrect assumptions about the landslide activity across much of the Parnella area. It was wrongly stated that within the southwestern zone "all the slopes north of Treloggen's track are stable", it was not recognised that there had been significant retreat of the cemented sand bluff, it was not recognised that there were active landslides within the central zone, and it was wrongly concluded that "over most of the area to the west of Yellow Bluff the present risk of landslip is small". It is revealing that Bowen *et al.* (1989) made no reference to any earlier geological or landslide investigation reports, and so had not understood the variability and distribution of landslide issues in the Parnella area.

The shoreline cliff below Treloggens Track, in the area of 1 St Helens Point Road (in the southwest), was observed to be undergoing significant collapse (landslide 1089) in 1992–1993 (Weldon, 1993*a,b*). Weldon (1993*b*) stated that the shoreline cliff had retreated inland by about ten metres at one point. The new detailed mapping shows that the amount of retreat in this area was probably not more than seven metres since 1981, although this is still significant. Further to the north, the large landslide that extends up to 50 m inland, at 117–119 St Helens Point Road (5085), was observed in 1990 to show evidence of activity within the backyards of these properties (Sloane, 1990*b*).

References to landslide activity within Parks and Wildlife Service correspondence tends to be quite general. It includes reference to ongoing active landslides at the shore and retreat of the shoreline cliff by up to six metres over a number of years in some places (Luttrell, 1993, and earlier correspondence).

It is strongly suspected that the pre-existing large, old landslide at 1–9 St Helens Point Road (landslide 5021) had been partly reactivated at some point before the early 1990s. The suspected movement would likely have been quite subtle and evidence on the ground was not found. Minor damage and distortion had occurred to the property at 1 St Helens Point Road (Map 1) that could not be easily explained (Sloane, 1992*b*; Weldon, 1993*a*), but could be explained by a partial reactivation of the old underlying landslide. This house is situated at the head of the old landslide and there had been significant erosion and landslide movement (landslide 1089) along the shoreline cliff at this time, which had possibly led to a minor reactivation of the larger upslope landslide.

Post-shoreline gravel wall (1993–1994) landslide activity

During 1993–1994 major mitigation works were undertaken with Tasmanian Government funding (see *Mitigation works*). The majority of this work involved the construction of shoreline gravel walls to protect the shore from erosion. These shore protection works were constructed along the shoreline cliffs of the Chimney Heights area (630 m) and from the southwest end to the cemented sand bluff (920 m), with an unprotected gap of 990 m remaining in the middle. The unprotected part of the shore largely corresponds with the central zone and the transitional zone. This shore protection was clearly targeted at where the landslide problems were most obvious and of greatest concern, i.e. the southwestern zone and the northeastern zone (fig. 1).

Since these shore protection works were constructed, in addition to some other measures put in place in the 1980s (see *Mitigation works*), there appears to have been relatively few obvious stability issues for nearly twenty years. During this period the climate was dominated by drought and this probably also contributed to the relative stability. However close inspection shows that some landslides were still active during this period within those areas that did not have shore protection. At the time of a site visit in July 2007 there was active collapse occurring at the shoreline along the toes of some of these landslides.

A resumption of large-scale landslide activity occurred in 2011. A very heavy rainfall event on 12–13 April 2011, which followed two particularly wet years, caused numerous landslides in the St Helens area, including large-scale failures at Parnella.

Detailed aerial photography is available from 2012, subsequent to the recent reactivation of landslide activity. The major change between the 1981 and 2012 aerial photography has been the significant development of housing subdivisions on the plateau inland of St Helens Point Road. Apart from the streets associated with these subdivisions, there was little change in the road infrastructure that existed in 1981. By 2012 there was only one extra shack built on the face of the shoreline scarp, along Treloggens Track, while an extra 36 houses or shacks were built within 50 m of the top of the shoreline scarp. There have been about 215 houses or shacks built on the plateau since 1981, at up to 500 m from the shoreline scarp. The stormwater for all of these subdivisions is piped to the natural watercourses that drain the plateau towards Chimneys Lagoon (Maps 1 and 2).

Southwestern zone (approximately 700 m in length) — southern Treloggens Track

The entire length of this zone has been protected since 1993–1994 by the shoreline gravel wall (fig. 1), and as a result all of the collapse at the shoreline has ceased. It also appears that this shoreline stability has resulted in the stabilisation of the large old landslide features that were reactivating upslope (landslides 1090, 5021).

The heavy rainfall of 12–13 April 2011 caused landslides on cut slopes immediately above St Helens Point Road. There were some minor failures along parts of the road cutting where collapse had occurred previously, but the most dramatic landslide was that which occurred behind the house at 64 St Helens Point Road (photo 10). The steep cutting behind the house collapsed and the landslide (4921), about 14 m across, came to rest against the back of the house. Another smaller landslide (4922) resulted from the collapse of the driveway cutting at the same address, which blocked access to the property. Only minor damage occurred and the landslide debris was subsequently removed, but these failures could potentially have been very dangerous for the occupant.

Cemented sand bluff (approximately 160 m in length) — southwest of 'The Springs'

The entire length of this bluff (landslide 1091) has also been protected since 1993–1994 by the shoreline gravel wall. There has been only minor retreat of the cliff line since 1981, and since the wall was constructed. This retreat (landslide 5049) has occurred over a length of about 25 m in the centre of the bluff with a maximum retreat inland of about two metres since 1981. Minor recent collapse was also observed here at the time of site visits in July 2007 (photo 8) and September 2012.

Central zone (approximately 800 m in length) — 'The Springs' to Yellow Bluff

Almost the entire central zone of the shoreline scarp has not been protected by the shoreline gravel walls. As stated above, it was found that those parts of the shore here that are not affected by active landslides showed very little change between 1969 and 1981. Over this period the outward push of the landslides onto the beach had outpaced the shore erosion, but from 1981 to 2012 the landslide toes had retreated. Most of the formerly active landslide toes receded about one to two metres from 1981 to 2012, but the toe of one of the landslides (5085), which was previously more active than the others, receded three to five metres in the same period. Thus from 1981 to 2012 the shore erosion, although having little effect on the overall shoreline, had outpaced any outward push of the active landslides within this zone.

Despite this, a number of the formerly active semi-rotational landslides within this zone (particularly 5063, 5082, 5085) appear to have remained at least partly active, with the possible exception of the landslide near the cemented sand bluff (5062), which was largely protected by the shoreline gravel wall. The continuing collapse and maintenance of a low scarp at the toe of these landslides, as observed in 2007 (photo 7), suggests ongoing activity, although the rates of movement would be very much slower than in the 1960s–1970s and possibly only moving during particularly wet periods.

The heavy rainfall of 12–13 April 2011 caused a parasitic earth flow (landslide 4924) to form out of one of the landslides (5063) below Treloggens Track (below 75–77 St Helens Point Road) — there appears to be a spring associated with this flow. The head of this failure caused partial collapse of the side of Treloggens Track (photo 11) and the earth flow spilled out over the beach. It is not readily apparent at this stage whether the heavy rain of 2011 caused an increase in activity of any of the other semi-rotational landslides in the central zone.

Transitional zone (approximately 300 m in length) — southwest from Yellow Bluff

All but 70 m of the 300 m-wide transitional zone is unprotected by a shoreline gravel wall. During the period 1981–2012, prior to the heavy rainfall of 2011, the exposed shoreline of this transitional zone had developed in much the same way as the central zone. The retreat of the landslide toes was in the order of one to five metres with little change in the shoreline otherwise, and there is evidence (from a 2007 site visit) of slow ongoing landslide movement at the shoreline (landslides 5089, 5090, 5095, 5096) during this period (photos 4 and 5).

Following the heavy rainfall of 12–13 April 2011, the existing landslides at the shoreline (5089, 5090, 5095, 5096) increased in activity. Large tension cracks opened at up to 25 m inland, but these have not progressed to major failure at this stage. These landslides are partial reactivations of large formerly active landslides (5087, 5094). Another partial reactivation (landslide 5107) has occurred on the western parts of another large, formerly active landslide zone (5098), except that this failure occurred behind the protection of the shoreline gravel wall. Major failures have occurred within the northwestern zone east from this point.

An unusual landslide (5093) occurred within the unprotected part of the transitional zone following the heavy rainfall event of 2011. It appears that this landslide (photo 15) involved detachment of a large mass from the steep slope; the mass then very rapidly slid down to the beach and moved out over the beach and into the water. This displaced mass completely separated from the source area while still remaining relatively intact. A planar failure surface was exposed that subsequently collapsed within the following few months.

Northeastern zone (approximately 600 m in length) — Chimney Heights area

The most significant of all the failures that occurred shortly after the heavy rainfall event of 12–13 April 2011 were those within the northeastern zone (Chimney Heights area). The steep shoreline scarp in this area underwent continuous, large-scale failure (landslide 5108) over a length of 280 m towards the Yellow Bluff end of this zone (photos 12 and 13). The adjacent 90 m of the scarp to the east was also affected by a number of earth flows (5112–5113, 5136–5141; photo 14), with a large isolated earth flow (5142) a further 115 m to the east. The scale and style of these failures are essentially the same as the failures which occurred within this zone in the late 1970s, and this occurred despite the entire length of this zone being protected by the shoreline gravel wall.

The large-scale landslides at the Yellow Bluff end of this zone (5108–5110, 5135) involved the failure of large slabs of material from above the steeper lower slopes (shoreline cliff), which then fell down onto the shore protection and the beach. There was a reasonable cover of trees and shrubs on this section of the scarp, which has now been destroyed. About 230 m of the shore protection is now buried beneath tonnes of landslide debris.

The largest of the mapped newly active landslide zones (5108) is about 190 m in length, and has undergone major failure with the headscarp advancing further inland from the 1981 failures (5098, 5121) by 7–15 m in most parts. This landslide zone has extended beyond the property boundaries of 155 St Helens Point Road by 9.5 m, of 159 St Helens Point Road by three metres, and of 161–163 St Helens Point Road by 9.5 metres. This represents an advance inland from the 1981 failures of 7.5 m for 155, 161 and 163 St Helens Point Road, and an advance inland of 15 m for 159 St Helens Point Road.

The earth flows (5112–5113, 5136–5142) are largely sourced from material at or above the top of the shoreline cliff (photo 14). These flows often create deep rills down the cliff face or follow pre-existing erosion rills. Some of the 2011 earth flows are of a large size given the short distance of travel, with terminal lobes of eight to 20 metres across (e.g. 5136).

A July 2007 site visit showed that occasional earth flows did occur within this northeastern zone prior to 2011, with one significant earth flow coming down onto the shoreline gravel wall (landslide 5136; photo 9). The few flows observed in 2007 were located in the same general area where flows were concentrated in the late 1970s and in 2011, and were of similar character. There is a close association between many of the earth flows and the deeply rilled and eroding part of the shoreline cliff in this area.

A major difference between the 2011 failures within this zone and those that occurred in the 1960s–1970s is that the eastern 200 m of the northeastern zone has been relatively unaffected by landslides, except for the one large earth flow (5142).

Vegetation

There has been a considerable increase in vegetation cover along the shoreline scarp since 1981, although it is evident that some house blocks are being illegally cleared. Significant areas of vegetation were lost with the large landslides in the Yellow Bluff area in 2011 (e.g. photo 12). Since 1981 large areas of the plateau have been cleared for the existing housing subdivisions, as well as other areas yet to be developed on the plateau. This large scale clearance, while not having any consequences for stability on the plateau, has potentially altered the hydrological conditions along the shoreline scarp.

A large part of the eastern 200 m of the northeastern zone that was largely unaffected by landslides has well established vegetation on the scarp, although this thins out to the west. It appears that this vegetation cover has, at least in part, protected this area from failure (see *Mitigation works*).

Past investigations

A summary of past investigations and chronology of mitigation measures is provided as Appendix 1. Full references are provided for the relevant reports and significant correspondence in the *Bibliography* section.

Proscriptive zonation — proclaimed Landslip Areas

First Landslip Area proclamation

In response to the threat that the landslide activity posed to Treloggens Track and the properties along the track in the 1960s and early 1970s, a Landslip Area was proclaimed on 10 July 1973, under the *Local Government Act 1962* (Statutory Rules 1973, No. 119). This proclaimed area is described in a short report by Stevenson (1973) and essentially covered the area of the southwestern zone and the cemented sand bluff (fig. 1). The proclamation included the properties along the southwestern half of Treloggens Track (1 to 53 St Helens Point Road) and St Helens Point Road where it ascends onto the plateau (from 1 St Helens Point Road up to Aerodrome Road). This earlier proclamation pre-dated the concept of separate Landslip A and B areas and was instituted where the greatest risk of landslide was perceived at the time — it essentially had the same effect as the Landslip A area of the later proclamation.

Second Landslip Area proclamation

Following major increases in the extent of landslide activity in the late 1970s, including the significant increase in activity at the northeastern end of the shoreline scarp, the proclaimed Landslip Area was quadrupled in length. The earlier Landslip Area was revoked and the new Landslip Area proclaimed on 4 August 1981, under the *Local Government Act 1962* (Statutory Rules 1981, No. 194). The new Landslip Area covered most of the shoreline scarp and included the concept of separate Landslip A and B areas (fig. 1). This proclamation remains current and includes the following properties (in whole or in part):

- 62 to 64 St Helens Point Road;
- 1 to 167 St Helens Point Road;
- 1 to 35 Chimney Heights Road;
- 179 St Helens Point Road;
- 1 to 19 and 19A Aerodrome Road;
- the western end of the Local Government property that includes the St Helens aerodrome;
- all of the onshore component of the Parnella Conservation Area;
- all of Treloggens Track;
- most of St Helens Point Road and Chimney Heights Road above and across the shoreline scarp.

Sloane (1985*a,b*) provided the rationale behind the proclaimed Landslip Areas at Parnella. In general terms:

Landslip A areas are designed to take in the areas considered most at risk from landslide movement. At St Helens this area takes in slopes with known past landslide movement, adjacent slopes of the same character, and all of the slopes directly above up to the minor convex break in slope above the shoreline scarp. An approximate 15 m buffer has been added on the upslope side of the Landslip A area to prevent development immediately on the edge of the shoreline scarp. Southwest from 'The Springs' area, due to the longer slopes, the boundary was moved downslope a little. The upper Landslip A area boundary here is broadly aligned with the major convex break in slope at the top of the shoreline scarp.

Landslip B areas are added to control development activities that may affect the stability of the adjacent Landslip A area. Therefore, the land within Landslip B areas is not necessarily susceptible to landslide movement, as is largely the case at Parnella, but activities within this land have a high potential to affect the stability of the land downslope. The drainage divide approximately follows St Helens Point Road and Chimney Heights Road above most of the shoreline scarp. These road reserves are used as the upper boundary of the Landslip B area in most places, and the boundary is aligned with cadastral boundaries where convenient. Southwest from the Aerodrome Road intersection the upper Landslip B area boundary was also moved downslope a little, and is broadly aligned with the minor convex break in slope above the shoreline scarp.

In essence the Landslip A area defines the zone with the greatest likelihood of future landslide movement, and where no more building is allowed. Landslip B areas, with their strict development controls, are a form of buffer zone to the Landslip A area, the purpose of which is to control inappropriate activities that could destabilise the adjacent Landslip A area.

The 1981 Landslip Area proclamation was defined on the basis of the mapping carried out by Sloane (1979, 1985*a,b*) and the few slope traverses surveyed as a base for this mapping (Benn, 1979). The survey also located a number of convex breaks of slope and appears to have been supplemented with slope measurements. As discussed previously, the poor topographic control meant that there were inherent inaccuracies (see *Geomorphological and Landslide Mapping*). With the benefit of a modern topographic base, it is apparent that the Landslip Area boundaries, other than those following cadastral boundaries, are generally straight-line approximations between sparse survey control points.

The Landslip Area proclamations have not necessarily identified all land in the general area that is susceptible to landslide failure. They have been proclaimed where the greatest risk was perceived to existing and likely future development. Mineral Resources Tasmania has subsequently provided advice that the steep slopes extending to the south alongside Parkside Lagoon (fig. 1) should be treated in a similar manner to the proclaimed Landslip Areas if development was being considered in that area (Sloane, 1990*a*, 1992*a*).

Beyond the eastern end of the shoreline scarp, where the slope turns southwards along Chimneys Lagoon, two small recently active landslides (5180, 5181; Map 2) were observed in the 1969 aerial photography. The layout of the proclaimed Landslip Areas suggests that these landslides were not recognised when the Landslip Areas were being defined in 1981. There is now a house constructed on one of these formerly active landslides. Another landslide (5043) has occurred outside the proclaimed Landslip Areas following the heavy rains of 12–13 April 2011, to the west of Parkside Lagoon (fig. 1). These examples serve to highlight that the existing proclaimed Landslip Areas do not necessarily identify all land at risk of landslide.

Mitigation works

1980s mitigation works

The 1981 aerial photography shows that the upper reaches of the watercourses that drain the plateau to the southeast and east, into Chimneys Lagoon, had been recently excavated. This work was apparently done to improve the drainage of the plateau prior to subdivision development, and this would also decrease groundwater infiltration toward the shoreline scarp. The majority of these excavated drainage lines have since been replaced by residential subdivisions.

Steane (1989, and associated correspondence) provided a summary of mitigation works carried out during the 1980s. In the early 1980s the St Helens Landslip Committee was set up at the request of the then Premier, with representatives from three State departments (Lands, Main Roads, and Mines), together with the Portland Municipal Council and local property owners. The three departments prepared reports on various aspects of the problem (e.g. Finch, 1981, 1982; Waters, 1983) and the Council's consultant engineers prepared a comprehensive drainage plan for the area (Scott and Furphy, 1984). Works were then undertaken by the Department of Main Roads to improve the drainage from St Helens Point Road and the Department of Lands constructed over one kilometre of discontinuous log walls, with geofabrics, along the shore to reduce erosion. Unfortunately the entire project came to a halt with the last meeting of the committee in October 1985. A survey of the property boundaries and Treloggens Track was also completed by the Lands Department in 1988 with a view to having the Department of Main Roads re-design and upgrade the track. These work programs stalled due to disagreements over funding and the responsibility for maintaining the illegally constructed Treloggens Track.

1990s mitigation works

The incomplete log-wall shore protection was failing by the late 1980s (Steane, 1989), so the Parks and Wildlife service commissioned an engineers' report to develop options for more permanent shore protection (Bowen *et al.*, 1989). A number of costed options were provided and the Tasmanian Government ultimately provided $100,000 in 1993 for the mitigation works to be undertaken. The work was carried out by the former Department of Lands (Parks and Wildlife Service), with the co-operation of Break O'Day Council, and the gravel was quarried from the Basin Creek area (Luttrell, 1994). An examination of the existing shore protection works would suggest that this construction was based on a variation of the least cost option of Bowen *et al.* (1989).

In addition to the shoreline gravel wall, drainage works and plantings were carried out in the northeastern zone, the Chimney Heights area (Luttrell, 1994; refer to Map 2). In this area a 180 m interception drain was excavated in a mid-slope position well above the steeper lower slope segment (the shoreline cliff). This drain was dug with a three-tonne excavator, the soil mixed with cement and edges constructed, apparently with the aim of reducing the erosion of the scarp caused by runoff and earth flows. Three outlets were installed for this interception drain that consisted of treated pine chutes that directed the flow down to the shoreline gravel wall. The eroded shoreline scarp in this area was 'hydro-mulched' and then planted with more than 400 native plants (*Eucalyptus seiberi*, *Casuarina stricta* and *Callitris rhomboidea*).

2012 road works

In 2012 that part of St Helens Point Road where it ascends onto the plateau was resealed and full kerb and guttering installed for the first time by Break O'Day Council. This work will aid in preventing runoff along St Helens Point Road from being dispersed onto the slopes below the road.

1980s mitigation works

The road works undertaken on St Helens Point Road by the former Department of Main Roads in the 1980s are likely to have significantly improved the stability along the road where it ascends through cuttings onto the plateau. Failures still do occur on the road cuttings within this area, but have tended to be of a much smaller scale than those occurring in the 1960s to 1970s, although this may also be due to other factors, such as revegetation. The greatest benefit of improved road drainage in this area is actually to the slopes below St Helens Point Road. It was reported that in the early 1990s (Weldon, 1993*a,b*) runoff from the road, although improved, was still affecting some properties immediately below the road, and had the potential, in combination with other factors, to destabilise these lower slopes. A number of site visits by MRT staff over many years would suggest that the maintenance of this roadside drainage has been less than ideal.

The discontinuous log walls constructed with geofabrics along the shore by the former Department of Lands were in a serious state of disrepair by the late 1980s, and had largely failed to prevent shore erosion (Bowen *et al*., 1989; Steane, 1989; Luttrell, 1993; Weldon, 1993*b*). In addition, the logs from the deteriorating shore protection were being taken out into Georges Bay by storms and presented a serious boating hazard (Luttrell, 1993). At the time of the subsequent shore protection works (see below) most of these logs were either removed or buried beneath the gravel (Luttrell, 1994), but a few still remain on the shore (Photo 6).

1990s mitigation works

The shoreline gravel wall constructed in 1993–1994 appears to have been successful in restoring stability in the southwestern zone, but in the northeastern zone continued failure has occurred despite the presence of the gravel wall.

The gravel wall runs the entire length of the southwestern zone of the shoreline scarp and the adjacent cemented sand bluff (fig. 1). As discussed, it is these zones that had the most vigorous shore erosion prior to construction of the mitigation works. Between 1969 and 1981 the low shoreline cliff had generally receded inland by one to four metres outside of active landslides, and up to seven metres at the cemented sand bluff. Other than some relatively minor collapse over a length of about 25 m of the cemented sand bluff, there has been no collapse at the shoreline within these zones since the construction of the shoreline gravel wall. This shoreline stability would also have removed the driver for reactivation of the large, old landslide features upslope (landslides 1090, 5021), with no obvious evidence of movement on these since the 1980s.

The gravel wall also runs the entire length of the northeastern zone of the shoreline scarp (fig. 1). Between 1969 and 1981 the base of the shoreline cliff in this area appeared to change little in its position, even though large-scale failure was active throughout this area. Occasional earth flows have continued to occur in this area since the shoreline gravel wall was constructed (e.g. 2007), and in 2011 large-scale failures occurred despite the presence of the gravel wall. In this zone it appears that the majority of failures are sourced from above the lower steep slope segment (the shoreline cliff). So while the gravel wall will have protected the shoreline cliff from developing any further, although it may not have been eroding rapidly at all, it has done very little to address the source of the upslope failures.

The gravel wall that forms the shore protection is now severely eroded and along some sections of the shoreline only about one metre thickness remains (photo 8). Shore erosion is steadily destroying the wall and the gravel has been re-distributed out from the base of the wall. As mentioned above, it appears that a variation of the least cost option of Bowen *et al*. (1989) was selected for the construction of the shoreline gravel wall. Field inspection suggests that the works may not have been up to the standard of the least cost option, particularly in regard to the size of rock and gravel used to form the wall. The use of under-sized rock and gravel seems likely to have been responsible for the rapid decay of the wall. Currently the wall is still serving to protect the shore from erosion but in some areas this will not be the case for much longer.

The drainage works and plantings that were carried out in the northeastern zone (Luttrell, 1994) appear to be responsible, at least in part, for the successful establishment of vegetation on a section of the scarp. As discussed earlier, the eastern 200 m of this zone that was largely unaffected by landslides now has well established vegetation, although this thins out towards the west. The drainage works in this area have not been maintained and are now largely non-functional. The broad, shallow drain is now filled with soil and the constructed edges have collapsed in places so that the three outlet chutes no longer capture runoff.

This study of landslide history, past investigations and the performance of past mitigation measures has identified a number of key considerations for the future successful and sustainable management of the Parnella landslide area.

Driving factors for landslides

A number of driving factors are identified in this report, but in reality it will always be a combination of factors that lead to a landslide failure. Some of these factors will act to pre-condition a particular site to failure, while other factors will act as the ultimate trigger for failure.

Human factors

Three factors that could be common to all areas are related to human activities; the removal of vegetation, modification of the hydrological/drainage conditions, and modification of the slopes. Almost all of the previous investigations for the Parnella area have emphasised the importance of managing the first two factors, vegetation clearance and hydrology/drainage modification. Changes in these two factors anywhere on the shoreline scarp, or over large parts of the plateau, have the potential to result in significant consequences for stability on the shoreline scarp. The location of where the consequences are felt could be quite removed from the site where the modification occurred.

Weather and climate

An important natural factor that is common to the entire area is the natural fluctuation in the weather and climate. Jennings (1972) noted that short bursts of high-intensity rainfall interspersed with dry periods are typical for this region. This means that much of the landslide activity in the Parnella area will tend to be episodic — periods of relative stability can be followed by short periods of major failure (e.g. April 2011). Sloane (1985*a*,*b*) observed that landslide movements seem to occur shortly after heavy rainfall, in the northeastern zone at least, and this was certainly the case in this zone immediately following the high intensity rainfall of 12–13 April 2011.

Factors specific to each zone

This study shows that other natural factors driving instability vary in their relative importance across the Parnella landslide area. Each of the identified zones of the shoreline scarp is discussed below (fig. 1).

Southwestern zone and the cemented sand bluff — southern Treloggens Track

Shore erosion and the geology appear to have been the dominant factors in pre-conditioning the southwestern zone and at the cemented sand bluff areas for landslide activity. Continual erosion of the shore creates a constant driver for semi-rotational landslide failure (fig. 3) as well as ongoing collapse of the cemented sand bluff. This ultimately leads to the reactivation of the pre-existing, larger upslope landslides. The hydrology of the area will also be an important pre-conditioning factor in driving the movement of the semi-rotational landslides, with failure planes extending to sea level or below. The relative stability observed since the shore protection was installed suggests that the hydrology, while important, is a less important factor here than the shore erosion. Other landslides within this zone are related to artificial cuttings and are therefore driven by human factors, with the ultimate failure usually caused by the triggering factor of heavy rainfall.

Central zone — 'The Springs' to Yellow Bluff

The semi-rotational landslides within the central zone are persistent failures that have remained active to varying degrees at specific locations for decades, despite relatively little shore erosion. This suggests that the geology and hydrology are the most important pre-conditioning factors within this zone, and indeed seepages have been noted in association with most of these landslides. The failure planes appear to extend to sea level or below so the lower aquifers, unlike the northeastern zone, are likely to be important to the instability. The landslide history demonstrates that the factor controlling the rate of movement of these landslides is long-term rainfall fluctuations. Shore erosion seems to have little influence on the stability within this zone other than steadily removing the advancing toes of the active landslides.

Northeastern zone — Chimney Heights area

The past landslide activity and mapping suggests that the slides and flows in the northeastern zone are most dependent on the pre-conditioning factors of geology and hydrology, in particular the geology and hydrology of the upper slopes of the shoreline scarp, which are those parts from the middle clay unit upwards (fig. 2). The aquifers located above the upper and middle clay units appear to be fundamentally important to the stability of this zone. Past large-scale landslide activity within this zone (late 1970s and 2011) shows that heavy rainfall is the most important triggering factor.

The evolution of the relatively steep slopes of the shoreline scarp in the northeastern zone has long-term consequences for ongoing instability in this area. The shoreline scarp has naturally evolved as a steep slope, in a process of 'parallel retreat', due to the long-term combined effect of shore erosion on the lower slopes (see below, *Controls on shore erosion*) and the other driving factors for instability acting on the upper slopes.

The installation of the shore protection in the 1990s will have altered how this shoreline scarp evolves — as shore erosion has now ceased, 'parallel retreat' will also have ceased. In the long term the steep scarp will now naturally evolve as a 'slackening slope' to a more stable slope, i.e. the upper parts of the slope will recede inland, leading to an overall lower slope angle. This process will be aided by the existing driving factors for instability, which are most active on the upper slopes. This has consequences for the long-term viability of any development sited above the steep shoreline scarp in the Chimney Heights area.

Transitional zone — southwest from Yellow Bluff

The instability within the transitional zone, between the central zone and the northeastern zone, has characteristics of both the neighbouring zones. As would be expected, the factors driving instability here are a mix of those from both zones — geology and hydrology, at both upper and lower levels of the scarp, as well as high rainfall triggered failures. Interestingly, field observations suggest that shore erosion is also an important factor within this short, complex zone.

Controls on shore erosion

The shoreline scarp at Parnella has two distinct alignments. The majority of the scarp has a generally northeast–southwest orientation, with the northeastern zone, approximately 600 m in length, having an almost east–west orientation (fig. 1). As stated previously, Sloane (1985*a,b*) suggested that shore erosion "is more dominant at the foot of the slopes to the north-east", and on this basis he concluded that this erosion "is related to slope aspect, since the dominant storm direction is north-westerly or north-easterly". This is not supported by the new detailed mapping (see *Late 1970s–early 1990s landslide activity*), which shows that the greatest shore erosion and shoreline retreat has occurred in the southwestern zone and at the cemented sand bluff. In addition the central zone, which has essentially the same aspect as the southwestern zone and the cemented sand bluff, has had very little shoreline erosion and little development of a shoreline cliff. While the northeastern zone has not shown dramatic shoreline retreat since the 1960s, it has maintained a steep shoreline cliff that reaches 6–12 mASL. The lack of significant shoreline retreat in this area is probably more related to a relatively resistant geological sequence on the lower slopes, rather than lower wave energy.

The development of waves on Georges Bay is determined by a number of factors, including the wind direction and speed, the 'fetch', and the nearshore shape of the floor to the bay. The strongest winds across Georges Bay come from the northwest and west, with the northwesterly winds being the dominant direction throughout the year, except for summer afternoons where northeasterly, easterly and southeasterly sea breezes are dominant (Mount *et al.*, 2005). Bowen *et al.* (1989) calculated that strong northwest winds sustained for 45 minutes could generate wave conditions of "significant wave height 0.6 m and peak spectral period 2.5 seconds". It was observed that while the mean higher high water (MHHW) within Georges Bay is 0.52 m Australian Height Datum (AHD), the highest astronomical tide (HAT) is 0.90 m AHD, but that this level could also be increased by storm surge. On the basis of these observations the recommended shoreline gravel wall was designed with a height of 2.0 m AHD.

Sloane (1985*a,b*) suggested that "the gently sloping nearshore region is a factor in wind-wave amplitude" in the northeastern zone. The available aerial photography shows that there is a gently sloping subtidal flat fronting the entire length of the southwestern zone, the cemented sand bluff, and the northeastern zone. The central zone is lacking a subtidal flat along its entire length, with a steep drop-off beyond the beach and intertidal zone into the deepest part of the bay. This deep zone forms a long, narrow basin along the southeastern side of Georges Bay (Mount *et al.*, 2005). Thus there is a strong correlation between the development of a nearshore subtidal flat and those parts of the shoreline scarp where there is the greatest landslide activity and the most vigorous shore erosion. Thick seagrass beds are evident along the outer edge of these subtidal flats in all of the aerial photography, with only sparse, patchy seagrass on the flats, which varies in density over the years. This scarcity on the subtidal flats, and absence in earlier photographs, may be an indicator of high wave energy, as Mount *et al.* (2005) note that the inner margins of seagrass beds are generally determined by wave exposure (when tidal exposure is not a factor).

The subtidal flats at Parnella show a variation in plan form that also appears to correlate with the identified zones of instability along the shoreline scarp. In front of the southwestern zone there is a broad recurved cuspate, subtidal flat extending from about 70 m up to 220 m offshore at its point. This merges eastward into a more typical shore-parallel subtidal flat in front of the cemented sand bluff, which extends 50–80 m offshore. Following the absence of a subtidal flat out from the central zone, another subtidal flat has developed in front of the northeastern zone that extends 50–100 m offshore. Mount *et al.* (2005) found that there is some evidence from satellite imagery that the clear oceanic water carried on the incoming tide penetrates furthest into Georges Bay along its southeastern side. This tidal inflow passes Stieglitz Beach (to the northeast of Parnella) and O'Connors Beach to Possum Tom (fig. 1), although mostly fails to enter the inner harbour (Mount *et al.*, 2005). The promontory of Possum Tom (to the west of Parnella) also has a subtidal flat in front that extends 50–90 m offshore. The recurved cuspate shape of the subtidal flat in front of the southwestern zone is possibly due to the opposing actions of the tidal inflow and wave action or fluvial flow into Georges Bay. Bowen *et al.* (1989) estimated that the tidal currents in the main channel would have a maximum velocity of 1.0 m/s, but decreasing towards the shoreline.

The controls on shore erosion along the shoreline scarp at Parnella do not appear to be straight forward. Shore erosion on the southwestern and central zones is very different, despite them having an almost identical aspect and exposure to waves generated on Georges Bay, and the variable development of subtidal flats suggests varying influence of currents and waves in the evolution of this shoreline. Further study would be required to more accurately resolve the controls on shore erosion along the various zones of the Parnella area.

Early observations on management

Many of the observations made in earlier investigations, although of a general nature, are still quite relevant to future management of the landslides at Parnella.

Jennings (1972), in relation to a 1970 investigation of the southwestern zone, states:

> "..... very active erosion has taken place over the past couple of years and it is still proceeding at an alarming rate. If this erosion is allowed to continue unchecked there can be no doubt that the entire settlement on this hillside is in grave danger. Shoreline erosion is a common and continuing natural process around exposed

coastlines. It proceeds in cycles with a few years of active erosion followed by a cycle of relative quiescence. However it is unremitting, and in time huge areas of land may be reclaimed by the sea. **Unless urgent remedial steps are taken the settlement must be regarded as facing extinction**. Measures to combat erosion of this kind can be extremely expensive and often result only in a temporary reprieve". [emphasis added]

Jennings (1972) also states:

"A rainfall pattern of this kind *[high-intensity rain interspersed with dry periods]* falling upon an area of porous, unconsolidated rocks, underlain by plastic clay, over-steepened by roadworks, subject to poor drainage systems, and being actively undermined by shoreline erosion is surely conducive to the promotion of landslips. **In such an area extreme care should be given to the design of cuttings, drainage systems and to the development of housing** upon steep slopes which are by nature extremely sensitively balanced". [emphasis added]

Steane (1989, and associated correspondence) reviewed the management and mitigation attempted during the 1980s.

"*[The members of the 'St Helens Landslip Committee']* agreed that **the stability of the area depended upon the conscientious completion of all the various measures** — the collecting and safe disposal of all waters, including stormwater from all roads, stormwater and all domestic waste waters from households, the protection of the foot of the landslip from marine erosion and consequent over-steepening of the face, and the revegetation of the degraded sections of the face of the landslip area with deep rooting and surface covering vegetation". [emphasis added]

Some of the measures advocated by earlier investigators were put into place, e.g. shore protection, but "the conscientious completion of all the various measures", necessary for long-term stability of the area, has not been achieved. The upgrading and maintenance of Treloggens Track was identified as a key consideration by the former St Helens Landslip Committee (Steane, 1989).

Future mitigation measures

A key observation from this study is that different zones of the shoreline scarp at Parnella have differing styles of landslide activity that are driven by differing factors. Consequently the performance of past mitigation measures has varied across these zones, dependent on how well they addressed the particular pre-conditioning and triggering factors.

Shore protection

The most significant past mitigation works are the shoreline gravel walls (fig. 1). These have clearly been quite successful in restoring stability to the southwestern zone and the cemented sand bluff, whereas in the northeastern zone the gravel wall appears to have had little benefit for the long-term stability. The central zone and transitional zone (fig. 1) have remained unprotected by shoreline gravel walls, but shore erosion appears to be a much less important factor here, so costly shore protection along this area may not be warranted. The past performance of the shore protection should be carefully considered before undertaking any further such works.

The shoreline gravel wall along the southwestern zone and the cemented sand bluff has deteriorated rapidly since it was constructed and is subject to significant shore erosion. The long-term stability in these areas is clearly dependent on the repair and maintenance of this shore protection. The rapid deterioration of this wall and observation of the materials used in its construction suggests that it was not made to the standards given in the Bowen *et al*. (1989) report. It may need to be entirely reconstructed with a more suitable grade of rock and gravel.

Vegetation clearance

There was widespread vegetation clearance when the Parnella area was first developed in the 1960s, but there has since been a steady general increase in the vegetation cover on the shoreline scarp, with the exception of some house construction and a few illegally cleared blocks (see *Management of proclaimed Landslip Areas*). After an initial increase in vegetation on the plateau there has been widespread clearance in association with subdivision development, particularly behind the central and northeastern zones of the shoreline scarp. The influence of this development on the hydrology of the area and the potential consequences for long-term stability at the shoreline scarp is not currently understood but may need to be considered.

Hydrology and drainage

The hydrology of the Parnella area is a key factor of importance to all of the zones along the shoreline scarp. The behaviour and course of the groundwater in the area is currently not well understood and a detailed hydrological study may be required. Whether or not hydrological studies are conducted, there is much that can be done to improve the drainage of the area and to decrease the infiltration of water into the ground, where it will supply water to the seepages on the shoreline scarp. The 1993–1994 drainage works on the far northeastern end of the shoreline scarp appear to have been reasonably successful in limiting instability in that particular area, but different zones are likely to require different approaches. Without comprehensive, well-planned drainage works across the whole Parnella area the long-term stability will always be in question.

In developing a drainage plan for the Parnella area there are some important questions to consider:

- ☐ Are all piped/channelled flows on the shoreline scarp carried all the way to the shoreline? None of these should be emptying directly onto the slopes of the scarp.
- ☐ How is stormwater being disposed of for all the houses currently on or above the shoreline scarp? There is a clear need for stormwater infrastructure along the length of St Helens Point Road, both in terms of kerb and guttering and stormwater drains for household disposal.

- How will the drainage system cope with the periodic high-intensity downpours that naturally occur in the St Helens area? These large downpours often trigger landslides.
- Will excavation into or exposure of the underlying geology increase the likelihood of erosion? Some of the materials in the Parnella area have been shown to be susceptible to erosion, so channels or trenches cut through these, especially directly down the slope, could potentially lead to increased erosion if not properly designed.
- Are all houses on or above the shoreline scarp connected to the sewer mains? There are apparently a few remaining properties along St Helens Point Road and Treloggens Track that are not yet connected to the sewer main. The Mount *et al.* (2005) report identifies the Parnella area as a source of seepage from septic tank systems.
- According to Mount *et al.* (2005) all of the treated wastewater from the Stieglitz sewerage plant is currently used to irrigate the St Helens aerodrome. Where does this water go once it infiltrates? Does it, at least in part, eventually re-emerge at the shoreline scarp, and thus potentially add to instability?
- Where does all the stormwater collected from the subdivisions and roads on the plateau end up after it is discharged? Currently most of it is discharged to the ill-defined, swampy heads of the natural watercourses on the plateau, at elevations of 28–40 mASL. How much of this stormwater discharge then infiltrates into the ground and subsequently re-emerges at the shoreline scarp?
- Do the natural watercourses on the plateau need to be lined so that the stormwater discharge is carried all the way down to Chimneys Lagoon? The only improvement of these watercourses appears to have been excavation of the upper parts about 1980. Has this improvement been maintained?
- Will the drainage plan take into account the need for long-term maintenance? The ongoing maintenance of the drainage measures is vital to the long-term sustainability of development within the area.

Stakeholders

There are a number of stakeholders associated with the Parnella landslide area, including property owners and residents (both on or above the shoreline scarp and on the plateau behind), the Break O'Day Council, the Parks and Wildlife Service (managers of the Parnella Conservation Area), and the Tasmanian Government. Mineral Resources Tasmania, and its previous incarnation as the Department of Mines, has been involved with this area since the late 1960s in a scientific advisory capacity.

The long-term sustainable management of the Parnella landslide area will ultimately require a co-operative approach from all of the stakeholders. One of the most contentious issues in the past has been the responsibility for maintaining Treloggens Track.

Treloggens Track

Treloggens Track was originally constructed illegally and is now largely within the Parnella Conservation Area. This history has led to disagreement over who is responsible for its maintenance. Treloggens Track, along the face of the shoreline scarp, now provides the only access to many of the properties below St Helens Point Road and also hosts some of the sewerage infrastructure (Map 1 and 2).

The works undertaken by the Department of Main Roads and the Department of Lands in the 1980s have not addressed any issues in relation to Treloggens Track. Steane (1989) provides a summary of the circumstances at the time. The upgrading, proper drainage and on-going maintenance of Treloggens Track was considered an essential part of the overall management scheme, but none of this work was implemented. Apparently the entire project came to a halt when neither the Portland Municipal Council and landowners nor the Tasmanian Government would accept responsibility for this service road.

The responsibility for upgrading and maintaining this road needs to be settled to allow the necessary mitigation works to proceed. A drainage plan for the whole Parnella landslide area cannot be implemented without a major upgrade of Treloggens Track. The management of this track is fundamental to the long-term management of the stability in the whole area, so addressing this issue should be a priority.

Management of the proclaimed Landslip Areas

The legislation for proclaimed Landslip Areas is administered under the *Building Act 2000* and the associated *Building Regulations 2004*. As stated previously, the Landslip A area defines the zone where no more building is allowed, and the Landslip B area, with its strict development controls, is a form of buffer zone to the Landslip A area.

While the land within Landslip A areas is considered to be highly susceptible to landslides, the land within Landslip B areas is not necessarily susceptible to landslide movement. However activities within Landslip B areas have a high potential to affect the stability of the land within the adjacent Landslip A areas. This is a fundamentally important distinction that needs to be considered when a landslide risk assessment is being undertaken for a proposed development within the Landslip B area.

MRT staff have reviewed a number of stability assessments conducted within recent years for proposed developments within the Landslip B area. In nearly all cases the issue of potential effects on downslope stability has not been considered. Many of these reports have only considered the stability of the building site itself, which is of little relevance in this case. All such assessments need to show that there will be no adverse consequences for stability anywhere within the proclaimed Landslip Area, as required by the legislation. One of the key factors to consider in this regard is the downslope disposal of stormwater and waste water.

The legislation for proclaimed Landslip Areas prohibits the clearance of vegetation, except as required for the construction of an approved building. The available aerial photography shows that this requirement of the legislation has clearly been flouted within the proclaimed Landslip Areas by a number of landowners in the past. Thirteen properties have been identified where there has been significant vegetation clearance since the Landslip Area was proclaimed in 1981. If this is allowed to continue unchecked then there could be significant stability implications, which will not necessarily be restricted to the properties that have been cleared.

Conclusion

The Parnella landslide area is naturally prone to landslides and this instability has been exacerbated by human modification of the landscape. Major landslide issues that threatened infrastructure started soon after the first development of the area in the 1960s, but landslide activity remains episodic, as the most significant triggering factors are natural and related to weather and climatic fluctuations.

The new geomorphological mapping provides a detailed inventory of landslides in the area and an understanding of landslide evolution from the 1960s to the present. The study of the landslide history, past investigations and the performance of past mitigation measures has identified the key considerations required for the future management of the Parnella landslide area.

It is intended that the information compiled in this report should form the basis for the future sustainable management of the Parnella landslide area. With the aid of further studies, the stakeholders should be able to develop a landslide risk management strategy and ensure the long-term sustainability of development, both within the Parnella landslide area and on the surrounding plateau.

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Reports and maps issued by Mineral Resources Tasmania, and the former Tasmania Department of Mines, are available for downloading from the MRT website using the online search facility:

www.mrt.tas.gov.au – *Publications – Document Search*

www.mrt.tas.gov.au – *Publications – Geoscience Maps – Map Catalogue Search*

In addition to the reports and maps available on the MRT website, there are also various other resources available in regard to landslides in Tasmania. This includes general advice, brochures, a Web Map Viewer (choose *Map: Landslides*) and access to various other databases, e.g. sample analyses.

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Landslide Risk Management Guidelines

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[28 October 2013]

Photo 1

Active erosion below Treloggens Track, southwestern zone [landslide ID 5020?] — January 1971.

Photo 2

Site of removed holiday house above Treloggens Track (25 St Helens Point Road) [landslide ID 1090] — 1978(?)

Photo 3

Cliffs near Yellow Bluff showing extensive failure where vegetation has been cleared (Yellow Bluff area, transitional zone) [landslide IDs 5094 and 5098] — 1978.

Photo 4

Erosion and collapse at the shoreline continues, with trees falling onto the beach. This removes support for the slope behind, causing a layer of material to slowly slide down onto the beach (southwest of Yellow Bluff, transitional zone) [landslide ID 5089] — 26 July 2007.

Photo 5

Undercutting of the shoreline causing the ground to slide over the top (many trees on the beach) (southwest of Yellow Bluff, transitional zone) [landslide ID 5089 and 5090] — 26 July 2007.

Photo 6

Remains of 1980s shore protection works that formed a discontinuous log wall (approximately below properties 79–89 on Treloggens Track, central zone) — 26 July 2007.

Photo 7

This landslide has continued to be active with ongoing erosion of the landslide toe (below northern end of Treloggens Track, central zone) [landslide ID 5082] — 26 July 2007.

Photo 8

Shore protection works (constructed 1993–1994) are now significantly eroded (at cemented sand bluff, approximately below properties 41–45 on Treloggens Track) [landslide ID 1091, 5049] — 26 July 2007.

Photo 9

Landslides and flows are occurring despite the 1993–1994 shore protection works (particularly in the Yellow Bluff/Chimney Heights area, northeastern zone) [landslide ID 5136] — 26 July 2007.

Photo 10

Landslide [ID 4921] up against a house, and another [ID 4922] blocks the driveway, following a heavy rainfall event (cutting above 64 St Helens Point Road, southwestern zone) — 14 April 2011.

Photo 11

Landslide [ID 4924] affecting Treloggens Track (below properties 75–77, central zone) — 14 April 2011.

Photo 12

Major landslides caused by a heavy rainfall event following two particularly wet years (Yellow Bluff/ Chimney Heights area, northeastern zone) [landslide ID 5108] — 14 April 2011.

Photo 13

Major landslides now extend upslope into the rear of private properties in this area (Yellow Bluff/Chimney Heights area, northeastern zone) [landslide ID 5108] — 14 April 2011.

Photo 14

Series of earth flows over the 1993–1994 shore protection works following a heavy rainfall event (Chimney Heights area, northeastern zone) [landslide ID 5141 in the foreground] — 14 April 2011.

Photo 15

Unusual landslide involving complete separation and rapid movement of a block across the beach following heavy rainfall event (southwest of Yellow Bluff, transitional zone) [landslide ID 5093] — 14 April 2011.

APPENDIX 1

Summary of landslide investigations at St Helens (Parnella–Stieglitz)

1970, October 21 — Inspection by I. R. Mortimore (Report to Portland Council)

- **Two areas affected by landslide in southwestern third of current proclaimed Landslip Areas**.
- The southwestern area is about 150 m long (below 1–9 St Helens Point Road).
- The northeastern area is about 180 m long (below 19–33 St Helens Point Road).
- **Tension cracks up to 14 m above Treloggens Track, some within 10 m of holiday homes**.
- The geology of the area consists of quartz grit and sand overlying a thick bed of plastic clay.
- The **landslides are caused by both natural and human influences**.
- "The most important natural influence is the constant undermining of the foreshore by wave and current action within Georges Bay, ... the dominant winds ...... generate waves across the bay which eventually break on this coastline".
- "Old charts of the Georges Bay area show that this section of **the coastline has changed considerably over the past 60 years** and is subject to coastal erosion".
- "The inevitable result of settlement has been the disruption of drainage and the profound disturbance of equilibrium due to additional loading by houses and roads".
- "Trees and vegetation have been cleared .... this has serious effects on the stability".
- The drainage pattern on the slopes has been disrupted and the installed drains are discharging directly onto the lower slopes — one drain discharges directly into the head of a major landslide.
- Further water is directed underground from French drains, septic tanks, garden watering, etc.
- **Recommends shore protection works and improved drainage of the slopes** — drains are to carry the water all the way down to the beach and away from active landslides.

1970, November 18 — Inspection by I. B. Jennings (Department of Mines, 1972, Technical Reports 15:87–90)

- Investigates same area as Mortimore (1970) and largely concurs with his report.
- Also **a series of small landslides or embankment failures along St Helens Point Road** have occurred, mainly on the steeper slopes to the southwest, which have blocked drains.
- "**Very active shoreline erosion**" and "a great number of trees have fallen into Georges Bay".
- It appears a new and vigorous cycle of erosion has been initiated over the past couple of years — the previous two years of above average rainfall have followed at least two years of very much below average rainfall [similar to the situation in 2011].
- "**Unless urgent remedial steps are taken the settlement must be regarded as facing extinction**".
- The drainage from St Helens Point Road and Treloggens Track must be reconstructed.
- Water moves downward through the sand and then horizontally along the clay layers and emerges along the slopes as springs — water-softened clay layers can become slip surfaces.
- Warns that Treloggens Track is in danger of failing in the very near future.
- **Permanent protection will require expensive, large-scale engineering works that will then require continuing maintenance.**

1973, March 8 — Inspection by P. C. Stevenson (Department of Mines, Unpublished Report 1973/29)

- Report prepared in preparation for first proclamation of a Landslip Area at St Helens.
- This first proclamation only covered properties 1 to 53 on St Helens Point Road and slopes above St Helens Point Road upslope from property numbers 1 to 19.
- Landslide activity was reduced at the time of inspection following a dry summer.
- Main areas of recent movement listed as:
  - below Treloggens Track downslope from property numbers 7 to 11;
  - the seaward end of property numbers 23 to 33, and includes a section of **Treloggens Track that has dropped 1.0–1.5 m**;
  - the shoreline cliffs below property numbers 37 to 47 are collapsing;
  - small failures in the road cuttings on St Helens Point Road upslope from property numbers 1 to 19.

1973, July 10 — First Landslip Area proclamation

- *Local Government Act 1962*, Statutory Rules 1973, No. 119 (revoked in 1981).
- This was prior to the introduction of separate Landslip A and B areas.

1979, December 10 — Report by D. J. Sloane (Department of Mines, Unpublished Report 1979/53)

- The recommendations of the Mortimore and Jennings reports "have either been unheeded or forgotten".
- **The period 1975–1979 had seen considerable renewed and new landslide activity**.
- Two distinct areas of landslide activity:
  - **the 'Treloggens Track area'** — northwest-facing slopes, including area described by Mortimore and Jennings and extending northeast up to Yellow Bluff;
  - **the 'Chimney Heights area'** — generally north-facing slopes from Yellow Bluff eastwards to the outlet of Chimneys Lagoon.
- The geology of the area is Tertiary sediments consisting of gravel, sand and clay with the coarser sediments largely derived from granitic rocks. There is a repeated sequence of sand and gravel beds overlying clay beds, which tend to be laterally inconsistent.
- About 25% of rainfall on the area infiltrates to the water table or an impermeable clay layer at the base of the upper gravel — **groundwater is commonly seen issuing from the base of this gravel on the slopes along Georges Bay and seems to be the main source of seepages**.
- A large **gravel horizon ten metres above sea level, and another overlying clay just above sea level, also act as aquifers in some areas**. 'The Springs' area is a large zone of seepage.

- The natural drainage is complicated by drainage from houses, roads and pathways/tracks.
- Most of the French drain dispersal systems associated with stormwater and septic tanks are located close to the top of the slope and this water permeates into the aquifers.
- Drainage from St Helens Point Road is drained down to Georges Bay but some of these drains are in poor repair, are unlined, do not continue down to the water's edge, or drain directly into the heads or sides of landslide features.
- **The landslide affecting Treloggens Track has continued to be periodically active and has led to one holiday home (property no. 25) being removed and the foundations of another (property no. 21–23) being affected, and Treloggens Track has had to be periodically repaired** — the toe of this landslide has formed a distinct bulge onto the beach and is under wave attack.
- This active landslide is set within a much older landslide extending upslope to within about 25 m of the top side of the property boundaries, and showed signs of reactivation in 1979.
- **A similar landslide has occurred at the north end of the track** (below numbers 101 and 103).
- Several smaller landslides have occurred on the slopes below property numbers 113 to 133.
- There is a large landslide just west of Yellow Bluff, below property numbers 139 to 145, that appears to be affected by an upper and middle-slope gravel aquifer.
- **The 'Chimney Heights area' is undergoing very active shore erosion** with common bare cliffs, mudflows, debris slides and planar slab failures, exposing the clay and gravel on slopes.
- Failures here have become more obvious in the last three years and have extended into the properties upslope — the main aquifer is at the base of the upper gravels.
- The clays exposed appear to be both dispersive and highly plastic.
- This area is failing due to the over-steepening of the slope foot, the removal of vegetation, the introduction of water from septic tanks and stormwater drainage, and natural aquifers.
- **For the entire area, the removal of vegetation is undoubtedly a contributing factor in increased landslide activity** — many properties have been cleared of trees in recent years and there has been considerable removal of vegetation within the Crown Reserve.
- Above average rainfall has also contributed to increased landslide activity.
- Shore protection (logs, etc.) has helped in some places, but will not stop the landslides.
- Recommendations:
  - **greatly improved drainage from roads**;
  - **stormwater from properties to be piped away**;
  - **sewerage system installed for the area**;
  - **tree planting in areas of instability and all other trees should not be removed**;
  - **shore protection is desirable but not sufficient by itself**.

1981, August 4 — Second Landslip Area proclamation

- *Local Government Act 1962*, Statutory Rules 1981, No. 194.
- Expanded previous Landslip Area and defined separate Landslip A and B areas.

1985 — Paper by D. J. Sloane (reproduced as Department of Mines Unpublished Report 1985/71)

(Landslide zoning at Beauty Point and St Helens, Tasmania. *Proceedings of the Fourth International Conference and Field Workshop on Landslides, Tokyo, August 1985*, p. 47–54).

- Provides a description of extensive investigations and explanation of methodology for the zoning of proclaimed Landslip A and B areas at St Helens.
- Testing of the Tertiary age clays shows that they have effective residual shear strength values of c'_r 5 kPa and ($'_r$) 14° to 16°.
- **Landslide movements seem to occur soon after heavy rainfall**.
- Investigations suggest that rain falling on the plateau above the slopes is largely directed inland away from the watershed, which is close to the plateau edge above Georges Bay — an iron pan at 1–2 m depth within the sand and gravel has a regional slope towards the inland.
- **The Landslip A area identifies the areas considered most at risk from landslide movements and has had an approximate 15 m buffer added on the upslope side**.
- **The Landslip B area was added to control development activities that may affect the downslope stability**.

1989, February — Report by David Steane & Associates (to Department of Lands, Parks and Wildlife)

- *St Helens Landslip — an updating review and outline of options*.
- **Without improved drainage works the protection of the toe of the slopes at the shoreline cannot ensure the safety of the properties upslope**.

1989, July — Report by D. F. E. Bowen *et al.* (Unisearch Ltd, Report No. UT 89/11)

- Commissioned by Department of Lands, Parks and Wildlife to investigate appropriate methods of stabilising slopes between O'Connors Beach and Stieglitz Beach and their costs.
- **Main causes of instability are vegetation removal; infiltration of rain water, stormwater and sullage; together with toe erosion at the shoreline**.
- Testing of the Tertiary age clays by triaxial undrained quick tests gives shear strength values of c'_r = 4 to 8 kPa and $'_r$ = 3° to 16° — these are very low values.
- Clay samples showed high dispersivity and flow or slump when saturated.
- **Previous shore protection involved log walls along much of the area, but this has largely been unsuccessful** due to large gaps in the wall allowing material to leach through.
- The past use of geotextiles at the shoreline has also failed due to lack of structural support.
- Bituminous sprays have been used in some areas without success.
- Past use of rock at the toe of the log wall is of insufficient quantity to be useful.
- **Rock protection is the substantially cheaper option given that there are nearby sources**.
- Ideally requires minimum rock masses of 30 kg on a 1 in 1.5 slope or 22 kg on a 1 in 2 slope.
- To minimise materials a layered rock wall with a geotextile filter over fill is recommended.
- An alternative design is to use run of quarry material with 50% of rock greater than 30 kg and a wider wall to avoid the necessity of using a geotextile filter cloth.
- **Recommends using the layered rock wall along most of the shoreline and using the alternative design in the**

Chimney Heights area where the rock wall is to be constructed in two stages — firstly as 1.0 m (AHD) causeway (3.5 m wide) to deposit material and secondly reshaped up to 2.0 m (AHD) to the design profile.

- **Recommends prohibition on vegetation removal along the entire length of the area**.
- **Recommends carefully designed drainage — lined and impermeable, of adequate capacity and not running near parallel to the contours of the slope**.
- Other slope stabilisation measures seem to be focussed on addressing shallow failures along steeper slopes in the Chimney Heights area and do not address deeper failures to the southwest.
- They estimate the present risk of minor landslides as occurring annually with severe landslides on a 35 year return period and disastrous landslides on a 140 year return period.
- "**there is potential at this site for a major disaster to be realised**".

1993–1994 — Shore protection works undertaken

- Some of the rock/gravel wall shore protection works recommended by Unisearch were implemented from the southwest and northeast ends, with a gap of 990 m left in the centre.
- These protection works were carried out in part along the shoreline cliffs of the Chimney Heights area (630 m) and from the southwest end to the sandy cliff (920 m), although it appears these works were not up to the specifications outlined in the Unisearch report.
- **There has been significant erosion of these shore protection works** and only a relatively thin remnant of them remains along some sections of the shoreline.

1990, June 29 — Correspondence with Portland Council, D. J. Sloane (Department of Mines)

- In relation to one particular property the Portland Council requested confirmation of the extent of the proclaimed Landslip Areas and advice on any other landslide prone areas.
- A map was provided showing **an additional landslide prone area, extending southwards from the southwestern end of the proclaimed Landslip Areas**, with a recommendation that "a stability assessment be required before any proposed development of this area is considered" as is the case with proclaimed Landslip B areas.

1992, July 22 — Correspondence with Town and Country Planning Commission, D. J. Sloane (Department of Mines)

- In reviewing the proposal for a new Portland Planning Scheme, 1992, it was recommended that, in addition to the regulation governing the proclaimed Landslip Areas, **the area as defined above should be included in the planning scheme as an area where proposed developments require a stability assessment**.

1993, February 17 — Correspondence with Portland Council & others, B. D. Weldon (MRT)

- Council was notified of concerns about **severe shore erosion below the southwestern end of Treloggens Track**.
- Former shore protection works, consisting of geotextiles and tree trunks spiked together, had been removed over a length of 30–40 m — presumably by storms.
- Recent erosion had advanced inland about ten metres and could threaten slope stability.
- Above this area the table drain on the upslope side of St Helens Point Road has been poorly maintained and as a result water is now infiltrating into the ground and affecting the road surface, and this could potentially add to slope instability.
- It is **strongly recommended that the shore protection be reinstated** and that the drainage be repaired and maintained into the future.

2000, April–May — Subdivision application and subsequent tribunal hearing

- One aspect of this subdivision proposal, which was partly within both the proclaimed Landslip A and B areas, concerned **a conflict between the requirements of the Building Act**, in regard to building in proclaimed Landslip Areas, **and the requirements of the 'Bushfire Prone Areas Code'** in the Break O'Day Planning Scheme.
- The *Building Act 2000* requires that a person must not remove any vegetation in a proclaimed Landslip Area, except in accordance with the Building Regulations. The Building Regulations 2004, as did preceding landslip legislation back to the 1970s, only allow, with the written agreement of a permit authority, vegetation removal "**for, or in connection with, building work** on land in a landslip area".
- The 'Bushfire Prone Areas Code' in the Break O'Day Planning Scheme 1996 required the establishment of a 'Building protection zone (BPZ)' and a 'Fuel modified buffer zone (FMBZ)' around developments within areas identified as prone to bushfire — these zones would require the clearance of certain vegetation.
- Ultimately the conflict was not resolved at the tribunal because the requirements of the 'Bushfire Prone Areas Code' alone were enough to disallow the proposed subdivision.

2011, April

- Major reactivation of large parts of the proclaimed Landslip Area following heavy rain on 12–13 April 2011 caused numerous landslides in the St Helens area.

APPENDIX 2

Sample descriptions, St Helens

by R. S. Bottrill and R. N. Woolley

Introduction

Four samples submitted to the MRT laboratories from the St Helens area were analysed and described; the sample details are shown below.

Regist. Number	MRT (TIGER) Sample ID	Location	Sample description
E202419	148052	St Helens Point Road, cutting	stratified, coarse sand
E202421	148054	St Helens Point Road, cutting	pale, fine-medium sand
E202422	148055	St Helens Point Road, cutting	gravelly sand
E202424	148060	Chimney Heights, shoreline scarp	stratified sand

The samples were examined by low power stereomicroscopy and high power polarised light microscopic techniques in the MRT laboratories, Rosny Park. Sand fractions were separated, washed and examined, and photographed.

Sample descriptions

E202419 (ID 148052)
St Helens Point Road, cutting
Stratified coarse sand

The sample is a pale yellowish coarse gravelly sand. Under the stereomicroscope the sample contains mostly coarse sand to fine gravel (<5 mm) with a pale yellowish silty, limonitic, clayey matrix, partly cementing some of the sand. The sand is mostly greyish, granitic-like quartz, with some white, possibly vein-style, quartz. The quartz is rounded to well rounded, some is quite polished and smooth; it is mostly quite equant to spherical. Some contains some attached white feldspar. There are minor iron oxides and possible lithic particles.

The sample is probably a beach sand or dune sand, from its high roundness, and of granitic derivation.

E202421 (ID 148054)
St Helens Point Road, cutting
Pale, fine–medium sand

The sample is an off-white, fine to coarse-grained sand. Under the stereomicroscope the sample contains subequal amounts of medium to coarse-grained quartz sand (<3 mm) and particles of hard, white kaolinitic clay. The clay particles are angular and appear to be replacements of granitic feldspar. The quartz sand is all greyish, granitic-like quartz. The quartz is angular to highly angular, and is mostly quite equant to irregular in shape. There are rare opaques (tourmaline?) but no lithic particles.

Based on its angularity and constitution, the sample is probably a decomposed granite, or material derived from such, which has undergone very little or no transport or mixing with other material.

The sample is a creamy coloured, coarse gravelly sand. Under the stereomicroscope the sample contains mostly coarse sand to fine gravel (<10 mm) with a pale yellowish to white, silty-clayey matrix. The sand is mostly greyish, granitic-like quartz, with some white siliceous sandstone clasts. The quartz is highly angular to rounded, and slightly frosted; it is mostly quite equant to spherical. There are abundant iron oxides and possible tourmaline and other heavy mineral particles.

Based on its angularity, surface textures and constitution, the sample is probably a fluviatile sediment.

E202424 (ID 148060)
Chimney Heights, shoreline scarp
Stratified sand

The sample is a creamy coloured, coarse gravelly sand. Under the stereomicroscope the sample contains mostly coarse sand to fine gravel (<5 mm) with a little pale yellowish to white, silty-clayey matrix. The sand is mostly greyish, granitic-like quartz, with some white to yellowish clay grains, probably kaolinised feldspars, and traces of lithic particles (siltstone or basalt?). The quartz is highly angular to rounded, and slightly frosted; it is mostly quite equant to spherical. There are traces of iron oxides and possible tourmaline and other heavy mineral particles.

Based on its angularity, surface textures and constitution, the sample is probably a fluviatile sediment.

Conclusions

Based on the constitution and textures in these samples, they show a range of origins, from decomposed granite, probably with little or no transport, to fluviatile sediments, to dune or beach sands. They are all mostly of granitic, derivation.

[4 October 2013]

Photo 1

Sand extract from sample E202419 (sample ID 148052).

Photo 2

Sand extract from sample E202421 (sample ID 148054).

Photo 3

Sand extract from sample E202422 (sample ID 148055).

Photo 4

Sand extract from sample E202424 (sample ID 148060).