

1977/53. Investigation of the Lawrence Vale landslip.

C.J. Knights

*Abstract*

Between 1956 and 1970, slope instability in the Lawrence Vale area of Launceston destroyed 30 houses, while a less severe slip in nearby Powena Street destroyed a further five houses.

Tree planting and drainage programs were undertaken in the late 1960's and the area has become more stable in recent years, although slow upslope development of the slip has cut back into Bellvue Avenue.

From studying the history of the slip, the surface expression and from subsurface investigations which includes twenty shallow auger holes, it appears that the main zone of instability is actually a complex of relatively shallow slips.

An aquifer of fine sand exists in the vicinity of Effingham Street and Lawrence Vale Road. This aquifer has a channel downwarp and it contains water under pressure, which may be supplemented by sewage. Materials in, and closely above the aquifer, are weak, and form a base upon which the upslope land can slip. Land downslope of the aquifer receives seepage and the sediments are soft and moist. Clay is close to its  $c' = 0$  condition. Land-slipping below the aquifer takes place in these softened materials. The movements are at variable depths.

Downslope of the aquifer, movement can be divided into two lobes. The northern lobe is 8 m deep near hole 1 but becomes shallow and translational downslope and does not disturb the embankment below Meredith Crescent. The southern lobe is about 7 m deep and crosses Meredith Crescent and extends down to Vernon Street.

The conditions which caused this landslip exist along the slope, and the extent may be defined by further work.

## 1977/53. Investigation of the Lawrence Vale landslip.

C.J. Knights

During 1956, slope instability occurred in the Lawrence Vale area of Launceston [EQ127107] and during the following 15 years about 30 houses were destroyed. Most of the movement occurred below Bellvue Avenue and in Lawrence Vale Road and Meredith Crescent, with a lobe of instability extending down Vernon Street. A lesser zone of instability destroyed five houses on the corner of Powena and Curena Streets (fig. 1).

In recent years, both slip areas appear to have become more stable, probably due to the tree planting and drainage programs which were instigated in the late 1960's. Some upslope extension of the main slip area has occurred above Bellvue Avenue.

From studying the history of instability, the surface expression, and from subsurface investigations, the author considers that the main slip area is actually a complex of relatively shallow slip lobes. Below Lawrence Vale Road, these shallow slips have occurred within moist, fully softened, sandy clay which occurs downslope of a bed of wet, fine sand containing pressure water. This bed is thought to be a major source of moisture for the fully softened materials downslope. The fine sandy bed has very little inherent strength and it forms a basal failure zone for the land upslope of Lawrence Vale Road.

It would appear that the bed of sand and water, located above Lawrence Vale Road, is a major factor in initiating and continuing the instability.

## HISTORY OF THE LANDSLIP

Damage to roads and houses became evident in 1956 near the junction of Bellvue Avenue and Lawrence Vale Road. Carey (1958) wrote a detailed description of the, then, well developed landslide in which he described the slip as being compound, with two principle lobes side by side and each comprising two masses, one above the other. Houses riding passively on these slips were little damaged, but houses at the edges, the head scarps or toe heaves were severely damaged. By this time scattered damage had occurred throughout most of the area now affected.

From Carey's report, there is evidence of an older slide which existed prior to house building and which had a head scarp below Lawrence Vale Road and a toe which formed a marked terrace above Meredith Crescent. At least two houses above Bellvue Avenue, both of which are now destroyed, had their foundations built over an old head scarp.

The slip in Powena and Curena Streets is described by Carey as being a simple failure, 67 m in length and 36 m wide. The heave zone ran through houses in Legana and Powena Streets, with incipient tension cracks extending back to the south part of 66 Lawrence Vale Road.

During the late 1950's, extensive drilling by Aitchison and Gill led them to believe that the present landslip was part of an older, deep seated structure and that the similar conditions were present throughout Windmill Hill (Aitchison and Gill, 1960). The investigations led them to believe that structural dips in the sediments and zones of subsurface leaching were involved.

By 1961, three houses had been removed in the main slip area and a



Figure 1



Aerial photograph of slip area, September 1960. Stars indicate houses subsequently demolished.

further fourteen were due for demolition to allow for tree planting and conversion of the area to parkland. Planting of tree Lucerne began in 1967, but the trees failed to take root and the area was replanted in 1968. Wet winters in 1968 and 1969 caused the slip to be particularly active, so that the trees had difficulty in becoming established.

In September 1969, deep drainage trenches, backfilled with rubble, were dug by backhoe into the toe of the slip above Meredith Crescent. Although the slip had been recently active and had flowed onto the roadway, the 5.4 m deep southern trench, extending 3.6 m below road level, only encountered moist material in the upper levels. The bottom 1.8 m of the trench was dug in dry, medium grained sand. (Stevenson and Jennings, 1971).

The northern drain encountered soft patches in the upper 1.8 m only. A diagonal trench was cut across the slope and caused a localised failure, again at a depth of about 2 m.

Despite the wet winters of 1973/74, the slip has stabilised in the last few years and the trees have become established. Lawrence Vale Road and Bellvue Avenue continue to suffer regular damage as the slip drops away from the stable land and continues to slowly extend upslope into Bellvue Avenue.

#### EXTENT OF RECENTLY ACTIVE AREA

The area in which active movement has recently occurred is shown in Figure 1. The main complex has an uneven shape and has flowed out over Meredith Crescent on many occasions. Drainage trenches dug through the steep bank below the road encountered lithic sand and show that this bank has not been affected by the slip.

The southern side of the slip extends in a lobe across Meredith Crescent and down Vernon Street. The affected section of Meredith Crescent has repeatedly subsided. These two sides of the slip correspond to the lobes discussed by Carey (1958).

#### PROGRAMME OF INVESTIGATION

During the recent investigation, 20 auger holes were bored to a maximum depth of 12.5 m. The augering was done without adding water and recovered disturbed samples. This method of drilling allows full sample recovery of material at their natural moisture content but destroys the structural characteristics of the material.

Bore logging was done on site and the sample condition noted. Aquifers and piezometric levels were recorded.

Bores were drilled on the slip and laterally away from the slip to compare presently stable and unstable areas, and also to locate the extent of the water filled sand horizon. A seismic survey was also undertaken.

#### DRILLING RESULTS

Drilling results are summarised in Appendix 1 and sections are shown in Figure 3.

#### LOWER SECTION OF SLIP

In this section of the slip, which is downslope of the sandy horizon



53-7

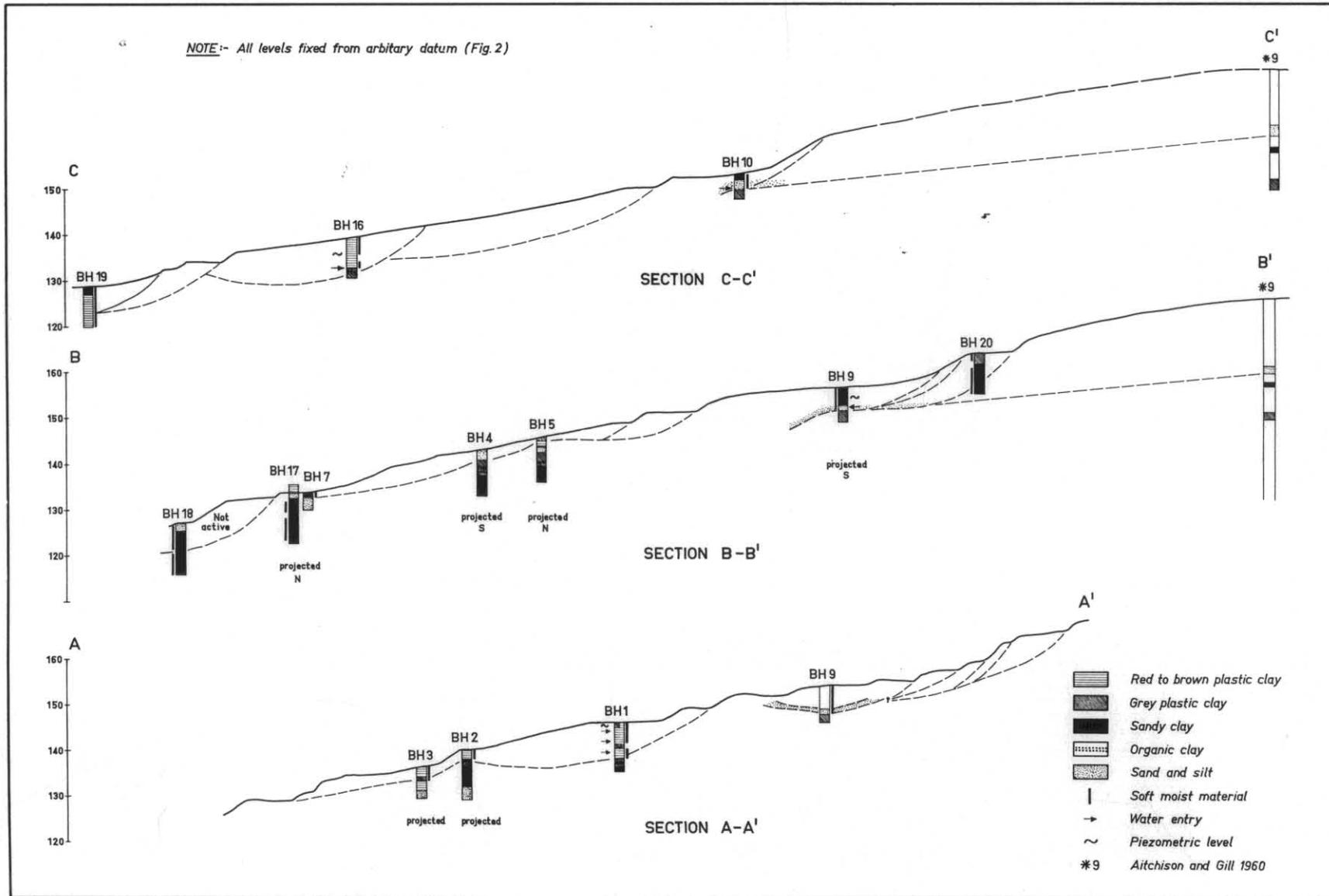


Figure 3a. Sections through landslide.

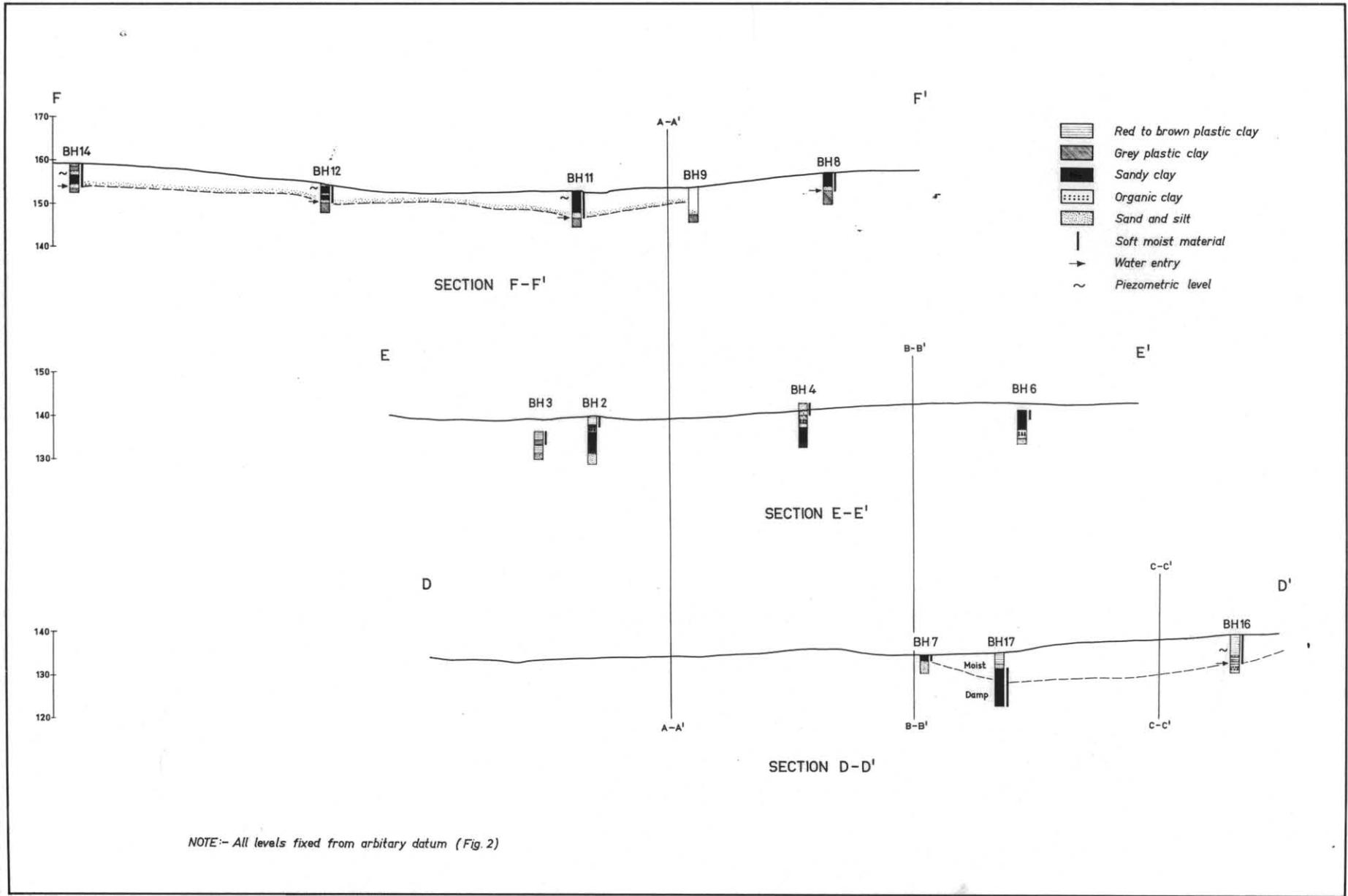


Figure 3b. Sections through landslide.

8/22

which traverses Lawrence Vale Road and Effingham Street, red and grey plastic clay with carbonaceous horizons, sandy clay and sand were encountered.

The grey clay is usually very plastic, high in the CH range, even when it contains up to 20% sand. Organic horizons containing carbonaceous fragments, where the clay is a deep purple colour, also occur. Deep red to fawn clay may also be plastic.

The sandy clay tends to be orange or fawn in colour, grading into orange yellow, lithic clayey sand.

#### *Material consistency*

While the plastic clay is very stiff when damp or moist, it becomes hard and cracked on drying. Soft wet plastic clay was only encountered in hole 3.

Dry and damp sandy clay has a crumbly consistency and becomes very soft when moist. Many of the holes in the lower section of the slip encountered moist sandy clay in its fully softened state (i.e.  $c' = 0$  condition). Dry, crumbly or free running sandy clay and lithic sand occurred in the lower, northern section of the slip.

Free groundwater from about 6.5 m in hole 16 was analysed (Appendix 2). The high salinity indicates a long percolation path within the Tertiary sediments.

#### UPPER SECTION OF SLIP

A wet silt and sand horizon containing pressure water was intercepted by holes 8, 9, 10, 11, 12 and 14. The general drilling sequence was firm sandy clay near the surface, underlain by wet sandy clay, which increased in permeability with depth until reaching an horizon where pressure water flowed into the hole. Stiff plastic grey clay occurred below this level.

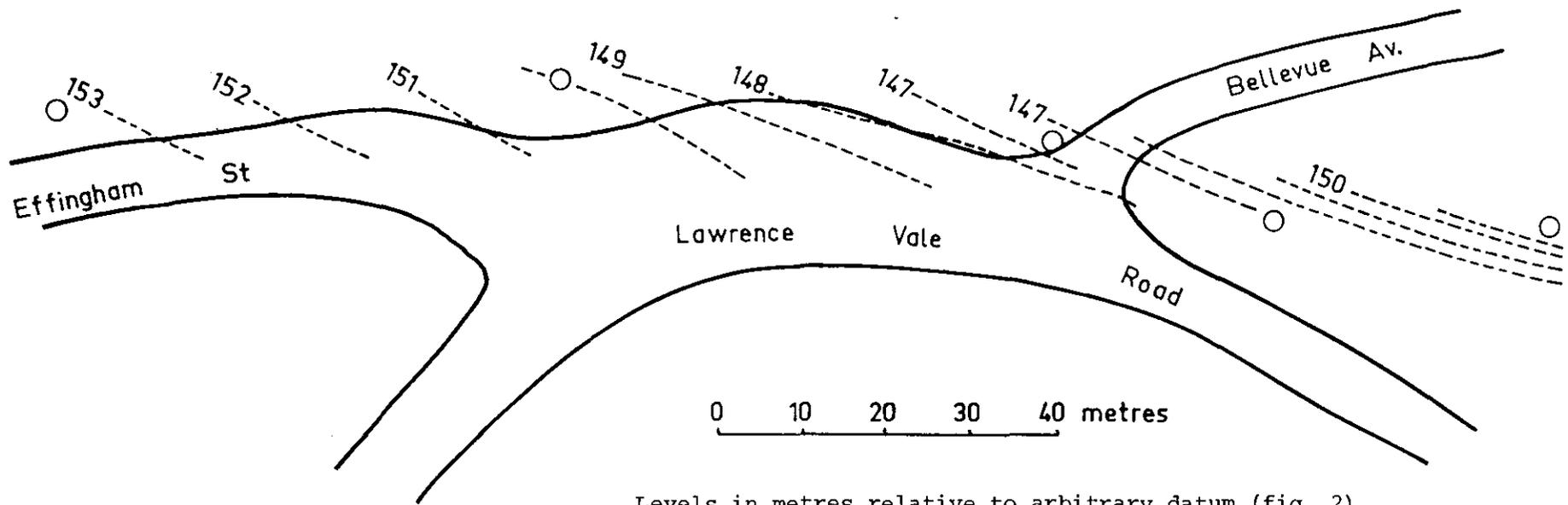
By contouring the depth to the base of the sand and the piezometric surface (figs. 4, 5), a channel flowing along Effingham Street and Lawrence Vale Road at about 6 m below the present ground surface can be recognised. A sandy bed was located in bores 8 and 9 of Aitchison and Gill (1960). This is shown in sections B-B' and C-C' in Figure 3. This sandy aquifer is considered to be an horizon within the Tertiary sediments and the "channel" below Lawrence Vale Road is a downwarp in the aquifer.

Local residents report that there used to be a spring, or a stream, which crossed the junction of Lawrence Vale Road and Effingham Street and which was covered over by road building. This stream is closely in line with the subsurface channel and a number of springs probably occurred, which were surface expressions of the deeper groundwater flow. Blocking of these springs may have increased the water pressure in the aquifer.

#### GROUNDWATER CHEMISTRY

A water sample taken from the sandy aquifer in August 1976 (Appendix 2) contained 520 ppm total dissolved solids, with a pH of 7.4, which is normal. A further sample taken in September 1977 contained 380 ppm TDS with a pH of 5.8, which is unusually low. The low salinities demonstrate that the aquifer is closely connected with surface waters. A pH of 5.8 suggests contamina-

53-10



Levels in metres relative to arbitrary datum (fig. 2)

○ Bore hole

Figure 4. Levels to base of sandy aquifer.

5 cm

10/32

53-11

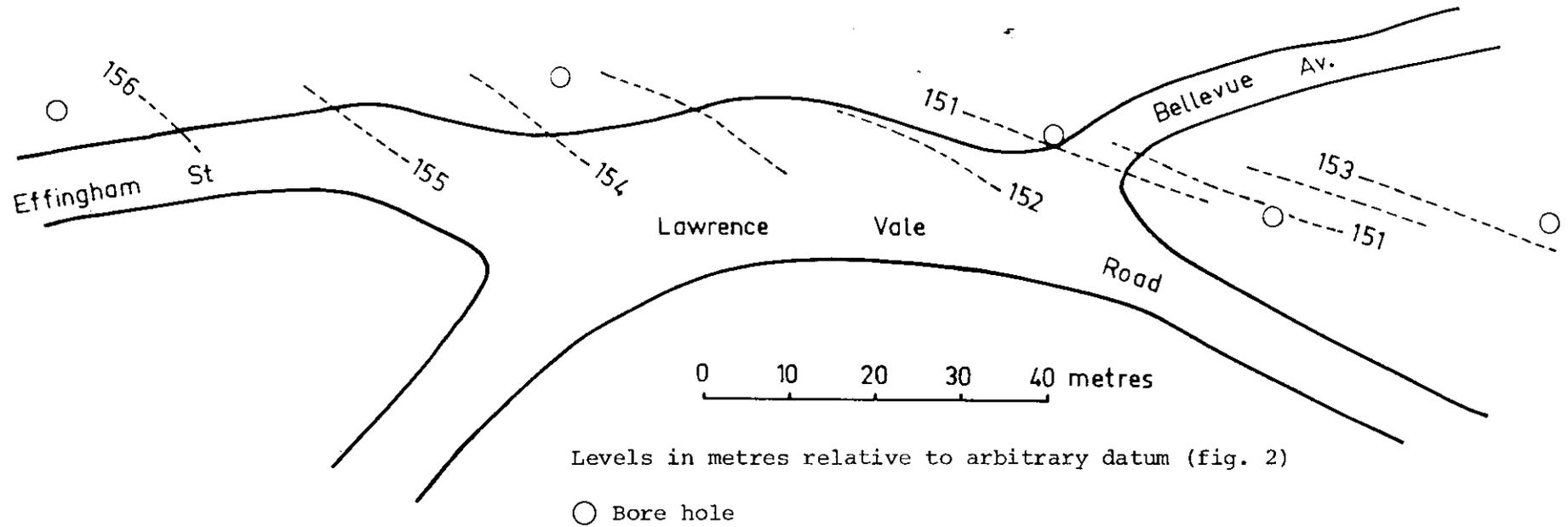


Figure 5. Piezometric levels of groundwater in the sandy aquifer, October 1977.

5 cm

11/22

tion by acid water, possibly by sewage. This should be investigated.

#### TRAFFIC VIBRATIONS

A previous investigation by Knights (1974) recorded vehicle vibrations in the landslip area. Results showed that in the upper part of the slip, near Lawrence Vale Road, and also in the toe of the slip above Meredith Crescent, the vibration amplitudes were very slow to attenuate. However in the bank below Meredith Crescent, the attenuation was normal, which again suggests that this bank is dry and stable.

#### SEISMIC SURVEY

Two seismic spreads were fired, one across the slip below Lawrence Vale Road and the other across the slip above Meredith Crescent. Geophone spacing was 7.6 m.

The results of these spreads are difficult to interpret, but the following general conclusions can be drawn. There is a near surface layer with a velocity of less than 360 m/s overlying an extensive layer with a velocity of 450 - 900 m/s. Beneath this layer, materials have the normal velocity for Tertiary sediments (1 200 - 1 500 m/s). There also appears to be a deeper fast layer with a velocity of 3 000 m/s.

The 450 - 900 m/s layer extends to 14 - 16 m below the surface in the lower part of the slip and up to 29 m below surface beneath the upper spread. This indicates that the materials have been disturbed by landslip or by stress release. Beneath the lower spread, the seismic velocities are slow in the northern section, rising to 900 m/s in the south.

The deep, fast layer, 39 m below Meredith Crescent, may represent the Tertiary pebble beds which were located by Aitchison and Gill (1960).

#### THE FORM OF THE LANDSLIP

##### *Below Lawrence Vale Road*

No evidence was found to suggest that this part of the present slip is of a deep rotational nature. Rather, it appears to be a composite of at least two shallow rotational, and translational slips. As the drill used could only reach to a maximum depth of 12 m, it is important to establish that drilling was not into an intact slip block, missing the slip plane horizon at depth. If such a deep rotational slip plane exists, it must reach the surface at the edges, head and toe of the slip. No such disturbed layer was found, despite the fairly close network of holes.

Deep rotational slips occur within the Tamar region, but these have a distinctive topographic expression and a smoother edge outline than this slip. All of the known present day slips are shallower than 12 m.

This does not exclude the possibility that the existing slip movement is a minor reactivation of a deeper, more extensive landslip which existed in earlier times. Drilling off the slip, such as in holes 13 and 18, encountered a considerable depth of soft moist sandy clay, which is probably disturbed. The seismic survey also indicated 15 - 27 m of rather low velocity substratum. Ancient, very large landslips are a common feature within the Tamar Valley.

The general sequence of drilling was:

Surface - air dried soil and clay (dependant on surface drainage).

- moist fully softened sandy clay.

Base - less moist to dry material.

On the slip itself, the moist, soft material is considered to indicate the depth of recent movement, although this wet zone will have been modified by the trees and the improved drainage. The depths are variable, but there is a pattern which correlates with the two slip lobes observed by Carey (1958).

The southern lobe is less extensive in surface area, but is deeper. It was reached by holes 16, 17 and 19 and appears to be about 7 m deep (Fig. 3, Section C - C' and D - D'). The more extensive northern lobe does not affect the embankment below Meredith Crescent and appears to be largely translational and only 2 - 3 m in depth. This lobe was drilled by holes 2, 3, 4, 5, 6 and 7 (Fig. 3, Section E-E'). Hole 1 encountered a deeper soft section, which suggests that this is shallow rotational and that downslope of this is a shallow flow. (Section A-A').

Section B-B' shows that the slip is shallow above Meredith Crescent and does not affect the embankment below, although hole 18 intersects a considerable depth of moist or damp, soft sandy clay. A fairly soft and damp clay below the moist, soft layer occurs in holes 17 and 1. Soft moist clay was also present in hole 13, suggesting that a deeper and more extensive slip has existed in that part.

#### *Form of the landslide above Lawrence Vale Road*

A sandy aquifer which is very wet and has significant pore pressure occurs above Lawrence Vale Road. This horizon is believed to form a basal slip zone of low strength and relatively high pore pressures on which the upper slopes can fail. (Fig. 3, Sections A-A', B-B', C-C'). Thus the slip is able to eat back into the hillside.

#### CONCLUSIONS

An aquifer of fine sand exists in the vicinity of Effingham Street and Lawrence Vale Road.

This aquifer has a channel downwarp and it contains water under pressure, which maybe supplemented by sewage.

Materials in, and closely above the aquifer, are weak, and form a base upon which the upslope land can slip.

Land downslope of the aquifer receives seepage and the sediments are soft and moist. Clay is close to its  $c' = 0$  condition.

Landslipping below the aquifer takes place in these softened materials. The movements are at variable depths.

Downslope of the aquifer, movement can be divided into two lobes. The northern lobe is 8 m deep near hole 1 but becomes shallow and translational downslope and does not disturb the embankment below Meredith Crescent (Section A-A'). The southern lobe is about 7 m deep and crosses Meredith Crescent and extends down to Vernon Street.

The conditions which caused this landslide extend along the slope.

REMEDIAL MEASURES

Shallow based landslips can respond to relatively cheap remedial measures. The trees which have now become established and the drains dug into the top of the slip already work in drying the ground to a useful depth. Such methods would be far less use in a deep slip.

The sand aquifer does need some form of drainage. Drainage in this aquifer would reduce pore pressure, thus increasing upslope stability and would also lessen infiltration of water into the material downslope.

As the aquifer is shallow, drains could be installed without undue expense, certainly for considerably less than the cost of one house. However, owing to the high proportion of fines in the sand, a filter or screen will be required in the drainage system.

The first method which suggests itself is digging deep drains by backhoe and filling with irrigation pipes and rubble. This method is probably not feasible, as the walls of the trench would probably collapse.

Another method of drainage is to drill horizontal auger holes from the access road below Lawrence Vale Road. When the auger is withdrawn the hole will collapse, but plastic pipe could be installed using a bailer. The pipe should have wide slots cut in it and once installed should be filled with sausages of gravel (pre-formed gravel packs).

For the above method to be effective, a small number of vertical auger holes may be needed to design the horizontal holes. The process should be supervised by a geologist, and the intercepted drainage must be taken away to a recognised channel.

Trees are considered to be excellent for shallow drying work and more trees should be planted above Lawrence Vale Road and in Bellvue Avenue.

Tree planting should also be extended throughout the area known to be underlain by moist softened clay.

FURTHER WORK

More work is needed to determine the extent and nature of the sandy aquifer, and to determine the extent of hillside which is underlain by moist, fully softened clay. This may be done by auger drilling and geophysical methods, working outwards from the known area. From such work it will be possible to delineate areas of risk with reasonable accuracy. It may also be possible to reduce infiltration into the aquifer, once more is known about it.

Soil mechanics and stability analysis could be a useful addition in deciding stability. Unless a slip is previously known to exist, remoulded soil strengths are appropriate. Where previous areas of movement are involved, residual strengths should be used.

More work should also be done on the analysis of groundwater of the sandy aquifer to determine whether it is contaminated by sewage.

REFERENCES

AITCHISON, G.D. 1961. *Landslides in Launceston and the Tamar Valley*.  
 [Public lecture, Albert Hall, Launceston, 11.12.1961].

AITCHISON, G.D.; GILL, E.D. 1960. Progress with the investigation of  
 landslips in the Lawrence Vale area. *C.S.I.R.O. Division of Soil  
 Mechanics* [Letter to Mayor, City of Launceston, 12.9.1960].

CAREY, S.W. 1958. Preliminary examination of landslides in Lawrence Vale  
 area, City of Launceston. [Report to Town Clerk, City of Launceston].

GILL, E.D. 1961. *The geological background to problems of landslip in  
 Launceston, Tasmania*. [Public lecture, Albert Hall, Launceston,  
 11.12.1961].

KNIGHTS, C.J. 1974. Traffic vibrations, Lawrence Vale. *Dep.Mines.Tasm.*  
 [Memorandum to Town Clerk, City of Launceston, 12 November 1974].

STEVENSON, P.C.; JENNINGS, I.B. 1971. Further report on a landslip in the  
 Lawrence Vale area. *Tech.Rep.Dep.Mines Tasm.* 14:84-88.

[28 November 1977]

## APPENDIX 1

## Logs of bore holes, Lawrence Vale.

Hole	Depth (m)	Description
1	0-0.9	Laminated red, orange and grey clay. Shiny, plastic and damp.
	0.9-1.8	As above, then into moister red-orange clay at about P.L. Very plastic.
	1.8-3.6	As above.
	3.6-4.5	Light orange brown clay, patches of grey and some moist, black organic matter in thin laminae.
	4.5-5.5	Higher proportion of grey clay than above, dryer and quite stiff.
	5.5-6.4	Softer, homogeneous orange brown clay.
	6.4-7.3	Medium soft clay, predominately orange brown with some grey and red laminae.
	7.3-8.2	Sudden change to grey very plastic clay, shiny, grey to dark purple-grey. Some lignite pieces. Stiffer, but still easily squashed by finger pressure.
	8.2-9.1	Fawn and grey clay, very plastic. Grey clay is stiff, fawn clay is soft.
	9.1-10	Stiff orange fawn clay with sandy laminae and ironstone fragments.
	Hole dry after drilling, and dry next day. Water level at 0.75 m below surface after 14 days.	
2	0-0.9	Soft orange clay with laminae of fawn clay and sand.
	0.9-1.8	Soft orange-brown clay, ironstone fragments and some sand.
	1.8-2.7	Fawn clay and very stiff plastic grey clay, yellow laminae.
	2.7-3.6	Stiff, very plastic clay. Grey to purple-grey. Lignite laminae.
	3.6-4.5	Moderately dry and crumbly clay. Orange-fawn and some grey.
	4.5-5.4	Crumbly clayey sand to sandy clay with ironstone pieces. Orange, minor grey patches and small organic fragments.
	5.4-6.4	As above. Orange sandy clay and about 30% clayey sand.
	6.3-7.3	Crumbly sandy clay.
	7.3-8.2	Crumbly, sandy, orange to fawn clay.
	8.2-10	Fine, dry, loose, lithic, clayey sand.
	10-10.9	Plastic clay layered with sand. Dry.
3	0-0.9	Soft, orange, laminated plastic clay.
	0.9-1.8	Soft, plastic clay, with red, grey, fawn and yellow laminae.
	1.8-2.7	Predominately grey plastic clay. Very soft and very plastic. Light grey colour with no organic matter.

Hole	Depth (m)	Description
3	2.7-3.6	Stiff red clay, very shiny and plastic.
	3.6-4.5	As above but dryer.
	4.5-5.4	Dry, crumbly sandy clay and clayey sand. Red and yellow colour and some ironstone pieces.
	5.4-6.3	Fine dry clayey sand.
Dry hole. Pipe installed.		
4	0-0.9	Road metal over wet, dark grey sand.
	0.9-1.8	Moist, stiff yellow clayey sand and ironstone pieces. Water present.
	1.8-2.7	Soft, wet, yellow clayey sand.
	2.7-3.6	Still, very plastic light grey clay. Also laminated orange, yellow and grey clay with peaty layers and rootlets.
	3.6-4.5	Very plastic shiny clay with grey, purple, red and black laminae. Also organic matter and ash like material.
	4.5-5.4	Stiff, green-grey slightly sandy clay with organic flecks.
	5.4-6.3	Crumbly fawn sandy clay and some grey clayey sand. Small ironstone pieces.
	6.4-7.3	As above.
	7.3-8.2	Similar, but more nodules of clayey sand, some orange and some grey.
	8.2-9.1	Crumbly, light brown sandy clay over light, friable dry clayey sand.
9.1-10	As above, over less crumbly, sandy clay.	
5	0-0.9	Wet sand over stiff, plastic sandy clay. Orange and grey colour.
	0.9-1.8	As above.
	1.8-2.7	Friable orange sand over grey crumbly sand made up of clayey sand, organic flecks and soft ironstone.
	2.7-3.6	Dry clayey sand with nodules of clay and organic material.
	3.6-4.5	Stiff, plastic, grey and red clay with friable oxidised patches and ironstone pieces.
	4.5-5.4	Stiff plastic clay. Mostly grey and red with some dark grey.
	5.4-6.4	Plastic clay, laminated, grey and purple.
	6.4-7.3	Crumbly light brown clay.
	7.3-8.2	Crumbly grey and brown clayey sand and sandy clay.
	8.2-9.1	Friable light brown sandy clay and clayey sand.
9.1-10	Less crumbly light brown sandy clay. Some fibrous organic material.	
6	0-0.9	Medium soft, laminated sandy clay with red, orange and grey colours.
	0.9-1.8	Medium soft sandy clay, with patchy grey and orange brown colours.
	1.8-2.7	Crumbly sandy clay. Orange, red and grey with some organic matter in grey bands.
	2.7-3.6	Crumbly clay of medium plasticity, mostly orange and red.

Hole	Depth (m)	Description
6	3.6-4.5	Stiff grey sandy clay, some red friable clay and some very plastic clay.
	4.5-5.4	Stiff, very plastic, shiny blue-grey clay.
	5.4-6.4	As above with black and brown laminae.
	6.4-7.3	Fine, crumbly clayey sand over tough sandy clay with sand laminae.
7	0-0.9	Damp sandy laminated orange clay.
	0.9-1.8	Dry, orange clayey sand.
	1.8-2.7	As above.
	2.7-3.6	As above.
8	0-0.9	Damp orange clay, laminated with sand.
	0.9-1.8	Laminated grey and orange clay and sand, moist.
	1.8-2.7	Soft, sandy, plastic, clay.
	2.7-3.6	Soft wet sandy orange clay with ironstone pieces. Some plastic clay with shiny texture.
	3.6-4.5	Sand and water about 4.2 m, over very soft orange sandy clay. Small return.
	4.5-5.4	Tougher drilling no return.
	5.4-7.2	Small return of wet sandy clay and stiff, plastic, purple clay of smooth texture, over very stiff grey and orange clay. Probable depth of clay about 6 m.
9	0-0.9	Medium to dark brown plastic, hard clay.
	0.9-1.8	Light grey-brown sandy clay.
	1.8-3.6	Medium brown sandy and silty material, becoming damp below 2.7 m.
	3.6-7.2	No return on auger except some sandy, clayey water till about 6 m when brick red clay overlying sandy clay was encountered.
10	0-0.9	Stiff, moist orange and grey clay with wet layers.
	0.9-1.8	Stiff, moist, sandy clay.
	1.8-2.7	Moist, grey clayey sand.
	2.7-3.6	Moist, orange clayey sand.
	3.6-4.5	Stiff grey plastic clay.
	4.5-5.4	As above. Plastic and shiny.
Water seeps slowly into the hole. Level at 5.37 m after one day.		
11	0-0.9	Stiff, laminated orange sandy clay.
	0.9-1.8	Soft, moist orange clayey sand.
	1.8-2.7	Soft fawn to orange clayey sand.
	2.7-3.6	Soft orange clayey sand.
	3.6-4.5	As above, wetter.
	4.5-5.4	As above and more sandy.
	5.4-6.4	Water and clayey sand. The sand is fine-grained.
	6.4-7.3	Probable clay.

Hole	Depth (m)	Description
11	7.3-8.2	Stiff grey clay.
Hole collapsed. Pipe installed to 6.4 m.		
12		House upslope of this bore has pressure water and sand flowing into the basement. No movement recorded.
	0-0.9	Damp soil over wet clayey sand.
	0.9-1.8	Very moist yellow sandy clay.
	1.8-2.7	Wet sandy clay and clayey sand. Yellow and grey. Some quartz gravel.
	2.7-3.6	Some stiff grey, and oxidised clay, with yellow sandy clay and lignite pieces. Fairly soft fawn plastic clay with 30% sand.
	3.6-4.5	At about 4.2 m there is very wet, shiny, sandy clay and some stiff grey sandy clay. Water.
	4.5-5.4	No return.
	5.4-6.4	Stiff grey clay.
Pipe installed to 6.4 m. Water level 1.5 m.		
13	0-0.9	Sandy fill.
	0.9-1.8	Stiff orange clay with about 30% sand. Becomes softer with depth and contains grey sandy laminae.
	1.8-2.7	Soft, moist, orange sandy clay (CH).
	2.7-3.6	As above, dryer and firmer.
	3.6-4.5	Firm orange clay with less sand than above, into paler, more crumbly fawn clay.
	4.5-5.4	Very plastic grey clay with about 10% sand and shiny but less plastic orange clay.
	5.4-6.4	Mostly softish fawn clay with some stiff grey clay.
	6.4-7.3	As above.
Hole dry after drilling, but after 3 days water level at 4 m.		
14	0-0.9	Soil was very wet, clayey quartz sand.
	0.9-1.8	Stiff grey clay and damp orange sandy material (reported to be fill).
	1.8-2.7	Wet, clayey sand.
	2.7-3.6	Soft, damp clay.
	3.6-4.5	Wet orange sandy clay and stiff grey sandy clay.
	4.5-5.4	Water and fine sand.
	5.4-6.4	Stiff grey and orange clay with gritty pieces.
Pipe installed to 6.4 m.		
15		Located behind reservoir, at base of steep sandy cut with a spring nearby.
	0-0.9	Damp, fairly stiff grey and orange plastic clay, over wet grey sand, over clay.
	0.9-1.8	Fairly wet sandy clay over firmer grey plastic clay and soft orange clay. The grey clay is smooth and plastic, the orange is sandy.

Hole	Depth (m)	Description
15	1.8-2.7	Stiff, very plastic grey and orange clay with some black clay. Also very stiff to hard black and fawn clay with little sand.
	2.7-3.6	Stiff grey clay over softer grey and fawn clay.
	3.6-4.5	Stiff grey plastic clay and stiff fawn clay.
16	0-0.9	Sandy fill over moist, stiff, orange and grey clay.
	0.9-1.8	Moist red, orange and grey plastic clay over paler orange clay.
	1.8-2.7	Moist, fairly soft, plastic, fawn clay.
	2.7-3.6	As above, then into stiffer, fawn and grey clay.
	3.6-4.5	Moderately soft, fawn plastic clay.
	4.5-5.4	As above, then into stiff grey and softer orange clay with organic material.
	5.4-6.4	As above, very stiff grey clay and softer orange clay.
	6.4-7.3	Poor return. Moderately soft orange clay, probably from sides of the hole.
	7.3-8.2	Water, very stiff grey and black plastic clay and stiff oxidized clay.
17	0.0-0.9	Moist, stiff, very plastic orange clay.
	0.9-1.8	Stiff grey and orange plastic clay.
	1.8-2.7	Lithic sand and clay. Orange and some grey. Dry.
	2.7-3.6	Damp, crumbly, orange clay.
	3.6-4.5	As above, moister.
	4.5-5.4	Moist, crumbly, orange clay.
	5.4-6.4	Moist, crumbly, orange clay.
	6.4-7.3	Damp sandy orange clay, crumbly.
7.3-12.1	As above.	
18	0-0.9	Wet red sand over orange sandy clay.
	0.9-1.8	Moist, sandy red clay.
	1.8-2.7	Damp, crumbly, orange, plastic clay.
	2.7-3.6	Moist, soft, sandy, orange clay.
	3.6-4.5	Moist plastic clay with about 50% sand. Very crumbly.
	4.5-5.4	Moist orange to fawn clay with laminae of very soft grey and yellow plastic clay.
	5.4-6.4	Damp, orange, sandy crumbly clay.
6.4-11.4	As above.	
19	0-0.9	Moist sandy clay.
	0.9-1.8	Moist soft plastic orange clay with 30% sand.
	1.8-2.7	Soft fawn plastic clay.
	2.7-3.6	As above with hard clay nodules.
	3.6-4.5	As above.
	4.5-5.4	Red-brown soft plastic clay.
	5.4-6.4	As above.
	6.4-7.3	Stiffer, red-brown medium plastic clay which comes as nodules. Some grey and red clay.
7.3-9	As above with ironstone pieces.	

Hole	Depth (m)	Description
20	0-0.9	Grey and fawn laminated plastic clay, fairly soft and moist.
	0.9-1.8	Light coloured plastic clay and lithic sand which becomes clay when worked. Moderately soft.
	1.8-2.7	Firm red clay with high proportion of sand. Some grey sand laminae.
	2.7-3.6	Orange sandy clay.
	3.6-4.5	Soft orange sandy clay.
	4.5-7.3	As above.
	7.3-8.2	As above with some stiff grey clay and ironstone pieces.
	8.2-9	Soft sandy clay.

Logs of bore holes from Aitchison and Gill (1960).

Hole	Depth (m)	Description
8	6.1-7.3	Part sampling only Muck, fawn siliceous sandstone
	13.1-13.7	Clay to silt, red with fawn mottles
	19.8-20.4	Pale fawn silt.
	27.4-28	Fawn siliceous sandstone
	35.4-36	Reddish fawn sandstone
	45.1-45.2	Pale grey and fawn sandstone
9	6.1-7.6	Part sampling only Mottled pale grey, fawn and red slightly clayey sand. More siliceous than greywacke sandstone. (600 mm extruded from 1.5 m (5 foot) core barrel).
	12.2-15.2	Light grey sandstone. More impurities than above (70 mm extruded from 1.5 m core barrel).
	18.5-20.1	Clayey silt to silty clay, coarser at top (only 1 m mottled light grey, fawn and reddish. Sample recovered) red with fawn mottles 380-560 mm from top, then 3 colour mottles again.
	24.7-26.2	Mid-grey clay and silty clay, homogenous (1.2 m recovered) in colour and composition.
	31.0-32.5	As above, sandy band 305-405 mm (1 m recovered) from top. Slip surface at bottom and 70 mm above bottom at approximately 45°.
	37.1-38.6	Permeable and largely siliceous sandstone (1.2 m recovered) of even grain size; not usual greywacke sandstone.
	48.8-50.2	Grey clay to silt, homogenous 0.6 m recovered.
	50.2-51.8	Fawn siliceous sandstone. Samples oxidized if sandstone but not if clay.

Hole abandoned at 51.8 m.

## APPENDIX 2

## Analysis of water samples, Lawrence Vale.

<i>Item</i>		772404	772682
PH	7.4	5.8	7.4
Conductivity	-	420 mhos	990 mhos
	mg/l	mg/l	mg/l
CO <sub>3</sub>	Nil	Nil	Nil
HCO <sub>3</sub>	140	36	265
Cl	150	61	3816
SO <sub>4</sub>	70	93	380
SiO <sub>2</sub>		0.2	11
Ca	1.1	0.6	88
Mg	4.3	1.6	263
Fe	<0.1	2.3	3.8
Al	<0.2	11	5.3
K	3.9	2.9	66
Na	160	85.7	2125
TDS	520	330	7205
Hardness (as CaCO <sub>3</sub> )	-	73.4	1340
Hardness (permanent)	-	43.4	1158
Alkalinity (as CaCO <sub>3</sub> )	-	30	220
Date	8/76	8.9.77	13.10.77
Bore Hole	9	8	16

Analysis by Department of Mines Laboratory Launceston.