TRI6_169-176

30. Subsurface investigations of proposed dam site, Nunamara.

W.L. Matthews

Following the geological mapping of the area around the dam site (Matthews, 1973), further investigations have included seismic and resistivity surveys, and diamond and auger drilling. Trenches and test pits have been dug with a back hoe. Seismic work has also been undertaken on a possible quarry site and preliminary examinations have been made on a possible source for clay should a clay-cored rock-fill dam be recommended.

GEOPHYSICAL SURVEYS

Nine seismic spreads were fired along three approximately parallel traverses, across the proposed dam site area and four cross spreads were fired at right angles to these. The traverse lines were 15 m apart. Geophone spacings were 3 m and 6 m for the central traverse, 7.5 m for the traverses on either side and 3 m for the cross spreads (figs. 49, 50, 51).

Resistivity measurements in Wenner configuration with constant electrode separations of 3 m and 12 m were carried out along the seismic traverse lines. The electrode separation was 3 m and 9 m along the cross spread lines.

The seismic survey indicated 2 layers of material exhibiting seismic velocities of about 300 m/s and 3,000-5,000 m/s. Spread 7, a cross spread, gave strong indications of material with an intermediate velocity of about 900 m/s which was not obvious from the results of any of the other spreads. Drawing on a knowledge of the geology of the area, the material having the lowest velocity was interpreted as being weathered dolerite and dolerite talus and the material with the highest velocity was thought to be unweathered dolerite, the variation in velocity in this being due to different degrees of jointing. The material with the intermediate seismic velocity of about 900 m/s was interpreted as being clay derived from the weathering of dolerite *in situ*. Spread 7 is crossed by Spreads 4 and 5 at its ends and by Spread 3 about the middle. Although each of these spreads suggests slightly higher velocity than the 300 m/s figure used in the interpretation, a 900 m/s layer is not obvious. This could be due partly to the closer geophone separation used in Spread 7 (*i.e.* 3 m compared with 6 m for Spread 3 and 7.5 m for Spreads 4 and 5) and also partly due to the fact that the seismic traverses are approximately parallel to the principal faults in the area whereas Spread 7 a cross spread is at right angles to the fault directions. If weathered and unweathered zones of dolerite have a linear form then the directions of these lineations could be expected to parallel the fault directions.

The resistivity traverses indicated zones where resistance is high and other areas where it is much lower. The high zones were interpreted as being where unweathered dolerite is near surface and the zones where the resistivity profile is low and relatively flat were regarded as areas where the near-surface dolerite is weathered. In general, the profiles of the resistivity travers support the occurrences of near-surface unweathered dolerite suggested by the seismic data.

DIAMOND DRILLING

Diamond drilling commenced after the geophysical work around the dam site was completed. In addition to sampling the material underlying the dam site, losses from water pressure tests in the drill holes were measured where possible to indicate whether loss of water by seepage through the abutments would be a serious problem.

Ten diamond drill holes have been drilled and a brief summary of each hole is given below. The positions of these holes are shown on Figure 52.

D.D.H. 1 (vertical)

This hole entered unweathered dolerite at about 1.2 m and continued in this material to the final depth of 18.4 m. The dolerite is fresh, medium- to fine-grained with relatively few joints and a low permeability.

D.D.H. 2 (60° inclination)

Probable *in situ* dolerite was struck at about one metre and extended to the bottom of the hole (24 m). Jointing is fairly common in some sections and the zone 9.2-12.2 m has some open joints resulting in moderate water losses from pressure tests but otherwise the dolerite exhibited low permeabilities. The dolerite is medium- to fine-grained.

D.D.H. 3 (vertical)

Predominantly unweathered dolerite was struck at 6.9 m with the section from 5.4 to 6.9 m consisting of unweathered and weathered dolerite sections. The dolerite is fine-grained, particularly at lower levels and this can be explained by the fact that baked Permian mudstone was struck at 22.6 m. Apart from two thin seams of dolerite this continued to the final depth of 24.3 m. Jointing, although fairly common throughout is not open, as evidenced by the relatively low permeabilities including the section containing the contact between the two rock types. Slip surfaces were noted near the contact and a little pyrite can be seen in the dolerite near the mudstone.

D.D.H. 4 (60° inclination)

Largely unweathered medium- to fine-grained dolerite was struck at about one metre and continued to the final depth of 24.5 m. Some narrow zones of weathered dolerite were encountered to about 18 m and slip surfaces were noted on some joints indicating movement along them and suggesting the possibility of a nearby fault. Although jointing is common, permeabilities throughout the hole are very low.

D.D.H. 5 (60° inclination)

Mainly unweathered medium- to fine-grained dolerite was struck at about 2 m and extended to the final depth of 24.2 m. Apart from moderate water losses from 2.8-5.9 m and 21.1-24.2 m (the former instance could be due to water escaping around the packer as was noted in later holes) permeabilities are low despite the frequent joints.

D.D.H. 6 (65° inclination)

Largely unweathered medium- to fine-grained dolerite was struck from 2.9-24.0 m. Jointing is common but closed, resulting in low water losses from pressure tests.

D.D.H. 7 (vertical)

This hole commenced in a surface boulder under which some clay and unrecoverable material was encountered. Definite *in situ* fine- to medium-grained and largely unweathered dolerite was struck at 2.9 m and continued to the final depth of 15.1 m. Thin clay seams on joints were struck about 6 m from the surface. Water losses from 5.8-8.9 m were moderate to low and at lower levels the dolerite is tight.

D.D.H. 8 (60° inclination)

Some unweathered dolerite was struck at 2.1 m but sections of weathered dolerite (low core recovery) continued to 6.1 m after which largely unweathered dolerite (with some broken sections) was drilled until 21.9 m when Permian mudstone was struck. The dolerite is weathered near the contact. Water losses from pressure tests were small throughout.

D.D.H. 9 (60° inclination)

Largely unweathered dolerite was struck from 5.9 to 17.8 m although the section 4.4 to 5.9 m contains a large proportion of unweathered dolerite. The dolerite is medium- to fine-grained and joints are fairly frequent. Water losses were moderate to small throughout.

D.D.H. 10 (vertical)

Unweathered medium- to fine-grained dolerite was struck at 11.8 m and continued to 19 m. Above 11.7 m unweathered centres of dolerite in clay was drilled. Baked Permian mudstone was struck at 19 m and the hole ended in mudstone at 21.2 m. Water losses for the sections on which pressure tests could be conducted, were comparatively low.

AUGER DRILLING

In addition to the diamond drill holes around the proposed dam centre-line, an attempt was made to locate the Permian rocks upstream from the centre-line in a number of places. A Gemco drilling rig which is capable of auger drilling in unconsolidated material and also vertical diamond drilling was used. Two holes were drilled on the east side and three on the west side of the river in the positions shown on Figure 62. The results of this drilling are given below.

	Depth (m)	*Description*
Hole 1	0- 1.5	Brown and blue clay with a little sand towards the lower end.
	1.5- 2.0	Brown clay with gravel fragments.
	2.0- 2.9	Gravel, clay and possibly weathered dolerite.
	2.9- 3.5	Sandy mudstone (dip 13°-15°), Permian.
Hole 2	0- 1.8	Blue and grey-brown plastic clay.
	1.8- 2.0	Clay with gravel fragments.
	2.0- 2.7	Baked brown mudstone, Permian.
Hole 3	0- 6.0	Clay and very weathered dolerite.
	6.0- 7.3	Baked brown mudstone, Permian.
Hole 4	0- 0.6	Soil, dolerite boulders and limonite gravel.
	0.6-19.0	Weathered dolerite
	19.0-20.1	Weathered and unweathered dolerite.
Hole 5	0- 0.8	Dolerite boulders.
	0.8- 5.3	Weathered dolerite.
	5.3- 9.8	Weathered dolerite with occasional unweathered centres.
	9.8-11.0	Mainly unweathered dolerite.
	11.0-11.6	Baked Permian mudstone (dip about 15°).

TEST PITS AND TRENCHES

Diamond Drill Hole 3 encountered a considerable thickness of unconsolidated or weathered material and as recovery from diamond drilling in this kind of material is often poor, 4 backhoe holes were dug to a maximum depth of about 6 m. In addition, 2 trenches were cut into the upstream side of the east embankment to determine whether the material underlying it is likely to permit seepage and also to attempt to expose the dolerite/Permian contact. The test holes were dug after an extended period of rain and the water table was high. The positions of the test pits and trenches are shown on Figure 62.

Test Pit 1

This pit was dug to 6 m and contained much-weathered dolerite with a few unweathered kernels of dolerite. During a period of about 18 hours after excavation about 5,700 litres of water entered the hole.

Test Pit 2

Hole 2 was dug to about 6 m and contained clay derived from the weathering of dolerite (with crystal outlines still visible) with a few unweathered kernels. About 4,500 litres of water entered the hole about 26 hours after excavation.

Test Pit 3

The entire section of this pit was in clay almost certainly derived from the deep weathering of dolerite. This pit made water at a faster rate than any of the others and about 11,400 litres seeped into it in 21 hours.

Test Pit 4

Large unweathered kernels of dolerite in clay were struck in digging this pit and the hole was abandoned when only 2 m deep. There was no seepage into the hole; when water was pumped into it to a depth of about 0.6 m no appreciable seepage out of the hole was noted over a period of 4 hours.

Trench 1

This was excavated to a depth of about 3 m at its deepest point where vertical blocks of unweathered dolerite were encountered. No Permian was exposed at the base of the trench. Water ran from the trench at the rate of about 450 l/h.

Trench 2

Excavation was discontinued when the trench was about 3 m deep at its deepest point. The material struck was clay, derived from deep weathering of dolerite. The trench made water at the rate of about 180 l/h.

WATER PRESSURE TESTING

Water pressure tests were carried out in the diamond drill holes where it was possible. In holes where unconsolidated or weathered material is encountered, casing has to be inserted to guard against collapse of the hole and this prevents a test being made and in addition it is difficult to make the packers watertight in such material. The water pressure testing has therefore been almost entirely confined to the parts of the holes where unweathered rock was drilled. Even where solid rock is struck near the surface it is sometimes difficult to seal the hole completely with the packer.

In general, the losses measured in the water pressure tests are low to very low although there are occasional sections of some holes where the losses are moderate. As the intended height of the dam is about 8 m, the magnitude of the permeabilities calculated from the pressure tests indicates that losses through seepage could be expected to be small. As noted, little information is available on the amount of seepage that could be expected through the weathered material. The rate of seepage into the test pits suggests that the permeabilities of this material are low and variable. Even in Test Pit 3, although no accurate calculations can be made, the average permeability of the material is probably no greater than 100 m per year and is probably much less.

Calculation of the loss of water by seepage through the abutments cannot be made accurately from the water pressure testing because of the variability of the permeability in the sections tested and also because there are no accurate figures for the weathered material, but the order of the likely losses can be estimated. Taking an average figure for the permeability of the abutments material of 120 m/yr (probably much higher than the real figure) the loss of water through the abutments above river level would be about 13.5 Ml/yr. Even if this figure was doubled by seepage below river level and around the ends of the section considered, seepage would be low in comparison to the volume of the proposed reservoir.

DISCUSSION OF SUBSURFACE INVESTIGATIONS

The drilling has indicated that unweathered dolerite occurs close to the surface on the west abutment of the dam and also up the main part of the slope of the east abutment. The depth of weathering of the dolerite is a little greater in D.D.H. 3 but much greater in Hole 10 than was expected from the seismic interpretation. Hole 10 is situated about a metre to the south of Spread 3 and the 11 m of weathered material overlying unweathered dolerite could be due to either a local, deeply weathered zone not occurring on Spread 3 or the seismic spread could have picked up a false bottom to the layer with the slower velocity, as there were some unweathered sections of dolerite in the first 12 m of the hole. The test pitting however confirmed that the dolerite is deeply weathered between the highway and Hole 10. Deep weathering of the dolerite was also found in the Gemco holes on the west side of the river and this, together with the general lack of outcrops around the dam site is unusual for areas underlain by dolerite. It seems likely that the present surface is approximately the same as the Tertiary surface. Areas of deep Tertiary weathering were probably protected from erosion by later Tertiary basalt flows which have now been largely stripped leaving the old surface exposed.

In some areas where the dolerite is deeply weathered, the clay produced has a pellety nature, the pellets being the size of the original crystals forming the dolerite *i.e.* up to 2-3 mm. Bonding between the pellets is not strong and although the possibility should not be excluded completely, the permeability of the material is probably too low for piping to develop.

The drilling has shown that the Permian rocks dip underneath the dam site at about 12-15° with a strike approximately parallel with the dam axis as was suggested from the surface geology. It is apparent that the dolerite is a sill-like body and that the dolerite/Permian contact dips to the south-west. Permian rocks were struck in D.D.H. 3, 8 and 10 and Gemco holes 1, 2, 3 and 5 and with the exception of Gemco holes 1 and 2, dolerite was intersected above the Permian. Gemco holes 1 and 2 are situated on the edge of the flood plain of St Patricks River and it is likely that some erosion of the Permian below the level of the dolerite/Permian contact has taken place although in Hole 2 the mudstone is a little baked.

Using the depths that Permian rocks were struck in D.D.H. 3, 8 and 10, the base of the dolerite dips at about 14°40' SW with a strike of 317°.

Projecting the strike determined from D.D.H. 3, 8 and 10 on the east bank, across the river to the west bank and assuming that the dip of the base of the dolerite is constant throughout the area, the Permian was struck at a depth of 3.6 m greater than would have been expected in the Gemco hole 5 and 11.6 m deeper than expected in Hole 3. It is therefore unlikely that there is any large scale post-dolerite faulting along the river. Longman (1964) mapped a possible fault through the dam site, along the line of the river, which from his map would have a throw of a few hundred metres. It is possible that the fault pre-dates the dolerite intrusion in which case the dolerite would not be displaced. A report on the surface geology prepared before subsurface investigations began (Matthews, 1973) suggested the possibility that Upper Permian occurs both north and south of the river in the dam site area whereas Longman mapped Lower Permian south of the river and Upper Permian to the north. No information was gained from the drill cores as to the position of the mudstones in the Permian sequence because of the small sections drilled, but it can be concluded that there is little chance of any large scale post-dolerite faulting and there is a reasonable chance of no large scale pre-dolerite faulting passing through the dam site. There is however a possibility of small scale faulting. The discrepancies in depth at which the Permian was struck in Gemco holes 3 and 5, could be due to faulting or it could be due to a change in dip or the dolerite could have been intruded at slightly different levels in the Permian (*i.e.* it is slightly transgressive). There could also be a fault between Gemco holes 3 and 5 as the discrepancy is different and such a fault in this case could be a NW-trending fault which would parallel the main fault direction in the area. The fact that slip surfaces were noted in the core from D.D.H. 4 indicates the likelihood of some past movement in the area.

Gemco drilling on the flood plain of St Patricks River just upstream from the east embankment demonstrated that the Permian mudstone is at shallow depth and if there was any doubt about the ability of this embankment to form part of the dam, such as depth of weathering seepage or possible piping, a cut-off to bedrock along the edge of this flood plain would ensure that this part would only act as part of the fill. The cut-off would probably have to be a concrete membrane as a clay facing could be damaged by wave action and possibly by logs coming downstream in times of flood. The cut-off could be extended up the embankment and downstream to the area where the main barrier across the river would be built.

CONSTRUCTION MATERIALS

Possible Quarry Site

An existing quarry about 3 km south-west of the dam site could be used as a source of rock if a rock fill dam is built. The quarry at present has a face of up to about 10 m and the country behind it is steep so that with further working, a higher face would quickly develop. There are widespread outcrops uphill from the quarry and it could be expected that good rock could be found at shallow depth over extensive areas. The best rock, with least weathering, is in the southern part of the quarry (fig. 53).

Four seismic spreads covering land from 80-100 metres south of the quarry, were fired and the results suggest that there are areas where weathered material and boulders of dolerite extend to about 6 m below the surface but in general this material is less than 3 m thick. The most continuous unweathered rock, from the seismic spreads, appears to extend towards the highest point on the hill.

Because the overburden is fairly thin where dolerite is not exposed, there is little doubt that adequate supplies of rock could be obtained from the area. The one drawback of the site appears to be the wide opening of the joints in the dolerite since more explosives would be required than if the joints were closed.

Clay for a Clay Core

Some preliminary investigations have been made to establish the occurrence of clay that could be used as a core. Shallow auger holes were drilled to about 1.5 m in a number of places upstream from the dam on the east side. The flood plain material is variable in composition and in some areas sand, clayey sand and gravel occur at shallow depth but in others plastic clay occurs at depths of at least 1.6 m. The best clay appears to occur just upstream from Gemco holes 1 and 2 and further upstream in the areas where reeds are growing.

Whether this clay is suitable for use in a clay core is unknown. It is known that some clays derived from the weathering of Permian rocks are unsuitable for cores of dams but dolerite derived clays are generally regarded as suitable. It could be expected that some of this clay material would be derived from the weathering of both rock types and tests would need to be carried out to determine its suitability.

CONCLUSIONS

The investigations have established that a dam of the size envisaged could be built on the site with reasonable safety. A cut-off to bedrock could be installed where the main part of the dam would be built. On the east embankment, east of the main part of the dam, a cut-off to bedrock would not be possible because of the depth of weathered material. Because there is some doubt about the permeability of this material an impervious membrane should be inserted to the deepest practical level in this area so that the leakage path is made as long as possible. Alternatively, in order to remove all doubts about this material, a cut-off to bedrock along the line joining Gemco holes 1 and 2 is suggested.

Water pressure tests in the sections of the diamond drill holes suitable to be tested, indicate that seepage will not be a problem. Examination of the weathered dolerite and the rate at which water flowed into the test pits suggests that leakage through this material should not be excessive.

An existing quarry about 3 km from the dam site could produce the rock required for a rock fill dam.

Clay occurs upstream from the dam site but its suitability as a core material would need to be tested.

The eastern part of the east embankment is weathered and it would be unsuitable material to form part of the spillway without some protection *e.g.* a concrete lining.

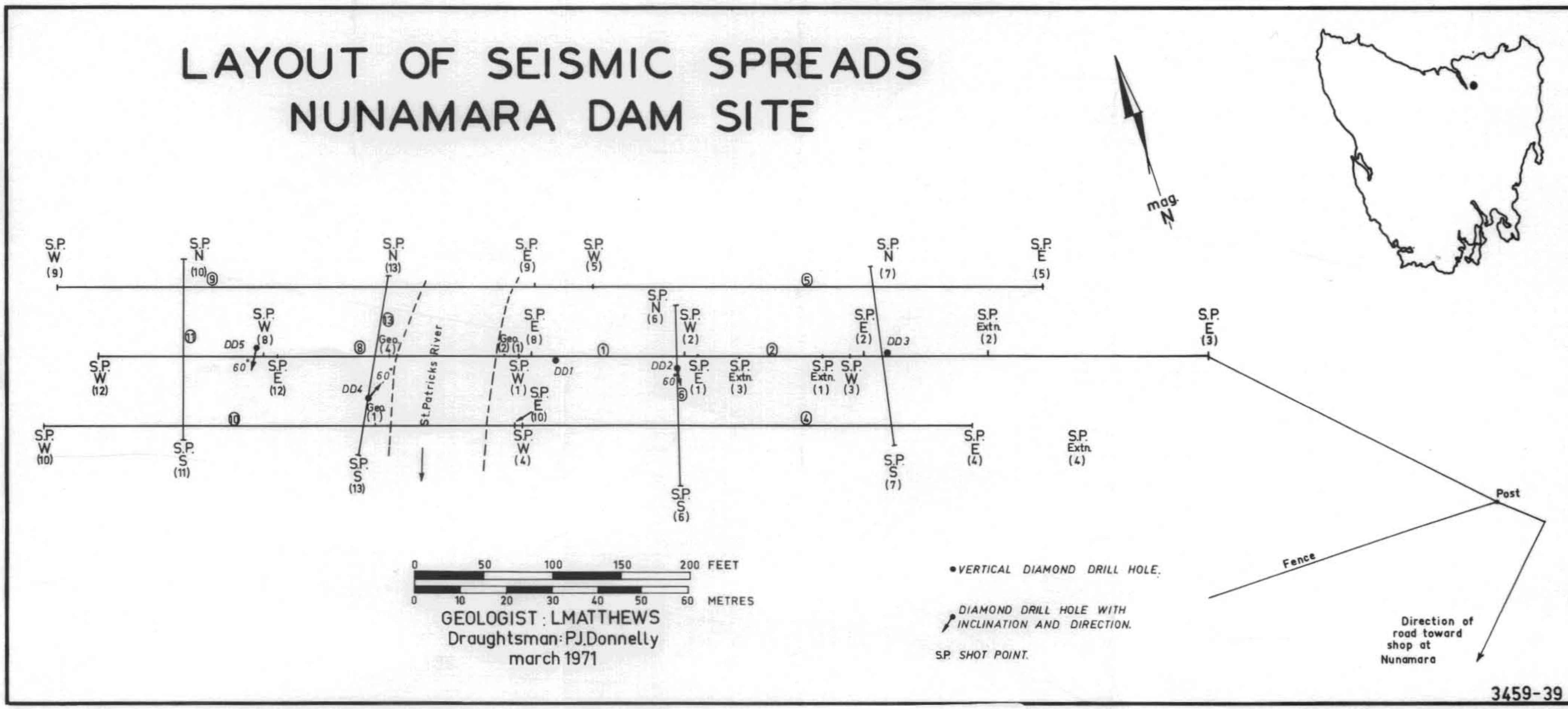

Figure 49.

Tech.Rep.Dep.Mines Tasm. 16.

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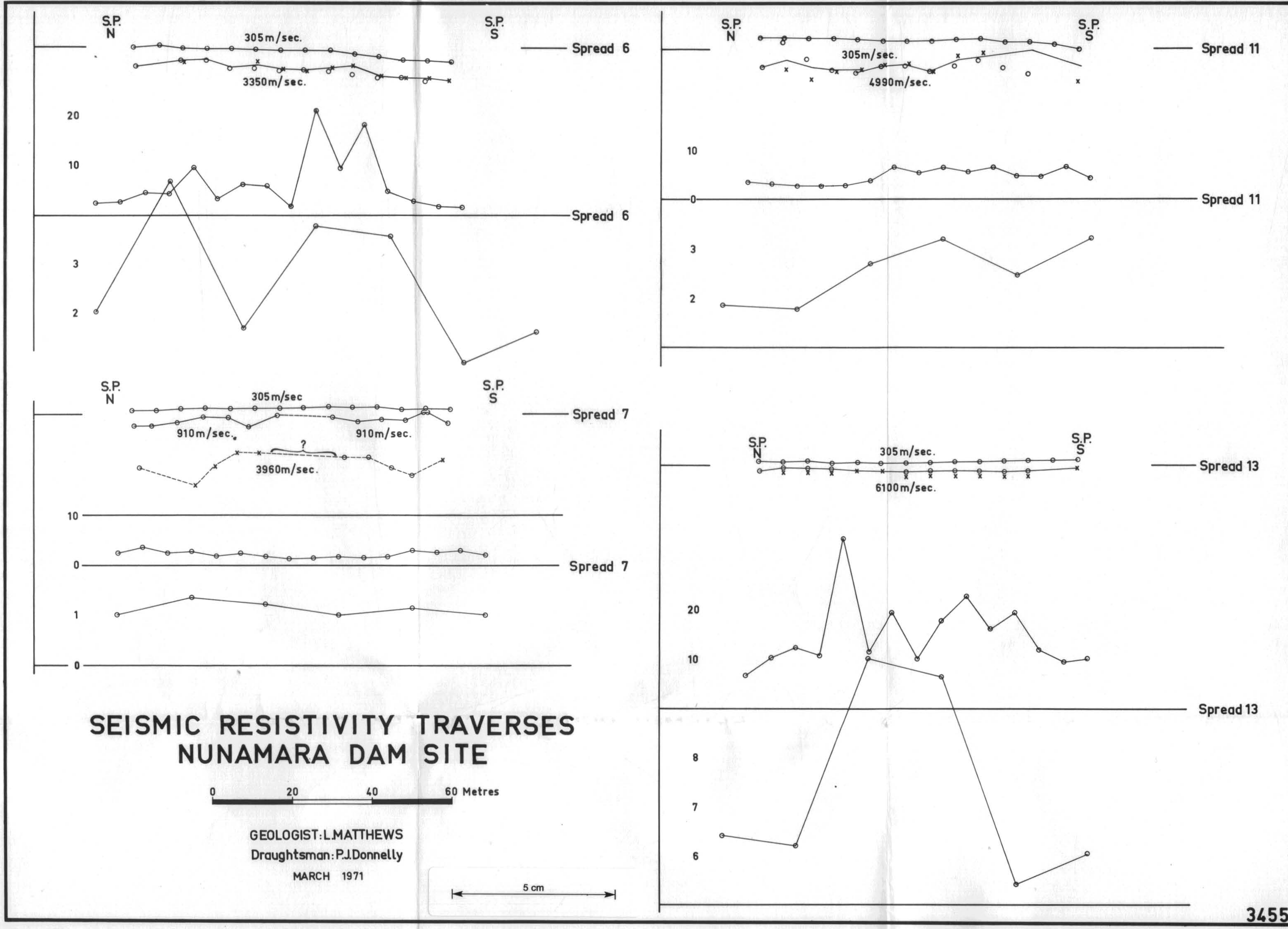

Figure 50.

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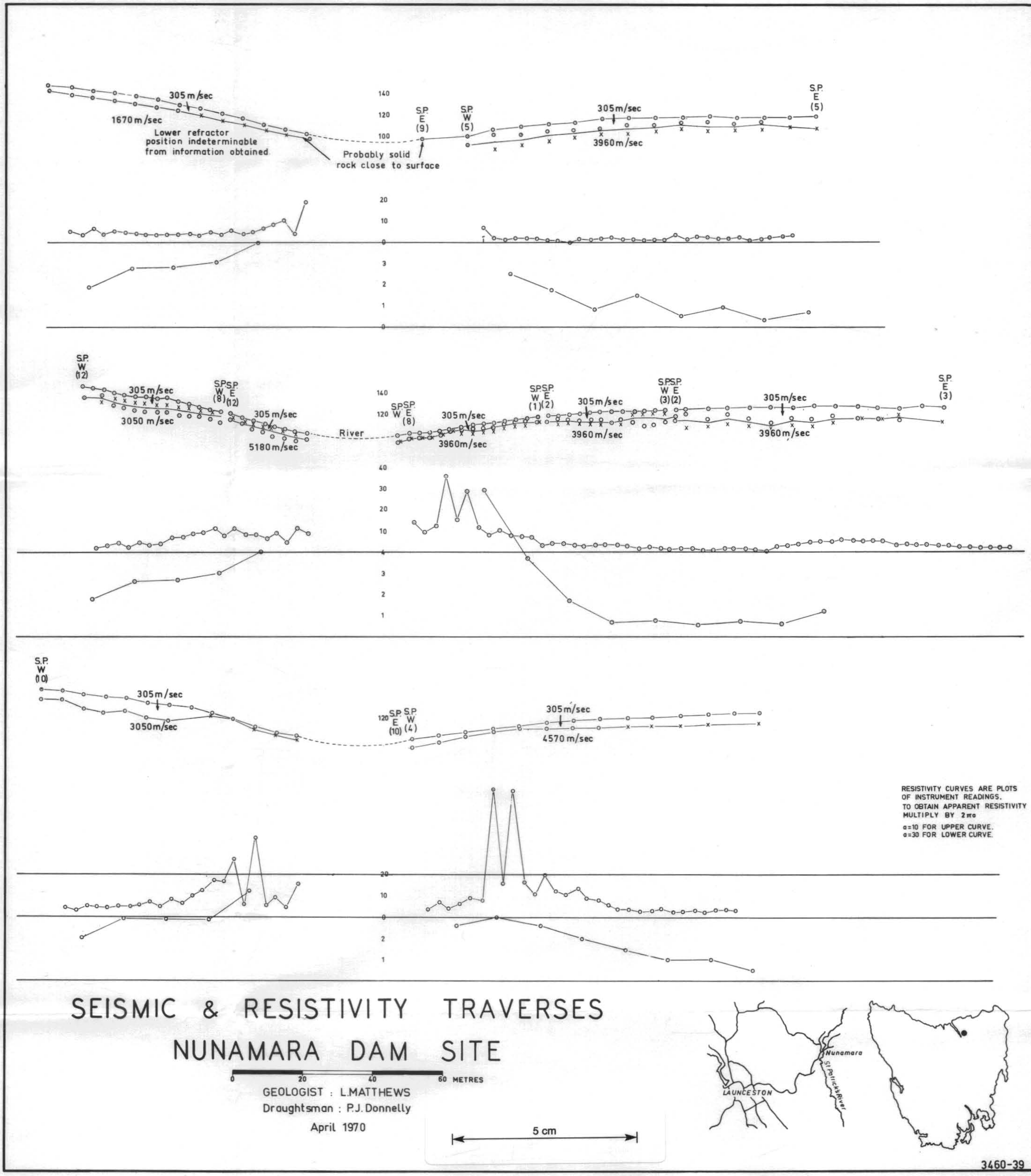

SEISMIC & RESISTIVITY TRAVERSES NUNAMARA DAM SITE

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April 1970

Figure 51.

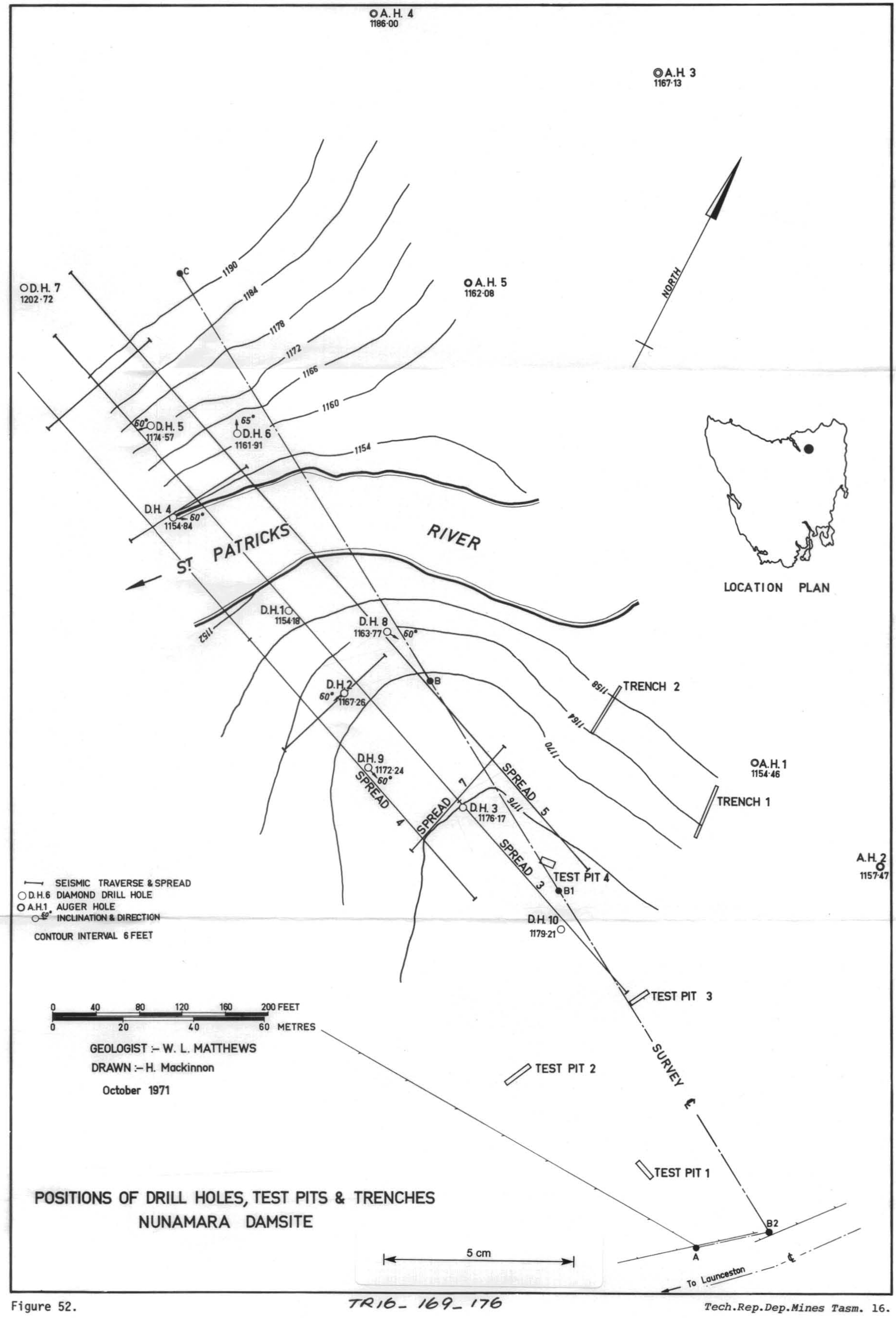

Figure 52. TR16_169_176

The middle seismic traverse appears to be along the line where unweathered dolerite is nearest the surface and this line would be the most suitable centre-line for the dam.

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LONGMAN, M.J.; MATTHEWS, W.L.; ROWE, S.M. 1964. Geological atlas 1 mile series. Zone 7 Sheet 39 (8315S). Launceston. *Department of Mines, Tasmania.*

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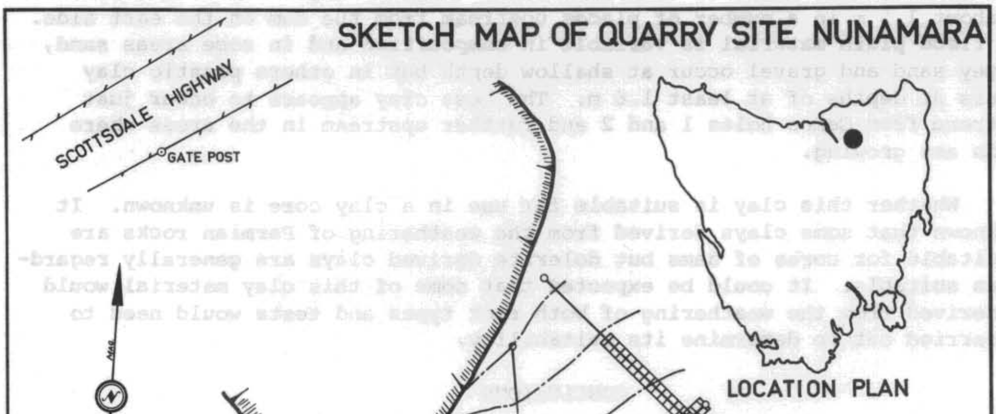

Figure 53.

5 cm