

1022/00. Site investigations at a proposed dam site on Nicholls Rivulet, near Cygnet

D.J. Sloane

*Abstract*

The construction of a 15 m high thin-arch concrete dam is proposed at a site on Nicholls Rivulet, near Cygnet.

The proposed storage area is underlain by Permian siltstone and sandy siltstone, Jurassic dolerite, and Quaternary talus. The siltstone-dolerite contact is located in the middle of the storage area on the western side, with siltstone to the south and dolerite to the north. Alluvium covers the valley floor.

The western bank abutment of the proposed dam is a large, near-vertical siltstone rock face, while the eastern bank is covered by dolerite talus which may extend to a depth of five or six metres. Main joint directions in the right bank are 70° and 130°, with the main leakage potential along the latter, which is approximately at right angles to the proposed dam. Joint relaxation may extend to a depth of ten metres on the western bank.

Thorough subsurface investigations are required in both abutment areas in order to determine the stability, permeability, and condition of the talus and siltstone founding materials. Suggestions for further investigations are presented.

#### INTRODUCTION

At a request from consulting engineers Gutteridge, Haskins and Davey on behalf of the Cygnet Municipal Council, investigations have been conducted at a proposed dam site on Nicholls Rivulet [EN123264], about two kilometres downstream from Nicholls Falls.

The proposed dam is a concrete thin-arch type, about 15 m in height, and which will impound approximately 68 ML of water in a storage area extending about 300 m upstream. The position of the dam is restricted, as it is proposed to construct the arch from a near-vertical siltstone outcrop on the western side with a gravity block abutment on the eastern side.

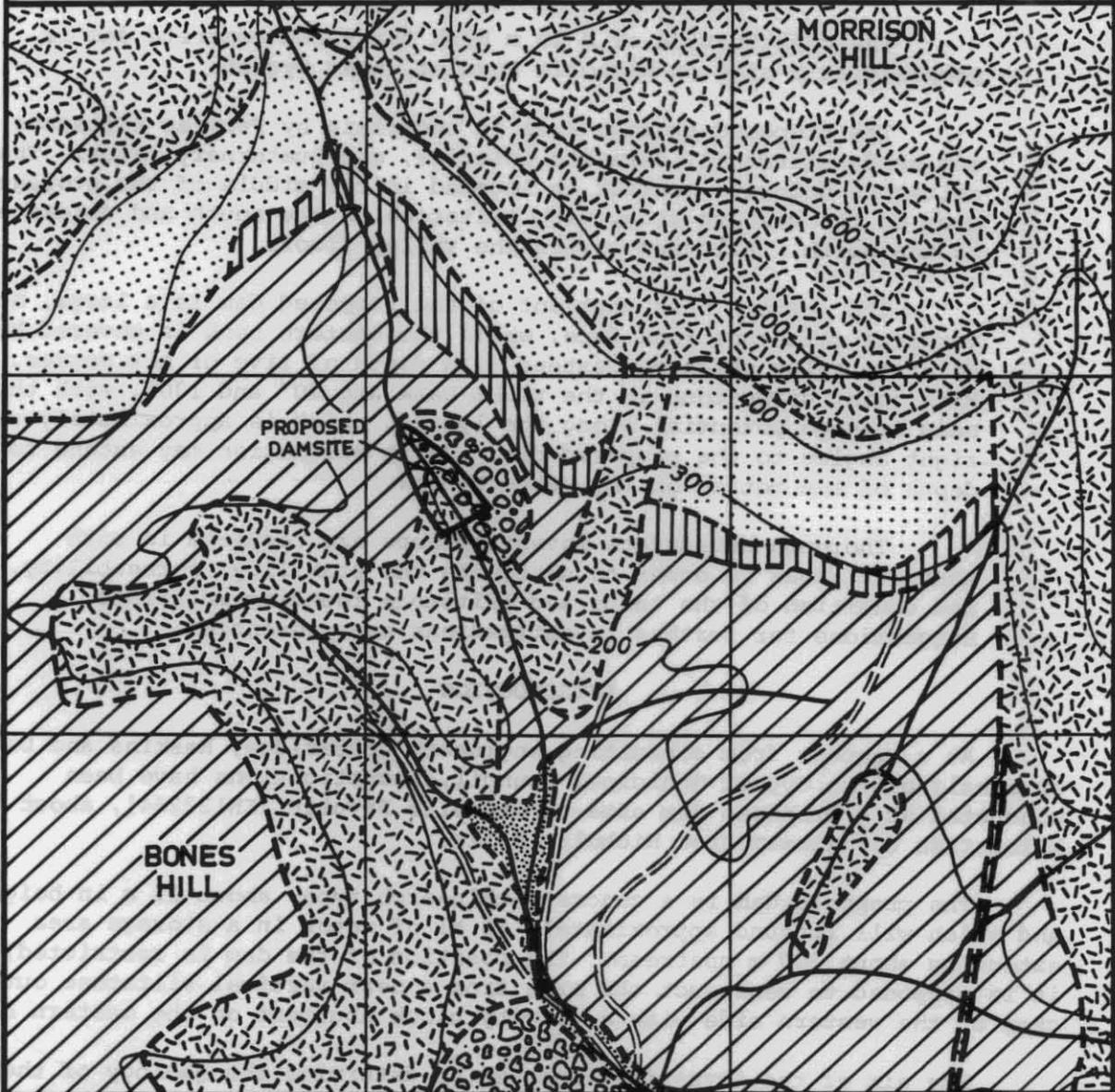
The aim of the investigations was to determine the geology of the dam site and storage areas. A surveyed grid with 10 m spacings was used for detailed mapping of the dam site and pegs with 25 m or 50 m spacing were surveyed in at approximately full water level of the storage area. The survey was required due to the poor scale of available base maps. The geological mapping was conducted at a scale of 1:500.

Six refraction seismic traverses (Appendix 1) were located in areas where an indication of the depth, nature, and condition of subsurface materials was required. Geologists W.L. Matthews and W.R. Moore advised and assisted with field procedures and interpretation.

#### REGIONAL GEOLOGY

The regional geology of the area is shown in Figure 1, which has been reproduced from Farmer (1981). The bulk of the sedimentary rocks of the area consist of siltstone and sandy siltstone of the Abels Bay Formation, a correlate of the Fernree Mudstone of Upper Permian age.

# PROPOSED DAMSITE NICHOLLS RIVULET LOCATION AND REGIONAL GEOLOGY ADAPTED FROM FARMER (1981)



-  QUATERNARY ALLUVIUM
-  QUATERNARY TALUS PREDOMINATELY DOLERITE
-  TRIASSIC MEDIUM TO COARSE GRAINED QUARTZ SANDSTONE
-  CYGNET COAL MEASURES
-  ABELS BAY FORMATION SILTSTONE AND SANDY SILTSTONE
-  JURASSIC DOLERITE

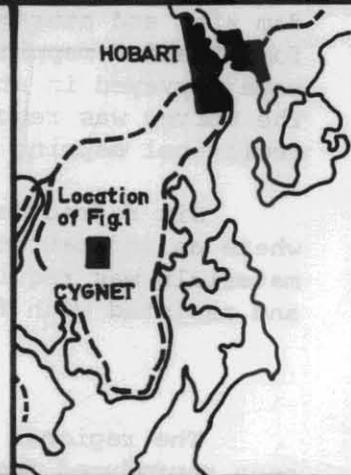


FIGURE 1

5 cm

Further north, at higher altitudes on the flanks of Morrison Hill, Lower Triassic sandstone crops out. The sedimentary rocks have been faulted and intruded by Jurassic dolerite. Leaman (1968) considers that the dolerite intrusions have often occurred along pre-existing faults. Dolerite talus, considered to be of Quaternary age, occurs on the eastern side of the Nicholls Rivulet valley in the area of the proposed dam. The talus is probably of Last Glacial age and has formed under cold climatic conditions. During this time vegetation cover was sparse and physical weathering and mass movement were the dominant processes.

Leaman (1968) considered that the Ferntree Formation shows the strongest jointing of any Permian Formation. A study at Abels Bay indicates that the most pronounced directions are  $244^{\circ}$  and  $159^{\circ}$ . The dolerite is also extremely jointed, with joints vertical or near-vertical, columnar in large masses, but platy and close columnar adjacent to contacts.

#### GEOLOGY OF THE STORAGE AREA

The geology of the dam site and storage area has been mapped in detail and is shown in Figure 2. Rock outcrops in the storage area are mainly restricted to the western side of the valley, within about 120 m of the proposed dam site. Dolerite and siltstone crop out up to the 190 m contour level on the western side of the valley, with the contact between the two rock types located adjacent to the old weir [1080N, 970E]. The contact is difficult to accurately locate in the field due to contact metamorphism of the siltstone and the fine-grained nature of the dolerite. The contact is further masked by close irregular jointing. A bioturbated siltstone to sandy siltstone crops out to the south of the contact. Contact metamorphism has altered the siltstone to hornfels; this rock is slightly weathered and of high strength. Higher outcrops also show alteration, and the presence of hornfelsed fragments in the talus above the main, near-vertical outcrop face indicates a close proximity to the dolerite contact. A small hornfelsed siltstone outcrop also occurs on the eastern side of the rivulet, above the small flood plain adjacent to the old weir. The rock appears to be *in situ* and possibly indicates that siltstone is present beneath the talus in this area. The large dolerite outcrop adjacent to the old weir varies in grain size, from fine-grained near the contact to fine to medium-grained at the northern part of the exposure. Dolerite also crops out in the area of the existing weir at the northern extremity of the storage area. The dolerite in this area is fresh, medium-grained, and of high strength.

Valley slopes in the northern half of the storage area are almost entirely mantled with talus and soil. On the eastern side of the storage area the talus is predominantly of dolerite origin, with large boulders of slightly weathered dolerite up to three metres in diameter in a matrix of weathered dolerite-derived material exposed in a cutting face on the upper side of the track. The boulders are medium-grained dolerite, slightly to highly weathered, angular to moderately well-rounded, and with low to moderate sphericity. Boulder or rock fragment density varies between 20% and 70%, but generally averages about 50% of the deposit. A maximum size of three metres diameter has been measured, but average values would be between 0.15 m and 0.2 m. The matrix is a moderate to low plasticity red-brown gravelly to sandy clay (CL) with constituents derived from weathered dolerite. In places the fabric of the deposit is almost grain supported, but is generally matrix supported. The talus is overlain by a dark brown silty and sandy clay (CL) A<sub>1</sub> topsoil horizon which extends from 0.2 m to 0.4 m below the ground surface. Dessication cracking,

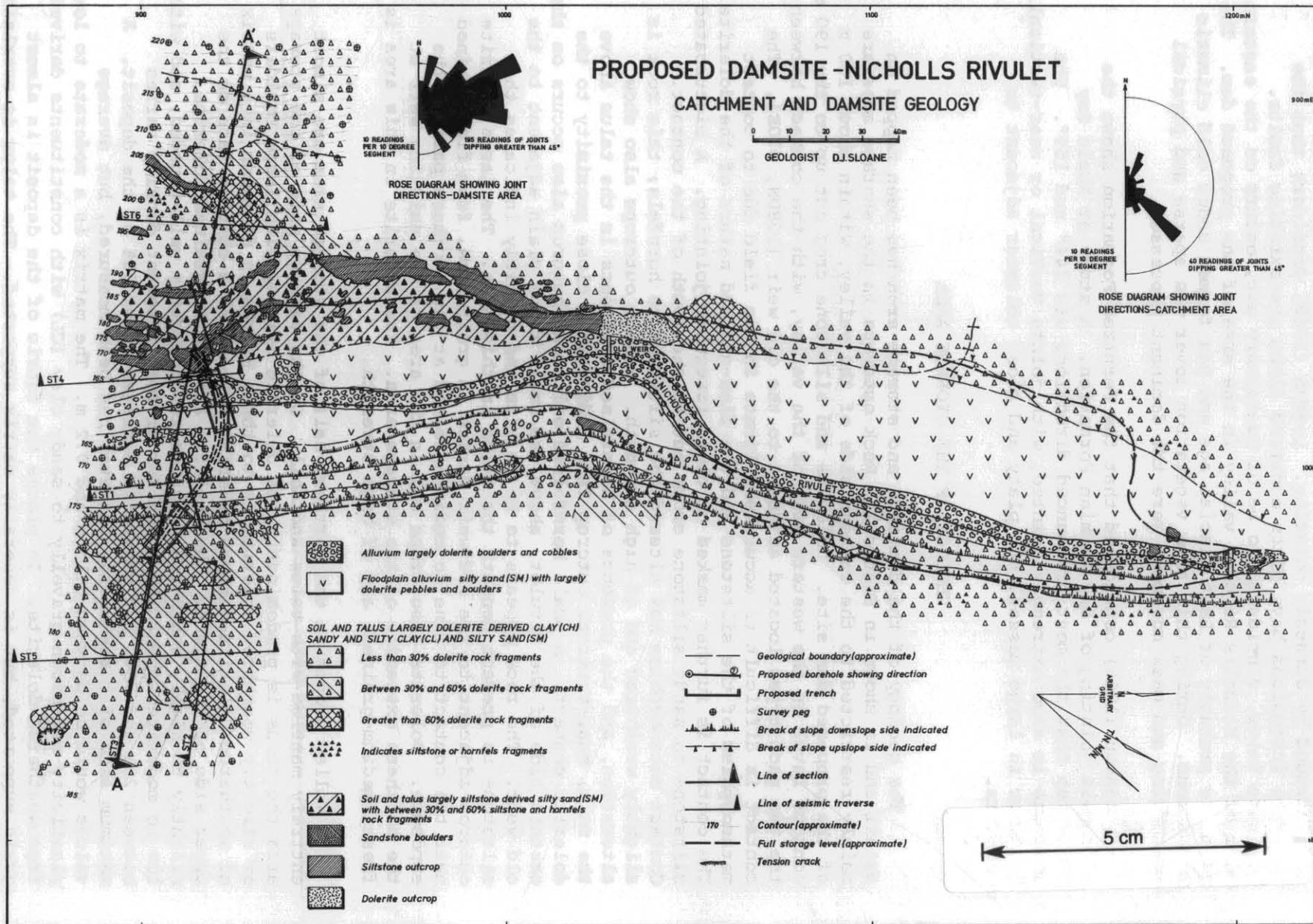


Figure 2.

extending to a depth of about one metre, is evident in exposures. The soil has a columnar structure and soil peds are blocky and irregular, and about 20 mm in diameter.

Surface geological mapping of the dolerite talus has attempted to delineate areas of varying rock fragment density. However, this does not often reflect the density of rock fragments in the underlying material; this can be seen when comparing densities observed in the track cutting with surface exposures.

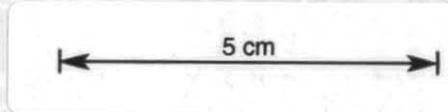
The talus exposed on the eastern side of the valley approximately 150 m north of the dam site grid contains some siltstone rock fragments (2%). The siltstone content increases towards the north. In the cutting adjacent to the existing weir at the northern end of the storage area, approximately 25% of the talus is composed of Permian siltstone or Triassic sandstone rock fragments with an average size of 0.3 m. Triassic sandstone rock fragments up to 0.7 m diameter and dolerite rock fragments up to 0.5 m diameter also occur. The matrix has a higher sand content and also contains small, well rounded quartzite pebbles. Only one sandstone rock fragment has been found in the dam site area; a fragment 0.15 m in diameter was found in the road cutting 15 m south of the dam site grid.

The eastern side of the storage valley appears, therefore, to be mantled with talus which in the southern half is entirely derived from dolerite, but in the north contains a large proportion of siltstone and sandstone rock fragments. This variation in talus composition is considered to be related to the location of source areas of the constituent materials. Permian and Triassic rocks have been mapped close to the northern end of the storage area and crop out on the steeper slopes of Morrison Hill. A large Triassic sandstone boulder has been mapped approximately 20 m downstream from the upper weir. This boulder measures 3 m in diameter and shows fine examples of large scale truncated current bedding in coarse-grained siliceous sandstone.

The western slopes of the northern part of the storage valley are mantled by stony soils containing about 10% of rock fragments up to 0.2 m diameter. Surface soils are generally yellow-brown clayey and silty sands (SM), but clay content increases with depth and underlying materials are silty or sandy clays of moderate plasticity (CL). Rock fragments are composed of medium-grained dolerite with densities of up to 70% in the area adjacent to the dolerite exposure in the centre of the storage area. Siltstone rock fragments are present in soils within approximately 50 m of the upper weir. As with the eastern exposures, siltstone rock fragments increase towards the upper weir.

Soils close to the proposed dam site contain a large proportion of siltstone fragments and mantle the steep slopes below the Permian siltstone exposures on the western side of the valley. Rock fragments compose between 30% and 60% of the soil and talus, which has a light grey to dull yellow-brown clayey and silty sand matrix (SM - SC).

A large proportion of the floor of the storage valley is covered by alluvium in the form of a flood-plain terrace about 1.5 m above stream level. Only fragments of the terrace can be found close to the dam site, but further north the terrace is up to 35 m wide. The alluvial terrace sediments are yellow-brown silty sands (SM) containing dolerite rock fragments between 0.15 m and 0.2 m in diameter. The alluvium also contains siltstone rock fragments in the area near the upper weir. The flood-plain deposits are considered to be between one and two metres in thickness.



### PROPOSED DAM SITE NICHOLLS RIVULET

BASED ON SURFACE GEOLOGICAL MAPPING  
AND SEISMIC REFRACTION INTERPRETATION

0 10 20 30m

GEOLOGIST D.J.SLOANE

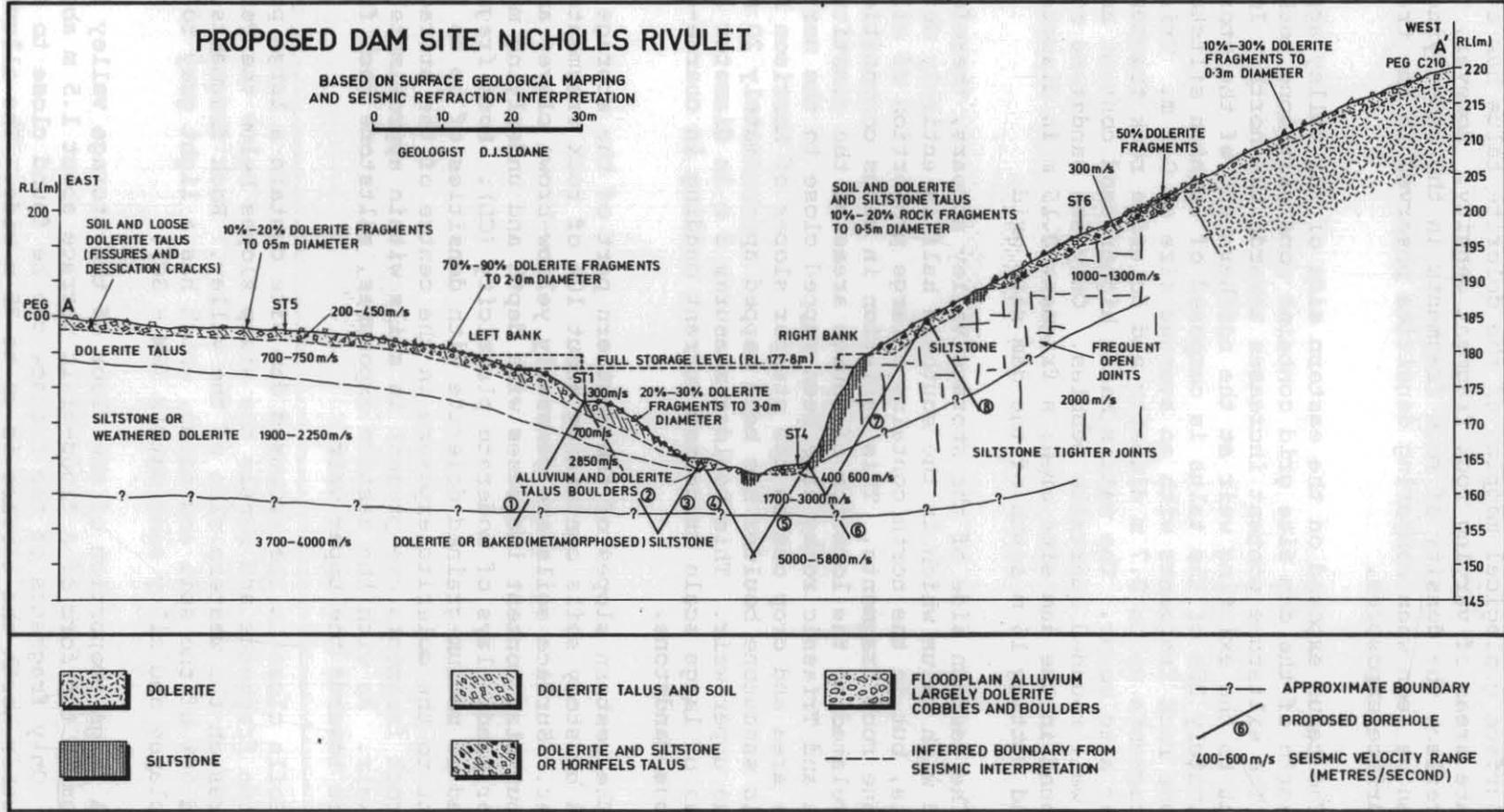


Figure 3

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ROCK DEFECTS IN THE STORAGE AREA

Joints are the main rock defects occurring in the storage area. A small, steeply dipping sheared zone of close irregular jointing on or close to the dolerite/siltstone contact is located near the old weir in the centre of the catchment area. This zone appears to trend approximately at right angles to the rivulet direction. Elsewhere joints are generally clean and planar but are sometimes curved, irregular and discontinuous. The rose diagram (fig. 2) shows the direction of steeply dipping joints, and the poles to 53 joint planes measured have been contoured after plotting on an equal area stereographic projection (fig. 4). There is a scatter in the results, with five or six sets apparent, but two major sets. One major set is vertical to near-vertical with a strike of 130°. Most joints are clean and planar, and some are curved, irregular and discontinuous. Where joint filling is observed there is minor iron mineral deposition and staining. The second major set strikes at 40° with a dip of about 40° towards the south-east. This latter set is similar in type to the 130° set previously described, but with a defect spacing of about 0.8 m. Occasional small areas of closer jointing occur where defect spacing may be as low as 10 or 20 millimetres. Again, joints are often curved, irregular, and discontinuous, especially near the siltstone/dolerite contact.

Access to outcrops is difficult due to the steep nature of the terrain. The sample size is small and the scatter of the joint diagram could be partially attributed to this, together with the effect of the contact zone resulting in the irregular and often curved joints.

DAM SITE GEOLOGY

*Western bank*

The geology of the dam site and storage area is shown in Figure 2. Rock outcrops were mapped on a scale of 1:500, apart from the main 15 m high near-vertical rock face in the immediate vicinity of the western bank abutment.

Siltstone crops out on the western bank below the 182 m contour, where large, near-vertical, joint controlled rock faces are exposed, striking approximately 130°. The lower part of the outcrop is a grey, bioturbated, sandy siltstone. The rock is fresh and of high strength. Bedding is indistinct, but where measured generally dips at about 5° towards 360°. Outcrops show alternating bands of fissile and non-fissile layers. The fissile layers break easily into platy fragments about 10 mm thick and 30 mm long. The layers are often difficult to trace laterally. The basal beds of the western abutment are massive, up to 1.4 m in thickness, and show examples of small scale current bedding. The fissile beds vary between 0.2 m and 0.75 m in thickness and average 0.3 m thick. Massive siltstone beds vary between 1.7 m and 0.3 m, averaging approximately one metre in thickness. Exposures of siltstone above the 175 m contour are more weathered than the basal beds, varying between slightly and highly weathered. Weathering generally results in a yellow-brown rock discolouration and sometimes a slight increase in porosity. The siltstone outcrop just below the 205 m contour shows evidence of baking with the rock altered to hornfels, indicating a proximity to the dolerite/siltstone contact, thought to be further upslope.

An outcrop of sandy siltstone also occurs in the bed of Nicholls Rivulet. It is therefore possible that the siltstone continues under the eastern bank of the dam site.

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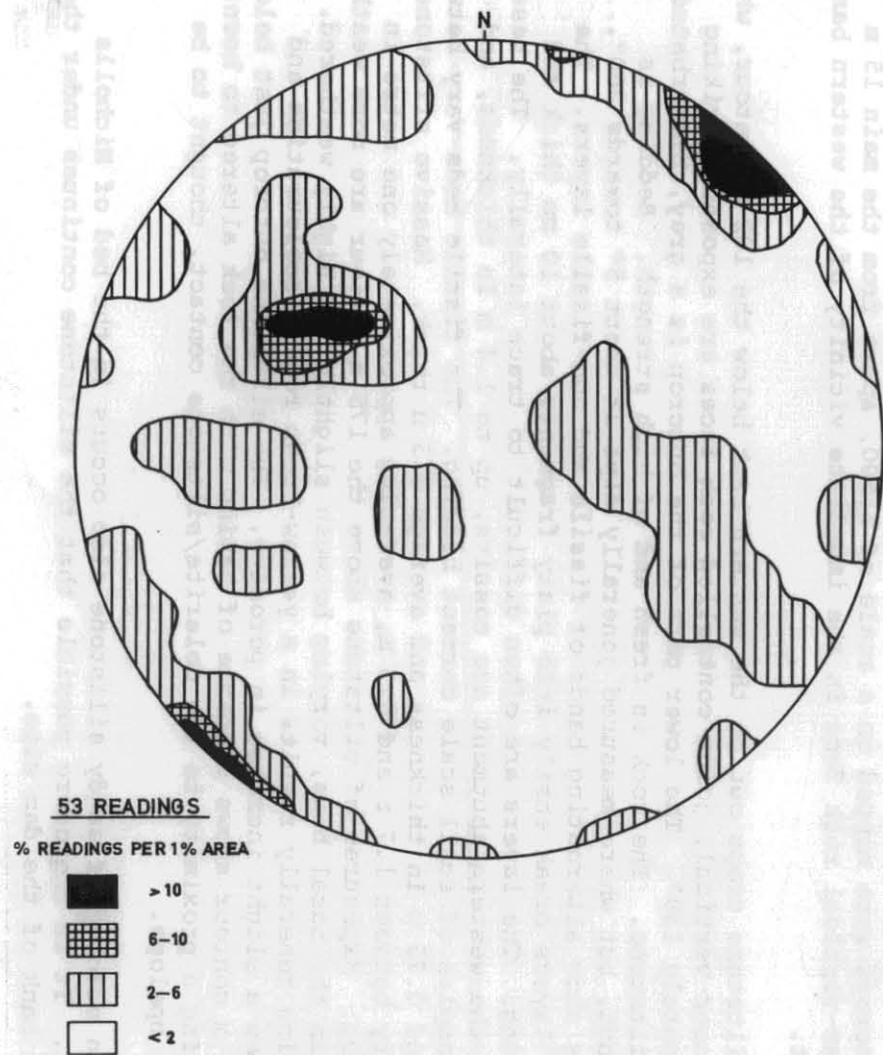


Figure 4. Contoured stereoplot of catchment joints

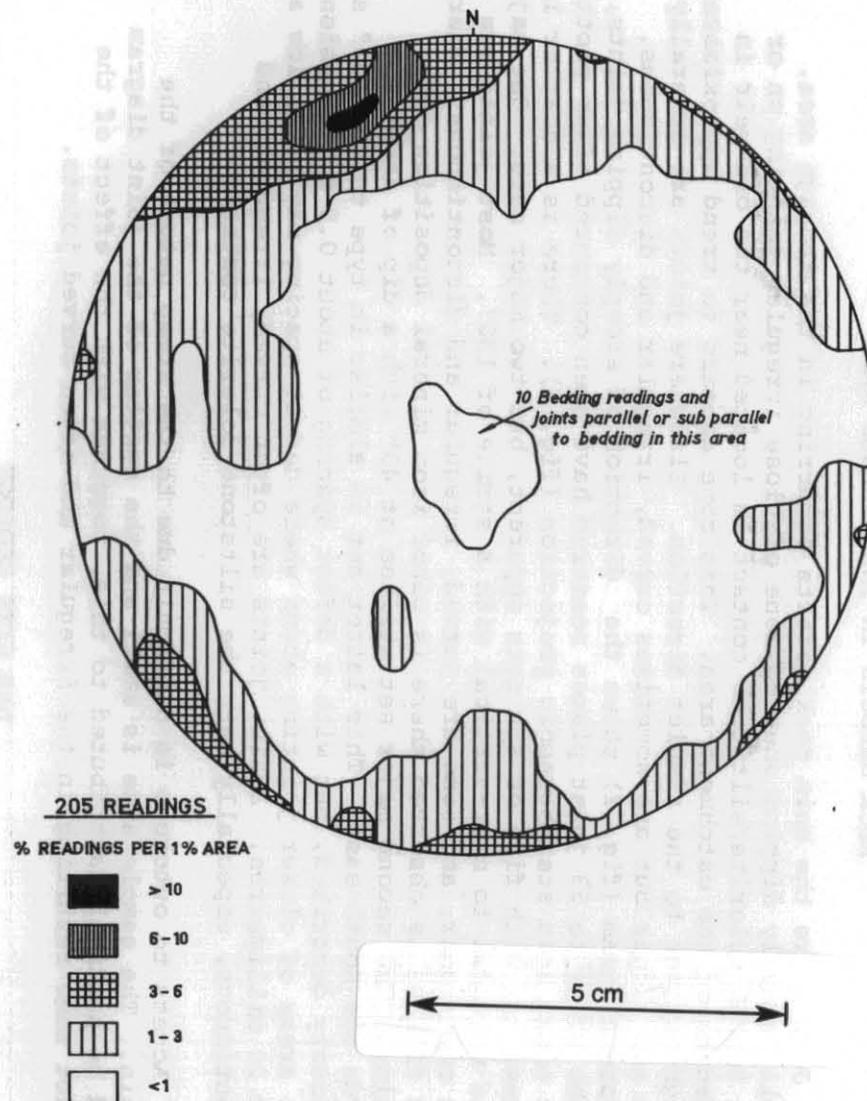


Figure 5. Contoured stereoplot of dam site joints

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Areas not mapped as outcrop are covered with thin soil containing rock fragments. Below about the 190 m contour the soils are grey-brown silty and clayey sands. They are of low plasticity and friable on the surface, with an open, porous structure. Angular siltstone rock fragments constitute between 30% and 60% of the soil. These fragments vary in size, averaging between 0.2 m and 0.3 m, but up to 0.8 m in diameter.

Above the 190 m contour break of slope, slope angles are much flatter (with values of 25°) and the soil contains about 10% of rock fragments. The soil is largely a dolerite-derived brown to yellow-brown silty and sandy clay (CL) of moderate plasticity. Angular rock fragments are predominantly medium to fine-grained dolerite and average 0.15 m diameter. Siltstone and hornfels rock fragments are incorporated in the soil adjacent to exposures.

*Eastern bank*

The eastern bank of the proposed dam site is entirely covered by dolerite talus. Surface rock fragment density has been mapped, but as described previously, does not necessarily reflect the rock fragment density in the underlying deposit. Rock fragments are composed of medium-grained dolerite, apart from one sandstone fragment found south of the grid. Track cutting exposures show that the dolerite boulders range up to 1.5 m in size (averaging 0.2 m), while densities vary between 30% and 50%. Fragments vary from angular to rounded, are of low to moderate sphericity, and are slightly to highly weathered. The matrix is a low to moderate plasticity gravelly and silty clay (CL), but becomes a clayey gravel (GC) where abundant gravel-sized decomposed rock fragments occur. Some fill is present at the foot of the eastern bank where large boulders of dolerite up to 3 m in diameter are mixed with logs and talus. Seismic spreads indicate that the dolerite talus is likely to extend to a depth of five to six metres. Below this depth it is possible that Permian siltstone occurs, as indicated by seismic information and creek bed exposures. Alluvial deposits in the valley floor have been described above. In the dam site area these deposits appear to be between 1.0 m and 1.5 m in thickness.

ROCK DEFECTS AT THE DAM SITE

Joints and bedding fissility are the major rock defects observed on siltstone exposures. Three minor and two major joint sets have been mapped. The rose diagram on Figure 2 shows the direction of all steeply dipping joints, and the poles to joint planes have been plotted on an equal area stereographic projection and contoured (fig. 5). One major joint set strikes at 70° with a dip of about 75° to the south-east, while the other is near-vertical with a 130° strike. Fissile beds generally dip at about 5° towards 360° and some jointing or bedding parting occurs in this direction. The major set striking at 130° controls the major exposure faces. Major joint spacing is at about one metre, and this is reflected by outcrop benches and terraces. Major joints are continuous, but discontinuous joints with a spacing of between 0.2 m and 0.3 m also occur with a 130° strike direction. The 70° joint set is not as continuous and joint spacing varies between 0.3 m and 0.7 metres. All joints are generally planar and clean, but curved, irregular, and discontinuous joints do occur. Joints are often not continuous across bedding, with small scale joints restricted to a single bed. Iron mineral deposition and staining has occurred along occasional joints. Joint relaxation is evident in exposures above about the 170 m contour. Joint blocks approximately one metre in diameter and rock fragments 0.2 m to 0.3 m in diameter are often found at the base of exposures, again reflecting joint control. Information

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obtained from seismic spread 6 indicates that joint relaxation may extend to a depth of about ten metres. The major vertical to subvertical joint set with a strike direction of 130° will require further investigation because of its leakage potential, with the joint direction being almost parallel to the Nicholls Rivulet.

#### SEISMICITY

Moon (1979) reported that levels of seismic activity in south-eastern Tasmania are generally low, with earthquake events uncommon. The major event occurring in the Cygnet area was a 2.1 to 2.5 magnitude earthquake in August, 1962. This information should be considered and further advice sought at the dam design stage.

#### CONCLUSIONS AND RECOMMENDATIONS

Surface geological mapping has been conducted in detail and the results presented. Six seismic spreads were undertaken in an attempt to determine the thickness of talus on the eastern bank, the type and condition of rock beneath the talus, the degree and depth of weathering and jointing of the siltstone exposed on the western bank and valley floor, and the depth of alluvial deposits on the valley floor (Appendix 1).

Further work is required to investigate potential leakage areas. The western bank abutment may have joint relaxation extending to about 10 m in depth and a major joint direction lies parallel to the rivulet. Siltstone beneath the valley floor appears to be in better condition, as evidenced by much higher seismic velocities. The number and condition of joints in this area requires further investigation. The nature, permeability and stability of the talus requires investigation in the eastern bank area. Trenching and sluicing are required on the western bank abutment and valley floor to enable detailed mapping, probably at a scale of 1:100. Bedrock in these areas is considered to be between one and two metres below the ground surface. Suggested diamond drill sites with borehole length, inclination, and direction are shown in Figures 2 and 3 and Appendix 2. These holes will require detailed logging and water pressure tests to determine rock permeability and possible grouting treatment. Their final location will depend on the results of the detailed mapping suggested above. Access to the western bank drill site will be difficult due to the steepness of the terrain. It is, however, considered essential to accurately determine the nature and condition of the rock which has a seismic velocity of between 1000 m/s and 1300 m/s (Appendix 1) and which may extend to a depth of about ten metres. This seismic velocity may indicate extensive jointing, joint relaxation, and/or weathering.

Suggested investigation of the eastern bank abutment includes trenching, material testing, and possible diamond drilling. Trenching should be attempted first, in the area indicated on Figure 2. Excavation is required to determine the nature, permeability, and depth of the talus material.

Excavation to a depth of about 5 m to 6 m is required to attempt to determine the nature and condition of the 1900 m/s to 2250 m/s seismic velocity layer. Permeability tests of the talus material are required as well as stability calculations, especially under fully saturated and rapid drawdown conditions. In talus areas investigated elsewhere in Tasmania (Sloane, 1978), a highly permeable talus horizon often occurs at the talus-bedrock interface. This should be considered during site investigations. Diamond drilling may be required, depending on the results of the eastern bank trenching. Suggested sites showing hole lengths, direction, and

inclination are shown in Figures 2 and 3 and Appendix 2. Core obtained must be logged in detail and water pressure permeability tests conducted to determine possible leakage and grouting treatment required.

The soil and talus on the valley slopes may require testing to determine their stability, especially under rapid water table drawdown situations. Track cutting slumping has occurred and a small tension crack is evident in soil on the western bank below the 170 m contour, 20 m north of the proposed dam site. Dispersion tests on storage area soil and talus should be performed. Elsewhere in Tasmania, soils developed on Permian age rocks are sometimes dispersive, often resulting in tunnel and gully erosion.

REFERENCES

FARMER, N. 1981. Geological atlas 1:50 000 series. Sheet 88 (8311N). Kingborough. *Department of Mines, Tasmania.*

LEAMAN, D.E. 1968. Geological survey - Nicholls Rivulet dam site. *Tech.Rep.Dep.Mines Tasm.* 12:74-77.

LEAMAN, D.E.; NAQVI, I.H. 1967. Geology and geophysics of the Cygnet district. *Bull.geol.Surv.Tasm.* 49.

MOON, A.T. 1979. Report on pre-feasibility geological site investigations, Metropolitan Water Board Dunns Creek Project. *Unpubl.Rep.Dep.Mines Tasm.* 1979/30.

SLOANE, D.J. 1978. Slope stability in the Mt Punter area, eastern Tasmania. *Unpubl.Rep.Dep.Mines Tasm.* 1978/41.

[2 March 1983]

## APPENDIX I

## Interpretation of refraction seismic traverses

The positions of six seismic refraction traverses are shown on Figure 2. Depth interpretations were made by critical distance, reciprocal, and time delay methods. The interpretations are included in the cross-section (fig. 3) and the results are summarised below.

## LEFT BANK

## 3 to 4 layer case

<i>Layer</i>	<i>Seismic velocity (m/s)</i>	<i>Thickness (m)</i>	<i>Interpretation</i>
1	200 - 450	1 - 2	Soil, loose talus
2	700 - 750	4 - 5	Dolerite talus
3	1900 - 3000	12 - 15	Siltstone or weathered dolerite
4	3700 - 4000	?	Dolerite or dense metamorphosed siltstone

## VALLEY FLOOR

## 3 layer case

<i>Layer</i>	<i>Seismic velocity (m/s)</i>	<i>Thickness (m)</i>	<i>Interpretation</i>
1	400 - 600	1 - 2	Alluvium
2	1700 - 3000	5 - 7	Siltstone, massive, closed joints
3	5000 - 5800	?	Dolerite or dense metamorphosed siltstone

## RIGHT BANK

## 3 layer case

<i>Layer</i>	<i>Seismic velocity (m/s)</i>	<i>Thickness (m)</i>	<i>Interpretation</i>
1	300	1 - 1.5	Soil and siltstone talus
2	1000 - 1300	9 - 11	Siltstone - open joints and/or weathered
3	2000	?	Siltstone - closed joints

APPENDIX 2

Proposed diamond drill holes (see figs. 2 and 3)

<i>Hole Number</i>	<i>Length (m)</i>	<i>Direction (mag)</i>	<i>Inclination</i>
1	20	30°	60°
2	22	210°	60°
3	13	50°	60°
4	15	230°	60°
5	15	30°	60°
6	12	210°	60°
7	30	30°	60°
8	<u>15</u>	210°	60°
Total	<u>142</u> m		

Note that the above are proposed sites. Changes in site may be necessary, especially of Holes 7 and 8, because of access. The length of boreholes will be governed by information to hand at the time as will directions and inclinations. Difficulties are often experienced in drilling angled holes, especially where vertical joints etc. may cause deflection. The proposed holes have been inclined in order to intersect vertical joints. The hole directions are suggested to enable good intersection of the two major joint directions of 130° (mag) and 70° (mag). Alterations to the above may be required depending on the continuing assessment of the program.

## APPENDIX 3

## Rock mass classification and joint measurement

*WEATHERING PRODUCTS CLASSIFICATION*

<i>Term</i>	<i>Abbreviation</i>	<i>Definition</i>
Fresh	Fr	Rock shows no sign of decomposition.
Slightly weathered	SW	Rock is slightly discoloured but generally shows little or no change of strength from fresh rock.
Highly weathered	HW	Rock strength changed by weathering. The rock may be highly discoloured, usually by iron staining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.
Extremely weathered	EW	Rock is weathered to such an extent that it has soil strength properties, i.e. it either disintegrates, or can be remoulded, in water and can be described according to the Unified Soils Classification system.

*ROCK STRENGTH CLASSIFICATION*

<i>Rock strength class</i>	<i>Abbreviation</i>	<i>Point Load strength index, Is (50) (MPa)</i>	<i>Equivalent Unconfined strength, Qu (MPa)</i>
Extremely low	EL	< 0.03	< 0.7
Very low	VL	0.03 to 0.1	0.7 to 2.4
Low	L	0.1 to 0.3	2.4 to 7
Medium	M	0.3 to 1	7 to 24
High	H	1 to 3	24 to 70
Very high	VH	3 to 10	70 to 240
Extremely high	EH	> 10	> 240

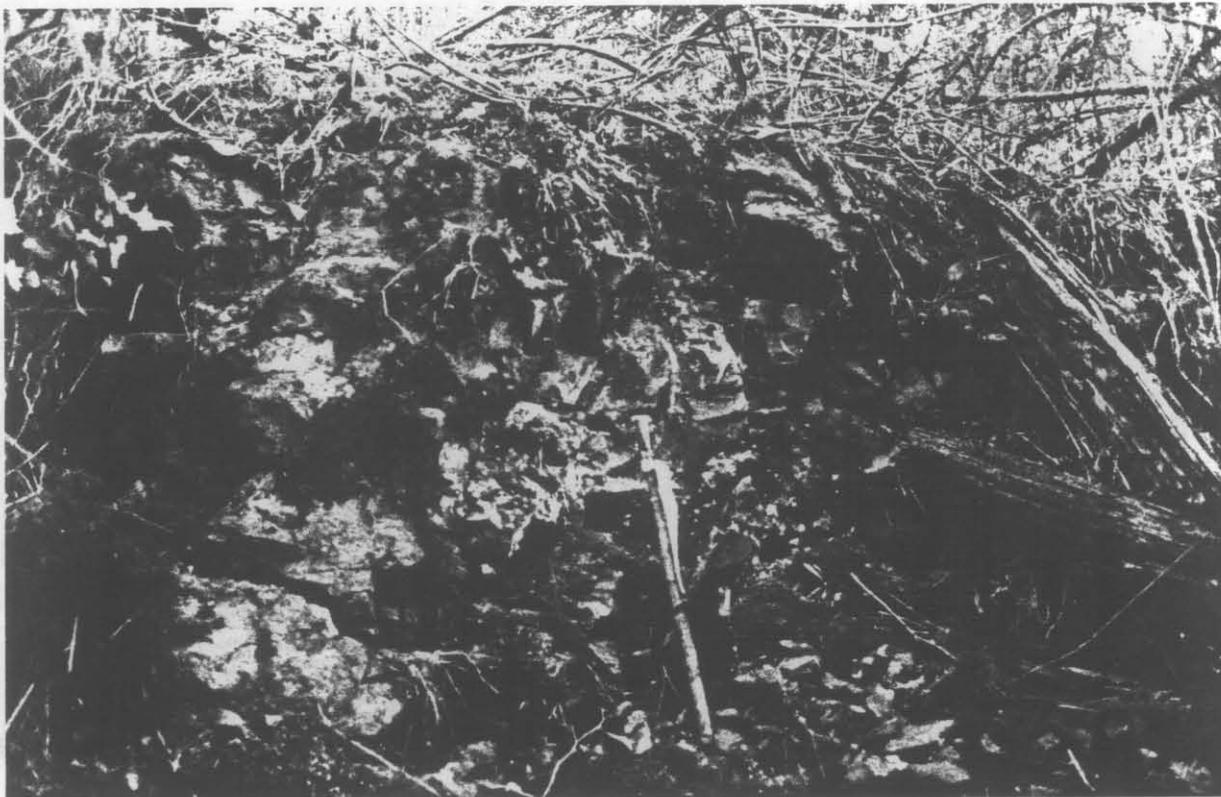


Plate 1. Siltstone outcrop at the foot of the western abutment rock face. Note the major joint set of  $70^\circ$  strike and dipping at about  $75^\circ$  to the south-east.



Plate 2. Northern part of the western abutment siltstone outcrop (looking south). Major  $130^\circ$  strike vertical joint set can be clearly seen.

5 cm



Plate 3. *Dolerite talus. Exposure in track cutting, eastern bank of dam site.*



Plate 4. *Dolerite, siltstone and sandstone talus exposed in track cutting in the northern part of the storage area.*



Plate 5. *Siltstone outcrop of western bank abutment, showing alternating fissile and non-fissile beds.*