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1979/30. Report on pre-feasibility geological site investigation, Metropolitan Water Board Dunns Creek Project.

A.T. Moon

Abstract

The proposed Dunns Creek Project involves a 15 to 20 m high dam on Dunns Creek, a tributary of Browns River, close to Kingston. Pre-feasibility geological studies have been carried out in the period March to May 1979.

The project area is underlain by siltstone, with minor sandstone and conglomerate, of Permian age. Sandstone of Triassic age occurs outside the storage area and dolerite crops out upstream from the site. The rocks have been subjected to faulting, uplift, weathering and erosion. Residual soils have developed on ridges and slopes and alluvium covers valley floors. Topographically, the most striking feature is the narrow Right Bank Ridge, separating Dunns Creek from Browns River close to the dam site.

The dominant rock type exposed at the dam site is highly weathered coarse siltstone in alternating fissile and non-fissile beds. The surface soil on the valley sides consists of sandy silty clay with weathered rock fragments. The valley floor contains 0.5 to 2.5 m of alluvium. Three main defect sets occur. The weathering profile below the surface is not known.

The storage area is underlain by either siltstone or river alluvium. Apart from the Right Bank Ridge near the dam site, the reservoir is expected to be watertight.

Possible quarry sites in siltstone within the storage area have been indicated but not mapped in detail.

The south-east of Tasmania has a low level of seismic activity and felt earthquakes are rare.

Although the investigations have not revealed any major geological problem a thorough subsurface investigation is required before the feasibility of the project can be confirmed from the geotechnical point of view. Recommendations for feasibility investigations and some cost estimates are given in the final section of the report.

INTRODUCTION

The Dunns Creek Project involves the construction of a dam of 15 to 20 m maximum height on Dunns Creek [EN243433], about 100 m upstream of its junction with Browns River (fig. 1). Browns River flows into the River Derwent at Kingston, 10 km south of Hobart. The dam will impound about 200 Ml of water in a storage area extending about 600 m upstream. It is understood that a faced rockfill dam is proposed, but the final choice of dam type may depend on foundation conditions and the availability of suitable construction materials.

In March 1979, the Metropolitan Water Board requested the Department of Mines to undertake geological investigations for the project. This report describes the results of the investigations carried out between March and May 1979 and recommends a programme of subsurface investigation considered necessary to assess project feasibility from the geotechnical viewpoint.

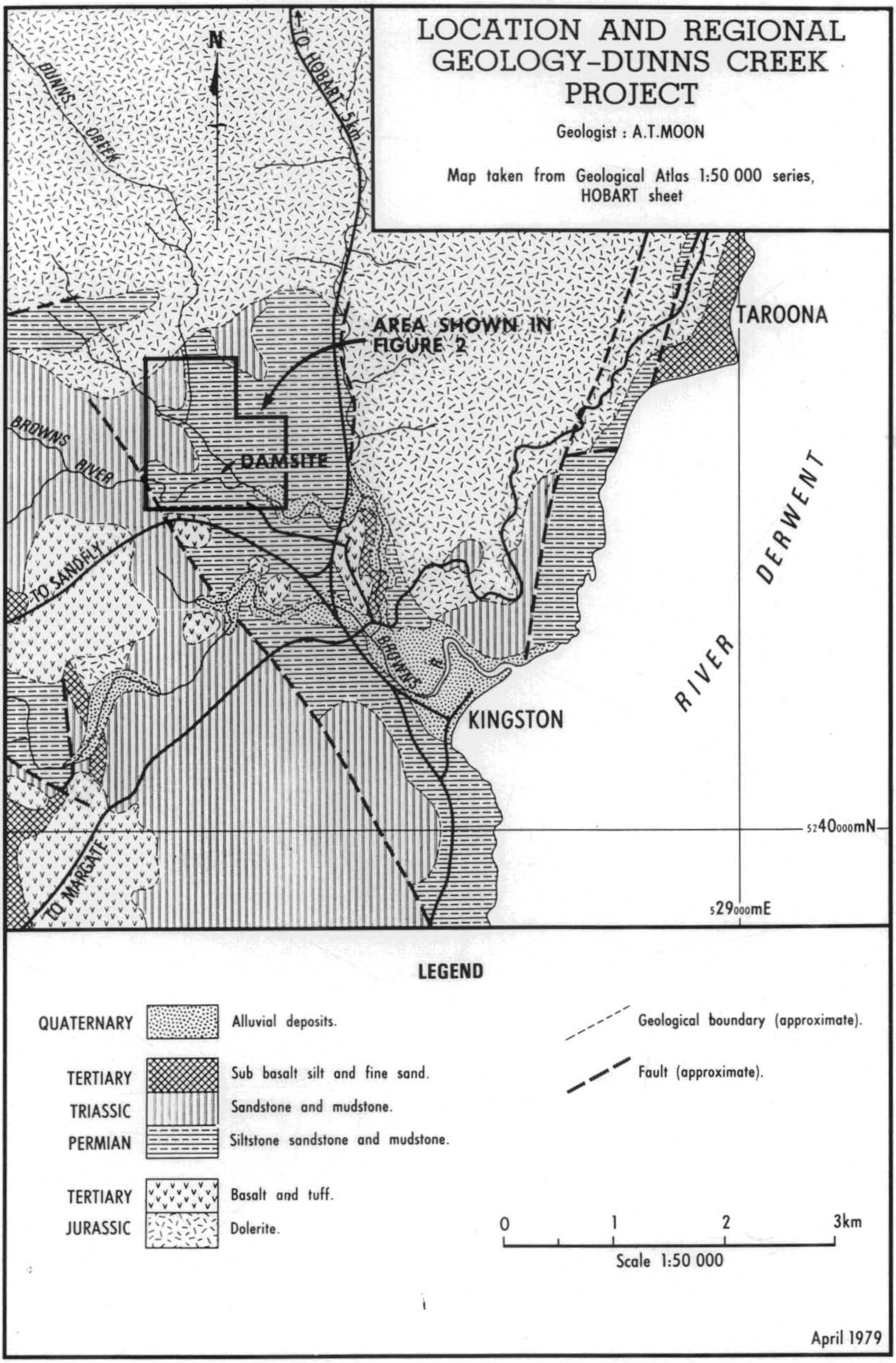

LOCATION AND REGIONAL GEOLOGY-DUNNS CREEK PROJECT
Geologist : A.T.MOON
Map taken from Geological Atlas 1:50 000 series, HOBART sheet
N
DUNNS CREEK
TO HOBART 5km
AREA SHOWN IN FIGURE 2
DAMSITE
BROWNS RIVER
TO SANDFLY
TAROONA
RIVER DERWENT
BROWNS R
KINGSTON
TO MARGATE
5240000mN
529000mE
LEGEND
QUATERNARY
Alluvial deposits.
TERTIARY
Sub basalt silt and fine sand.
TRIASSIC
Sandstone and mudstone.
PERMIAN
Siltstone sandstone and mudstone.
TERTIARY
Basalt and tuff.
JURASSIC
Dolerite.
Geological boundary (approximate).
Fault (approximate).
0
1
2
3km
Scale 1:50 000
April 1979

Figure 1.

5 cm

The investigation has involved geological mapping on scales of 1:2500 and 1:250 and seismic refraction traverses which were carried out under the direction of Senior Geologist W.R. Moore.

REGIONAL SETTING AND GEOLOGY OF PROJECT AREA

The project area is underlain by siltstone and sandstone of the Ferntree Group (fig. 1 and 2). These rocks were originally deposited as marine sediments during the Permian period. The rocks exposed in the project area consist mainly of coarse-grained siltstone, commonly with alternating fissile and non-fissile bands, but some sandstone and thin conglomerate does occur. The siltstone often contains rounded to sub-angular pebbles of quartz or quartzite up to 300 mm across. Ellipsoidal holes, flattened parallel to bedding, occur in some beds of siltstone. These holes can be up to two metres in diameter and appear to be the result of the removal of more erodible material during the weathering process.

The Ferntree Group is reported to be 165 to 180 m thick (Leaman, 1976) and fossils found at the dam site, *Megadesmus grandis* (Dana) and *Vacunella curvata* (Morris), correlate with Horizon B, a fossiliferous horizon 35 to 50 m below the top of the group (Clarke, 1973).

Sandstone, believed to have been deposited in freshwater during the Triassic, overlies the Ferntree Group siltstone to the west and north of the storage area. The massively bedded medium- to coarse-grained quartz sandstone is exposed in cliffs overlooking the major tributary to Dunns Creek. Thin shale beds might be expected to occur but were not observed in the field.

The third major rock type in the area is dolerite which was intruded into the Permian and Triassic rocks during the Jurassic period. Dolerite crops out in Dunns Creek about 2 km upstream from the dam site (fig. 1).

During the Tertiary period, sediment and basalt were deposited in basins between outcrops of older rocks. Since the basalt eruptions, erosion and weathering have been the dominant geological processes in the area. All the rocks exposed on the surface are highly weathered. Residual soils have developed, silty sandy clay (CL)* overlying siltstone, and silty sand (SM) overlying sandstone. Talus, silty sandy clay (CL-CH) with many rock fragments, has developed on steeper slopes and may be up to three metres thick at the base of slopes. Alluvium, consisting of pebbles, cobbles and boulders in a matrix of clayey silty sand (SC) has been deposited in valley floors.

The whole of the lower Derwent Valley is divided into blocks by north and north-westerly trending faults. Most of these faults first developed during the Jurassic period, but many were also active during the Tertiary period. Most of the blocks are gently tilted towards the west. The silt-stone of the Ferntree Group in the project area dips south-west at 5° to 15°.

The most striking topographic feature in the project area close to the dam site is the narrow ridge separating the lower part of the Dunns Creek valley from the Browns River valley (fig. 2). In the vicinity of the dam this ridge has been termed Right Bank Ridge (fig. 3 and 4) and is significant to the project because of the potential leakage out of the reservoir through the ridge.

* Unified Soil Classification System, S.A.A. Site Investigation Code AS1726-1975. Addendum 1, Appendices A-D (1978).

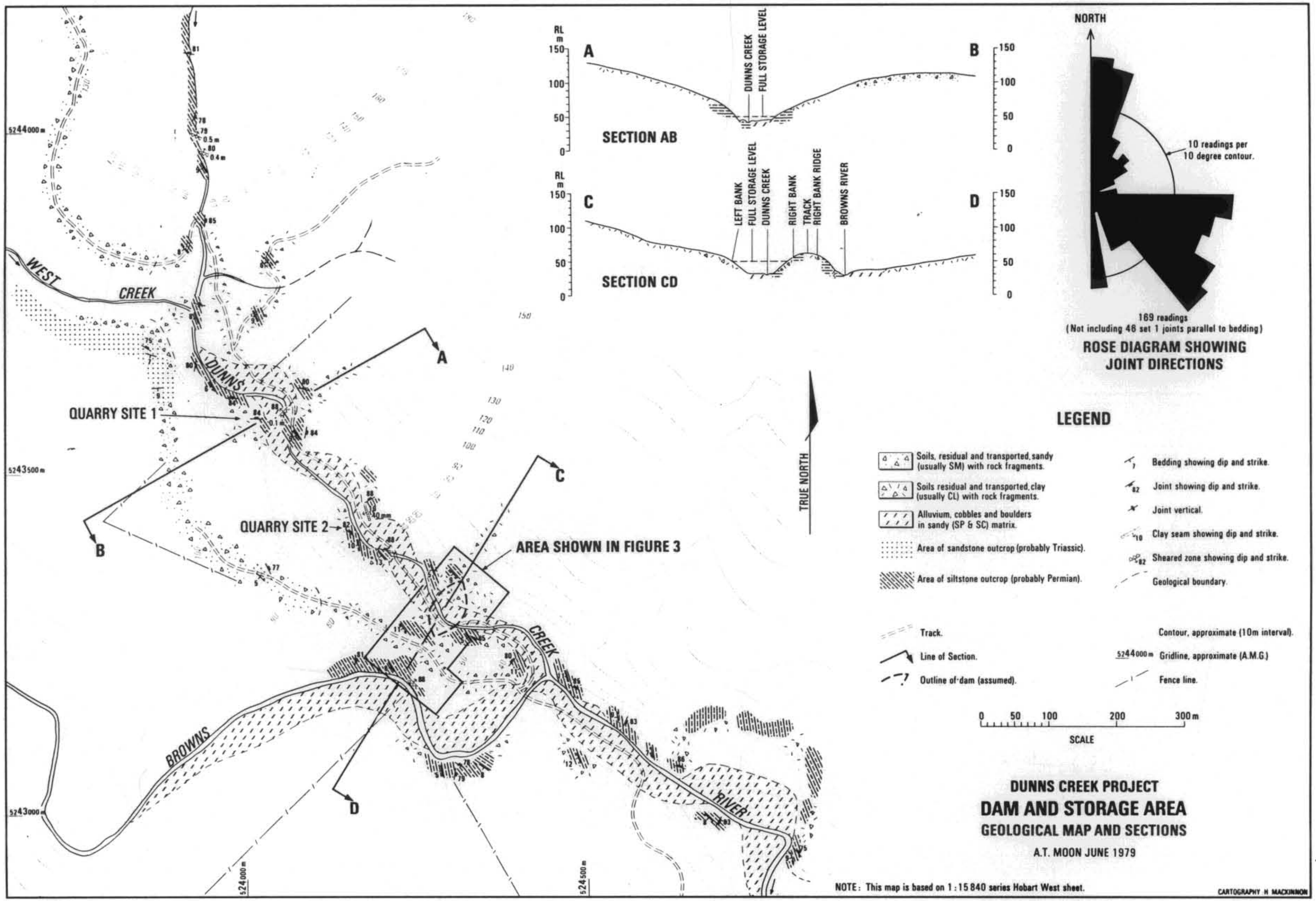


Figure 2.

30-4

6/23

DAM SITE AND RIGHT BANK RIDGE

Rock and soil types and their distribution

Rocks

In the dam site and Right Bank Ridge area (fig. 3) the rock exposed is dominantly siltstone with minor sandstone and conglomerate. The beds strike south-east (roughly parallel to Dunns Creek) and dip at 5° to 15° towards the south-west (right bank). The distribution of the rocks is shown in plan on Figure 3 and in section on Figure 4.

The rocks exposed at the surface are highly weathered. The siltstone is coarse-grained, mottled grey and yellow-brown and generally of high strength (see Appendix 1 for strength and weathering classifications). The siltstone mostly shows bedding in the form of alternating pale and dark layers. Some outcrops show alternating beds of fissile and non-fissile siltstone. The proportion of each type varies, but bed thickness is generally between 200 and 600 mm. The fissile beds break more readily into platy shaped fragments about 10 to 30 mm thick.

The sandstone is yellow-brown when highly weathered, slightly friable and of medium strength. It is medium- to coarse-grained. A two metre thick bed of sandstone crops out close to Browns River (see section GH, fig. 4) and sandstone was observed cropping out on the right bank. In this preliminary investigation, no attempt was made to distinguish between the sandstone and coarse siltstone in the weathered outcrops. The sandstone beds will be mapped in detail during the feasibility studies after trenching and drilling has exposed the complete succession.

The conglomerate consists of angular to rounded pebbles of quartzite, quartz, and hornfels in a gravelly sandstone matrix. The pebbles are generally 30 to 100 mm in diameter. The maximum thickness of conglomerate observed is 500 mm and the beds may be impersistent.

Soils overlying rocks on the ridge and valley sides

Most of the valley sides and Right Bank Ridge is covered by soil with scattered rock fragments and locally boulders up to 1.5 m in diameter. The surface soil generally consists of a grey-brown sandy silty clay (CL) of low to medium plasticity containing angular, highly to extremely weathered rock fragments, up to 300 mm in diameter. The rock fragments are mainly siltstone with some sandstone and conglomerate. The proportion of rock fragments increases with depth. The seismic refraction results (Appendix 2, fig. 7) indicate that soil and rock fragments (V = 400 - 700 m/s) occur to a depth of up to three metres, but are generally 1 to 2 m thick.

Locally large angular rock fragments almost cover the surface (fig. 3). These fragments are up to 1.5 m in diameter and consist mainly of highly weathered siltstone. The presence of these boulders appears to indicate that a more resistant band of rock is close to the surface.

Slope deposits have accumulated at the base of some of the valley sides. These deposits consist of closely packed angular rock fragments in a matrix of silty sandy clay (CL). Where small exposures have revealed deposits containing greater than 50% rock fragments, the area has been mapped as talus on Figure 3. Talus deposits may be up to three metres thick at the base of slopes.

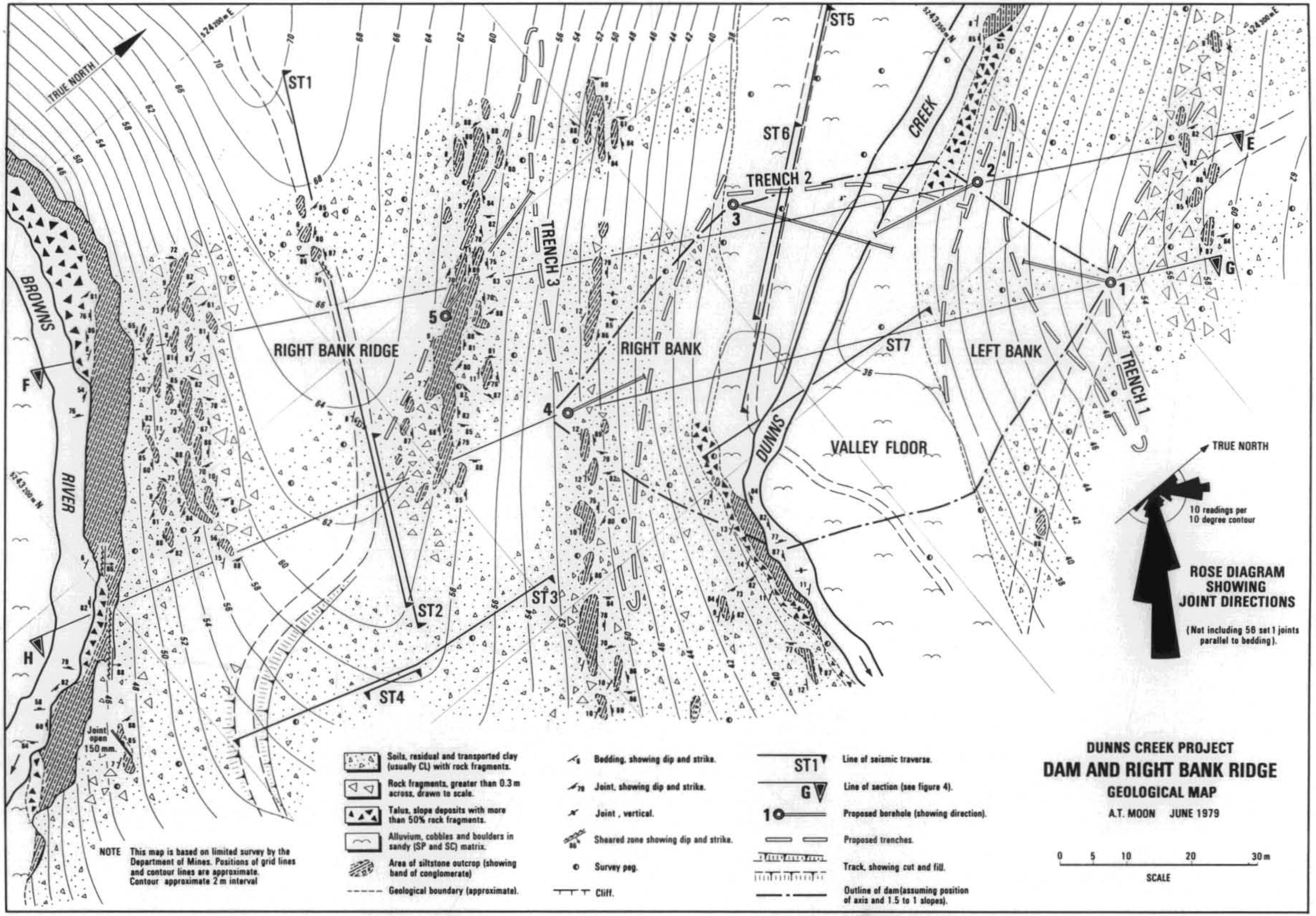


Figure 3.

30-6

5 cm

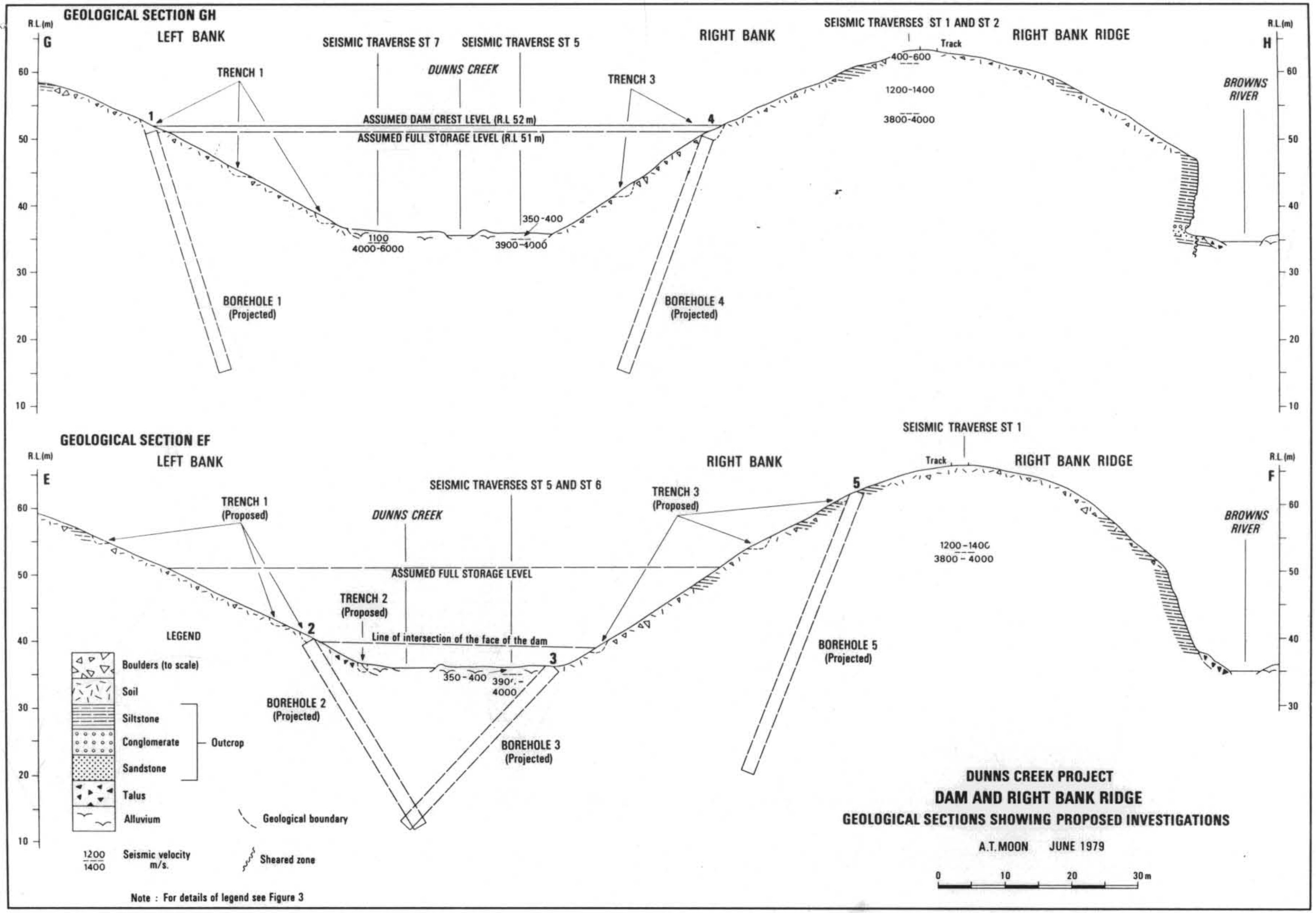


Figure 4.

5 cm

30-7

Alluvium

Alluvium occurs in the valley floors. It consists of pebbles, cobbles and boulders of slightly to highly weathered rock in a matrix of gravelly clayey silty sand (SC). The rock fragments are rounded to sub-angular and consist of sandstone, siltstone and dolerite. The matrix is grey-brown, moist and of low plasticity. In places, the alluvium is overlain by a top soil of dark grey, organic, clayey silty sand (SC) up to 200 mm thick.

The seismic refraction results indicate that the alluvium varies from 0.5 to 2.5 m thick. The velocity varies from 300 - 600 m/s in the centre of the valley up to 800 - 1100 m/s at the sides of the valley. The increase in velocity may be due to a denser matrix.

Part of one of the seismic traverses (ST6, fig. 7) showed an intermediate velocity layer (V = 1300 m/s) to a depth of three metres. This may be due to the presence of an old buried creek channel or it may represent weathered or loosened bedrock.

Defects in the rock mass

Defects in the rock mass at and near the dam site include joints and sheared zones (faults) as defined in Table 7, Appendix 1.

Apart from the joints parallel to the bedding, most joints and sheared zones measured are near vertical. The rose diagram (fig. 3) shows the main joint directions for the dam site and Right Bank Ridge area and the poles to joint planes are plotted on a stereographic projection in Figure 6 (Appendix 1). Although six or seven steeply dipping joint sets occur, two main sets dominate, which, with the joints parallel to bedding (not shown on the rose diagram or stereographic projection) make up the three main defect sets shown in Table 1.

Table 1. MAIN DEFECT SETS IN DAM SITE AND RIGHT BANK RIDGE AREA

Set No.	*Attitude*	*Description*
1	Parallel to bedding, strike 130° to 150°, dip 5 to 15° towards south-west (into right bank).	Joints of large extent (greater than 10 m), usually planar but sometimes irregular, surfaces rough.
2	Strike 110° to 140°, near vertical or dipping steeply south-west.	Joints or sheared zones of large extent (greater than 10 m) usually planar with rough surfaces.
3	Strike 020° to 050°, near vertical or dipping steeply south-east.	Joints, extent unknown (because striking across topography). Planar or irregular, surfaces rough.

The spacing of the defects varies. For Set 1, the spacing is generally 0.3 to 1.0 m and for Sets 2 and 3 generally 1 to 3 m, but sometimes closer. It was noted that where sandstone beds are interbedded with coarse siltstone, defects are more common in the sandstone beds. Joints in the sandstone

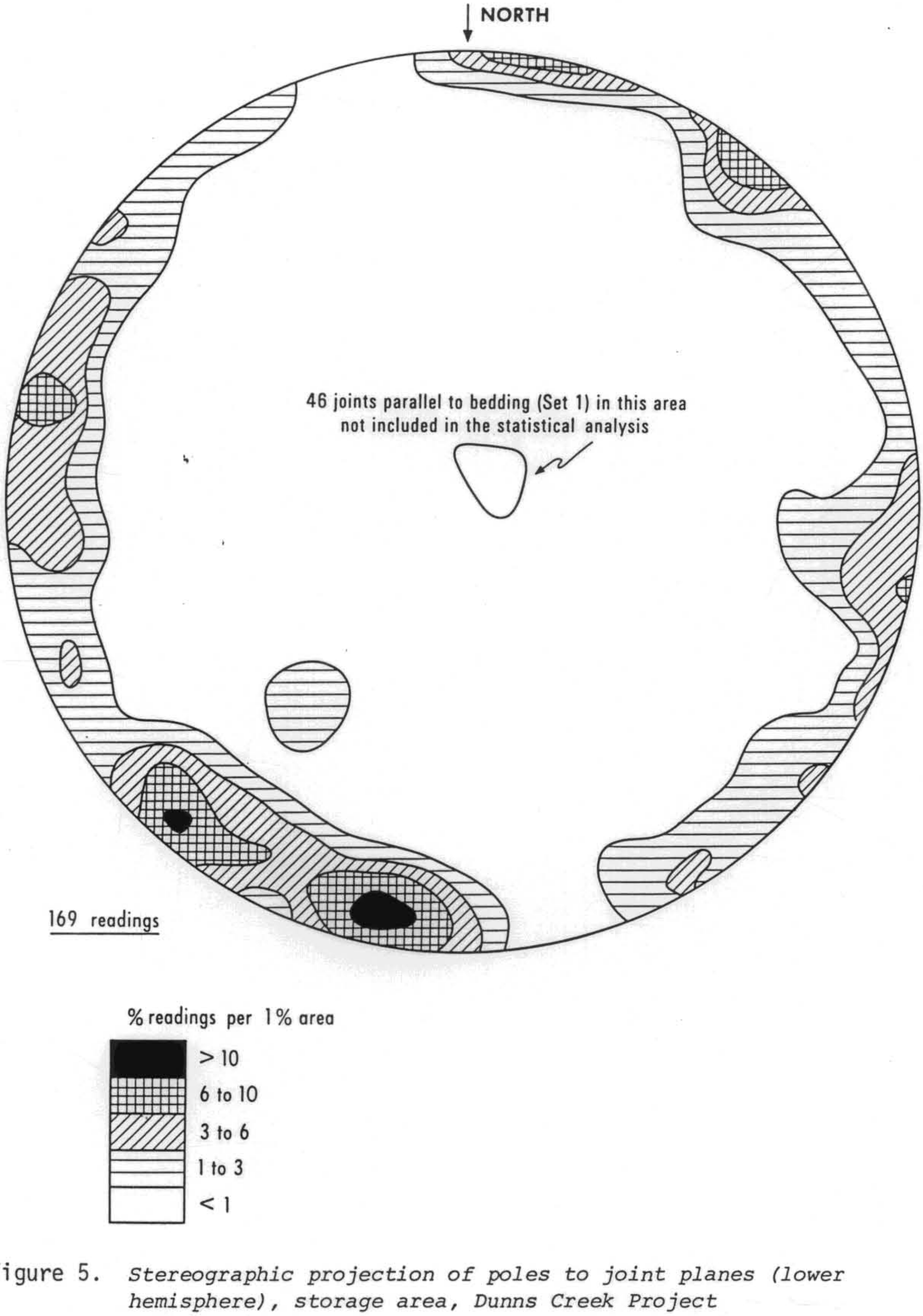
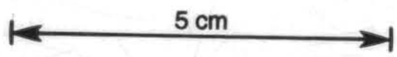


Figure 5. *Stereographic projection of poles to joint planes (lower hemisphere), storage area, Dunns Creek Project*



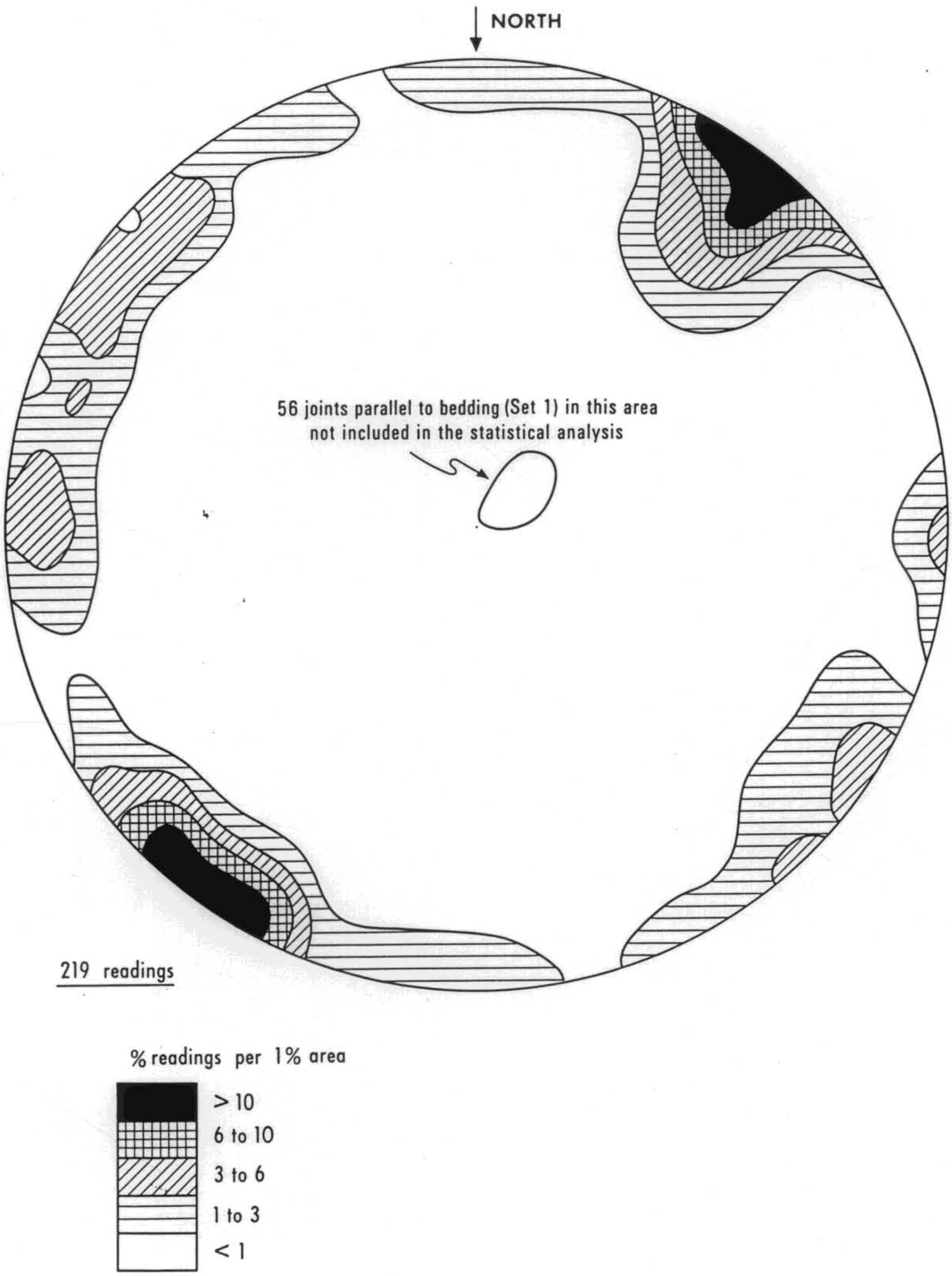
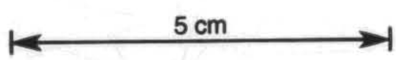


Figure 6. *Stereographic projection of poles to joint planes (lower hemisphere), dam and Right Bank Ridge, Dunns Creek Project*



sometimes do not continue into the adjacent siltstone.

In outcrop, joints are open or filled with soil, but most may be expected to be closed below the surface. One very prominent open joint has been mapped in an outcrop above the cliff overlooking Browns River (fig. 3). In this locality the whole rock mass is probably loosened and open joints may extend down to river level. This is caused by movement of the rock mass towards the river along Set 1 defects.

The highest velocity obtained in the seismic refraction traverses was about 4000 m/s and this probably represents a rock mass consisting of fresh or slightly weathered rock with tightly closed defects. The intermediate velocity (1200 - 2200 m/s) obtained below the Right Bank Ridge may be due partly to the more weathered condition of the rock and partly due to the presence of open or infilled defects in a slightly loosened rock mass.

The most prominent sheared zone (fault) observed was adjacent to Browns River (fig. 3 and section GH, fig. 4). It consisted of a zone of closely spaced fractures about 500 mm wide. There is no apparent displacement across the fault.

Depth and degree of weathering

All of the rocks exposed in outcrop are highly weathered. The weathering profile below the surface is not known and can only be determined by trenching and drilling. It is likely that fresh rock will be closer to the surface below the valley floor than under the ridges. The material 0.5 to 2.5 m below the alluvium and 8 to 15 m below the crest of the ridge, with a seismic velocity of about 4000 m/s, probably represents fresh or slightly weathered rock.

STORAGE AREA

Assuming a 15 m high dam, the storage area extends up Dunns Creek as far as its junction with West Creek (fig. 2). Geological mapping has shown that the entire storage area is underlain by either siltstone of Permian age or river alluvium.

There is potential for leakage of the reservoir through the Right Bank Ridge (fig. 3) close to the dam. The remainder of the reservoir is likely to be watertight.

The sides of Dunns Creek valley generally slope at 20 to 30°, but locally there are slopes up to 50° and small cliffs. Minor instability may develop on the left (north-west) side of the valley, particularly if there are rapid changes in water level. The soils overlying the siltstone are similar to those described at the dam site. It is not known whether the soils are dispersive.

CONSTRUCTION MATERIALS

Assuming a 15 m high dam in the position shown in Figure 3, with 1.5 to 1 slopes, the total volume of the dam will be about 25 000 m^3. It is understood that a faced rockfill dam has been proposed and, if possible, the dam should be constructed from siltstone quarried within the storage area. Two possible quarry sites have been indicated on Figure 2. Both are located on the right (south-west) bank of Dunns Creek where the bedding will be in a more stable orientation (dipping into the face).

The geological mapping in the storage area and at the dam site indicates that quarries at the sites shown will encounter the same sequence of rocks exposed on the right bank of the dam site. The sequence will consist mainly of interbedded fissile and non-fissile coarse siltstone with minor sandstone and conglomerate. Detailed geological mapping of potential quarry sites has not been carried out and further work may indicate a preferred site.

Geological mapping in the storage area indicates that the main defects differed slightly in orientation to those at the dam site. Set 1 is similar (5 to 15° towards the south-west) and the other main sets are shown by the rose diagram (fig. 2) and the stereographic projection (fig. 5) (Appendix 1). Defect spacing is generally 0.3 to 1 m for Set 1 and 1 to 3 m for the other sets.

All of the rocks exposed in outcrop are highly weathered, but the depth and degree of weathering is not known. The highly weathered siltstone has a high strength.

If dolerite is preferred as a construction material there are operating quarries in the Hobart area. Dolerite also crops out about 2 km upstream from the dam site.

SEISMICITY

The south-east of Tasmania has a low level of seismic activity and felt earthquakes are rare. The two most significant events close to the site recorded in the last 20 years were;

Date	*Magnitude*	*Location*	*Distance from Site*
21 August 1962	2.1 to 2.5	Cygnet	25 km south-west of site
September 1975	1.5	Storm Bay	30 km south-east of site

The maximum acceleration at the site caused by these events is likely to have been less than 0.01 g.

Seismic risk studies have been carried out for the Tasman Bridge and the results of that study may be applicable to the site. Further information can be provided by R. Underwood of the Hydro-Electric Commission, if required.

CONCLUSIONS

The pre-feasibility geological investigations have not revealed any major problem that could throw doubt on the feasibility of the project. However, the work to date has been based on surface investigations only and a thorough sub-surface investigation is required before the feasibility of the project from a geotechnical point of view can be confirmed. Recommendations for feasibility investigations and some cost estimates are given below.

RECOMMENDATIONS FOR FEASIBILITY INVESTIGATIONS

The overall objective of the investigation is to confirm the feasibility of the project from a geotechnical point of view and to gather sufficient information to allow preliminary design. Regular progress reports will be provided throughout the investigation and a formal report will be prepared on completion of the work.

For convenience, the objectives of each of the major aspects of the work are set out at the beginning of the section describing the proposed activities.

Regional setting and geology of the project area

Studies of the regional and project area geology are aimed at;

- providing an understanding of the geological history of the region
- assessing whether any geological processes are still active to the extent that they could affect the project
- locating the main geological features of significance to the dam and storage
- checking that the area containing the dam site fits into the regional geological picture.

This work has already started and will continue during the feasibility studies. The work has included a review of published geological work in the region (Leaman, 1976; Clarke, 1973), interpretation of aerial photographs, and geological mapping on a scale of 1 to 2500 (produced at 1 to 2500 and 1 to 5000).

Dam site and Right Bank Ridge

Studies in the dam site and Right Bank Ridge area should provide a picture of the sub-surface geological conditions in sufficient detail to allow;

- adoption of the best dam and spillway location (geologically)
- confirmation of the suitability of the site
- estimation of the requirements for excavation and foundation treatment, for the type and size dam proposed
- an estimation of the potential leakage out of the reservoir through the Right Bank Ridge and grouting treatment required (if any).

The following field activities are proposed to achieve the above objectives:

(a) geological mapping on a scale of 1 to 250 (produced at 1 to 250 and 1 to 500). This has already been started.

(b) excavation of about 450 m of trenches in the positions shown on Figure 3. Trenches 1 and 3 should be excavated with a Caterpillar D7 and ripper and cleaned up by a backhoe and sluicing. These trenches will also serve as access tracks for the drill. Trench 2 should be excavated with a backhoe. Trenching should also be carried out at the site chosen for the spillway.

(c) geological logging of the trenches on scales of 1 to 250 and 1 to 100.

(d) drilling of 5 (or 6 depending on the quality of the Right Bank Ridge rock mass) diamond core holes totalling about 200 m in depth. The positions of the proposed holes are shown in Figures 3 and 4 and the details are given in Table 2. The positions shown are tentative and final siting will depend on the results of the previous activities.

(e) logging of the cores on a scale of 1 to 50 and the production of coloured photographs of the cores.

(f) testing the rock mass permeability by water pressure (Lugeon) tests in the boreholes.

(g) Seismic refraction traverses where appropriate.

Consideration may also be given to grouting tests depending on the results of the previous activities.

Table 2. PROPOSED BOREHOLES, DAM AND RIGHT BANK RIDGE

Borehole No.	*Bearing*	*Inclination*	*Length (m)*	*Approximate RL* (m) *Top*	*Bottom*
1	165°	70°	38	51	15
2	195°	60°	34	40	11
3	055°	45°	36	36	11
4	015°	70°	37	50	15
5	345°	60°	46	60	20

An additional hole may be required into the Right Bank Ridge depending on the results of logging trench 3 and if high leakages occur in boreholes 4 or 5. This should be allowed for in cost estimates.

Storage area

The storage area should be studied to confirm its watertightness, to assess the nature of any soil erosion problems, and to check for any areas of potential slope instability.

It may also be necessary to consider the feasibility of constructing a diversion channel around the edge of the reservoir to divert the waters of Dunns Creek.

The study will involve:

(a) stereoscopic examination of aerial photographs of the storage area (already started)

(b) geological mapping on a scale of 1 to 2500 (produced at 1 to 2500 and 1 to 5000) and at more detailed scales where necessary (already started)

(c) dispersion tests on soils

(d) seismic refraction traverses where appropriate

Construction materials

Studies of construction materials should be aimed at;

- locating a quarry site within the storage area
- assessing the quantity and quality of the material
- confirming its suitability as a construction material for the dam
- confirming that the selected quarry will provide material cheaper than can be obtained from existing quarries

The study will involve:

(a) geological mapping of selected sites on a scale of 1 to 250

(b) excavation of about 200 m of trenches at the preferred site with a Caterpillar D7 tractor and ripper. The trench should be cleaned up with a backhoe

(c) geological logging of the trenches on scales of 1 to 250 and 1 to 100

(d) drilling of one vertical diamond core hole to a depth of about 25 m. The position of the borehole will be selected after completion of the trenching

(e) logging of the core on a scale of 1 to 50 and the production of coloured photographs of the core

(f) seismic refraction traverses where appropriate

(g) testing of the material. Point load tests (induced tensile) and petrological examination can be carried out by the Department of Mines. Other testing can be carried out by the Hydro-Electric Commission. The HEC usually carry out Modulus testing on their construction materials. This involves load/deformation tests on graded samples in a 200 mm high, 200 mm diameter cylinder. Such tests are useful for comparative purpose and the results can be correlated with the field performance of material in many dams in operation in Tasmania.

Seismicity

If further information is required on the seismic risk at the site it is recommended that the advice be sought of R. Underwood of the HEC.

SUMMARY OF MAIN ACTIVITIES INVOLVING COSTS TO THE METROPOLITAN WATER BOARD

The main activities involving costs to the Metropolitan Water Board will be trenching, drilling, and material testing by the HEC.

It is estimated that the Caterpillar D7 tractor will be required for two weeks to excavate about 650 m of trenches at the dam and Right Bank Ridge and quarry site. A backhoe will be required for about 2 1/2 weeks to excavate trench 2 across the valley floor and to clean up the dozer trenches.

Drilling can either be carried out by the Department of Mines or by private contractors. An *approximate estimate only* of relative costs of Department of Mines, or private drilling based on a verbal quote from H. Stacpoole, is given in Table 3 and an estimate of total costs of the investigation is given in Table 4.

Table 3. COMPARISON OF DRILLING COSTS BETWEEN DEPARTMENT OF MINES AND PRIVATE CONTRACTORS

Verbal quote from H. Stacpoole, drilling contractor, Launceston.

Item	*Amount*	*Rate*	*Cost ($)*
Establishment		Lump sum	100.00
Drilling	260 m	@ $45.00 per m	11 700.00
Pressure testing	60 tests	@ $40.00 per test	2 400.00
Moving	6 moves	@ $20.00 per move	120.00
Standby (at clients' request)	Estimate 8 hrs	@ $30.00 per hour	240.00
Core boxes	45	@ $9.60 per box	432.00
		Total	14 952.00
		say	15 000.00

This estimate is based on the 5 boreholes proposed for the dam and Right Bank Ridge (Table 2), one additional hole 44 m in length which may be required should leakages be high, and a 25 m hole at the quarry site.

Based on the same programme the Department of Mines estimate a total cost of $14 500. In actual fact, all costs such as wages, travelling, diamonds, overheads, maintenance etc. would be charged as they occur and the final cost could vary considerably either way from the estimated figure.

Table 4. ESTIMATE OF TOTAL COSTS TO THE METROPOLITAN WATER BOARD OF FEASIBILITY INVESTIGATIONS

Item			*Cost*
Drilling		allow	$15 000.00
Caterpillar D7 tractor	allow 80 hrs @ $47.50 per hr		3 800.00
Backhoe	allow 100 hrs @ $16.00 per hr		1 600.00
Material testing at HEC		allow	500.00
		Total	19 900.00
		say	20 000.00

This estimate makes no allowance for sluicing and final clean up of the trenches. It is assumed that day labour will be provided by the Metropolitan Water Board for this activity.

No allowance is made for grout testing which may be considered necessary.

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CLARKE, M.J. 1973. Faunas from the Ferntree Group of south-eastern Tasmania. *Tech.Rep.Dep.Mines Tasm.* 16:50-65

LEAMAN, D.E. 1976. Geological atlas 1:50 000 series. Sheet 82 (8312S). Hobart. *Explan.Rep.Dep.Mines Tasm.*

[24 July 1979]

APPENDIX 1

Rock mass classification and joint measurement

Table 5. WEATHERING PRODUCTS CLASSIFICATION

Term	*Abbreviation*	*Definition*
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.

Table 6. ROCK STRENGTH CLASSIFICATION

Rock strength class	*Abbreviation*	*Point Load strength index, Is (50) (MPa)*	*Equivalent Unconfined strength, Qu (MPa)*
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

Table 7. DEFINITIONS OF ROCK DEFECTS

Defect Name		*Description*
Bedding / Cleavage (No cleavage at this site)		Layered or parallel arrangement of mineral grains or microfractures, giving rise to planar anisotropy in the substance.
Joints		Almost planar surfaces or crack, across which the rock has little or no tensile strength. May be open or water or clay or soil filled. Joint surfaces may be rough, smooth or slickensided.
Sheared zone	These are faults in the geological sense	Zones of rock substance, with roughly parallel almost planar boundaries, cut by closely spaced joints and/or cleavage planes. The joints are usually smooth or slickensided and curved, intersecting to divide the mass into lenticular or wedge-shaped blocks.
Crushed seam		Seam with roughly parallel, almost planar boundaries, composed of disoriented, usually angular fragments of host rock substance. The fragments may be of clay, silt, sand, or gravel sizes, or mixtures of these. Soil properties.
Infill seam		Seam of soil substance, usually with very distinct roughly parallel boundaries. Formed by migration of soil into open cavity or joint.
Extremely weathered seam		Seam of soil substance, usually with gradational boundaries. Formed by weathering of the rock substance in place.

If the geological origin of the seam is not apparent the term Clay Seam etc. has been used.

APPENDIX 2

Seismic refraction traverses

Seismic traverses ST1, ST3, ST4, ST5 and ST7 were carried out with a Texas Geospace Instruments GT2 refraction seismograph. Seismic traverses ST2 and ST6 were carried out with a Bison hammer seismograph. The positions of the traverses are shown on Figure 3 and on the sections EF and GH on Figure 4.

Depth interpretations were carried out by critical distance and reciprocal methods and the interpretations are plotted in profile on Figure 7. Field work and interpretation were supervised by Senior Geologist W.R. Moore.

Three layers were detected under the Right Bank Ridge and two layers under the valley floor. The seismic velocities and interpretated materials are given in Table 8.

Table 8. SEISMIC VELOCITY AND INTERPRETED MATERIAL

Location	*Velocity* (m/s)	*Interpreted Material*
Right Bank Ridge	400 - 700	Soil and highly weathered rock fragments
	1200 - 2200	Weathered rock, possibly slightly loosened
	3800 - 4300	Compact, fresh or slightly weathered rock
Valley floor	350 - 600 800 - 1100 close to valley sides	Alluvium, cobbles and boulders in gravelly, clayey, silty sand.
	3900 - 6000	Compact, fresh or weathered rock.

An intermediate velocity of 1300 m/s located on seismic traverse ST6 may be due to an old buried creek channel or weathered and/or loosened siltstone.

30-21

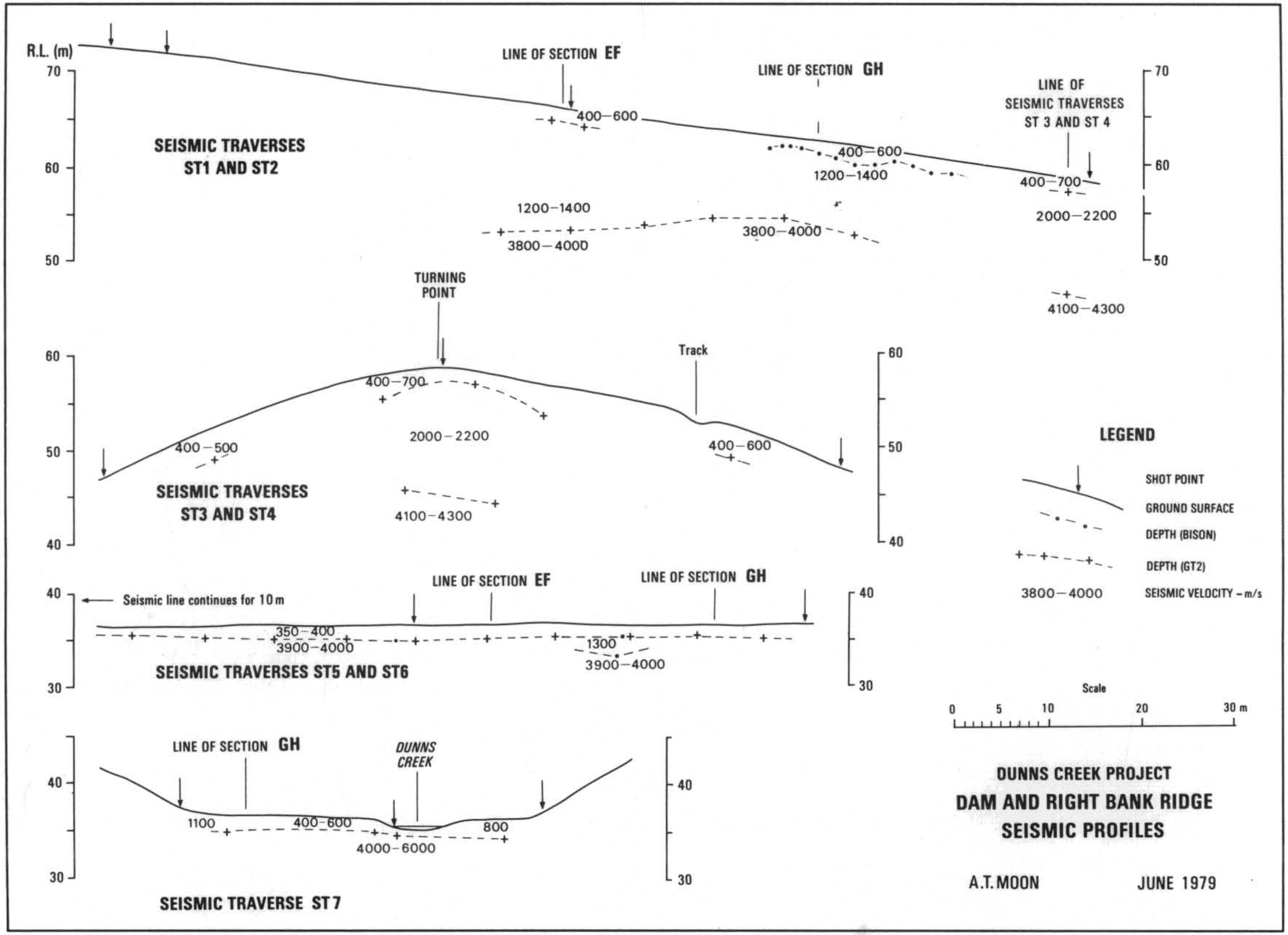

Figure 7.

5 cm

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