# DEPARTMENT OF NATIONAL RESOURCES

# BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1977/58



## GEOLOGICAL AND GEOPHYSICAL INVESTIGATION OF RESERVOIR SITES IN TUGGERANONG, ACT, 1976

by

G. Briscoe and D.G. Bennett

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SUMMARY

The Bureau of Mineral Resources, Geology, and Geophysics has carried out a geological and geophysical evaluation of several reservoir sites in Tuggeranong, ACT. The survey was undertaken at the request of Department of Construction to assist with the planning of a water supply system for Tuggeranong.

Tuff and sandstone of Silurian age are the two main rock types underlying the reservoir sites. Seismic refraction results indicate that of thirteen separate sites investigated for the seven reservoirs, two should be completely rippable, five may be rippable or require light blasting, and six will probably require blasting.

## 1. INTRODUCTION

To assist in the planning of a water supply system for Tuggeranong, the Department of Construction (DC) requested the Bureau of Mineral Resources, Geology, & Geophysics (BMR) to carry out a geological and geophysical evaluation of a number of reservoir sites. Seismic refraction techniques were used in the prediction of excavation and foundation conditions, and to locate unfavourable subsurface features such as faults and deep or irregular weathering. The results will assist in the selection of reservoir sites with adequate foundation conditions and which require the least amount of blasting in excavation.

Thirteen separate reservoir sites were investigated, covering alternative sites for Upper and Lower Theodore, Tuggeranong Hill 3, Tharwa 1 and 2, Lanyon, and Calwell Reservoirs. The location of these reservoirs are shown in Plate 1. Field work for the survey was done between December 1975 and June 1976. Geological mapping was done by G. Briscoe and geophysical interpretation by D. Bennett. Results of geological and geophysical surveys covering West Murrumbidgee reservoir sites are covered in separate reports (Hohnen & Briscoe, in prep., and Bennett & Polak, 1976).

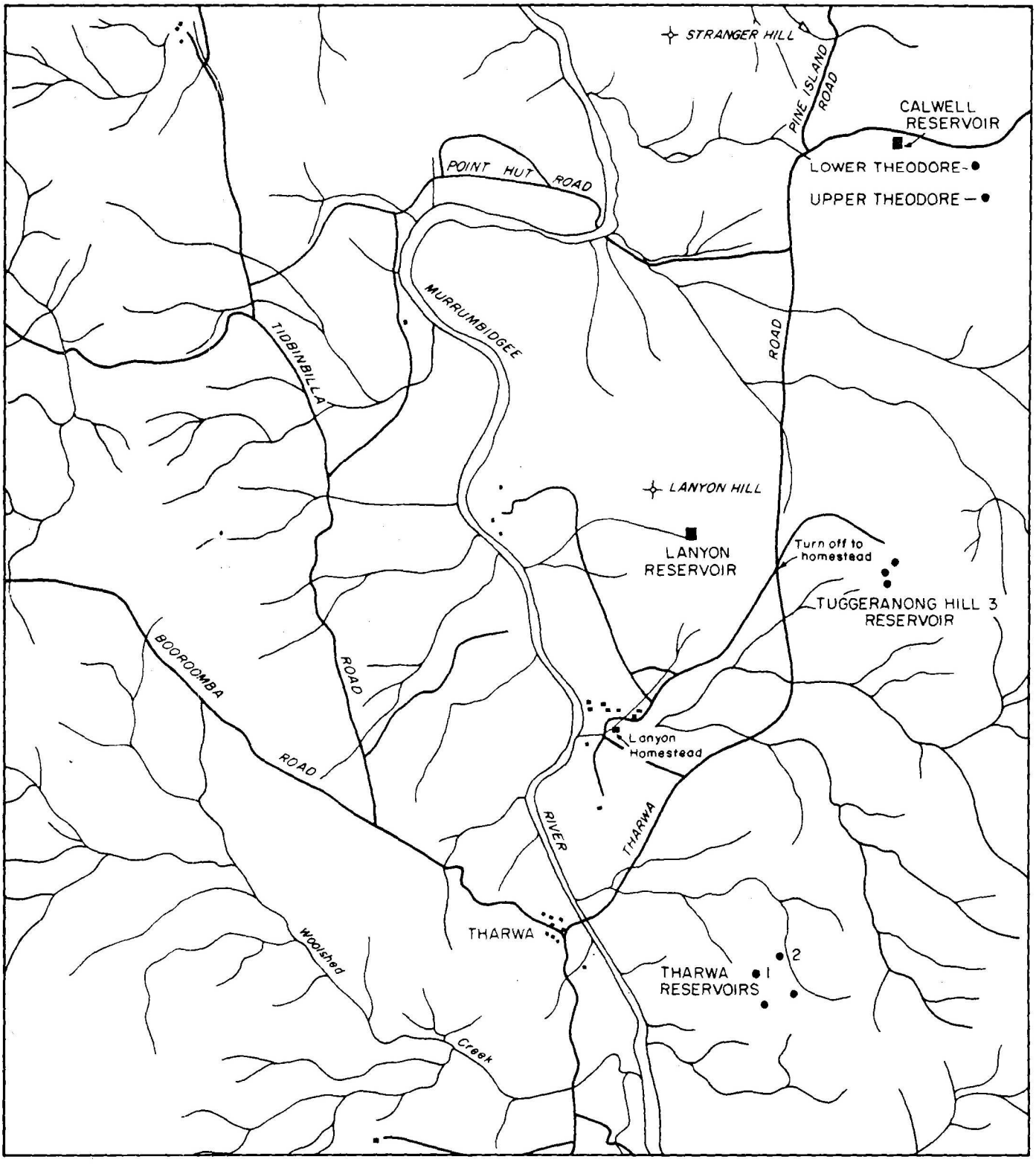
## 2. REGIONAL GEOLOGY

The geology of the Tuggeranong area is well documented in the BMR Journal and in Records (Jacobson et al., 1976). Plate 2 shows the generalised geology.

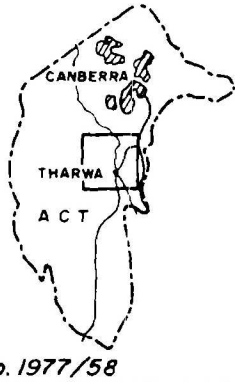
In brief, rocks can be divided into three main stratigraphic and structural units. The Murrumbidgee Fault separates the granitic rocks of the Murrumbidgee Batholith on the west from volcanics and sediments to the east. An unconformity separates the tightly folded and faulted Silurian volcanics and sediments from the overlying gently folded Siluro-Devonian volcanics.

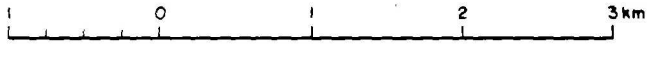
The Murrumbidgee Fault is the dominant structural feature. Faulting probably occurred over 350 million years ago, with renewed activity during the Late Tertiary Kosciusko uplift.

PLATE 1




LOCATION DIAGRAM




LOCATION OF TUGGERANONG RESERVOIRS

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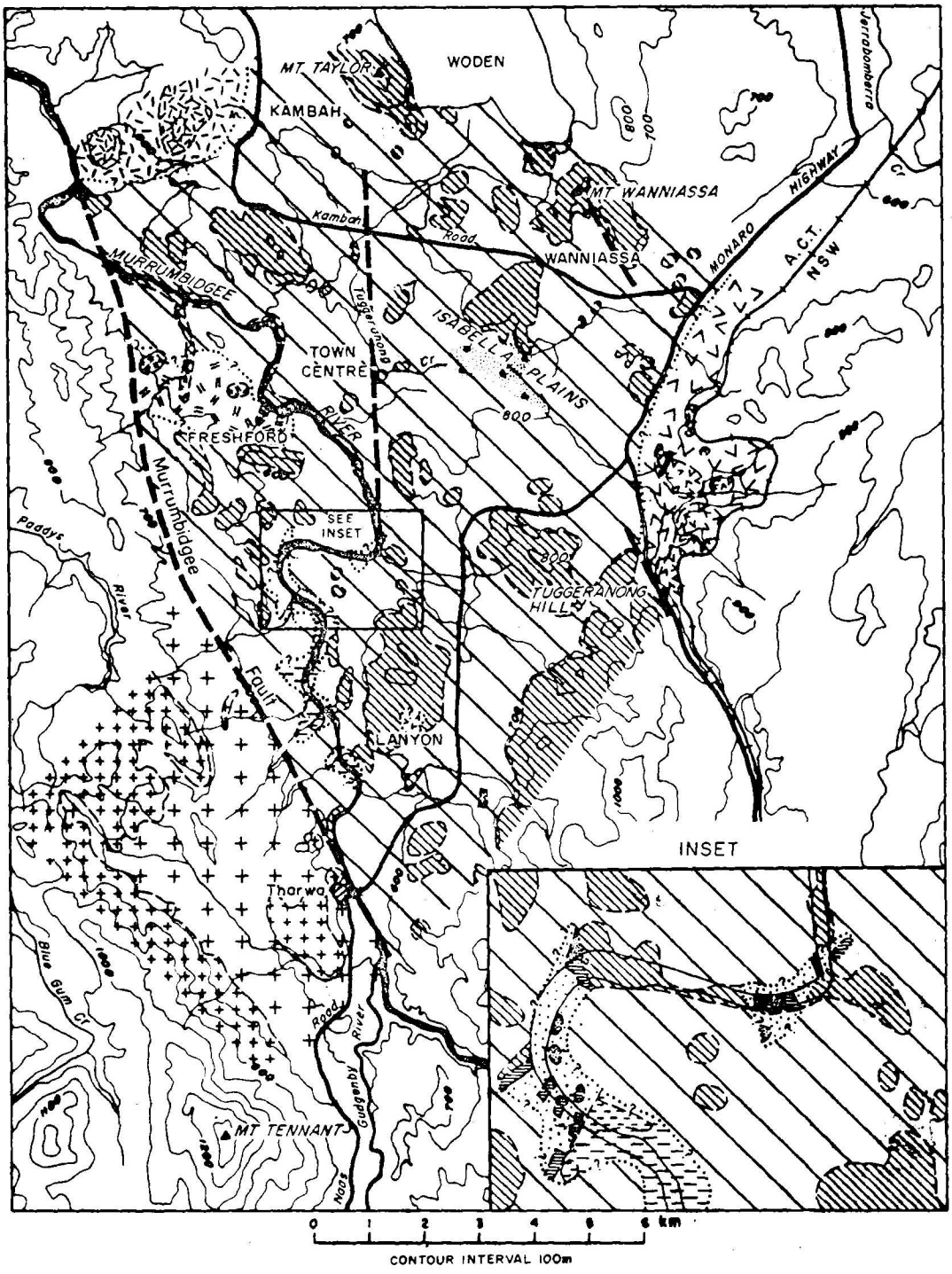
# GENERAL GEOLOGY OF TUGGERANONG AREA

PLATE 2




| | Scattered outcrops | Overlain by soil | |
|---|---|---|---|
| DEVONIAN ? | | | *Dacitic porphyry* |
| DEVONIAN | | | *Rhyolitic - rhyodacitic welded tuff* |
| SILURIAN - DEVONIAN | | | *Dacitic - rhyodacitic welded tuff* |
| | | | *Granite* |
| | | | *Rhyolitic porphyry* |
| SILURIAN | | | *Tuff, tuffaceous sandstone* |
| | | | *Sandstone, quartzite* |
| | | | *Slate, shale* |

*Geological boundary, inferred and concealed*

*Position of outcrop*

*Fault, position approximate*

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BASED ON 158/AIG/1502 ("URBAN GEOLOGY OF TUGGERANONG, A.C.T." BY G. JACOBSON et al)

I55/B5-341A

## 3. SEISMIC METHOD AND EQUIPMENT

The seismic refraction method (Dobrin, 1960) was used in this survey to determine depths and velocities of refracting horizons beneath the proposed reservoir sites. Spreads consisted of 23 geophones placed in a straight line at a constant spacing of either 3 or 4 m. Five shots were fired for each spread; one in the centre, one at each end and one offset at a distance between 40 and 88 m from each end.

Recording was done using standard 24-channel SIE Seismograph (Dresser-SIE Inc.) and 8 hz GSC 20D geophones (Geospace Co.). Data reduction and interpretation was based on the intercept method (Dobrin, 1960) and the reciprocal method (Hawkins, 1961).

Seismic velocities of rocks provide an approximate index of rippability (Caterpillar, 1966). From past experience in the Canberra district the following relationship between seismic velocity and rippability has been used.

| Velocity m/s | Geology | Excavation conditions |
|---|---|---|
| Less than 1200 | Soil; completely-highly weathered rock | Rippable |
| 1300-1600 | Highly-moderately weathered rock | Marginal - rip or blast |
| Greater than 1600 | Moderately-slightly weathered rock; fresh rock | Blasting required |

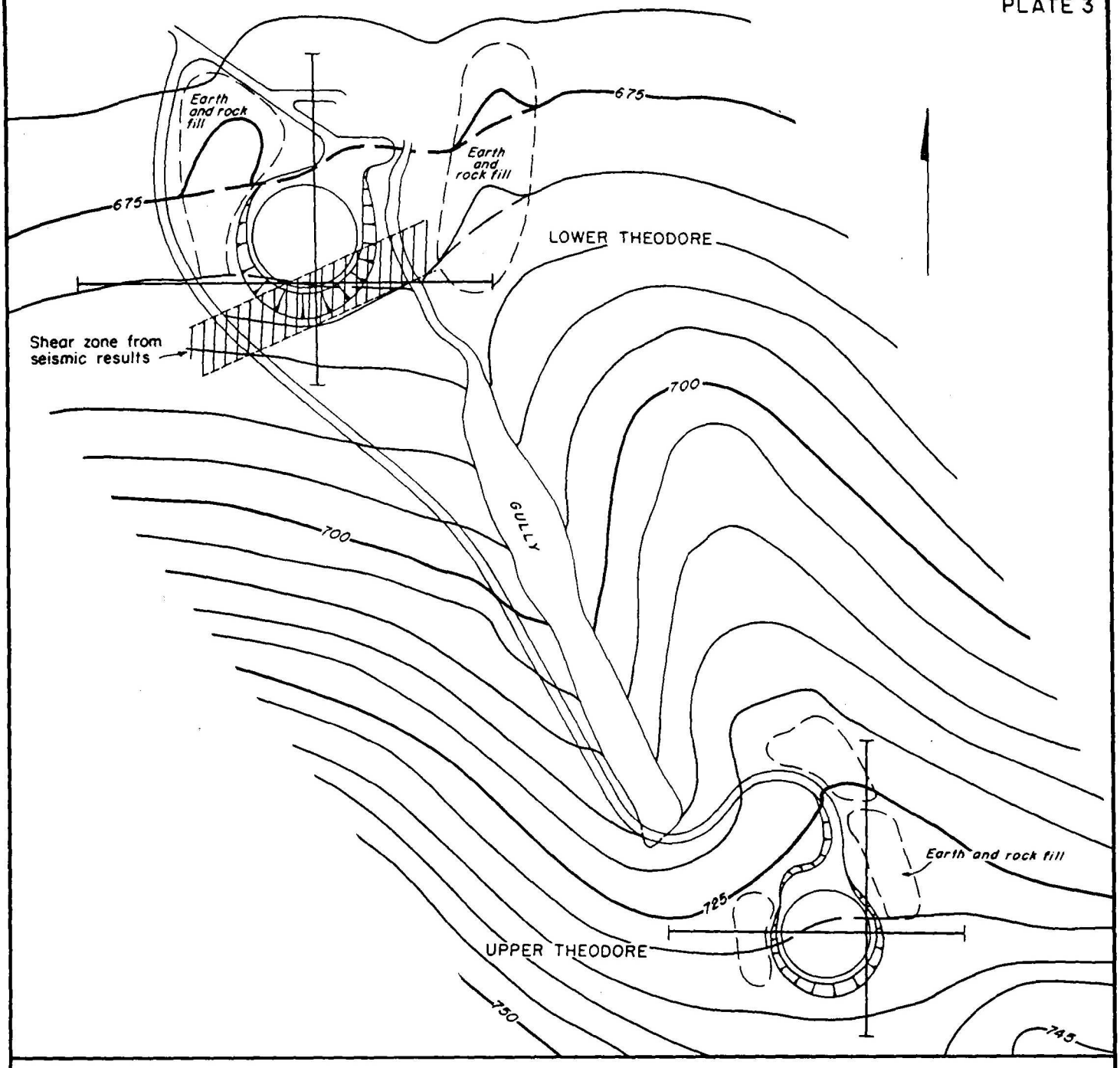
The term bedrock is used in this report to refer to the deepest recorded refractor which may be moderately to slightly weathered rock.

## 4. DETAILED GEOLOGY AND SEISMIC RESULTS

### 4.1 Lower Theodore (Tuggeranong Hill 1)

One site on the lower northern slopes of Tuggeranong Hill, approximately 120 m south of the Tharwa Road, was investigated (Plate 3). The proposed reservoir will be a circular tank, 52 m in diameter, with a floor level of R.L. 675.5 m and top water level of 685.0 m.

PLATE 3




50 0 50 100 150 m

CONTOUR INTERVAL 5m

## SITING OF UPPER AND LOWER THEODORE RESERVOIRS

Seismic traverse

Shear zone from seismic results

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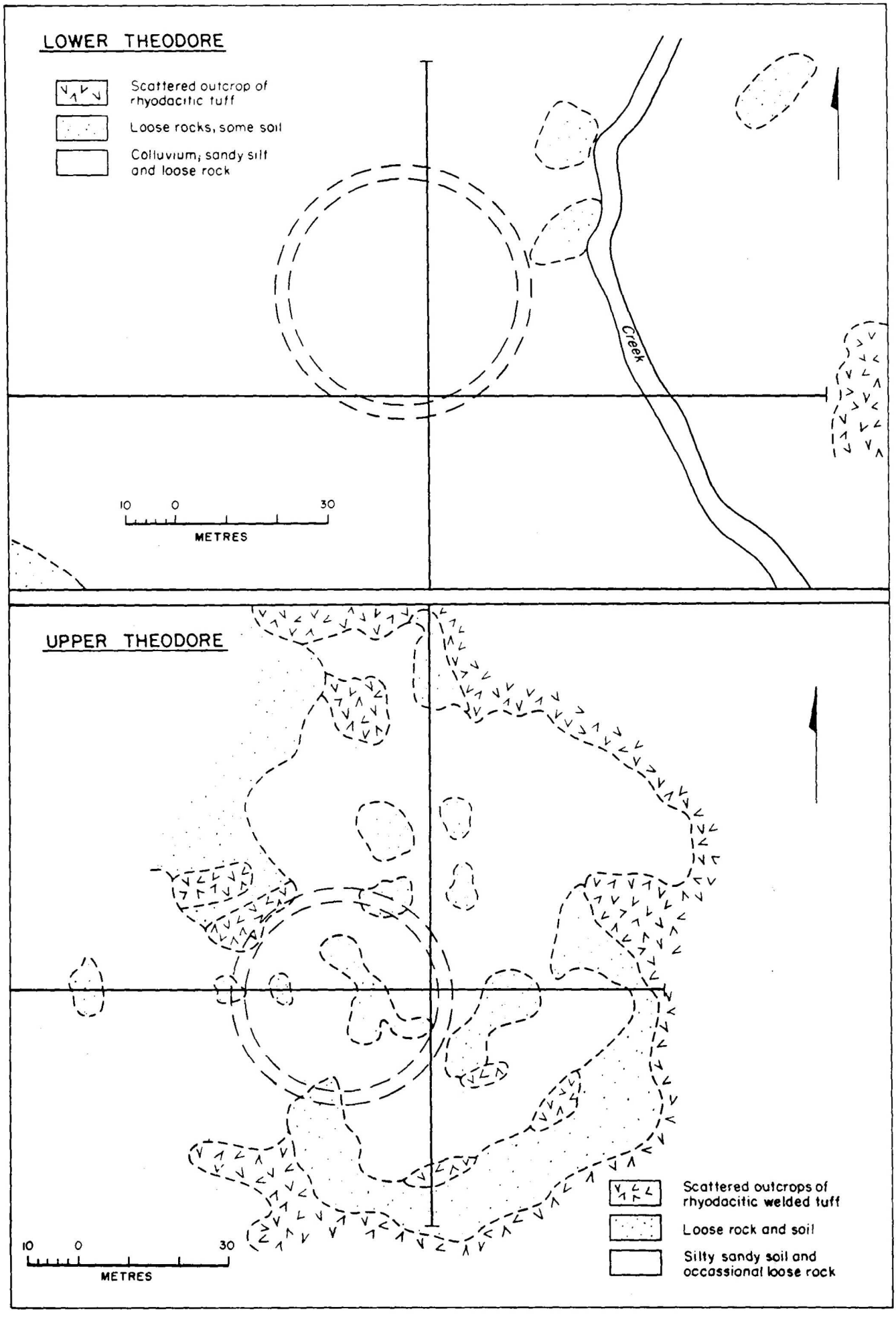
A geological evaluation of this site is difficult owing to the lack of outcrop. Most of the site is covered by unsorted colluvium, consisting of blocky fragments of rhyodacitic tuff in silty sand with some gravel-sized fragments (Plate 4). This material, which is often cemented at depth, is exposed in the small gully which runs through the site. The seismic results indicate that the colluvium varies in depth from 0.5 m to approximately 4 m with the greater thickness of material occurring in the southern and western ends of the traverses (Plate 5). The cemented colluvium has a seismic velocity between 800 and 1000 m/s (although it may be higher) and should be rippable. Accurate determinations of the thickness of these layers are difficult because of the low velocity contrast between successive layers.

Rhyodacitic tuff crops out on the eastern end of the east-west traverse. The rock is highly weathered and moderately closely jointed and probably underlies the colluvium. The seismic results show that it has a velocity of 1200-1400 m/s and may be rippable, although light blasting may also be required. This highly weathered layer extends to depths between 7 and 14 m and underlying this is slightly weathered rhyodacitic tuff with a seismic velocity between 1800 and 2050 m/s. At even greater depth, fresh bedrock was detected. A possible shear zone was detected in the bedrock layer and is shown on the seismic sections.

4.2 Upper Theodore (Tuggeranong Hill 2)

One site, located on a topographic bench on the northeastern slopes of Tuggeranong Hill was investigated (Plate 3). The proposed reservoir will be a circular tank, 45 m in diameter, with a floor level of R.L. 728 m and top water level of 737.5 m. The terrain is gently sloping, with a steeper fall in the northwest at the head of a small gully. The rock at the site is a dark grey rhyodacitic welded tuff, containing large crystals of quartz and smaller white feldspars in a fine-grained groundmass (Plate 4). Where the rock crops out is is moderately weathered, strong, and moderately closely jointed. The outcrops are low, rounded to blocky with many loose rocks. About 10% of the site is outcrop, the rest is covered by a thin silty sandy soil and occasional loose rock.

PLATE 4




GEOLOGY OF UPPER AND LOWER THEODORE RESERVOIR SITES

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The seismic results indicate that apart from a thin surface layer, less than 1 m thick (300 m/s), blasting will probably be required throughout (Plate 5). A layer of moderately weathered tuff which may be marginally rippable (1350-1600 m/s) underlies most of the N-S traverse to a depth of 6 m but lenses out to the north. Similarly on the E-W traverse, this layer lenses out to the west. Underlying it is a slightly weathered tuff layer with a seismic velocity of 2400-2700 m/s which will require blasting. Bedrock (4500-4800 m/s) comes to within 5 m of the surface at the western end of the E-W traverse.

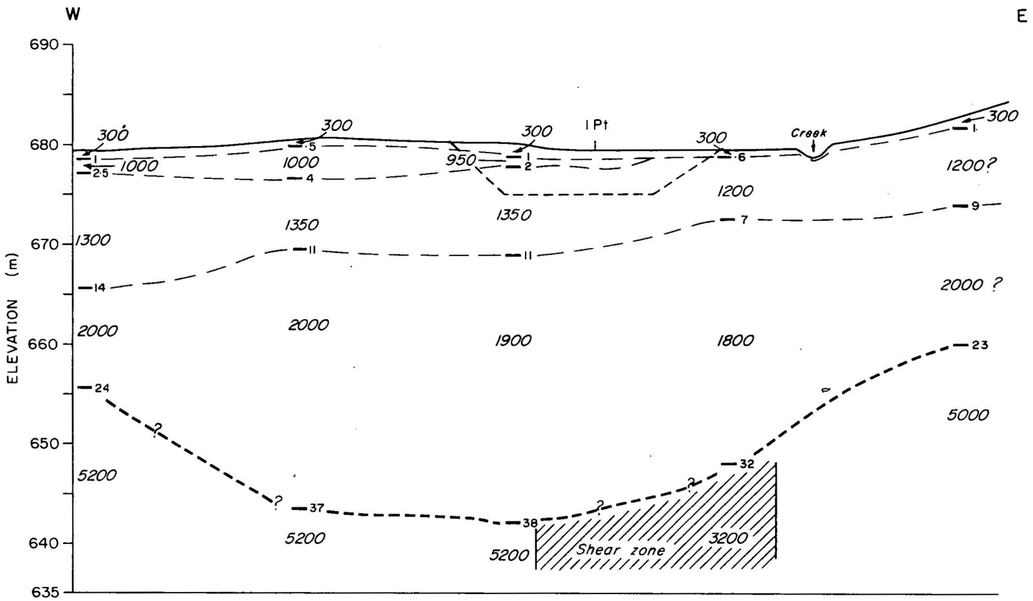
4.3 Tuggeranong Hill 3

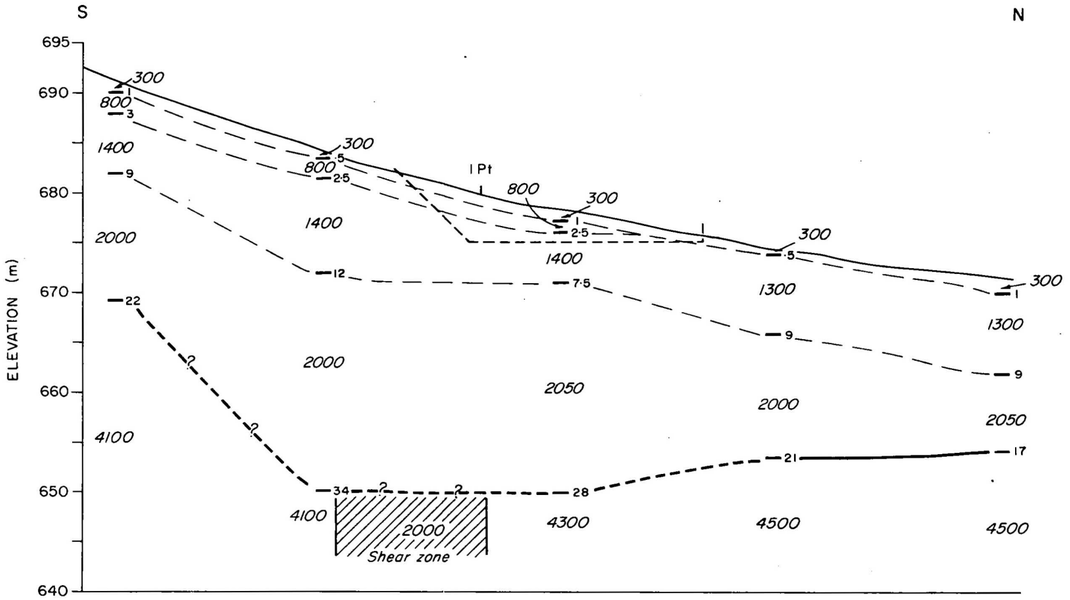
Three alternative sites located on the lower slopes of the range of hills to the east of Lanyon were investigated (Plate 6). The reservoir sites are covered by thin colluvial soil with scattered outcrops of tuff containing angular blocks of loose rock. Excavations for the reservoir to the floor level of R.L. 675.5 m, will involve a maximum cut of 10.5 m at site 3A, and 8.5 m at sites 3B and 3C. Blasting will be necessary for the removal of most rock at all three sites.

Site 3A. This reservoir will be located across a small gully which runs northwest through the site. Medium-grained tuff crops out in the gully and to the northwest where it is strong and moderately closely jointed (Plate 7). Low outcrops are also found to the north and east of the site. The remainder of the site is covered by less than 1 m of unconsolidated colluvium consisting of angular blocks of tuff in sandy silt. This surface layer has a seismic velocity of 300 m/s and the underlying layer has a velocity of 2000 m/s, requiring blasting in excavation. This unit may be moderately weathered tuff or cemented colluvium (rounded tuff boulders in a sandy silt, cemented by silica, calcite, or limonite) which is exposed in a gully to the north. Accurate depths below the surface are difficult to determine because the seismic velocity is gradational between 2000 and 2800 m/s on the SW-NE traverse (Plate 8). The cross-traverse indicates high-velocity material at shallow depth. For the proposed cut of 10.5 m, blasting will be necessary for removal of all except the upper 1 m.

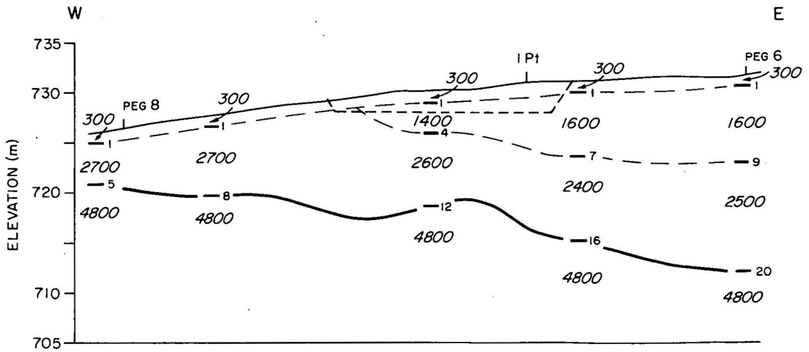
At the head of the gully, swampy conditions are likely after heavy rain and remedial drainage will be needed.

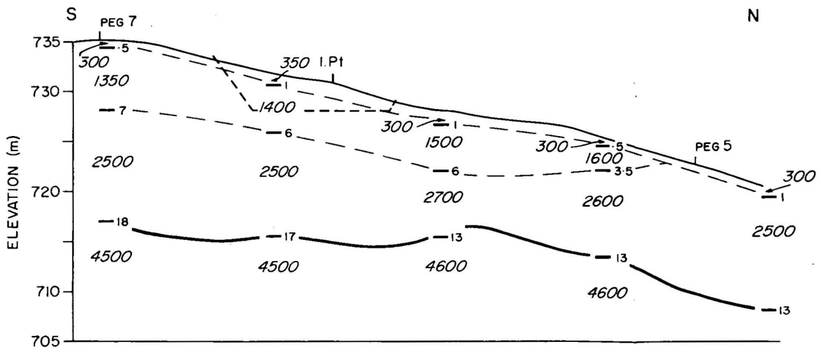
## LOWER THEODORE (TUGGERANONG HILL 1)

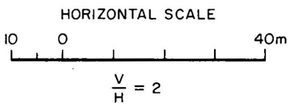



## UPPER THEODORE (TUGGERANONG HILL 2)



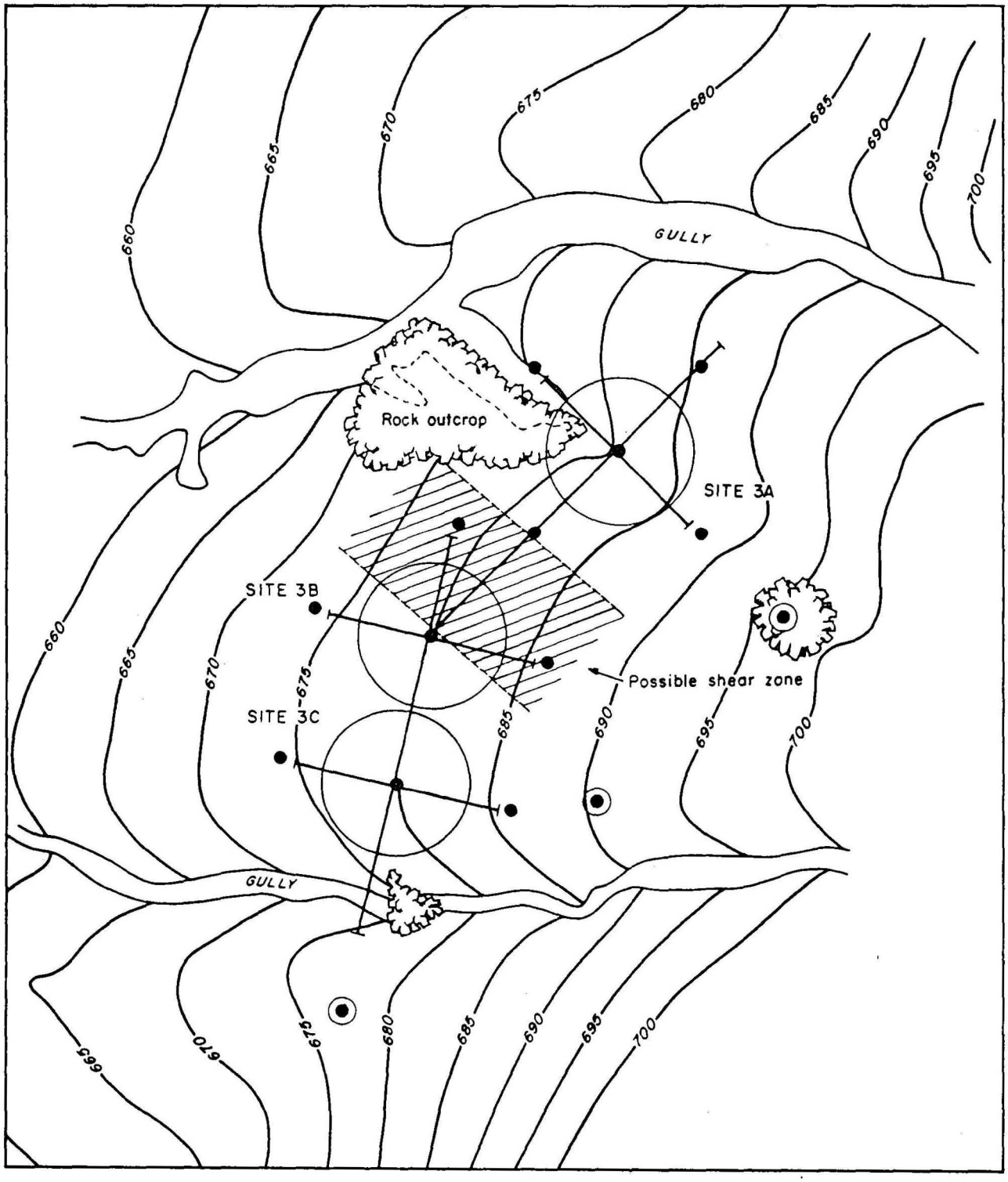




LEGEND

| | |
|---|---|
| 1500 | Seismic velocity (m/s) |
| — 6 | Depth of refractor (m) |
| — — | Intermediate refractor |
| ——— | Bedrock refractor |
| - - - - | Depth of excavation |

SEISMIC SECTIONS FOR UPPER AND LOWER THEODORE RESERVOIR SITES




50 0 50 100 150

CONTOUR INTERVAL 5m

# SITING OF TUGGERANONG HILL 3 RESERVOIR SITES

- Temporary marker
- Permanent reference marker
- Seismic traverse
- Possible shear zone from seismic results

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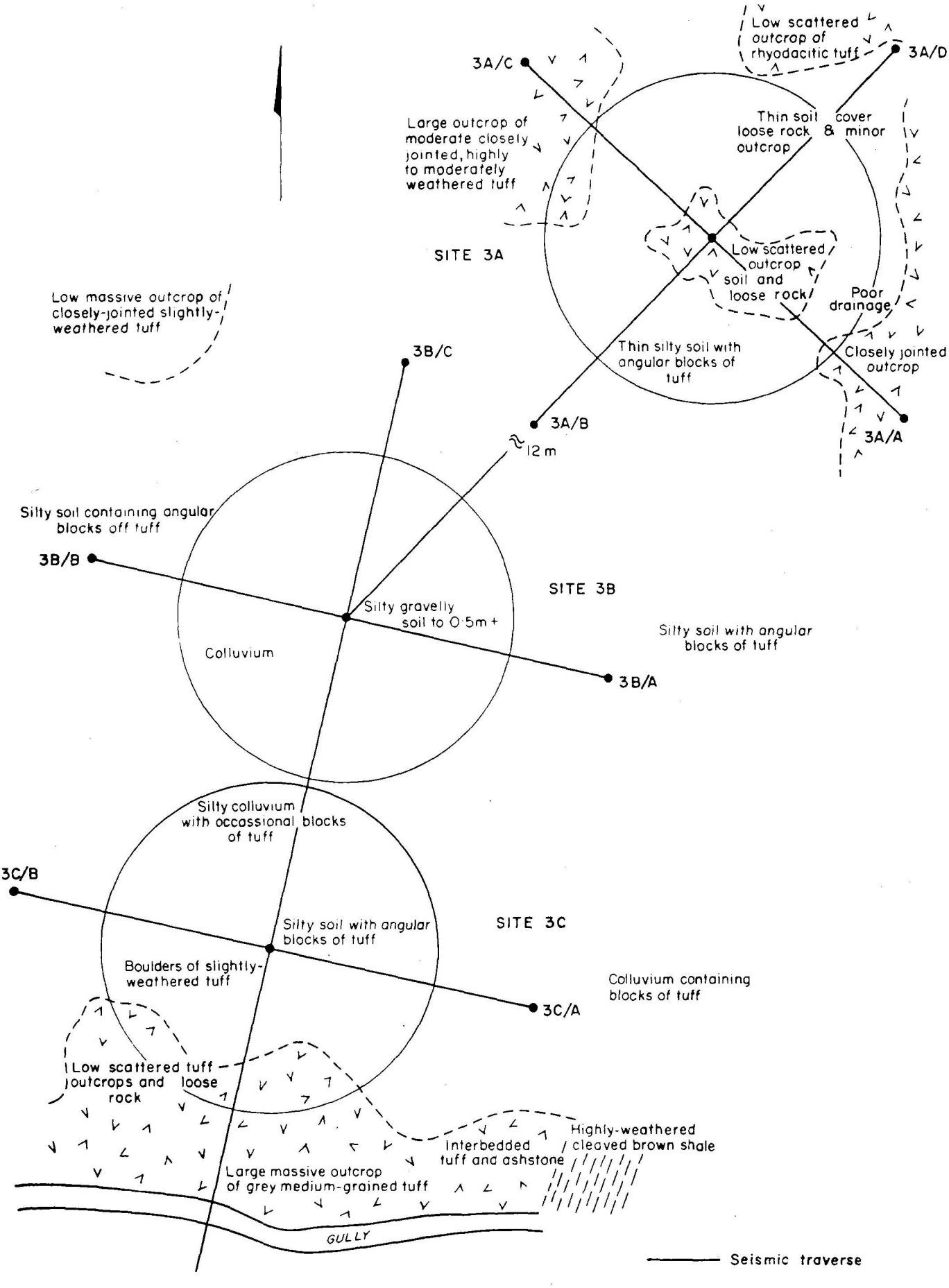
I55/B5-345A

PLATE 7




# GEOLOGY OF TUGGERANONG HILL 3 RESERVOIR SITES

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Site 3B. This reservoir site is located 112 m southwest of site 3A and the geology is essentially the same. The seismic velocity of the second layer ranges from 1600 to 1900 m/s and will probably require blasting in excavation (Plate 8). A change in bedrock velocity from 2800 to 2000 m/s was noted on the N-S traverse and a similar change noted on the E-W traverse. A shear zone approximately 40 m wide was detected on the SW-NE traverse between site 3A and 3B and is indicated by a lowering of the velocity in both the intermediate and bedrock layers (Plate 6). This shear zone separates the shallow weathering profile at site 3A from the deeper weathering at site 3B.

Site 3C. This site is to the south of site 3B. The surface is covered by silty colluvium with angular blocks of tuff. The southern side of the reservoir is adjacent to a small gully, and where the topography steepens, rock outcrop and scattered angular blocks of tuff are common. The predominant rock type is a grey medium-grained rhyodacitic tuff which is strong and moderately closely jointed (Plate 7). Coarser-grained porphyritic bands occur which are highly weathered and weak. Extremely fine-grained tuff (ashstone) also crops out; it is strong, closely jointed, parallel to bedding, and is often finely interbedded with coarser tuff. Farther to the east of marker 3C/A, highly weathered fissile shale crops out.

Seismic results indicate that only 0.5 m of surface material will be removed without blasting (Plate 8). The underlying moderately weathered layer has a seismic velocity between 1400 and 1800 m/s and extends to a depth of 9-14 m. The maximum cut of 8.5 m will be within this layer. The bedrock velocity is 2800-3400 m/s.

### 4.4 Tharwa 1

Two reservoirs are planned for the supply of water to the south-eastern suburbs of Tuggeranong and Tharwa. Seven alternative sites were investigated for Tharwa 1, and two for Tharwa 2 (Plate 9). The reservoir sites are underlain by volcanic and sedimentary rocks of the Colinton Volcanics; most are located on a coarse-grained sandstone unit.

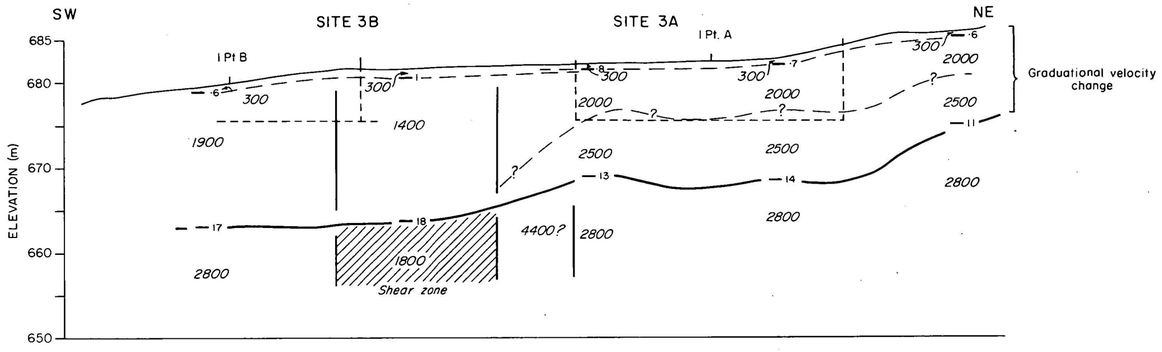
The proposed Tharwa 1 reservoir will be a circular tank, diameter 40 m with floor level of R.L. 675.5 m and top water level of 685 m, containing about 9300 $m^3$. There are three alternative sites at location 1A and four alternative sites at location 1B.

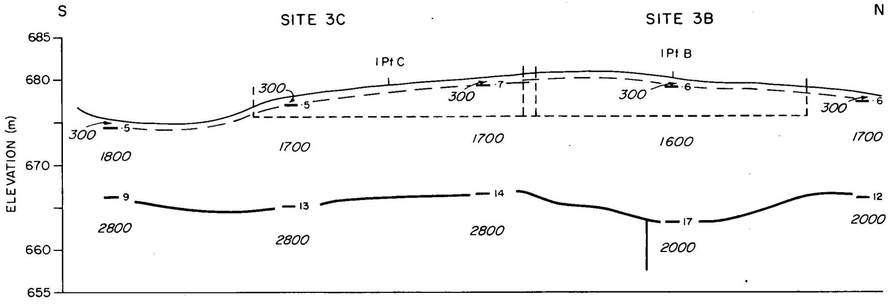
Location 1A. Location 1A is in a wide enclosed valley which is covered by a brown-grey silty, sandy soil, 2.5 m thick (Plate 9 and 10). Coarse-grained sandstone crops out on the surrounding hills and the soil contains angular blocks of sandstone and quartz.

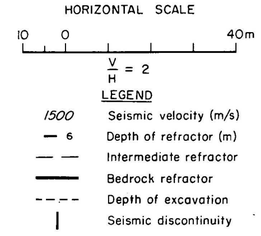
At the centre of site 1A (west) the seismic results show 8 m of rippable material consisting of 2.5 m of soil (450 m/s) overlying extremely to highly weathered sandstone (900-1000 m/s) (Plates 9, 10 and 13). To the southwest the rippable material thins to 4 m near peg 1A2 and to the east it thickens to 11-12 m. A layer with a seismic velocity of 1700-1800 m/s beneath the rippable material extends to a depth of 20-24 m before bedrock (3000-3200 m/s) is reached.

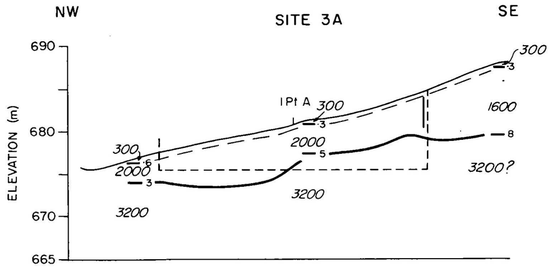
At site 1A (east) the soil grades into a clayey sand, beneath which is extremely to highly weathered sandstone up to 7.5 m thick at the centre. Although the seismic velocity of the second layer (950-1200 m/s) is slightly higher than 1A (west) it should still be rippable. The rippable material thins to 4-5 m over a bedrock high towards the north. Moderately weathered sandstone (1800 m/s) overlies bedrock (3000-3200 m/s) to depths between 10 and 22 m. The present siting of both reservoirs indicate that they will be founded partly on extremely to highly weathered sandstone and partly on soil. The soil will need to be removed and replaced with stronger fill material.

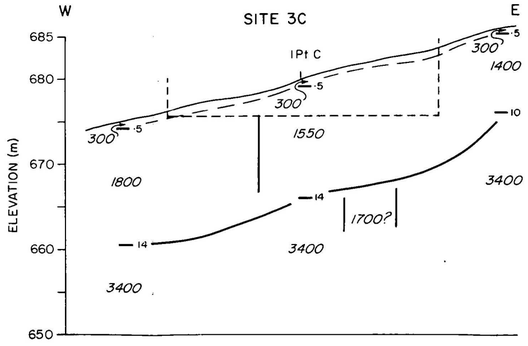
The provisional site (Plate 10) was crossed by one traverse and shows the extremely weathered sandstone lensing out towards the northeast past peg 1A6, and beneath this is moderately weathered sandstone with a seismic velocity of 1800 m/s. A change in bedrock velocity from 3000 to 3900 m/s was observed towards the northeastern end of the traverse. The reservoir is currently sited over material which could be ripped to a depth of 5 m although some blasting may be required at the northeastern end.

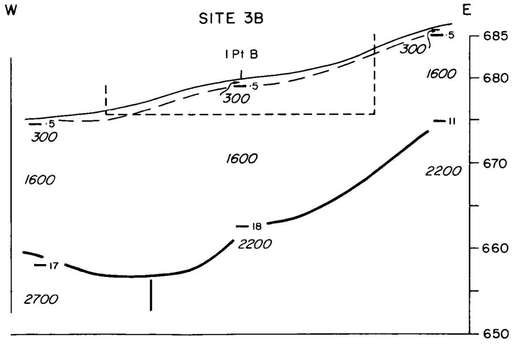


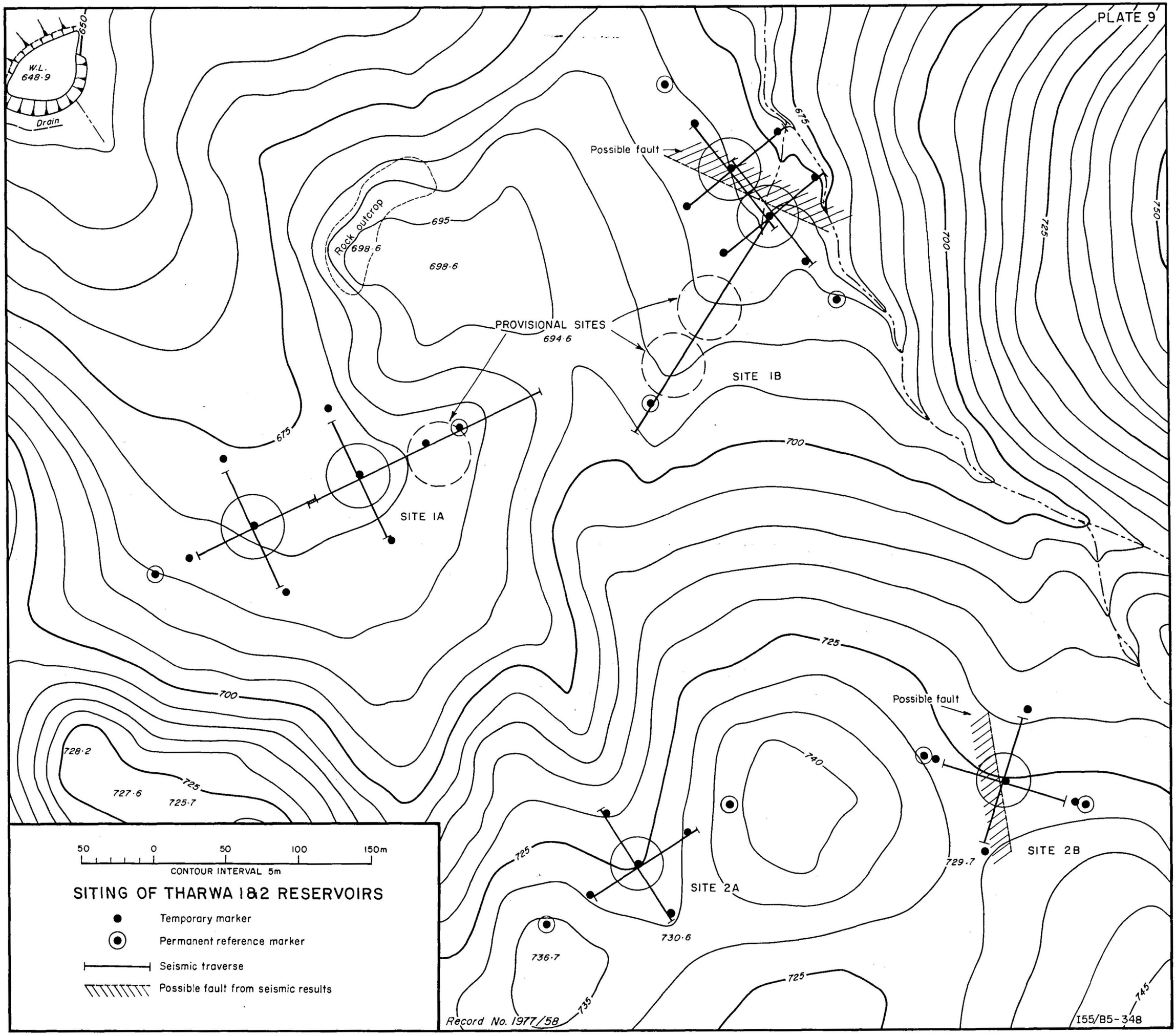




SEISMIC SECTIONS FOR TUGGERANONG HILL 3 RESERVOIR SITES

PLATE 9


W.L. 648·9
Drain
650
675
700
725
750
Possible fault
Rock outcrop
695
698·6
698·6
PROVISIONAL SITES
694·6
SITE 1B
SITE 1A
675
700
725
700
728·2
727·6
725
725·7
740
Possible fault
725
SITE 2A
730·6
729·7
SITE 2B
736·7
725
735
745
50 0 50 100 150m
CONTOUR INTERVAL 5m
SITING OF THARWA 1&2 RESERVOIRS
Temporary marker
Permanent reference marker
Seismic traverse
Possible fault from seismic results
Record No. 1977/58
I55/B5-348

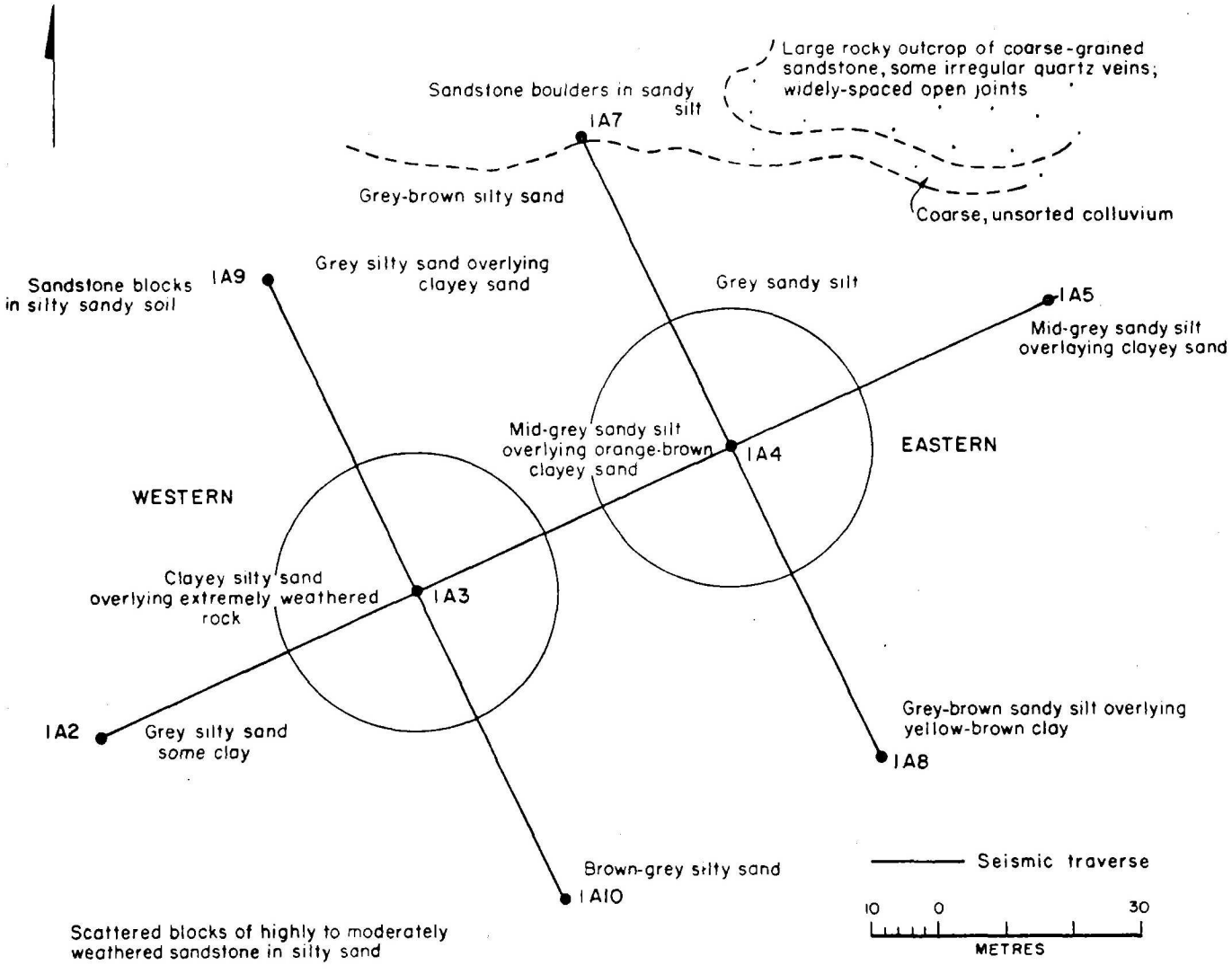
Location 1B. Location 1B is a wide valley which slopes gently to the north-east (Plate 9). On the southeastern side are low scattered outcrops of coarse-grained sandstone with many loose sandstone blocks. Much of the valley is covered by thin grey silty sand overlying clayey sand. Interpretation of the seismic results from this location was quite complex and a fault has been suggested near the centre of site 1B (south). Extremely to highly weathered sandstone (950-1000 m/s) was detected only over a 60-70 m wide zone near the centre of the two reservoir sites on the SE-NW traverse.

At site 1B (south), weak, extremely weathered sandstone (950-1000 m/s) underlies the centre and the northwestern ends of the proposed reservoir, and this should be rippable to a maximum depth of 4.5 m (Plates 11 and 13). Towards the southeastern and northeastern ends highly to moderately weathered sandstone occurs within one metre of the surface and its seismic velocity of 1500-2000 m/s indicates light blasting may be required in excavation.

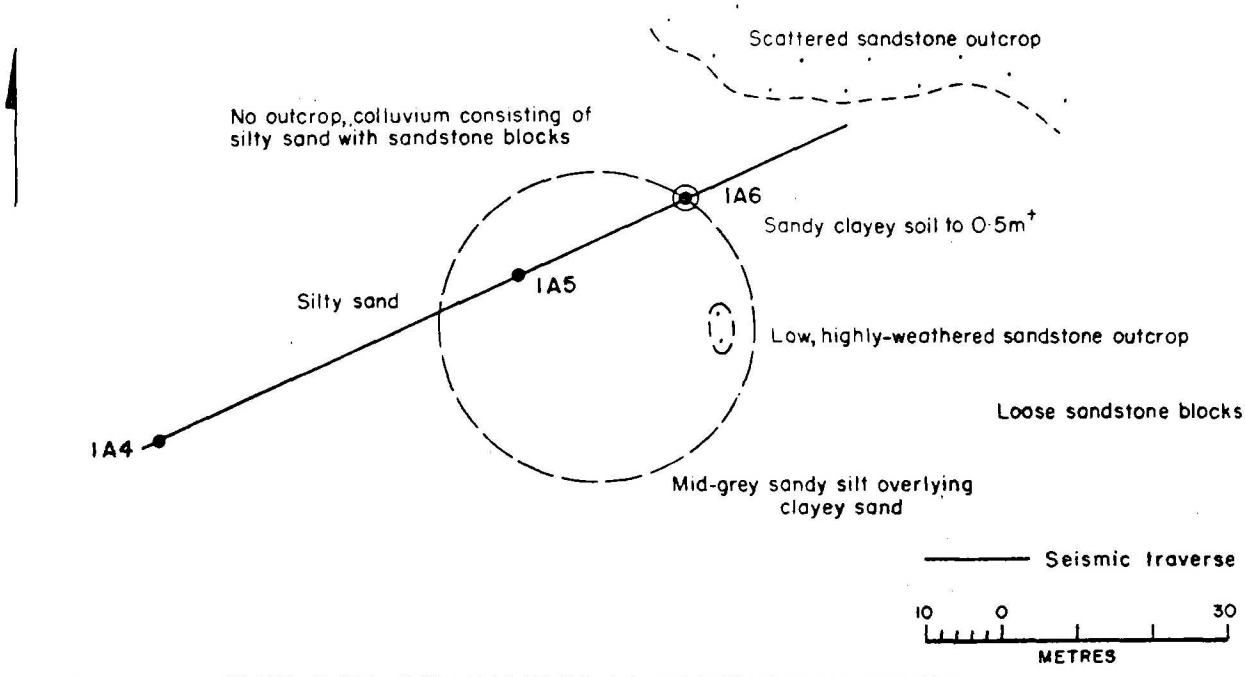
At site 1B (north) clayey sand soil grades into extremely weathered rock overlying highly to moderately weathered sandstone (1500 m/s) to a maximum depth of 4 m. The present siting of this reservoir suggests only minor blasting may be required at the northwestern end of the NW-SE traverse. Along the SW-NE traverse through site 1B (north) the extremely weathered layer is continuous to an average depth of 3 m but the cut of 7 m at the southwestern end may require minor blasting to remove the highly to moderately weathered sandstone with a seismic velocity of 1500 m/s. Variations in velocities and depths of the deepest refractor are shown on the seismic sections.

Two provisional sites were also investigated and one seismic traverse crossed these sites. Beneath less than one metre of silty, sandy soil, the seismic velocity of the extremely to highly weathered sandstone layer changes from 1500 m/s in the southwest to 1000 m/s in the northeast. The depth of this layer ranges from 3 to 7.5 m and beneath this, moderately weathered sandstone (1900-2150 m/s) overlies bedrock (3200-3400 m/s) at depths between 19 and 27 m. The rock to the northeast of this traverse has slightly lower velocities in all layers indicating more intense weathering or closer and more open jointing. For a floor level of 675.5 m, a considerable amount of excavation, mainly by blasting, will be necessary, especially if the reservoir is located towards the southwest.

# THARWA 1A




**PROVISIONAL**




## GEOLOGY OF THARWA 1A RESERVOIR SITES

*Record No. 1977/58*

I55/B5-349

4.5 Tharwa 2

The proposed Tharwa 2 reservoir will be a circular tank, diameter 30 m, with floor level of R.L. 721.7 m and top water level of 731.3 m, containing about 4600 $m^3$. Two possible locations, 2A and 2B, were investigated.

Location 2A. At location 2A the reservoir will be sited on sloping ground on the northern side of a small saddle (Plate 12). Coarse-grained sandstone crops out on the hill to the northeast and dacite crops out to the southwest. The site is covered by approximately one metre of soil (300-400 m/s) and beneath this, moderately weathered rock with a seismic velocity of 1700-2100 m/s extends to depths of between 12 and 15 m (Plate 13). Bedrock at this site has a seismic velocity of 3400-4000 m/s and a bedrock high was noted just northeast of the centre. An area of extremely weathered rock and loose boulders (1000 m/s) was detected in the northwest but this is outside the proposed excavation zone. Excavation will be mainly in moderately weathered rock which will require blasting except in the northwest where the soil will have to be replaced by stronger fill.

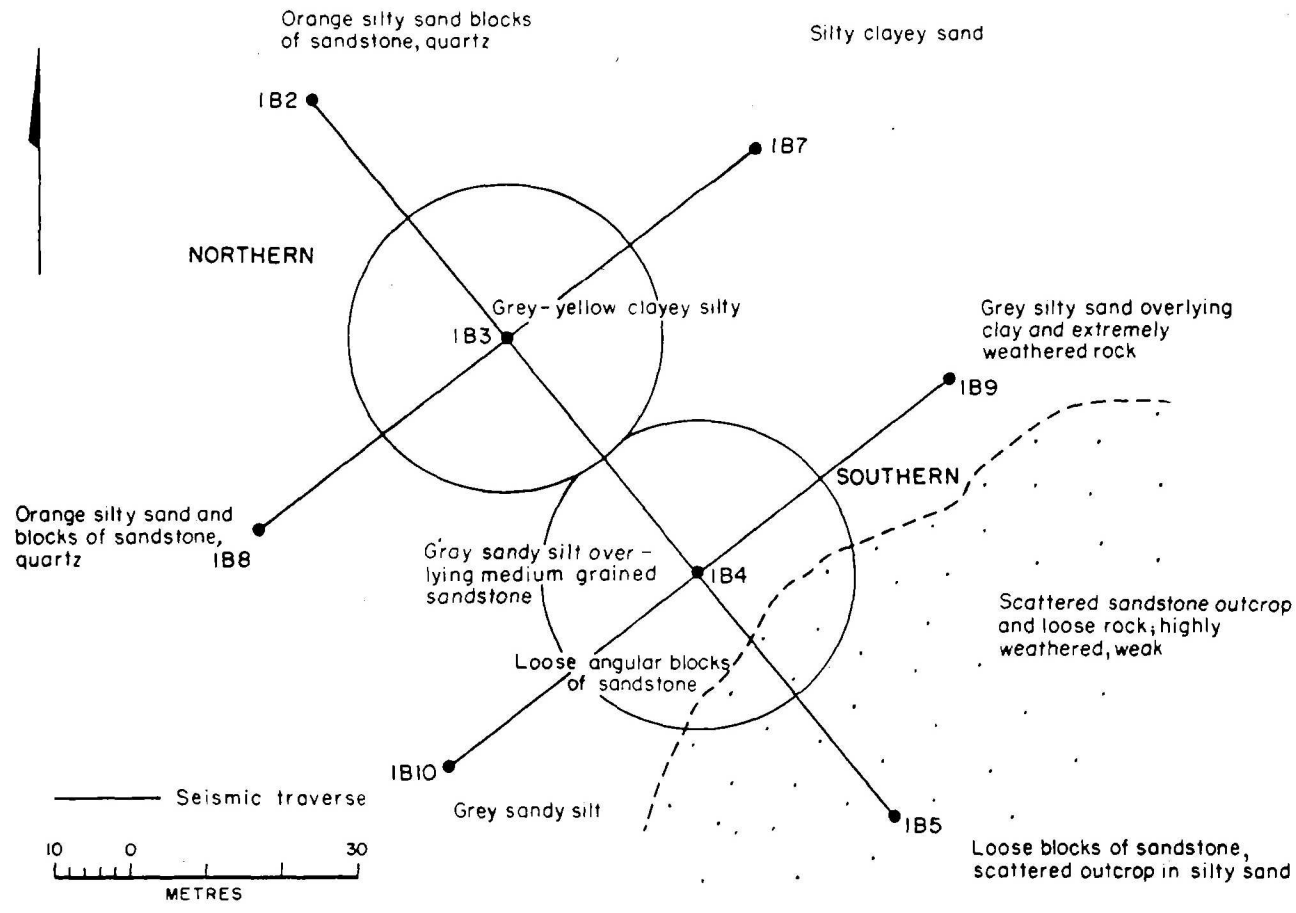
Location 2B. At location 2B highly to moderately weathered, coarse-grained sandstone crops out to the south and north (Plate 12). The seismic results show that less than one metre of soil covers highly to moderately weathered rock (1450-2250 m/s); a layer of extremely to highly weathered rock and soil (850 m/s) occurs to a maximum depth of 4 m to the south (Plate 13). The reservoir will be founded on highly to moderately weathered rock that will need blasting. A change in the intermediate and bedrock velocities (from 3300 m/s to 2400 m/s) and an increase in the depth of weathering (from 13 to 20 m) suggests that a fault passes near the centre of the reservoir site. Differential settlement may occur on either side of this fault.

4.6 Calwell

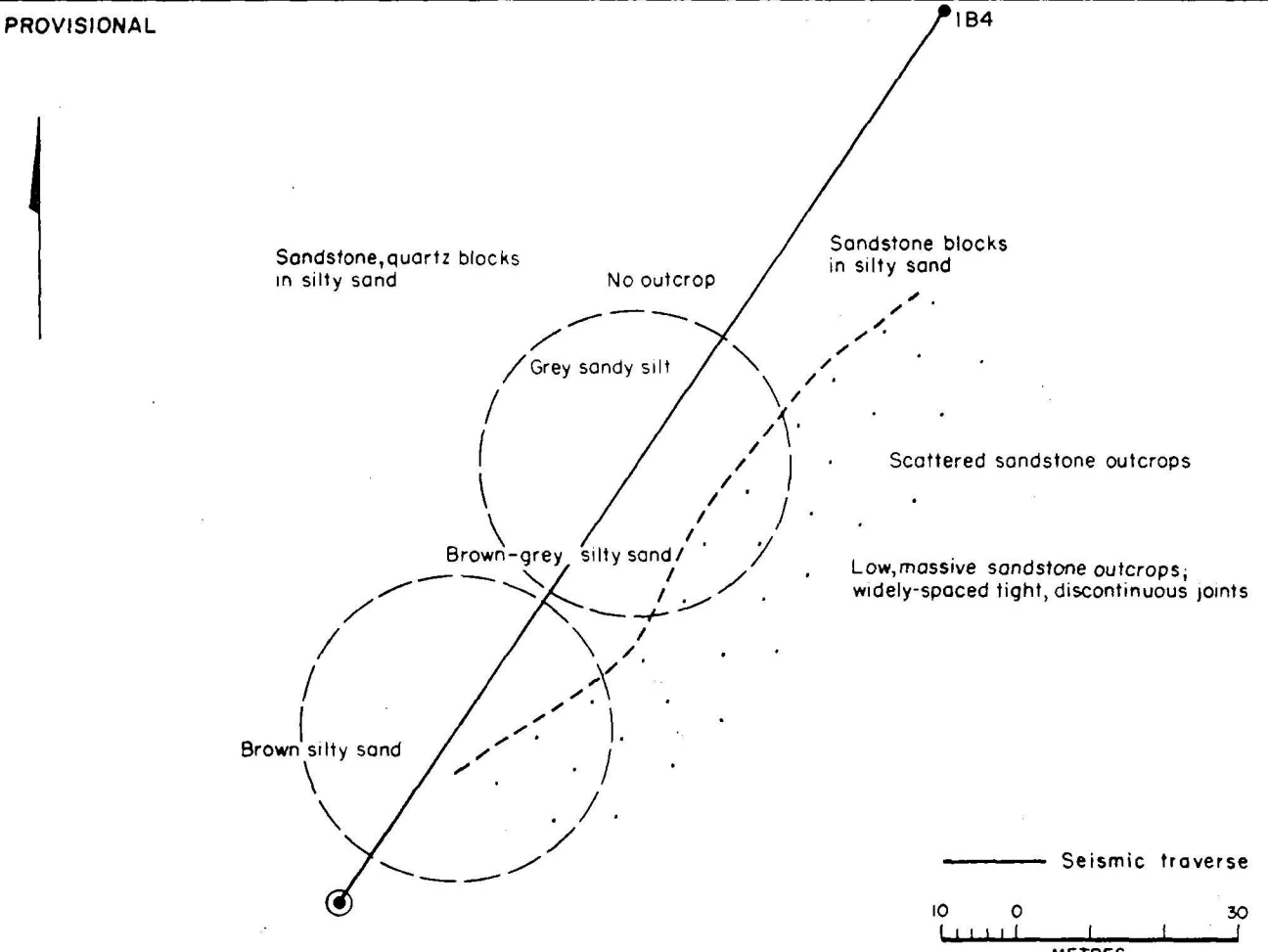
One site on the lower northwestern slopes of Tuggeranong Hill was investigated for this reservoir (Plate 14). The proposed reservoir will be a rectangular embankment type and will have a floor level of R.L. 644 m and top water level of 655 m. This site is approximately 700 m west of the Lower Theodore site and the general geology and seismic results are similar.

THARWA 1B

PLATE II




PROVISIONAL



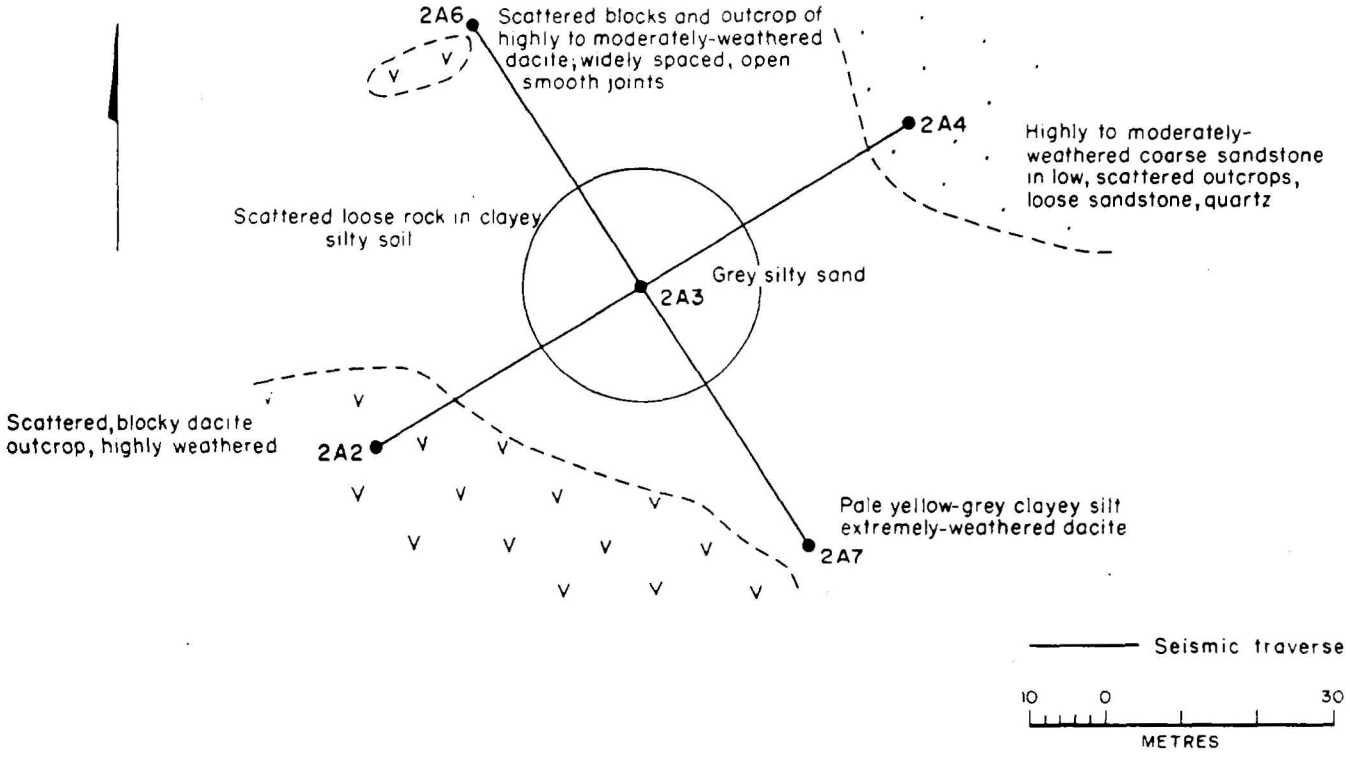

# GEOLOGY OF THARWA 1B RESERVOIR SITES

*Record No. 1977/58*

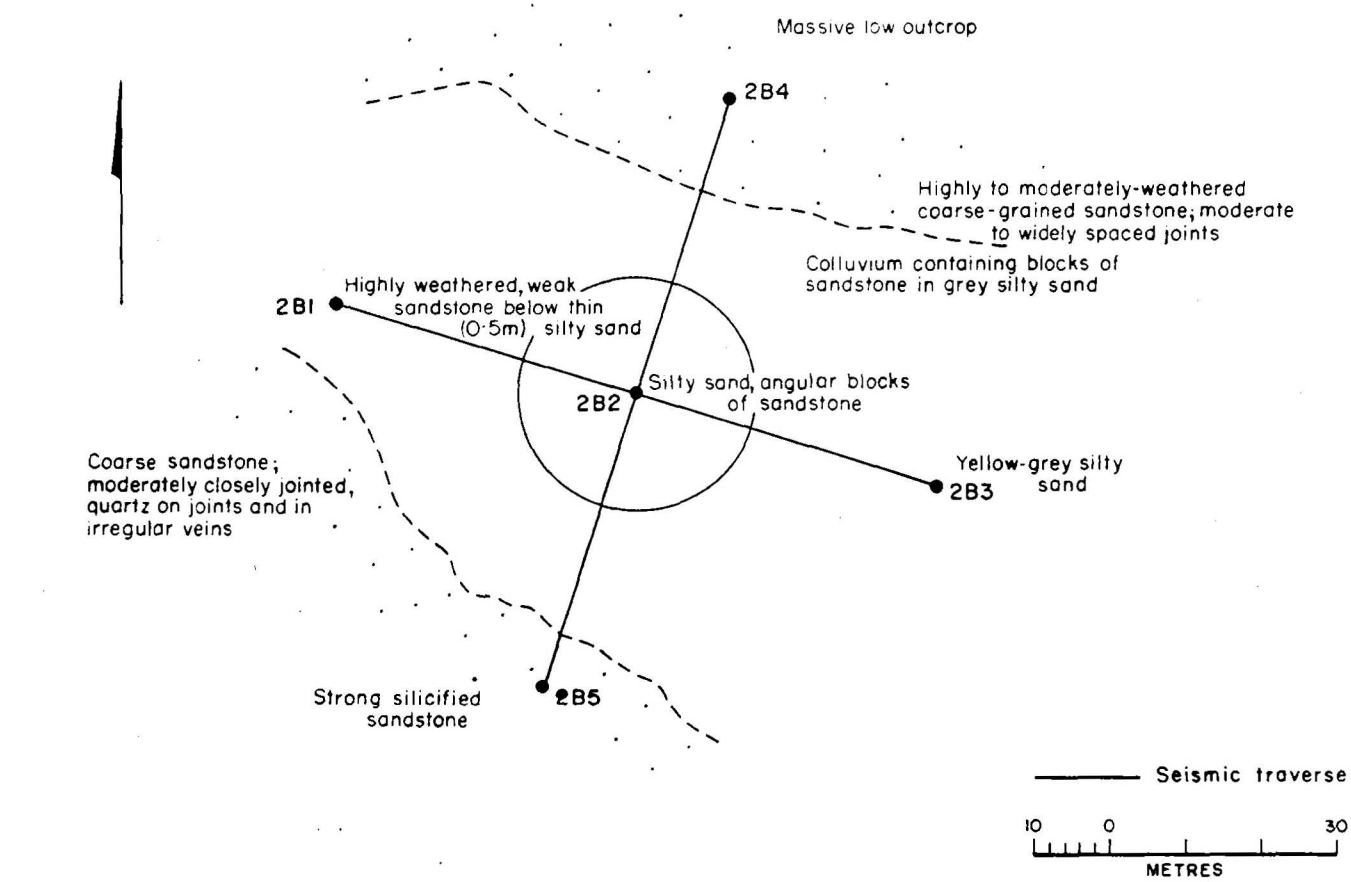
I55/B5-350A

# THARWA 2A & 2B

## SITE 2A

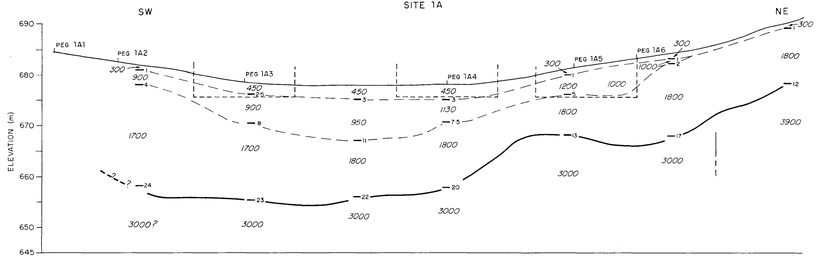


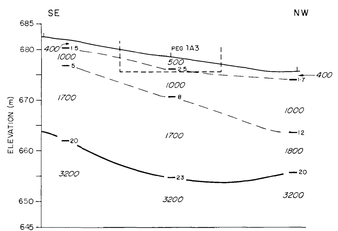

## SITE 2B

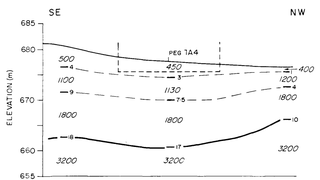


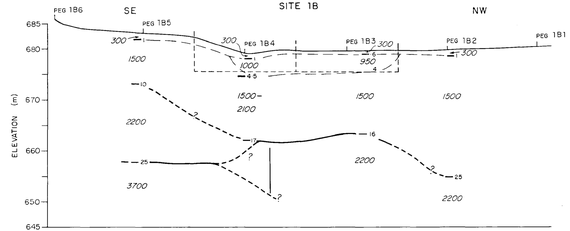

# GEOLOGY OF THARWA 2A AND 2B RESERVOIR SITES

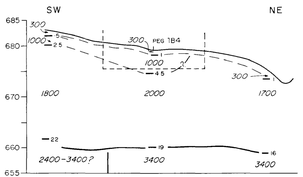
*Record No. 1977/58*

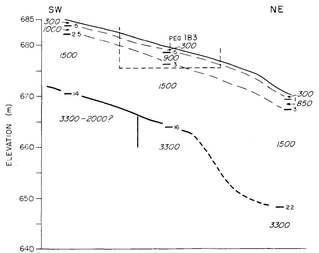


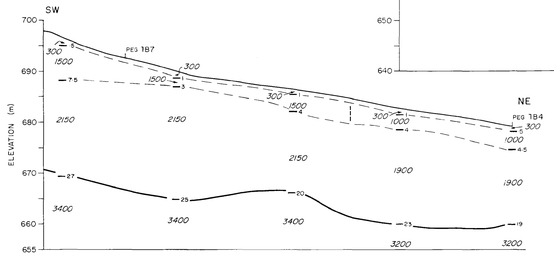



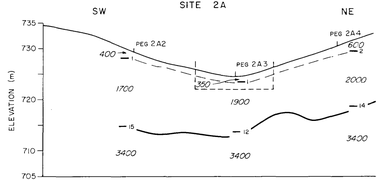



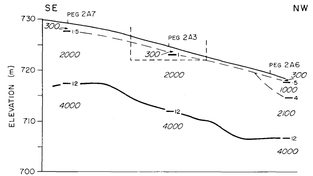



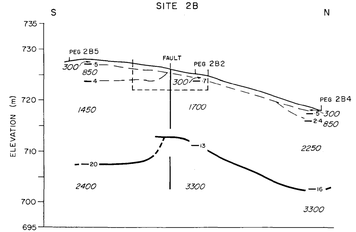



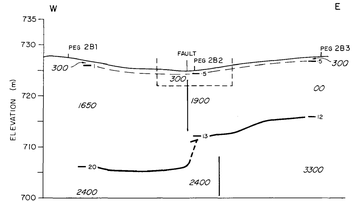




LEGEND

- 1500 Seismic velocity (m/s)
- 6 Depth of refractor (m)
- Intermediate refractor
- Bedrock refractor
- Depth of excavation
- Seismic discontinuity

HORIZONTAL SCALE

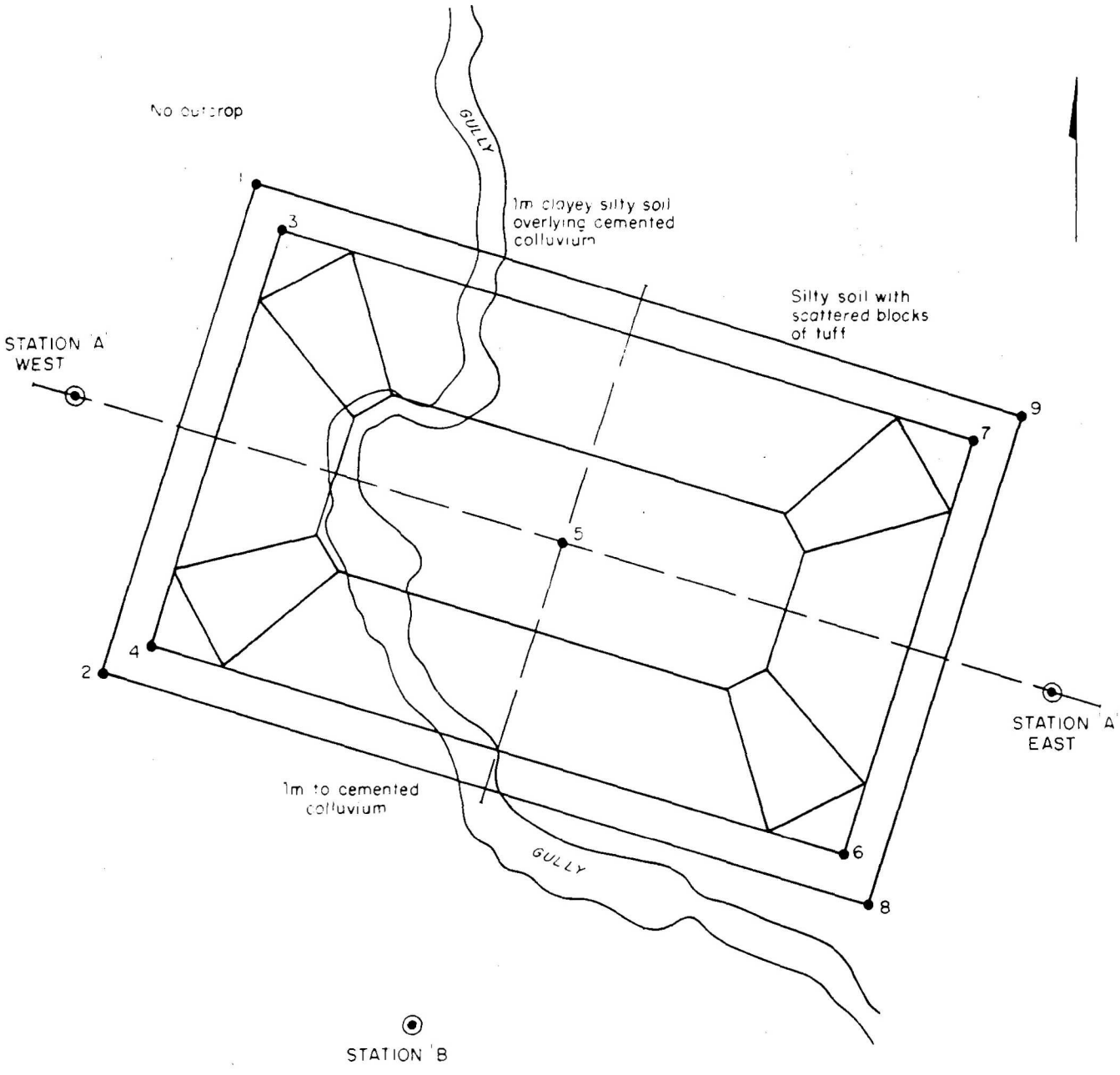
10 0 40m

V/H = 2

# SEISMIC SECTIONS FOR THARWA I AND 2 RESERVOIR SITES

Record No. 1977/58

[55/85-352




# GEOLOGY OF CALWELL RESERVOIR SITE

- Temporary marker
- Permanent marker
- Seismic traverse
- Reservoir outline

A thin soil consisting of grey gravelly silt and grey yellow clay covers the site. Highly weathered and moderately closely jointed rhyodacitic tuff crops out farther upslope and loose blocks occur in the soil. The soil is underlain by 3 to 5 m of cemented colluvium which consists of rounded boulders of tuff in sandy silt cemented by silica, calcite and/or limonite. This layer has a seismic velocity between 700 and 1000 m/s and should be rippable (Plate 16). This colluvium is underlain by highly to moderately weathered tuff (seismic velocity 1300-1500 m/s) to an average depth of 12 m. The reservoir will be founded on this rock which should be marginally rippable although light blasting may be required to the east. Slightly weathered tuff (1900-2400 m/s) extends to 27-33 m depth and overlies bedrock with a seismic velocity between 5200 and 6000 m/s. A variation in the bedrock velocity was noted at the eastern end of the W-E traverse.

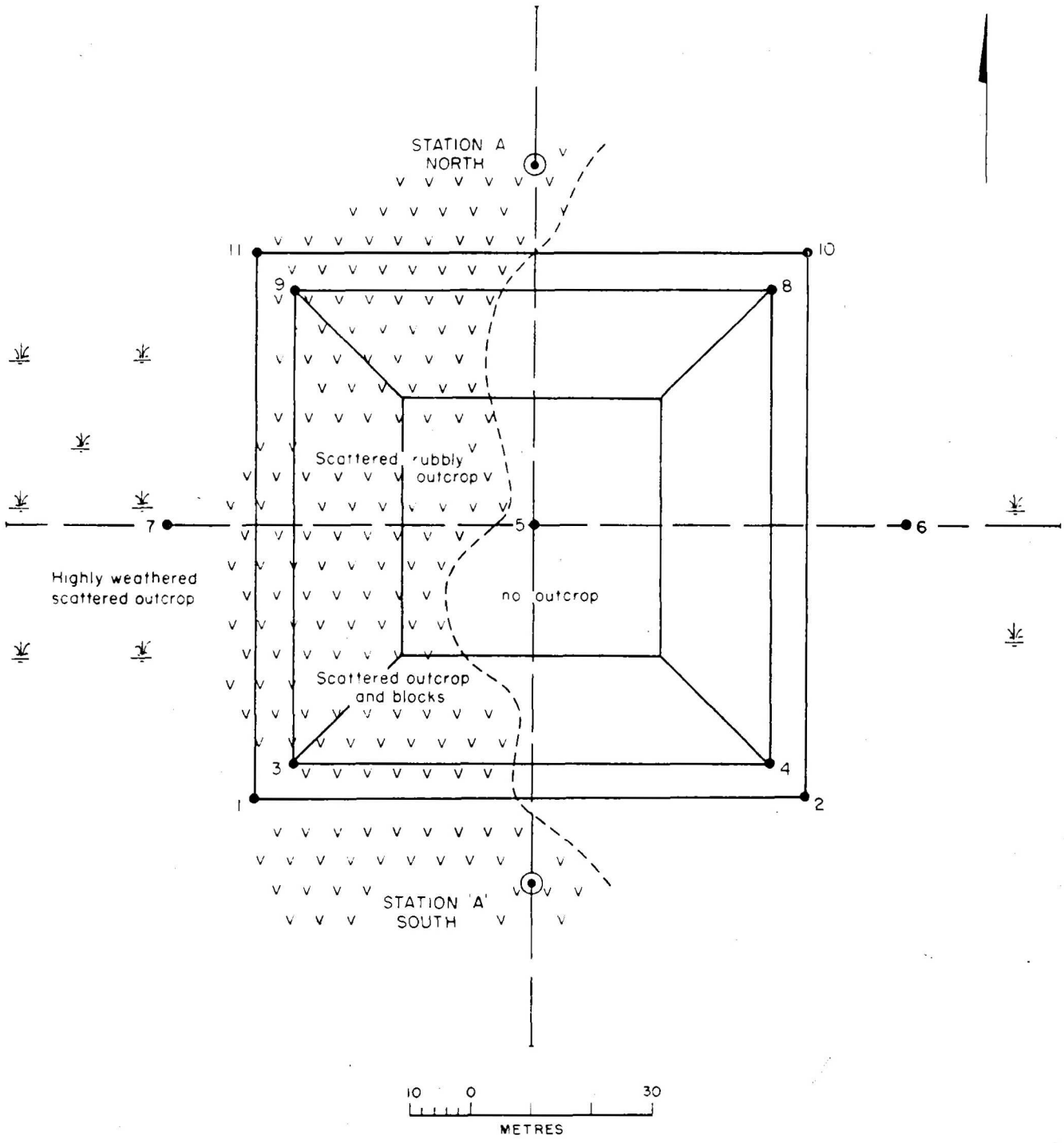
The excavation material from this site should be suitable for use as embankment fill in construction of the reservoir.

4.7 Lanyon

One site, located in a saddle on Lanyon Hill on the western side of the Tharwa Road, was investigated for this reservoir (Plate 15). The proposed reservoir will be a square embankment type and will have a floor level of R.L. 645 m and a top water level of 655 m. Highly weathered dacitic tuff occurs in scattered outcrops near the site.

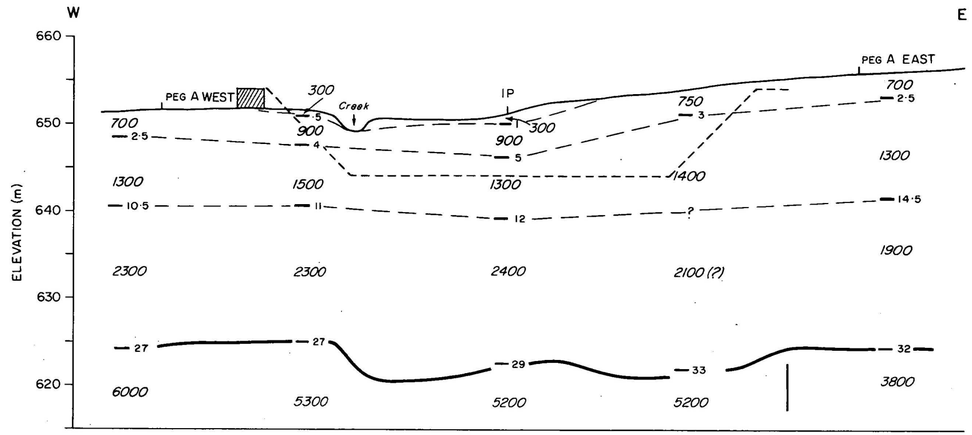
The seismic results show that the site is covered by a thin (less than 1 m) layer of silty soil which overlies moderately weathered tuff (seismic velocity of 2000-2300 m/s) to an average depth of 4.5 m (Plate 16). Beneath this, slightly weathered tuff (2700-3300 m/s) overlies bedrock (4600-4800 m/s) at depths ranging between 12 and 23 m. For a floor level of 645 m, the reservoir will founded on slightly weathered rock, and blasting will be necessary to excavate all the rock from the site. A velocity change from 2100 to 1450 m/s was noted towards the eastern end of the W-E traverse and light blasting may suffice here.

The excavated rock from this site may not be suitable for the construction of a watertight embankment.

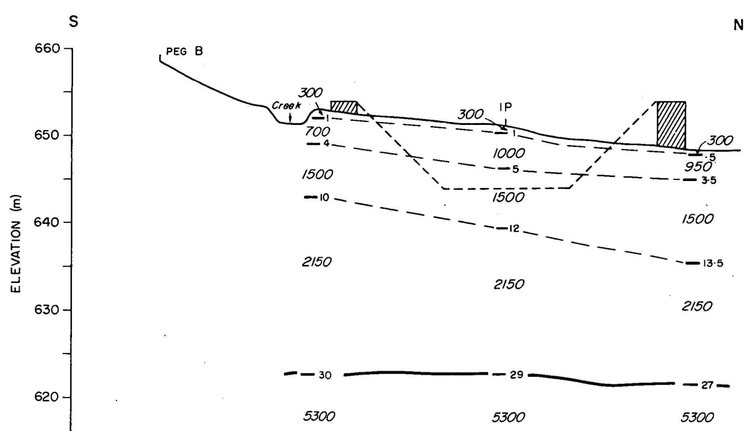


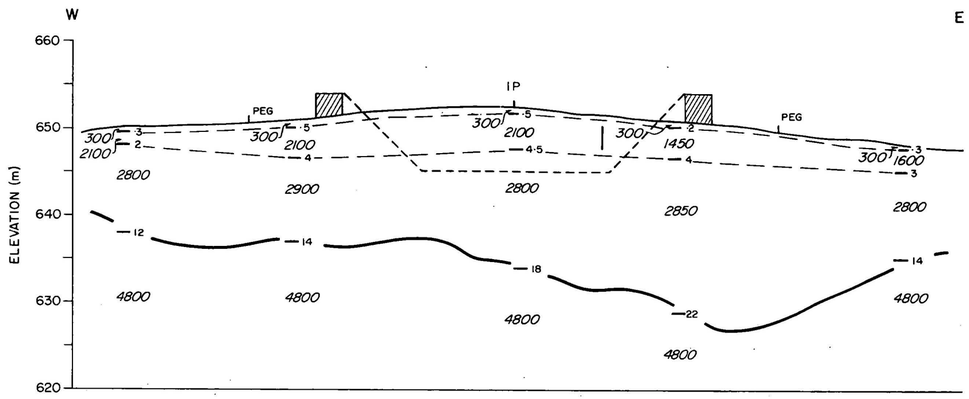

# GEOLOGY OF LANYON RESERVOIR SITE

- Temporary marker
- Permanent marker
- Dacitic tuff
- Swampy ground
- Seismic traverse
- Reservoir outline

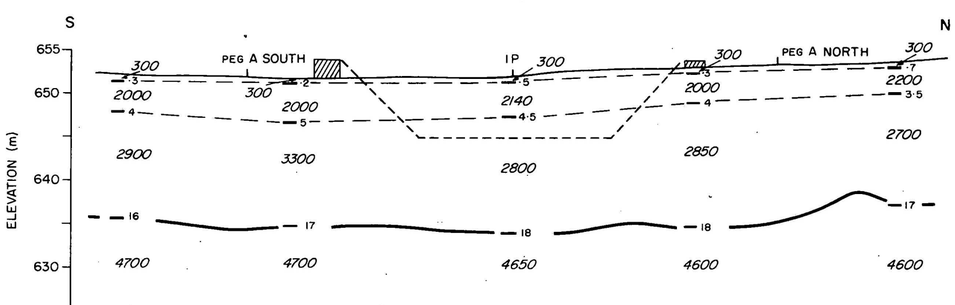



CALWELL




LANYON




SEISMIC SECTIONS FOR CALWELL AND LANYON RESERVOIR SITES

LEGEND

| | |
|---|---|
| 1500 | Seismic velocity (m/s) |
| — 6 | Depth of refractor |
| — — | Intermediate refractor |
| ——— | Bedrock refractor |
| - - - - | Depth of excavation |
| \| | Seismic discontinuity |

HORIZONTAL SCALE

10 0 40m

V/H = 2

Record No. 1977/58

I55/B5-355

## 5. CONCLUSIONS

Lower Theodore reservoir would be founded on cemented colluvium or weathered rhyodacitic tuff and the site should be marginally rippable (1300 m/s).

Upper Theodore reservoir would be founded on rhyodacitic welded tuff and the site may require light blasting (1500 m/s).

The three alternative sites for Tuggeranong Hill 3 are underlain by tuff and all will require blasting in excavation (1600-2000 m/s).

The four alternative and three provisional sites for Tharwa 1 are all underlain by weathered sandstone. Site 1A should be rippable (1000 m/s), but some blasting may be required at site 1B (1500-2000 m/s).

Of the two alternative sites for Tharwa 2, a reservoir at site 2A would be founded on sandstone and dacite which require blasting in excavation (2000 m/s), and at site 2B would be founded on sandstone which also requires blasting (1450-1900 m/s). Precautions may be necessary to prevent differential settlement at this site.

Calwell reservoir would be founded on rhyodacitic tuff which may be marginally rippable (1500 m/s).

Lanyon reservoir would be founded on dacitic tuff and blasting will be necessary in excavation of the site (2100-2800 m/s).

## 6. REFERENCES

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