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TENNENT DAM SITES NOS. 2 AND 3 SEISMIC INVESTIGATIONS, A.C.T., 1975/76

by

C.L. Horsfall

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SUMMARY

Seismic refraction traverses were carried out along the axes of the proposed Tennent dam sites No. 2 and 3, and on the proposed locations of the dam site spillways and water-treatment plant. The aim of the surveys was to determine the nature of and depths to the bedrock and the character of the overlying material, with particular attention being given to the location of shear zones in the area.

The depth of weathering is generally less than 25 m, except in shear zones. Seismic velocities of fresh bedrock range from 3400 m/s to 5800 m/s. Several shear zones were detected by the seismic traverses in the east abutments of both dam sites where lower bedrock velocities (less than 3500 m/s) were encountered. In contrast the western abutments are relatively unsheared and show high bedrock velocities at shallow depths.

1. INTRODUCTION

The Gudgenby-Naas River System is one of several in the Australian Capital Territory being investigated for major water-supply dams. Three dam sites in a gorge on the Gudgenby River near Mount Tennent are being considered. The purpose of the seismic investigations is to provide data for feasibility studies and cost comparisons between the sites.

Seismic refraction work was carried out on Tennent dam site No. 1 by the Department of Works and the Bureau of Mineral Resources, Geology and Geophysics (BMR) before 1968. The results are described by Buchhorn (1968, drawing CD68/1798). Further seismic refraction work on dam site No. 1 was carried out by the Engineering Geophysics Group of BMR in 1971, and the results were summarized by Dolan (1972).

This report presents the results of seismic refraction surveys on dam sites Nos. 2 and 3 by the Engineering Geophysics Group of BMR in November-December 1975 and in February 1976.

The interpretation of the field results by C.L. Horsfall was checked by G.R. Pettifer.

2. GENERAL GEOLOGY

The geology of the dam site area has been described by Buchhorn (1968), Henderson (pers. comm. 1973), and Goldsmith & Briscoe (in prep.). The Tennent dam sites are located on Tharwa Adamellite, an orthoclase-rich granite which is part of the Siluro-Devonian Murrumbidgee Batholith. The eastern boundary of the batholith is the north-trending Murrumbidgee Fault, within 1 km east of the dam sites. Silurian and Devonian sediments and volcanics crop out east of this fault.

The adamellite has a primary foliation, striking 345° and dipping 70° east, defined by the orientation of platy xenoliths. It has a superimposed secondary foliation which trends between 320-002° and dips steeply west or is vertical. The adamellite is cut by aplite dykes and veins up to 15 cm thick. The dykes and veins are generally concordant with the secondary foliation.

The adamellite is jointed: one set of joints is parallel to the foliation, and another set is perpendicular to it. The joints are widely spaced (1-2 m), commonly open (1-10 cm), and a few are filled with clay.

Weathering in the adamellite, particularly on the western abutments where the adamellite is less sheared, is controlled by jointing. On the eastern abutments, the depth of weathering is controlled by the presence or absence of strong shearing.

Moderately weathered to fresh unsheared adamellite (seismic velocity greater than 2000 m/s) should provide good dam foundations, as the rock is homogeneous and strong with few defects. In general, the adamellite is weathered to irregular (and in places great) depths on the abutments, particularly on the eastern abutments.

A vertical fault zone, about 110 m wide and trending at about 000° intersects the east abutments of the dam sites. The zone appears to consist of a number of discontinuous subparallel faults, and is associated with pegmatite and blastomylonite and deeper weathering.

3. METHOD

The spreads were shot along the dam axes on traverse lines pegged by the Engineering Geology Group of BMR between reference points located by the Department of Construction (DC). These lines were surveyed by DC at 10-m station spacing after the seismic work was completed.

Most traverses were shot as a 23-geophone spread with 4-m inter-geophone spacing and a 24th geophone (reciprocal geophone) at 42 m or 94 m along the traverse from the spread. Adjacent spreads were linked by a common geophone position. Details of equipment and operational statistics are given in Appendix 1.

The intercept method was used for interpretation (Heiland, 1946). Depths to bedrock were calculated under each geophone using the reciprocal-time method (Hawkins, 1961).

The errors in depth and velocity of the layers are expected to be generally less than 15 percent for the deeper layers, and of the order of 50 percent for the topmost soil layer. Where the depths to the deepest refractor were not known to better than 15 percent accuracy, the upper surface of the deepest refractor was indicated by a broken line on the seismic sections.

Where low-velocity zones in the bedrock corresponded to geologically mapped faults, or to extrapolations from known faults, they were marked as faults on the seismic section; where such zones did not correspond to a known fault they were marked as shear zones.

4. SEISMIC VELOCITIES

The velocity with which a vibration is transmitted through rock varies with rock type and in general increases with the soundness of the rock. The seismic velocity of a rock mass in situ is decreased by the presence of faults, joints, cracks, and other discontinuities (Onodera, 1963; Polak, 1968). For porous rock and unconsolidated material, seismic velocity also generally increases with the degree of water saturation.

Since relatively homogeneous adamellite forms the bedrock throughout the entire dam site area, changes in seismic velocity can be attributed to variations in the degree of weathering of the rock and in the concentration of joints, cracks, and faults. Dolan (1972) classified the condition and soundness (after Onodera, 1963) of the adamellite at Tennent dam site on the basis of its in situ velocity. A table relating rock condition to in situ seismic velocity is presented below. The table is adapted from Dolan (1972) and D.C. Purcell (pers. comm.).

In situ seismic velocity (m/s)	Rock mass description
1000 - 1700	Extremely weathered. Soft. May be some open joints but joints are generally clay-filled.
1000 - 2000	Highly weathered rock. Fairly soft, closely jointed. Can be ripped or jack-picked.
2000 - 3050	Partings are open and wide or closely spaced, and usually contain clay or muddy materials accompanied by fissure water; rock substance may be only moderately weathered and strong. Individual zones of this velocity in higher-velocity rock probably represent sheared or faulted zones.
3050 - 3650	Rock substance is slightly weathered to fresh, with its surface weathered. Joints and cracks are moderately to closely spaced, partly open, with or without clay.

In situ seismic velocity (m/s)	Rock mass description
3650 - 4600	Moderately spaced joints and cracks with only slight parting. Rock substance is rather fresh with weathering on the surfaces of partings.
4600 -	Fresh, or fresh with stained joints. Any defects are tight with little or no clay. Continuous defects are widely spaced.

Unsheared (non-faulted) adamellite of seismic velocity greater than 2000 m/s should provide good dam foundations (D.C. Purcell, pers. comm.). Depths of rippability are given in this report on the assumption that rock material of seismic velocity greater than 1300 m/s is not rippable by a D8 bulldozer.

5. TENNENT DAM SITE NO. 2

Plates 2 and 3 show the spread locations and the seismic sections respectively for dam site No. 2 and its spillway, the water-treatment plant and the clear-water storage.

5.1 Dam abutments

Spreads 30 to 35 traversed the axis of dam site No. 2. The line of the traverse intersected the rock foliation at about 90°. The section between spreads 31 and 32 was omitted owing to difficult terrain, but has subsequently been investigated by P.J. Hill (in prep.).

Geological mapping in the untraversed section indicated the presence of a shear zone at 390 m (Pl. 3). This shear zone also intersects the eastern abutments of dam sites 1 and 3 and appears to mark the contact between unsheared adamellite to the west and sheared adamellite to the east. Spread 31 indicates a sharp increase in the depth of weathering at its western end, which may be related to the shear zone. However, an accurate interpretation was not possible at this end of spread 31 owing to the lack of a reciprocal geophone and long shot, and to the problems created by irregular terrain. West of the shear zone (Pl. 3) an unstable zone with some rock toppling was mapped by Goldsmith & Briscoe (in prep.).

On the west abutment the seismic records of spreads 33-35 showed marked local velocity changes within the indicated overall average velocity of the bedrock. These are probably associated with irregular weathering of the massive adamellite along widely-spaced joint planes. Two zones with bedrock velocities of 3450 m/s and 3800 m/s probably represent slightly weathered rock with more closely spaced or more open joints.

On the eastern abutment, where the adamellite is more sheared, the rock is more uniformly weathered and the deepest-refractor velocity is 3800 m/s.

The 6-8-m thick refractor of 1000 m/s seismic velocity on the terrace near the river may represent alluvial gravels and sands deposited by the river on fresh to slightly weathered bedrock.

The seismic section indicates slightly weathered bedrock at 15-25 m depth on the eastern abutment and slightly weathered to fresh bedrock cropping out or just under the surface on the western abutment. Assuming a seismic velocity of 1300 m/s for material rippable with a D8 bulldozer, the western abutment is rippable to a depth of 0 to 1 m and the eastern abutment is rippable to a depth of 3 to 6 m.

5.2 No. 2 spillway, water-treatment plant, and clear-water storage

Spreads 36, 37, and 38 (Pl. 3) - across the spillway site - make an acute angle with the foliation, and show changes in bedrock velocity which are considered to represent shear zones and associated deeper weathering. The spillway site rock is expected to be rippable with a D8 bulldozer to a depth of 6 m. The remaining material down to the base of the excavation will have to be blasted.

Velocity anisotropy is indicated with the change in traverse direction at the intersection of spreads 30 and 36. Higher bedrock and weathered-layer velocities were recorded by spread 36, which intersects the direction of shearing and foliation in the adamellite at a more acute angle.

The section below the site for the water-treatment plant (spreads 38, 39, and 40) shows mostly high bedrock velocities, with two small zones of low bedrock velocity which may represent shear zones and associated weathering. The rock is expected to be rippable with a D8 bulldozer to the base of the treatment-plant excavation at 704 m.

Spread 41, at the site of the clear-water storage, indicates a low-velocity zone in the bedrock which may represent a shear zone with associated deeper weathering. The rock is expected to be rippable with a D8 bulldozer to the base of excavation at 710.15 m.

6. TENNENT DAM SITE NO. 3

Plates 2 and 4 show the spread locations and the seismic sections respectively, across dam site No. 3 and its spillway, and along the eastern extension of the centre line of the dam.

6.1 Dam abutments

Seismic spreads 1 to 8 were located along the axis of dam site No. 3. Spreads 1 to 6, on the western abutment, indicate an average depth of 10 m to fresh bedrock. The seismic records indicate local marked changes in bedrock velocity as on the western abutment of dam site No. 2. This is interpreted to represent irregular weathering of massive adamellite along widely spaced joints. This interpretation is supported by the highly irregular surface of the bedrock indicated in spreads 1 to 6. A cutting on the Naas Road on the western abutment shows that there is generally a weathering zone up to 30 cm wide adjacent to joints. This abutment has a 1-m thick silty soil cover between rounded boulders and outcrops of highly to slightly weathered adamellite. The depth of rippability using a D8 bulldozer is roughly 1 m, but is likely to be quite variable. The 700-m/s refractor adjacent to the river probably represents river alluvium.

Spreads 7 and 8 on the eastern abutment indicate a depth to slightly weathered bedrock of 15 to 20 m. The bedrock velocities are lower than on the western bank and may be related to shearing and deeper weathering. An alternative explanation for the lower bedrock velocities and the changes in seismic velocity at the ends of spread 8 is given later (6.3). Geological mapping indicates the contact between unsheared adamellite to the west and sheared adamellite to the east to lie at the present position of the Gudgenby River at the dam axis. The depth of rippability using a D8 bulldozer is 5 to 7 m, assuming a limiting seismic velocity of 1300 m/s.

6.2 No. 3 spillway

Spreads 10 and 11, across the spillway site (Pls. 2 and 4), indicate the presence of low-velocity zones at the sidewalls of the spillway; these correspond to mapped faults. The fault at 805 m also passes through the east abutments of dam sites Nos. 1 and 2. This fault dips to the east, and the ground trace of the fault runs subparallel to the spillway. The gully at 930 m may be related to the fault at 915 m.

The spillway site rock is expected to be rippable with a D8 bulldozer to a depth of 6 m. Blasting to the base level of excavation will be required for the remaining material. The rock with a seismic velocity of 2900 m/s is expected to provide a firm foundation, whereas the lower-velocity rock at the sides of the spillway may affect the design of the spillway.

6.3 East of dam site No. 3

Spreads 9 to 20 (Pls. 2 and 4) show that depths to bedrock range from 15 m to 25 m; depths of rippability using a D8 bulldozer range from 5 to 10 m.

Some zones of low velocity in the bedrock on this traverse are assumed to represent shear zones. However, some low-velocity zones may not be related to shearing and their contacts may not be steep. The changes in velocity recorded in the deepest refractor, from 3700 to 3500 to 2600 m/s in spreads 7 to 9, occur exactly on the ends of spread 8 on the eastern abutment, and were accompanied by large discrepancies in the depth to the bedrock surface at these points. This may indicate that the changes in bedrock velocity are gradual and that the velocity recorded depends on the locations of the spreads and shot-points.

Such a gradual decrease in bedrock velocity upslope from spreads 7 to 9 may reflect a remnant of an older land surface of deep weathering, which may have developed on the low-relief interfluves between the Gudgenby and Murrumbidgee Rivers. Uplift to the west of the Murrumbidgee Fault would have resulted in rejuvenation of the Gudgenby River, which would have cut down through the older weathering profile and exposed the deeper fresher rock. Further weathering on the river banks would have then been superimposed on the older weathering profile. Thus the changes in bedrock velocity coinciding with the ends of spread 8 may reflect seismic velocity changes in depth in the older weathering profile and the inferred contacts may be quasi-horizontal.

Some problems were encountered in the interpretation of spreads 12 to 20, since the long shots were not placed far enough away from the geophone spreads. It was sometimes difficult to resolve whether low calculated bedrock velocities at the ends of the spreads were true bedrock velocities or the average of the velocities of the bedrock and the overlying refractor.

The low-velocity zone of 3200 m/s at 1130 m (Pl. 4) is near a gully which forms part of a north-trending photo-lineament.

The low-velocity zone of 2600 m/s at 1300 m is not in line with the Murrumbidgee Fault, which lies east of spread 20, but the marked change in bedrock velocities either side of this zone suggest that it is a significant contact. This low velocity zone is in line with a strike-slip fault striking 030° true in the Siluro-Devonian rocks to the northeast. No corresponding change in lithology has been mapped so far, and surface rock samples either side of this low-velocity zone did not exhibit any easily identifiable change in lithology.

The exposure of rock of seismic velocity from 2000-2300 m/s between 210 m and 1290 m may be a further example of incision by streams through an older weathering profile as described earlier for the area of spreads 7 to 9.

7. CONCLUSIONS

7.1 West abutments

Seismic investigation of the western abutments of both dam sites indicates relatively high-velocity bedrock at shallow depth. The depth to fresh bedrock is 10 m at dam site No. 3 and is less than 1 m at dam site No. 2. The depth of rippability using a D8 bulldozer is less than 1 m on the west abutments of both dam sites, but is expected to be quite variable. The western abutment of dam site No. 3 has more consistent and higher bedrock velocities than that of dam site No. 2. On the western abutments of both dam sites the seismic records showed marked velocity changes within the indicated overall average velocity of the bedrock. This may be caused by tor-like weathering along widely spaced joint planes in the adamellite.

7.2 East abutments

The eastern abutments of both dam sites are more evenly and deeply weathered, as the adamellite is extensively sheared. The depths to slightly weathered bedrock on the eastern abutments are 15-25 m at dam site No. 2 and 15 to 20 m at dam site No. 3. The depths of rippability using a D8 bulldozer are 3 to 7 m on the east abutments of both dam sites - assuming a limiting seismic velocity of 1300 m/s.

A generally north-trending fault zone which dips to the east passes to the east of the eastern abutment of dam site No. 3. This fault, however, intersects the dam site No. 2 axis at a low level on the eastern abutment. Immediately west of this fault at dam site No. 2 is a large unstable zone with some rock toppling. The depth to the base of the zone and the underlying rock conditions are unknown, but are presently being investigated by Hill (in prep.).

7.3 Spillway sites

The seismic sections east of both dam sites show evidence of many shear zones and associated variations in the depths of weathering. Both spillway sites are located over shear zones in the bedrock and have depths of rippability by D8 bulldozer of 6 m. Blasting to spillway floor level will be required at both sites. Problems may be encountered at the present site of No. 3 spillway owing to the presence of faults with deep weathering at the sidewalls of the spillway.

8. RECOMMENDATIONS FOR FURTHER WORK

a) Seismic work should be carried out over the unstable area on the east abutment of dam site No. 2 to establish whether the low velocities encountered at the western end of spread 31 are due to opening of joints on the unstable slope or to an increased depth of weathering associated with shearing.

b) The depth of weathering in shear and fault zones on the dam abutments and spillway sites should be investigated.

c) The continuity and trend of faults and shear zones should be examined by parallel seismic or resistivity traverses, or both.

d) A ground magnetic traverse at 5 m spacing should be carried out from 1150 m to 1450 m along the Tennent dam site No. 3 seismic traverse. This will provide further information toward an understanding of the nature of the change in bedrock character either side of the low-velocity zone at 1300 m.

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APPENDIX 1 - OPERATIONAL DETAILS

PERSONNEL

Party Leader	:	C.L. Horsfall
Technical Staff	:	D. Francis A. Martindale
Field Assistants	:	E. Chudyk M. Ellis T. Hegvold M. Preston-Stanley

OPERATIONAL STATISTICS

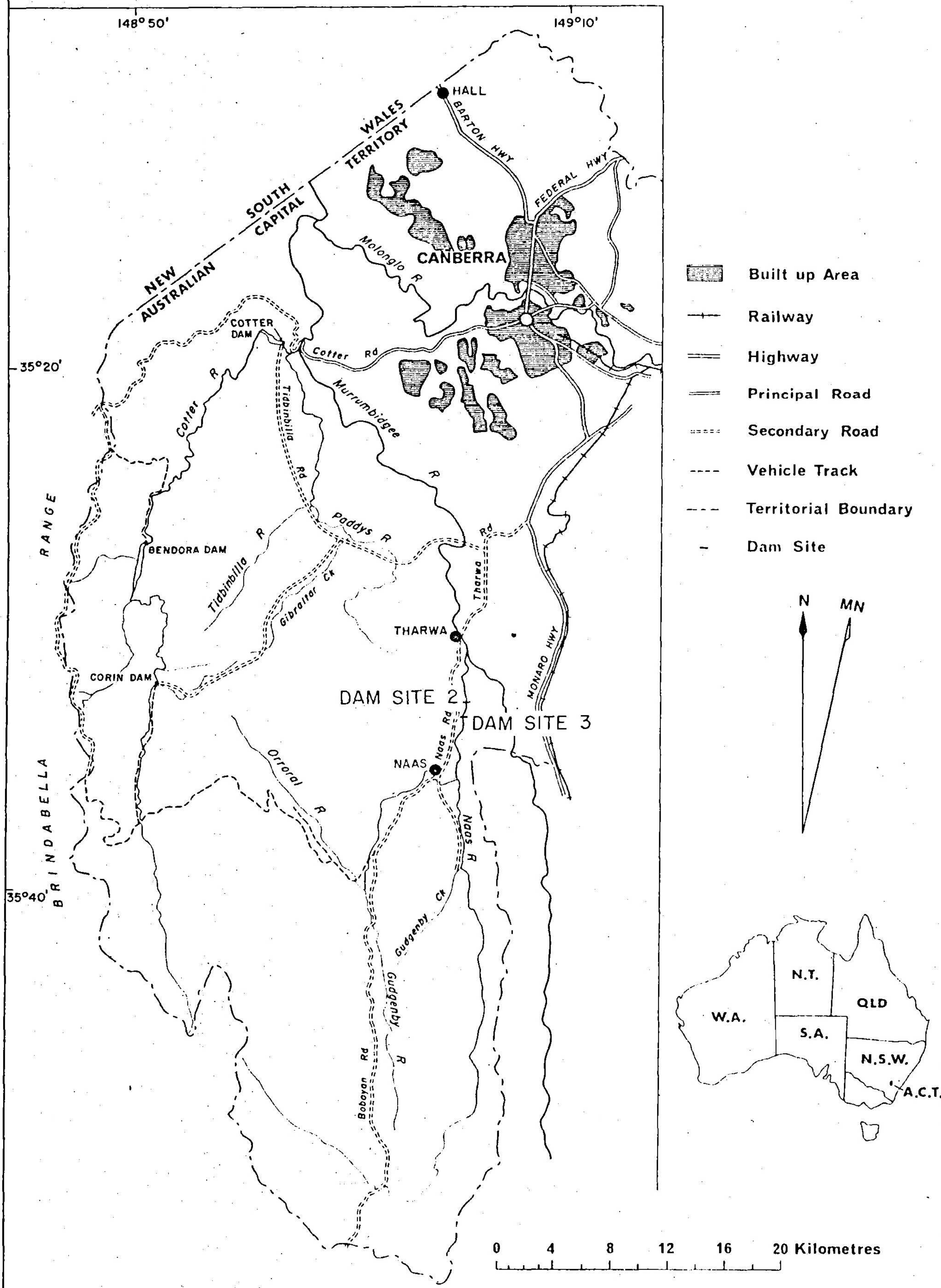
No. of spreads	32
Distance covered	2816 m
No. geophones/spread	24
Geophone spacing	4 m
Length of spread	88 m
No. shots/spread	5
Explosives used	588 sticks = 98 Kg
Long shot/reciprocal geophone distance from each end of spread	42 m
Short shot distance from each end of spread	2 m
No. of shots fired	166
No. of reshoots	7
No. of detonators used	166
No. of days of fieldwork	14
Period over which field work was done	24-11-75 to 9-2-76

EQUIPMENT

Amplifers	SIE PSU-19
No. Channels	24
Camera	SIE VRO-6D
Geophones	8Hz GSC-20D
Blaster	BC8A
Vehicles	1 shooting truck 1 recording van

PLATE I

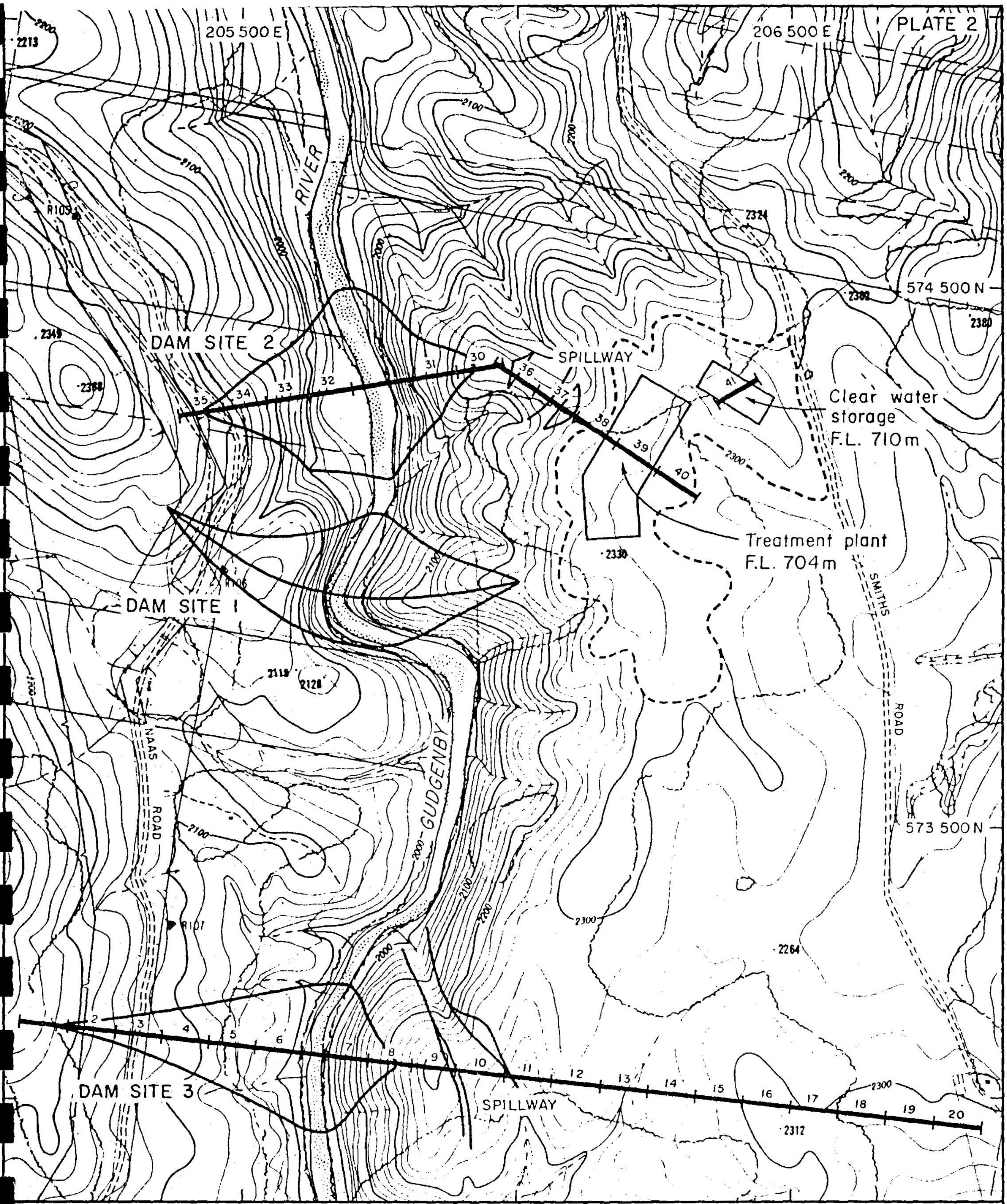
TENNENT DAM SITES 2 & 3
LOCATION MAP



Record No. 1976/105

I55/B5-325A

(Based on M(Pf)171)



Seismic spread

Contour interval 20 feet

Limit of excavation

TENNENT DAM SITES 2 & 3 TRAVERSE LOCATION PLAN

50 0 100 200 300 400 m

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I55/B5-326A


PLATE 3
WEST
DIRECTION 81° 09' 42"
EAST
SURVEY PERMANENT MARKER
TELEPHONE LINE
SPREAD 35
DAM
ROAD
STN 2
SPREAD 34
STN 3
STN 4
SPREAD 33
SPREAD 32
STN 5
STAR PICKET
GUDGENBY RIVER
UNSTABLE ZONE
TOP OF CLIFF
STN 6
SPREAD 31
FENCE
SPREAD 30
STN 7
STN 8
MAPPED SHEAR ZONE
CHANGE IN DIRECTION OF TRAVERSE
ELEVATION (m)
500 metres
LEGEND
Interpolated formation boundary
(3800) Seismic velocity in formation (m/s)
Bedrock boundary
TENNENT DAM SITE 2
SEISMIC REFRACTION SECTIONS
V/H = 1
GEOPHONE SPACING 4m
NORTHWEST
DIRECTION 122° 26' 59"
SOUTHEAST
end of levelling
SPREAD 36
SPREAD 37
SPREAD 38
SPREAD 39
SPREAD 40
F.L. 672m
F.L. 704m
SHEAR ZONE
SPILLWAY EXCAVATION
TREATMENT PLANT
1000 metres
DIRECTION 58°
SOUTHWEST
NORTHEAST
SPREAD 41
F.L. 710m
CLEAR WATER STORAGE
Record No 1976/105
I55/B5-327


PLATE 4
TENNENT DAM SITE 3
SEISMIC REFRACTION SECTIONS
WEST
DIRECTION 96° 22' 04"
EAST
ELEVATION (m)
SPREAD 1
SPREAD 2
SPREAD 3
SPREAD 4
SPREAD 5
SPREAD 6
SPREAD 7
SPREAD 8
SPREAD 9
DAM
ROAD
FENCE
STN 1
STN 2
STN 3
STN 4
STN 5
STN 6
STN 7
STN 8
GUDGENBY RIVER
750 metres
SPREAD 10
SPREAD 11
SPREAD 12
SPREAD 13
SPREAD 14
SPREAD 15
SPREAD 16
SPREAD 17
SPREAD 18
SPREAD 19
SPREAD 20
STN 9
STN 10
GULLY
FAULT
FAULT ?
F.L. 672m
SHEAR ZONE
SPILLWAY EXCAVATION
GRAVEL ROAD
1850 metres
LEGEND
Interpolated formation boundary
(2600) Seismic velocity in formation (m/s)
Bedrock boundary
Seismic discontinuity
GEOPHONE SPACING 4 m
V/H = 1
Record No 1976/106
I55/85-328