DEPARTMENT OF NATIONAL RESOURCES

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1977/37

WANNIASSA RESERVOIR NO. 2 SEISMIC REFRACTION AND BLAST-INDUCED VIBRATION INVESTIGATION, A.C.T., 1977

by

P.J. Hill

Record 1977/37

WANNIASSA RESERVOIR NO. 2 SEISMIC REFRACTION AND BLAST-INDUCED VIBRATION INVESTIGATION, A.C.T., 1977

by

P.J. Hill

Contents

SUMMARY

The investigation of foundation conditions at the site of the proposed Wanniassa Reservoir No. 2 indicated suitable foundation rock; appreciable drilling and blasting are anticipated, however, to achieve excavation to floor level (elevation 673.5 m).

From the blast-induced vibration tests carried out, figures for maximum size of explosive charges and minimum delay times are derived which should ensure that ground vibrations at the adjacent Karralika homestead caused by blasting on the site are kept below a damaging level.

1. INTRODUCTION

The two-stage construction of Wanniassa Reservoir No. 2 is planned by the Department of Construction in Tuggeranong, A.C.T., about 50 metres (m) south of the Karralika homestead (see Plate 1). Excavation to a maximum depth of 5.5 m is proposed for the reservoir foundations and as blasting may be required to achieve this, there is the possibility of resultant damage to the homestead.

A request was put to the Bureau of Mineral Resources, Geology and Geophysics (BMR) by the Department for a foundation investigation of the proposed site and an assessment of the likely effects on the homestead of blasting during excavation. The BMR Engineering Geophysics Group carried out a seismic refraction investigation on the site and conducted a series of blast-induced vibration tests to determine the size of explosive charges that could be safely used on the site.

The seismic refraction field work was done on 28 June 1977 by a party consisting of the author (geophysicist and party leader), D. Francis, D. Bennett, and M. Preston-Stanley. The author and D. Bennett conducted the vibration tests on 6 and 8 July 1977.

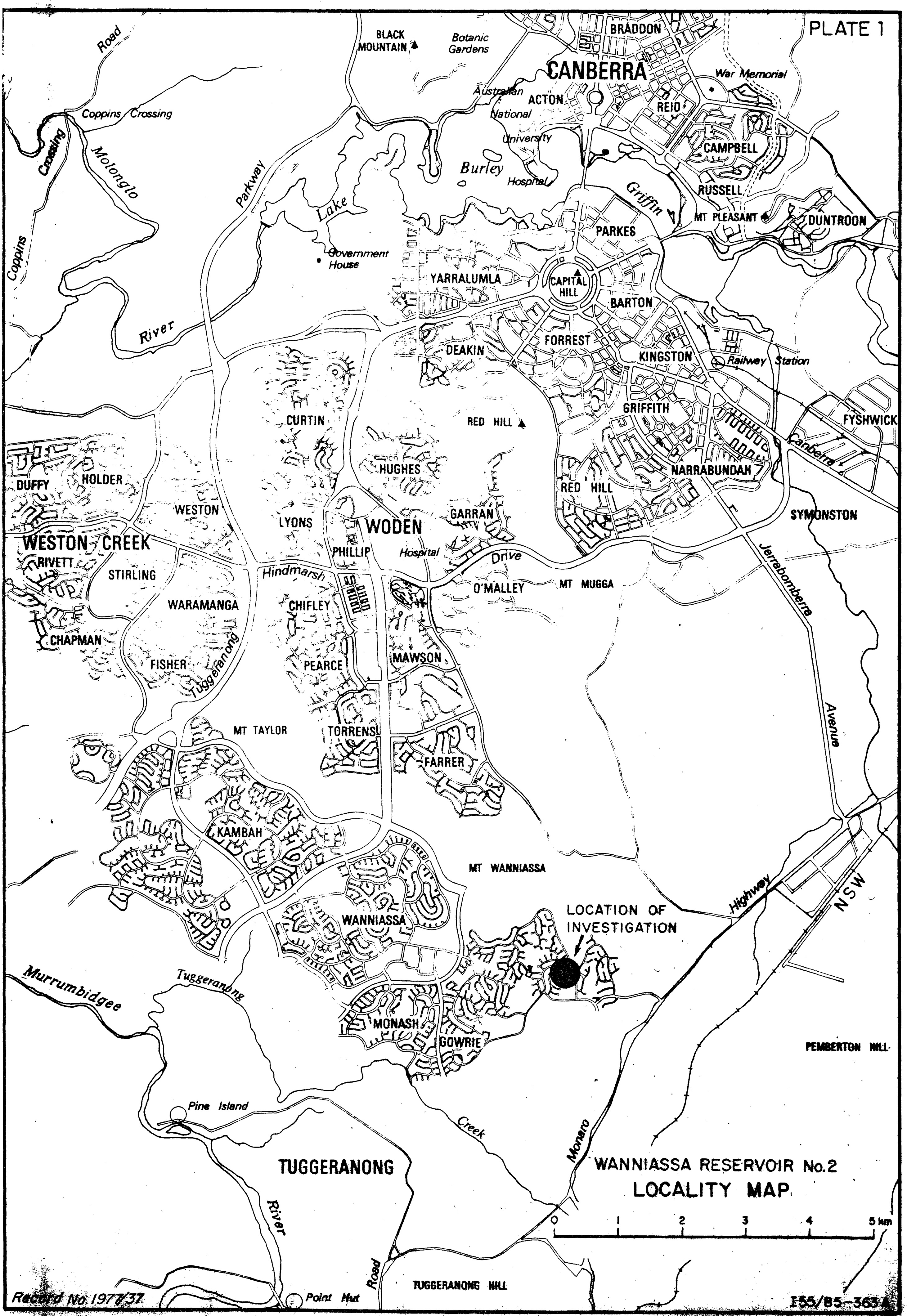


PLATE 1
BLACK MOUNTAIN
Botanic Gardens
BRADDON
CANBERRA
War Memorial
Australian National University
ACTON
REID
CAMPBELL
Coppins Crossing
Road
Crossing
Molonglo
Burley
Hospital
Griffin
RUSSELL
MT PLEASANT
DUNTROON
Parkway
Lake
Government House
PARKES
Coppins
YARRALUMLA
CAPITAL HILL
BARTON
River
FORREST
DEAKIN
KINGSTON
Railway Station
GRIFFITH
FYSHWICK
CURTIN
RED HILL
Canberra
HUGHES
NARRABUNDAH
DUFFY
HOLDER
RED HILL
WESTON
LYONS
WODEN
GARRAN
SYMONSTON
WESTON CREEK
RIVETT
PHILLIP
Hospital
Drive
Jerrabomberra
STIRLING
Hindmarsh
O'MALLEY
MT MUGGA
WARAMANGA
CHIFLEY
CHAPMAN
Tuggeranong
MAWSON
FISHER
PEARCE
MT TAYLOR
TORRENS
Avenue
FARRER
KAMBAH
MT WANNIASSA
LOCATION OF INVESTIGATION
WANNIASSA
Highway
NSW
Murrumbidgee
Tuggeranong
MONASH
GOWRIE
PEMBERTON HILL
Pine Island
Creek
Monaro
TUGGERANONG
WANNIASSA RESERVOIR No.2
LOCALITY MAP
River
0
1
2
3
4
5 km
Road
TUGGERANONG HILL
Record No. 1977/37
Point Hut
I55/B5-363A

2. GEOLOGY

The site lies in a region of Upper Silurian acid volcanics. Gold-smith (1976) in his General Geology map of Tuggeranong shows a northwest-striking fault crossing the site, with a change in rock type from rhyodacite and dacitic tuff to rhyolite (Tuggeranong tuff) occurring in the northeast corner of the site area.

The surface geology in the vicinity was mapped by Wilson (Wilson & Hill, 1977) who confirmed the presence of a major fault zone, describing it, where exposed in a cut to the south of the reservoir site, as being about 15 m wide and consisting of closely jointed and weathered rock. On the site plan (Plate 2) the fault zone is inferred to pass approximately below Pegs 1 and 2. Between these pegs, the few boulders that outcrop on the surface here show quartz and epidote veining.

On the higher ground immediately to the south, moderately to slightly weathered rhyodacite outcrops are present; the actual site area is, however, almost devoid of surface rock, the cover consisting of soil, sandy clay, and colluvium. Of all the hand-augering done in the area (for the seismic refraction work and vibration tests) the maximum depth of penetration obtained was about 0.7 m.

3. SEISMIC REFRACTION INVESTIGATION

Two traverses of seismic refraction work were considered adequate to provide sufficient sub-surface information on the reservoir site. These are shown in Plate 2, with Traverse A intersecting the centre points (C1 and C2) of the proposed reservoirs, and Traverse B running along the line of deepest cut. This involved the shooting of four seismic spreads, each 44 m long and 2 m geophone spacing, making the total length of traverse 176 m.

The field work was carried out with BMR's truck-mounted 24-channel SIE (PSU-19 amplifiers and PRO-11 oscillograph) refraction equipment using 8 Hz GSC-20D geophones. A.N. Gelignite "60" (maximum charge 0.30 kg) with instantaneous electric detonators served as the seismic source. Shots were fired between geophones 12 and 13, 1 m and 45 m off the ends of each spread. Reciprocal geophones were used in conjunction with the long shots, channel 24 being reserved for the recording of reciprocal times.

For the computations, near-horizontal layering of the seismic refractors beneath the shot points was assumed; the seismic velocities being determined from plotted time-distance curves, while depths to the refractors were computed according to the formulae derived by Nettleton (1940). Depths below geophone positions to bedrock (here defined as the deepest refractor mean observed reciprocal times (Hawkins, 1961). The final seismic cross-sections of Traverse A and B are shown in Plate 3.

Based on the surficial evidence and experience in areas of similar geology in the A.C.T., the following interpretation of the various seismic velocity layers is presented:

360-620 m/s	Soil, clay, colluvium, or extremely weathered bedrock
1100-1260 m/s	Highly weathered bedrock
1800-2700 m/s	Moderately weathered bedrock
3100-4450 m/s	Slightly weathered to fresh bedrock

The lower bedrock velocities recorded along the western sections of Traverses A and B can be attributed to greater jointing and weathering along the mapped geological fault.

The results indicate that only about the top metre of material can be readily excavated by mechanical means. Because the rock is typically massive and homogenous, ripping is likely to be unsuccessful except where the rock has been highly weathered, or weakened by joints and weathering as may be the case in the fault zone. Material with seismic velocity to 1200 m/s can be considered rippable (Caterpillar Tractor Co., 1966). Therefore it should be possible to excavate a further one metre of material near Peg 1 by this method; the 1260 m/s material around Pegs 5 and C2 would be marginal as regards rippability. Below the near-surface materials mentioned, drilling and blasting will be required to excavate to the proposed floor level of 673.5 m. It is estimated that about 7400 cubic metres of rock will require breaking up by blasting.

4. MEASUREMENTS OF BLAST-INDUCED VIBRATIONS AT KARRALIKA HOMESTEAD

As indicated by the seismic refraction investigation, excavation for the reservoirs is expected to involve a substantial amount of blasting. To estimate the size of explosive charges that could be tolerated without causing damage to the nearby Karralika homestead a series of vibration tests were conducted.

Basically the tests consisted of the firing of explosive charges at a number of locations (Pegs 2, 5, 6, C2 and 3) on the site and recording the subsequent ground vibrations at the homestead (Sites 1 and 2). Plate 2 shows the layout. At each of the test shot locations a 5 cm diameter hole was hand-augered to refusal (0.4 to 0.7 m depth) and loaded with A.N. Gelignite "60" fitted with an instantaneous detonator. Tamping of the hole was done with a compacted soil and water mixture. After each firing a fresh hole was augered close to, but outside the zone of soil disturbance of the previous shot, and loaded with a different-sized charge. Generally charges of ¼, ½, 1 and 2 (25 mm x 200 mm) sticks were detonated at each location. Recording of the blast vibrations was by Sprengnether VS-1200 Engineering Seismograph used in the particle velocity mode, with the seismometer at the homestead buried flush with the soil surface and directed towards the reservoir site.

The results of the measurements are set out in Table 1, and illustrated in Plate 2 as a log-log plot of maximum resultant particle velocity (Av) against W/d^2 (where W = weight of explosive, d = shot to seismometer distance).

Attewell and others (1965) relate these quantities in the form $Av = K (W/d^2)^n$, where K (site factor) and n are constants.

From the plot it is immediately apparent that compared with Site 1, Site 2 is appreciably more vibration-sensitive to blasting. The results of shots at Peg C1 and 3 are in approximate agreement (the 0.30 kg explosion at Peg 3 produced a significant air blast - this loss of energy caused the observed decreased primary ground vibration. Thus for the test locations selected, the worst case (maximum amplitude of particle velocity) is represented by the expression

$$Av = 570 \ (W/d^2)^{1.0} \qquad (1)$$

where Av, W and d are in units of cm/s, kg and m respectively.

The Standards Association of Australia (SAA, 1967) recommends that in built-up areas Av caused by blasting should not exceed 1.9 cm/s if possible damage is to be avoided. Thus, by using this figure and taking equation (1) as being applicable over the whole reservoir site, and substituting d = 50 m (which is the closest distance to the homestead that blasting appears necessary), a value of 8.3 kg is obtained for W. For the most remote part of the site d = 110 m, for which W $\doteqdot$ 40 kg. Therefore to remain below the threshold of vibration damage to Karralika homestead, explosive changes used on the reservoir site should not exceed about 8 to 40 kg (depending on distance) of A.N. Gelignite "60" or its equivalent.

These values should serve as a guide only, the reasons for this being:

(a) it is possible that higher vibration levels could result from different shot - homestead site combinations not covered by the tests.

(b) the test shot conditions may not be truly representative of the hard-rock blasting that will be finally carried out. (Some blow-out of soil, particularly with the larger charges, did occur in the tests. This loss of energy, due to a certain degree of unconfinement, would be compensated to some extent by the fact explosions in unconsolidated or semi-unconsolidated materials tend to generate ground vibrations of greater magnitude).

The upper limit range of safe charge sizes quoted above apply per delay. From the vibration records of the tests, it can be seen that the effective length of the wave-train is about 200 ms. Therefore in cases where the total explosive charge is such as to produce possible damage, it should be divided into smaller charges each of acceptable size with delays of at least 200 ms between them.

The possibility of damage resulting from fly rock and air blast should be mentioned. The former can be reduced by delay detonation and blasting mats, if found troublesome, while the latter is likely to be significant only in unconfined shots. Window panes, which are most susceptible to air blast, commonly break under a peak pressure of 1 psi (6.89 kPa). The weight (kg) of unconfined T.N.T. to produce this at distance d (m)

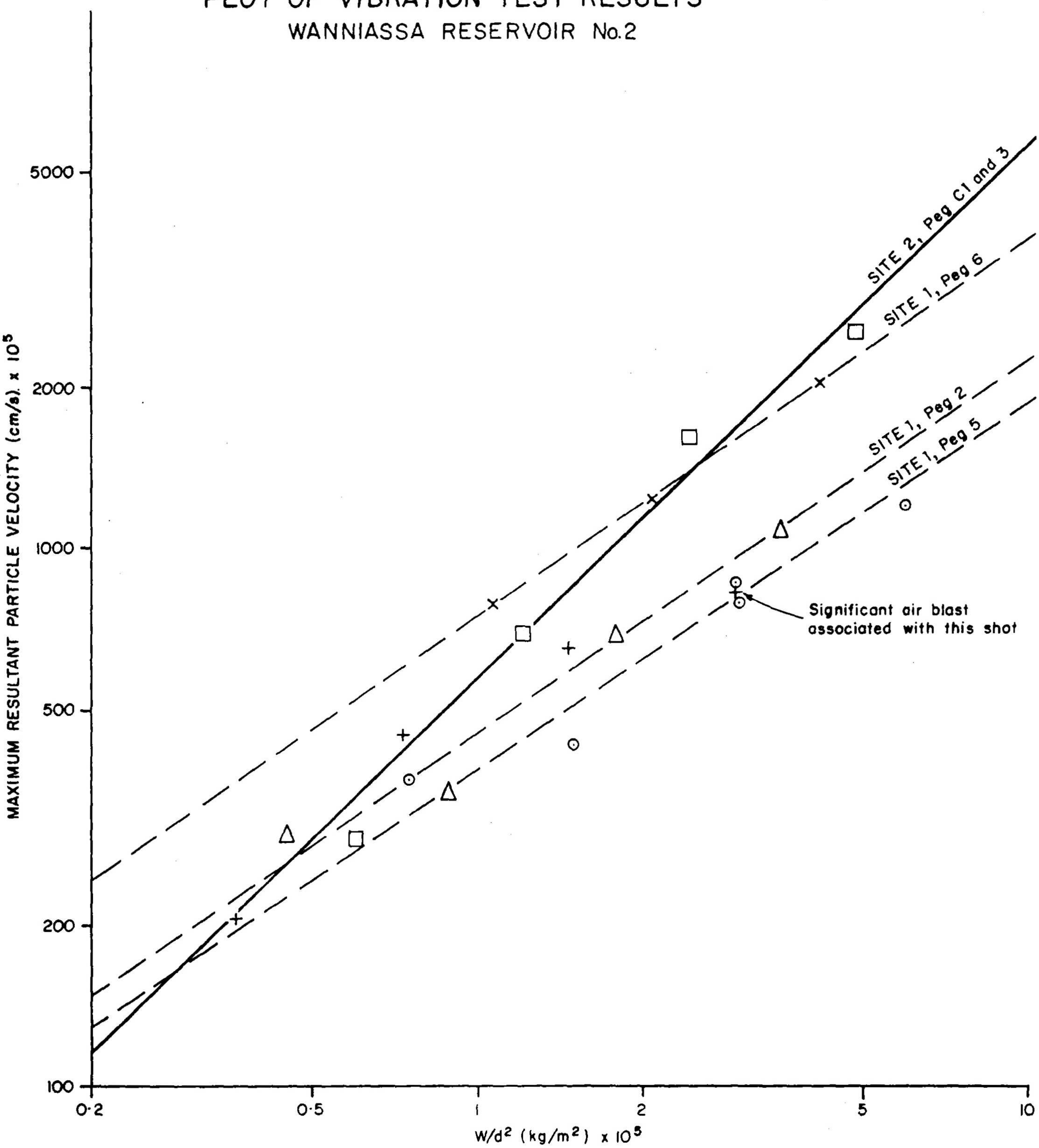
$= 2.60 \times 10^{-4} d^3$

$= 32.5$ kg at 50 m

(ref. Encyclopedia of Science and Technology, 1960)

This is several times greater than the amount of explosive which can be safely used to avoid damage by ground vibration. Therefore air blast effects (apart from psychological) are not likely to be a problem if charges are kept within the limits previously specified.

PLOT OF VIBRATION TEST RESULTS
WANNIASSA RESERVOIR No.2



KEY

Symbol	Source Location	Seismometer Location
△	Peg 2	SITE 1
⊙	" 5	" "
×	" 6	" "
□	" C1	SITE 2
+	" 3	" "

5. CONCLUSIONS

The material on which the reservoirs are to be founded appears to be of adequate strength and soundness for such structures, consisting, at floor level, mainly of moderately weathered bedrock south of the centre line (i.e. the line through Pegs C1 and C2) and moderately to highly weathered bedrock north of this line. Excavation will entail an appreciable amount of drilling and blasting as it is expected that only the first metre or so of material will readily lend itself to removal by mechanical equipment.

The results of the blast-induced vibration tests indicate that the total weight of explosive detonated at any one time on the site should not exceed 8 to 40 kg (depending on distance) of A.N. Gelignite "60" or equivalent to avoid possible damage to Karralika homestead. It would, however, be permissible to fire a number of charges, each within the above limits, by using delays of at least 200 ms between successive blasts.

It is suggested, if blasting on the reservoir site is to involve charge sizes approaching those mentioned in this report as possibly causing damage, that the initial blasts be monitored at the Karralika homestead to assess their affect on potential damage.

TABLE 1

VIBRATION TEST RESULTS

SEISMOMETER LOCATION	TEST SHOT LOCATION	SEPARATION d (m)	GELIGNITE CHARGE (kg)	W/d^2 $(kg/m^2) \times 10^5$	DEPTH OF SHOT (m)	MAXIMUM TRANSVERSE PARTICLE VELOCITY $(cm/s) \times 10^5$	MAXIMUM VERTICAL PARTICLE VELOCITY $(cm/s) \times 10^5$	MAXIMUM LONGITUDINAL PARTICLE VELOCITY $(cm/s) \times 10^5$	MAXIMUM RESULTANT PARTICLE VELOCITY $(cm/s) \times 10^5$	DOMINANT FREQUENCY (Hz)
SITE 1	PEG 2	92	0.038	0.45	0.55	160	105	220	290	56
			0.075	0.89	0.75	160	110	290	350	56
			0.15	1.77	0.5	360	250	530	690	54
			0.30	3.54	0.5	608	332	810	1070	56
SITE 1	PEG 5	71	0.038	0.75	0.4	170	190	260	370	52
			0.075	1.49	0.45	220	230	290	430	56
			0.15	2.98	0.45	500	410	580	870	56
			0.15*	2.98	0.4	480	440	670	800	50
			0.30	5.95	0.5	740	550	770	1200	56
SITE 1	PEG 6	60	0.038	1.06	0.6	640	330	340	800	39
			0.075	2.08	0.6	990	520	530	1240	35
			0.15	4.17	0.65	1650	910	780	2040	35
SITE 2	PEG C1	79	0.038	0.60	0.6	140	120	220	290	48
			0.075	1.20	0.7	480	230	440	690	47
			0.15	2.40	0.7	1120	460	1080	1620	47
			0.30	4.81	0.7	1900	670	1540	2540	45
SITE 2	PEG 3	101.5	0.038	0.36	0.4	140	100	110	200	48
			0.075	0.73	0.5	250	190	330	450	47
			0.15	1.46	0.5	370	310	430	650	47
			0.33**	2.91	0.4	520	360	540	840	47

* SQUARE (0.5 m SIDE) SHOT PATTERN - 0.038 kg OF GELIGNITE IN EACH HOLE

** SIGNIFICANT AIR BLAST ASSOCIATED WITH THIS SHOT

6. REFERENCES

ATTEWELL, P.B., FARMER, I.W., & HASLAM, D., 1965 - Prediction of ground vibration parameters from major quarry blasts. Mining and Minerals Engineering, Dec, 1965, 621-6.

CATERPILLAR TRACTOR COMPANY, 1966 - HANDBOOK OF RIPPING: A GUIDE TO GREATER PROFITS, 3rd edition. Peoria, Illinois, Caterpillar Tractor Company

ENCYCLOPEDIA OF SCIENCE AND TECHNOLOGY, Vol. 5, 1960. McGraw-Hill, New York, 147-8.

GOLDSMITH, R. C. M., 1976 - Murrumbidgee Park Drive, Tuggeranong, A.C.T. geological investigation. Bureau of Mineral Resources, Australia, Record, 1976/106 (unpublished).

HAWKINS, L.V., 1961 - The reciprocal method of routine shallow seismic refraction investigations. Geophysics, 26 (6), 806-19.

NETTLETON, L.L., 1940 - GEOPHYSICAL PROSPECTING FOR OIL. McGraw-Hill, New York, 251-5.

STANDARDS ASSOCIATION OF AUSTRALIA, 1967 - SAA EXPLOSIVES CODE. Australian Standard CA23-1967. SAA, Sydney.

WILSON, E.G., & HILL, P.J., 1977 - Wanniassa Reservoir No. 2. Bureau of Mineral Resources, Australia, File 1973/1168 (unpublished).

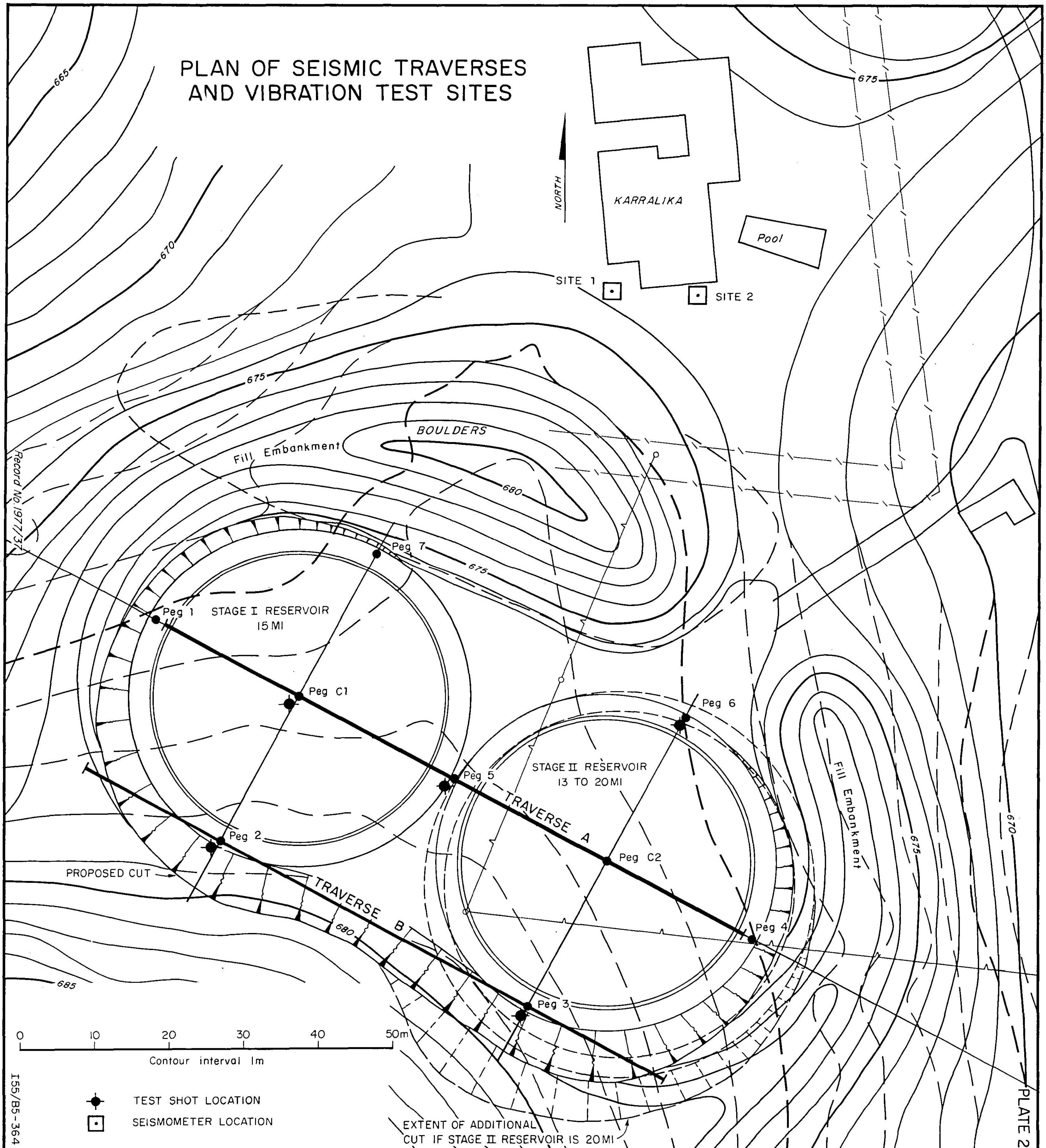
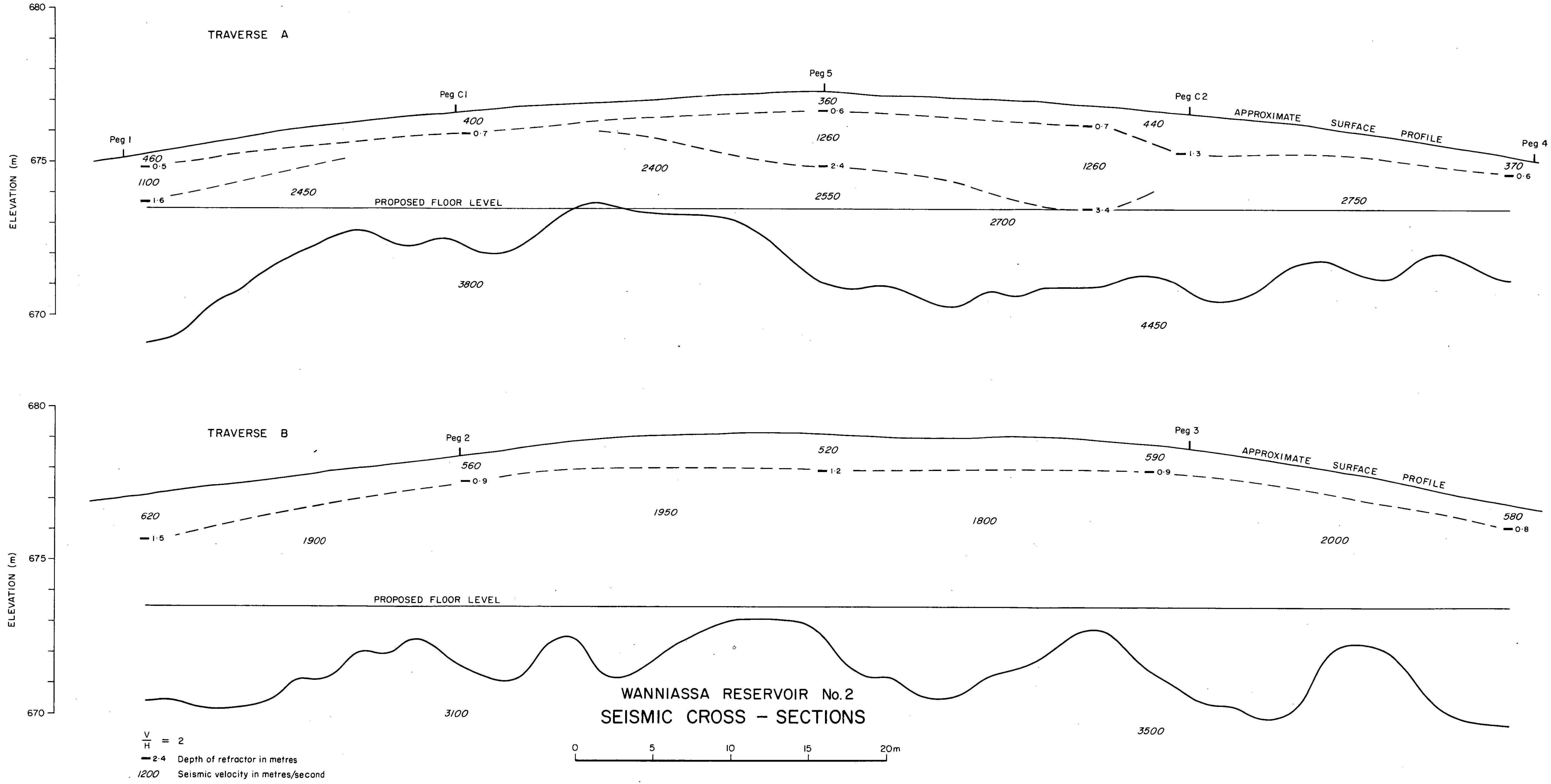

PLAN OF SEISMIC TRAVERSES
AND VIBRATION TEST SITES
NORTH
KARRALIKA
Pool
SITE 1
SITE 2
BOULDERS
Fill Embankment
STAGE I RESERVOIR
15 Ml
STAGE II RESERVOIR
13 TO 20 Ml
Peg 1
Peg 2
Peg 3
Peg 4
Peg 5
Peg 6
Peg 7
Peg C1
Peg C2
TRAVERSE A
TRAVERSE B
PROPOSED CUT
Fill Embankment
665
670
675
680
685
0 10 20 30 40 50m
Contour interval 1m
TEST SHOT LOCATION
SEISMOMETER LOCATION
EXTENT OF ADDITIONAL
CUT IF STAGE II RESERVOIR IS 20 Ml
Record No. 1977/37
I55/B5-364
PLATE 2

PLATE 3



WANNIASSA RESERVOIR No. 2
SEISMIC CROSS - SECTIONS