COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1968 / 86

Lake Buffalo Dam Site Geophysical Survey,

Victoria 1966

by

P.E. Mann and M. Wainwright

Record No. 1968 / 86

Lake Buffalo Dam Site Geophysical Survey,

Victoria 1966

by

P.E. Mann and M. Wainwright

CONTENTS

ILLUSTRATIONS

SUMMARY

A seismic refraction survey was made at a dam site on the Buffalo River, 12 miles upstream from Myrtleford, at the request of the State Rivers and Water Supply Commission of Victoria.

The unweathered bedrock is too deep to be used as a foundation rock but a rock with a seismic velocity of about 7000 ft/s, corresponding to a compressive strength of about 13,000 lb/in^2 and a Young's modulus of about 10^6 lb/in^2, is probably sufficiently high for an earth dam.

A contour plan of the 7000-ft/s rock surface indicates the presence of an older and a younger river valley, separated by an island or river terrace.

The survey indicates that the best position for a new dam is upstream from the 800-ft contour, where the present dam is located.

1. INTRODUCTION

The State Rivers and Water Supply Commission of Victoria proposes to enlarge the existing dam on the Buffalo River, about twelve miles upstream from Myrtleford in Victoria. The dam is to provide more water for the irrigation of the rapidly increasing acreage of crops in the Ovens and Murray valleys.

The centre line of the proposed dam is about 500 feet downstream of the existing dam; the approximate co-ordinates of the site are 425623 on the Wangaratta sheet of the Australia 1:250,000 map series.

In response to an application from the Commission, the Bureau of Mineral Resources, Geology and Geophysics made a geophysical investigation of the site to determine the depth and nature of the bedrock. Approximately 40,000 feet of traverse was surveyed with the seismic refraction method and 5000 ft with the resistivity method. The survey was carried out between 2nd March and 16th April 1966 by a party consisting of P.E. Mann, party leader and geophysicist, and D. Tarlinton, field assistant. L. Kevi and M. Wainwright, BMR geophysicists, were attached to the party for part of the survey. The Commission provided four field assistants and ancillary supplies and also surveyed the traverse lines.

The term 'unweathered bedrock' used in this record refers to the deepest refractor with the highest measured seismic velocity, which ranged between 13,000 and 17,000 ft/s. The Commission plans to construct an earth dam, for which a rock of considerably lower seismic velocity is acceptable as foundation.

2. GEOLOGY

The general geology of the dam site is given by Cormack (1963). Additional geological information is given by Currey (1964). Geological logs of drill holes, trenches, benches, auger holes, and shafts are available from investigations made for the existing dam, and other drilling carried out after the seismic survey (Jacobson, 1966).

At the dam site the left bank is very steep; the right bank consists of gradual slopes, possibly old river terraces. The bedrock consists of partly weathered interbedded quartzites, hornfels, and slates, metamorphosed sandstones, siltstones, and mudstones of Ordovician age. The river bed is in hard, fresh metamorphics with a strike of about 330° magnetic and a dip of 60° to 80° to the west. Three principal joint systems exist of which two are of major importance: one parallel to the bedding strike but with a small upstream dip; the second one with a strike of about 40° and approximately a vertical dip has a marked effect on the course of the Buffalo River. Several small shear zones have been mapped.

Drilling results suggest a buried river channel on the right bank. In recent time this channel was filled and covered with gravel, sand, and clay. Later the river degraded its old bed by vertical and lateral erosion, successively cutting lower terraces. Today the river flows against the western side of the valley with its present bed about 30 feet below the older bed.

3. METHODS AND EQUIPMENT

The seismic refraction method has been described in a previous report to the Commission (Sedmik, 1961).

A 24-channel refraction seismograph manufactured by South-Western Industrial Electronics Co. was used with Technical Instruments Co. geophones with a natural frequency of 20 c/s. To determine the transverse velocity, three-component Hall-Sears geophones, model HS-1-LP 3D with a natural frequency of 14 c/s, and a miniature three-component Hall-Sears geophone, model HS-1-LPJ 3D with a natural frequency of 7½ c/s, were used. The following types of spread were used:

(1) Weathering spreads: to obtain the thickness and seismic velocity of the near-surface layers. Geophones were spaced 10 feet apart and shots were fired at 10, 50, and 200 ft in line at each end of the spread.

(2) Normal spreads: Geophones were spaced 50 ft apart and shots were fired at 50 and 200 ft in line from each end of the spread. A shot was also fired in the centre of the spread wherever practicable. On some traverses additional shots at 600 ft were detonated to record the highest velocity refractor.

(3) To determine the elastic constants in situ, a spread 150 ft long consisting of vertical and three-component geophones, spaced 25 feet apart, was laid out on the excavated surface of the secondary spillway of the existing dam. Shot distances of 25, 100, and 350 ft were used.

Some laboratory measurements were made on drill hole cores. The bulk velocity was determined on cores in the wet and dry state. The bar velocity of the cylindrical specimens could not be measured because they were too short. The equipment and the measuring technique has been described by Kevi (1966).

Resistivity traversing with an electrode spacing of 100 feet, used on Traverses C and D, did not give any significant results, and the resistivity profiles are not presented in this Record.

4. RESULTS

Plate 1 shows the locality and the layout of the seismic traverses.

Seismic velocities

Seismic velocities are a good measure for rock quality or rock strength (Wiebenga and Manganwidjoyo, 1960).

The following table gives an interpretation in geological terms, of the seismic refractors recorded during the survey.

Velocity (ft/s)	Rock type
1000	Soil
2000 to 3000	Clayey material. This could be alluvial clay or clay as a final stage of weathering on the hill side.
3100 to 5600	Alluvium: the lower the velocity the higher the clay content. Alluvial sands and gravels saturated with water have a velocity of 5000 ± 600 ft/s.
3800 to 5900	Very weathered, decomposed bedrock or alluvial hillside material.
6000 to 11000	Jointed weathered bedrock to slightly weathered bedrock. Weathering starts on the joints.
13000 to 17000	Unweathered, jointed to unjointed rock.

It may be observed that the geological interpretation of seismic velocities can be quite ambiguous, e.g. a 5000 ft/s velocity could mean:

(a) alluvial sand or gravel deposit, water saturated.

(b) weathered, decomposed bedrock underneath sediments.

(c) weathered, washed out, alluvial hillside material.

The above ambiguities also make the checking of the seismic results against drill hole information of little use. For instance, the place in a drill hole where sedimentary sands or gravels change into weathered bedrock may show up from hand samples, but it may not be possible to discriminate between the rock types seismically. Two examples may illustrate the point:

At drill hole PD 100, on Traverse D between intersections with M and N, the drilling shows gravel to 64 ft and decomposed bedrock to 81 ft (bottom). The seismic work shows 1000 ft/s to 6 ft, 3500 ft/s to 30 ft, 5500 ft/s to 103 ft, 10,000 ft/s to 240 ft, and 14,000 ft/s below this.

At drill hole PD 110, on Traverse O between intersections with D and E, the drilling shows hill wash, sandy clay loam to 4 ft, soft decomposed clayey rock to 29 ft, and soft to hard weathered rock to 36 ft. The seismic work shows 1000 ft/s to 7 ft, 3500 ft/s to 30 ft, 5400 ft/s to 90 ft, 8500 ft/s to 171 ft, and 15,000 ft/s below this.

Plates 2 to 6 give the seismic cross-sections with some of the relevant drill hole information. The sections are self-explanatory.

Contour plans

Plate 7 shows a contour plan of the top of the weathered bedrock. The deepest area, below the 700-ft contour line, apparently underlies the old river course. The plan indicates the maximum limit of excavation required for a dam foundation.

For an earth dam, a bedrock with a seismic velocity of about 7000 ft/s may be sufficient. Using an empirical formula (Wiebenga and Manganwidjoyo, 1960), the strength of a 7000-ft/s rock in terms of a standard compression test is about 13,000 $\pm$ 35% lb/in^2. Plate 8 shows the contours of formations with a seismic velocity of greater than 6500 ft/s, say about 7000 ft/s. The control points for this contour plan were located at either end of the seismic spreads, about 500 ft apart along the traverses. On the cross-sections (Plates 2 to 6) this contoured surface is indicated by a dashed line.

Following the 800-ft contour in Plate 8, it can be observed that the elongated depression near the intersection of Traverses K and C co-incides with the present course of the Buffalo River, but the depressions near the intersections of Traverses A and N and Traverses D and N co-incide with older river courses. The subsurface island near the intersection of Traverses A and L possibly represents a river terrace.

Young's Modulus

Young's modulus may be estimated from an empirical formula (Wiebenga, 1958):

$$E = 68.9V^{2.34}$$

where E is Young Modulus in $dynes/cm^2$ and V the longitudinal seismic velocity in kilo-feet/s.
For V = 7000 ft/s, $E = 6.3 \times 10^{10}$ $dynes/cm^2$ or $E = 0.9 \times 10^6$ lb/in^2.

Young's Modulus and Poisson's ratio were also determined from longitudinal and vertically polarised transverse wave velocities on a 150-ft long spread near station A 65, close to the spillway:

Longitudinal velocity 7200 ft/s
Ratio longitudinal to traverse velocity 1.92
Poison's ratio 0.31
Mean density from cores 2.25 g/cm^3
Young's modulus 1.1×10^6 lb/in^2

Summarising, Young's modulus determined with dynamic methods is of the order of 10^6 lb/in^2.

Accuracy of seismic depth measurements

An estimate of the accuracy of seismic depth measurements is not easily made because very little relevant drill hole information can be used. In the present survey the difference between two depth estimates for the deepest refractor at the intersection of two traverses gave some information. Thirty seven pairs of values were obtained. The greatest difference from the mean was found to be 20%. The standard deviation for the percentage difference from the mean was 11%. These figures agree with the usual accuracy of a seismic engineering survey of this type.

5. CONCLUSION

The results of the survey show that the depth of unweathered bedrock is up to 380 ft below ground level (near Station 00, Traverse 0), suggesting that the use of unweathered bedrock is impractical. However, a rock with a seismic velocity of about 7000 ft/s is probably sufficiently strong as a foundation rock for an earth dam. Plate 8 shows that the best location for such a dam is at the place where the present dam is located, upstream from the 800-ft contour line.

6. REFERENCES

CORMACK, G.	1963	Buffalo Dam regional geology, dam geology, geomorphology. Progress report No. 1. State Rivers and Water Supply Commission.
CURREY, D.T.	1964	Buffalo River, geology of dam site. Memorandum Senior Designing Engineer. State Rivers and Water Supply Commission.
JACOBSON, G.	1966	Personal Communication.
KEVI, L.	1966	Nillahcootie dam site geophysical survey, Victoria 1965. Bur Min. Resour. Aust. Rec. 1966/39.
SEDMIK, E.C.E.	1961	Buffalo River No. 1 dam site geophysical survey, Victoria 1961. Bur. Min. Resour. Aust. Rec. 1961/136.
WIEBENGA, W.A.	1958	Exploration Geophysics applied to the Dolerites of Tasmania. Dolerite Symposium, Uni. of Tasmania.
WIEBENGA, W.A. and MANGANWIDJOYO,	1960	Some correlations between rock parameters, derived from Wuerker's "Annotated tables of strength and elastic properties, 1956". A.I.M.E. Trans. 217.

APPENDIX

Seismic velocities of core samples

Waxed and unwaxed core samples from eight drill holes were received for velocity tests in the laboratory. Waxed cores were from PD 100, PD 101, and PD 103. Bulk velocities were measured but it was not possible to measure the bar velocity because the cores were too short or had been broken up, probably during transport. Because the poor condition of the cores and the inconclusive nature of the results, they are included only for completeness. The results are given in the following table:

Drill hole	Depth (feet)	Description	Density (gm/cm^3)		Bulk velocity ($ft/s \times 10^3$)	
			Dry	Wet	Dry	Wet
D31	20.0	Hard weathered siltstone	2.41	2.48	13.9	12.9
D31	23.7	Hard weathered sandstone	2.48	2.58	12.4	12.9
D42	52.0	Hard weathered sandstone	2.14	2.32	6.9	5.8
D42	99.0	Hard weathered sandstone	2.26	2.38	9.8	8.7
D20	67.0	Hard weathered sandstone	2.18	2.37	11.5	9.2
D20	79.0	Hard weathered sandstone	2.28	2.39	9.4	8.3
D57	68.0	Hard weathered siltstone	2.13	2.35	7.9	6.5
D46	80.2	Hard fresh sandstone	2.43	2.43	16.0	16.9
PD100	83.0	Hard weathered mudstone	2.15	2.36	5.2	5.2
PD100	102.0	Hard weathered mudstone	2.04	2.17	11.3	8.5
PD100	116.5	Hard weathered siltstone	2.11	2.33	9.2	8.5
PD100	141.0	Hard fresh sandstone	2.23	2.30	9.9	8.6
PD100	149.0	Hard fresh mudstone	2.22	2.38	5.5	8.3
PD100	151.0	Hard fresh siltstone	2.20	2.33	15.0	8.1
PD101	99.5	Hard weathered sandstone	2.47	2.52	7.2	6.0
PD101	115.0	Hard weathered sandstone	2.15	2.30	6.9	4.5
PD101	127.0	Hard fresh mudstone	2.22	2.28	10.0	9.5
PD103	49.0	Hard weathered mudstone	2.04	2.34	5.6	4.2
PD103	88.0	Hard weathered sandstone	2.52	2.59	6.8	66.1

LAKE BUFFALO DAM SITE, VICTORIA, 1966

LOCALITY MAP AND GEOPHYSICAL TRAVERSES

TO ACCOMPANY RECORD No 1968/86 Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics. J55/B5-34

BUFFALO D., VIC. 1966

TRAVERSES A and C
SEISMIC CROSS-SECTIONS

TO ACCOMPANY RECORD No 1968/86 Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

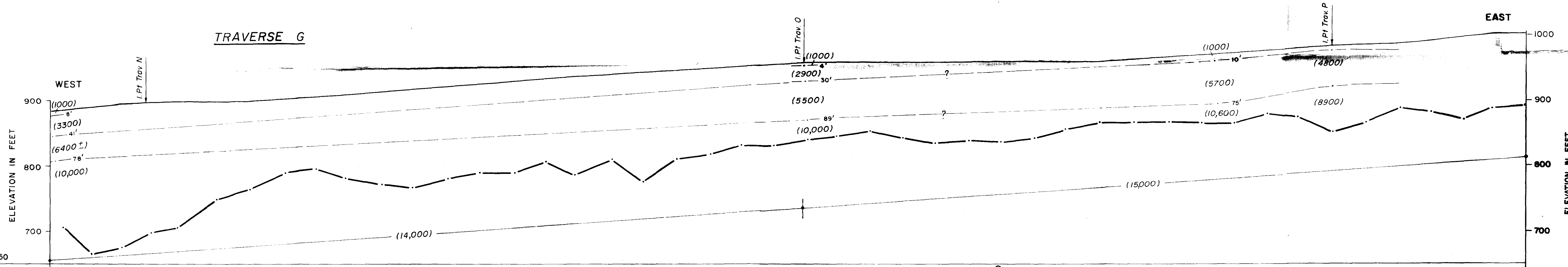
J55/B5-35

TRAVERSES D and E
SEISMIC CROSS-SECTIONS

(BASED ON STATE RIVERS AND WATER SUPPLY COMMISSION PLANS No. 77480)

TO ACCOMPANY RECORD No 1968/86 Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics J 55/B5-36

PLATE 4



STATION NUMBER	STATION ELEVATION (FEET)	DEPTH TO BEDROCK (FEET)
71	885	183
	891	228
	896	222
	899	201
75	900	195
	900	151
	901	139
	903	114
	907	115
80	912	132
	915	146
	919	154
	922	143
	926	138
85	930	143
	935	130
	937	152
	940	130
	943	169
90	945	137
	949	132
	952	120
	966	126
	959	120
95	960	115
	961	108
	961	120
	961	127
	962	124
100	962	127
	962	120
	960	104
	959	96
	962	96
105	967	99
	970	106
	974	110
	976	96
	978	104
110	979	129
	983	118
	989	112
	994	112
	1000	134
115	1003	117
116	1003	111

STATION NUMBER	STATION ELEVATION (FEET)	DEPTH TO BEDROCK (FEET)
71	869	131
	878	139
	880	157
	884	178
75	886	188
	883	191
	887	205
	892	211
	895	166
80	896	170
	898	151
	902	158
	903	137
	908	132
85	914	147
	920	125
	925	125
	929	154
	935	137
90	939	138
	945	135
	951	138
	958	153
	964	140
95	972	143
	979	127
	987	128
	993	130
	999	128
100	1005	141
	1007	132
	1010	159
	1015	185
	1024	207
105	1032	214
	1038	188
	1041	166
	1042	156
	1049	143
110	1057	162
	1062	143
	1061	122
	1058	134
	1059	136
115	1059	149
	1058	150
	1052	145
	1046	131
	1040	123
120	1037	120
	1034	120
	1032	115
	1029	110
	1025	99
125	1021	97
126	1020	108

LEGEND

- LPI — Traverse intersection point
- (5500) — Seismic velocity (ft/s) in formation
- 8' — Depth to formation with different seismic velocity
- —·— Unweathered bedrock boundary

Based on State Rivers and Water Supply Commission Plans 77480

TRAVERSES G and F

SEISMIC CROSS-SECTIONS

FEET

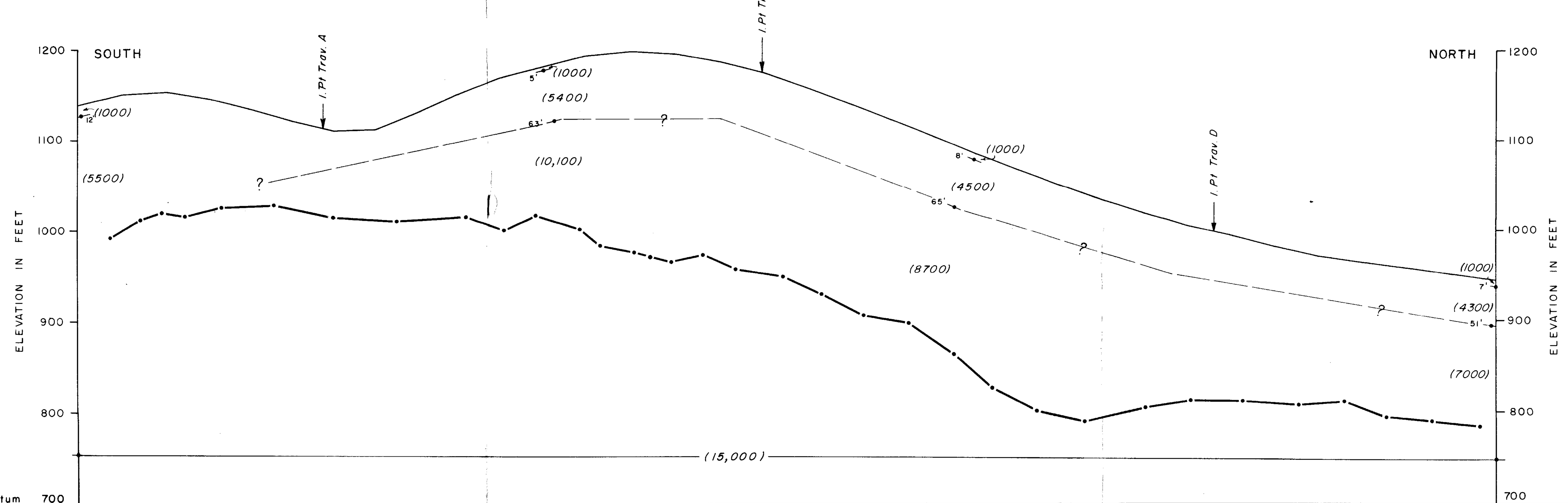
100 0 100 200 300 400

(Horizontal and Vertical)

BUFFALO DAM SITE, VIC. 1966

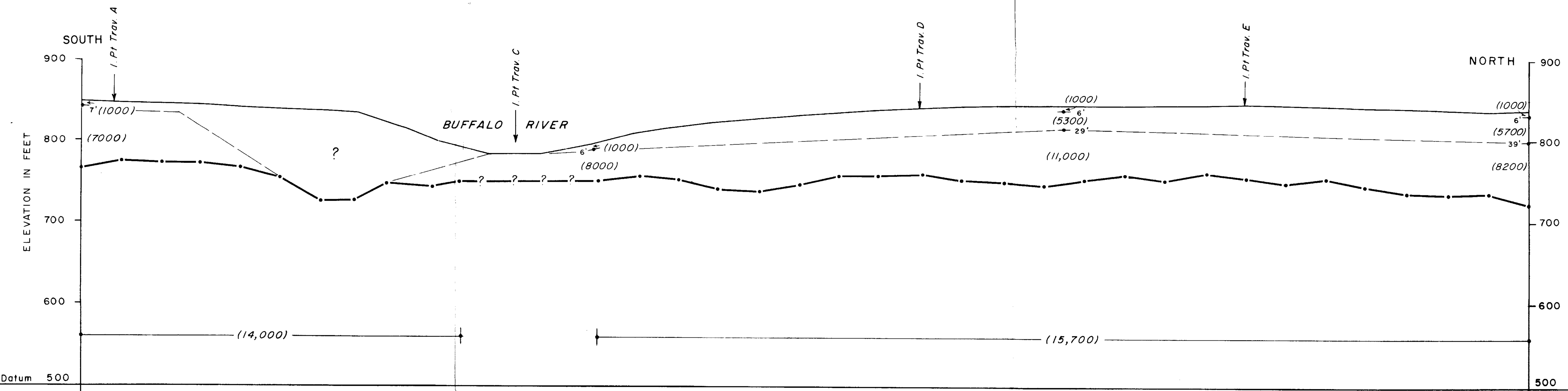
TO ACCOMPANY RECORD No 1968/86 Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics J55/B5-37

TRAVERSE H



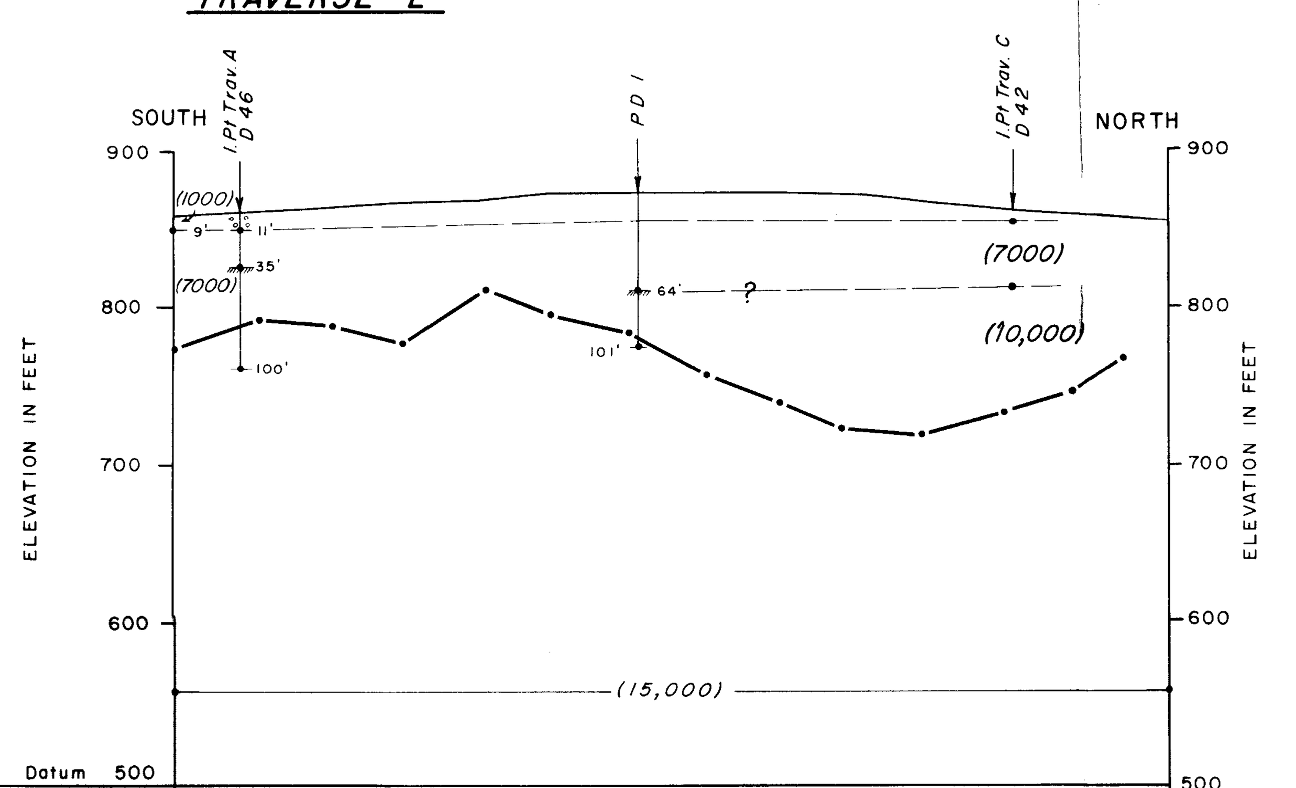
STATION NUMBER	0					5					10					15					20					25					30			33
STATION ELEVATION	1138	1151	1154	1145	1135	1121	1110	1112	1132	1150	1168	1182	1193	1198	1195	1186	1173	1157	1139	1121	1102	1084	1066	1050	1033	1119	1005	993	982	972	965	958	951	945
DEPTH TO BEDROCK	152	142	135	135	115	96	96	105	129	162	158	187	213	224	230	230	214	218	208	211	215	205	217	240	247	242	208	188	176	167	156	168	165	164

TRAVERSE K



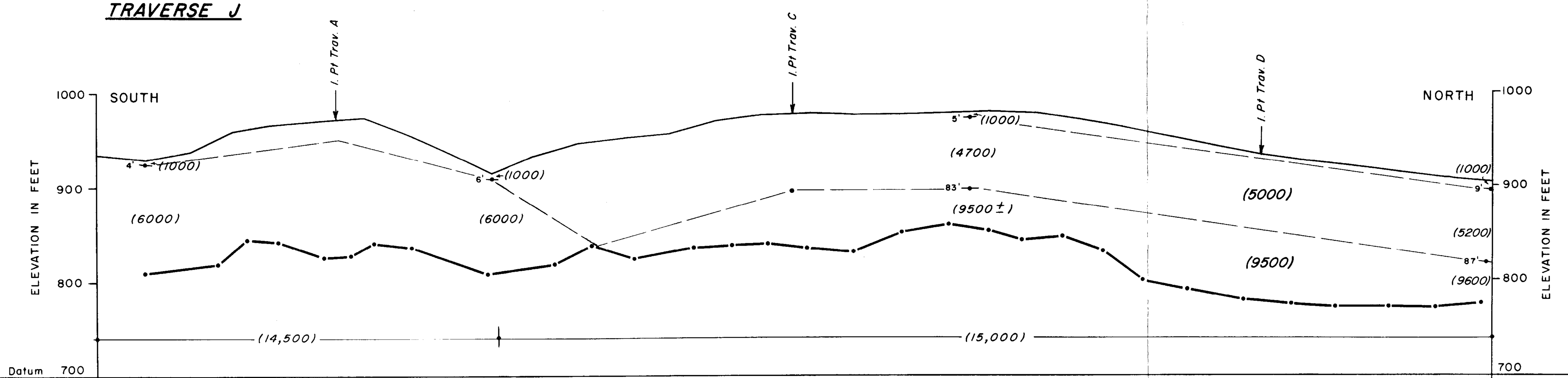
STATION NUMBER	0					5					10					15					20					25					30					35	36
STATION ELEVATION	848	847	846	844	840	838	836	834	814	797	792	782	786	793	806	815	821	825	829	833	836	838	840	841	842	841	841	842	842	843	843	842	841	839	838	837	837
DEPTH TO BEDROCK	83	74	73	73	76	86	112	109	73	56	43			46	54	66	82	89	86	79	82	82	92	96	99	91	85	93	83	91	97	90	99	104	104	102	117

TRAVERSE L



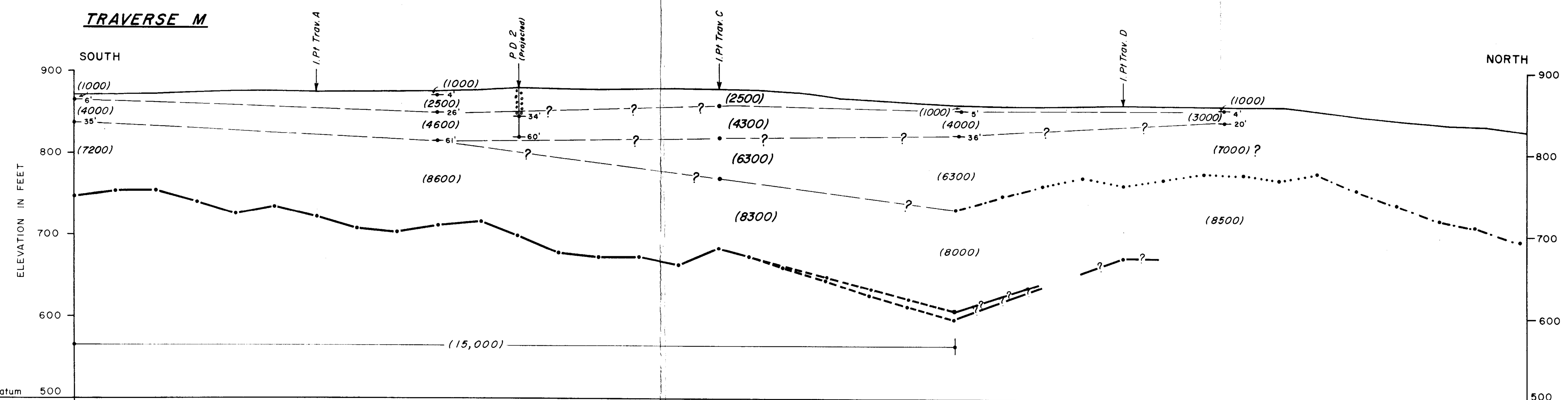
STATION NUMBER	5					10					15			18
STATION ELEVATION	859	862	864	867	868	873	874	874	874	872	867	863	860	855
DEPTH TO BEDROCK	85	70	76	70	58	78	90	118	135	150	147	130	115	91

TRAVERSE J



STATION NUMBER	0					5					10					15					20					25					30	31
STATION ELEVATION	935	929	937	958	967	970	974	953	933	915	933	946	952	956	969	976	977	975	975	977	980	978	970	962	952	942	933	926	921	914	908	903
DEPTH TO BEDROCK		120	125	117	126	146	149	122	109	108	118	110	130	125	133	138	144	146	126	119	127	137	127	134	156	156	156	154	151	144	139	130

TRAVERSE M



STATION NUMBER	0					5					10					15					20					25					30					35	36
STATION ELEVATION	871	871	872	874	876	876	875	875	876	876	877	879	879	878	879	879	879	878	875	868	865	862	859	853	859	859	860	859	859	859	859	853	843	843	838	836	828
DEPTH TO BEDROCK	125	119	119	135	151	143	155	168	174	165	162	182	202	206	208	218	197	206	214	222	232	242	254 (128)	(110)	(99)	(88)	(99) (188)	(91)	(83)	(83)	(91)	(77)	(91)	(105)	(118)	(126)	(136)

LEGENG

I. Pt	Traverse intersection point
(5500)	Seismic velocity (ft/s) in formation
4'	Depth to formation with different seismic velocity
•——•	Unweathered bedrock boundary
•– – –•	Interpolated or extrapolated unweathered bedrock boundary
•·····•	Highest velocity refractor observed above unweathered bedrock
•–·–·–•	Extrapolated boundary of highest velocity refractor observed above unweathered bedrock

TRAVERSES H, J, K, L, and M

SEISMIC CROSS-SECTIONS

FEET

100 0 100 200 300 400 500

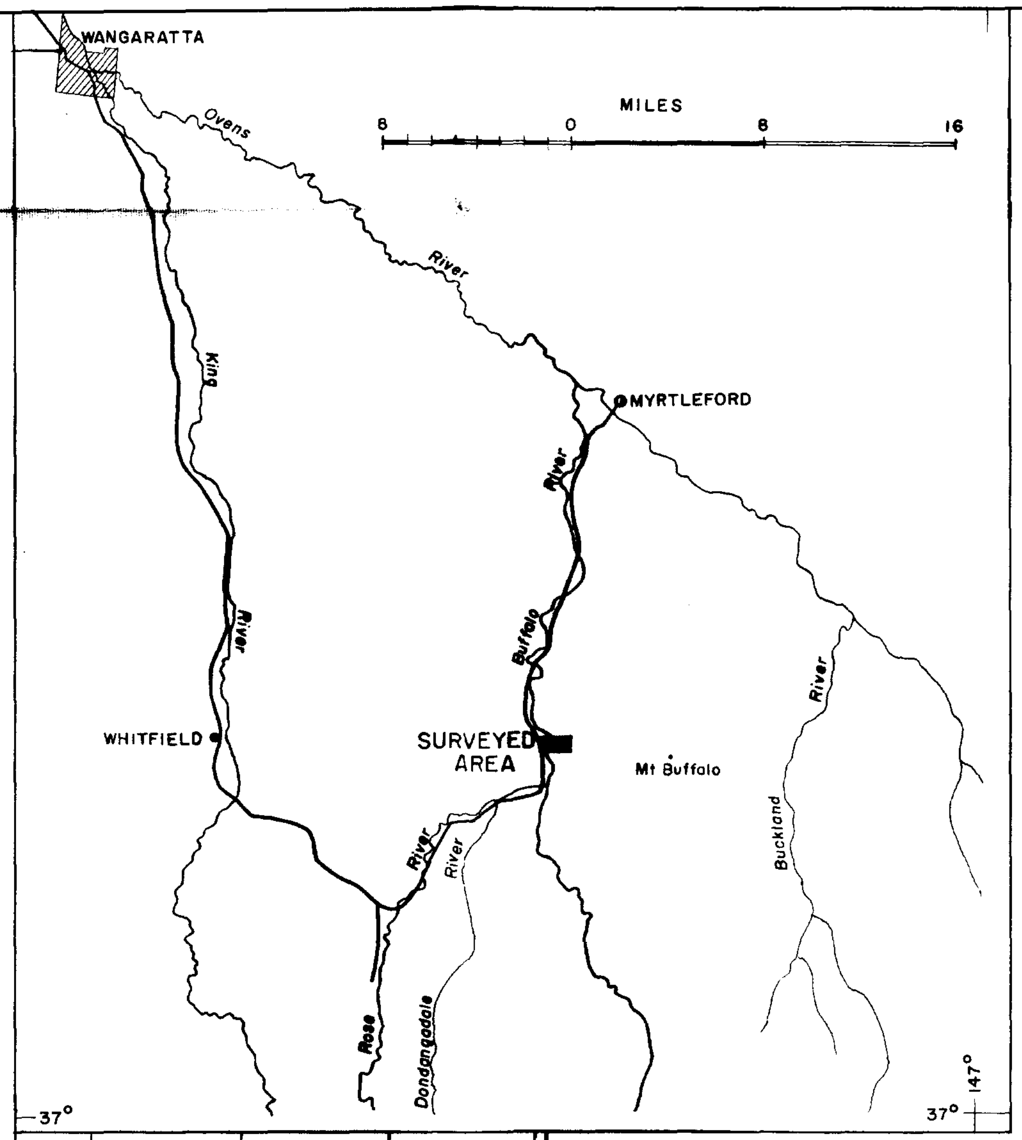
(Horizontal and Vertical)

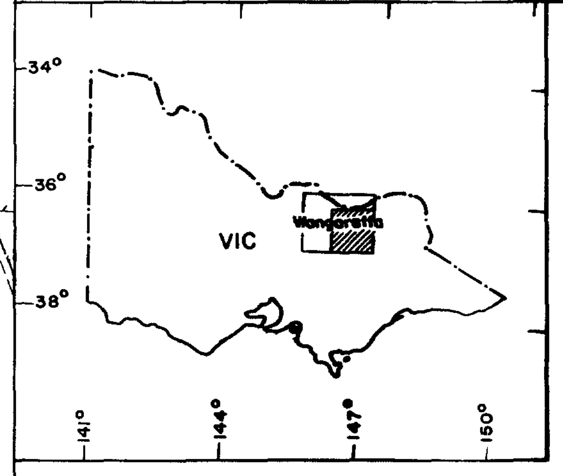
(BASED ON STATE RIVERS AND WATER SUPPLY COMMISSION PLANS No 77480)

TO ACCOMPANY RECORD No 1968/86 *Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.* J 55/B5-38

TRAVERSES N, O, P, and Q
SEISMIC CROSS-SECTIONS


PLATE 7
LEGEND
Seismic traverse with station number
D21 Diamond-drill hole
PD103 Percussion and diamond-drill
Fence
Existing building
Approximate boundary of proposed wall
Unweathered bedrock contour in feet above sea level
Possible drainage path
LOCATION OF TRAVERSES
SHOWING BEDROCK CONTOURS
BASED ON SEISMIC RESULTS
(Contour interval 50 feet)
FEET
REFERENCE TO AUSTRALIA STANDARD
1:250,000 MAP SERIES: WANGARATTA
MILES
WANGARATTA
MYRTLEFORD
WHITFIELD
SURVEYED AREA
Mt Buffalo
VIC
TRAVERSE A
TRAVERSE C
TRAVERSE D
TRAVERSE E
TRAVERSE F
TRAVERSE G
TRAVERSE H
TRAVERSE J
TRAVERSE K
TRAVERSE L
TRAVERSE M
TRAVERSE N
TRAVERSE O
TRAVERSE P
TRAVERSE Q
BUFFALO RIVER
LAKE BUFFALO RESERVOIR
EXISTING DAM
EXISTING ROAD
EXISTING SPILLWAY
TRACK
TO ACCOMPANY RECORD No 1968/86 Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics. J55/B5-40





REFERENCE TO AUSTRALIA STANDARD
1:250,000 MAP SERIES: WANGARATTA

LEGEND

- F71 — Seismic traverse with station number
- • D21 — Diamond – drill hole
- • PD 103 — Percussion and diamond- drill hole
- Fence
- Existing building
- Approximate boundary of proposed wall
- 850 — Formation contour in feet above sea level
- Below 750 feet
- Below 800 feet

CONTOURS OF FORMATIONS WITH SEISMIC VELOCITIES GREATER THAN 6500 FT/S

FEET
300 0 300 600 900 1200

(Contour interval 50 feet)