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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

RECORDS

1957, No.23

SEISMIC REFRACTION SURVEY OF THE LATROBE RIVER DAM SITE, YALLOURN, VICTORIA

by

W.A. Wiebenga, E.J. Polak

and L.V. Hawkins

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CONTENTS

ILLUSTRATIONS

ABSTRACT.

This report gives the results of a seismic refraction survey carried out by the Bureau of Mineral Resources for the State Electricity Commission of Victoria at a proposed damsite on the Latrobe river, about 1½ miles upstream from the Yallourn power station.

The thicknesses and seismic velocities of alluvial terrace material, eluvial material, weathered layers, and a rock referred to as a hard oxidized rock were successfully determined within the indicated limits of accuracy.

1. INTRODUCTION

The proposed Latrobe River Dam is part of the Yallourn thermal-electric scheme of the State Electricity Commission of Victoria. When the power stations ("D" and "E") now under construction are completed, an additional supply of cooling water will be required, and the Commission plans to construct a concrete dam across the Latrobe River for this purpose.

The proposed dam site (Plate 1) is located in a gorge of the Latrobe River, approximately 1½ miles upstream from the Yallourn power station. The proposed site was selected from aerial photographs and geological information.

The Commission applied to the Bureau for a seismic survey to be made at the proposed site, with the object of determining the thickness of the alluvial deposits and weathered rock, and the nature of the bedrock, with special reference to the river bed proper.

The field work was done during November, 1956, by a geophysical party consisting of E.J. Polak and L.V. Hawkins, geophysicists. The topographical survey was carried out by the Commission.

It is desired to acknowledge the assistance and co-operation of the staff of the Civil Construction Engineer, Yallourn.

2. GEOLOGY

The geology of the area has been described by Beavis (1956a). The following stratigraphic units are present (see also Plate 1) :-

(i) Siluro-Devonian rocks crop out in the gorge. They include compact, laminated, fine-grained rocks ranging from typical shales to siltstones and have a high density of 2.74 (Beavis, 1956b). Sandstones are present also and are composed of quartz grains about 2 mm. in diameter, bounded by an argillaceous or ferruginous cement. These rocks are discussed in more detail below with the results from test pits.

(ii) Haunted Hill Gravel (Pliocene) overlies the older rocks uncomformably. This formation consists of sandy clay with gravel and sand lenses.

(iii) Eluvial deposits, consisting of soil and fragments of weathered rocks.

(iv) "Older" terrace deposits of Recent age, consisting of boulders of rocks in a sandy clay matrix.

(v) "Newer" terrace deposits of Recent age, consisting of silty and sandy clay, sands and gravels, with a few large boulders.

(vi) Since the construction of the weir close to the power station, alluvial deposits consisting of coarse sand with silt and clay have been deposited.

No drilling has been done at the proposed site, but four test pits have been sunk (see Plate 1). The conclusions reached by Beavis (1956a), from the examination of these test pits are :-

1. Beneath the terrace deposits, the Siluro-Devonian rocks are weathered into a hard oxidized rock. The hardness of the rock is caused by limonite cementing the individual grains (Beavis, 1956b).

2. Where the Siluro-Devonian rocks crop out at the surface, or are covered by eluvium, they are completely weathered to a depth of 10 to 15 feet. Below this depth, the rocks are oxidized and hardened by a limonite cement.

The Commission's geologists showed by laboratory tests that the "hard oxidized rock" would be satisfactory as a foundation for the structure proposed by the Commission (Beavis, 1956b).

Table 1 shows the stratigraphy in the area investigated and the properties of the rocks as derived from the results of the seismic survey.

TABLE 1.

Age	Formation	Member	Lithology	Seismic velocity (ft/sec)(Obtained from weathering spreads)
Recent	Eluvium		Soil and fragments of weathered rock	900 - 1,100
	Alluvium	"Newer" terrace deposits	Silt, sandy clay, sand, gravel and boulders	900 - 1,100
		"Older" terrace deposits	Boulders and sandy clay	Not determined
Pliocene	Haunted Hill Gravel		Gravel, sand and sandy clay	1,000 ±
Siluro-Devonian	Jordan River ?		Highly weathered sandstones, shales, slates and siltstones.	4,500
			Hard oxidized rock.	6,000 - 8,000
			Unweathered sandstones, shales, slates and siltstones.	8,700 - 11,600

3. METHOD

The seismic refraction method of survey was used. The successful use of this method depends on the contrast in the velocity of elastic waves through different rock formations.

The velocity in unweathered rocks is higher than that in their weathered and fractured counterparts. The velocity in soil and scree is considerably lower than that in weathered and fractured rocks.

The method of differences (Heiland, 1946, p.548) was used in the present survey and the following types of spreads were shot :-

(i) Weathering spreads. These were used to obtain the seismic wave velocity and the thickness of the soil and near-surface layers. Geophones were placed at intervals of 10 feet and shot points were at distances of 10, 25 and 50 feet from each end of the spread.

(ii) Normal spreads. Geophones were placed at intervals of 50 feet and shot points were at distances of 20 feet and 150 feet from each end of the spread.

(iii) Broadside spreads. This type of spread was used on all cross-river traverses. The geophones were spaced at 50-foot intervals. Shot points were 200 feet from the spread along a line approximately at right angles to the spread from its mid-point.

The geophysical equipment used in the survey consisted of a Century 12-channel refraction recorder and Technical Instruments Co. geophones with a natural frequency of about 19 cycles per second. For stations in the river bed, "marsh-type" geophones were used. The geophones were fitted into concrete blocks to obtain better coupling with the rock in the bottom of the river.

4. RESULTS

Longitudinal wave velocities recorded in the various rock types are shown in Table 1. These velocities were obtained on weathering spreads located on traverse CD (stations 20 to 22), on traverse EF (stations 1 to 3, and near station 6), and on traverse HI (stations 5 to 7 and 9 to 11).

The depth to unweathered rock (the deepest refractor recorded) was computed from the velocities shown in Table 1. Along traverses CD, MN and part of KL, the depth to unweathered rock was computed by using the average velocity recorded from weathering spreads on traverses CD and EF (station 6). In using an average velocity, two assumptions are made:-

(i) the ratio of the thickness of the alluvial deposits to the thickness of the weathered rock is constant along the traverse, and

(ii) the velocities are constant laterally.

As those two conditions are not always fulfilled, they may introduce an error in depth computation. For example, in places where the river current has removed the silt from the river bed, as for instance at station 10 on traverse CD, the depth to unweathered rock may be underestimated by up to 6 feet.

Detailed cross-sections, based on the seismic results, are shown in Plate 2.

Cross-sections AB, EF, HI and KL show that the terrace material or soil of velocity about 1,000 ft/sec. thins out rapidly towards the centre of the valley. This low-velocity material is absent near station 10 on traverse KL, and may be absent at other places in the river bed.

Comparison of cross-sections EF and HI with results from the test pits shows that the formation with a velocity of 6,000 to 8,000 ft/sec. can be identified as the "hard oxidized rock" referred to in the section on Geology. Cross-section KL shows a thick layer of velocity 4,500 ft/sec. underneath a thin layer of eluvium (velocity 1,000 ft/sec.). On comparison with results from test pits, the layer of 4,500 ft/sec. velocity can be identified as highly-weathered, Siluro-Devonian shale.

Underlying the highly-weathered and hard, oxidized formations is unweathered rock with seismic velocity ranging between 8,700 and 11,600 ft/sec. North of station 13 on traverse CD, the velocity of unweathered rock is 11,600 ft/sec., and south of station 13 it is 10,400 ft/sec. The geology on the left bank of the river suggests that this velocity change coincides with the sandstone/shale boundary (see Plate 1) and that the sandstones have a higher velocity than the shales.

Assuming a Poisson's ratio of 0.3 (Birch, Schairer and Spicer, 1950) and a measured density of 2.74 for the Siluro-Devonian rocks, Young's Modulus (E) and Bulk Modulus (K) are as shown in Table 2 below :-

TABLE 2.

	Seismic Velocity (ft/sec.)	
	8,000	11,000
Young's Modulus (E) (dynes/cm^2)	1.3×10^{11}	2.4×10^{11}
Bulk Modulus (K) (dynes/cm^2)	0.9×10^{11}	1.6×10^{11}

Though the results have not been checked by test pits or drill holes close to the traverses, it is considered that the thickness of the unconsolidated deposits and weathered layers on both banks of the river has been determined within a maximum error of ± 15 to 20 per cent of depth. It has already been stated that the thickness of the weathered layer in the river bed may be underestimated by about 6 ft., which would amount to a maximum possible error of 65 per cent of depth in the river bed proper.

5. CONCLUSIONS

The seismic refraction survey successfully indicated within limits the depth to unweathered rock in the river bed. North of station 13 on Traverse CD, the depth is between 9 to 15 and 15 to 21 feet and south of Station 13 it is between 10 to 16 and 30 to 36 feet.

In the bed of the river a formation with velocity of 6,000 ft/sec. underlies the sand and silt. This formation corresponds to a rock referred to by the Commission's geologist as a "hard, oxidized bedrock of Siluro-Devonian age".

On the river terrace on the right bank and on the hillside on the left bank (traverse AB, stations 5 to 8 and traverse EF, stations 8 to 0"), the same formation, with a velocity of 6,000 to 8,000 ft/sec., underlies the alluvial terrace material. The depth to the base of this layer ranges from 4 to 65 feet.

On traverse KL (stations 1 to 7 and 11 to 13) and on traverse HI (stations 15 to 18) a weathered layer with a velocity of 4,500 ft/sec. (referred to by the Commission's geologist as "highly weathered Siluro-Devonian sandstones and shales") underlies alluvial material. The depth to the base of this layer ranges from 3 to 40 feet.

The depth to presumably unweathered rock of velocity 8,700 to 11,600 ft/sec. is indicated on all traverses with an estimated accuracy of 15 to 20 per cent.

Young's modulus for rock of 8,000 ft/sec. velocity is estimated at 1.3×10^{11} dynes/cm^2, and for rock of 11,000 ft/sec., at 2.4×10^{11} dynes/cm^2.

6. REFERENCES

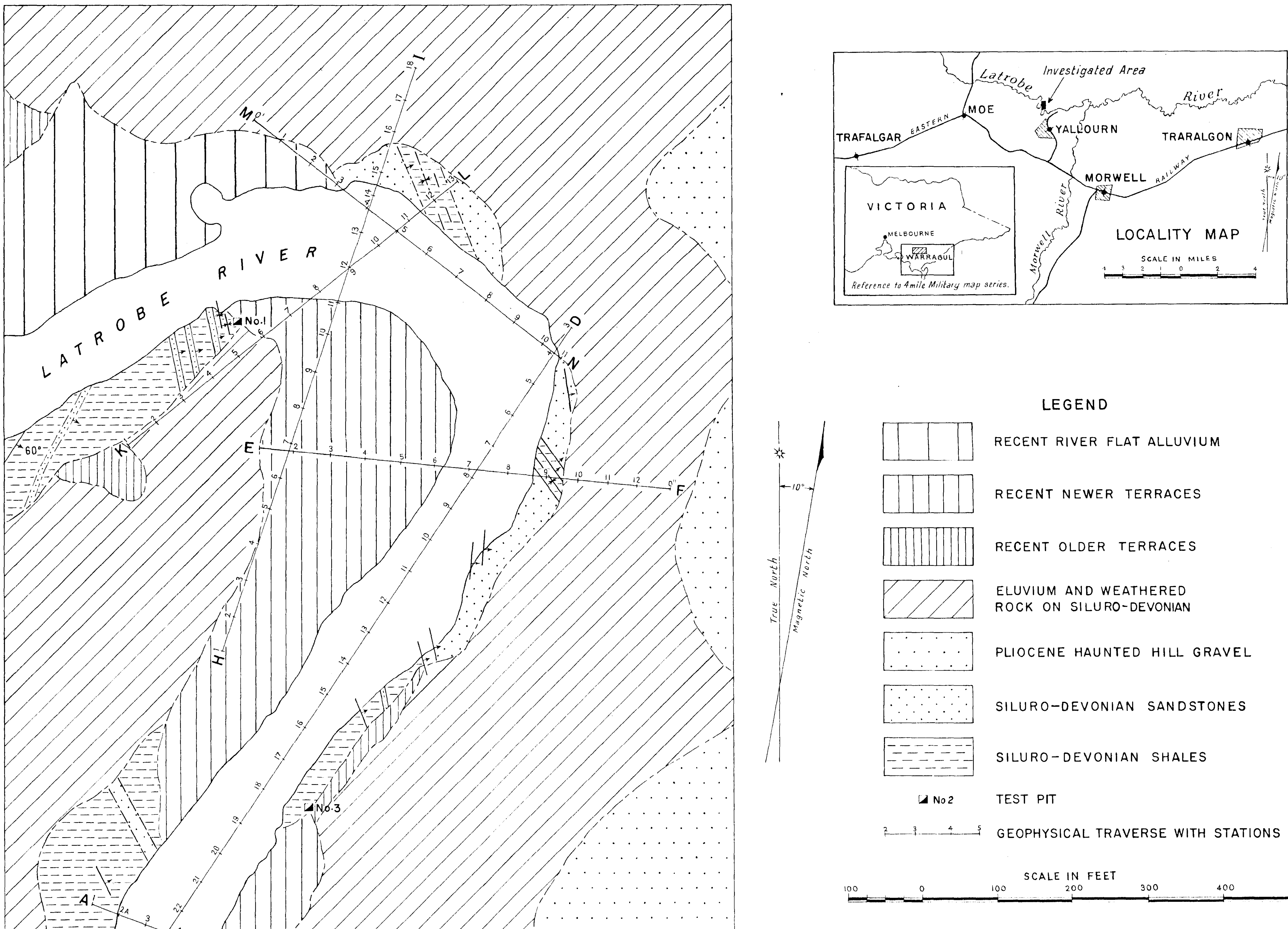
Beavis, F.C., 1956a - Geology of the Latrobe River Dam Sites. (Unpublished internal report, S.E.C.).

Beavis, F.C., 1956b - Personal Communication.

Birch, F., Schairer, J.F., and Spicer, H.B., 1950 - Handbook of Physical Constants. U.S. Geol.Soc. Special Paper No. 36.

Heiland, C.A., 1946 - GEOPHYSICAL EXPLORATION. Prentice Hall Inc., New York.

PLATE I



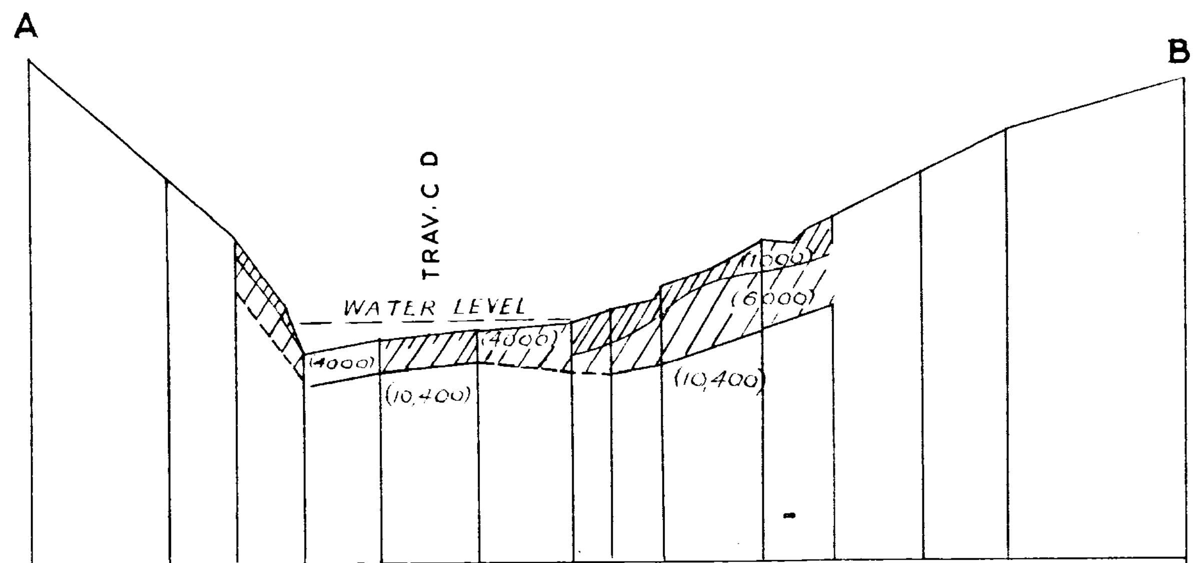
SEISMIC REFRACTION SURVEY OF THE

LATROBE RIVER DAM SITE, YALLOURN

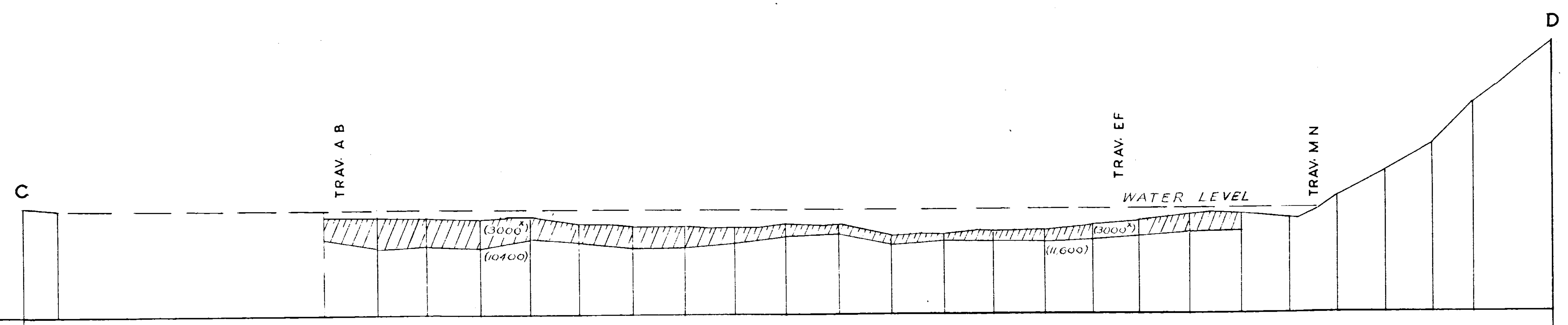
GEOLOGY AND LOCATION OF GEOPHYSICAL TRAVERSES

GEOLOGY FROM S.E.C. PLAN C.S.56/1/53

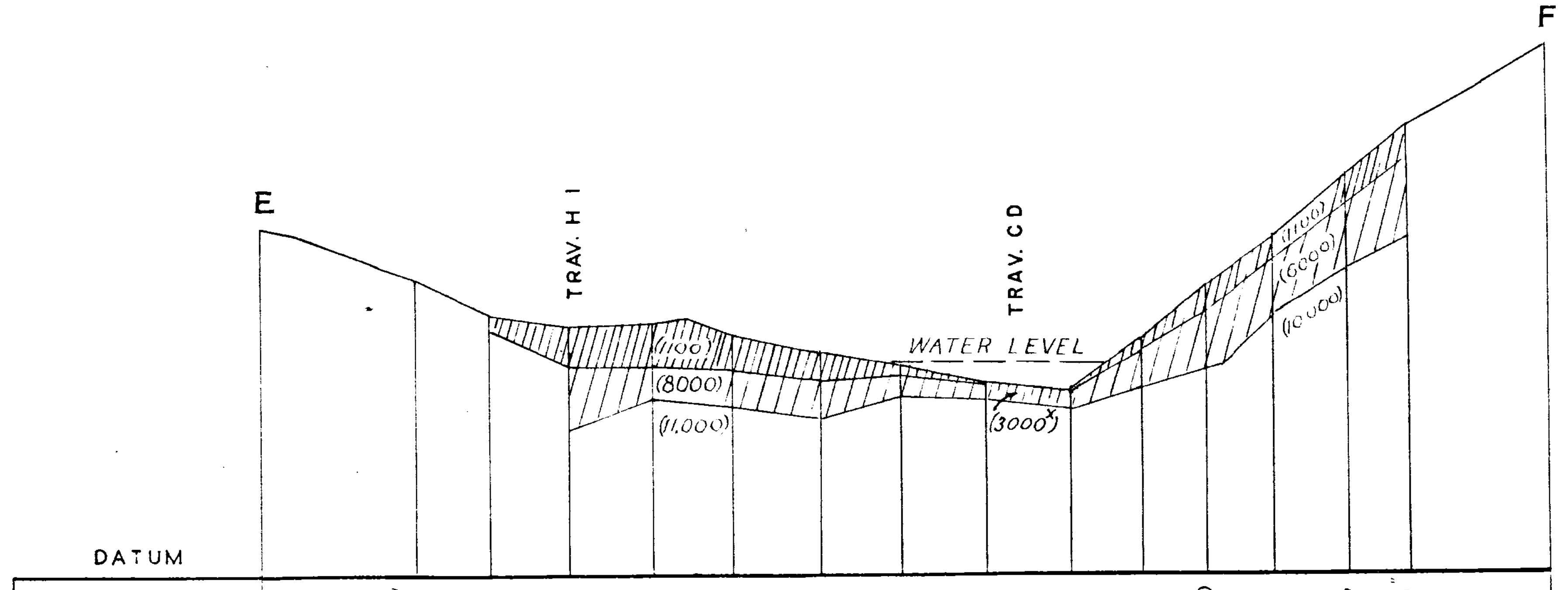
Geophysical Section, Bureau of Mineral Resources, Geology & Geophysics. G 273-1



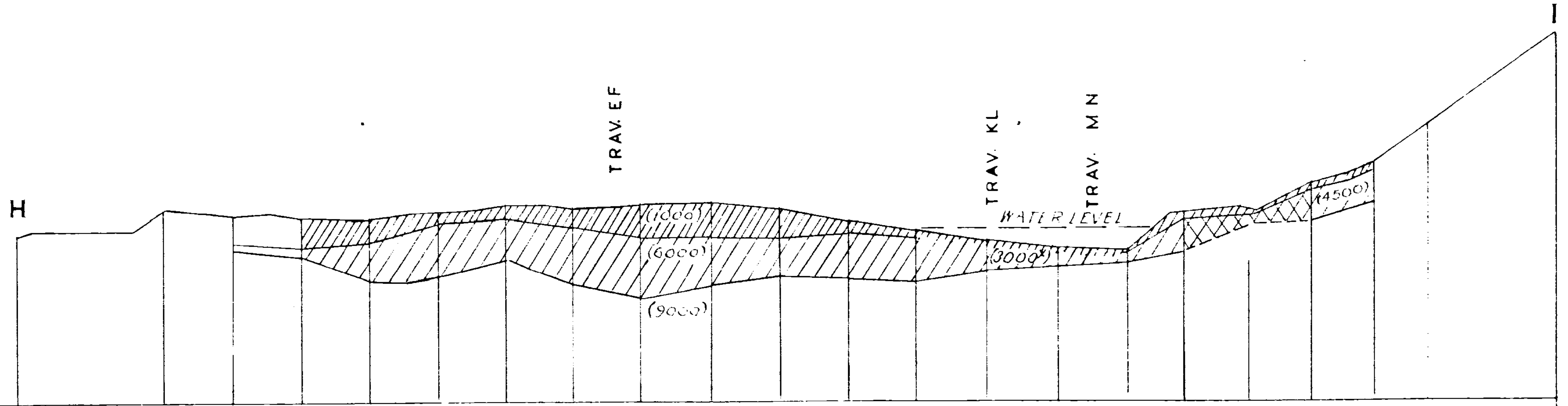
STATION NO.	0'	1	2A	3	4	5		6	7	8	9
SURFACE LEVEL	207	176	117	122	130	131	136	146	173	186	207
THICKNESS OF ALLUVIAL DEPOSITS						18	16	10	13	15	
DEPTH TO UNWEATHERED ROCK		26	12	15	16	25	32	40	45	45	



STATION NO.	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0'
SURFACE LEVEL	130	131	131	128	131	123	121	123	120	122	123	112	115	117	117	122	125	132	132	128	150	174	197	235
DEPTH TO UNWEATHERED ROCK	22	30	21	26	21	16	22	20	12	10	9	10	9	9	10	12	15	15	15					



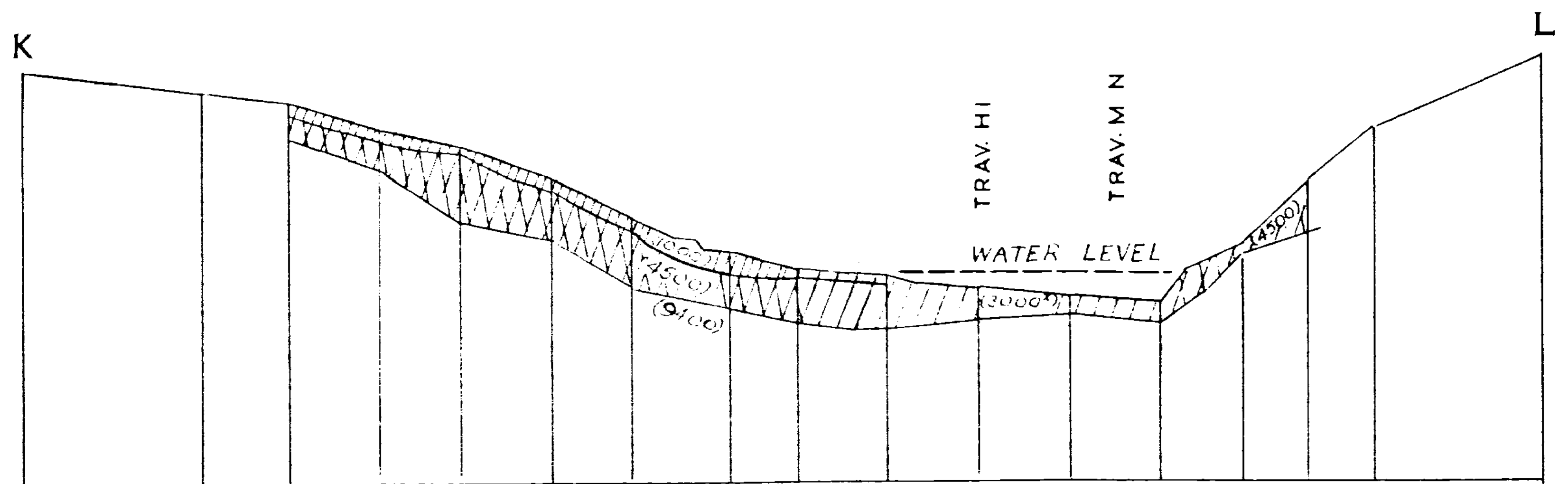
STATION NO.	0'	1	2	3	4	5	6	7	8	9	10	11	12	0"
SURFACE LEVEL	184	162	155	158	149	140	129	122	121	148	179	209	244	216
THICKNESS OF ALLUVIAL DEPOSITS	4	9	23	29	22	16	7	2	3	8	13	11	13	16
DEPTH TO UNWEATHERED ROCK			65	47	44	37	16	9	15	28	50	40	50	61



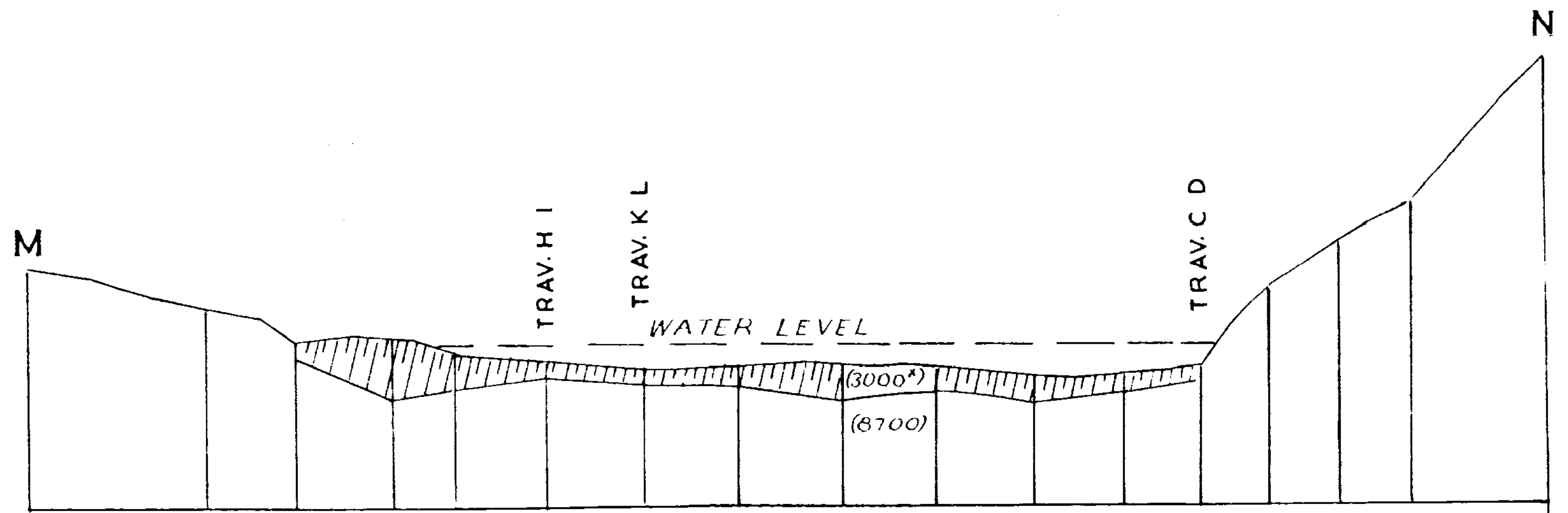
STATION NO.	0'	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	0"
SURFACE LEVEL	154	149	148	148	152	156	154	155	156	153	143	137	128	123	122	149	150	165	183	209
THICKNESS OF ALLUVIAL DEPOSITS			20	16	9	7	12	21	22	19	9	7	3	4	3	6	2	6	7	
DEPTH TO UNWEATHERED ROCK		23	24	44	45	35	52	65	58	43	38	35	18	13	6	21	6	24	30	

SCALE IN FEET

100 0 100 200 300



STATION NO.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	0'
SURFACE LEVEL	230	225	214	203	186	164	146	136	132	128	123	122	148	184	215
THICKNESS OF ALLUVIAL DEPOSITS		8	1	4	6	6	10								
DEPTH TO UNWEATHERED ROCK		18	21	40	32	31	31	33	30	18	9	15	3	27	



STATION NO.	0'	1	2	3	4	5	6	7	8	9	10	11	12	13	0"
SURFACE LEVEL	151	138	136	128	121	119	122	122	122	116	116	122	165	198	231
DEPTH TO UNWEATHERED ROCK		10	30		4	9	10	18	13	12	10	5			

ALLUVIAL DEPOSITS (THICKNESS INDEFINITE) (USED IN CONJUNCTION WITH OTHER SYMBOLS)

ALLUVIAL DEPOSITS

WEATHERED ROCK

HARD OXIDISED ROCK

(8000) SEISMIC VELOCITY IN FT/SEC.

(3000)x AVERAGE SEISMIC VELOCITY IN FT/SEC.

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SEISMIC REFRACTION SURVEY OF THE LATROBE RIVER DAMSITE, YALLOURN

CROSS SECTIONS ALONG TRAVERSES

(INDICATED BY SEISMIC SURVEYS)

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics

G 273-2