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COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

RECORDS 1954. No. 68

SEISMIC REFRACTION SURVEY
WAYATINAH 'A' POWER STATION SITE AND PENSTOCK LINES
TASMANIA

by

W.A. WIEBENGA and L.V. HAWKINS

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CONTENTS

ILLUSTRATIONS.

ABSTRACT

Details and results are given of a seismic refraction survey made at the request of the Hydro-Electric Commission of Tasmania, to investigate the proposed site for a power station with penstock lines and tail race. The power station is part of the Wayatinah "A" project. The object of the survey was to determine the thickness of the alluvial gravel formation on the river flat, the weathered section of the sandstone and the dolerite, and to indicate the presence of shear zones. Three traverses parallel to the proposed penstock line, and 100 feet apart, and three cross traverses were surveyed in January and February, 1954. After completion of the original survey two additional traverses were surveyed on the location chosen for the power station, penstock lines and tail race site.

The average thickness of the gravel on the river flat is about 15 feet, and above the dolerite the average thickness of the overburden is about 45 feet.

On the river flat a drainage or river channel was disclosed. On the hillside, an east-west shear zone showed up by a thick overburden and lower velocities in the formation underneath.

The following velocities (in feet per second) were recorded:

Soil and talus 700-1,700.
Alluvial gravel 4,500.
Weathered sandstone 8,000-9,000.
Weathered and/or fractured dolerite 2,000-4,000.
Fractured and/or partly weathered dolerite 6,000-13,000.
Fresh, jointed dolerite 15,000-18,000.

All formations with velocities up to 5,000 ft/sec are classed as overburden.

A comparison with drilling data shows that the average thickness of overburden indicated by the seismic method is 16 ± per cent too small. After correcting for this error, the remaining average error, irrespective of sign, is ± 15 per cent.

1. INTRODUCTION

The Wayatinah "A" power scheme of the Hydro-Electric Commission in Tasmania comprises the construction of:-

(i) A diversion dam on the Nive river near Wilson's Creek, approximately 1½ miles south-east of Tarraleah power station.

(ii) A tunnel at a level between 1,050 and 1,090 feet, from the storage dam to the power station.

(iii) The power station with tail race and penstock lines on the west bank of the river Nive, about 900 feet south-west from the point where the road to Wayatinah leaves the Tarraleah Highway.

This report describes a seismic refraction survey which was made to assist in the selection of the sites for the power station, tail race and penstock lines. The survey was made at the request of the Commission, to assist its designing section. The problems to be solved were:-

(a) Determination of the thickness of the gravel formation in the river flat.

(b) Determination of the thickness of the weathered section of the sandstone and the dolerite.

(c) Indication of possible shear zones.

The seismic survey was made along traverses A,B,C,D,E,F,G and H shown on Plate 1. Traverse R follows the line of the proposed Wayatinah "A" tunnel. The geophysical surveys along this traverse will be described in a separate report. The locations of exploratory drill holes sunk by the Hydro-Electric Commission are shown on Plate 1. The holes drilled prior to the geophysical survey are listed in Table 2.

The field work was done in two stages, the first from 13th January to 23rd February, 1954, and the second about four months later. The geophysical party, which consisted of W.A. Wiebenga as party leader and L.V. Hawkins as assistant, was based at Wayatinah Construction Camp.

A survey party and two field hands were provided by the Hydro-Electric Commission. It is desired to acknowledge the ready co-operation received by the geophysical party from officers of the Investigation Branch of the Hydro-Electric Commission, Hobart, and from personnel of the Resident Engineer's Office at Wayatinah.

2. GEOLOGY

The rock types in the investigated area are:-

(i) Soil. The whole area is covered by a layer of soil, ranging in thickness from 2 to 20 feet, with an average thickness of about 3 to 4 feet. In this report the term soil includes the loose material on the surface of the hillside, usually called talus.

(ii) Alluvial gravel. On the river flat, below the soil, is a formation of alluvial gravel up to 40 feet thick (this estimate is based on geophysical interpretation).

(iii) Sandstone. The sandstone is medium-grained to fine-grained. In its weathered state it is a soft, decomposed rock consisting of clay and sand (information from drill log). It is found near the surface between the dolerite/sandstone contact on the hillside and the river flat. It underlies the alluvial gravel of the river flat.

(iv) Dolerite. The hills bordering the north-western side of the river flat consist of dolerite. Fresh dolerite is a coarsely crystalline, hard rock with a dark appearance. A qualitative description of the weathering of dolerite is of considerable importance for the interpretation of the seismic data.

Near the surface, dolerite is usually completely weathered into a clayey material containing hard fragments of fresher rock. Different transitions exist between fresh and completely weathered dolerite. Seismically, these transitions are characterised by different velocities, ranging from 2,000 ft./sec. in weathered dolerite to 23,000 ft./sec. in fresh dolerite.

Shearing in dolerite causes fracturing and thus opens the way for easy penetration by solutions from the surface. Weathering extends into the dolerite from the fractures and joints, and the very thick weathered sections in dolerite can usually be interpreted as shear zones.

The dolerite is intrusive into the sandstone. The power station site is located approximately on the contact between dolerite and sandstone.

In this report the term overburden is used to indicate the material of low seismic velocity, (in general below 5000 ft./sec.), including the weathered layer of the dolerite, part of the more weathered section of the sandstone, the alluvial gravel deposit, soil and talus.

3. SEISMIC REFRACTION METHOD.

(a) General description.

For a general description and the applications of the method the reader is referred to Boniwell (1952, p.2), Heiland (1946, p.548) and Edge and Laby (1931, p.339).

(b) Equipment and field operations.

The equipment used in the survey was a "Century" 12-channel portable refraction equipment, model 506, manufactured by the Century Geophysical Corporation, Tulsa, Oklahoma, U.S.A. For operation the reader is referred to the company's manual.

The geophone cable has 12 take-offs at 50-feet intervals, and the maximum station interval is therefore 50 feet. In view of the obstacles found on traverses, it is impractical in most of the area to make the normal station interval more than 40 feet. Two types of geophone spread were used, namely weathering spreads with a geophone spacing of 10 feet and normal spreads with a geophone spacing of 25 to 50 feet.

Weathering spreads were shot 10 to 50 feet from the extreme ends of the spread. They were used to obtain the thickness and velocity of the top soil, and the velocity in the overburden underneath the top soil. From these data a so-called "soil correction" was computed. (See Appendix.)

Normal spreads were shot from 40 to 50 feet and 160 to 200 feet from the extreme ends of the spreads.

4. RESULTS.

(a) Interpretation of data along traverses. (See Plates 2 and 3)

On the river flat the average thickness of the overburden (gravel and soil) is about 15 feet, but ranges between a few feet and 40 feet. The thicker sections of the gravel deposit indicate old drainage or river channels. One of these channels intersects Traverse B between L168B and L169B, continues to L173 on Traverse C and bends southeasterly to L175B (Traverse D). On the hillside the westward continuation of the channel shows up as a gully, indicated by the surface contour lines on Plate 1.

On the sandstone strip between the hillside and the river flat the thickness of overburden (weathered sandstone and soil) ranges from 20 to 50 feet. A high velocity formation at a depth of 100-120 feet, observed along traverse E, is interpreted as dolerite underlying the sandstone. The interpretation of this part of the traverses is uncertain because velocities are difficult to estimate.

Above the dolerite the average thickness of overburden is approximately 45 feet but it ranges between wide limits. As explained in Section 2, a very large thickness of weathered dolerite can usually be interpreted as a shear zone. The velocities in dolerite also give an indication of the degree of fracturing and weathering. As the formation velocity determined from the seismic observations is the average velocity over a geophone spread, the boundaries of the shear zones cannot be determined precisely from the observed velocities. A shear zone with an east-west strike is indicated on traverses A, C and G. The approximate limits of the zone are shown on the plan (Plate 1) and sections (Plates 2 and 3).

(b) Seismic velocities

Table 1 gives details of the rock types and their corresponding velocities.

TABLE 1.

	Type of rock	Seismic velocity (feet per second)
	Soil and talus	700 - 1,700
	Alluvial gravel	4,300 - 4,800
	Weathered sandstone	8,000 - 9,000
	Weathered dolerite in a shear zone	2,200
*	Weathered dolerite	3,000 - 3,200
*	Very closely jointed dolerite, fresh in appearance but weathered at joints	3,200 - 3,700
	Fractured and/or weathered dolerite in shear zone	6,700 - 11,000
*	Fractured dolerite with weathering at joints	13,000
*	Fresh dolerite, jointed	15,000 - 18,000
	Fresh dolerite (velocity measured along sandstone contact)	23,000±

NOTE:- Descriptions preceded by * are taken from drill-logs.

The above table leads to the following conclusions:-

(i) Seismic velocities are a fair indication of the type of rock but to make a definite interpretation a certain amount of geological control is needed. For instance, an alluvial gravel could have the same velocity as a fractured and weathered dolerite.

(ii) Depending on the degree of fracturing and weathering the velocities in dolerite range between 2,000 and 23,000 ft./sec.

(iii) There is some evidence for anisotropy in the dolerite. The maximum velocity measured on traverses approximately perpendicular to the dolerite/sandstone contact is about 18,000 ft./sec.; parallel to and near the dolerite/sandstone contact it is about 23,000 ft./sec.

Fortunately, the distribution of velocities is such that for practical engineering purposes material with a velocity below 5,000 ft./sec. can be classed as overburden. Such material includes weathered and/or very closely jointed dolerite, alluvial gravel, soil and talus.

Dolerite underneath overburden may have a range of velocities between 5,000 and 23,000 ft./sec. Velocities in the lower part of this range, say from 5,000 to 13,000 ft./sec., will usually indicate shear zones or fracturing.

(c) <u>Comparison of seismic results and drilling data</u>.

Before the start of the geophysical survey the Commission had made several drilling tests. A comparison of the drilling data with the seismic data is shown in Table 2.

Two sources of uncertainty affect the usefulness of the comparison. Firstly, there is considerable relief in the boundary surface between overburden and the underlying rock, and the figures are strictly comparable only where the drill hole coincides with a geophone position. Secondly, core recovery from the drilling was low, and it was sometimes difficult therefore to assign depths to certain discontinuities.

TABLE 2.

COMPARISON OF SEISMIC RESULTS WITH

DRILL LOG DATA

Drill Hole No.	Location	Thickness of overburden		Remarks (from drill logs)
		Seismic	Drilling	
8567	L163	42'	43'	Weathered sandstone to 43'
8570	L110	21'	27'-36'	Top layers weathered sandstone; below 36' fresh dolerite.
8565	L112/L113	32'	50' ?	No drill core recovery 0'-50'; below 50' fractured dolerite, weathered at joints.
8564	L113/L114	46'	59'	Weathered dolerite to 59'.
8569	L115/L116	40'±	45'	No drill core recovery 0'-32'; dolerite extensively weathered at joints 32'-45'.
8568	L117/L118	45'±	40'	Very closely jointed dolerite; joints, weathered 6'-40'; fresh, but jointed dolerite 40'-70'.
8563	35' south of L114B	>45'	58'	Deeply weathered or closely jointed dolerite; poor drill core recovery 0'-58'; closely jointed and weathered dolerite 58'-89'.

5. ACCURACY

Though the amount of drilling is insufficient to permit computation of a standard error, Table 2 gives sufficient information to obtain an approximate estimate of the accuracy and to show whether systematic errors are present.

According to the drill logs, the average thickness of overburden is approximately 45 feet. If it is assumed that the drill logs give the correct figures for overburden thickness, the average error in the seismic results, taking into account the sign, is 7,0 feet. The average error, irrespective of sign, is 8.7 feet. These figures indicate that the errors do not balance and a systematic error is present.

The average thickness of overburden estimated by the seismic method is 16± per cent too low. After increasing the thickness as found by the seismic method by 16 per cent, the average error in thickness, irrespective of sign, is still ±15 per cent.

For a discussion on the source of errors the reader is referred to the Appendix.

6. CONCLUSIONS

The survey has provided information to assist the designing engineer in the selection of a location for the power station, in the choice between pressure-shaft or penstock lines and in the selection of the best position for a tunnel-portal. The survey has also provided information on the thickness of gravel overlying the sandstone in the river flat. This information gives a useful indication of the nature of the material to be excavated for the tail race.

The most favourable location for the power station is in the vicinity of the road between Traverses A and G, where a thin overburden has been indicated. Furthermore, the sections along Traverses A and C indicate that there is a bench of dolerite at a shallow depth (situated about 200-250 feet north-west of the road), which would be favourable for the penstock construction.

Based on topographical features only, it was originally planned to construct a pressure shaft near station L201A. The seismic survey showed that L201A is located on a shear zone and the idea of a pressure shaft was therefore abandoned in favour of penstock lines.

The portal of the tunnel should be placed outside the shear zone marked on Plate 1.

7. REFERENCES.

Boniwell, J.B., 1952 - Seismic Survey of the Mossy Marsh Tunnel Area, Tasmania, Bur.Min.Res. Geol.&Geophys., Records 1952, No.16.

Edge, A.B. and Laby, T.H., 1931 - THE PRINCIPLES AND PRACTICE OF GEOPHYSICAL PROSPECTING, Cambridge University Press.

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

Melbourne
February 1955.

APPENDIX

SOURCE AND MAGNITUDE OF ERRORS

Consider a simple two layer case. The depth (z) of a discontinuity is the product of velocity (v) and vertical travel time (t).

$$z = vt$$

$$\Delta z = \partial(vt)/\partial t . \Delta t \quad + \quad \partial(vt)/\partial v . \Delta v$$

$$= v . \Delta t \quad + \quad t . \Delta v$$

or $z = v \Delta t + avt = \sigma_1 + \sigma_2$--------(1)

in which :

$a = \frac{\Delta v}{v}$, $\sigma_1 = v \Delta t$, $\sigma_2 = avt$,

and

Δz = possible error in depth

Δt = " " " vertical travel time

Δv = " " " overburden velocity

100a = " percentage error in overburden velocity.

σ_1 = error in z due to erroneous travel time

σ_2 = " " z " " " overburden velocity

σ_1 is believed to be an error caused by variations in soil thickness. Weathering spreads to estimate soil thickness are shot at regular intervals and the influence of the soil on the determination of overburden thickness is eliminated by applying a "soil correction" to the vertical travel time. For instance, if 3 feet of soil with a velocity of 1000 ft./sec. overlies a formation of 3000 ft./sec., then the soil correction is $-(3/_1 - 3/_3) = -2$ milliseconds. However, variations in soil thickness between the weathering spreads may result in the application of an erroneous soil correction. Also, in the computation of the vertical travel time the reciprocal times have errors up to 2 or 3 milliseconds, thereby introducing errors of 1 to 1½ milliseconds in the vertical travel time. Summarizing, it can be said that vertical travel times can easily have errors of 2 milliseconds. With an overburden velocity of 4000 ft./sec., this implies errors of ±8 feet. σ_1 does not depend on depth and hence its influence is most important when considering discontinuities at shallow depth. Its relative importance decreases with increasing depth.

σ_2 is due to errors in the estimation of overburden velocities. Because the composition of overburden can vary markedly within short distances both horizontally and vertically, errors in velocity estimates may easily amount to 15%, i.e. a = 0.15. σ_2 varies with t and therefore increases with increasing overburden thickness.

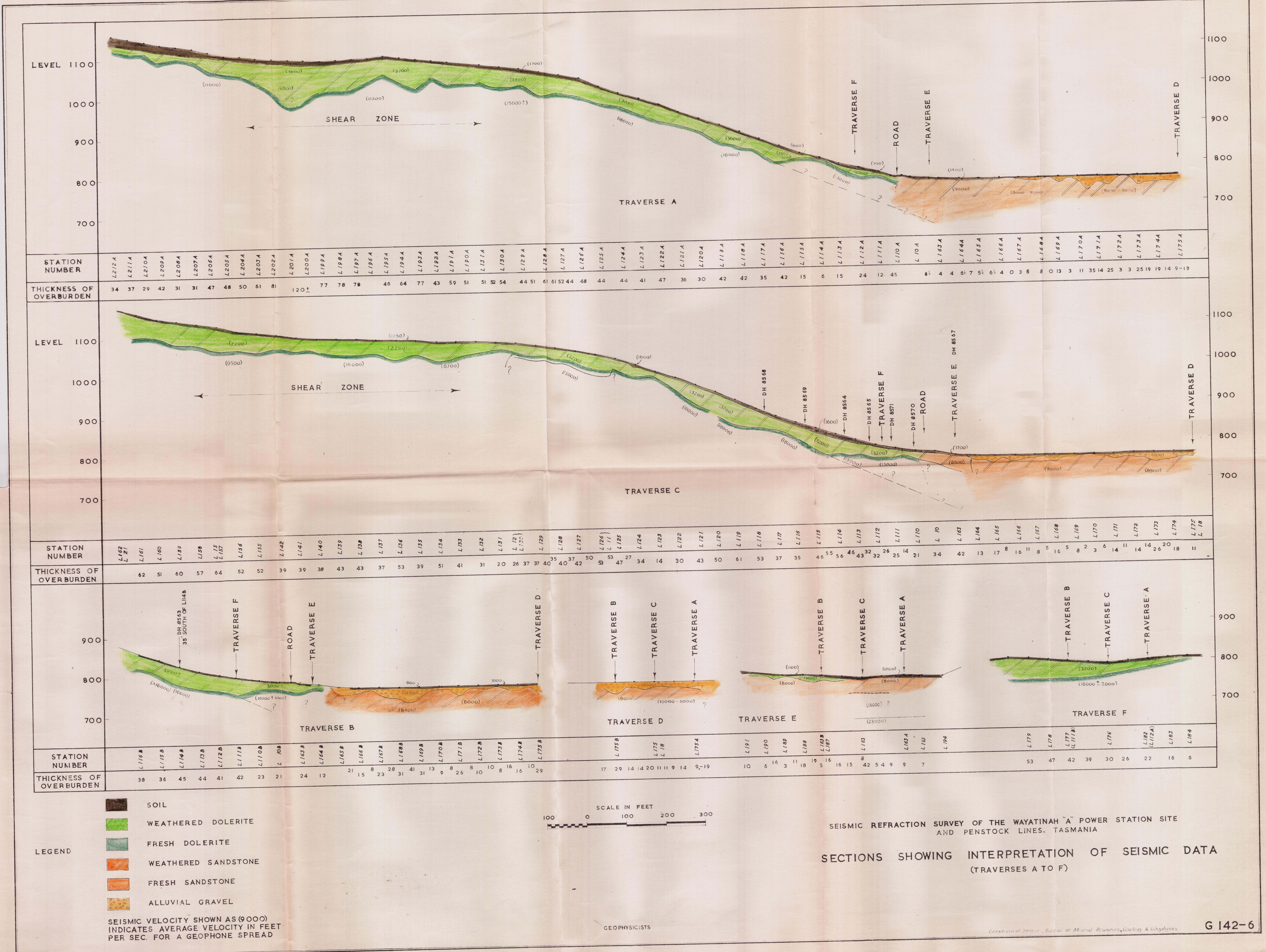
The following table illustrates the possible magnitude of errors in examples which may be representative of engineering problems. The figures are chosen conservatively.

Overburden velocity, v = 4000 ft./sec.
Possible error in overburden velocity = 15%, i.e. a = 0.15.
Possible error in vertical travel time, t = 2 milliseconds.

z (feet)	σ_1 (feet)	σ_2 (feet)	$\sigma_1 + \sigma_2$ (feet)	$100 \frac{\sigma_1 + \sigma_2}{z}$ (%)
20	8	3	11	55
50	8	7.5	15.5	31
100	8	15	23	23
200	8	30	38	19

SEISMIC REFRACTION SURVEY OF THE WAYATINAH 'A' POWER STATION SITE AND PENSTOCK LINES, TASMANIA

LOCALITY MAP, SURFACE CONTOURS AND SEISMIC TRAVERSES



SEISMIC REFRACTION SURVEY OF THE WAYATINAH "A" POWER STATION SITE AND PENSTOCK LINES, TASMANIA

SECTIONS SHOWING INTERPRETATION OF SEISMIC DATA

(TRAVERSES A TO F)

G 142-6

PLATE 3

LEGEND

- SOIL
- WEATHERED DOLERITE
- FRESH DOLERITE
- WEATHERED SANDSTONE
- FRESH SANDSTONE
- ALLUVIAL GRAVEL

SEISMIC VELOCITIES ARE INDICATED AS (3000) FEET PER SECOND

SCALE IN FEET

100 0 100 200 300

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GEOPHYSICISTS

SEISMIC REFRACTION SURVEY OF THE WAYATINAH "A" POWER STATION SITE AND PENSTOCK LINES, TASMANIA

SECTIONS SHOWING INTERPRETATION OF SEISMIC DATA

(TRAVERSES G AND H)

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G 142-7