COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

**BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS**



RECORDS 1960 No. 99

# HOBART TUNNEL SITE SEISMIC REFRACTION SURVEY
# TASMANIA 1960

by

E.J. Polak and M.J.W. Duggin

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## CONTENTS



## ILLUSTRATIONS



## ABSTRACT

This report describes a seismic refraction survey in Hobart. It was done at the request of the Hobart City Council, and the aim was to find the type of bedrock and depth to bedrock along two alternative sites for a flood relief tunnel.

The methods are described, and Plates show the results in the form of cross-sections along the tunnel lines.

## 1. INTRODUCTION

The Hobart City Council is investigating flooding of the Hobart Rivulet, which drains the slopes of Mt. Wellington. During floods, the Rivulet carries large quantities of water into the centre of the city. Its channel is very narrow and is obstructed by several bridges.

It is proposed to drive a flood relief tunnel from Hobart Rivulet and two schemes have been chosen for further investigation. In one scheme (Plate 1) the tunnel would be taken under Anglesea Barracks and Battery Point into the Derwent River; in the alternative scheme the tunnel would be taken from Gore Street under Fitzroy Gardens into the Sandy Bay Rivulet.

The Hobart City Council requested the Bureau of Mineral Resources, Geology and Geophysics to conduct a geophysical survey to determine the depth to the bedrock and the nature of both bedrock and overburden.

The survey was done from the 9th to 15th June 1960 by a geophysical party consisting of E.J. Polak, party leader and M.J.W. Duggin, geophysicist.

It is desired to acknowledge the help given by the Hobart City Engineer's Department, especially by Mr. H.D. Nichols, and the help of the H.E.C. officers, Messrs. G.A.E. Hale, R. Hawkes, and K. Rand.

## 2. GEOLOGY

Some geological information is shown on Plate 1. North of the tunnel line area there is an outcrop of Triassic sandstone. Most of the remaining area is covered by soil and other erosion products but there are a few outcrops of dolerite in the north-eastern part of the map area, and accordingly this part of the map is marked as dolerite.

There is no information about the type of bedrock in the south-western part of the map area.

## 3. METHOD AND EQUIPMENT

The seismic refraction method was selected as the one most likely to give the depth to bedrock and the nature of the bedrock.

In the seismic method an explosive charge, detonated near the surface of the ground (or water nearby), produces seismic waves. These waves are reflected and refracted at boundaries between the various sub-surface formations. The reflection and refraction of energy at a boundary is governed by laws closely resembling those of optical phenomena and depends on a contrast between the elastic properties of the materials either side of the boundary. For this survey, only the refracted energy was considered.

If energy strikes a boundary at the critical angle it will travel along the boundary, continuously transmitting energy back to the surface at the critical angle. In a seismic survey this energy is detected at the surface by a line of geophones connected to a set of seismic amplifiers and a multi-channel photographic recorder. Plate 2, Fig. 1 is a copy of part of a record obtained in this way; the shot instant S.I. is marked by a break in the bottom trace.

For each individual geophone the arrival time of the refracted energy, measured from the shot instant, is plotted against the horizontal distance of the geophone from the shot-point. The slopes of this time-distance curve (Plate 2, Fig. 2) are a measure of the velocity of seismic waves in the successive formations below the surface.

In a "normal spread" the geophones are placed at 50-ft intervals in a straight line, and shots are fired at points 25 ft and 300 ft beyond the ends of the geophone spread.

In a "weathering spread" the geophones are more closely spaced to give more accurate velocities in the near-surface formations. Plate 2, Fig. 3 shows the time-distance curves from four shots on a weathering spread on St. Georges Terrace near the Colville Road corner. Geophones were at 10-ft intervals in a straight line, and shots were fired at points 5 ft and 100 ft beyond each end of the spread. This time-distance curve is an example where different velocities are recorded from shots fired from opposite directions; this indicates that the boundaries between the refractors are not parallel.

### 3.1. The "method of differences"

A normal spread is used in this method, which has been described by Heiland (1946, page 548). The method is illustrated in Plate 3, Fig. 1 of this report. A shot is fired at A and the travel times $T_{AB}$ and $T_{AC}$ are recorded at B and C. A shot is then fired at C and the travel times $T_{CB}$ and $T_{CA}$ are recorded at B and A. $T_{CA}$ of course equals $T_{AC}$. From these recorded travel times the following equation of Heiland (corrected for slope of the refracted rays) may be used to relate depth and velocities:

$$d = (V_2V_1)/\left(\sqrt{V_2^2 - V_1^2}\right) \times \tfrac{1}{2}(T_{AB} + T_{CB} - T_{AC})$$

where $V_1$ is the velocity of seismic waves in the formation between the surface and the first discontinuity, and $V_2$ is the velocity immediately below it.

The "method of differences" was used on two parts of the survey:

(a) across the Anglesea Barracks, with shots fired at two specially drilled holes, DDH 1 and DDH 2.

(b) on the traverse Gore Street - Fitzroy Gardens, with shots fired in shallow water and surrounded by sand bags in the Hobart and Sandy Bay Rivulets.

Because of buildings and traffic in the area, it was not always possible to use normal spreads or to fire shots in the best positions. In some places the "step-out time method" or "broadside spreads" had to be used.

### 3.2. The "step-out time method"

The geophones are placed as in a normal spread, but shots are fired only at one end of the spread. The first arrival times are corrected for the time taken by the seismic waves to travel from shot to geophone along the refractor. The depths are then calculated relative to a known depth (obtained from outcrops or drilling, or found by the "method of differences"). This method was used in the traverse along St. Georges Terrace and along Bath Street, with shots fired in the Derwent River.

### 3.3. Broadside spreads

In a broadside spread (Plate 3, Fig. 3) the geophones are placed in a line along the traverse, and the shot-point is offset some distance from the traverse line. The travel times are corrected for the time taken by the seismic waves to travel along the refractor from shot-point to geophone, and depths are then calculated relative to a known depth. This method was used in Molle Street, Montpelier Street, Newcastle Lane, Colville Road, and Napoleon Street; some of the shots were fired in the Derwent River, and others in hole DDH 1.

In both the "step-out time" and "broadside" methods the calculations depend on an assumed value for the velocity in the bedrock.

### 3.4. Equipment

For most of the survey, a set of S.I.E. 12-channel seismic refraction equipment was used with T.I.C. geophones whose natural frequency is 20 c/s. On some weathering spreads an "Engineering" seismograph was used; this had been borrowed from the Hydro-Electric Commission.

## 4. RESULTS

Recorded seismic velocities for the various formations are shown in Table 1. The term "overburden" will be used in this report to represent all the material above the highest-velocity refractor. This may include alluvial material ranging in size from soil to boulders (either naturally-occurring or dumped), and highly weathered or slightly weathered bedrock. The term "bedrock" will apply to the highest-velocity refractor recorded.

Table 1

| Rock type | Velocity, ft/sec. |
|---|---|
| Overburden | 1000 to 5000 |
| Dolerite bedrock | 16,000 to 18,000 |
| Bedrock on tunnel line from Gore St. to Fitzroy Gardens. | 10,000 to 12,000 |

(The velocities in the overburden were determined from weathering spreads).

The weathering of dolerite often results in various transition layers between completely weathered dolerite with seismic velocity of 5000 ft/sec and unweathered dolerite with seismic velocity of 18,000 ft/sec. No rock transition layers with intermediate velocities were observed on the tunnel line under Anglesea Barracks, which means that they are either absent or too thin to be recorded.

It is very difficult to assess the percentage error in the bedrock depth determination, where the overburden is so thin and the difference of only a few feet produces a considerable percentage error. It is considered however that errors in the determination of the thickness of the overburden do not exceed 20 per cent.

### 4.1. Molle St. - Derwent River tunnel line

(a) Section along St. Georges Terrace and Bath St. (Plate 4).

The survey was carried out using the "step-out time" and "broadside" methods. A value of 16,000 ft/sec was assumed for the bedrock velocity; this was the seismic velocity measured near DDH 2. The results indicate that the overburden is thin near De Witt St., where outcrops of dolerite have been found (Nichols, 1960). Weathering spreads were placed on Napoleon St., near Colville Rd., on Newcastle Lane, and near DDH 2.

(b) Section across Anglesea Barracks (Plate 5).

On this part of the survey the "method of differences" was used. Overburden velocities were determined from weathering spreads located near DDH 1, DDH 2, and on the parade ground.

The velocities in the bedrock are 16,000 to 18,000 ft/sec, indicating an unweathered dolerite.

(c) Section along Molle St. (Plate 5)

The survey was carried out using the "broadside spread" method. A value of 17,000 ft/sec was assumed for the bedrock velocity; this was the seismic velocity measured near DDH 1.

4.2. Gore St. - Fitzroy Gardens tunnel line (Plate 6).

The "method of differences" was used to determine the depth to the bedrock. Weathering spreads were placed near Hobart Rivulet and in Fitzroy Gardens.

The bedrock velocity is 10,000 to 12,000 ft/sec. As no higher velocities were observed, it is possible that the bedrock here is not dolerite; in earlier surveys in Tasmania velocities of 10,000 to 12,000 ft/sec were associated with sandstone, mudstone, or basalt.

## 5. CONCLUSIONS

The geophysical survey provided information on the depth to the bedrock along the two tunnel lines.

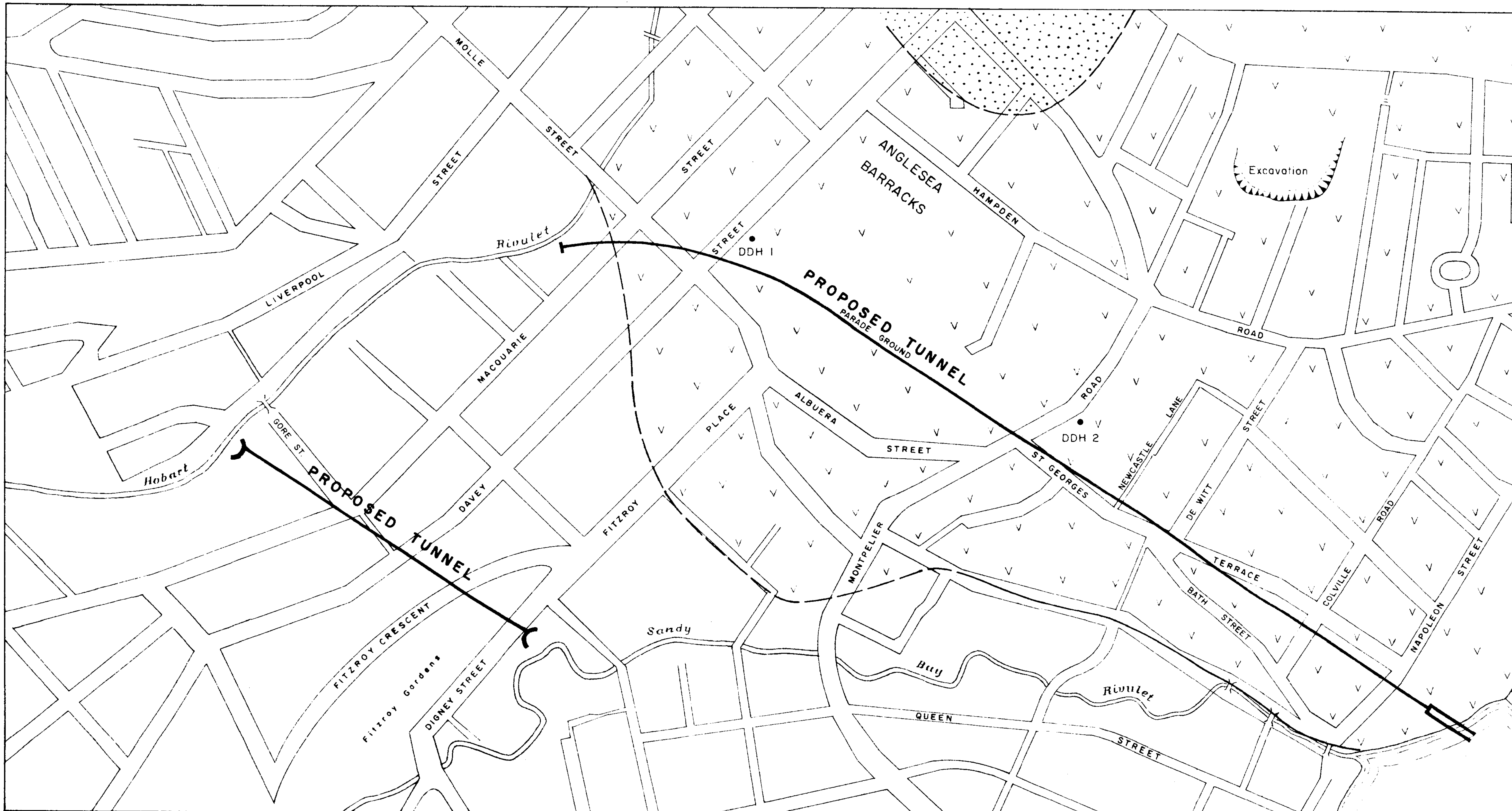
(a) A tunnel along the Molle St. - Derwent River route would be located in dolerite except for the first 350 ft. The dolerite has a very high seismic velocity, and is therefore fresh and probably does not have open joints.

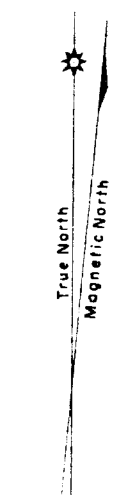
(b) A tunnel on the Gore St. - Fitzroy Gardens route would be wholly in rock of low velocity. The bedrock velocities of 10,000 to 12,000 ft/sec suggest that the bedrock is sandstone, mudstone, or basalt.

## 6. REFERENCES

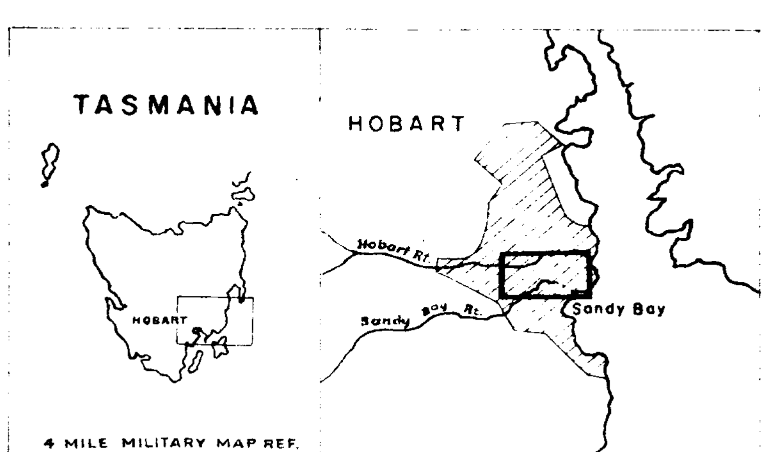
HEILAND, C.A., 1946 - GEOPHYSICAL PROSPECTING Prentice-Hall, New York.

NICHOLS, H.D., 1960 - Personal Communication.




Geology after G.A.E. HALE




LEGEND

- Alluvium etc.
- Dolerite (Mainly concealed)
- Triassic sandstone (Outcropping)

## HOBART, TASMANIA

SEISMIC REFRACTION SURVEY
FOR
PROPOSED FLOOD RELIEF TUNNEL

## GEOLOGY AND PROPOSED TUNNELS

SCALE IN FEET

400 200 0 400 800 1200 1600

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G 361-1

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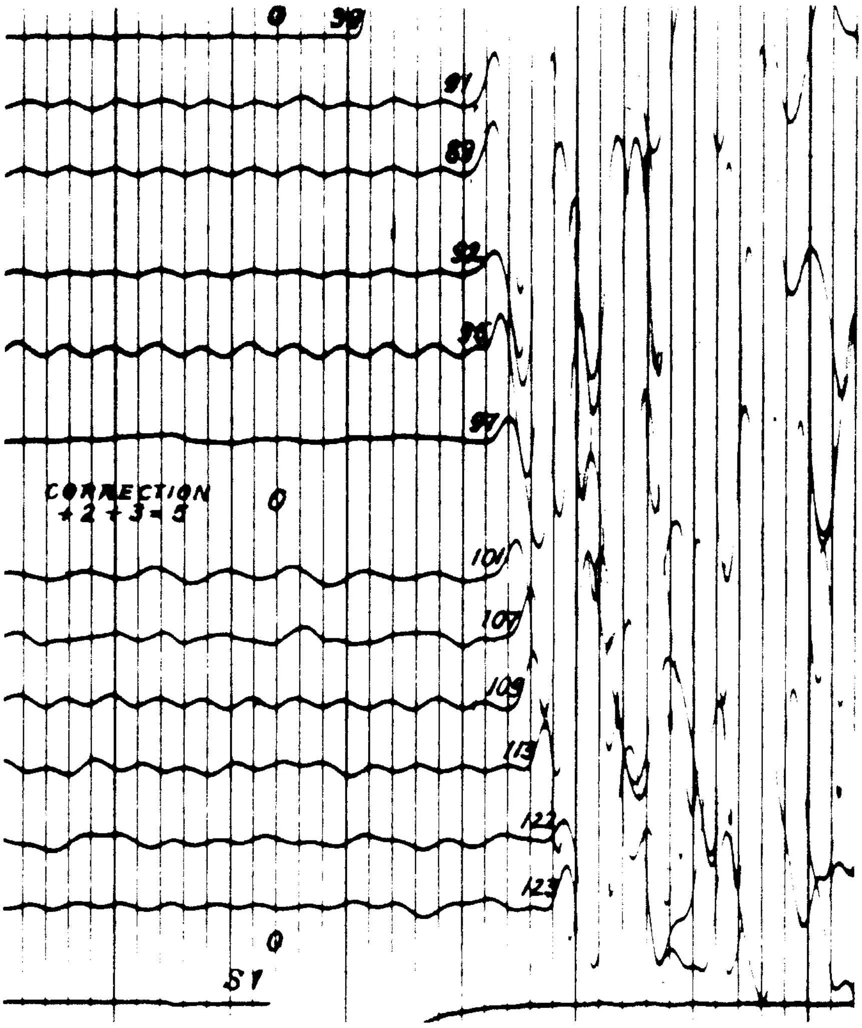
PLATE 2




| BUREAU OF MINERAL RESOURCES GEOLOGY & GEOPHYSICS | | |
|---|---|---|
| AREA Hobart | RECORD No. 1504 | |
| TRAV. S.G.T | INST. SIE | DATE 10/6/60 |
| SHOT POINT D.R. | SHOT No. 5 | |
| CHARGE ½ lb | DEPTH 6 ft. | |
| SPREAD 750 - 1250 | | |
| INTERVAL 50 ft. | GAINS .1 - 15 | |
| R.G. Napoleon St | CHANNEL 1 | |
| WORKED M.D | CHECKED R.J.P. | |
| Step-out | | |

Fig. 1

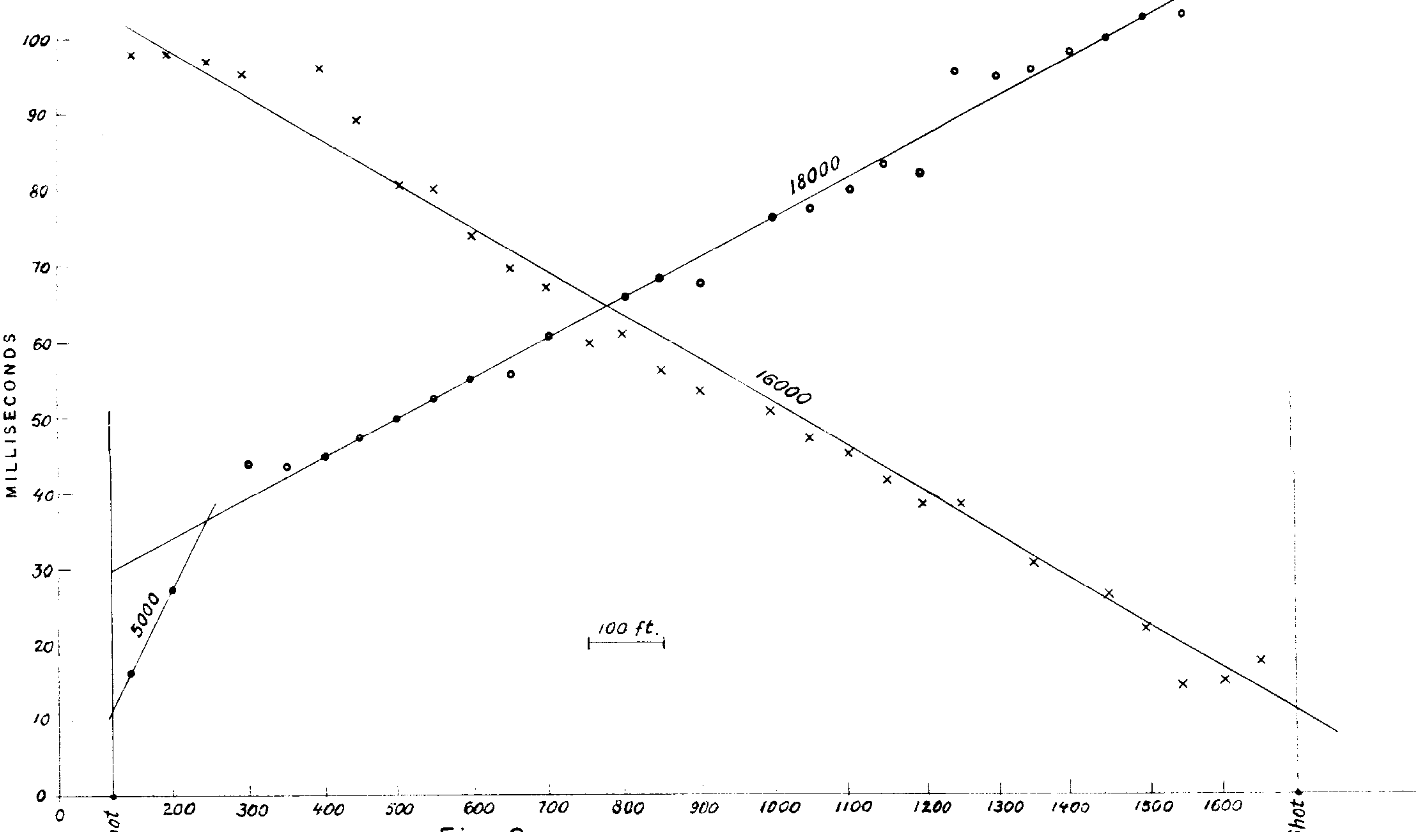



Fig. 2 Time-Distance Curve - Anglesea Barracks

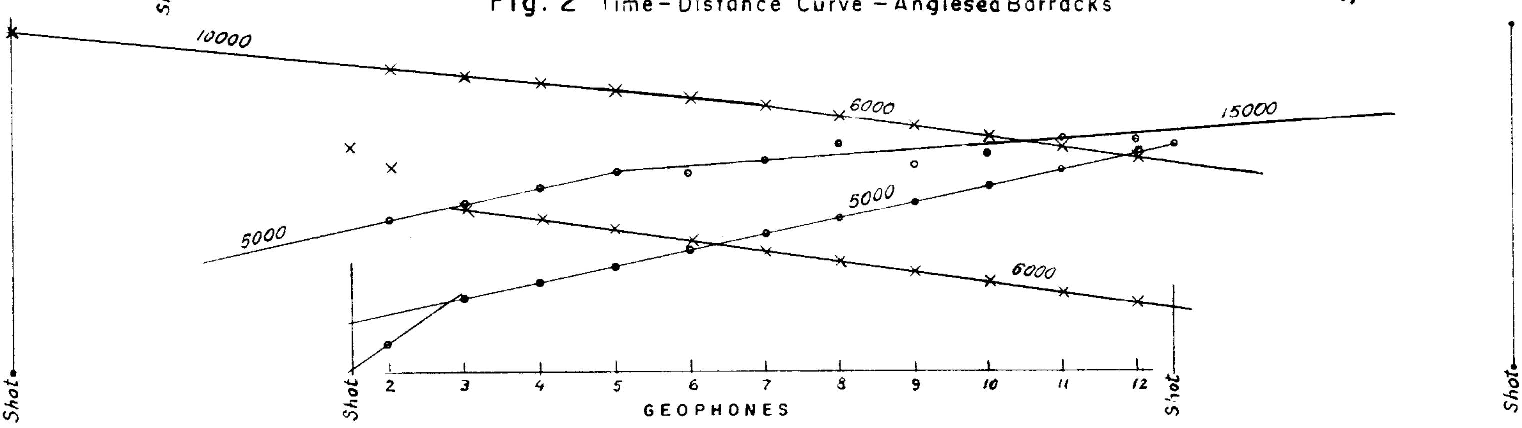



Fig. 3 Time - Distance Curve - Weathering Spread on St. Georges Terrace

HOBART, TASMANIA

SEISMIC REFRACTION SURVEY FOR PROPOSED FLOOD RELIEF TUNNEL

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G 361-2

PLATE 3

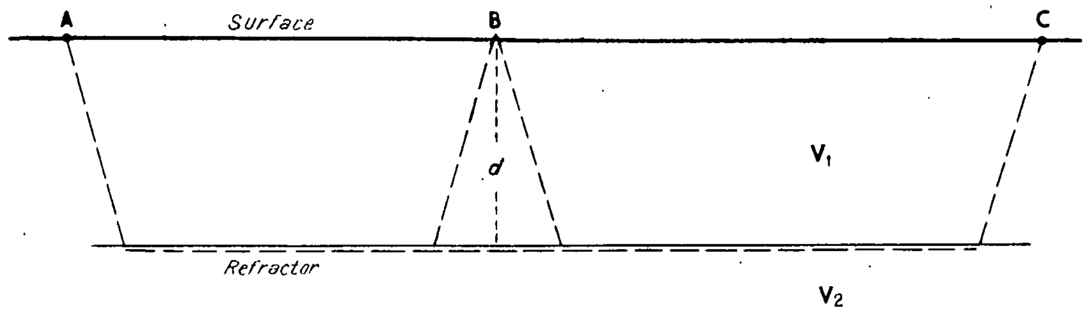



FIG. I. METHOD OF DIFFERENCES.

CROSS-SECTION SHOWING SEISMIC WAVE PATHS.

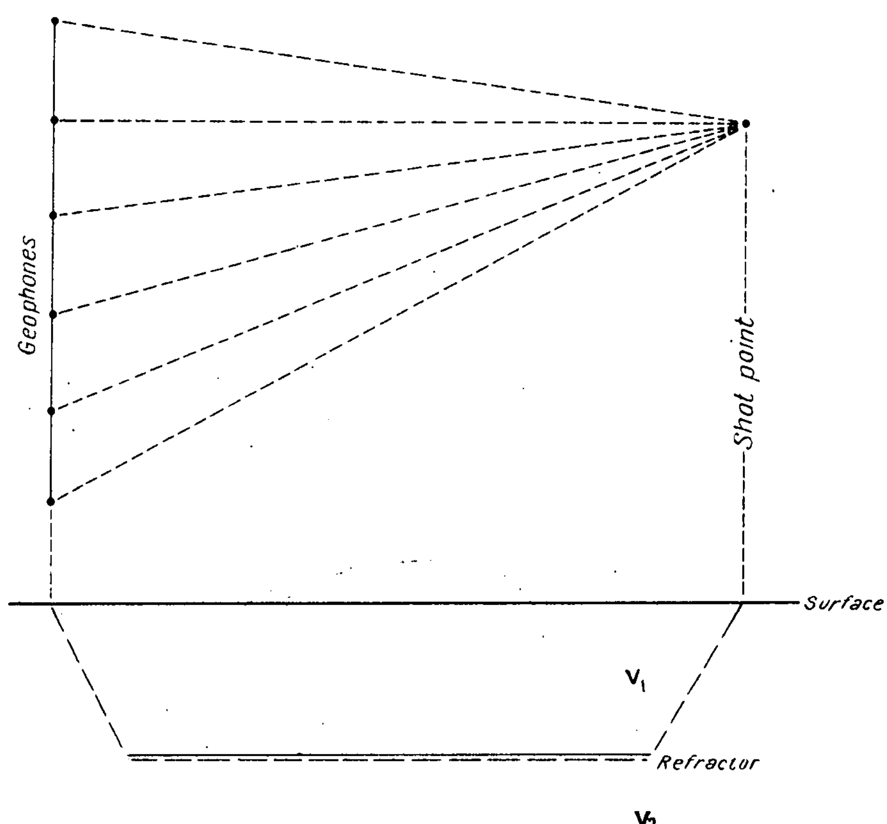
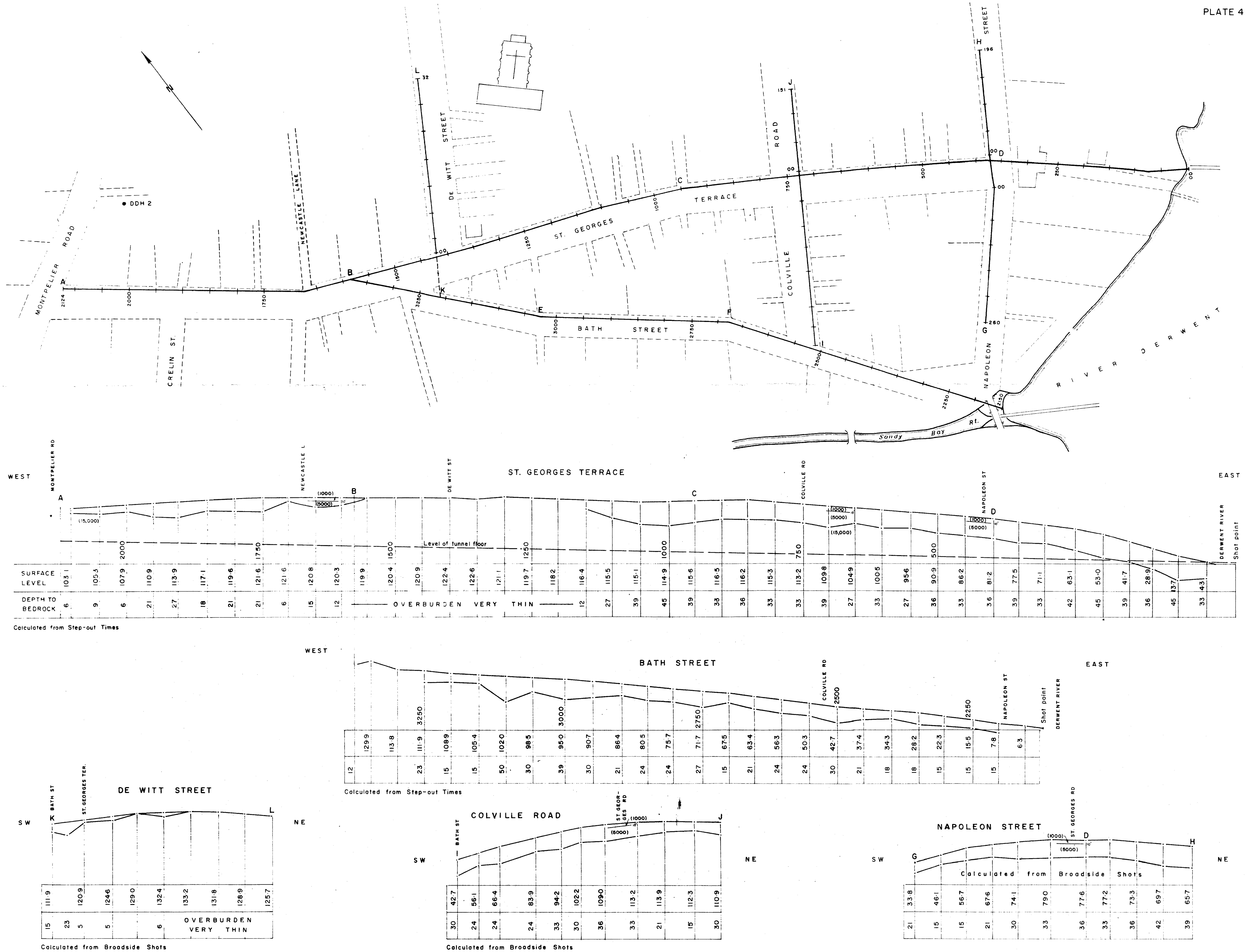



FIG. 2. BROADSIDE SPREADS

PLAN AND CROSS-SECTION SHOWING

SEISMIC WAVE PATHS.




ST. GEORGES TERRACE AND BATH STREET

# PLAN AND SEISMIC CROSS-SECTION

(5000) Seismic Velocity in ft./sec.

SCALE IN FEET

100 0 100 200 300

GEOPHYSICIST

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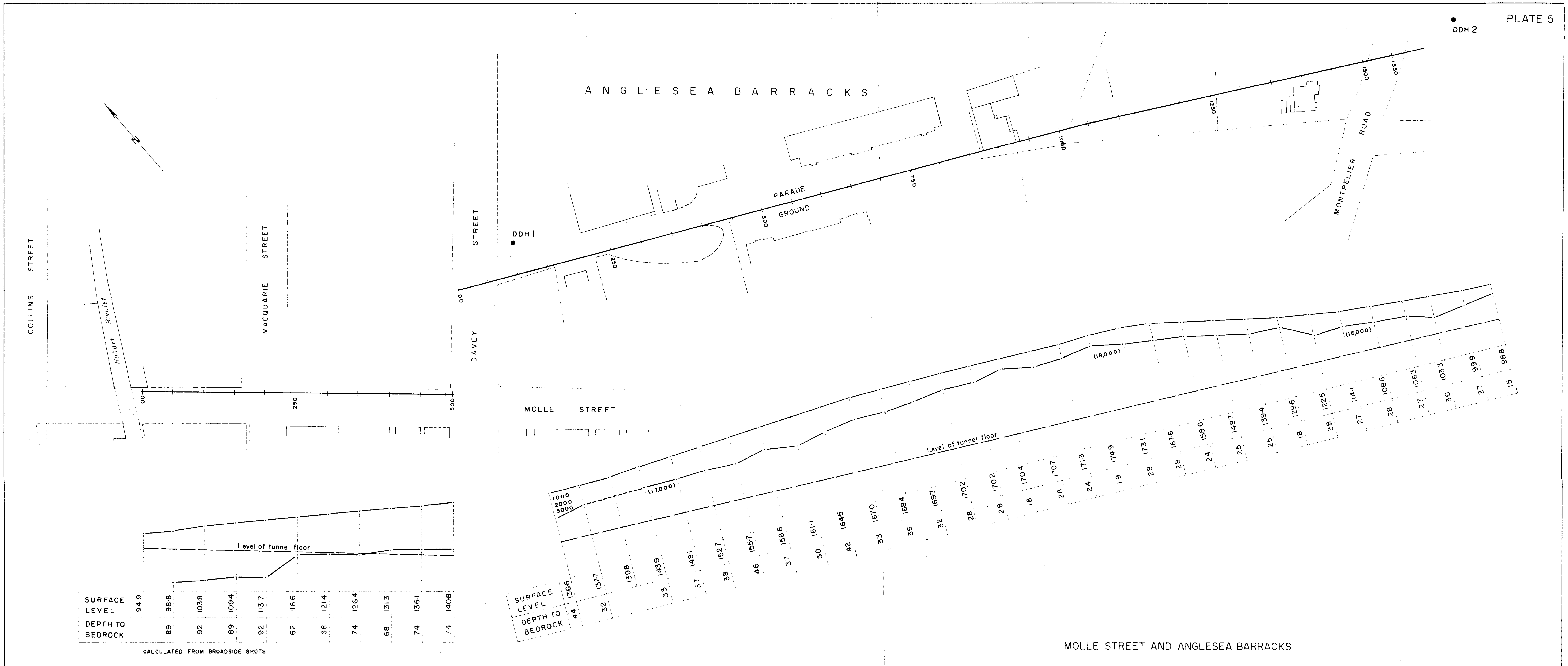
PLATE 5




| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SURFACE LEVEL | 94.9 | 98.8 | 103.8 | 109.4 | 113.7 | 116.6 | 121.4 | 126.4 | 131.3 | 136.1 | 140.8 |
| DEPTH TO BEDROCK | | 89 | 92 | 89 | 92 | 62 | 68 | 74 | 68 | 74 | 74 |

CALCULATED FROM BROADSIDE SHOTS

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SURFACE LEVEL | 136.6 | 137.7 | 139.8 | 143.9 | 148.1 | 152.7 | 155.7 | 158.6 | 161.1 | 164.5 | 167.0 | 168.4 | 169.7 | 170.2 | 170.2 | 170.4 | 170.7 | 171.3 | 174.9 | 173.1 | 167.6 | 158.6 | 148.7 | 139.4 | 129.8 | 122.5 | 114.1 | 108.8 | 106.3 | 103.3 | 99.9 | 98.8 |
| DEPTH TO BEDROCK | 44 | 32 | | 33 | 37 | 38 | 46 | 37 | 50 | 42 | 33 | 36 | 32 | 28 | 28 | 18 | 28 | 24 | 19 | 28 | 28 | 24 | 25 | 25 | 18 | 38 | 27 | 28 | 27 | 36 | 27 | 15 |

(17,000) Seismic Velocity in ft./sec.

MOLLE STREET AND ANGLESEA BARRACKS

# PLAN AND SEISMIC CROSS-SECTION

SCALE IN FEET

100 0 100 200 300

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| SURFACE LEVEL | 129·2 | 133·9 | 141·0 | 147·3 | 153·9 | 158·9 | 162·9 | 166·6 | 170·8 | 173·1 | 173·9 | 176·0 | 178·6 | 180·0 | 180·1 | 178·5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEPTH TO BEDROCK | 51 | 54 | 54 | 60 | 64 | 64 | 64 | 69 | 70 | 72 | 72 | 76 | 73 | 79 | 82 | 79 |

| SURFACE LEVEL | 178·6 | 176·7 | 174·7 | 172·3 | 169·1 | 164·7 | 159·9 | 153·6 | 147·0 | 138·7 | 127·5 | 115·3 | 109·9 | 106·2 | 102·1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEPTH TO BEDROCK | 82 | 85 | 85 | 90 | 85 | 90 | 87 | 78 | 78 | 70 | 66 | 60 | 63 | 67 | 48 |

(10,000) Seismic Velocity in ft./sec.

SCALE IN FEET

100 0 100 200 300

GORE STREET TO FITZROY GARDENS

# PLAN AND SEISMIC CROSS-SECTION

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