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SEISMIC TESTS FOR WATER TABLE MEASUREMENT, COBRAM AREA, VICTORIA

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Plate I. (G113-1) Portion of Murray Valley Irrigation District, showing location of seismic tests.

Plate 2. (G113-2) Time versus distance graphs of seismic recordings.

Plate 3. (G113-3) Vertical sections showing seismic results and measured height of standing water.

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I. INTRODUCTION

At the request of the State Rivers and Water Supply Commission of Victoria, seismic tests using the refraction method were conducted over six well locations near Cobram in the Murray Valley Irrigation District of Central Northern Victoria. The purpose of the tests was to determine whether the depth of the water table in that area could be measured by seismic refraction methods.

The problem of rising water tables is one which occurs commonly in irrigation districts. In some areas the problem in purely a local one in which only perched water tables, say within ten feet of the surface, are involved, but it is also possible that the level of the general water table over a large area may be raised by deep percolation. The State Rivers and Water Supply Commission have maintained a check on the water table depth in the Murray Valley Irrigation District for some time by measurement in existing wells. These wells are not necessarily in the best positions, and some are falling in. The seismic method was considered as an alternative to expensive test boring for ground water measurement.

II. TOPOGRAPHY AND GEOLOGY.

The Murray Valley Irrigation District covers 269,000 acres of land extending westward from Cobram for a distance of some 40 miles to Picola, and is bounded by the River Murray on the north and the Broken Creek to the south. The area is a plain with negligible topographical relief apart from an average fall of about 2 feet per mile from east to west.

Little is known about the underlying rocks in the Cobram area because of the scarcity of reliable bore data. At Oaklands, approximately forty miles to the north east in New South Wales, many bores have been sunk by the Water Conservation and Irrigation Commission. The shallow sediments consist of flatlying alternating beds of sands, gravels, and clays, believed to be of Tertiary age. In each bore, water was struck and rose to a static level, indicating that it had been confined in a pervious aquifer under pressure. In some bores, several aquifers were encountered.

More recently, bores sunk at Katunga Soldier Settlement Area, fourteen miles south-west of Cobram, encountered alternating beds of sands, gravels and clays, and water flows at various depths. It is reasonable to assume that the geological section at Cobram is similar to that At Oaklands and Katunga.

III. SEISMIC METHOD AND APPLICABILITY TO PROBLEM.

The seismic method of subsurface exploration is based on the contrast in velocities of wave propagation through different kinds of rocks in the earth's crust. The properties of a rock which determine the velocity of a compression wave within it are its density and elastic moduli. The seismic waves undergo refraction and reflection at any interface between two different types of rock characterised by different velocities of propagation.

The seismic method employed for shallow depth determinations is the refraction method. A small amount of explosive is placed at a depth of approximately two feet below the surface. Geophones are set in the ground at measured distances along a straight line from the shot point. The detonator for the shot and the geophones are electrically connected to photographically recording galvanometers. This enables the shot instant and the times of arrival of the first wave disturbance at each geophone to be recorded on a film, with a time scale controlled by an electrically driven tuning fork.

Consider a number of layers, where each successively deeper layer has a higher velocity than the layer above it. The first wave disturbances to reach the geophones near the shot point will be those which have travelled directly through the first layer of low velocity. At a certain distance from the shot point, the first arrivals at the geophones will be those waves which have travelled down through the first layer, been refracted along the interface of the first and second layer with a velocity of the second layer, and returned to the surface again. Geophones still further away will receive their first arrivals from waves refracted from deeper interfaces with higher velocities and so on.

The travel times of the waves are plotted against distance of the geophones from the shot point as shown in Plate 2. The slopes of the curves represent the characteristic velocities of the layers and the depths to the refracting horizons are calculated from the discontinuities in the curves.

Many factors, such as moisture, texture, compaction, void space, and cementation, contribute to the elastic properties of sedimentary rocks. Sediments which lie above the natural ground water level usually exhibit lower velocities than similar sediments beneath that level. Previous investigators have observed that in certain areas, the velocity contrast is great enough in otherwise uniform sediments to enable the depth of the water to be determined accurately by seismic refraction methods.

In California, Rieber observed distinct breaks in near-surface travel-time curves on the ground water. (Heiland, 1940, p.475).

Shepard (1939) states that it is often possible to determine the elevation of the water table in silty or sandy soil by an abrupt change in velocity from normally low values in the upper strata to values of 6000 to 7000 f.p.s. On two sand beaches at Hampton, New Hampshire, a velocity of 2300 f.p.s. above sea level, and velocities from 4500 to 5600 f.p.s. below sea level were recorded. Supersaturated porous soils such as mucks, silts, and sands appear to exhibit velocities comparable to that of water itself, about 5000 f.p.s. However the physical properties of well compacted clays are such that even well below the saturation point, they frequently exhibit velocities of 4500 to 6000 f.p.s.

Seismic surveys have shown that there is nearly always present a comparatively thin surface layer with a low velocity, generally between 2,000 and 3,000 f.p.s. Lester (1932) states that the low velocity of this layer is a function of the amount of aeration of the shallow layers. He produces theoretical curves to show the change in velocity with change in air-earth mixture. He concludes that there whe water table is sufficiently shallow, the thickness of the aerated layer is determined by the depth to the water table and an abrupt change in velocity at that depth can be expected. However if the water table is at a considerable depth, the bottom of the layer exhibiting the characteristic low velocity is determined by the depth to which any appreciable amount of air penetrates.

In a previous seismic refraction survey conducted by the Bureau at Oaklands to determine the configuration of deeper sediments, a velocity discontinuity from approx. 3000 f.p.s. to approx. 6000 f.p.s. occurring over most of the area was interpreted as the static water table because the bores showed no obvious lithological change of sediments and the depth to the water in the bores was of the order of the calculated seismic depth.

With these results in view, experimental tests were carried out in the Cobram area to compare the depths of velocity discontinuities with the observed depths of water in the wells.

IV. OUTLINE OF OPERATIONS.

The seismic party consisting of three geophysicists was engaged in the area from January 23rd to January 31st, 1952. Mr. A. Webster, a Research Officer of the State Rivers and Water Supply Commission, accompanied the party to locate the wells and study the technique of the operations.

Seismograms were recorded at six wells, using the Heiland 12 Channel Recording Equipment mounted in a truck. The locations of the wells where tests were made are shown in Plate No.1. Alongside each well two shots were fired. For the first shot, the twelve apache geophones were set at distances of 5, 10, 15, 20, 30, 40, 60, 80, 100, 120, 140 and 160 feet from the shot point. For the second shot, the geophones were set at distances of 140, 160, 180, 200, 220, 240, 280, 320, 360, 400, 450 and 500 feet from the shot point. The explosive charges were laid about two feet below the surface of the ground for each shot.

V. RESULTS OF TESTS.

From the recorded seismograms, the time-distance graphs shown in Plate No.2 were drawn. Velocities of the layers and depths to successive refracting horizons have been calculated.

These are shown on the time-distance graphs and are listed in Table I below:-

TABLE I

WELL NO.	WELL-WATER DEPTH	VELOCITY OF LAYER	DEPTH TO BOTTOM OF LAYER
59/2	74-feet	1180 f.p.s. 2350 5150	9 feet 56 -
27/3	81-feet	1000 f.p.s. 3175 5425	8 feet 105 -
13/2	36-feet	1800 f.p.s. 4950	59 feet -
11/1	45-feet	1000 f.p.s. 1800 2800 5450	3 feet 28 87 -
5/1	47-feet	1200 f.p.s. 2130 5650	7 feet 73 -
4/2	26-feet	1475 f.p.s. 2150 6500	14 feet 80 -

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The layers and their velocities shown by the seismic tests at the four wells 59/2, 27/3, 5/1 and 4/2 are probably representative of the area. These show a layer of surface soil from 3 to 14 feet thick with a velocity of 1000 to 1475 f.p.s. The second layer ranges in velocity from 2130 to 3175 f.p.s. and the third layer, from 4950 to 6500 f.p.s. At well 11/1, an additional layer of 1800 f.p.s. underlies the soil layer; at well 13/2 a layer with velocity of 1800 f.p.s. extends from the surface down to a depth of 59 feet.

However, in each of the six tests a definite discontinuity is recorded (represented by the greatest depth shown in Column 4 of Table I), which marks the upper boundary of the layer with characteristic velocity between 5000 and 6000 f.p.s. At this interface, there is an increase in velocity of about 3000 f.p.s. at each well. In view of the work of previous investigators, this increase in velocity is of the order of the change which would be expected between the layer above the water table and the saturated layer below it, and in the absence of other control data would be accepted as indicating the water table. This was the assumption made in the interpretation of the results of the seismic survey at Oaklands. Table 2 below shows the depth of this discontinuity compared with well-water depths at Cobram.

WELL NO.	WELL-WATER DEPTH	DEPTH OF SEISMIC DISCONTINUITY.
59/2	74-feet	56-feet
27/3	81	105
13/2	36	59
11/1	45	87
5/1	47	73
4/2	26	80

At all six wells there are discrepancies between the well-water depths and the seismic depths. In five wells, the seismic depth is considerably greater than the well-water depth. In the sixth well, the seismic depth is less. If the depth of water measured in the wells represents the true depth of the water table, it appears that the seismic discontinuity has no relation to the water table.

VI. DISCUSSION OF RESULTS.

The seismic discontinuity with increase of velocity from approx. 3000 f.p.s. to approx. 6000 f.p.s. is similar to that observed at Oaklands, where the discontinuity was assumed to represent the water table. The interpretation of this discontinuity was not important for the purpose of the Oaklands survey but it is relevant to the discussion of the Cobram results.

A more detailed examination has been made of bore information and seismic results at Oaklands. Table 3 below shows the comparison between seismic discontinuities and the depths of water in neighbouring bores. The depths of water indicated are average values at a seismic shot point interpolated from the depths in the bores around that point. The seismic discontinuity is an increase in velocity from about 3000 f.p.s. to 6000 f.p.s. A correction has been applied to the depths previously calculated. This was done because no account had been taken in the travel times of the low velocity soil horizon at the surface. Based on the results at Cobram, a soil layer of thickness five feet and velocity 1100 f.p.s. has been assumed over the Oaklands area. This involves a subtraction of 6 to 10 feet from the depths calculated without this correction.

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TABLE 3

SHOT POINT	DEPTH TO SEISMIC DISCONTINUITY	CORRECTED SEISMIC DEPTH	AVERAGE BORE WATER DEPTH	
			Struck at	Rose to
No. 9	138-feet	130-feet	191-feet	127-feet
12	145	136	150	116
15	165	157	180	133
16	148	140	170	130
19	190	180	175	146
20	266	256	175	140
21	159	151	170	130
25	125	118	194	138
26	115	108	194	138
32	135	126	135	93
33	132	124	120	98
34	129	121	124	100
37	126	118	156	126
38	153	145	156	123
40	103	96	118	95
41	91	84	117	90
48	173	163	114	93
49	160	150	122	91
50	86	79	97	79
51	102	95	97	79
56	144	136	141	120
57	136	128	141	120
E	132	124	142	132
F	140	132	142	132

This comparison shows that at fifteen of a total of twenty four short points, the corrected seismic depth is considerably greater than the static level of the water in the bores, at two points it is less; at seven points there is reasonably good agreement, with a discrepancy between 0 and 8 feet.

When the seismic depths are compared with the depths at which water bearing aquifers were struck in the bores, it is found that at 12 bores, the seismic depth is considerably less; at 3 bores it is considerably greater; and at 7 bores there is reasonably good agreement with a maximum discrepancy of 10 feet. The seismic depths compare as favourably with the depths of the aquifers as with the depths of standing well water. There is a similarity between the results of Cobram and those at Oaklands, namely that in the majority of cases, the seismic depth exceeds the depth of standing water in the well.

It is difficult to arrive at an entirely satisfactory explanation for the disagreement between the siemic results and the depths of water in the wells in the Cobram area without detailed information on the subsurface formations. The possibility of a lithological discontinuity to account for the observed abrupt change in velocity must be considered. At Oaklands there is no evidence in the bore logs of a distinct change of sedimentary types sufficient to produce the increase in velocity at the depths indicated by the seismic results. Alternating beds of sands, gravels and clays are logged from the surface down to the bottom of each bore. All these sediments are believed to be of Tertiary age. At Cobram no such bore information is available but the section is probably similar to that at Oaklands. There is a necessity for detailed bore logs in the Cobram area to decide whether the seismic discontinuity is due to a lithological change.

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Another question which arises is whether the depth of water in the wells represents the level of free ground water. At Oaklands, the water is known to occur in aquifers and under some pressure causing it to rise when struck in the bores. The static reduced level to which it rises is not uniform over the whole area. Mr. Martin of Naaia, a well-sinker who has been engaged in the Cobram area for many years, stated that in his experience, over the Cobram area generally there exist three bands of water, one at 40 - 50 feet approx., the second at 90 feet approx., and a third at 135 feet approx. These bands are about 10 feet thick, and water tapped in the lowest bed (135 feet) rises to 90 feet in the bore. No hard beds of rock were encountered in the sinkings at least to 135 feet, and in one location to 240 feet. The above evidence strongly suggests that at both Oaklands and Cobram the underground water is wholly or partly confined to pervious layers by underlying and overlying impervious formations. Water confined in a pervious bed will rise when struck by a bore to a level depending on the hydraulic gradient between the intake level of the bed and the discharge level. Hence the depth of standing water in the wells may not represent the level of a free water table and this could account for the absence of a marked increase in seismic velocities at that level. It is probably only in a pervious formation with the free water table marking a definite upper limit to the zone of saturation that an abrupt increase in velocities could be expected at the same level as the standing water in the wells. It also follows that if the section includes more or less impervious formations, it is unlikely that the observed seismic discontinuity will be due to a free water table existing at a level below that of the water in the wells. These considerations tend to support the earlier suggestion that the seismic velocities recorded at Cobram are determined by the lithology rather than by the presence of ground water.

VII. SUMMARY AND CONCLUSIONS.

Seismic refraction tests were conducted over six wells in the Cobram area of the Murray Valley Irrigation District to determine whether the depth of the water table could be measured by seismic methods. The calculated depths of the seismic discontinuities recorded were considerably greater than the depths of water in the wells in 5 of the six tests.

Possible explanations for the discrepancies are :-

(1) Seismic discontinuities are due to lithological changes and not to water table.

(2) The well-water depth does not represent the true water table depth, but is the static level to which confined water rises in the wells.

A satisfactory interpretation of the seismic results will be possible only when a detailed geological section is available. As the observed seismic discontinuity bears no relation whatever to the level of standing water in the wells, it is clear that the seismic refraction method cannot be used in place of the test wells and bores as an alternative method for studying the changes of the ground water level in the irrigation area.

Melbourne April 22nd, 1952.

- R E F E R E N C E S -

Heiland, C.A., 1940 - GEOPHYSICAL EXPLORATION, Prentice-Hall, New York.

Lester, O.C., 1932 - Seismic weathered or aerated surface layer, A.A.P.G. Bull., 16 (12), 1230-1234.

Shepard, E.R., 1939 - Seismic method of exploration applied to construction projects, Military Engineer, Sept-Oct. 1939.

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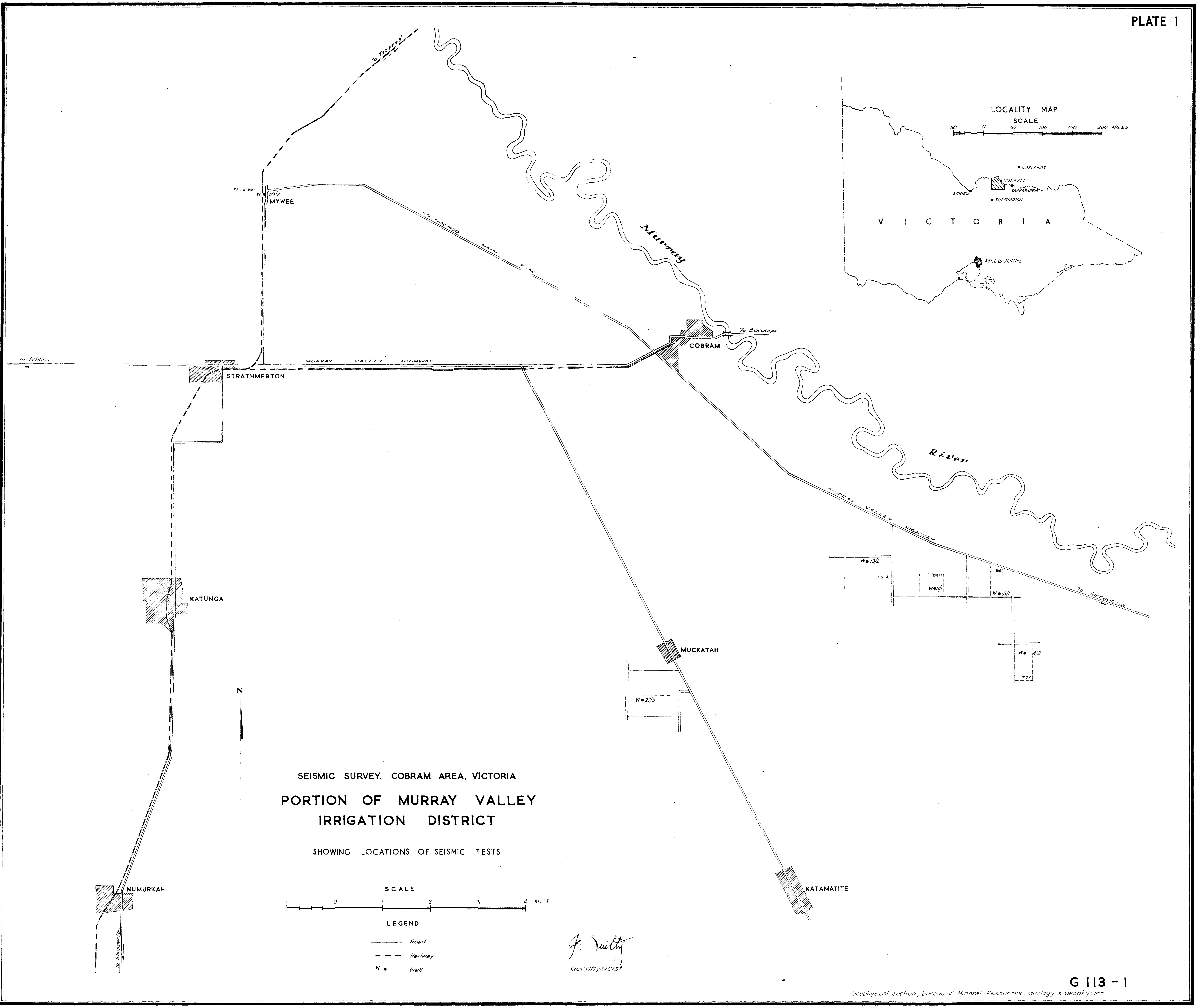


PLATE 1
To Tocumwal
Shire Wel
W 59/2
MYWEE
KOONOOMOO MAIN ROAD
Murray
River
To Barooga
COBRAM
To Echuca
STRATHMERTON
MURRAY VALLEY HIGHWAY
MURRAY VALLEY HIGHWAY
To Yarrawonga
W 13/2
112 A
62 B
W 11/1
84
W 5/1
W 4/2
77A
W 27/3
KATUNGA
MUCKATAH
KATAMATITE
NUMURKAH
To Shepparton
N
LOCALITY MAP
SCALE
50 0 50 100 150 200 MILES
OAKLANDS
COBRAM
YARRAWONGA
ECHUCA
SHEPPARTON
VICTORIA
MELBOURNE
SEISMIC SURVEY, COBRAM AREA, VICTORIA
PORTION OF MURRAY VALLEY
IRRIGATION DISTRICT
SHOWING LOCATIONS OF SEISMIC TESTS
SCALE
1 0 1 2 3 4 MILES
LEGEND
Road
Railway
W • Well
Geophysicist
G 113 - 1
Geophysical Section, Bureau of Mineral Resources, Geology & Geophysics

PLATE 2

SEISMIC SURVEY, COBRAM AREA, VICTORIA

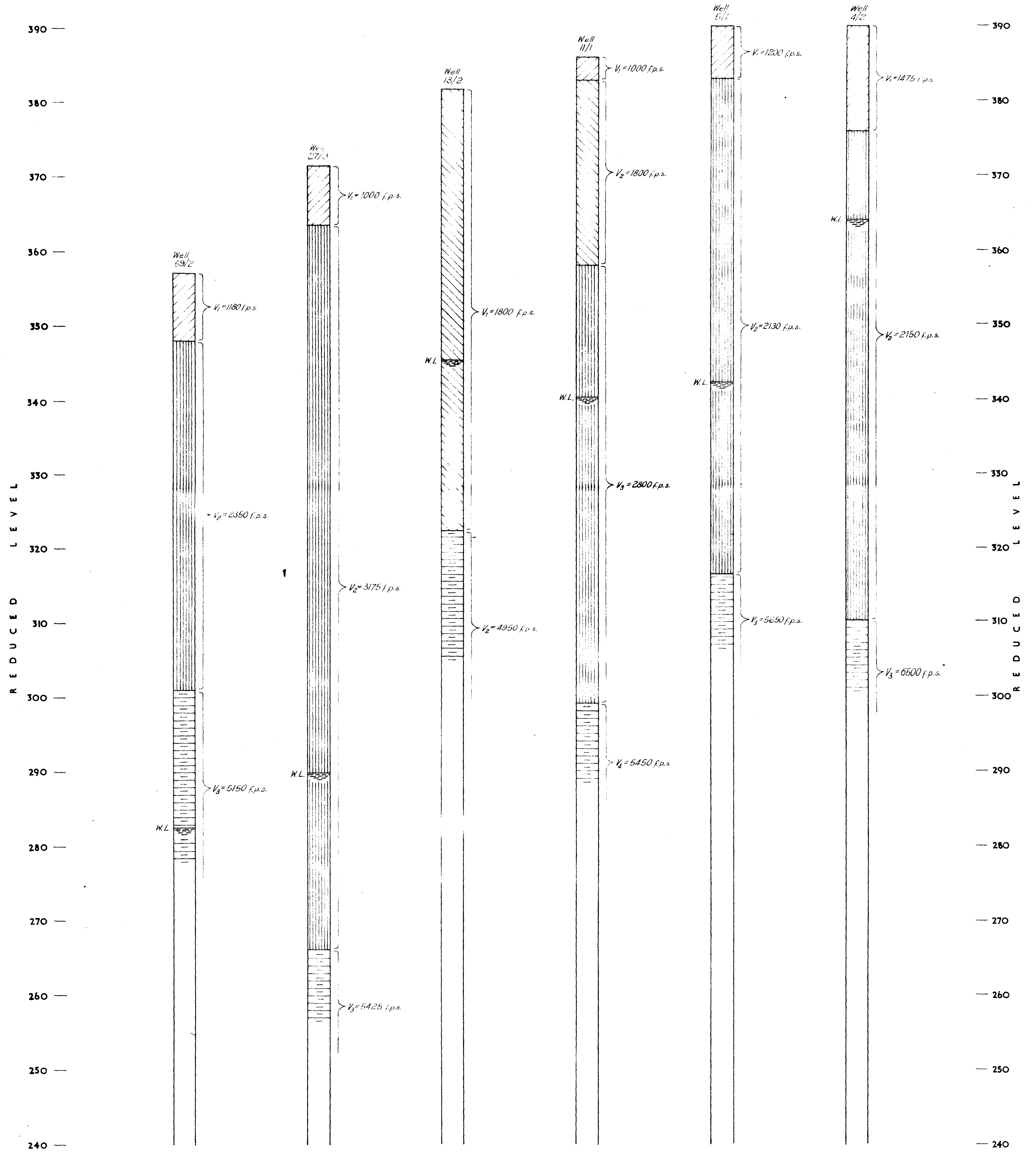
TIME VERSUS DISTANCE GRAPHS OF SEISMIC RECORDINGS

Geophysicist

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics.

G 113-2

PLATE 3



REFERENCE

Velocities:
1000-1500 f.p.s.
1800 "
2100-3200 "
Over 4900 "
Water Level

SEISMIC SURVEY, COBRAM AREA, VICTORIA

VERTICAL SECTIONS SHOWING SEISMIC RESULTS AND MEASURED HEIGHT OF STANDING WATER

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G 113-3