DEPARTMENT OF MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1974/3

TUGGERANONG URBAN DEVELOPMENT AREA, SEISMIC REFRACTION AND RESISTIVITY SURVEYS, A.C.T., 1971 - 1972

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SUMMARY

Seismic refraction and resistivity work has been used to investigate aspects of the geology of the proposed Tuggeranong urban development area. At the site of the proposed town centre, up to 15 m of highly weathered and rippable bedrock material is present. This will have to be taken into account in the foundation designs of large buildings. Seismic refraction and resistivity investigations of an extensive colluvial fan in the Tuggeranong South area revealed up to 37 m of colluvium; depths to fresh bedrock are as much as 52 m.

Resistivity-traversing and depth-probing in the Isabella Plains area of Tuggeranong North indicated a bed of clay underlain by a compact, slightly weathered bedrock high. The presence of these features contributes to high water-tables and development of swampy conditions in the lower part of the Isabella Plains watershed.

1. INTRODUCTION

The Bureau of Mineral Resources (BMR) has been requested by the National Capital Development Commission to conduct a geological and geophysical investigation of the proposed Tuggeranong urban development area. The northeastern part of the urban development area around Isabella Plains has problems of low drainage slopes and high water-tables with occasional development of swampy conditions owing to the presence of a subsurface barrier to natural underground drainage. Resistivity traversing and three depth probes were carried out to attempt to determine the nature of the drainage barrier.

General foundation conditions and weathering and soil profiles were investigated over selected areas as outlined below:

(1) A deep alluvial fan in the southern part of the area was investigated by seismic refraction and resistivity depth probing.

(2) Four sites over the area of the proposed town centre were investigated by seismic refraction.

(3) Seismic refraction was carried out on two sites on the west bank of the Murrumbidgee River.

(4) A drainage divide between the northern and southern urban areas on the side of Mount Stranger was also investigated by seismic refraction.

A total of 11 sites was investigated by seismic refraction. A geophysical party consisting of G.R. Pettifer (party leader), I.D. Bishop (geophysicist), S. Hall (field assistant), and two field hands conducted the survey during August 1971 and April-July 1972.

2. GEOLOGY

The geology of the Tuggeranong urban development area has been described by several authors (Gardner, 1968; Jackson, 1970; and Rossiter, 1971). Plate 1 shows the bedrock geology and location of traverses. The bedrock in the area consists of dacitic to rhyolitic welded tuffs of Silurian and Devonian age. Southeast of the survey area the Tuggeranong Granite crops out.

The geological strike in the area varies from 320° to 360° (true bearing), and several faults have been mapped. Extensive alluvial deposits have developed in the Isabella plains area (Plate 4) producing a large, gently sloping catchment area drained by Tuggeranong Creek. Surface stream-flow diminishes at the top of the alluvial fan and the water drains underground through the more permeable layers of the alluvium. At the western edge of the Isabella Plains the water-table is almost at the surface and occasionally swampy conditions develop indicating the presence of a subsurface impermeable barrier to the flow of underground water.

In the southern urban development area a large colluvial fan extends from the Tuggeranong Granite outcrop north to the Murrumbidgee River near Point Hut Crossing. A fault that may occur between the Silurian and Devonian volcanics is mapped as passing beneath this colluvial fan; however, the exact position of the fault is obscured by the colluvium.

3. EQUIPMENT AND METHODS

For the seismic refraction work the standard BMR 24-channel refraction seismograph (Dresser SIE Co.) and 20 Hz geophones (Technical Instruments Co.) were used. Each seismic spread consisted of 23 geophones with reciprocal geophones placed 50 to 100 m off each end of the spread. The geophone spacings used were 1 m, 2 m, and 4 m giving spread lengths of 22, 44, and 88 m respectively. The smaller spacings were used in an attempt to resolve possible thin layers above bedrock. The four-metre spacings were used to give bedrock profiles over the site of the proposed town centre. Shots were fired at the centre and ends of each spread. Shots were also fired 15 and 30 m off each end of the 22-m spreads and 50 to 100 m off each end of the 44-m and 88-m spreads.

Using a Megger Earth Tester (Evershed and Vignoles), resistivity work was undertaken in the Isabella Plains, where three resistivity depth probes were carried out with the standard Wenner electrode configuration (Heiland, 1946). In this method of depth-probing, four electrodes are arranged in a line with a spacing, 'A', between adjacent electrodes. A current, I, is passed through the two outer electrodes and a potential difference, 'ΔV', is measured between the two inner electrodes. The ratio $\frac{\Delta V}{I}$, or the apparent resistance 'R', is measured directly by the Megger Earth Tester and the apparent resistivity, ρ, is equal to $2\pi AR$. The electrode spacing is varied from small to larger spacings to obtain increasingly deeper penetration. The field results are plotted as log-log plots of resistivity versus electrode spacing, and are interpreted using standard 2-layer and 3-layer curve-matching techniques. In general this depth-probing technique can resolve only those subsurface layers which have a thickness similar to the depth to the layer. Two depth probes were carried out initially, and from the interpreted results a resistivity-traverse spacing of 15.2 m (50 ft) was adopted. The Wenner configuration was used and readings were taken every 15.2 m (50 ft) along the traverse. A total traverse length of 793 m (2600 ft) was covered. A resistivity high revealed by the traversing was further investigated by depth probes. Water samples were taken and their resistivities were measured as an aid to interpretation.

Four resistivity depth probes (Sites 5 to 8, Plate 1) were carried out to supplement the information obtained from the seismic refraction work over the alluvial fan area in the south of the urban development area. Owing to the very deep weathering in that area, the available resistivity equipment (BMR resistivity-meter ERR-1 and Megger Earth Tester) did not have sufficient power to detect bedrock and gave information only on the near-surface layers.

The seismic and resistivity traverses were located by magnetic compass bearings on local survey trigonometrical stations.

4. SEISMIC REFRACTION RESULTS

Plates 2 and 3 show the seismic refraction results.

Sites 1, 2, 3, and 4 (Plate 2) were investigated with geophone spacings of 1 and 4 m to give general coverage of the proposed town centre. The results indicate that reasonably uniform foundation conditions occur over the area of the town centre. Table 1 summarizes the interpreted geological significance of the main seismic velocity layers detected over the site of the town centre.

TABLE 1

Velocity (m/sec)	
300 - 1000	Soil (including totally weathered bedrock)
1100 - 1700	Highly weathered bedrock
2000 - 2500	Weathered bedrock
4300 - 5000	Fresh bedrock

Soil and highly weathered bedrock was detected by the 1-m-spacing spreads to be between 1.5 and 9 m thick. Underlying this, over most of the sites investigated, is a highly weathered bedrock layer with thickness ranging up to 15 m. The seismic veolocity of this layer (1100 - 1700 m/sec) suggests that the highly weathered bedrock in the lower range (1100 - 1500 m/sec) could be ripped with an excavator which has a ripping capability similar to a D-9 bulldozer (Caterpillar Tractor Co., 1966). The presence of the highly weathered bedrock layer may affect the design of the foundation of large multistorey buildings on the site of the town centre (Gardner, 1968). However, the upper limit of the 1100 - 1700 m/sec range should be good foundation material. Over most of the sites investigated a weathered bedrock layer (2000 - 2500 m/sec) was not detected. Weathered bedrock may underlie the area, but appears to be too thin to be detected by seismic refraction. Fresh bedrock depths were detected as varying from 12 to 22 m.

Sites 5, 6, 7, and 8 investigated the colluvial fan south of Point Hut crossing in the southern urban development area. The results are presented schematically with resistivity data in Plate 3 (note the difference in vertical scales). Resistivity probing did not reach bedrock (see resistivity results 5.1).

Site 5 is located at the top of the colluvial deposits close to mapped outcrop of the Tuggeranong Granite. The results are interpreted as showing a possibly slightly indurated soil layer (750 m/sec), 4 m thick, overlying either an indurated or highly weathered bedrock layer (1700 m/sec). Weathered bedrock (3100 m/sec) is interpreted as occuring at 13 m; the relatively high velocity suggests it has a low degree of weathering. Fresh bedrock (4300 m/sec) occurs at 29 m.

At Site 6 the results indicate 0.7 m of soil (400 m/sec) overlying colluvial material (1350 m/sec), which appears to be thicker than at Site 5. Weathered bedrock (2200 m/sec) occurs at 17 m, and is interpreted as being 35 m thick, with fresh bedrock (4400 m/sec) occuring at 52 m. The lower velocities (2200 - 2400 m/sec) of weathered bedrock at Sites 6 and 8 compared with the 3100 m/sec velocity of weathered bedrock of Site 5 suggest a greater degree of weathering in the lower regions of the alluvial fan. The very deep weathering of bedrock below Site 6 may be a result of the closer proximity of this site than the other sites to the fault (position uncertain, Plate 1) between the Devonian and Silurian volcanic tuffs.

Site 7 results are interpreted as showing a thicker (4 m) development of alluvial soil cover (400 m/sec) and alluvial material (1400 m/sec) near the centre of the colluvial fan. The alluvium is up to 37 m thick in the area of Site 7 and appears to directly overlie fresh bedrock (5600 m/sec). The 2000-2500 m/sec, slightly weathered bedrock is either absent or too thin to be detected beneath the extensive thickness of the 1400 m/sec material. If a weathered bedrock layer is present it may be up to 16 m thick; then the depth of alluvial deposits would be reduced to 26 m, and fresh bedrock depth would occur at 42 m.

Site 8 is located close to weathered volcanics outcrop near the base of the colluvial fan. The interpretation shows a thin alluvial soil (350 m/sec) overlying a slightly indurated soil (750 m/sec), which is possibly derived from the nearby rock outcrop. No colluvial layer (1300 - 1700 m/sec) was detected, and weathered bedrock (2400 m/sec) is interpreted as occuring at 6.5 m. Fresh bedrock depth is 28 m.

Site 9 results (Plate 2) reveal alluvial soil cover (300 - 350 m/sec), generally 0.5 m thick, overlying possibly slightly indurated soil of 700 m/sec velocity. Weathered bedrock (2000 m/sec) occurs at 2 m. At depths of 5 to 11 m a layer of velocity 3300 m/sec occurs; it is interpreted as slightly weathered bedrock. Fresh bedrock depths range from 12 to 18 m.

Sites 10 and 11 (Plate 2) investigated the western bank of the Murrumbidgee River near Pine Island. The interpretation indicates a deeper-weathering profile on the upper slopes (Site 11) in this part of the Tuggeranong west urban development area.

5. RESISTIVITY RESULTS

(1) Tuggeranong South area.

The resistivity results for Sites 5, 6, 7, and 8 over the colluvial fan are shown in Plate 3. The depth of penetration is at best about 14 m (Site 7). Very high near-surface resistivities are present at all the depth probes indicating dry surface conditions. The resistivity results provide better definition of near-surface layers.

(2) Isabella Plains area.

The location of the resistivity traverse and depth probed is shown in Plate 4. Plate 5 shows the resistivity traverse and depth probe results. Extensive augering was carried out over the area of Isabella plains by the Engineering Geology section of BMR (Vanden Broek & Kellet (in prep)) to find the path of natural underground drainage. Water samples taken from the auger holes have resistivities ranging from 10-40 ohm-m, biased toward the lower end of the range.

The auger results indicate that the alluvial deposits are a complex unconsolidated sequence of sand, silt, and clay. Knowing interstitial water resistivities, an estimate of the porosity of the alluvial material can be made from the in-situ resistivity measured by electrical depth-probing. The Archie Formula (Schlumberger, 1963), which relates porisity Ø (expressed as a fraction), resistivity of interstitial water Rw, and formation restivity R, is:

$$R = a \, Rw/\text{Ø}^2 \qquad (1)$$

where 'a' is an empirical constant which varies from 0.8 for unconsolidated sediments to 1 for hard or highly cemented rocks. This formula applies strictly only for sediments in which electrical conductivity arises from ionic conduction within the interstitial water. Where a rock or unconsolidated sand contains either interbedded or dispersed clay, the estimate of porosity obtained from the Archie Formula may be in error. Pure unconsolidated water-saturated clays have resistivities less than 10 ohm-m (Wiebenga & Jesson, 1962). Estimates of porosity contained in this report are based on the assumption of 100-percent water-saturation and absence of clay in the sediments.

The three depth probes probably reveal simple 3-layer situations, and all show a thin, high-resistivity surface layer underlain by 6 to 20 m of water-saturated unconsolidated alluvials. This in turn is underlain by a highly resistive layer, which, from augering results, is interpreted as weathered bedrock. The results are summarized in Table 2; calculated porosities assume Rw values of 10-40 ohm-m, with values of a=0.8 for water-saturated alluvium and a=1.0 for weathered bedrock. Table 2 shows the resistivity of the saturated unconsolidated alluvium layer for Depth Probe No. 2 as 10 ohm-m, which approaches that of saturated clays. The value of porosity calculated by equation (1) for this layer (Table 2) is physically impossible; thus, the assumptions on which the use of equations are based appear to be involved in this region. The alluvium layer is thus interpreted as predominantly clay in the region of Depth Probe No. 2. This suggests the presence of an impervious clay barrier within the alluvial cover.

The results also show a high-resistivity weathered bedrock in the area of Depth Probes 2 and 3. The resistivity traverse revealed a resistivity high in the same area extending over some 300 m and reflecting the rise in the highly resistive weathered bedrock. The high resistivity of the weathered bedrock in the areas investigated indicates low porosity compared with the overlying saturated alluvium.

Subsequent augering has shown that, within the alluvium overlying the weathered bedrock, highly impermeable clays occur, and these prevent the continuation of the water-flow within the alluvium. This effect coupled with the presence of a weathered bedrock high, as revealed by resistivity results, prevents escape of water from the Isabella Plains catchment by underground flow, and hence produces high water-tables and occasional swampy conditions.

6. CONCLUSIONS

The presence of up to 15 m of highly weathered bedrock over the proposed town centre of Tuggeranong may affect foundation design. Rock suitable for foundations is present at shallow depths in some places, but detailed seismic refraction investigations of the site of any major building within the town centre area is recommended. The weathered bedrock material is rippable up to 1500 m/sec, and few problems with excavation can be expected.

Up to 37 m of colluvium occurs in the colluvial fan of the Tuggeranong South area. Deep weathering of the bedrock beneath the colluvium has been detected with up to 35 m of weathered bedrock; depths of 52 m to fresh bedrock are estimated. The colluvial deposits thin from the centre of the colluvial fan both to the north and the south.

In the Isabella Plains area, a resistivity survey revealed an increase in content of clay in alluvium. The clay formed a natural barrier preventing the underground flow of water. Further work is advocated in this area.

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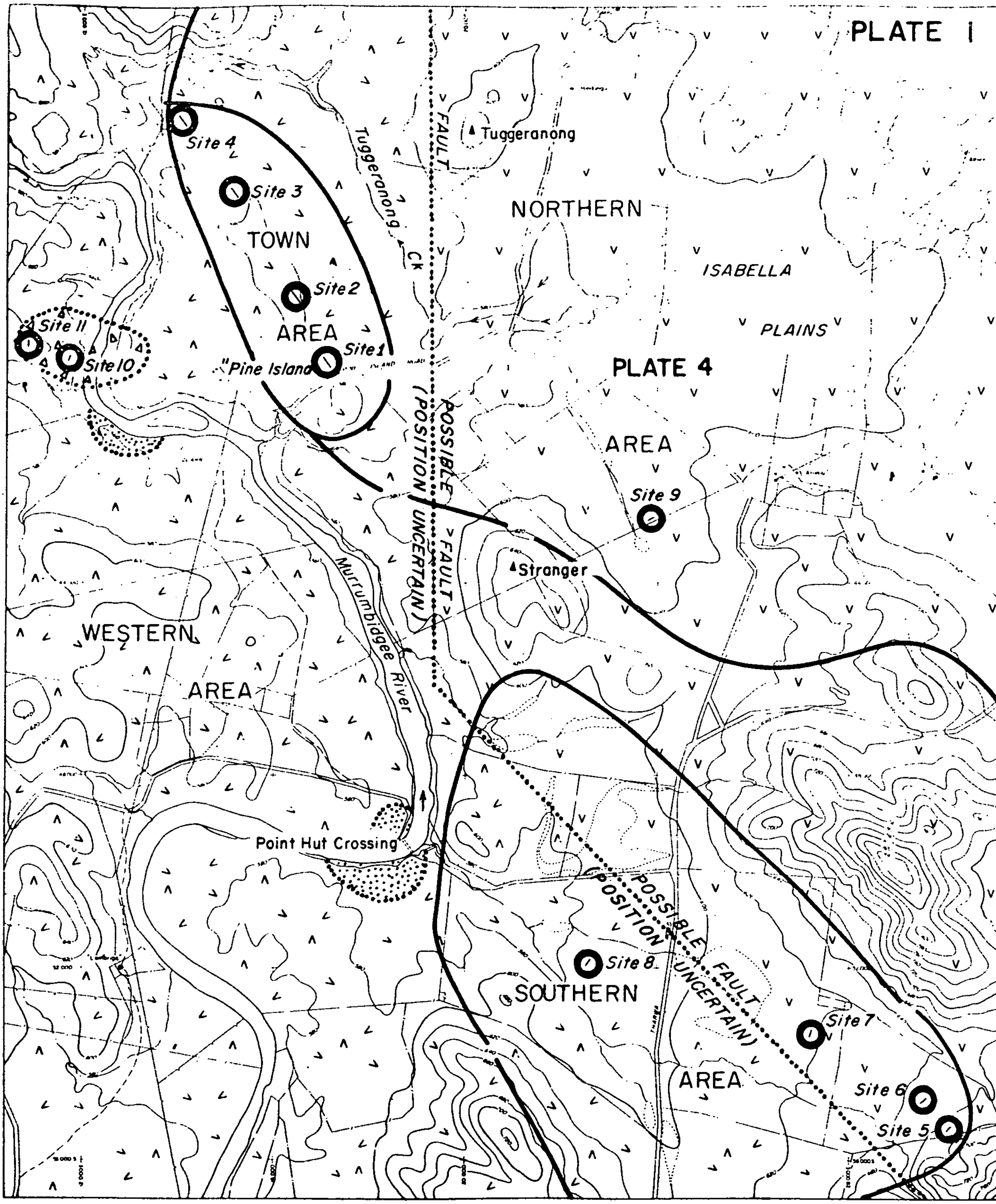
TABLE 2

Surface Elevation (a.s.l.)	Depth Probe No. 1 593 m			Depth Probe No. 2 586 m			Depth Probe No. 3 586 m		
	Resistivity (ohm m)	Thickness (m)	Caloulated Porosity (%)	Resistivity (ohm m)	Thickness (m)	Calculated Porosity (%)	Resistivity (ohm m)	Thickness (m)	Calculated Porosity (%)
Surface Layer	160	0.3	-	400	0.8	-	850	0.9	-
Water Saturated Alluvium	65	19.2	30-70	10	4.5	90(?)	40	4.8	40-90(?)
Weathered bedrock	65	-	39	240	-	20-40	600	-	12-26
Elevation of weathered bedrock surface a.s.l.		573 m			581 m			580 m	



GEOLOGY AFTER D.E.GARDNER (1968)
AND M.J.JACKSON (1970)

200 0 200 400 600 800 1000 1200 1400 1600 METRES
1000 0 1000 2000 3000 4000 5000 6000 FEET

CO-ORDINATES ARE IN FEET BASED ON STROMLO
TRIGONOMETRICAL STATION

LEGEND

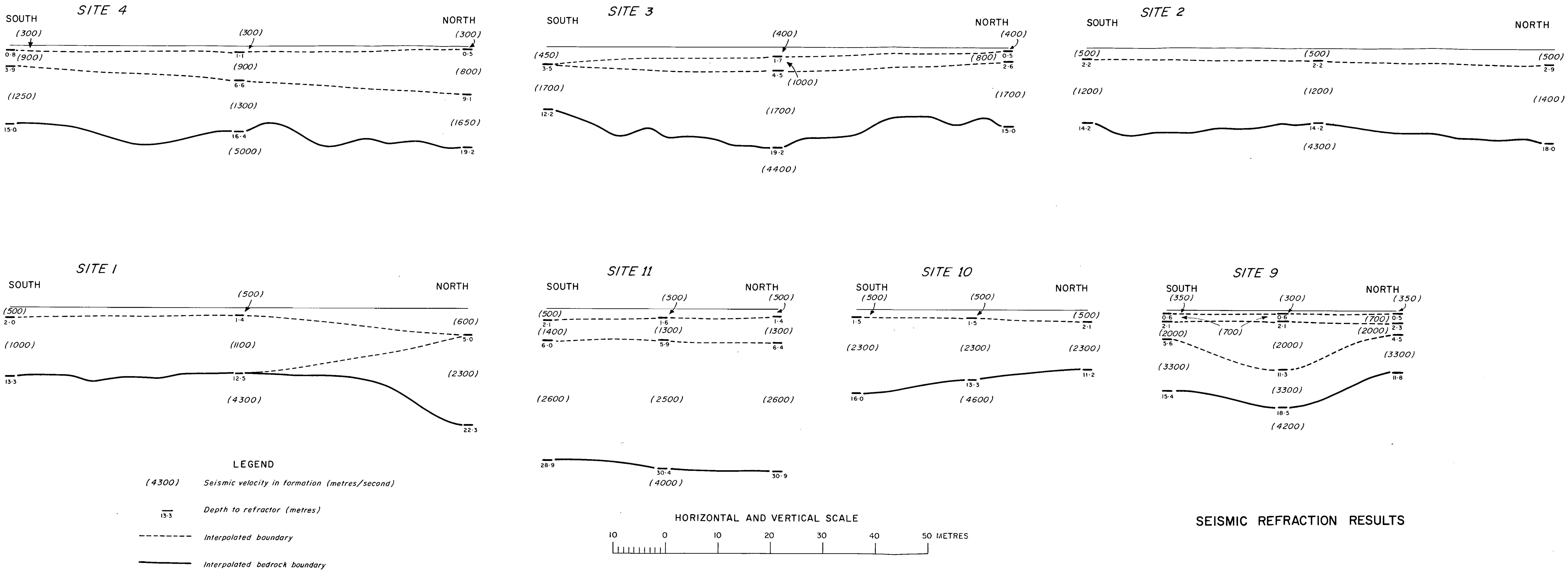
- STREAM
- FENCE
- TELEPHONE LINE
- POWER TRANSMISSION LINE
- MARSH BOUNDARY
- TRIG. STATION
- ROAD OR TRACK
- GEOPHYSICAL TRAVERSE
- 700 ELEVATION CONTOURS (METRES
- GEOLOGICAL BOUNDARY
- RHYOLITE TUFF
- VOLCANICS, MAINLY TUFFS
- SANDSTONES AND SHALES
- PORPHYRITIC RHYO-DLACITE

TUGGERANONG URBAN DEVELOPMENT
LOCALITY MAP

To Accompany Record No 1974/3

I55/B5-172A

PLATE 2



SEISMIC REFRACTION RESULTS

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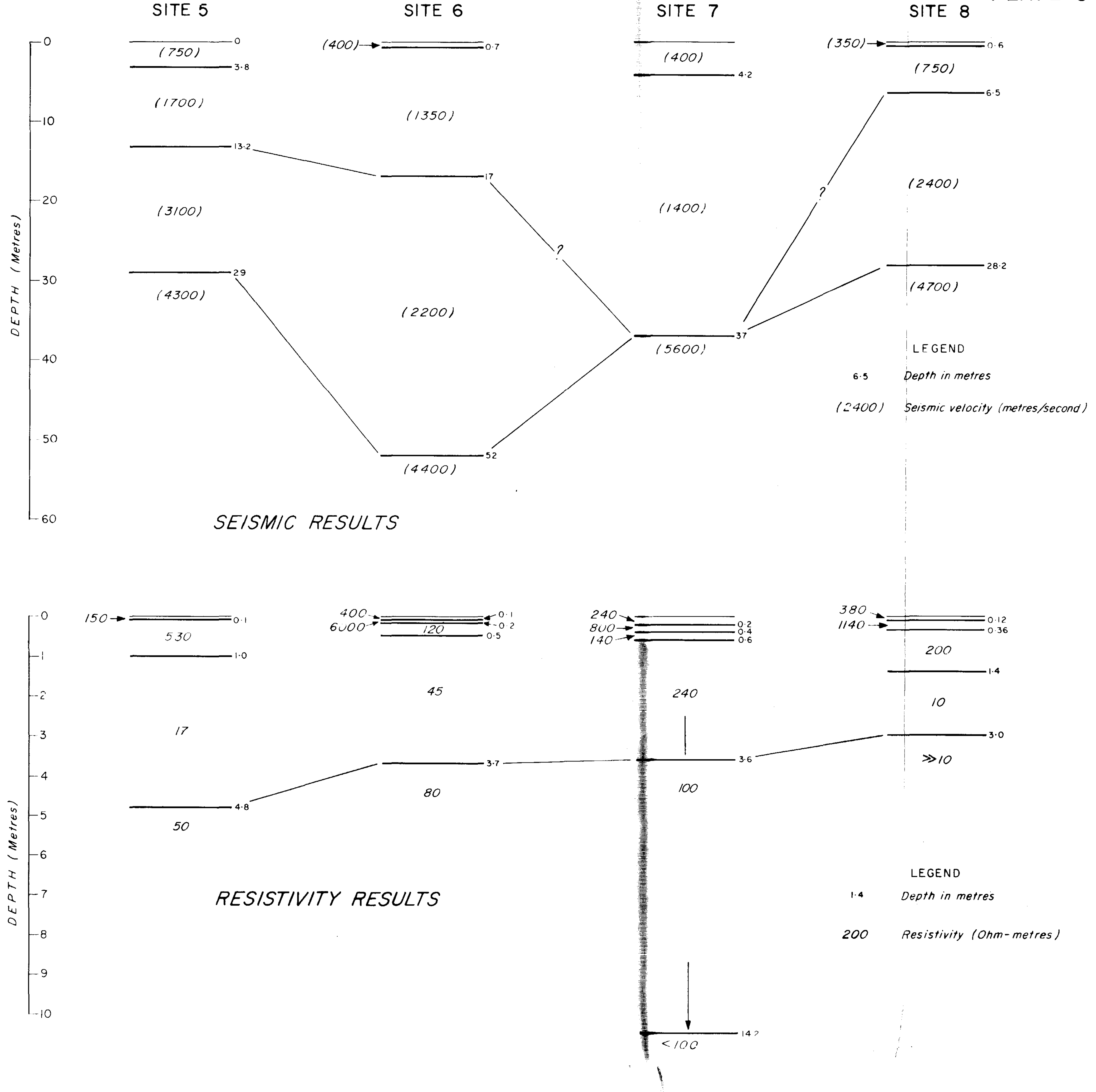
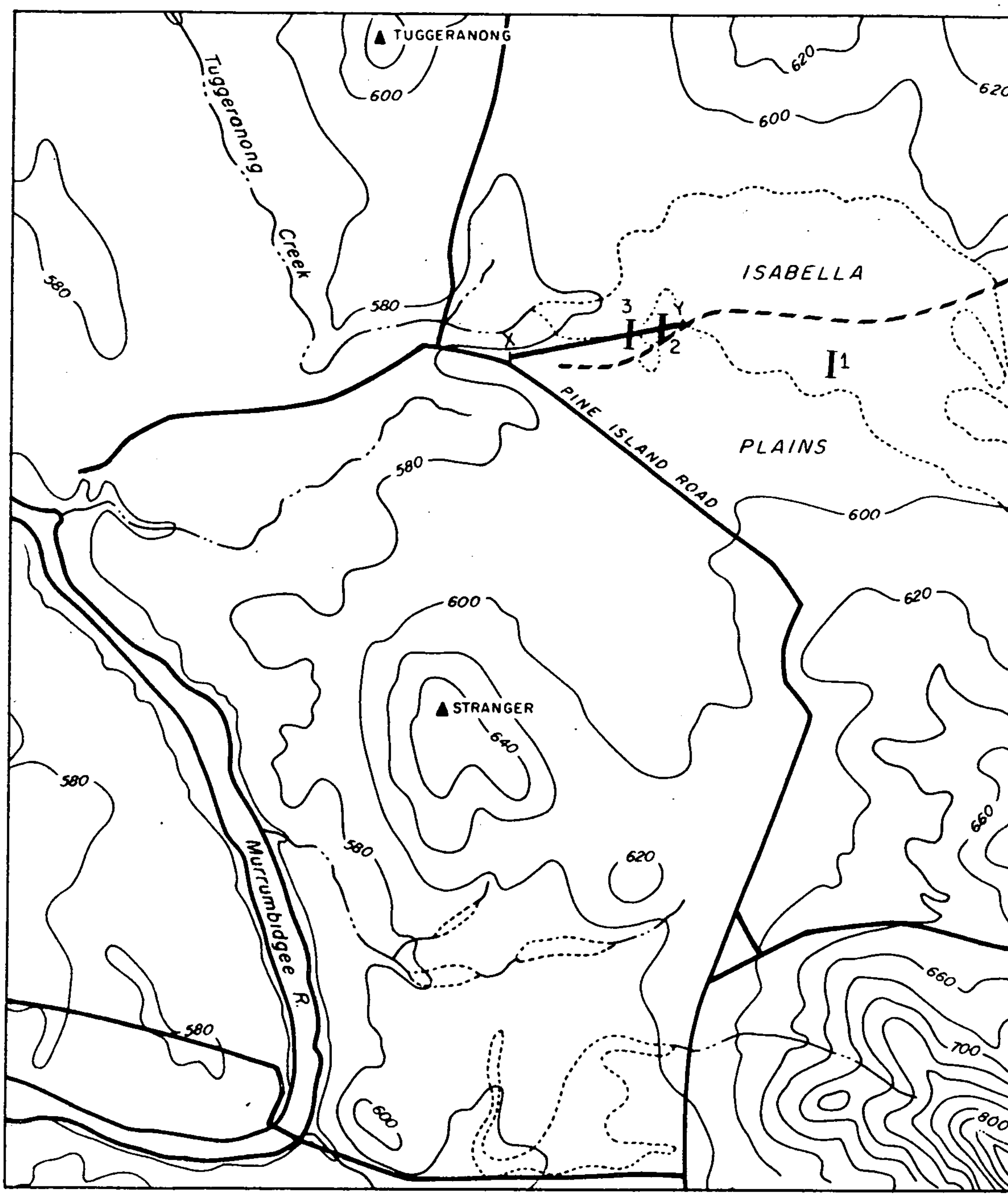
I55/B5-173

PLATE 3



SEISMIC REFRACTION AND RESISTIVITY INTERPRETATIONS

PLATE 4



200 0 200 400 600 800 1000 1200 1400 1600 METRES

1000 0 1000 2000 3000 4000 5000 6000 FEET

ISABELLA PLAINS.

LOCATION OF RESISTIVITY TRAVERSE AND DEPTH PROBES

LEGEND

ROAD	TRIG. STATION
STREAM	X—Y RESISTIVITY TRAVERSE
600 ELEVATION CONTOUR (METRES)	3 RESISTIVITY DEPTH PROBE
SWAMP BOUNDARY	PROPOSED LOCATION OF ARTERIAL ROAD

FOR LOCALITY MAP SEE PLATE 1

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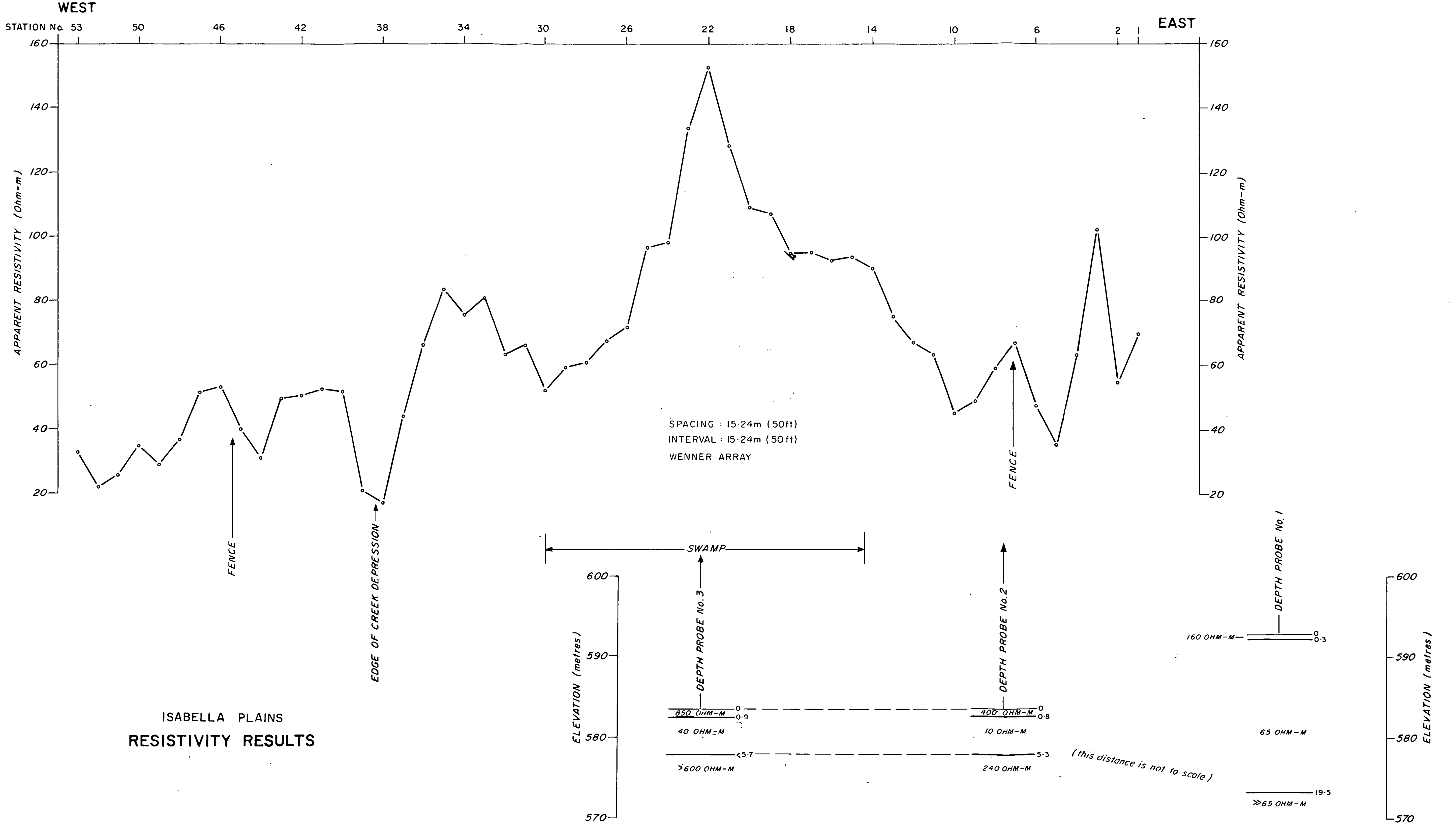
I55/B5-176A



ISABELLA PLAINS

RESISTIVITY RESULTS

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I55/B5-174