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FIELD TESTS OF GEONICS EM 31 AND EM 34-3

TERRAIN CONDUCTIVITY METERS

by

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SUMMARY

The Bureau of Mineral Resources, Geology and Geophysics has tested two electromagnetic terrain conductivity meters, the Geonics EM 31 and EM 34-3. These instruments are designed to measure conductivity (or resistivity) traverses with a fairly shallow depth of exploration. The aim of the tests was to compare the results produced by these instruments with results previously obtained using conventional resistivity equipment.

It was found that the resistivity profiles recorded by these instruments closely resembled, in most cases, the previously measured profiles. Further, it was found that a given length of traverse could be recorded more easily and more quickly with these instruments than with conventional resistivity equipment.

1. INTRODUCTION

Between 27 February and 9 March 1979, the Engineering Geophysics Group of the Bureau of Mineral Resources tested two electromagnetic survey instruments on loan from Geoex Pty Ltd, Adelaide. These instruments, the Geonics EM 31 and EM 34-3, provide direct measurements of terrain conductivity without contact with the ground.

The instruments were tested in a number of locations: in a catchment of the upper Yass River, at the proposed Tennent dam site, on the Murray flood plain near Wodonga, and in the Murray-Goulburn irrigation area near Tatura. Most of the work was done along lines where resistivity measurements had previously been recorded. Records containing the results of this previous work are listed in the Reference section.

2. EQUIPMENT

EM 31

This instrument consists of a 4-m boom divided into three equal sections, with the console mounted on the central section. The two outer sections contain the dipole transmitter and receiver, 3.66 m apart, and when not in use can be removed and clamped to the central section. The instrument weighs 9 kg and can be carried for several hours without causing undue discomfort. For most surveys the instrument is carried at hip height and is supported by a shoulder strap.

Operating instructions and equipment functional checks are set out in the EM 31 manual, a copy of which is kept with the Engineering Geophysics Group. In general we found these instructions and checks easy to follow and carry out, and many did not require alteration over the period of testing.

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The instrument has a time constant of about one second, and so can be used to provide a continuous reading of terrain conductivity. More commonly, and to extend battery life, the instrument can be switched on only at each measurement station. The EM 31 can be used by one person. In open areas it is simple to control and align along the traverse, but problems were encountered in manoeuvring the 4-m boom in thick growth. If the station interval has not been marked in advance, the survey requires two persons, with the first person marking the station positions and recording measurements, and the second person operating the instrument. The EM 31 is claimed to produce results similar to a constant-spacing resistivity traverse, and its effective depth of penetration is claimed to be 6 metres.

EM 34-3

This instrument operates on the same principles as the EM 31, but its depth of penetration can be varied by varying the coil geometry. The EM 34 has separate transmitting and receiving coils which can be set 10, 20, or 40 m apart. The coils can be used in the horizontal coplanar position, which allows sensing to a depth of 1.5 times the separation, or in the vertical coplanar position, which allows sensing to 0.75 times the separation. In the horizontal position, coil misalignment errors are more serious than in the vertical position. During testing, we used only the vertical position. As with the EM 31, operating instructions and equipment functional checks are easy to follow and carry out.

When taking a measurement, the separation between transmitter and receiver is critical. A meter on the receiver has to be nulled by finely adjusting the inter-coil spacing before a conductivity reading is

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taken. This means that an unmarked traverse may be recorded with a station interval equal to the inter-coil spacing, a time-saving feature.

It is relevant to note that since these EM instruments require no contact with the ground, the common problem of contact resistance is avoided. To overcome this problem, particularly prevalent in regions of dry surface material, in normal resistivity work the areas around the grounded electrodes must be copiously doused with saline water to allow sufficient current to flow through the ground. When this has to be done, the progress of the resistivity traverse is naturally slowed.

3. RESULTS

The recorded traverses are shown in Plates 1 to 5.

Upper Yass Valley, NSW (Pl. 1)

Both the EM 31 and EM 34 were tested along a traverse which crosses a sub-catchment of the upper Yass River valley. Several geophysical methods had been used to investigate the hydrogeology of the area as part of a joint BMR and CSIRO study. The area consists of tightly folded interbedded siltstones, sandstones, and slate covered by valley-fill deposits of colluvium, alluvium, and soil up to 4.5 m thick. Most of the groundwater is thought to flow along shoestring aquifers within the valley-fill deposits.

Previous resistivity work along the traverse included Wenner profiling with an electrode spacing (a) of 10 m. Deeper resistivity information was obtained using an asymmetrical Schlumberger or gradient array.

The results of the tests are shown in Plate 1 and the correlation between the two sets of data is good. The EM 31 profile follows the shallow-resistivity Wenner profile very closely on the flanks of the valley where the sediments are thin. In the central part of the valley the EM 31 recorded generally lower apparent resistivity values but still reflected the same peaks and troughs as the Wenner profile. This difference may be due to different groundwater levels between this survey and the previous survey in August 1977, or to different depths of sampling of the two instruments. The EM 31 produced a smoother profile between chainages 40 and 100 m, probably due to the lack of ground contact problems.

The EM 34 was used with a coil separation of 20 m, and its profile plots between the shallow-resistivity Wenner profile and the deep-resistivity gradient array profile. Again the correlation is good. In the central part of the valley the EM 34 profile follows the EM 31 profile more closely which suggests that hydrological conditions have changed since the Wenner profile was recorded.

The anisotropic nature of the jointed bedrock was clearly shown when resistivity values were recorded with the EM 31 in different orientations. For example at chainage 20 the apparent resistivity ranged from 132 ohm-m parallel to strike, to 170 ohm-m normal to strike. Used in this manner the EM 31 could quickly locate the orientation of bedding or major joint sets in bedrock concealed by a thin layer of sediment. The recorded anisotropy was less in the centre of the valley where the sediments were thicker. Similar results were obtained with the EM 34 when it was tested at chainage 800 in different orientations and with transmitting and receiving positions interchanged: N-S, 74 ohm-m; S-N, 74 ohm-m; E-W, 208 ohm-m; W-E, 211 ohm-m. Repeatability of both instruments is good.

Tennent Dam Site 3, ACT (Pl. 2)

The EM 31 was used along a traverse at the proposed Tennent Dam Site 3, south of Tharwa, ACT. The area is underlain by steeply dipping adamellite. Seismic refraction had been used to determine the nature of and depth to bedrock and overlying layers, and to identify any shear zones. Since resistivity profiling had not previously been used on this traverse a direct comparison with the EM 31 results cannot be made. However, there is good correlation between these results and seismic features such as highly sheared zones and faults as shown in Plate 2.

Northern Victoria (Pl. 3, 4, and 5)

In the surveyed area around Wodonga (Stock Route and Sheather's Road traverses), the subsurface consists of an old river plain with unconsolidated sediments - alluvial silt, clay, sand and gravel - up to 100 m or more in depth. The previous resistivity profiling had been carried out to locate near-surface channels containing coarse material - sand and gravel - for the construction industry.

Further west in the Goulburn valley (Tatura and Numurkah traverses), the geological background is similar. This area suffers problems of saline groundwater and high water-tables. In this case, the aim of the previous survey work was again to locate channels of coarse material, but this time to utilise their qualities as aquifers.

On the Stock Route traverse (Pl. 3), the agreement with the earlier resistivity traverse is excellent. Although the absolute magnitudes do not correspond, the relative highs and lows, which are diagnostic in this type of work, do correspond. Further, by comparing profiles obtained over the same traverse using the EM 31 and EM 34, it is possible to judge whether the average resistivity is increasing or decreasing with depth, since the two instruments have different effective depths of penetration. This should help the operator to distinguish between anomalous features caused by near-surface and more deep-seated effects.

It is of interest to note that the Stock Route traverse, which is 2.6 km long, was recorded using the EM 31 by two men in about 2.5 hours. The earlier constant-spacing resistivity traverse, which gives the same amount of information (i.e. a profile consisting of discrete readings 10 m apart) required four men for one whole day.

On the Sheather's Road traverse (Pl. 3), the similarities between the EM and conventional resistivity profiles are again obvious. It should be noted that the earlier profiles were recorded several years ago, so the height of the water table and the chemical composition of the groundwater, both of which markedly affect the recorded resistivity, may well have changed. Nevertheless, the relative highs and lows still indicate the most prospective parts of the traverse.

On the Merrigum traverse (Pl. 4), four EM profiles were recorded over the same traverse, each with a different effective depth of penetration. This was to compare with the previously recorded dipole-dipole resistivity pseudo-section, which indicated a large resistivity high anomaly centred 200 m east of Ryans Road. The present measurements show a slight high in the shallowest profile, extending from about chainages 140 to 240 m, and peaking at 170 m. The deeper profiles however show only slight highs centred at about 110 m, but no anomalous features around 200 m. Although it is not possible to assign reliable depth scales to either the earlier or present pseudo-sections, it is likely that they overlap to some extent; however, only the shallowest EM profile shows any correlation with the dipole-dipole section. Since the disposition of subsurface solid material cannot have changed in the interval between recording the different profiles, we must assume that the groundwater content and/or constitution has changed. The most likely explanation is that the salt concentration of the water in this permeable zone has increased in the intervening time. This would have the effect of lowering the resistivity and thus making this zone less distinguishable from the surrounding clays.

It was found that on this traverse at 40 m coil separation, the background conductivity was close to, and sometimes greater than, the maximum of the EM 34 range. (The maximum conductivity this instrument can measure is 300 millisiemens per metre, i.e. a minimum resistivity of 3.3 ohm-m). Under these circumstances it was sometimes necessary to extend the intercoil spacing beyond 40 m to obtain a null; at other times, the instrument could not be nulled at all. Apart from this limitation, the instrument proved simpler and quicker to use than the dipole-dipole resistivity method.

The Numurkah seismic line traverse is shown in Plate 5. This again indicates a resistivity high in the same location as in the earlier dipole-dipole pseudo-section.

4. CONCLUSIONS

As a result of our brief tests of these EM conductivity meters, we conclude that they do measure, in a number of different geological environments, the same apparent conductivity (or resistivity) as would be measured with conventional galvanic resistivity equipment. We also found that they are simpler and quicker to use than conventional equipment. Accordingly, they would be especially useful for reconnaissance surveys where the apparent resistivity of near-surface material was of interest. For example they could be used in locating sand and gravel deposits for construction of roads, bridges, and small dams. Because of the simplicity of operation of the instruments this work could be done by relatively untrained field staff, representing a saving in professional time.

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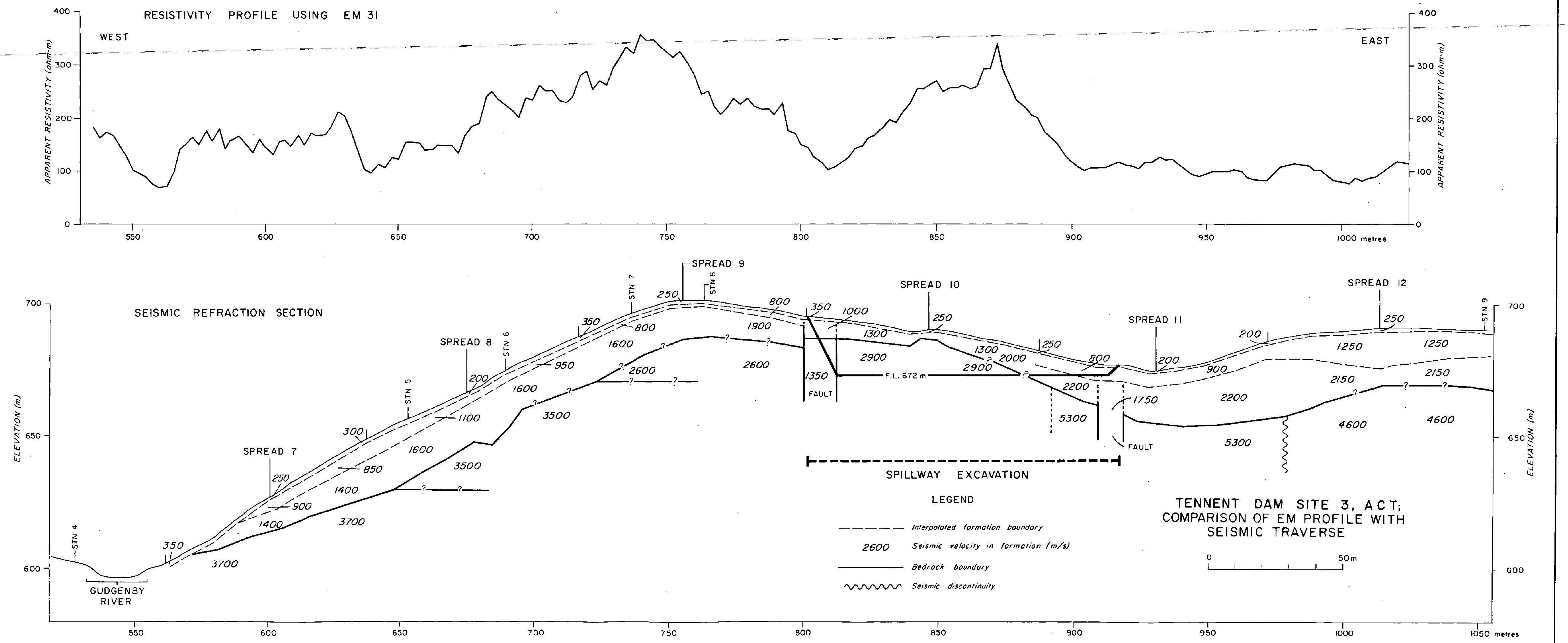
PLATE 1


CHAINAGE (m)
DEEP RESISTIVITY PROFILE — GRADIENT ARRAY (AB = 750m, MN = 10m)
APPARENT RESISTIVITY (ohm·m)
EM 34-3 (20m coil spacing)
EM 31
SHALLOW RESISTIVITY — WENNER ARRAY (a = 10)
SEISMIC CROSS-SECTION
ELEVATION (m)
CREEK
VES 1
VES 2
VES 3
VES 4
UPPER YASS VALLEY, NSW;
COMPARISON OF EM PROFILES WITH
RESISTIVITY AND SEISMIC TRAVERSES
1·5 Depth of seismic refractor in metres
1760 Seismic velocity in metres/second
Boundary between layers of different resistivities
60 Resistivity of layer in ohm-metres
V/H = 2
1979/65
I55/85-409

PLATE 2



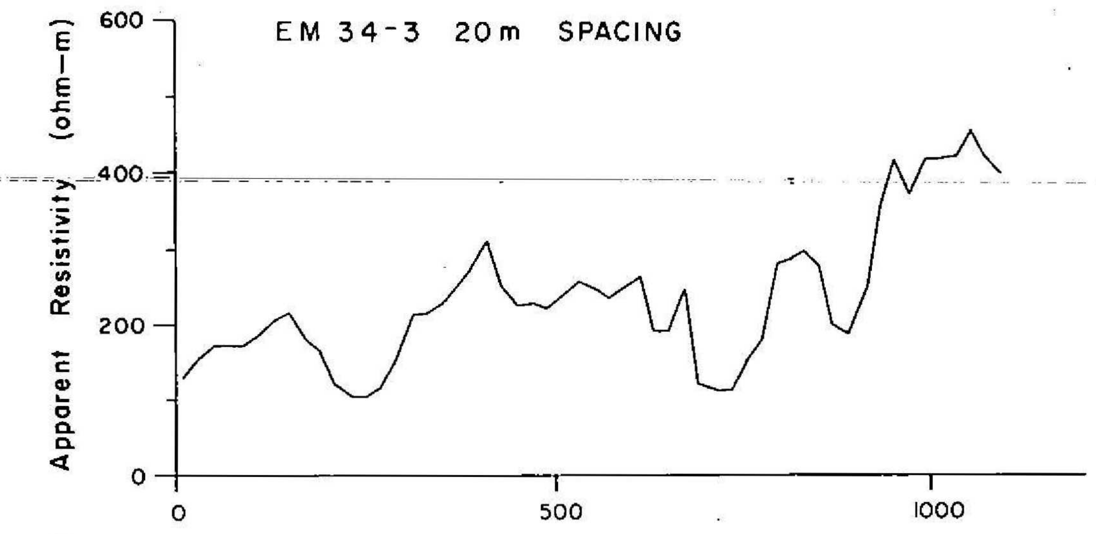
TENNENT DAM SITE 3, ACT; COMPARISON OF EM PROFILE WITH SEISMIC TRAVERSE

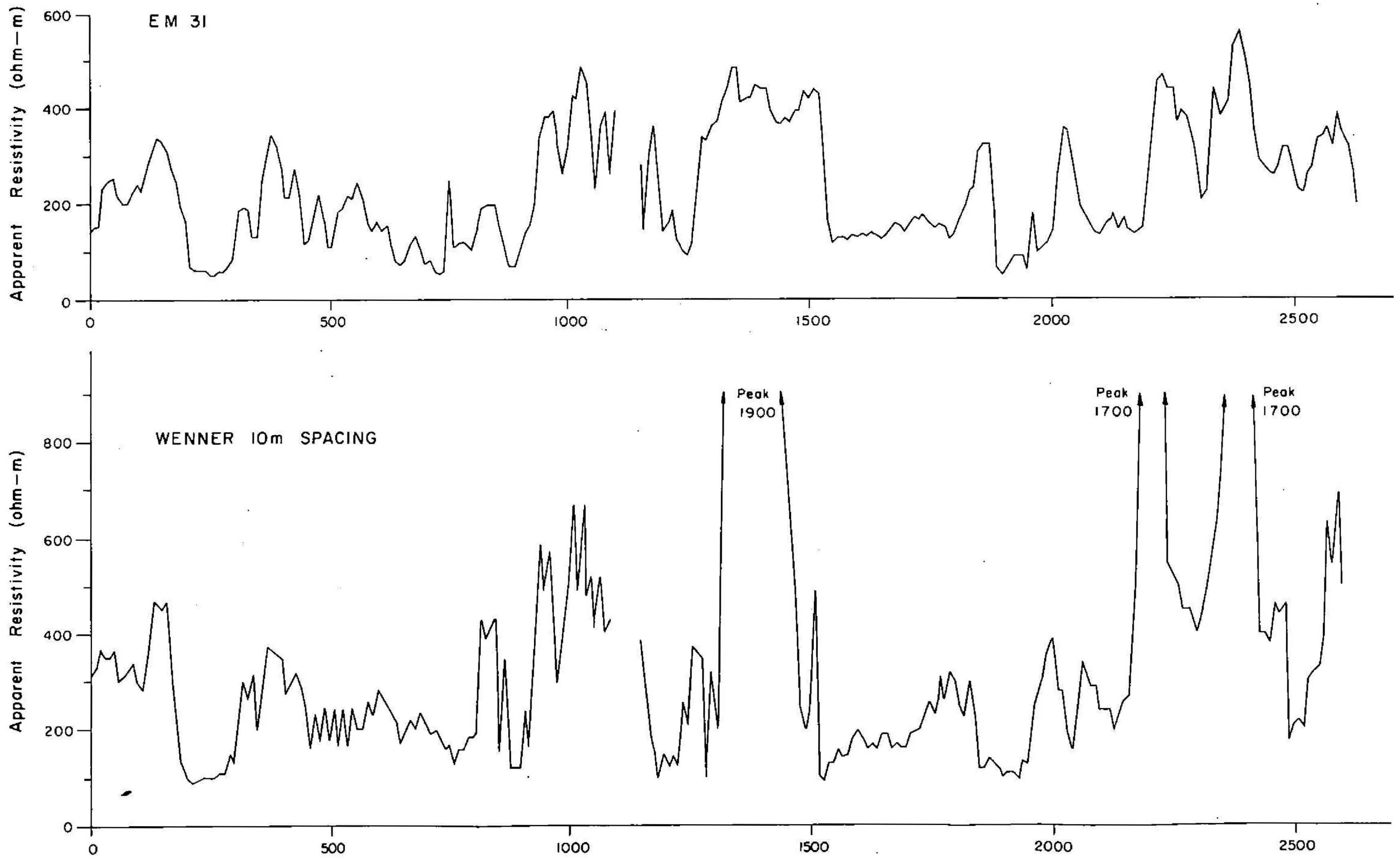
Record No. 1979/65

I55/B5-410

MURRAY FLOOD PLAIN, WODONGA, VIC; COMPARISON OF EM PROFILES WITH RESISTIVITY TRAVERSES.

STOCK ROUTE TRAVERSE





SHEATHER'S ROAD TRAVERSE

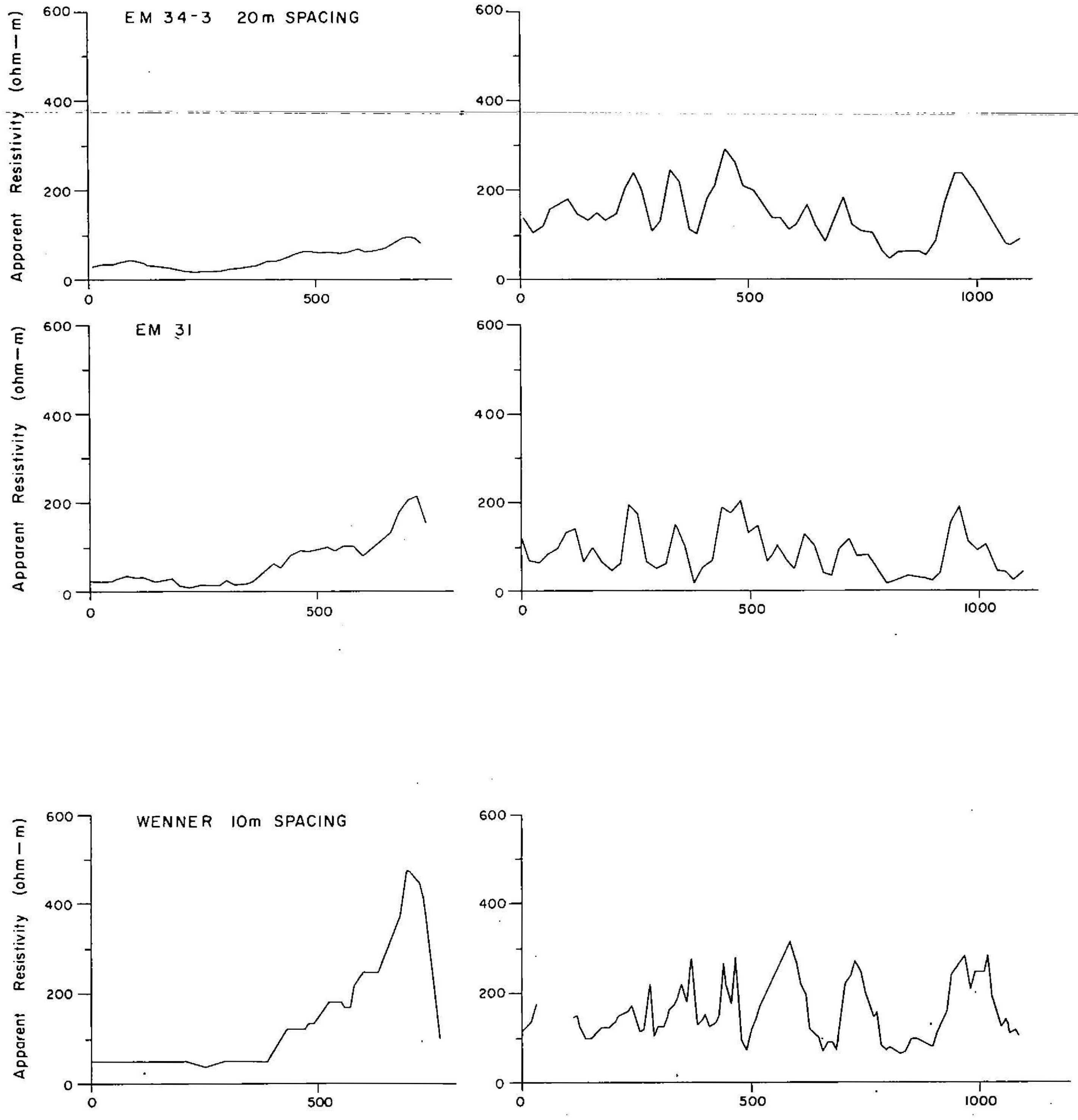
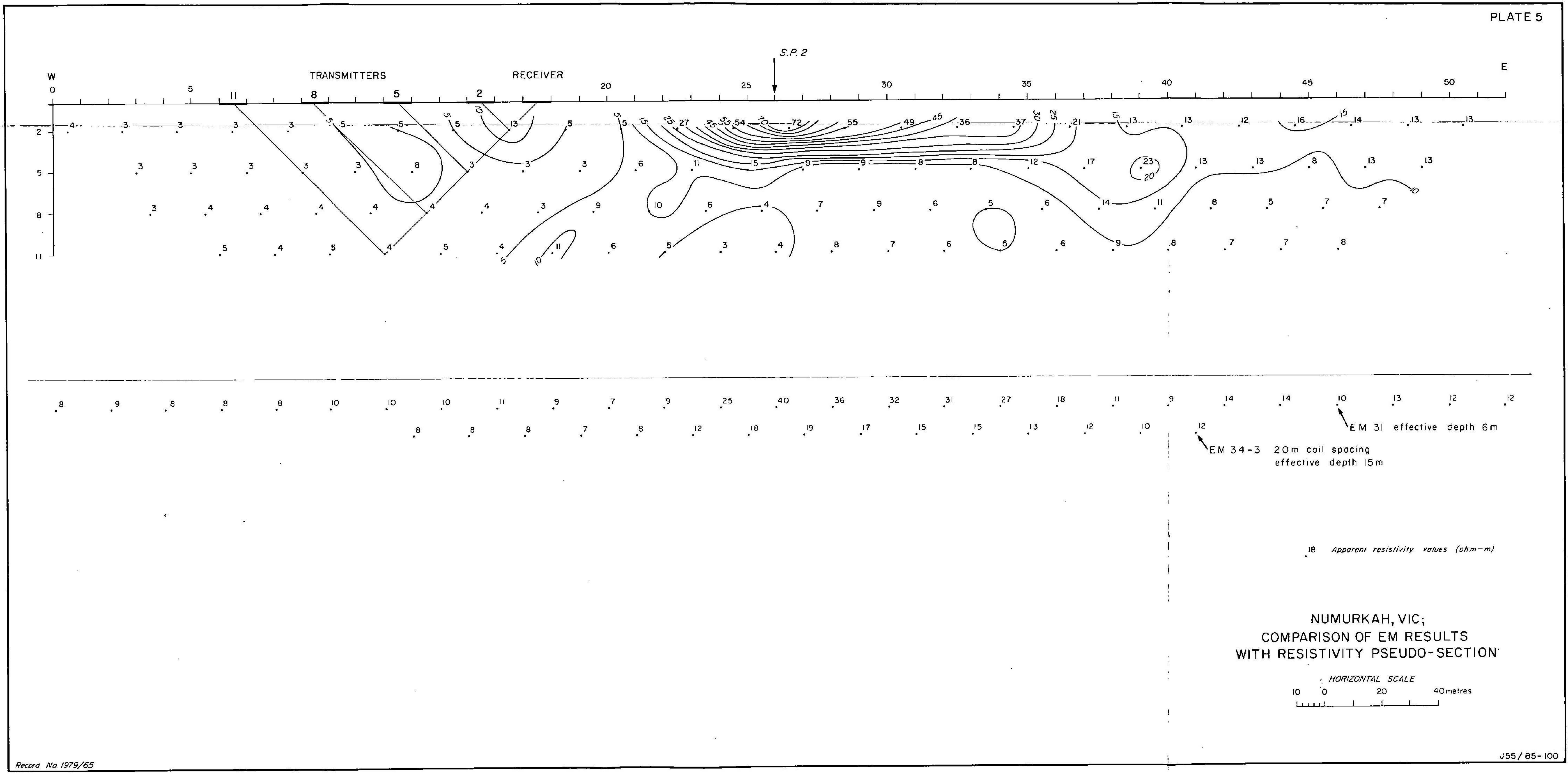


PLATE 4

MERRIGUM, VIC;
COMPARISON OF EM RESULTS WITH
RESISTIVITY PSEUDO-SECTION

Record No 1979/65

J55/B5-163



NUMURKAH, VIC;
COMPARISON OF EM RESULTS
WITH RESISTIVITY PSEUDO-SECTION