DEPARTMENT OF MINES AND ENERGY

GEOLOGICAL SURVEY

SOUTH AUSTRALIA

REPORT BOOK 92/7

GREAT ARTESIAN BASIN GROUNDWATER STUDY SIROTEM SURVEY, 1988

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DEPARTMENT OF MINES AND ENERGY
GEOLOGICAL SURVEY
SOUTH AUSTRALIA

REPORT BOOK 92/7 DME NO 221/85

GREAT ARTESIAN BASIN GROUNDWATER STUDY
SIROTEM SURVEY, 1988

A R DODDS

This report describes a TEM survey done in the south-western GAB. The objective is to assess the method for providing extensive information on leakage from the aquifer cheaply and quickly.
The survey covered 57 line kilometers in 2 weeks, which compares favourably with most ground geophysical methods. The results indicate two thick, strong conductors intercalated with three resistors. Since these layers appear to bear no relation to stratigraphy, it is anticipated that both lateral and vertical resistivity variations indicate changes in fracture patterns, and in the salinity of the groundwater. It seems probable that there is a relationship between these parameters and upward leakage from the aquifer. It is recommended that follow-up work concentrate initially on defining this relationship.

INTRODUCTION

A five-year plan of geophysical investigations in the Great Artesian Basin (GAB) was proposed by the Engineering and Groundwater Section of the Geological Survey in 1985. While the interest is in the movement of water in the basal aquifer throughout the GAB, the investigations are centred in the area south of Lake Eyre.

Earlier investigations by the Department and by other entities are described in Cockshell (1988). In particular, measurements of ground resistivity by galvanic and transient electromagnetic (TEM) methods indicated the desirability of more extensive testing of electrical methods for possible application as an economical way of getting initial extensive information. The data contained herein are the product of that follow-up work.

57.3 km of line were covered with the SIROTEM technique, using the coincident loop configuration with a 100 m square loop. The line extended from Gregory Creek in the west, close to earlier investigations, past Morris Creek Bore and Crows Nest Bore and on towards Muloorina. Stations west of Morris Creek were 100 m apart, while those to the east comprised groups of three 100 m spaced readings at 1 km intervals. Two detail line sections were also surveyed, parallel to the original line and approximately 1 km north of it.

The field work was done in October, 1988, by N. Dunstan, with assistance from various personnel from the South Australian Department of Mines and Energy. The survey design, data processing and interpretation were done by A.R. Dodds.

GEOLOGY

The whole area is part of the GAB, with Adelaidean basement at a depth of 100 metres at the west end (Gregory Creek) deepening fairly monotonically to the east and reaching 300 metres depth at Morris Creek. The overlying sediments dip gently to the east with Bulldog shale, Coorikiana sandstone, Oodnadatta formation, Mackunda formation and Winton formation outcropping sequentially to the east. The sequence is shown diagrammatically under the resistivity sections in Figures 7-12. The aquifer, comprising Jurassic Algebuckina sandstone and Cretaceous Cadna-owie formation, occurs directly above bedrock, with the Bulldog shale as the confining bed. However, it appears that at this location the aquifer is absent at the west end of the survey line (Cockshell, 1988).

PRESENTATION OF RESULTS

The data are presented as apparent resistivity pseudosections at a scale of 1:20 000 (Figures 2 to 6). The values in these pseudosections are contoured at a logarithmic scale of 9 intervals per decade to show the qualitative variations in this parameter along the survey line and with delay time, the latter being related to depth. Selected readings, identified by the letter I on the sections, were then inverted using a one-dimensional (resistivity variation in the vertical direction only) inversion package named GRENDL. The results of these inversions are shown in the form of resistivity sections in Figures 7 to 12, along with generalized geology.

INVERSION PROCEDURE

The GRENDL TEM inversion package is automated but requires the selection of a viable initial model, the number of layers selected being particularly critical. If too many or too few layers are selected the resultant model is bound to be in error. The initial thickness and resistivity of each layer is less critical. Data points can be weighted and model parameters fixed, if so desired.

Once a final model has been achieved, based on reaching either a predetermined convergence level or a maximum number of iterations, error statistics are generated which indicate the quality of the fit and whether the initial model was reasonable. These include the standard error(SE), which is an indicator of the general quality of the fit, confidence intervals for each final model parameter, which defines how well the given parameter is resolved, and a predicted residual error (APRE) which indicates whether the number of layers selected is appropriate. The standard error at each data point is also provided to indicate whether the errors are randomly scattered (noise) or systematic (a bad fit). A study of these and other data gives a good idea as to whether further adjustment is required and what to do to improve the inversion.

The most probable reasons for bad fits are:

(a) the data are noisy, indicated by a random scatter of errors increasing in the later channels.

(b) the number of layers in the initial model is wrong, indicated by an APRE much larger than the SE, and a systematic variation of errors among the data points.

(c) the data do not fit a one-dimensional model, indicated by a systematic variation of errors among the data points.

Apparent resistivity pseudosections give a general idea of qualitative resistivity variations, while resistivity sections resulting from inversions are an interpretation of true resistivities and depths. While the former are actual measurements, and therefore fact so far as noise levels permit, the latter are one simple interpretation of the facts, out of an infinite number available. The initial model chosen, which effectively comprises the operator intervention into the inversion process, is based on simplicity, geological knowledge, and an examination of the basic resistivity data and preliminary inversions.

The initial models chosen had three layers, two resistive with a conductive layer sandwiched between them, to represent dry top soil, moist saline sediments and impervious basement. Fits proved to be poor, and generally better fits were obtained with a four or five layer model, incorporating two conductive layers with or without a resistive layer between them. This general model shape was adopted for all inversions, and only modified if the error indicators were unfavourable. The initial values of a resistivity and thickness for each layer are relatively unimportant compared to the model shape.

DISCUSSION OF RESULTS

The general model for these data comprises two thick conductive layers, with possible resistive layers above, between and below them (Figures 7-10). It is well known that thin resistive layers tend to be transparent to the TEM method, and that thicker resistive layers are usually poorly defined. Thus our simplest model for these data is most likely to omit resistive layers, rather than conductive ones. All resistive layers that are included have a poorly defined resistivity, but the depth to the layer is usually well defined.

The two conductive layers have similar resistivity ranges of 0.5-1.1 ohm-metres for the upper conductor and 0.6-2.2 for the lower, but the lower layer is almost always slightly more resistive, as indicated by the average resistivities of 0.7 ohm-metres (upper) and 1.1 ohm-metres (lower). The difference is fairly subtle in most cases, but necessary to a good fit.

The thickness of the upper conductor is well defined and, though highly variable, tends to increase from west to east until Crow's Nest Bore, after which its general trend is to get thinner. This is shown on the graphical presentation of layer parameters in Figure 13. This figure also shows the relative invariance of the upper conductor resistivity compared to that of the lower conductor.

One of the consistent problems in the inversion of resistivity data lies in the separation of the conductivity from the thickness of a layer. While the product of these parameters may be well defined, individually they may have a wide range of possible values. Figure 14 shows the variation in the conductivity-thickness product of the upper conductor along the survey line. Although there is considerable local variation, there is also a clear trend in these values, increasing from Gregory Creek to 35 000E, then decreasing to the east end of the line. The break in the trend in the vicinity of Frances Creek is very pronounced.

The depth to the bottom of the lower conductor is often poorly defined, being close to the limit of detection for this equipment and loop configuration. At the west end it is fairly well defined, at a depth of 160 metres or less, but all depths below this are suspect. The figures given for the resistivity of the bottom layer are arbitrary, and highly dependant on the value given in the initial model. All that can be said is that they are over 10 ohm-metres.

The two conductive layers are very conductive in groundwater terms, indicating groundwater with a salinity of the order of sea-water or higher saturating a relatively porous rock. If the rock is less porous, as appears to be the case here if the Bulldog shale, for example, is to be an aquiclude, then the groundwater must be much more saline, perhaps many times the salinity of sea-water. This would be quite possible if the upwards percolating water from the aquifer were gradually concentrating salts as it cooled or evaporated, over many millenia, to tend towards a saturated saline solution.

The geological significance of these layers is only clear in a general sense. The upper resistor is evidently dry, with the possibility that the saline content is also low because any salts that have percolated upwards have been flushed back down by periodic rains. Either or both reasons could result in a resistive layer. Both conductive layers extend through all of the sedimentary strata with no apparent correlation with rock-type. Thus both lateral and vertical variations in resistivity may result from changes in fracture patterns rather than the inherent porosity of the rock. Since the main objective of this survey is the detection of just such lateral variations, this hypothesis is favourable to the end result. The higher conductivity zones indicate areas of higher fracturing and consequently increased upwards percolation of the groundwater.

The middle resistive layer, between the two conductors, likewise appears unrelated to stratigraphy. Although the thickness of the layer is poorly defined, with an apparent range from 0-40 metres, it is rarely superfluous. The origin of this layer is presumably also related to the percolation and evaporation process, although the specific cause is not clear.

Two of the inversions, at 16 000E and 33 500E, do not fit this general pattern, at least at depth where a thick, very conductive layer underlies the middle resistor and precludes the detection of deeper layers. These features may indicate a combination of very saline groundwater with higher porosities.

SUMMARY

The survey shows a consistent layered resistivity pattern which appears unrelated to stratigraphy.

The anticipated cause of the major pattern features is the percolation of groundwater upwards from the aquifer, the flushing action of periodic rains, and the concentration effects of evaporation.

Since these are of significance to the study problem, identification of the precise mechanisms relating to these resistivities is advised. In particular, what are the porosity and salinity contributions to the conductive layer formation resistivity and what factors are involved in the production of the middle resistive layer and the change in conductive layer resistivity at this depth? Answers to these questions would indicate whether the resistivities are indicating a condition which is pertinent to the main problem of GAB aquifer leakage.

REFERENCES

Cockshell, C.D., 1988. Great Artesian Basin Groundwater Study, Geophysical Progress Report 1988. S. Aust. Dept. Mines unpublished report 88/91.

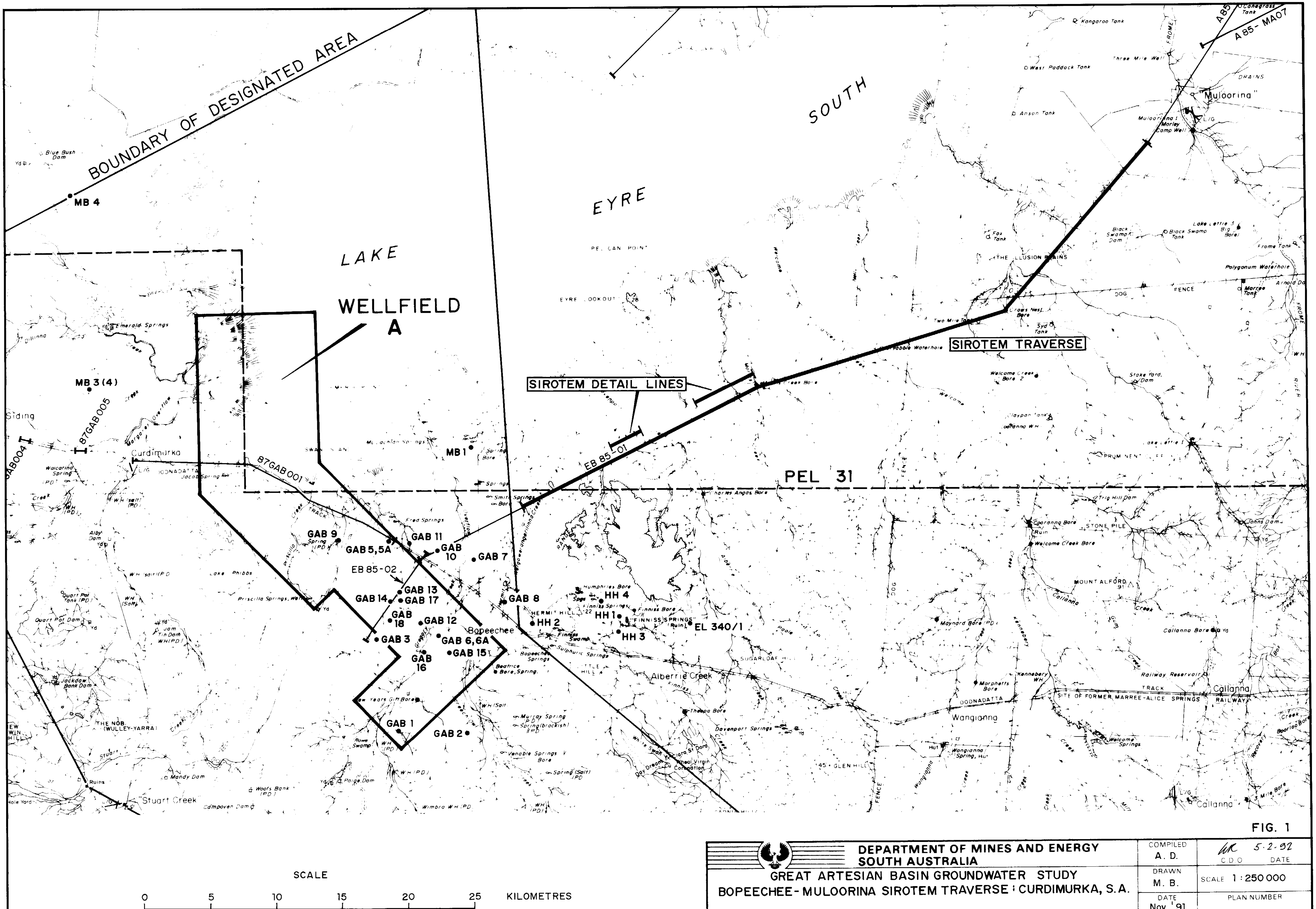

FIG. 1

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA

GREAT ARTESIAN BASIN GROUNDWATER STUDY
BOPEECHEE-MULOORINA SIROTEM TRAVERSE : CURDIMURKA, S.A.

LOCALITY MAP

COMPILED	A. D.	5-2-92 C D O	DATE
DRAWN	M. B.	SCALE 1 : 250 000	
DATE	Nov. '91	PLAN NUMBER	
CHECKED		91-657	

5477

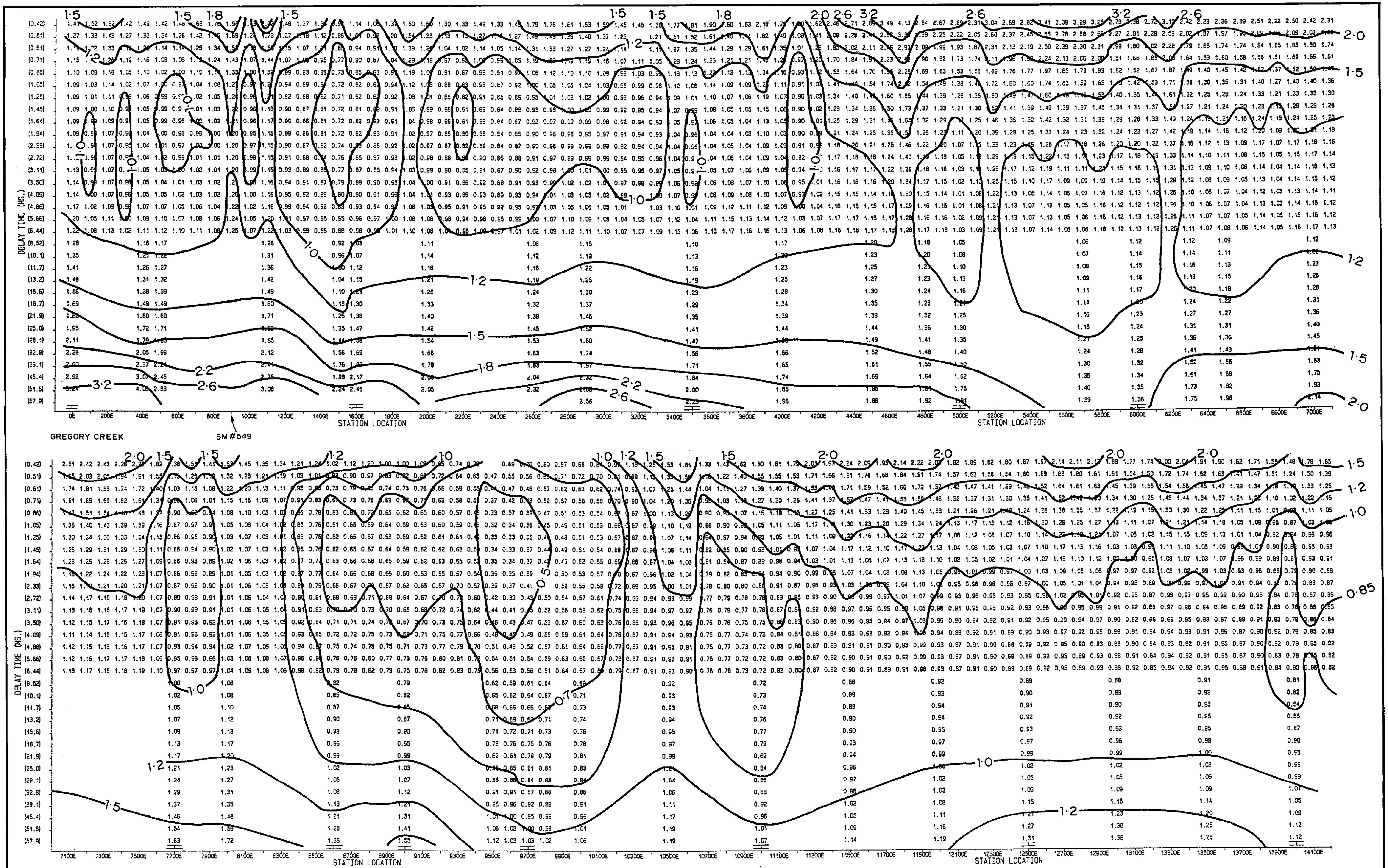

FIG. 2

UNITS: OHM-METRES

SURVEY SPECIFICATIONS	
INSTRUMENT:	SIROTEM
CONFIGURATION	100M SQ. COINCIDENT LOOPS
READING INTERVAL	100M
SURVEY DATE	OCTOBER 1988
MAP	BOPEECHEE

⌶ Station at which data were inverted (see FIGS. 7&8)

Contours: 0·5, 0·7, 0·85, 1·0, 1·2, 1·5, 1·8, 2·0, 2·2, 2·6, 3·2

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA

GREAT ARTESIAN BASIN GROUNDWATER STUDY

BOPEECHEE-MULOORINA SIROTEM TRAVERSE: CURDIMURKA, S.A.

LINE 0N, 0 - 14200 E

APPARENT RESISTIVITY PSEUDO-SECTIONS

COMPILED	A.D.	5·2·92
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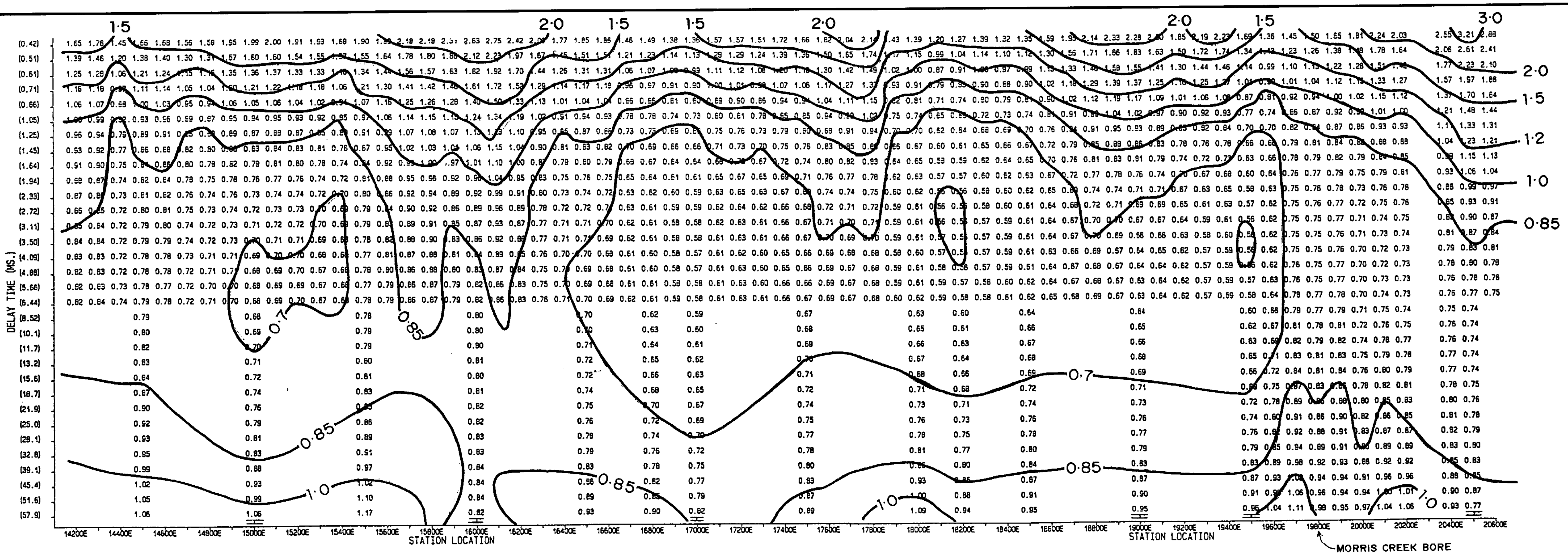
DATE	Nov '91	PLAN NUMBER
CHECKED		91-658

5477



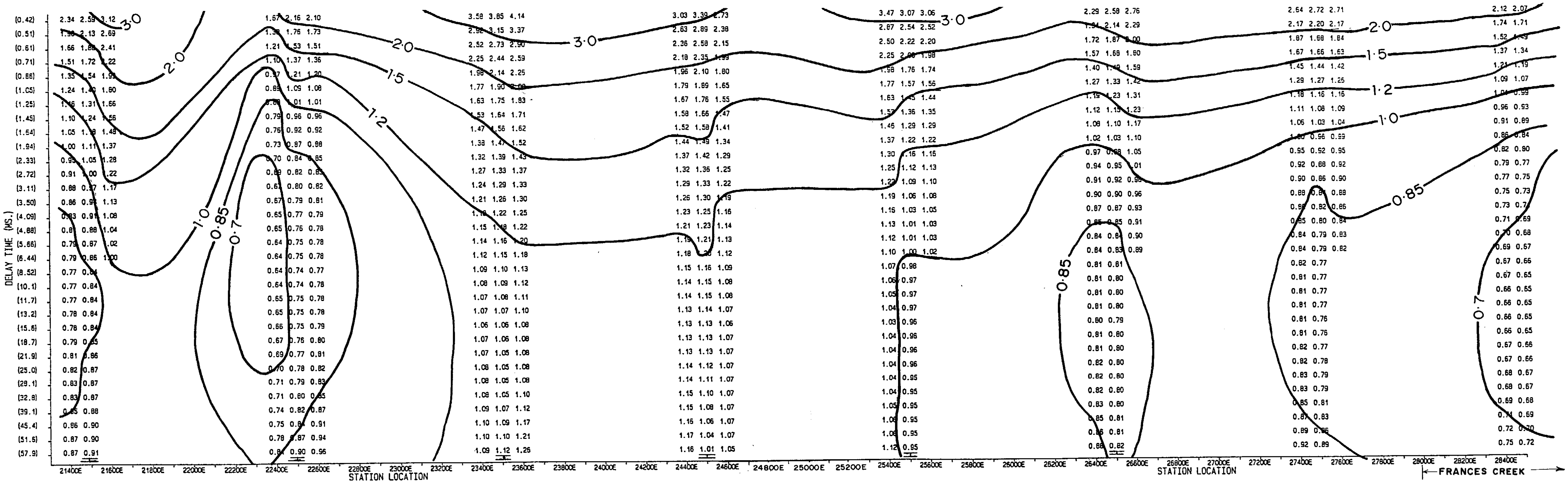


FIG. 3

UNITS: OHM-METRES

SURVEY SPECIFICATIONS	
INSTRUMENT: SIROTEM	
CONFIGURATION 100M SQ. COINCIDENT LOOPS	
READING INTERVAL	100M
SURVEY DATE	OCTOBER 1988
MAP	BOPEECHEE

Station at which data were inverted (see FIGS. 8 & 9)

Contours : 0·55, 0·7, 0·85, 1·0, 1·2, 1·5, 2·0, 3·0

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA

GREAT ARTESIAN BASIN GROUNDWATER STUDY
BOPEECHEE-MULOORINA SIROTEM TRAVERSE : CURDIMURKA, S.A.

LINE 0N, 14200 - 28500E

APPARENT RESISTIVITY PSEUDO-SECTIONS

COMPILED	A. D.	*[signature]* 5·2·92 (CDO / DATE)
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DATE	Nov. '91	PLAN NUMBER
CHECKED		91-659

5477

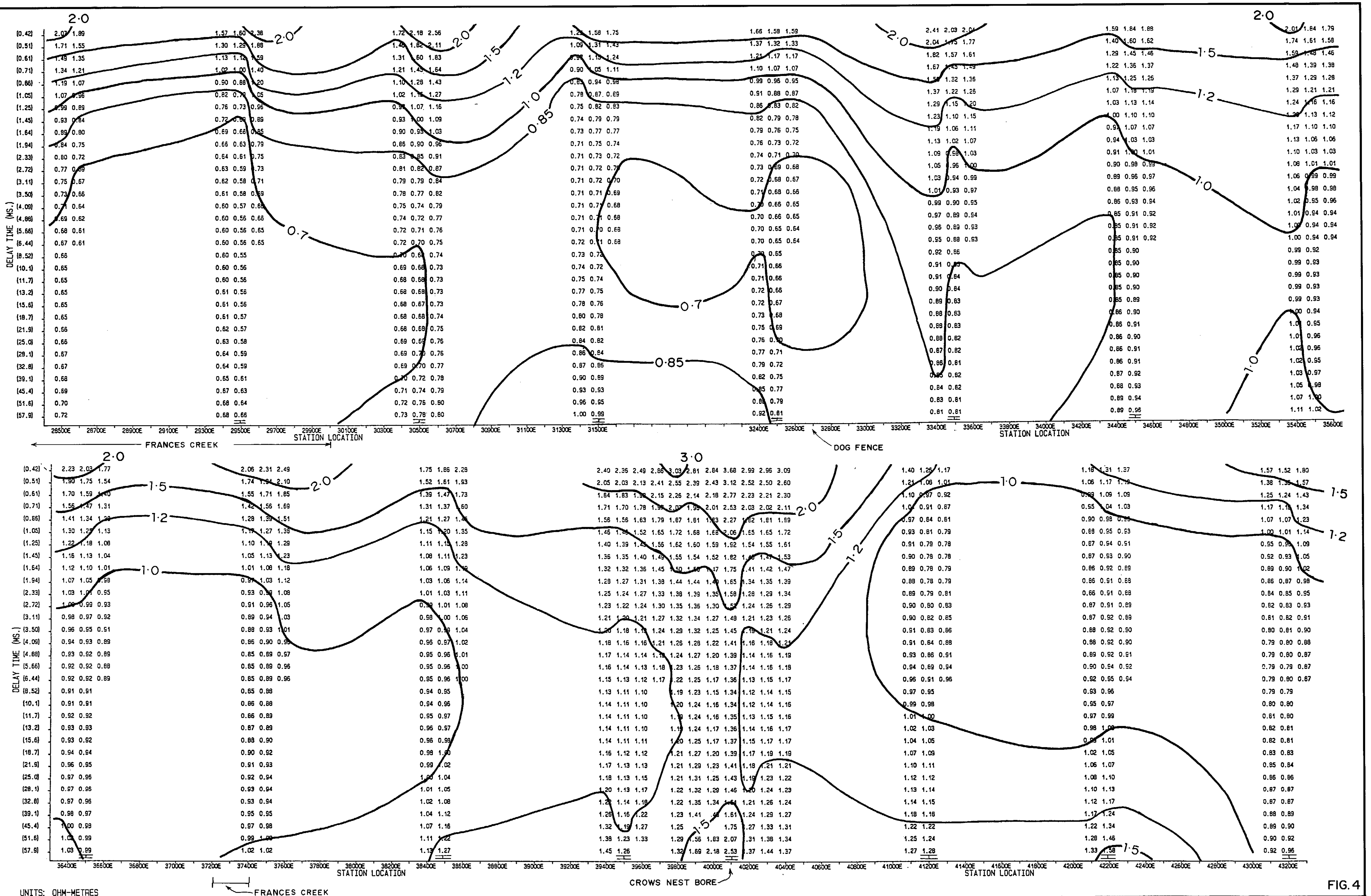

FIG. 4

UNITS: OHM-METRES

SURVEY SPECIFICATIONS	
INSTRUMENT: SIROTEM	
CONFIGURATION 100M SQ. COINCIDENT LOOPS	
READING INTERVAL	100M
SURVEY DATE	OCTOBER 1988
MAP	BOPEECHEE

⌶ Station at which data were inverted (see FIGS. 9-11)

Contours: 0·7, 0·85, 1·0, 1·2, 1·5, 2·0, 3·0

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SOUTH AUSTRALIA

GREAT ARTESIAN BASIN GROUNDWATER STUDY
BOPEECHEE - MULOORINA SIROTEM TRAVERSE : CURDIMURKA, S.A.

LINE 0N, 28500 - 43500E

APPRESENT RESISTIVITY PSEUDO-SECTIONS

COMPILED	A. D.	C D O	5 · 2 · 92
DRAWN	M. B.	SCALE	1 : 20000
DATE	Nov. '91	PLAN NUMBER	91-660
CHECKED			

5477

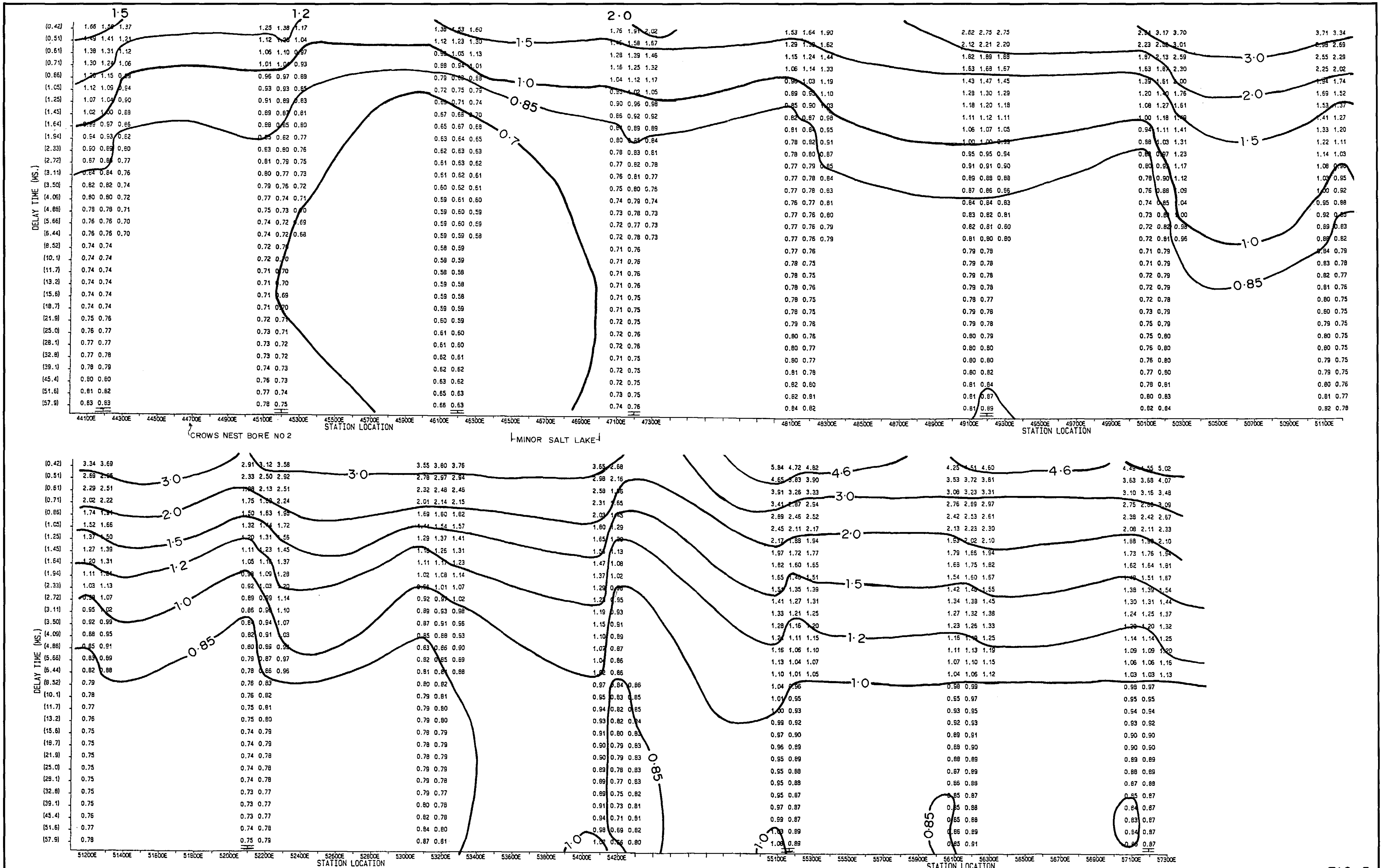


FIG. 5

UNITS: OHM-METRES

SURVEY SPECIFICATIONS	
INSTRUMENT:	SIROTEM
CONFIGURATION	100M SQ. COINCIDENT LOOPS
READING INTERVAL	100M
SURVEY DATE	OCTOBER 1988
MAP	BOPEECHEE

Contours: 0·7, 0·85, 1·0, 1·2, 1·5, 2·0, 3·0, 4·6

⌶ Station at which data were inverted (see FIGS. 11 & 12)

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

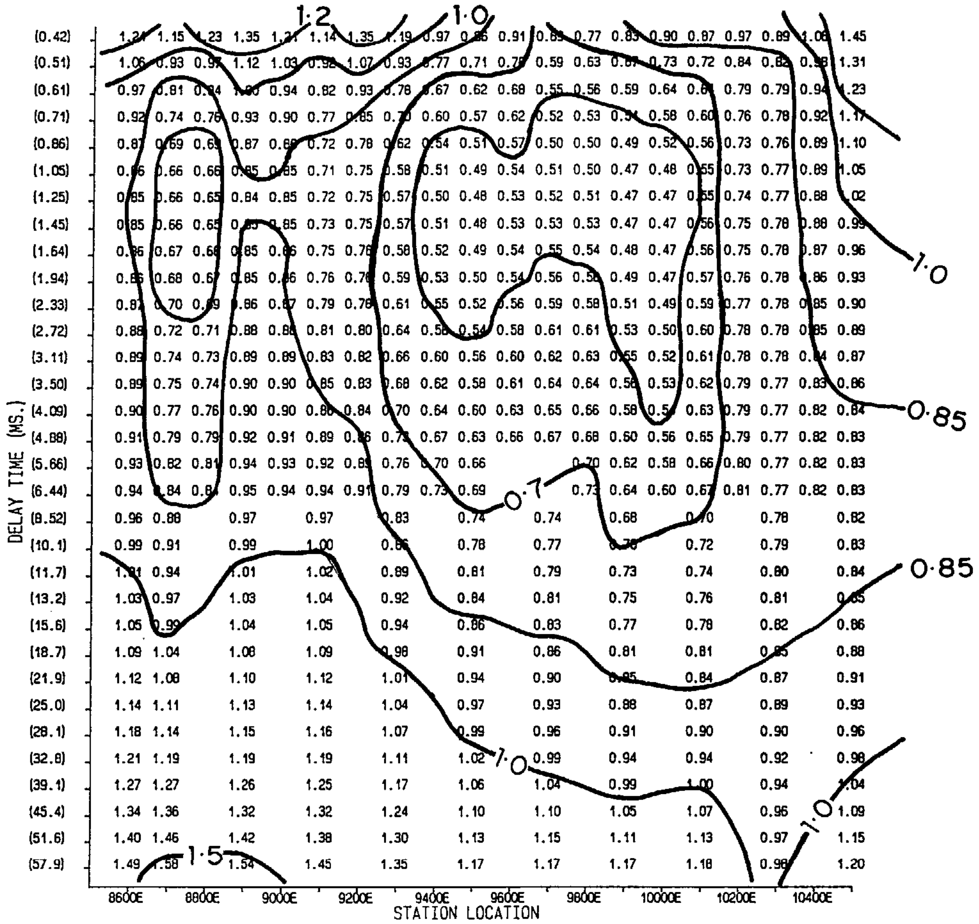
GREAT ARTESIAN BASIN GROUNDWATER STUDY
BOPEECHEE - MULOORINA SIROTEM TRAVERSE : CURDIMURKA, S.A.

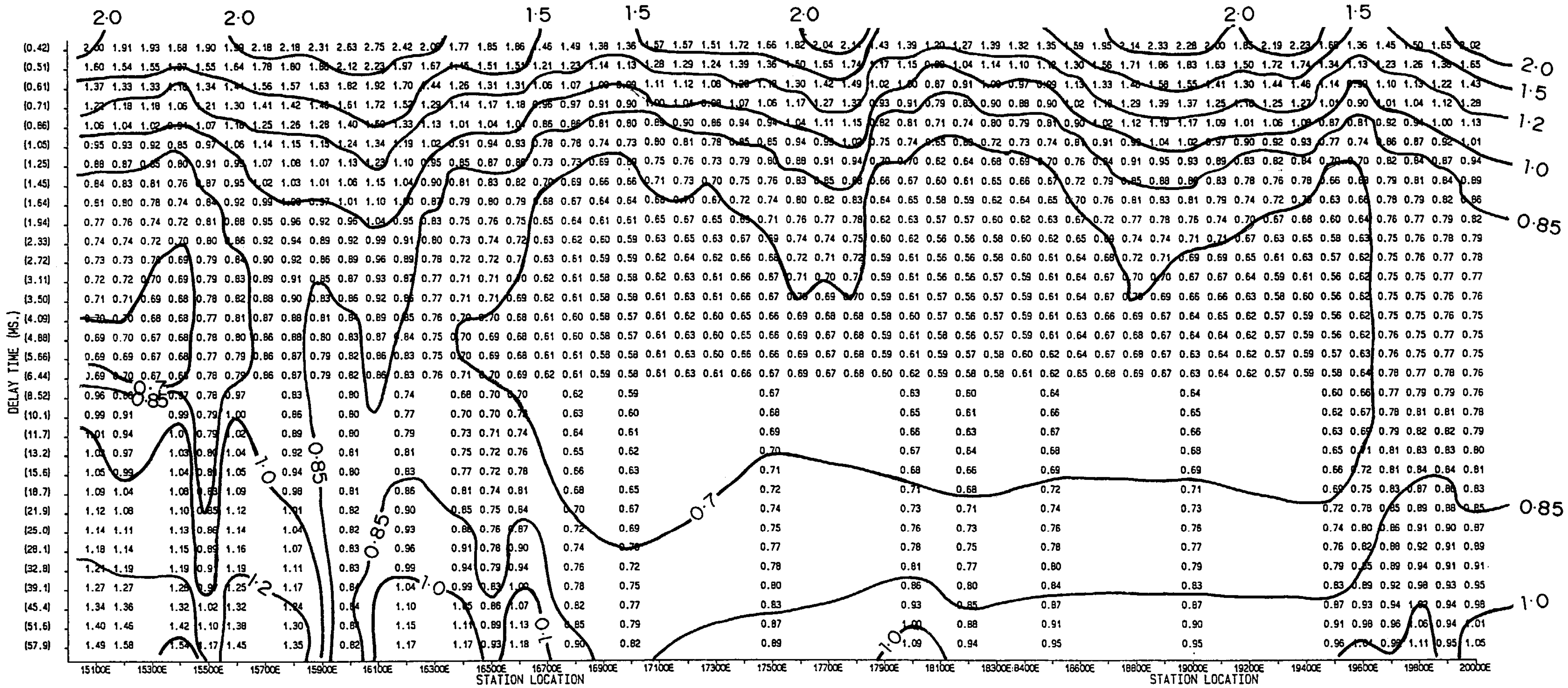
LINE 0N, 43500 - 57300 E

APPARENT RESISTIVITY PSEUDO-SECTIONS

COMPILED	A. D.	5·2·92 CDO DATE
DRAWN	M. B.	SCALE 1 : 20 000
DATE	Nov. '91	PLAN NUMBER
CHECKED		91-661

5477





UNITS: OHM-METRES

SURVEY SPECIFICATIONS	
INSTRUMENT: SIROTEM	
CONFIGURATION 100M SQ. COINCIDENT LOOPS	
READING INTERVAL	100M
SURVEY DATE	OCTOBER, 1988
MAP	BOPEECHEE

FIG. 6

Contours: 0·55, 0·7, 0·85, 1·0, 1·2, 1·5, 2·0

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GREAT ARTESIAN BASIN GROUNDWATER STUDY
BOPEECHEE-MULOORINA SIROTEM TRAVERSE: CURDIMURKA, S.A.

LINE 1000N, 8600-10000E, 15100-20000E
APPARENT RESISTIVITY PSEUDO-SECTIONS

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DATE	Nov. '91	PLAN NUMBER	91-662
CHECKED			

5477

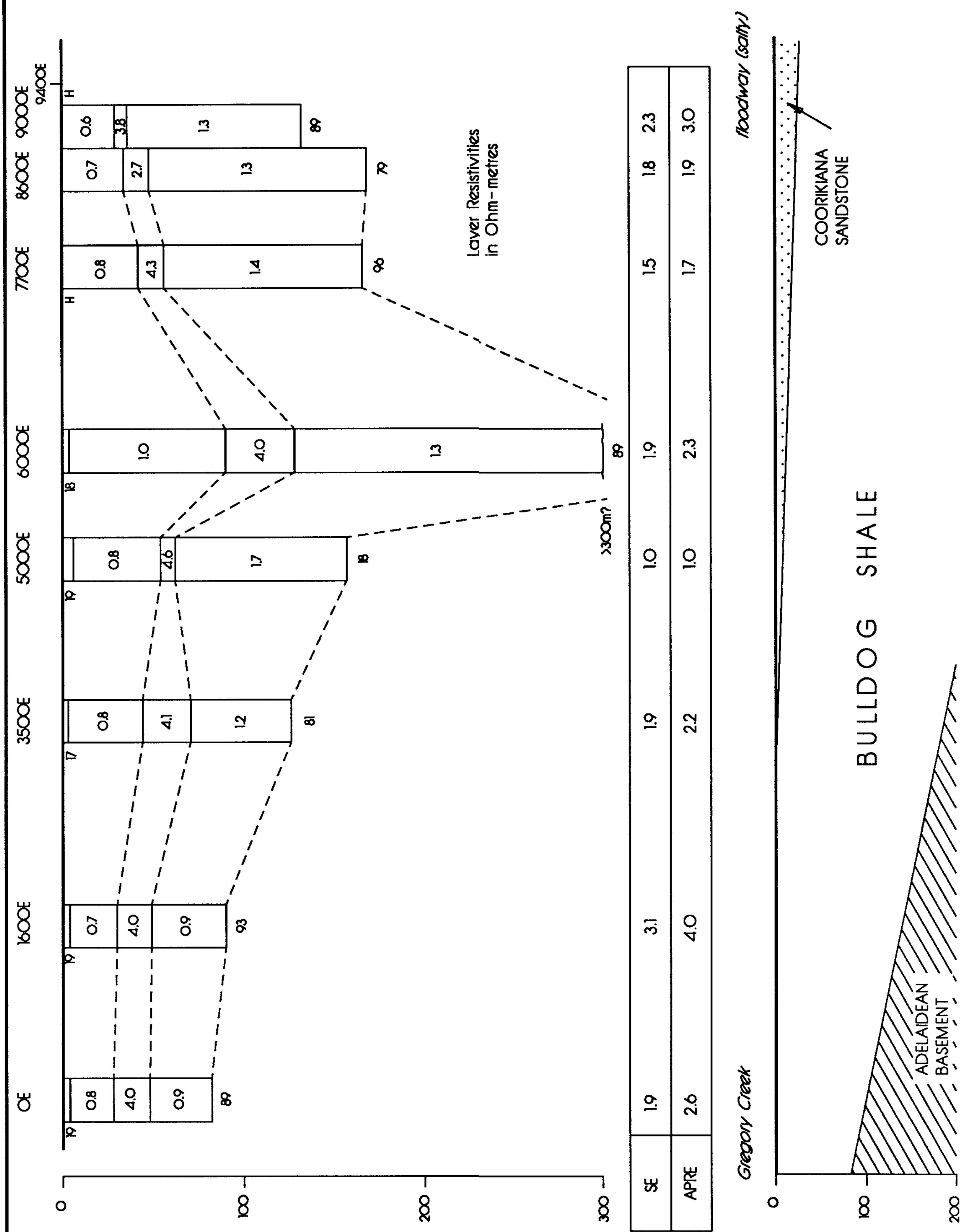

Figure 7

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GREAT ARTESIAN BASIN GROUNDWATER STUDY
BOPEECHEE-MULOORINA SIROTEM TRAVERSE:CURDIMURKA, S.A.

OE-9000E

RESISTIVITY SECTIONS FROM TEM INVERSIONS

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DATE	SCALE
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JOB NUMBER	PLAN NUMBER
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CDO	
MR	

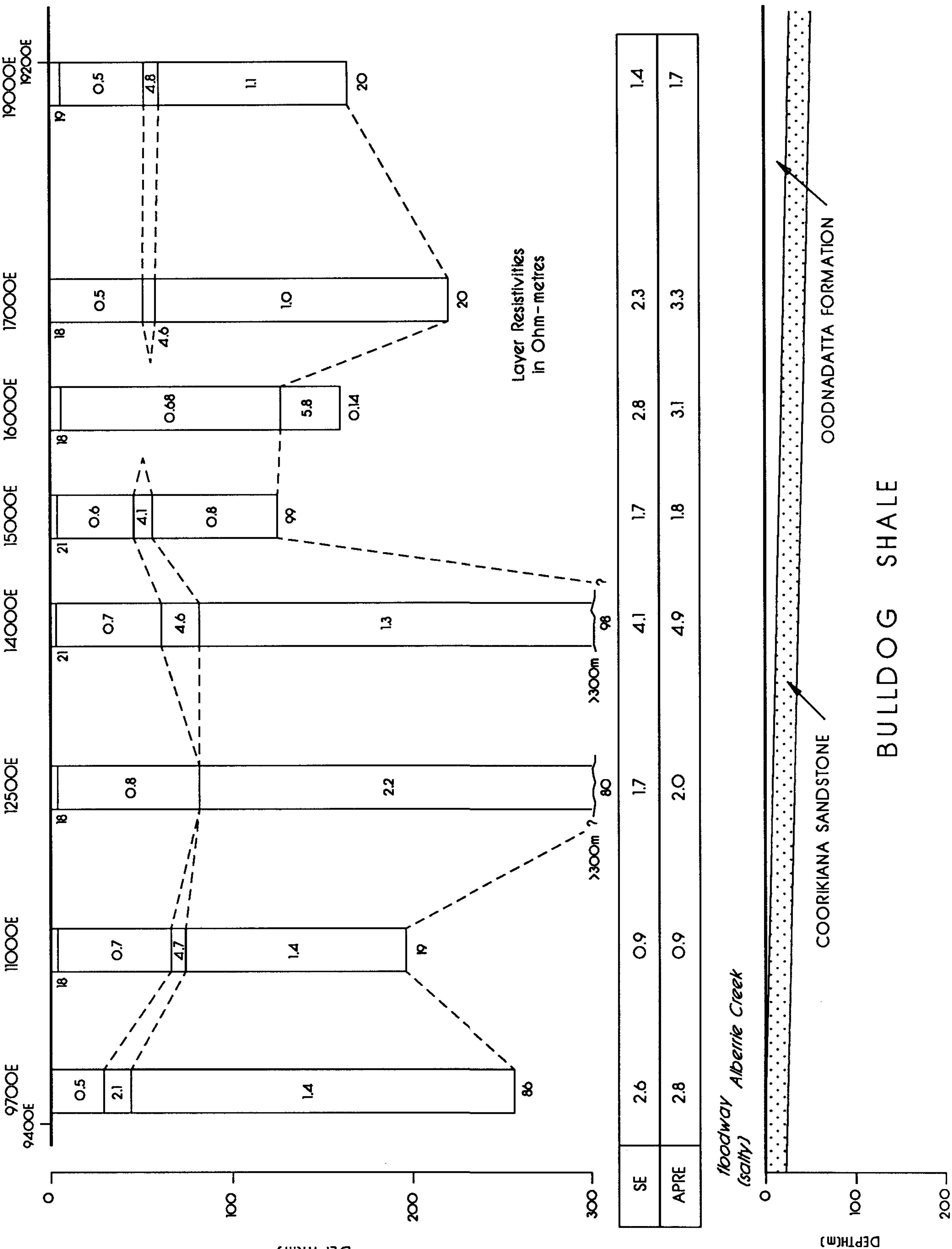

Figure 8

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GREAT ARTESIAN BASIN GROUNDWATER STUDY
BOPEECHEE-MULOORINA SIROTEM TRAVERSE:CURDIMURKA, S.A.

9700E-19000E

RESISTIVITY SECTIONS FROM TEM INVERSIONS

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DATE	SCALE
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JOB NUMBER	PLAN NUMBER
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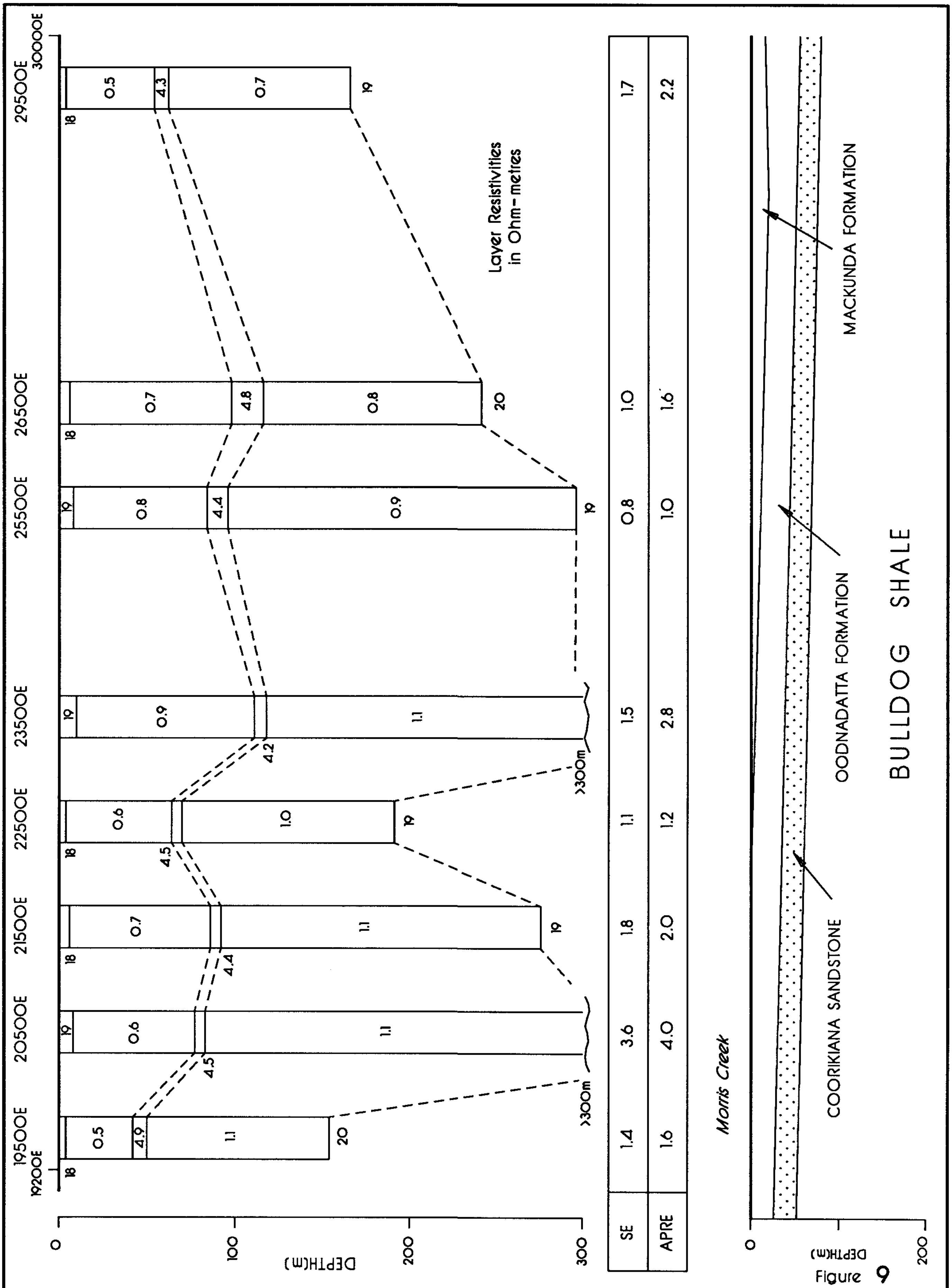
CDO	



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GREAT ARTESIAN BASIN GROUNDWATER STUDY
BOPEECHEE-MULOORINA SIROTEM TRAVERSE:CURDIMURKA, S.A.

19500E-29500E

RESISTIVITY SECTIONS FROM TEM INVERSIONS

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DATE	SCALE
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JOB NUMBER	PLAN NUMBER
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CDO	

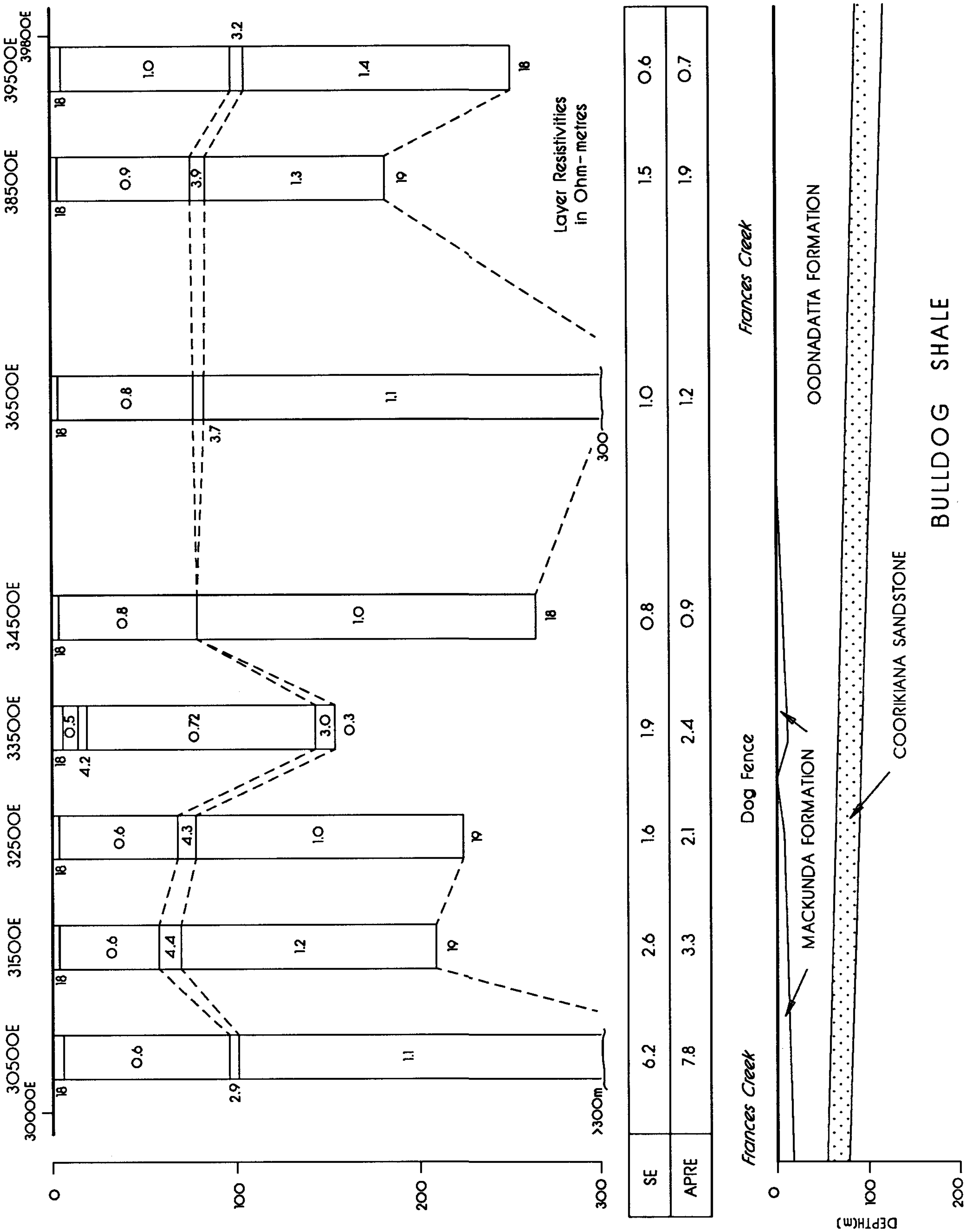

Figure 10

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GREAT ARTESIAN BASIN GROUNDWATER STUDY
BOPEECHEE-MULOORINA SIROTEM TRAVERSE:CURDIMURKA, S.A.

30500E-39500E

RESISTIVITY SECTIONS FROM TEM INVERSIONS

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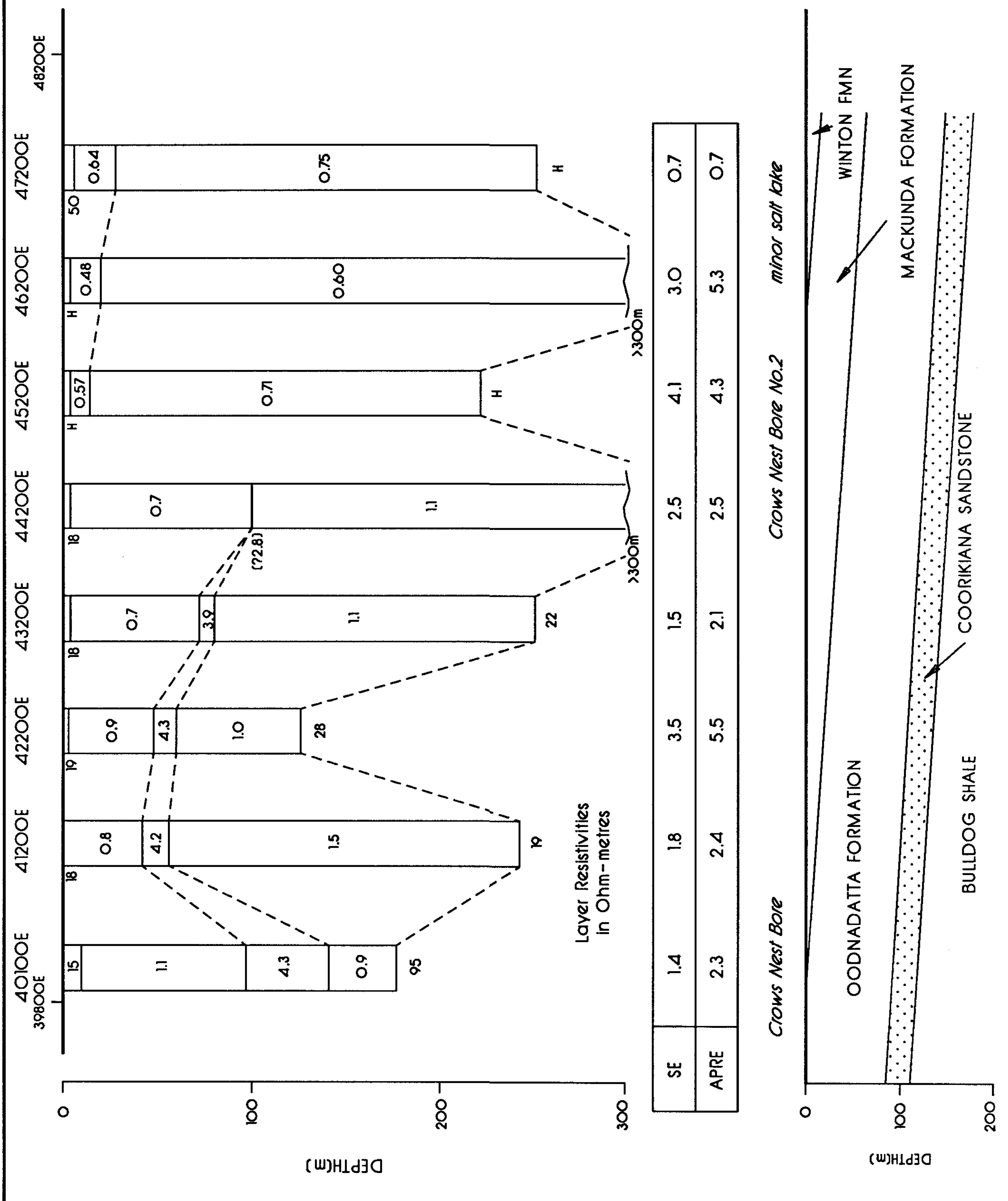

Figure 11

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SOUTH AUSTRALIA

GREAT ARTESIAN BASIN GROUNDWATER STUDY
BOPEECHEE-MULOORINA SIROTEM TRAVERSE:CURDIMURKA, S.A.

40100E-47200E

RESISTIVITY SECTIONS FROM TEM INVERSIONS

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CDO	

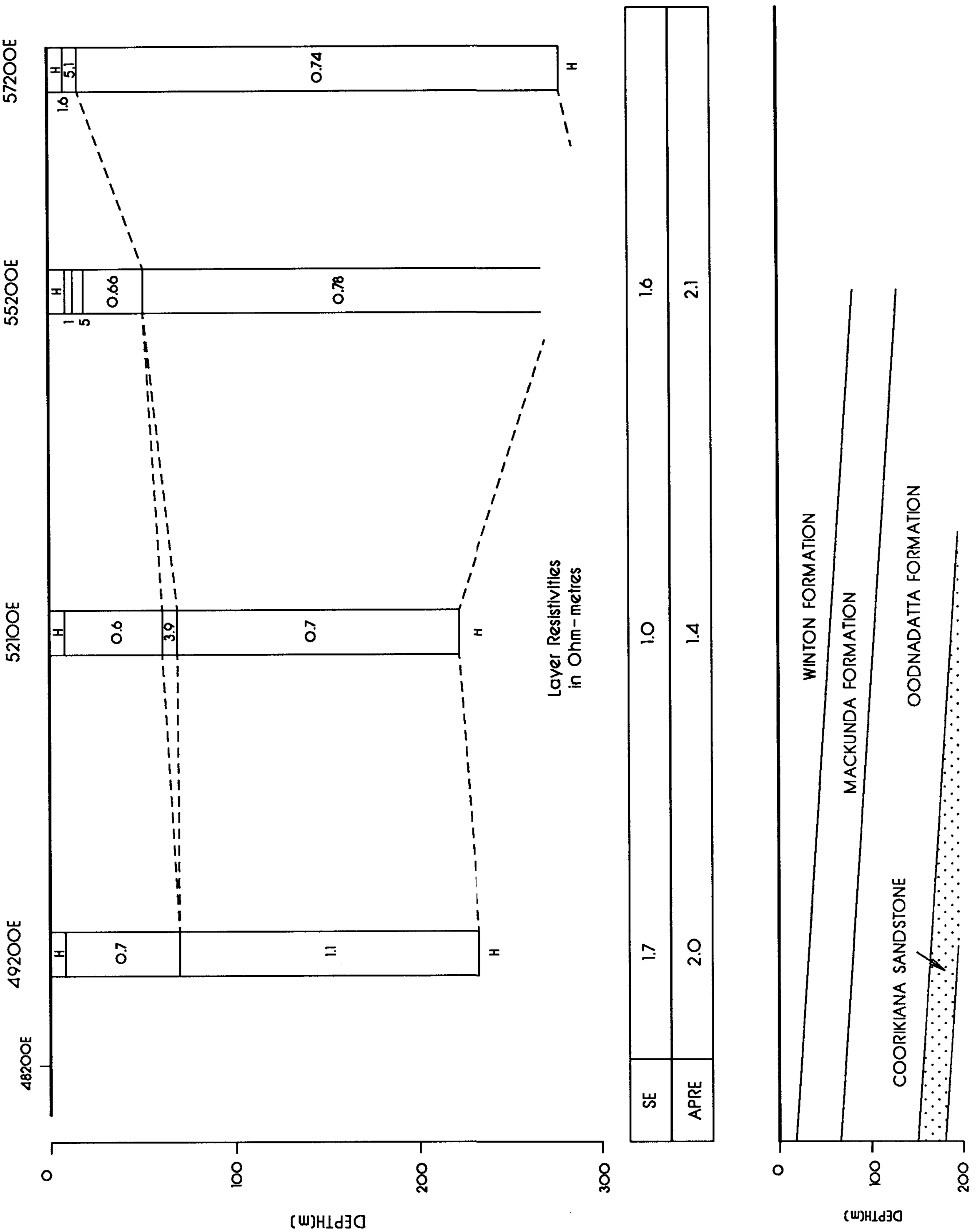

Figure 12

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	DRAWN J.G.	COMPILED A.D.
GREAT ARTESIAN BASIN GROUNDWATER STUDY BOPEECHEE-MULOORINA SIROTEM TRAVERSE:CURDIMURKA, S.A. **49200E-57200E** RESISTIVITY SECTIONS FROM TEM INVERSIONS	DATE 13DEC91	SCALE As shown
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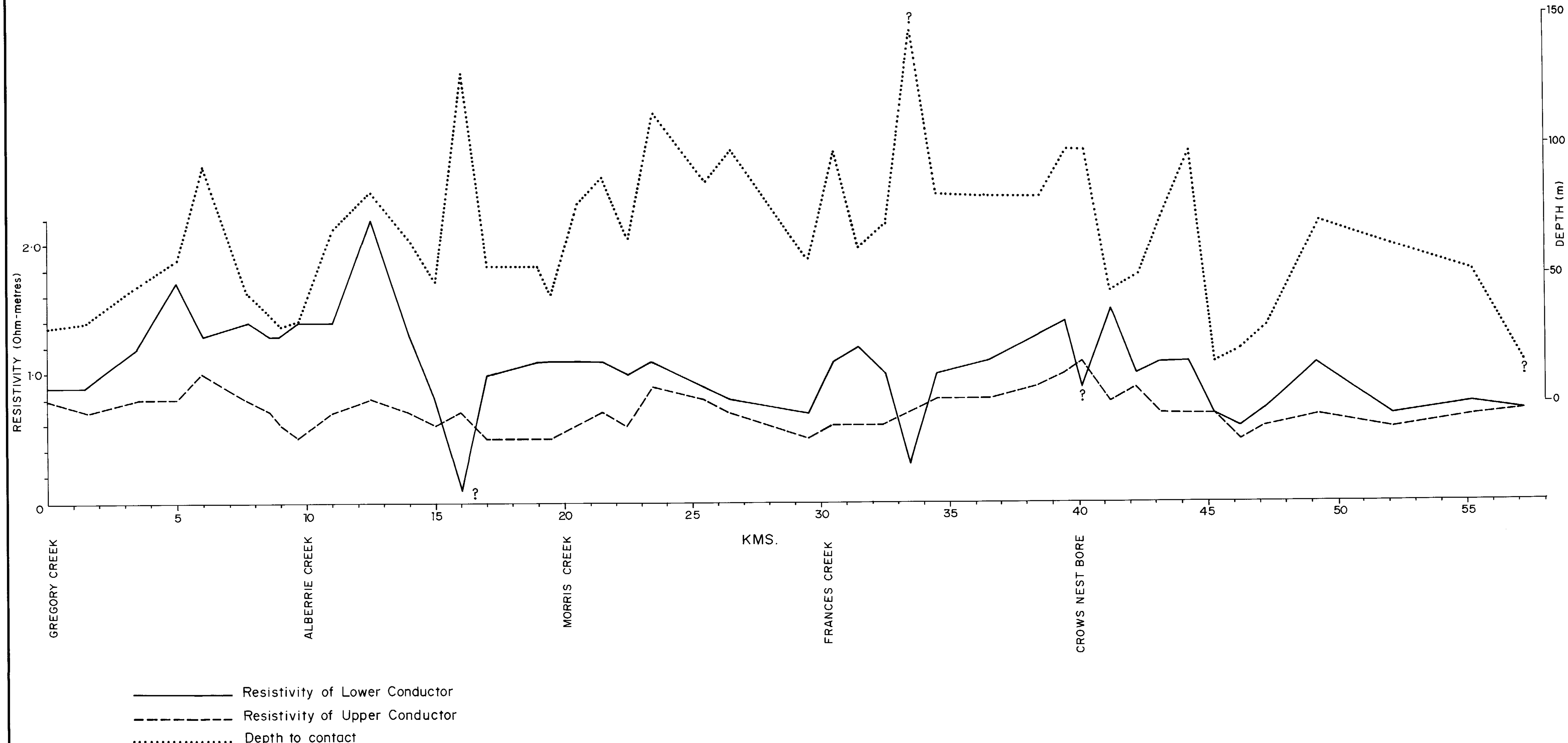

FIG. 13

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GREAT ARTESIAN BASIN GROUNDWATER STUDY
BOPEECHEE - MULOORINA SIROTEM TRAVERSE : CURDIMURKA, S. A.

BOPEECHEE RESISTIVITY PARAMETERS
TEM INVERSIONS

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DATE Nov '91	PLAN NUMBER	
CHECKED	91-663	

5477

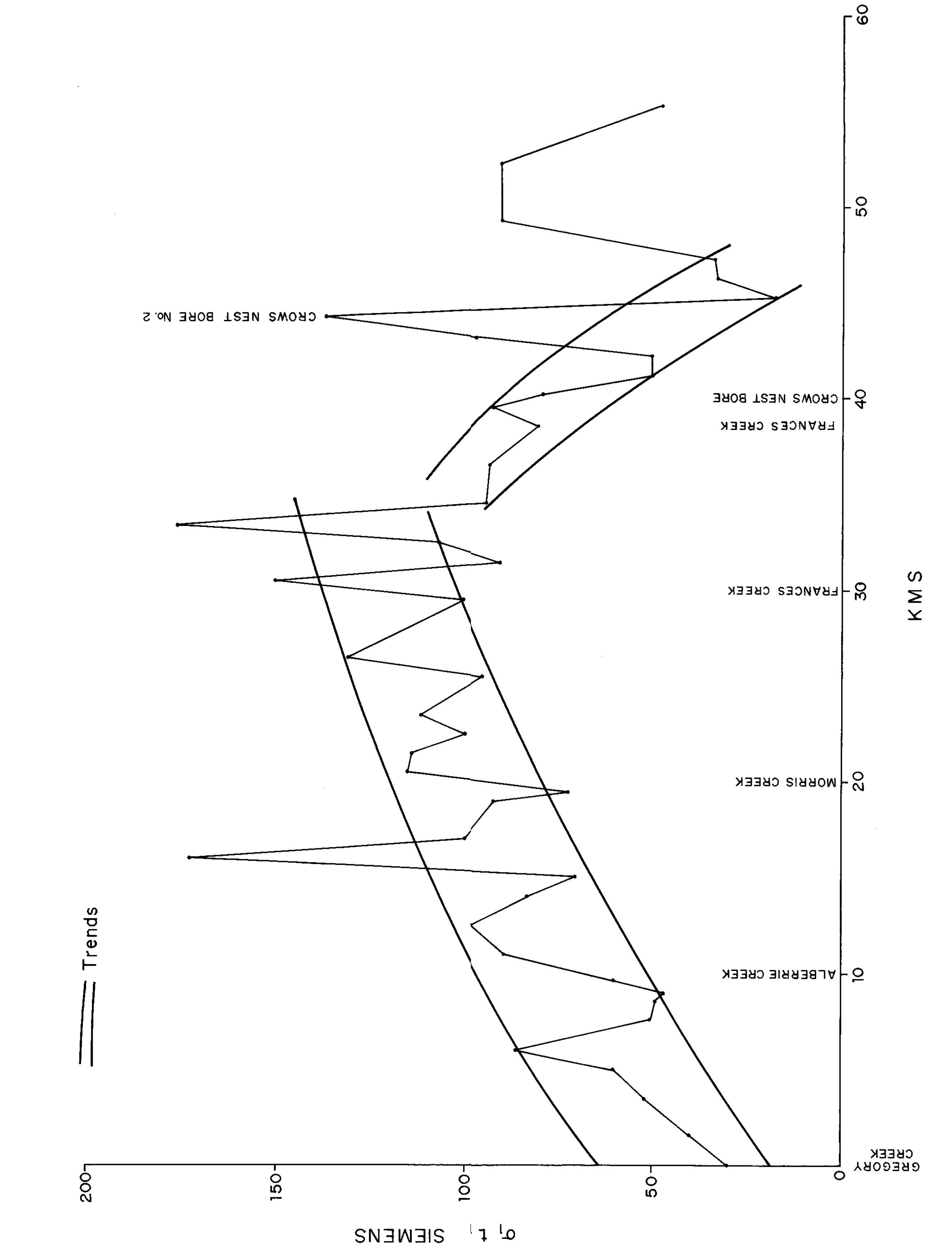

FIG. 14

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GREAT ARTESIAN BASIN GROUNDWATER STUDY
BOPEECHEE - MULOORINA SIROTEM TRAVERSE : CURDIMURKA, S. A.

BOPEECHEE TEM SURVEY — CONDUCTIVITY - THICKNESS PRODUCT OF THE UPPER CONDUCTOR

COMPILED A. D.	C.D.O. 5. 2. 92	DATE
DRAWN M.B.	SCALE	
DATE Nov '91	PLAN NUMBER S 22614	
CHECKED		

5477