HYDROGEOPHYSICAL REPORT 81/10

GOULBURN ISLAND GEOPHYSICAL SURVEY

PETER FURNESS
CONTENTS

1. INTRODUCTION
2. GEOLOGY OF THE AREA
3. SURVEY OBJECTIVES
4. INSTRUMENTATION
5. FIELD CONDITIONS
6. FIELD TECHNIQUES
7. RESULTS
8. CONCLUSIONS
1. INTRODUCTION

During the period 25 May to 1 June, 1981 surface geophysical investigations were undertaken on South Goulburn Island by the geophysical staff of the Hydrogeology Section, Water Division, N.T. Department of Transport and Works.

The field work was completed in a total period of five days by a crew comprising one geophysicist and two field assistants.

A breakdown of the field work completed during this period is as follows:

1) Seventeen vertical electric soundings were executed necessitating some 325 observations of apparent resistivity.

2) 625 meters of multiseparation two array resistivity profiling involving 108 measurements of apparent resistivity were completed.

3) 14.9 line Km of electromagnetic profiling was completed involving some 750 observations of apparent resistivity.

The above work was directed towards the investigation of both surfical and deep aquifers on the Island.
2. GEOLOGY OF THE AREA

The greater part of South Goulburn Island comprises argillaceous and fine-grained arenaceous sediments of the Moonkinu Member of the Cretaceous Bathurst Island Formation.

Borehole information over the Island indicates that these sediments unconformably overlie sandstone of the Proterozoic Kombolgie Formation. This information also suggests an increase in the grain size of the creataceous sediments at the base of the Member.

Over much of the Island the depth to the Proterozoic Sandstone appears to be in excess of 100 metres, however this sandstone does outcrop on Anyminali and neighbouring points on the western coast. Additionally, sandstone is known to occur at a depth of less than 7 metres in RN 8667 some two kilometres to the southeast (see map 1).

A well defined laterite profile exists over much of the Island. This particularly comprises a surficial ferruginous zone of dense, massive, ferrocrete underlain immediately by a mottle zone and ultimately by a clay ridge covered zone. In general the laterite appears to be absent or poorly developed in areas of outcropping or shallow sandstone.

Two aquifers are known to exist on the Island.

1) A surficial aquifer confined to the saturated and permeable upper zone of the laterite profile i.e. the mottled zone. This aquifer can be expected to be best developed in areas of deep laterization and therefore in regions remote from outcropping or subcropping sandstone. The water quality is known to be good.

2) A deep and fine aquifer is developed on and above the unconformity where coarser creataceous sediments overlie the Kombolgie sandstone. This aquifer is characterised by waters with a high value of total dissolved solids.
3. SURVEY OBJECTIVES

The purpose of the present survey was to investigate both the surfical and deep aquifers.

Specifically the aims of the survey were

1) to map the thickness of the surfical aquifer along lines A, C and D (see map 1) and

2) to outline the general topography of the top of the Proterozoic sandstone and in particular its behaviour along two traverses i.e.

   (i) traverse C between bores RN 8667 in the north and RN 8789 in the south, and

   (ii) traverse A along the northern boundary of the airstrip.

The relevance of the second objective to the investigation of the deep aquifer derives from the possibility of the sandstone exhibiting steep faceted slopes with associated coarse talers and scree deposits at their bases. This situation is typical with contemporary erosion of the Kombolgie sandstone elsewhere. Clearly such high permeability deposits at the base of the sandstone scarps would constitute priority targets for boreholes to intercept the deep aquifer.
4. INSTRUMENTATION

4.1 Resistivity

The resistivity instrumentation employed on the present survey is fully documented in Hydrogeophysical Report 80/2. Briefly, it comprises a transistorised 200 watt d.c. to d.c. converter (transmitter) and a digital d.c. millivoltmeter with an ultimate resolution of 10 microvolts and suitable provision for the bucking of S.P. and noise voltages.

4.2 Electromagnetic

The electromagnetic system used on the Goulburn Island survey was a commercial inductive terrain conductivity meter manufactured by Geonics Limited of Ontario, Canada.

This system employs a dual coil configuration in either horizontal coplanar or vertical coplanar mode with three selectable coil separations and frequencies. These latter parameters have been chosen to allow the system's operation at low induction numbers where an apparent conductivity is definable from the received quadrature response.

Apparent conductivities in the range of 0 - 3 to 300 millimhos/metre are read directly from the receiver.
5. FIELD CONDITIONS

Prevailing conditions at the time of survey for d.c. resistivity operations were less than ideal due to the presence over much of the Island of an extremely dense surficial surficrete layer. This layer made the implanting of driven-stake electrodes a most laborious task. Consequently, current electrode contact resistances were very high and often exceeded 20,000 ohms per electrode (in spite of wetting with salt water).

As a result of the above conditions transmitted currents (and consequently received voltages) tended to be quite low during much of the sounding operations. This problem was further exacerbated by the presence of a thick and mass conductive third layer over much of the island.

Fortunately, at the time of the survey S.P. voltages tended to be stable and noise free allowing the repeatable measurement of voltages of as little as 200 microwatts. Moreover, due to the excellent received signal to transmitted current ratio of the two array, the above problems did not affect the resistivity profiling operations to any great extent.

It should be mentioned that due to its inductive mode of operation (i.e. requiring not galvanic contact with the earth) the EM 34-3 showed to its best advantage under the prevailing conditions. Progress with this tool was excellent with no significant 50 Hz interference being observed except at the extreme southern end of line C close to a domestic power distribution line. No sign of interference was noted elsewhere along line C which over most of its length was within 50 metres of the high voltage power line supplying the northern borefield.
6. FIELD TECHNIQUES

The present field work involved two phases of investigations.

Initially nine Schlumberger vertical electric soundings were completed at various sites along the proposed traverses. Additionally, four parametric soundings were completed in the vicinity of outcrops and boreholes where geological control was available.

Normally all soundings were expanded from a half current electrode separation of 2.5 metres to in excess of 200 metres according to a logarithmic formula that resulted in the sampling of the sounding curve at 10 points per decade of expansion.

Based on considerations of the geoelectric section as derived from the electrical sounding subsequent electromagnetic profiling was conducted with the maximum available coil spacing of 40 metres in order to achieve a sufficient depth of investigation for the present purposes.

Electromagnetic profiles designed to investigate the surficial aquifer (A, C and D) were completed with both horizontal coplanar and vertical coplanar coil measurements in order to give some control on the vertical position of anomalous responses. Subsequent profiles X, Y and Z were designed to outline the southern boundary of the sandstone in the vicinity of profile C and were completed in the vertical coplanar mode only.

Four short follow-up Schlumberger soundings expanded from 2.5 to 32 metres were completed along line C to aid in the interpretation of the electromagnetic profiling results.

Some 650 metres of multiseparations two array profiles completed along the appropriate section of line C in order to determine the dip of the southern boundary of the subcropping sandstone completed the survey.

All electromagnetic profiles completed were surveyed by means of a measured reference cable and flagged at 200 metres. It is considered that surveying errors introduced by this technique would not exceed one percent. Profiles A and C were subsequently pegged at 1000 metre intervals while the more sinuous traverse D was pegged at 400 metre stations.
7. RESULTS

7.1 Soundings

The results of all Schlumbergeere vertical electric soundings are shown plotted in the conventional bilogarithmic format in plates 1 - 17. Here the field observations of apparent resistivity in ohm-metres are plotted against the appropriate half current electrode separations in metres.

The location of all soundings as well as their expansion directions are illustrated in map 1.

After appropriate smoothing and segment migration the sounding curves have been interpreted and their solutions illustrated in each plate above the relevant field data. Occasionally included in these plates are theoretical computer generated sounding curves based on the solution earth model. These are shown as continuous lines and are included to better facilitate an evaluation of the solutions.

7.1.2 Parametric Soundings

Sounding S1-1 completed over outcropping Kombolgie sandstone suggests that the resistivity of this unit at depth is somewhat under 1000 Ohm-metres.

Sounding S1-3 was executed near borehole RN 8667 where sandstone was intersected at less than seven metres. Quantitative interpretation of the curve was not attempted due to the possibility at this site of natural effects.

Sounding S1-6 and S2-3 were both completed in close proximity to borehole RN8789 where sandstone was encountered at a depth of 127.6 metres. The object of these soundings was to define the resistivity of the Cretaceous sediments.

To this end attempts were made to invert both soundings by means of a computerized non-linear least squares inversion scheme with appropriate constraints imposed on layer thicknesses (see Hydrogeophysical Report 80/7). While this procedure failed to yield an acceptable solution for sounding S1-6, sounding S2-3 was adequately fitted by an earth model with a value of 3.4 Ohm-metres for the resistivity of the Bathurst Island sediments.

A subsequent attempt at an unconstrained inversion of sounding S1-6 did however yield an acceptable solution with a value of 4.9 ohm-metres for the same unit, but with a rather unrealistic total depth to sandstone of in excess of 170 metres. For this reason, as well as the greater reliability of the field data of sounding S2-3, a figure of 3.4 ohm-metres is taken as being representative of the resistivity of the unlateritized Cretaceous sediments.
7.1.3 Routine Soundings

With the exception of Sl-2 all soundings were interpreted by means of the Orellana technique for H type curves or by total curve matching with two layer masters.

Ambiguity due to S equivalence in the case of H type curves was resolved by imposing a second layer resistivity of 3.4 ohm-metres. This figure however was found to be incompatible with the curve of Sl-2. Here an unconstrained least squares inversion yielded a second layer (Cretaceous sediments) resistivity of in excess of 8 ohm-metres with evidence for little scope for S equivalence.

It should be mentioned that in arriving at all the above interpretations the effect of any near surface layers on the sounding curves was neglected. This was due to the fact that in almost every case the shallow portions of the soundings were highly distorted but typically showed the presence of a non homogeneous, near surface conductor. This is attributed to the presence of the ferricrete layer.

Two sounding curves showed the presence of a thin, resistive surface layer. This was interpreted as the result of a surficial aerated zone of the laterite profile.

While it is acknowledged that a more detailed treatment of the soundings and in particular the incorporation of a surficial conductive layer into the majority of solutions would yield more accurate near surface results, the interpretation scheme described above is considered to be best fitted to the present situation.

In particular it is recognised that neglect of the surficial conductor in the interpretation will result in

1. An underestimation of the resistivity of layer 2, and
2. An overestimation of the depth to the top layer of 3 (i.e. in general an overestimation of the thickness of layer 2).

These facts should be borne in mind when assessing the solutions of the resistivity soundings.

In summary, typical sounding curves observed over areas of moderate to deep cretaceous cover on Goulburn Island over the KH and much more rarely the QH types. Figure 1 illustrates the prevailing geoelectric section in this terrain as well as its inferred correlation with the geological section.
FIGURE 1

GEOELECTRIC SECTION

SURFACE
layer 1 (100 ohm-metres)

layer 2 (100 - 700)

layer 3 (3.4 [8.3])

layer 4 (high [~1000])

GEOLOGICAL SECTION

ferricrete

mottled zone

pallid zone

Bathurst Island Formation

Kombolgie Sandstone
7.2 Electromagnetic Profiling

7.2.1 Lines A, C, D.

Inductively measured apparent conductivity profiles along traverses A, C, and D are illustrated in sheet 1.

In general the responses observed with both horizontal and vertical coplanar coil measurements are very similar. As expected from considerations of their respective investigations characteristics however the vertical coil observations are obviously most sensitive to the presence of the surficial conductor (layer 1) while the horizontal coil measurements exhibit a greater depth of investigation.

For the above reasons the horizontal coil profiles are useful as an indicator of thickness of the resistive mottled zone (i.e. depth to the conductive layer 3). The vertical coil profiles serve as a monitor of the near surface conductor (layer 1) which if well developed will significantly influence the horizontal coil measurements also.

Line A

The form of this profile closely follows the elevation of the traverse.

This behaviour appears to result from a near horizontal interface existing between layers 2 and 3 i.e. separating the resistive section of the laterite profile and deeper conductives. This circumstance can be reasonably expected considering the process and environment of lateritization. It follows that depressions in the present island surface, as for example exist around its perimeter, will result in shallower depths to the conductive layer 3 and consequently increased apparent conductivity measurements (particularly as observed in the horizontal coplanar mode).

Sounding S2-1, S2-2 and S2-3 substantiate this observation showing the greatest development of layer 2 at station S2-2.

Line C

The major feature seen on line C is the presence of a substantial block of resistive Kombolgie Sandstone subcropping between co-ordinates 340 S and 1740 N. The remainder of the profile comprises lateritized Bathurst Island Formation.

It is significant to mention that bore RN 20306 located on a minor conductive indication within the sandstone is the poorest producer on the borefield. Bore RN 20305 located just south of the sandstone boundary yields better while RN 20303 (well within the region of deep Cretaceous cover) is one of the best producers on the field.

When account is taken of the presence of the surficial conductor (layer 1) as indicated by the vertical coil
measurements, the horizontal coil profile is seen to be remarkably constant over the entire Cretaceous sections of the traverse. This would indicate a roughly equal development of the mottled zone over the sections of the profile and consequently a uniformly favourable groundwater potential in so far as the surficial aquifer is concerned. Closer inspection of the profiles along with the relevant sounding results do however indicate a number of area of above average potential. These are (not necessarily in order of increasing significance):

1. 1600 S to 1900 S,
2. 2000 N to 2600 N, and
3. 4000 N to 4600 N.

Line D

The comments made of line A are again relevant here.

Extremely conductive indications at the start of the traverse derive from the proximity of a swamp immediately to the west of the line at this point. Otherwise the thickness of the mottled zone can be expected to increase steadily from the south to the centre of the island.

7.2.2 Lines X, Y, Z

Electromagnetic profiles X, Y and Z as well as the relevant sections of line C are shown in contour form in sheet 2.

This plan clearly outlines the southern most area of the subcrop of the Kombolgie Sandstone. A rough indication of the outline of the sandstone boundary at some depth is given by the 50 millimho/metre contour. This would indicate a horizontal position of approximately 340 S on line C for the trace of the sandstone scarp.

Clearly the sandstone here forms a southward spur of limited width and bounded by slopes of probably moderate to high gradients (at least near the surface). There is evidence at 00 N on line C of dissection of the block or of a depression in the sandstone surface bearing at approximately 70°. Also suggested by the contour map is the presence of maximum gradients in the southern sandstone boundary along line C.

7.3 Resistivity Profiles

Two array apparent resistivity profiles run over the southern sandstone boundary along line C are illustrated in sheet 3.

The profiles suggest a steep dip to the south however these indications must be accepted with some reservations due to the three dimensional nature of the sandstone.
block (as evidenced by the electromagnetic results).

From these results a conservative estimate of the horizontal position of the base of the sandstone scarp would be approximately 400 - 450 S on line C.
8. CONCLUSIONS

1. The geoelectric section in areas of Cretaceous cover on Goulburn Island appear to be almost universally of the KH type with rare QH variations.

2. Correlation of geophysical responses with existing boreholes on the island indicates that the shallow aquifer is effectively confined to areas of lateritized Bathurst Island Formation.

3. Generally speaking the thickness of the mottled zone (upper aquifer) appears to vary in sympathy with the topography or height of the island.

4. As outlined in the survey objectives the aim of the surficial investigations was to map the thickness of the mottled zone of the laterite profile. In so doing it has been noticed that the resistivity of this unit (generally lying between 300 and 400 ohm-metres) varies from between 100 to 700 ohm-metres.

At this point the hydrogeological implications of aquifer resistivity cannot be categorically stated due to the nature of the aquifer and the likely modes of electrical conduction in operation. These include both electrolytic conduction by interstitial water as well as surface conduction due to the abundant clays. For this reason it is difficult to say whether an increase in resistivity indicates a diminished electrolytic component of conduction due to decreased permeability or increased water quality rather than a diminished surface conduction component caused by increased permeability due to a decreased clay fraction.

The resolution of this question should be considered of highest priority. Depending on its answer the resistivity of layer 2 as indicated by soundings could represent an excellent indicator of the potential yield of the mottled zone.

5. Sandstone areas on the island appear to represent the dissected remnants of a large sandstone plateau. Its present form suggests a number of residual hills of mesa-like form rather than one continuous body.

6. Lateral slopes of the sandstone appear to be faceted and extreme rather than gradual. One possible exception appears to be south of Anyminalie Point where sounding S4-2 estimates the depth to sandstone to be approximately 40 metres. The majority of other soundings conducted in areas of Cretaceous cover indicate depths in excess of twice this figure.
7. The area most favourable for extreme sandstone slopes appears to be the southern sandstone boundary along line C. It is suggested that any borehole designed to intersect the base of the sandstone slope on line C should not be positioned north of 450° S. This suggestion is made to minimize the chance of such a borehole intersecting the sandstone up-slope of its base. Clearly such an environment would be unlikely to yield high permeability scree sediments.
Plate 1

\[
\begin{array}{cc}
\rho & h \\
180 & 0.88 \\
5900 & 22 \\
950 & \\
\end{array}
\]
<table>
<thead>
<tr>
<th>$\rho$</th>
<th>$h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>550</td>
<td>1.06</td>
</tr>
<tr>
<td>92.2</td>
<td>9.15</td>
</tr>
<tr>
<td>8.3</td>
<td>11.44</td>
</tr>
<tr>
<td>3200</td>
<td></td>
</tr>
</tbody>
</table>
Plate 4

\[
\begin{array}{c|c}
\rho & n \\
3.0 & 11.8 \\
3.4 & 9.2 \\
\text{very high} & \\
\end{array}
\]
Plate 5

<table>
<thead>
<tr>
<th>( p )</th>
<th>( k )</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.40</td>
<td>5.8</td>
</tr>
<tr>
<td>3.4</td>
<td>69</td>
</tr>
<tr>
<td>&gt;100</td>
<td></td>
</tr>
</tbody>
</table>

![Graph](image-url)
Plate 6

\[
\begin{array}{cc}
\rho & \eta \\
385 & 5.7 \\
4.9 & 168.5 \\
740 & \\
\end{array}
\]
Plate 8

<table>
<thead>
<tr>
<th>$P$</th>
<th>$n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>27.0</td>
<td>18.5</td>
</tr>
<tr>
<td>3.4</td>
<td>13.3</td>
</tr>
<tr>
<td>$&gt;100$</td>
<td></td>
</tr>
</tbody>
</table>
Plate II
<table>
<thead>
<tr>
<th>( r )</th>
<th>( h )</th>
</tr>
</thead>
<tbody>
<tr>
<td>380</td>
<td>3.6</td>
</tr>
<tr>
<td>3.4</td>
<td>38.5</td>
</tr>
<tr>
<td>high</td>
<td></td>
</tr>
</tbody>
</table>

Plate 13

![Graph](image-url)
1. INTRODUCTION

During the period 25 May to 1 June, 1981 surface geophysical investigations were undertaken on South Goulburn Island by the geophysical staff of the Hydrogeology Section, Water Division, N.T. Department of Transport and Works.

The field work was completed in a total period of five days by a crew comprising one geophysicist and two field assistants.

A breakdown of the field work completed during this period is as follows:

1) Seventeen vertical electric soundings were executed necessitating some 325 observations of apparent resistivity.

2) 625 meters of multiseparation two array resistivity profiling involving 108 measurements of apparent resistivity were completed.

3) 14.9 line Km of electromagnetic profiling was completed involving some 750 observations of apparent resistivity.

The above work was directed towards the investigation of both surfical and deep aquifers on the Island.
2. GEOLOGY OF THE AREA

The greater part of South Goulburn Island comprises argillaceous and fine grained arenaceous sediments of the Moonkinu Member of the Cretaceous Bathurst Island Formation.

Borehole information over the Island indicates that these sediments unconformably overlie sandstone of the Proterozoic Kombolgie Formation. This information also suggests an increase in the grain size of the creataceous sediments at the base of the Member.

Over much of the Island the depth to the Proterozoic Sandstone appears to be in excess of 100 metres, however this sandstone does outcrop on Anyminali and neighbouring points on the western coast. Additionally, sandstone is known to occur at a depth of less than 7 metres in some two kilometres to the southeast (see map 1).

A well defined laterite profile exists over much of the Island. This particularly comprises a surfical ferruginous zone of dense, massive, ferrocrete underlain immediately by a mottle zone and ultimately by a clay ridge covered zone. In general the laterite appears to be absent or poorly developed in areas of outcropsing or shallow sandstone.

Two aquifers are known to exist on the Island.

1) A surfical aquifer confined to the saturated and permeable upper zone of the laterite profile i.e. the mottled zone. This aquifer can be expected to be best developed in areas of deep laterization and therefore in regions remote from outcropping or subcropping sandstone. The water quality is known to be good.

2) A deep and fine aquifer is developed on and above the unconformity where coarser creataceous sediments overlie the Kombolgie sandstone. This aquifer is characterised by waters with a high value of total dissolved solids.
3. SURVEY OBJECTIVES

The purpose of the present survey was to investigate both the surficial and deep aquifers.

Specifically the aims of the survey were

1) to map the thickness of the surficial aquifer along lines A, C and D (see map 1) and

2) to outline the general topography of the top of the Proterozoic sandstone and in particular its behaviour along two traverses i.e.

   (i) traverse C between bores RN 8667 in the north and RN 8789 in the south, and

   (ii) traverse A along the northern boundary of the airstrip.

The relevance of the second objective to the investigation of the deep aquifer derives from the possibility of the sandstone exhibiting steep faceted slopes with associated coarse talers and scree deposits at their bases. This situation is typical with contemporary erosion of the Kombolgie sandstone elsewhere. Clearly such high permeability deposits at the base of the sandstone scarps would constitute priority targets for boreholes to intercept the deep aquifer.
4. INSTRUMENTATION

4.1 Resistivity

The resistivity instrumentation employed on the present survey is fully documented in Hydrogeophysical Report 80/2. Briefly, it comprises a transistorised 200 watt d.c. to d.c. converter (transmitter) and a digital d.c. millivoltmeter with an ultimate resolution of 10 mirovolts and suitable provision for the bucking of S.P. and noise voltages.

4.2 Electromagnetic

The electromagnetic system used on the Goulburn Island survey was a commercial inductive terrain conductivity meter manufactured by Geonics Limited of Ontario, Canada.

This system employs a dual coil configuration in either horizontal coplanar or vertical coplanar mode with three selectable coil separations and frequencies. These latter parameters have been chosen to allow the systems operation at low induction numbers where an apparent conductivity is definable from the received quadrature response.

Apparent conductivities in the range of 0 - 3 to 300 millimhos/metre are read directly from the receiver.
5. FIELD CONDITIONS

Prevailing conditions at the time of survey for d.c. resistivity operations were less than ideal due to the presence over much of the Island of an extremely dense surficial furfiorete layer. This layer made the implanting of driven-stake electrodes a most laborious task. Consequently, current electrode contact resistances were very high and often exceeded 20,000 ohms per electrode (in spite of wetting with salt water).

As a result of the above conditions transmitted currents (and consequently received voltages) tended to be quite low during much of the sounding operations. This problem was further exacerbated by the presence of a thick and mass conductive third layer over much of the island.

Fortunately, at the time of the survey S.P. voltages tended to be stable and noise free allowing the repeatable measurement of voltages of as little as 200 mircovolts. Moreover, due to the excellent received signal to transmitted current ratio of the two array, the above problems did not affect the resistivity profiling operations to any great extent.

It should be mentioned that due to its inductive mode of operation (i.e. requiring not galvanic contact with the earth) the EM 34-3 showed to its best advantage under the prevailing conditions. Progress with this tool was excellent with no significant 50 Hz interference being observed except at the extreme southern end of line C close to a domestic power distribution line. No sign of interference was noted elsewhere along line C which over most of its length was within 50 metres of the high voltage power line supplying the northern borefield.
6. FIELD TECHNIQUES

The present field work involved two phases of investigations. Initially nine Schlumbeegees vertical electric soundings were completed at various sites along the proposed traverses. Additionally, four parametric soundings were completed in the vicinity of outcrops and boreholes where geological control was available.

Normally all soundings were expanded from a half current electrode separation of 2.5 metres to in excess of 200 metres according to a logarithmic formula that resulted in the sampling of the sounding curve at 10 points per decade of expansion.

Based on considerations of the geoelectric section as derived from the electrical sounding subsequent electromagnetic profiling was conducted with the maximum available coil spacing of 40 metres in order to achieve a sufficient depth of investigation for the present purposes.

Electromagnetic profiles designed to investigate the surficial aquifer (A, C and D) were completed with both horizontal coplanar and vertical coplanar coil measurements in order to give some control on the vertical position of anomalous responses. Subsequent profiles X, Y and Z were designed to outline the southern boundary of the sandstone in the vicinity of profile C and were completed in the vertical coplanar mode only.

Four short follow-up Schlumbeegees soundings expanded from 2.5 to 32 metres were completed along line C to aid in the interpretation of the electromagnetic profiling results.

Some 650 metres of multiseparations two array profiles completed along the appropriate section of line C in order to determine the dip of the southern boundary of the subcropping sandstone completed the survey.

All electromagnetic profiles completed were surveyed by means of a measured reference cable and flagged at 200 metres. It is considered that surveying errors introduced by this technique would not exceed one percent. Profiles A and C were subsequently pegged at 1000 metre intervals while the more sinuous traverse D was pegged at 400 metre stations.
7. RESULTS

7.1 Soundings

The results of all Schlumberger vertical electric soundings are shown plotted in the conventional bilogarithmic format in plates 1 - 17. Here the field observations of apparent resistivity in ohm-metres are plotted against the appropriate half current electrode separations in metres.

The location of all soundings as well as their expansion directions are illustrated in map 1.

After appropriate smoothing and segment migration the sounding curves have been interpreted and their solutions illustrated in each plate above the relevant field data. Occasionally included in these plates are theoretical computer generated sounding curves based on the solution earth model. These are shown as continuous lines and are included to better facilitate an evaluation of the solutions.

7.1.2 Parametric Soundings

Sounding SI-1 completed over outcropping Kombolgie sandstone suggests that the resistivity of this unit at depth is somewhat under 1000 Ohm-metres.

Sounding SI-3 was executed near borehole RN 8667 where sandstone was intersected at less than seven metres. Quantitative interpretation of the curve was not attempted due to the possibility at this site of natural effects.

Sounding SI-6 and S2-3 were both completed in close proximity to borehole RN8789 where sandstone was encountered at a depth of 127.6 metres. The object of these soundings was to define the resistivity of the Cretaceous sediments.

To this end attempts were made to invert both soundings by means of a computerized non linear least squares inversion scheme with appropriate constraints imposed on layer thicknesses (see Hydrogeophysical Report 80/7). While this procedure failed to yield an acceptable solution for sounding SI-6, sounding S2-3 was adequately fitted by an earth model with a value of 3.4 Ohm-metres for the resistivity of the Bathurst Island sediments.

A subsequent attempt at an unconstrained inversion of sounding SI-6 did however yield an acceptable solution with a value of 4.9 ohm-metres for the same unit, but with a rather unrealistic total depth to sandstone of in excess of 170 metres. For this reason, as well as the greater reliability of the field data of sounding S2-3, a figure of 3.4 ohm-metres is taken as being representative of the resistivity of the unlateritized Cretaceous sediments.
7.1.3 Routine Soundings

With the exception of Sl-2 all soundings were interpreted by means of the Orellana technique for H type curves or by total curve matching with two layer masters.

Ambiguity due to S equivalence in the case of H type curves was resolved by imposing a second layer resistivity of 3.4 ohm-metres. This figure however was found to be incompatible with the curve of Sl-2. Here an unconstrained least squares inversion yielded a second layer (Cretaceous sediments) resistivity of in excess of 8 ohm-metres with evidence for little scope for S equivalence.

It should be mentioned that in arriving at all the above interpretations the effect of any near surface layers on the sounding curves was neglected. This was due to the fact that in almost every case the shallow portions of the soundings were highly distorted but typically showed the presence of a non homogeneous, near surface conductor. This is attributed to the presence of the ferricrete layer.

Two sounding curves showed the presence of a thin, resistive surface layer. This was interpreted as the result of a surficial aerated zone of the laterite profile.

While it is acknowledged that a more detailed treatment of the soundings and in particular the incorporation of a surficial conductive layer into the majority of solutions would yield more accurate near surface results, the interpretation scheme described above is considered to be best fitted to the present situation.

In particular it is recognised that neglect of the surficial conductor in the interpretation will result in

1. An underestimation of the resistivity of layer 2, and
2. An overestimation of the depth to the top layer of 3 (i.e. in general an overestimation of the thickness of layer 2).

These facts should be borne in mind when assessing the solutions of the resistivity soundings.

In summary, typical sounding curves observed over areas of moderate to deep cretaceous cover on Goulburn Island over the KH and much more rarely the QH types. Figure 1 illustrates the prevailing geoelectric section in this terrain as well as its inferred correlation with the geological section.
FIGURE 1

GEOELECTRIC SECTION

SURFACE

layer 1 (100 ohm-metres)

layer 2 (100 - 700)

layer 3 (3.4 \( \sim 8.3 \))

layer 4 (high \( \sim 1000 \))

GEOLOGICAL SECTION

ferricrete

mottled zone

pallid zone

Bathurst Island Formation

Kombolgie Sandstone
7.2 Electromagnetic Profiling

7.2.1 Lines A, C, D.

Inductively measured apparent conductivity profiles along traverses A, C, and D are illustrated in sheet 1.

In general the responses observed with both horizontal and vertical coplanar coil measurements are very similar. As expected from considerations of their respective investigations characteristics however the vertical coil observations are obviously most sensitive to the presence of the surficial conductor (layer 1) while the horizontal coil measurements exhibit a greater depth of investigation.

For the above reasons the horizontal coil profiles are useful as an indicator of thickness of the resistive mottled zone (i.e. depth to the conductive layer 3). The vertical coil profiles serve as a monitor of the near surface conductor (layer 1) which if well developed will significantly influence the horizontal coil measurements also.

Line A

The form of this profile closely follows the elevation of the traverse.

This behaviour appears to result from a near horizontal interface existing between layers 2 and 3 i.e. separating the resistive section of the laterite profile and deeper conductives. This circumstance can be reasonably expected considering the process and environment of lateritization. It follows that depressions in the present island surface, as for example exist around its perimeter, will result in shallower depths to the conductive layer 3 and consequently increased apparent conductivity measurements (particularly as observed in the horizontal coplanar mode).

Sounding S2'-1, S2-2 and S2-3 substantiate this observation showing the greatest development of layer 2 at station S2-2.

Line C

The major feature seen on line C is the presence of a substantial block of resistive Kombolgie Sandstone subcropping between co-ordinates 340 S and 1740 N. The remainder of the profile comprises "lateritized" Bathurst Island Formation.

It is significant to mention that bore RN 20306 located on a minor conductive indication within the sandstone is the poorest producer on the borefield. Bore RN 20305 located just south of the sandstone boundary yields better while RN 20303 (well within the region of deep Cretaceous cover) is one of the best producers on the field.

When account is taken of the presence of the surficial conductor (layer 1) as indicated by the vertical coil
measurements, the horizontal coil profile is seen to be remarkably constant over the entire Cretaceous sections of the traverse. This would indicate a roughly equal development of the mottled zone over the sections of the profile and consequently a uniformly favourable groundwater potential in so far as the surficial aquifer is concerned. Closer inspection of the profiles along with the relevant sounding results do however indicate a number of areas of above average potential. These are (not necessarily in order of increasing significance):

(1) 1600 S to 1900 S,
(2) 2000 N to 2600 N, and
(3) 4000 N to 4600 N.

Line D

The comments made of line A are again relevant here.

Extremely conductive indications at the start of the traverse derive from the proximity of a swamp immediately to the west of the line at this point. Otherwise the thickness of the mottled zone can be expected to increase steadily from the south to the centre of the island.

7.2.2 Lines X, Y, Z

Electromagnetic profiles X, Y and Z as well as the relevant sections of line C are shown in contour form in sheet 2.

This plan clearly outlines the southern most area of the subcrop of the Kombolgie Sandstone. A rough indication of the outline of the sandstone boundary at some depth is given by the 50 millimho/metre contour. This would indicate a horizontal position of approximately 340 S on line C for the trace of the sandstone scarp.

Clearly the sandstone here forms a southward spur of limited width and bounded by slopes of probably moderate to high gradients (at least near the surface). There is evidence at 00 N on line C of dissection of the block or of a depression in the sandstone surface bearing at approximately 70°. Also suggested by the contour map is the presence of maximum gradients in the southern sandstone boundary along line C.

7.3 Resistivity Profiles

Two array apparent resistivity profiles run over the southern sandstone boundary along line C are illustrated in sheet 3.

The profiles suggest a steep dip to the south however these indications must be accepted with some reservations due to the three dimensional nature of the sandstone
block (as evidenced by the electromagnetic results).

From these results a conservative estimate of the horizontal position of the base of the sandstone scarp would be approximately 400 – 450 S on line C.
8. CONCLUSIONS

1. The geoelectric section in areas of Cretaceous cover on Goulburn Island appear to be almost universally of the KH type with rare QH variations.

2. Correlation of geophysical responses with existing boreholes on the island indicates that the shallow aquifer is effectively confined to areas of lateritized Bathurst Island Formation.

3. Generally speaking the thickness of the mottled zone (upper aquifer) appears to vary in sympathy with the topography or height of the island.

4. As outlined in the survey objectives the aim of the surficial investigations was to map the thickness of the mottled zone of the laterite profile. In so doing it has been noticed that the resistivity of this unit (generally lying between 300 and 400 ohm-metres) varies from between 100 to 700 ohm-metres.

At this point the hydrogeological implications of aquifer resistivity cannot be categorically stated due to the nature of the aquifer and the likely modes of electrical conduction in operation. These include both electrolytic conduction by interstitial water as well as surface conduction due to the abundant clays. For this reason it is difficult to say whether an increase in resistivity indicates a diminished electrolytic component of conduction due to decreased permeability or increased water quality rather than a diminished surface conduction component caused by increased permeability due to a decreased clay fraction.

The resolution of this question should be considered of highest priority. Depending on its answer the resistivity of layer 2 as indicated by soundings could represent an excellent indicator of the potential yield of the mottled zone.

5. Sandstone areas on the island appear to represent the dissected remnants of a large sandstone plateau. Its present form suggests a number of residual hills of mesa-like form rather than one continuous body.

6. Lateral slopes of the sandstone appear to be faceted and extreme rather than gradual. One possible exception appears to be south of Anyminalie Point where sounding S4-2 estimates the depth to sandstone to be approximately 40 metres. The majority of other soundings conducted in areas of Cretaceous cover indicate depths in excess of twice this figure.
7. The area most favourable for extreme sandstone slopes appears to be the southern sandstone boundary along line C.

It is suggested that any borehole designed to intersect the base of the sandstone slope on line C should not be positioned north of 4500 S. This suggestion is made to minimize the chance of such a borehole intersecting the sandstone up-slope of its base. Clearly such an environment would be unlikely to yield high permeability scree sediments.
Plate 1

\[ \begin{array}{c|c}
\theta & \eta \\
130 & 0.88 \\
5900 & 2.2 \\
950 & \ \\
\end{array} \]
Plate 6

<table>
<thead>
<tr>
<th>$p$</th>
<th>$h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>386</td>
<td>5.5</td>
</tr>
<tr>
<td>4.9</td>
<td>168.5</td>
</tr>
<tr>
<td>140</td>
<td></td>
</tr>
<tr>
<td>$P$</td>
<td>$n$</td>
</tr>
<tr>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>270</td>
<td>18.5</td>
</tr>
<tr>
<td>3.4</td>
<td>131.3</td>
</tr>
<tr>
<td>&gt;100</td>
<td></td>
</tr>
</tbody>
</table>
Map 1

South Coulburn Island

- geophysical traverses
- electrical sounding locations
- base locations

Legend:
- South West Bay
- Fletcher Point
- Anyimina Point
- Hourgui Point
- Marshal Bay

Scale: 1:5 000

North

Legend:
- South West Bay
- Fletcher Point
- Anyimina Point
- Hourgui Point
- Marshal Bay

Scale: 1:5 000