BATCHELOR WATER SUPPLY

INVESTIGATION OF GROUNDWATER RESOURCES
1981

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Synopsis

During 1981 a major groundwater investigation was undertaken at Batchelor resulting in the construction of three production bores capable of producing 59 litres per second. The total pumping capacity of all constructed production bores is now 74 litres per second (6450 cubic metres per day).

The annual safe yield of the borefield was calculated to be in the order of 1 000 000 cubic metres. As more data becomes available further refinement of this figure will be possible.

Based on available water demand figures, this supply will meet both peak water supply and annual water demand requirements to well into the twenty-first century.
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       (m) ditto RN 20720 - " " RN 20615.
       (n) ditto RN 20720 - " " RN 20618.
       (o) ditto RN 20720 - " " RN 20721.
       (p) ditto RN 20720 - " " RN 20722.
       (q) ditto RN 20722 - " " RN 8823.
       (r) ditto RN 20722 - " " RN 20618.
       (s) ditto RN 20722 - " " RN 20720.
       (t) ditto RN 20722 - " " RN 20721.
1. INTRODUCTION

Batchelor's water supply requirements, prior to the present investigation were met primarily from two bores - registered number (RN) 9127 and RN 8822 - which were located near the centre of the township. These bores could each produce in excess of 10 litres per second (L/s) when pumped individually. However interference between them reduced the combined safe yield from the two bores to 17 L/s.

Batchelor's peak requirements of 1980 and 1981 exceeded the output of these bores.

In 1980 a proposal was put forward to carry out a groundwater investigation with basically two aims:-

1. to identify groundwater resources to meet Batchelor's water supply requirements up to 1985 and construct production bores to meet these requirements; and

2. to identify groundwater resources to meet Batchelor's projected water supply requirements up to the year 2000.

To expand the present water supply to meet the 1985 requirements, it was decided to investigate areas outside the township where interference to existing bores should be minimal.

Preliminary assessment of the geology in the area indicated that the same aquifer as that penetrated by the existing production bores should exist to the west and the south-south east of Batchelor. Since the latter area had better 'wet' season access and was closer to the main water supply storage tank, it was chosen for further study. A geophysical survey of this area was undertaken in February and March 1981. (The results are given in Appendix A)

Based on this survey and on progressive assessment of results from drilling, ten bore holes were drilled between 28 March and 31 July, 1981. Three of these have been subsequently recommended for use as production bores.

Results from this investigation, together with results from stratigraphic drilling undertaken by the Bureau of Mineral Resources in the Batchelor area in 1973 - 74 (Reference 1) were then used to identify groundwater resources of significance.
2. HYDROGEOLOGY

The following is a summary of the interpretation of results obtained from drilling and field work in and around the borefield. Bores will be referred to by their registered numbers (RN) - other names for each are given in Table 2.4. Bores with registered numbers less than 20 000 were drilled prior to the present investigation. Bureau of Mineral Resources stratigraphic holes are referred to by the identification numbers used in BMR Record 1979/89 (Reference 1).

2.1 Geology

Prior to this investigation, work that had been carried out within a five kilometre radius of Batchelor was reassessed. It was found that the formations likely to yield supplies in excess of 10 L/s were the Coomalie Dolomite (primarily the altered top of the Dolomite) and the Beeston Formation. Geological mapping of the Batchelor area indicated that the Coomalie Dolomite formation subcropped under and around Batchelor township while the closest part of the Beeston Formation was 1.2 kilometres north of the township's main water storage tank (Figure 2.1 (a)). A decision was then made to concentrate primarily on investigating the potential of the Coomalie Dolomite in the area to the south and south-east of the township because of its ease of access and close proximity of the main water storage tank.

Previous drilling has indicated that the subcropping Coomalie Dolomite could be intersected at depths ranging from 7 m to in excess of 90 m in the study area. A geophysical survey was therefore carried out to delineate the subsurface structure in the area. Subsequent drilling based on this survey showed that the dolomite has been amphibolised to the west of bore RN 8823 (Figure 2.1 (b)). The areal extent of this amphibolite was defined by geophysics in the area covered by the survey. Its extent outside this area can only be surmised. Further geophysical studies would be required to confirm its extent. It is apparent that amphibolisation has resulted in a large decrease in the permeability of the dolomite.

The Crater Formation outcrops to the north of the Coomalie Dolomite. Its lithology indicates that it should have low permeability and should form the northern boundary of the main aquifer system in the study area (Figure 2.1 (a)).

The Masson Formation subcrops to the south-east of the Coomalie Dolomite. Its lithology also indicates that it should have low permeability except at its contact with the Coomalie Dolomite which it overlies. This formation should then form the major southern boundary of the main aquifer system in the study area (Figure 2.1 (a)).
LEGEND

Puo Depo Creek Sandstone.
Plo Ortho- and Para-amphibolite.
Pld Masson Formation.
Pls Coonalle Dolomite.
Pir Crater Formation.
Pil Cello Dolomite.
Pie Beestons Formation.
APgr Rum Jungle complex.

GEOLOGY OF BATCHELOR
(1981 Groundwater Investigation)
Plo Zone B Region where Coomalie Dolomite has been Metamorphosed into strata with differing Lithologies.

**LEGEND**
- Geological boundary.
- Geological boundary (predicted).
- Plo Zone A Region where Coomalie Dolomite has been Amphibolised with a corresponding decrease in permeability of the weathered top of the Dolomite.
- Plo Zone B Region where Coomalie Dolomite has been Metamorphosed into strata with differing Lithologies.
- Plo Masson Formation.
- Plo Coomalie Dolomite.
- Pli Crater Formation.
- PII Celia Dolomite.

**DETAILED GEOLOGY OF THE PROPOSED GROUNDWATER BOREFIELD**
Drilling during this investigation confirmed that the major aquifer in the study area is the altered top of the Coomalie Dolomite. Previous incorrect interpretation of drilling results had been due to the difficulty of obtaining accurate strata samples from rotary air-drilled boreholes. This problem only occurred in certain areas (see Appendix B). Based on the knowledge of these sampling difficulties gained during the drilling component of this investigation, bores drilled previously were re-logged (Interpretive logs of bores are given in Table 2.1(i)). It is apparent that bores drilled prior to the present investigation intersected the Coomalie Dolomite and most obtained their water supply from the altered top five to ten metres of the Coomalie Dolomite.

Geological mapping of the Batchelor area has shown that the composition of the Coomalie Dolomite varies from top to bottom as shown in Table 2.1(ii). The results obtained from this investigation confirmed that this occurs in the study area. Bore RN 20722 sited near the top of the Coomalie Dolomite intersected quartzite and ferruginous quartz sandstone. Bore RN 20720 sited near the middle of the sequence intersected dolomite.

The only bore of the ten that penetrated the altered top of the dolomite, which has obtained large supplied of water from below the altered top of the dolomite, was bore RN 20618. This indicates that the major aquifer in the study area is composed of the altered top ten metres of the Coomalie Dolomite.

**Table 2.1(i): Interpretative Logs of Boreholes**

<table>
<thead>
<tr>
<th>RN</th>
<th>Depth (m)</th>
<th>Interval (m)</th>
<th>Lithographic description (Interpretative)</th>
<th>Airlifted Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>8822</td>
<td>73</td>
<td>0 - 22</td>
<td>Very weathered brown/yellow shale</td>
<td>15 L/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 - 33</td>
<td>Slightly weathered brown/yellow shale</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>33 - 73</td>
<td>Vughy quartz overlying grey dolomite</td>
<td></td>
</tr>
<tr>
<td>8823</td>
<td>79</td>
<td>0 - 17</td>
<td>Weathered brown/yellow/grey shale</td>
<td>1 L/s at 24 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17 - 79</td>
<td>Vughy quartz overlying grey dolomite</td>
<td>3 L/s at 62 m</td>
</tr>
<tr>
<td>9124</td>
<td>97</td>
<td>0 - 28</td>
<td>Very weathered brown/yellow shale</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>28 - 31</td>
<td>Weathered brown/yellow shale</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>31 - 97</td>
<td>Vughy quartz overlying grey dolomite</td>
<td></td>
</tr>
<tr>
<td>9127</td>
<td>61</td>
<td>0 - 20</td>
<td>Very weathered brown/yellow shale</td>
<td>10 L/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 - 33</td>
<td>Slightly weathered grey/brown shale</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>33 - 61</td>
<td>Vughy quartz overlying grey dolomite</td>
<td></td>
</tr>
<tr>
<td>20615</td>
<td>114</td>
<td>0 - 52</td>
<td>Slightly to very weathered yellow/brown shale</td>
<td>2 L/s at 44 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>52 - 58</td>
<td>Brown/grey shale</td>
<td>20 L/s at 62.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>58 - 63</td>
<td>Vughy quartz</td>
<td>40 L/s at 68 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>63 - 114</td>
<td>Grey dolomite</td>
<td></td>
</tr>
<tr>
<td>20616</td>
<td>48</td>
<td>0 - 3</td>
<td>Brown clay</td>
<td>10 L/s at 24 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 - 24</td>
<td>White calcareous claystone with manganese dendrites on fracture surfaces</td>
<td>30 L/S at 42 m</td>
</tr>
<tr>
<td>RN</td>
<td>Depth (m)</td>
<td>Interval (m)</td>
<td>Lithographic description (Interpretative)</td>
<td>Airlifted Yield</td>
</tr>
<tr>
<td>-----</td>
<td>-----------</td>
<td>--------------</td>
<td>-------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Weathered dolomite (white) with manganese dendrites on fracture surfaces</td>
<td></td>
</tr>
<tr>
<td>24-35</td>
<td></td>
<td></td>
<td>Grey dolomite</td>
<td>1.5 L/s at 31 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very weathered brown/yellow shale</td>
<td>3.2 L/s at 37 m</td>
<td></td>
</tr>
<tr>
<td>20617</td>
<td>86</td>
<td>0-20</td>
<td>Weathered brown/black shale</td>
<td>20 L/s at 93 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20-56</td>
<td>Vughy quartz overlying grey dolomite</td>
<td></td>
</tr>
<tr>
<td>20618</td>
<td>96.5</td>
<td>0-44</td>
<td>Very weathered yellow/brown shale</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>44-67</td>
<td>Brown and grey shale</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>67-84</td>
<td>Vughy quartz</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>84-93</td>
<td>Grey and white dolomite</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>93-96.5</td>
<td>Cavity</td>
<td></td>
</tr>
<tr>
<td>20619</td>
<td>50</td>
<td>0-6</td>
<td>Red clay</td>
<td>1.5 L/s at 12 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6-14</td>
<td>Green/yellow siltstone</td>
<td>3 L/s at 20 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14-18</td>
<td>Weathered amphibolite</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>18-38</td>
<td>Amphibolite</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>38-50</td>
<td>Amphibolite plus minor calcite</td>
<td></td>
</tr>
<tr>
<td>20623</td>
<td>78</td>
<td>0-2</td>
<td>Red clay</td>
<td>2 L/s at 22 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-24</td>
<td>Olive clay with manganese dendrites</td>
<td>3.5 L/s at 35 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24-36</td>
<td>Banded grey calcareous siltstone</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>36-78</td>
<td>Grey dolomite</td>
<td></td>
</tr>
<tr>
<td>20565</td>
<td>96</td>
<td>0-7</td>
<td>Red silt and clay</td>
<td>0.5 L/s at 13 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7-50</td>
<td>Grey and fawn dolomite</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>50-96</td>
<td>Grey dolomite</td>
<td>25 L/s</td>
</tr>
<tr>
<td>20720</td>
<td>122</td>
<td>0-41</td>
<td>Weathered brown/yellow/grey shale</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>41-53</td>
<td>Vughy quartz</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>53-122</td>
<td>Grey and white dolomite</td>
<td></td>
</tr>
<tr>
<td>20721</td>
<td>90</td>
<td>0-6</td>
<td>Red soil</td>
<td>20 L/s at 47 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6-34</td>
<td>White clayey quartz sand becoming coarser with depth</td>
<td>50 L/s at 90 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>34-47</td>
<td>White quartz sand (subangular grains)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>47-51</td>
<td>Vughy quartz</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>51-66</td>
<td>No circulation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>66-69</td>
<td>Quartz and yellow clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>69-88</td>
<td>No circulation</td>
<td>25 L/s at 54.5 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>88-90</td>
<td>Angular quartz and yellow clay</td>
<td></td>
</tr>
<tr>
<td>20722</td>
<td>66</td>
<td>0-4</td>
<td>Red soil</td>
<td>25 L/s at 66 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4-48</td>
<td>White clayey quartz sand</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>48-54</td>
<td>Vughy quartz over dolomite</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>54-58</td>
<td>Orange clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>58-66</td>
<td>Poorly cemented porous yellow sandstone</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>Formation</td>
<td>Lithogy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------</td>
<td>-------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adelaidean</td>
<td>Depot Creek Sandstone</td>
<td>Pink quartz sandstone ripple marked, lenses quartz pebble conglomerate, haematite quartzite breccia.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Proterozoic</td>
<td>Coomalie Dolomite</td>
<td>Dolomite, magnesite, marble; algal in places. Quartzite (algal in places), chert, ferruginous chert. Ferruginous quartz sandstone, ferruginous breccia.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Proterozoic</td>
<td>Crater Formation</td>
<td>Shale, sandstone, siltstone, arkose, grit and pebble beds.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Proterozoic</td>
<td>Celia Dolomite</td>
<td>Undivided silicified dolomite, amphibolite, quartzite.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Proterozoic</td>
<td>Beeston Formation</td>
<td>Arkose, quartz sandstone, quartzite.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Proterozoic</td>
<td>Rum Jungle Complex</td>
<td>Coarse to medium granite, schists gneisses.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.2 Aquifer Parameters

Four bores were test pumped during this investigation and three others prior to it. Details of the type of tests and plots of the data obtained from them are given in Appendix A. A summary of the results is given in Table 2.2.

The results obtained from observation bores monitored during the tests indicate that a hydraulic boundary exists immediately to the west of bore RN 8823. The aquifer in the vicinity of the borefield has values for transmissivity and storage coefficient of 2000 square meters per day and 0.003 respectively. The diurnal variation exhibited by all bores, and the test pumping results, indicate that the aquifer in the borefield area is confined.

Analysis of data obtained from the pumped bores, and observation bores within a radius of approximately 20 metres from the pumped bores, produced results which differed markedly from the general aquifer parameters. It was considered that this was primarily due to two factors:

1) The contamination of the aquifer in the vicinity of the production bore by drill cuttings (see Appendix B) and the subsequent lack of vigorous development of the bore before testing, and

2) The large effective radius of the production bores.

The increased drawdowns in the production bores due to contamination of the aquifer and the subsequent inadequate development can be illustrated by reference to the test pumping data from the tests on production bores RN 20720 and RN 20722. During the constant discharge test run on bore RN 20720, the pump discharge became dirty at 50 minutes and at 3180 minutes. The plot of the test data (Figure A3(g)) shows clearly that at both these times the slope of the drawdown versus log time curve steepened, i.e., the performance of the bore deteriorated. Three step drawdown tests were carried out on bore RN 20722 - each test produced different results (Figure A4(d)).

The data from the observation bore used for the constant discharge test on bore RN 8822 illustrates that production bores in this area can have large effective radii. The drawdown in the observation bore approximately equalled that in the production bore until the potentiometric level was lowered to the top of the aquifer. The behaviour of the aquifer in the vicinity of the bore then changed from that of a confined aquifer to that of an unconfined aquifer.

The above results indicate that data from production bores cannot be used to obtain aquifer parameters in this area because of their dependence on near well conditions.
Test data obtained from production bores was utilised in estimating safe yields. This data, combined with information provided from the computer modelling exercise outlined in Section 4, was also used to estimate safe yields under various pumping regimes. The results are given in Table 4.

Table 2.2: Aquifer Parameters

<table>
<thead>
<tr>
<th>Pumped Bore</th>
<th>Q (L/s)</th>
<th>Test Type</th>
<th>Observation bore</th>
<th>r (m)</th>
<th>( r^2T ) (m²/day)</th>
<th>S</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>8822</td>
<td>37</td>
<td>Constant Rate</td>
<td></td>
<td>120</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9127</td>
<td>18</td>
<td>Constant Rate</td>
<td></td>
<td>180</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20616</td>
<td>15</td>
<td>Constant Rate</td>
<td></td>
<td>160</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20618</td>
<td>20</td>
<td>Constant Rate</td>
<td>20623</td>
<td>133</td>
<td>370</td>
<td>6x10^{-5}</td>
<td>Theis type curve match</td>
</tr>
<tr>
<td>20720</td>
<td>28</td>
<td>Constant Rate</td>
<td>20615</td>
<td>15.1</td>
<td>1100</td>
<td></td>
<td>Drawdown versus log time, early data</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8823</td>
<td>132</td>
<td>1850</td>
<td>1.8x10^{-2}</td>
<td>Theis type curve match</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8823</td>
<td>850</td>
<td>2560</td>
<td>7x10^{-4}</td>
<td>Theis type curve match</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20721</td>
<td>430</td>
<td>1920</td>
<td>5x10^{-3}</td>
<td>Theis type curve match</td>
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<td></td>
<td></td>
<td></td>
<td>20722</td>
<td>410</td>
<td>1900</td>
<td>5x10^{-3}</td>
<td>Theis type curve match</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20722</td>
<td>23</td>
<td></td>
<td></td>
<td>Steady state conditions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8823</td>
<td>540</td>
<td>1650</td>
<td>2x10^{-3}</td>
<td>Theis type curve match</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>20618</td>
<td>580</td>
<td>2550</td>
<td>2x10^{-3}</td>
<td>Theis type curve match</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20720</td>
<td>410</td>
<td>1780</td>
<td>3x10^{-3}</td>
<td>Theis type curve match</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20721</td>
<td>25</td>
<td>3500</td>
<td></td>
<td>Drawdown versus log time</td>
</tr>
</tbody>
</table>

2.3 Groundwater Movement and Recharge
The information from which groundwater movement and recharge can be predicted is very limited. Prior to this investigation there was only one bore in existence - RN 8823 - which could be utilised for monitoring water levels in the vicinity of the production borefield. Since there are no personnel involved in collecting water level data, even data from this one source is not in existence.
Since drilling ceased on this investigation, water level data has been collected from all available bores on two occasions. The data is given in Table 2.3 and plotted on Figure 2.3(a). This information indicates that even though groundwater was being extracted from production bores RN 8822 and RN 9127 at the rate of 1450 cubic metres per day, the groundwater movement through the borefield was from northwest to southeast.

Predicted regional recharge and groundwater movement for the main aquifer system is given on Figure 2.3(b). The predicted trends are based on (1) data held in the immediate vicinity of the borefield, (2) geology of the region, and (3) topography of the region. The regional geology and topography are shown on Figures 2.1(a) and 2.3(b) respectively. Some of the existing data on the aquifer has been utilised in calculating recharge and throughflow in Appendix C. The results of this exercise indicate that recharge is in the order of 1,400,000 cubic metres per year and that the groundwater flow through the borefield is in the order of 700,000 cubic metres per year.

The ratio between magnesium and calcium concentrations in the groundwater has also been used to indicate likely recharge areas (Reference 2). In recharge areas, high magnesium to calcium ratios exist. As water moves further away from the recharge area the ratio approaches unity. As illustrated on Figure 2.3(b), recharge for the main aquifer system is indicated to the east of bore RN 20618 and along the contact between the Crater Formation and the Coomalie Dolomite. No information is available to the west of production bore RN 8822.

Likely recharge for the aquifer intersected by bore RN 20616 is not predicted as further work is required to determine its extent before it is used to supplement Batchelor's water supply.

To confirm predicted trends further investigation work is needed to the west and east of the present borefield. Monitoring of potentiometric levels in boreholes drilled during that investigation will assist in determining groundwater recharge and movement.
LEGEND

- Potentiometric contours 5/8/81 (metres AHD).
- Potentiometric contours 25/1/82 (metres AHD).
- Geological boundaries.

POTENTIOMETRIC SURFACES
ON 5TH AUGUST 1981 AND 25TH JANUARY 1982
LEGEND

---

Expected recharge areas for major aquifer.

12

Value of Mg/Ca ratio.

—–—–

Expected groundwater movement under equilibrium non-pumping conditions.

—100—

Potentiometric Contour (metres AHD)

——-

Boundaries of main aquifer system.

PREDICTED GROUNDWATER RECHARGE AND MOVEMENT IN THE MAIN AQUIFER SYSTEM
Table 2.3: Survey and Potentiometric Level Data

<table>
<thead>
<tr>
<th>Bore RN</th>
<th>Ground Level at Bore (m AHD)</th>
<th>Top of Bore Casing (m AHD)</th>
<th>Potentiometric Level (mAHD) 5/8/81</th>
<th>Potentiometric Level (mAHD) 25/1/82</th>
</tr>
</thead>
<tbody>
<tr>
<td>8822</td>
<td>106.92</td>
<td>106.92</td>
<td>90.17</td>
<td>91.32</td>
</tr>
<tr>
<td>8823</td>
<td>107.96</td>
<td>108.57</td>
<td>90.17</td>
<td>91.32</td>
</tr>
<tr>
<td>8372</td>
<td>106.77</td>
<td>106.82</td>
<td>97.99</td>
<td>99.06</td>
</tr>
<tr>
<td>9127</td>
<td>106.68</td>
<td>106.90</td>
<td>95.38</td>
<td>95.15</td>
</tr>
<tr>
<td>20565</td>
<td>106.67</td>
<td>106.87</td>
<td>89.59</td>
<td>91.29</td>
</tr>
<tr>
<td>20615</td>
<td>107.09</td>
<td>107.59</td>
<td>89.59</td>
<td>91.29</td>
</tr>
<tr>
<td>20616</td>
<td>106.51</td>
<td>106.89</td>
<td>97.99</td>
<td>99.06</td>
</tr>
<tr>
<td>20617</td>
<td>104.08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20618</td>
<td>96.27</td>
<td>96.61</td>
<td>89.22</td>
<td>91.20</td>
</tr>
<tr>
<td>20619</td>
<td>104.01</td>
<td>104.46</td>
<td>97.89</td>
<td>101.93</td>
</tr>
<tr>
<td>20623</td>
<td>106.24</td>
<td>106.76</td>
<td>97.88</td>
<td>99.20</td>
</tr>
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<td>20720</td>
<td>106.83</td>
<td>107.25</td>
<td>89.59</td>
<td>91.29</td>
</tr>
<tr>
<td>20721</td>
<td>100.06</td>
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<tr>
<td>20722</td>
<td>99.61</td>
<td>99.81</td>
<td>89.39</td>
<td>91.46</td>
</tr>
</tbody>
</table>

2.4 Water Quality
All existing water quality data on bores in the study area is summarised on Table 2.4. All waters are typical dolomite waters with total hardness ranging from 106 milligrams per litre in bore RN 20722 to 260 milligrams per litre in bore RN 20720.

High manganese concentrations were recorded from samples taken during test pumping of bores RN 20720 and RN 20722. These bores were subsequently resampled and concentrations had dropped to 25% of those initially recorded (see Table 2.4). Previous sampling of production Bores RN 8371 and RN 8372, and current sampling of bore RN 20618, had indicated that acceptable manganese concentrations existed in the aquifer. It is considered that the high concentrations are due to water or chemicals introduced into the aquifer during drilling. In both bores (RN 20720 and RN 20722) large quantities of water were lost into the formation while drilling 'lost circulation' zones. Since this water could not be obtained from the town supply (as per instructions), various surface water supplies were utilised to enable completion of the bores. If these waters were responsible it would be expected that manganese concentrations should drop to an acceptable limit with time as dilution of the introduced waters occurs. Continuous monitoring of manganese concentrations in water from these bores should take place when they are introduced into the town water supply system.
Contamination of the aquifer is considered unlikely with the present and proposed developments in the area. However, any future development involving a possible pollution threat to the aquifer system should be carefully considered, particularly when located near likely recharge areas.

Since the aquifer system is a region known to be highly mineralised the production bores were sampled for heavy metals and radionucleides. With the exception of manganese concentrations, all samples were within acceptable limits as recommended by AWRC/NHMRC (1980) (Reference 3).
<table>
<thead>
<tr>
<th>Bore RN</th>
<th>Bore Index</th>
<th>Other Name</th>
<th>Total Dissolved Solids (mg/L)</th>
<th>Na</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Total Hardness</th>
<th>Total Alkalinity</th>
<th>Cl</th>
<th>SO₄</th>
<th>HCO₃</th>
<th>Mn</th>
<th>Si</th>
<th>pH</th>
<th>Mg/Ca ratio</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>8822 73/293</td>
<td>1/76</td>
<td></td>
<td>270</td>
<td>1</td>
<td>1</td>
<td>43</td>
<td>29</td>
<td>227</td>
<td>233</td>
<td>5</td>
<td>7</td>
<td>284</td>
<td>7.9</td>
<td>1.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8823 73/294</td>
<td>2/76</td>
<td></td>
<td>310</td>
<td>1</td>
<td>1</td>
<td>50</td>
<td>33</td>
<td>260</td>
<td>280</td>
<td>4</td>
<td>10</td>
<td>341</td>
<td>7.3</td>
<td>1.1</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>9127 73/300</td>
<td>2/77</td>
<td></td>
<td>250</td>
<td>1</td>
<td>1</td>
<td>42</td>
<td>26</td>
<td>212</td>
<td>215</td>
<td>4</td>
<td>9</td>
<td>262</td>
<td>7.6</td>
<td>1.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20565 73/478</td>
<td>6/81</td>
<td></td>
<td>300</td>
<td>2</td>
<td>2</td>
<td>48</td>
<td>31</td>
<td>247</td>
<td>251</td>
<td>4</td>
<td>10</td>
<td>306</td>
<td>69</td>
<td>7.5</td>
<td>1.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20615 73/474</td>
<td>1/81</td>
<td></td>
<td>280</td>
<td>1</td>
<td>1</td>
<td>36</td>
<td>43</td>
<td>266</td>
<td>262</td>
<td>8</td>
<td>9</td>
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<td>42</td>
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<td>9</td>
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<td>92</td>
<td>7.5</td>
<td>0.9</td>
<td></td>
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</tr>
<tr>
<td>20618 73/477</td>
<td>4/81</td>
<td></td>
<td>96</td>
<td>1</td>
<td>1</td>
<td>8</td>
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<td>85</td>
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<td>Depth 72m</td>
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<tr>
<td>20619 73/484</td>
<td>5/81</td>
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<td>1</td>
<td>1</td>
<td>25</td>
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<tr>
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<td>7/81</td>
<td></td>
<td>220</td>
<td>3</td>
<td>3</td>
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<td>10</td>
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<td>75</td>
<td>7.1</td>
<td>1.2</td>
<td></td>
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<tr>
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<td></td>
<td>290</td>
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<td>2</td>
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<td>40</td>
<td>252</td>
<td>258</td>
<td>6</td>
<td>9</td>
<td>314</td>
<td>1.5</td>
<td>7.1</td>
<td>1.8</td>
<td>6/8/81</td>
<td></td>
</tr>
<tr>
<td>20721 73/490</td>
<td>9/81</td>
<td></td>
<td>310</td>
<td>2</td>
<td>2</td>
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<td>269</td>
<td>255</td>
<td>2</td>
<td>28</td>
<td>311</td>
<td>4.2</td>
<td>37</td>
<td>6.5</td>
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<td>21/7/81</td>
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<td></td>
<td>240</td>
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<td>4</td>
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<td>34</td>
<td>165</td>
<td>15</td>
<td>5.3</td>
<td>1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20617 73/476</td>
<td>3/81</td>
<td></td>
<td>No Sample</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

... 11.
3. WATER DEMAND

The derived monthly water usage figures for Batchelor for the period September 1979 to September 1981 are shown on Figure 3(a). The actual population figures for the period 1971 to 1979 and the predicted population trends up to 2000 are given in Table 3. Based on these figures, the present per capita consumption for Batchelor varies from a low 0.5 kilolitres per day in 'the wet' to a high of 5 kilolitres per day in 'the dry'. (The peak per capita usage has not surpassed 5 kilolitres per day because this is the maximum output of the present system). The annual demand is in the order of 270 000 cubic metres.

If usage is continued at its present level, in 1985 Batchelor would have an annual demand of 475 000 cubic metres and would require a peak supply of 35 L/s. The basing of predicted water usage on present demand patterns is, however, not considered warranted. The high current per capita peak demand is due to the parkland nature of the township. It is estimated that over 80% of the peak demand is used to water lawns and gardens. Plans for the future extension of Batchelor do not include the same degree of parkland development as presently exists. It is also considered appropriate that a study be carried out to determine if the lawns and gardens are being efficiently watered at present. Taking both these points into consideration, it would be expected that the peak per capita consumption should be in the order of 3.5 kilolitres per day for the population predicted in 1985. If usage is considered at this level, in 1985 the annual demand would be 350 000 cubic metres and a peak usage of 24 L/s. These are considered to be more realistic values.

The postulated peak supply rates and annual demands up to the year 2000 are given on Figures 3(b) and 3(c). These figures are considered conservative as they are based on the population reaching 1270 by the year 2000 (a sustained growth rate of 7% from the 1979 census) and the peak per capita water usage remaining at 2.5 kilolitres per day for the period 1990 to 2000. The peak supply rate for the year 2000 would then be 43 L/s and the annual demand 660 000 cubic metres.

Batchelor's water supply requirements for the year 2000 are predictably very dependent on future developments in the area. The surrounding area is very mineralised and another large mineral development such as Rum Jungle could take place before the year 2000. If such development takes place, water supply requirements could easily exceed those predicted. However, it is not considered practical to base predicted water supply requirements on developments that are as yet unknown. In addition, it must be taken into consideration that such a large development would have a lead time of at least five years. This will enable the required water supply augmentation to be carried out.
DERIVED MONTHLY WATER USAGE FOR PERIOD
SEPTEMBER 1979, TO SEPTEMBER 1981.
PER CAPITA USAGE STABILISES

PER CAPITA USAGE DECREASES AS POPULATION INCREASES DUE TO PROPOSED DEVELOPMENT

2 BORES - MAXIMUM CAPACITY OF 10L/sec. FULLY UTILISED

DERIVED AND PREDICTED PEAK WATER REQUIREMENT
FIG. 3(c)

DERIVED AND PREDICTED ANNUAL DEMAND
Table 3: Population Figures and Predicted Growth for Period 1971-2000

<table>
<thead>
<tr>
<th>Year</th>
<th>Permanent (basis)</th>
<th>Peak (estimate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>142 (Census)</td>
<td>170</td>
</tr>
<tr>
<td>1976</td>
<td>266 (Census)</td>
<td>300</td>
</tr>
<tr>
<td>1979</td>
<td>277 (Census)</td>
<td>330</td>
</tr>
<tr>
<td>1985</td>
<td>490 (Projected)</td>
<td>560</td>
</tr>
<tr>
<td>1990</td>
<td>615 (Estimated)</td>
<td>730</td>
</tr>
<tr>
<td>1995</td>
<td>880 (Estimatee)</td>
<td>1050</td>
</tr>
<tr>
<td>2000</td>
<td>1270 (Estimated)</td>
<td>1500</td>
</tr>
</tbody>
</table>
4. MODELLING BOREFIELD PERFORMANCE

The performance of the main aquifer system was simulated using a computerised groundwater model which was a modification of the finite difference model developed by Prickett and Lonnquist (Reference 4).

Before computer modelling could be undertaken, a conceptual model of the aquifer system had to be developed. To do this, the following assumptions were made about the aquifer system:

1) Its areal extent in the study area is as shown on Figure 4(a)

2) It is bounded to the north by the Crater Formation and to the south predominantly by the Masson Formation and the amphibolised Coomalie Dolomite

3) There is no groundwater flow through the borefield

4) There is zero drawdown, due to pumping, 3.7 kilometres to the northwest and 5.2 kilometres to the east of bore RN 20720

5) It is isotropic with values for Transmissivity and Storage Coefficient of 2000 square metres per day and 0.003 respectively

6) It is fully recharged each wet season.

These assumptions were based on all available data. Throughflow was neglected because it was considered that insufficient data existed to accurately assess it. This should result in the model predicting greater drawdowns than would be measured in the field. This conservative approach was considered the best to take.

The model was calibrated against the test pumping data obtained from observation bores used during tests on bores RN 20720 and RN 20722. The drawdowns measured in the field were approximately 60% of those predicted by the model (i.e. 0.3 metre as compared with 0.5 metres) and followed similar trends (Figure 4(b)).

The model was then used to predict the drawdowns with production bores RN 8822, RN 20720 and RN 20722 pumping at 16 L/s, 22 L/s and 32 L/s respectively. The results indicate that drawdowns in the aquifer began to stabilise after 180 days. A plot of the predicted drawdown contours after one year's pumping is given on Figure 4(a).

The model was also used to predict interference between pumping centres under various pumping regimes. Recommended pumping rates based on the results of this exercise are given in Table 4.
LEGEND

- 4 — Predicted Drawdown Contours after one year's pumping at the following rates from each centre (metres)

A  16 L/sec.
B  22 L/sec.
C  32 L/sec.

- Boundary of aquifer system.

PREDICTED DRAWDOWN CONTOURS
AFTER PUMPING MAIN AQUIFER SYSTEM
AT 70 L/sec FOR ONE YEAR
COMPARISON OF FIELD AND MODEL DRAWDOWNS

- Field measurement of drawdown in bore RN20720 when bore RN20722 was pumped at 23L/sec.
- Field measurement of drawdown in bore RN20722 when bore RN20720 was pumped at 28L/sec.
- Predicted drawdown from model in bore RN20720 when bore RN20722 was pumped at 32L/sec.
- Predicted drawdown from model in bore RN20722 when bore RN20720 was pumped at 32L/sec.
The modelling exercise highlighted the requirement for more information to the west of production bore RN 8822 and to the east of bore RN 20618. Any major change in aquifer characteristics in either of these areas could have a significant effect on the performance of the borefield.

Table 4: Recommended Pumping Rates for Production Bores

<table>
<thead>
<tr>
<th>Production Bore RN</th>
<th>Recommended Pumping Rates (L/s) for Regime</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>8822</td>
<td>17</td>
</tr>
<tr>
<td>9127</td>
<td>12</td>
</tr>
<tr>
<td>20616</td>
<td>12</td>
</tr>
<tr>
<td>20720</td>
<td>22</td>
</tr>
<tr>
<td>20722</td>
<td>32</td>
</tr>
</tbody>
</table>

Note: The regimes listed above are

A - Production bores pumped by themselves
B - Production bores RN 8822 and RN 9127 pumping
C - Production bores RN 20720 and RN 20722 pumping
D - Production bores RN 8822, RN 20720 and RN 20722 pumping
E - Maximum exploitation of existing production bores
5. CONCLUSIONS

The 1981 investigation identified groundwater resources capable of meeting Batchelor's water supply requirements to well into the twenty first century providing population projections given in this report are correct. These projections could change dramatically if a major development such as a mine occurred in the vicinity of the township.

The major aquifers identified are in the altered top of the Coomalie Dolomite. Individual bore yields from these aquifers can range up to possibly 50 L/s or more (e.g. bore RN 20618). Production bores which have been constructed in these aquifers are capable of producing a total of 74 L/s.

An estimate of the safe yield and the groundwater flow through the borefield was made. However, the paucity of data limits the confidence with which this estimate can be accepted. The annual safe yield of the borefield was estimated to be in the order of 1 000 000 cubic metres and the annual groundwater throughflow 700 000 cubic metres.

The water is a typical dolomite water. High manganese concentrations recorded in two bores are considered to have resulted from the introduction of contaminated water into the aquifer and are expected to drop to acceptable levels once production begins.

The long-term behaviour of the aquifer system will be dependent on the characteristics of the aquifer outside the area covered by field work in the 1981 investigation. However, enough data has been collected to indicate that it should perform satisfactorily until at least 1988 when its performance should be reassessed.

Significant problems were encountered in the construction of bores in this area. The problems are outlined and discussed in Appendix B.

Other aquifers with the potential to supply significant quantities of water have been identified in the Beeston Formation within three kilometres of the centre of Batchelor. Present indications are that these sources will not be required within the foreseeable future.
6. RECOMMENDATIONS

The borefield at Batchelor should be developed in the following order as and when the water demand requires it.

1) Peak requirement up to 20 L/s (Predicted in 1983). Production bore RN 20722 to be pumped at 30 L/s with production bore RN 20720 utilised as a standby.

2) Peak requirement up to 29 L/s (Predicted in 1988). Production bore RN 20722 should be pumped at 30 L/s with production bores RN 8822 and RN 20720 utilised as standby bores.

3) Peak requirement up to 45 L/s (Predicted in 2001). Production bores RN 20720 and RN 20722 should be pumped at 29 L/s and 18 L/s respectively. Production bores RN 8822 and RN 20616 should be utilised as standby bores.

4) Peak requirement up to 74 L/s. Production bores RN 8822, RN 20616, RN 20720 and RN 20722 to be pumped at 12 L/s, 15 L/s 18 L/s and 29 L/s respectively. Standby capacity to be met from storage or new bores.

The performance of the borefield should be continuously monitored and reappraised before proceeding to development steps (2) and (3).

Further field work is required (as detailed on Figure 6) before the performance of the borefield can be satisfactorily monitored. Once this field work is completed, potentiometric levels should be taken at six weekly intervals from bores RN 8823, 9127, 20565, 20615, 20616, 20618, 20619, 20623, 20721 and bores at sites A, B, C and D. Continuous potentiometric level recorders should be installed on bores RN 8823 and bores at sites A and C for a period of not less than 30 months. Prior to this field work being undertaken three-monthly readings should be taken on all existing bores.

In 1988 a reassessment of the performance of the aquifer system should be undertaken and new recommendations for the operation, monitoring and development of the borefield should be made.

When production bores RN 20720 and RN 20722 are connected into Batchelor's water supply system monthly readings of the manganese concentrations should be taken until the level stabilises. Once this occurs the situation should be reviewed and recommendations made accordingly.
LEGEND

- Geophysical traverses required.

- Possible locations of investigation boreholes (dependent on Geophysics)

- Boundaries of main aquifer system.

NETWORK OF ADDITIONAL OBSERVATION BORES REQUIRED FOR MONITORING BOREFIELD PERFORMANCE
7. REFERENCES


7.2 JENNINGS, H.N. - KARST, AUSTRALIAN NATIONAL UNIVERSITY PRESS (1971).

7.3 AUSTRALIAN WATER RESOURCES COUNCIL, NATIONAL HEALTH AND MEDICAL RESEARCH COUNCIL - Desirable Quality for Drinking Water in Australia. AUSTRALIAN GOVERNMENT PUBLISHING SERVICE, CANBERRA, 1980.


The following is a summary of the field work carried out.

1. Geophysics
   A detailed report on geophysical surveys carried out for this project was compiled by J. Doherty (Reference 5).
   
   The survey's aims were two-fold -
   
   1) To assist in determining the horizontal disposition of the various rock units known to exist in the area, particularly the Coomalie Dolomite;
   
   2) To locate, within areas considered favourable from geological considerations, zones of anomalously high conductivity indicative of high porosity and thus suitable drilling targets.
   
   To achieve these aims 5.3 line kilometres of electromagnetic (EM) profiling and 8.9 line kilometres of resistivity profiling were carried out. The location of these lines is given in Figure A1(a) and the results are plotted on Figure A1(b).
   
   The better results were obtained from the resistivity profiling as the EM measurements were subject to interference. The resistivity profiling was very useful in defining the low permeability dolomite to the south west of the borefield.

2. Drilling
   Ten bores were drilled during the 1981 investigation. During the initial stages two drilling rigs were utilised. These were (a) an Ingersol Rand TH60 top head drive rotary rig, and (b) an Ingersol Rand RO300 Kelly drive rotary rig. For the latter part of the investigation only the TH60 was used. The reason for initially using two drilling rigs was that they were used for demonstration purposes for the National Drilling Industry Training Committee's Drilling School which was run concurrently with the investigation.
   
   A brief comment on each bore follows. Bore construction details are given in Table A2.
   
   Bore RN 20615 was drilled on a geophysical resistivity low which was postulated to be along strike of the existing production bores. The altered top of the dolomite was intersected at 58 metres and 40 L/s was airlifted from 68 metres. The hole was later continued to 114 metres to test the permeability of the dolomite below the altered top ten metres. No supplies were intersected in this interval.
FIG. A(a)

GEOPHYSICAL TRAVERSE

TRACK

BATCHelor GEOPHYSICAL SURVEY
Bore RN 20617 was drilled on a resistivity low which was postulated to be along strike from bore RN 20615. Drilling was severely hampered by compressor problems which resulted in the hole being mainly drilled with mud circulation. On completion it was backfilled. Later drilling results highlighted problems in obtaining accurate strata samples in this area. While this hole was considered initially unsuccessful in locating significant water supplies, later drilling indicated that this conclusion may not be justified.

Bore RN 20618 was drilled to give information on the eastern extent of the aquifer. Its location was controlled to some extent by access problems. Dolomite was intersected at 85 metres. A 3.5 metre cavity was intersected between 93 and 96.5 metres in the dolomite and in excess of 20 L/s was airlifted.

Bore RN 20619 was drilled on a resistivity low in an attempt to delineate the structure into which bore RN 20616 was drilled. Amphibolite was intersected at 14 m and 3.6 L/s was airlifted from 20 metres.

Bore RN 20623 was drilled as a second attempt to delineate the structure that bore RN 20616 was intended to investigate. This bore was successful in achieving this aim. However, the airlifted yield on completion was only 3.5 L/s.

Bore RN 20565 was drilled to determine the nature of the resistivity high between bore RN 20615 and bore RN 20619. Dolomite was intersected at 7 metres. A supply of 0.5 L/s was airlifted from 13 metres.

Bore RN 20720 was the first production bore drilled as a result of the investigation. It was sited near bore RN 20615 which was expected to be far enough away from the existing production bores so that there would be minimal overlap of cones of depression. Casing of 250 mm diameter was used to enable the use of submersible pumps capable of pumping 25 L/s, the expected yield. Considerable difficulty was encountered in constructing this bore. For further details see Appendix B.

Bore RN 20721 was drilled to intersect similar strata to that encountered in BMR stratigraphic hole RJ20. A supply of 50 L/s was airlifted on completion of this hole.

Bore RN 20722 was the second production bore drilled as a result of the investigation. It was sited near bore RN 20721. Casing 250 mm in diameter was used for the same reason as for bore RN 20720. As with bore RN 20720 considerable difficulty was encountered in constructing this bore. For further details see Appendix B.
<table>
<thead>
<tr>
<th>Bore RN</th>
<th>Construction Period</th>
<th>Casing Details</th>
<th>Final Well Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>20615</td>
<td>28.3.81 to 31.3.81</td>
<td>0-1m 153mm steel</td>
<td>Observation</td>
</tr>
<tr>
<td></td>
<td>14.5.81 to 19.5.81</td>
<td>0-21.6m 203mm steel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>22.7.81</td>
<td>0-44.9m 51mm GWP 44.9-64.4m 55mm slotted GWP</td>
<td></td>
</tr>
<tr>
<td>20616</td>
<td>1.4.81 to 2.4.81</td>
<td>0-24.8m 203mm steel</td>
<td>Production</td>
</tr>
<tr>
<td></td>
<td>28.7.81 to 29.7.81</td>
<td>24.8m-43m Open hole</td>
<td></td>
</tr>
<tr>
<td>20617</td>
<td>4.4.81 to 8.4.81</td>
<td>Nil</td>
<td>Filled in</td>
</tr>
<tr>
<td>20618</td>
<td>2.4.81 to 11.4.81</td>
<td>0-67.7m 203mm steel 0-84.4m 153mm steel</td>
<td>Private use and observation</td>
</tr>
<tr>
<td>20619</td>
<td>9.4.81 to 14.5.81</td>
<td>0-15.7m 203mm steel 0-15m 50mm PVC 15-19.7m 50mm slotted PVC 19.7-30.5m 50mm PVC 30.5-33.5m 50mm slotted PVC</td>
<td>Observation</td>
</tr>
<tr>
<td>20565</td>
<td>11.4.81 to 15.4.81</td>
<td>0-77m 203mm steel 0-46m 50mm PVC 46-48m 50mm slotted PVC 48-62.5m 50mm PVC 62.5-64.5m 50mm slotted PVC 64.5-68m 50mm PVC 68-70m 50mm slotted PVC 70-94.5m 50mm PVC 94.5-96.5m 50mm slotted PVC</td>
<td>Observation</td>
</tr>
<tr>
<td>20623</td>
<td>20.5.81 to 22.5.81</td>
<td>0-3.8m 203mm steel 0-31m 50mm PVC 31-37m 50mm perforated PVC 37-79m 50mm PVC</td>
<td>Observation</td>
</tr>
<tr>
<td>20720</td>
<td>23.5.81-7.6.81</td>
<td>0-7.5m 330mm steel 0-48m 250mm steel 46.9-53.7m 200mm S.S.screens 53.7-58.2m 200mm steel</td>
<td>Production</td>
</tr>
<tr>
<td></td>
<td>14.7.81-21.7.81</td>
<td>0-48m 250mm steel 46.9-53.7m 200mm S.S.screens 53.7-58.2m 200mm steel</td>
<td></td>
</tr>
<tr>
<td>20721</td>
<td>15.5.81-19.6.81</td>
<td>0-12m 200mm steel 0-60m 50mm GWP 60-66m 50mm slotted GWP</td>
<td>Observation</td>
</tr>
<tr>
<td></td>
<td>23.7.81-23.7.81</td>
<td>0-60m 50mm GWP 60-66m 50mm slotted GWP</td>
<td></td>
</tr>
<tr>
<td>20722</td>
<td>26.6.81 to 31.7.81</td>
<td>0-14m 330mm steel 0-48.3m 250mm steel 45.7-58.6m 200mm steel 58.6-65.1m 200mm S.S.screens</td>
<td></td>
</tr>
</tbody>
</table>
3. Test Pumping
Testing of bores followed the general format outlined below.

a) Development. This was usually carried out with the pump which was going to be used for testing the bore. One bore, RN 20722, was subsequently developed by duotube airlifting;

b) Step Tests. This test usually involved four steps (a step being an interval of time during which the discharge rate is held constant) each of 100 minutes duration;

c) Constant Rate Test. During this test each bore was pumped at a constant discharge rate for a duration of between 24 and 72 hours depending on the proposed future usage of the bore;

d) Recovery. On completion of the constant rate test, measurements were taken as the water level began to rise again. The period over which measurements were taken depended on how the bore recovered.

Bores RN 20616, RN 20618, RN 20720 and RN 20722 were tested to the above format. The plots of drawdown versus the logarithm of time for each of the tests is given in Figures A3(a) to A3(j). The plots of the logarithm of drawdown versus the logarithm of time for observation bores monitored during the constant discharge tests are given in Figures A3(k) to A3(t).
DATE  2.9.81

STEP DRAWDOWN TEST

PUMPED BORE  RN 20616
DATE 16.7.81

STEP DRAWDOWN TEST

PUMPED BORE RN 20618

DATE 16.7.81
STEP DRAWDOWN TEST

PUMPED BORE  RN 207:20

DATE  31.7.81
PUMPED BORE RN 20722

DATA POINT DATE OF TEST

xQ 11-8-81
⊙Q 17-8-81
Qa 1-9-81

STEP DRAWDOWN TESTS
PUMPED BORE    RN 20616
DISCHARGE       15L/sec
DATE            3-9-81

CONSTANT DISCHARGE TEST
FIG. A3(f)

PUMPED BORE  RN 20618
DISCHARGE  20 L/sec.
DATE  17.7.81

CONSTANT RATE TEST
PUMPED BORE: RN 20720
DISCHARGE: 28 L/sec.
DATE: 5-8-81

CONSTANT RATE TEST
PUMPED BORE  RN 20722
DISCHARGE  23 L/sec.
DATE  18.8.81

CONSTANT DISCHARGE TEST
PUMPED BORE    RN 20720

OBS. BORE     RN 20615

DATE        5·8·81

CONSTANT DISCHARGE TEST
CONSTANT DISCHARGE TEST

PUMPED BORE RN 20722
OBS. BORE RN 20721
DATE 18.8.81
PUMPED BORE RN 20616

OBS. BORE RN 20623

DATE 3-9-81

CONSTANT DISCHARGE TEST
PUMPED BORE RN20720
OBS. BORE RN 8823
DATE 5-8-81

CONSTANT DISCHARGE TEST
PUMPED BORE RN20720

OBS. BORE RN20615

DATE 5.8.81

CONSTANT DISCHARGE TEST
PUMPED BORE RN 20720

OBS. BORE RN 20618

CONSTANT DISCHARGE TEST

DATE 5-8-81
PUMPED BORE RN20720
OBS. BORE RN20721
DATE 5·8·81

CONSTANT DISCHARGE TEST

THEIS TYPE CURVE
DRAWD OWN

THEIS TYPE CURVE

PUMPED BORE RN20720

OBS. BORE RN20722

CONSTANT DISCHARGE TEST

DATE 5.8.81
PUMPED BORE RN 20722
OBS. BORE RN 8823

DATE 18-8-81

CONSTANT DISCHARGE TEST

THEIS TYPE CURVE
PUMPED BORE   RN20722
OBS. BORE      RN20618
DATE           18.8.81

CONSTANT DISCHARGE TEST
PUMPED BORE RN20722

OBS. BORE RN20720

DATE 18-8-81

CONSTANT DISCHARGE TEST
PUMPED BORE RN20722

OBS. BORE RN20721

DATE 18.8.81

CONSTANT DISCHARGE TEST
APPENDIX B

BORE CONSTRUCTION AND DEVELOPMENT

Considerable difficulty was encountered in the construction and development of large diameter (i.e. greater than 150 millimetres) boreholes. The particular problems depended on the strata penetrated. A description of the problems encountered in the construction of production bores RN 20720 and RN 20722 follows and recommendations for overcoming them are described.

(a) Production Bore RN 20720

The site for this bore was chosen based on the results of investigation bore RN 20615, which intersected the altered top of the Coomalie Dolomite at 58 metres. A supply of 40 L/s was airlifted from 68 metres. Bore RN 20720 was sited 15 metres to the east of RN 20720 and a pilot hole drilled (1) to locate the top of the altered Coomalie Dolomite, and (2) to establish the size of the supply since from past drilling the latered top of the Coomalie Dolomite had proven to be a highly variable aquifer. The construction of the bore from the pilot hole to completion was as follows:

(1) Drill 307 mm hole and run 270 mm surface casing to 3 metres.

(2) Drill 190 mm hole using rock roller bit and air to 12.2 m and run 150 mm casing.

(3) Using 140 mm button bit and hammer drill to 61 m in grey shale - supply airlifted 3 L/s.

(4) Hole collapsed into 31.4 m; retrieve 150 mm casing, ream hole using 250 mm button bit to 39 m and run 203 mm casing.

(5) Continue drilling 140 mm hole to 109.8 m. Airlifted strata samples were of grey shale and the airlifted yield fluctuated between 10 L/s and 25 L/s over the interval 79 m to 109.8 m.

(6) Reamed pilot hole to 175 mm diameter to 70 m to enable 250 mm hole opener to be utilised.

(7) Ream hole to 370 mm to 7.5 m and run 335 mm casing.

(8) Ream hole to 250 mm to 65 m. Ream hole using 310 mm rock roller and air to 55.8 m. Continual problems with grey shale slumping into hole.

(9) Run 250 mm casing. Extreme difficulty was encountered in running casing and casing was finally seated at 55.8 m. It was noted however that when the hole was cleaned out with the casing at 52 m a supply of 25 L/s was airlifted, and that when the casing was driven to 53 m and the hole was again airlifted there was no supply.
The hole was then reamed and drilled to 175 mm from 73 m to 122 m with strata samples being entirely of dolomite over this interval and an airlifted supply of 1 L/s.

A decision was then made to set screens between 46 m and 53 m. Based on the altered dolomite rocks being lifted from the hole while the 250 mm casing was being run, it was decided that slot size was not important and the largest slot size in our depot's stock of 203 mm screens was utilised. Considerable difficulty was encountered in placing the screens due mainly to formation instability. When they were finally in position a supply of 25 L/s was airlifted for five hours.

The problems encountered in this hole were primarily caused by the unstable grey shale above the dolomite. Based on knowledge gained during construction of the hole, and geophysical logging downhole, the altered top of the Coomalie Dolomite was located at 41 m. The reason why accurate strata samples and airlifted supplies were not lifted to the surface was that the slumping shales were pressurising the formation. The postulated consequences of this slumping was that the aquifer was so permeable that the dolomite cuttings were being forced into the aquifer and the true water supply was not being airlifted until the aquifer had been sufficiently pressurised.

The development of this hole was primarily carried out using the pump that was to be used for testing because it was considered that surging (such as occurs with airlift development) would seriously destabilize the hole.

If construction of future production bores in this locality and in similar strata is proposed, it is considered necessary to drill a pilot hole first. This hole must be geophysically logged during drilling. When the altered top of the Coomalie Dolomite is located, casing must be installed. The pilot hole can then be deepened to establish the yield. Reaming of the pilot hole to the required size and the subsequent construction and development of the production bore can then be based on accurate data.

(b) Production Bore RN 20722

The site for this bore was chosen based on the results of bore RN 20721 which intersected different strata to that encountered in any of the other investigation bores. It intersected the oldest member of the Coomalie Dolomite – primarily a quartzite and ferruginous quartz sandstone. A supply of 20 L/s was intersected at 48 m and 50 L/s was airlifted on completion of the hole at 90 m. The exact intervals where supplies were intersected could not be determined because large portions of the hole were either
mud drilled or drilled "blind". Bore RN 20722 was sited 20 m to the south of bore RN 20721 and a pilot hole was drilled for similar reasons for bore RN 20720. The construction of the borehole from the pilot hole to completion was as follows:

1. Drill 307 mm hole and run 270 mm surface casing to 2.5 m.
2. Air drill 225 mm hole to 11 m, hole caved in, change to mud and drill 225 mm hole (using drag bit) to 48.2 m.
3. Mud drill 320 mm hole (using rock roller bit) to 48.2 m.
4. Ream hole to 370 mm to 14 m and run 335 mm casing to 14 m.
5. Clean out hole and run 250 mm casing to 48.2 m with great difficulty. Casing seated on quartzite.
6. Mud drill 250 mm hole (using rock roller bit) to 57.1 m and place screens between 47.6 m and 54.5 m. Airlifted 25 L/s with a lot of fine sand. A decision was then made to develop a deeper supply.
7. Mud drill 250 mm hole (using rock roller bit) to 57.4 m and run 200 mm casing to 57.4 m.
8. Air drill 185 mm hole (using rock roller bit) to 66 m and airlift 25 L/s.
9. Pull 200 mm casing and mud drill 250 mm hole to 66 m.
10. Run 200 mm screens and casing with casing between 45.7 m and 58.6 m and screens between 58.7 m and 65.1 m. The outside of the 200 mm casing was built up to approximately 250 mm at 57.5 m in an attempt to restrict the passage of finer material from above. Slot size was based on strata samples collected between 57.4 m and 65 m. A supply of 25 L/s was airlifted for 4 hours on completion.

The problems encountered in this bore were mainly due to the unstable formation and lack of accurate data obtained from bore RN 20721. These problems could be alleviated by further investigation holes in this unit of the Coomalie Dolomite and by more use of downhole geophysical logging.

Development of this bore was initially done using the pump which was to be used for testing. The bore subsequently showed significant development during testing. Further development using duo pipe airlifting was then carried out to improve the bore's performance. Any bore constructed in this unit of the Coomalie Dolomite should be developed using airlifting techniques.
APPENDIX C

ESTIMATION OF THE SAFE YIELD OF THE MAIN AQUIFER SYSTEM

Two techniques have been used to estimate the safe yield. One is based on recharge and the other on groundwater throughflow.

1. Safe Yield - Calculated from estimated recharge.

There is little data available to derive better than a rough estimate of recharge. The estimate is based on a technique described in the Australian Groundwater Consultant's report on the Jabiru Water Supply Investigation (Reference 6). The technique is based on water chemistry and is applicable because the rock is a carbonate rock aquifer. In such aquifers the rock contributes only a very small quantity of the Chloride ion (Cl) to the water. The Cl in the rainwater is concentrated in the soil by evapotranspiration, is taken into solution by recharging water, and moves through the aquifer at approximately the same concentration as it enters. Hence the ratio of recharge to rain falling should approximately equal the ratio of the Cl concentration in the rainwater to that in the groundwater. This technique results in a recharge estimate of 600 millimetres. Applying this recharge to the areas shown in Figure 2.3(b) as likely recharge areas results in a mean annual recharge to the main aquifer system of 1,400,000 cubic metres.

Assuming that the safe yield equals the recharge to the system (not considered practical) the safe yield of the main aquifer system would be in the order of 1,400,000 cubic metres.

2. Safe Yield - Calculated from groundwater throughflow in the immediate vicinity of the borefield.

The calculation of throughflow was done for two different periods of the year. The reason for this was that only two sets of readings were taken for all available monitoring bores - one on the 5.8.81 and the other on the 25.1.82. These results are plotted and contoured on Figure 2.3(a). For both periods an aquifer width of 1,000 metres and a transmissivity of 2,000 square metres per day were assumed.

(a) Throughflow - 5.8.81

Even though bores RN 8822 and RN 9127 were being pumped at 1,450 cubic metres per day, throughflow was from north west to south east. Throughflow can be calculated from the following relationship:

Throughflow = T x i x W

where T = Transmissivity
i = Potentiometric level gradient
W = Aquifer width
Calculated throughflow for the 5.8.81 is 750 cubic metres per day. However, total throughflow would have to incorporate the 1 450 cubic metres per day being pumped. Therefore total throughflow for the 5.8.81 is 2 200 cubic metres per day.

(b) Throughflow - 25.1.82
Total output from bores RN 8822 and RN 9127 was 340 cubic metres per day. Calculated throughflow was 660 cubic metres per day. Total throughflow would then equal 1 000 cubic metres per day. It is believed that there is a decrease in throughflow due to the "blocking" effect of recharge occurring to the east of the borefield.

The total annual throughflow was calculated, assuming that throughflow ranges between the above two limits, to be in the order of 700 000 cubic metres. Assuming the safe yield equals the total annual throughflow, the safe yield would then be in the order of 700 000 cubic metres.

3. Safe Yield.
Considering the paucity of available data it is considered that the above calculations of safe yield can only be used to gain an indication of the safe yield of the system. It is expected that the safe yield would be in excess of the throughflow as water would be drawn in from recharge areas to the east of the borefield when potentiometric levels dropped low enough. Therefore it is considered that the annual safe yield of the main aquifer system would be in the order of 1 000 000 cubic metres.