Groundwater study of the Carnamah townsite

Russell John Speed

Follow this and additional works at: http://researchlibrary.agric.wa.gov.au/rmtr

Part of the Agriculture Commons, Natural Resources Management and Policy Commons, Soil Science Commons, and the Water Resource Management Commons

Recommended Citation


This report is brought to you for free and open access by Research Library. It has been accepted for inclusion in Resource Management Technical Reports by an authorized administrator of Research Library. For more information, please contact jennifer.heathcote@agric.wa.gov.au, sandra.papenfus@agric.wa.gov.au.
IMPORTANT DISCLAIMER

This document has been obtained from DAFWA's research library website (researchlibrary.agric.wa.gov.au) which hosts DAFWA's archival research publications. Although reasonable care was taken to make the information in the document accurate at the time it was first published, DAFWA does not make any representations or warranties about its accuracy, reliability, currency, completeness or suitability for any particular purpose. It may be out of date, inaccurate or misleading or conflict with current laws, polices or practices. DAFWA has not reviewed or revised the information before making the document available from its research library website. Before using the information, you should carefully evaluate its accuracy, currency, completeness and relevance for your purposes. We recommend you also search for more recent information on DAFWA's research library website, DAFWA's main website (https://www.agric.wa.gov.au) and other appropriate websites and sources.

Information in, or referred to in, documents on DAFWA's research library website is not tailored to the circumstances of individual farms, people or businesses, and does not constitute legal, business, scientific, agricultural or farm management advice. We recommend before making any significant decisions, you obtain advice from appropriate professionals who have taken into account your individual circumstances and objectives.

The Chief Executive Officer of the Department of Agriculture and Food and the State of Western Australia and their employees and agents (collectively and individually referred to below as DAFWA) accept no liability whatsoever, by reason of negligence or otherwise, arising from any use or release of information in, or referred to in, this document, or any error, inaccuracy or omission in the information.
Groundwater study
of the
Carnamah townsite

Russell Speed
Hydrologist, Geraldton

Resource Management Technical Report 207
Disclaimer

The contents of this report were based on the best available information at the time of publication. It is based in part on various assumptions and predictions. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

For further information contact the author or
Mr Mark Pridham
Rural Towns Program manager
Agriculture Western Australia
Locked Bag 4
Bentley Delivery Centre WA 6953
Telephone (08) 9368 3333

© Chief Executive Officer, Department of Agriculture Western Australia 2001
Summary

Carnamah townsite overlies a basin of Proterozoic meta-sediments. A groundwater system extends throughout the basin, bound to the east and west by granitic basement which appears to isolate groundwater below Carnamah from the Yarra Yarra Lakes to the west.

Regular groundwater monitoring within the basin of meta-sediments since November 1993 shows groundwater levels fluctuate in response to seasonal rainfall but no longer term trends are apparent. Groundwater levels within the basin may have reached a post-clearing equilibrium.

Groundwater investigations undertaken as part of the Rural Towns Program Community Bores Project aimed to establish present watertable depths beneath the townsite. The watertable depth ranged between about 10 and 15 m below the surface throughout the townsite. Hence, Carnamah is not currently threatened by a salinity problem.

The groundwater monitoring sites established as part of this investigation should be monitored on a regular long-term basis to provide early warning of any changes to this apparent equilibrium.
## Contents

1. Introduction ......................................................................................................... 1
2. Background information ..................................................................................... 2
3. Groundwater investigation .................................................................................. 6
4. Conclusions ...................................................................................................... 13
5. Recommendations ........................................................................................... 13
6. Acknowledgments ............................................................................................ 14
7. References ....................................................................................................... 14

## List of figures

2-1. Regional setting of Carnamah townsite .............................................................. 2

2-2. Carnamah townsite, its catchment, groundwater monitoring sites established in 1993 (CA15 and CA16) and sites drilled during the Community Bores Project ................................................................................... 3

2-3. Hydrograph for piezometer CA15D and daily rainfall bar chart ....................... 5

2-4. Hydrograph for piezometer CA16D and daily rainfall bar chart ....................... 5

3-1. Groundwater levels depth (metres below ground) on 8 June 2000 and salinities (milliSiemens per metre) on 27 July 2000 for the piezometers and observation bores and locations of cross-sections in Figures 3-2 and 3-3 ........................................ 9

3-2. Cross-section along open surface drain through Carnamah townsite .......... 11

3-3. Cross-section along the main drainage direction through the townsite extending to the eastern edge of the salt lake north-north-west of Carnamah ............. 12

## Table

3-1. Site, drilling, construction and groundwater details of the piezometers and observation bores) ........................................................................................................ 10
1. Introduction

The Rural Towns Program commissioned a hydrological investigation of the Carnamah townsite. It was part of a larger investigation (called the Community Bores Project) which covered 23 towns and aimed to accelerate the implementation of effective salinity management options.

As Carnamah does not have current salinity problems, the investigation aimed to establish present groundwater levels and to provide a groundwater monitoring network so that any future risk of salinity could be assessed. This report documents the background information for the town and its catchment (Section 2), the groundwater investigation (Section 3), conclusions (Section 4) and recommendations (Section 5).
2. Background information

Author: Russell Speed, Catchment Hydrology Group, Agriculture Western Australia

Carnamah is 250 km north of Perth and 160 km south-east of Geraldton (Figure 2-1). The district was settled in the 1880s and the current town population is about 370.

Figure 2-1. Regional setting of Carnamah townsite

Carnamah is close to the Yarra Yarra Lakes. Formed in the rift where the Urella Fault splays from the Darling Fault, the Yarra Yarra Lakes are the apparent terminus for a large drainage basin that captures Lake Moore and Mongers Lake (Figure 2-2). A small salt lake to the north of Carnamah townsite is east of the Darling Fault and not connected to the Yarra Yarra Lakes.

2.1 Description of the town catchment

Carnamah townsite is in the upper part of a 3,460 ha internally draining catchment ranging in elevation from 326 to 244 m above Australian Height Datum (AHD). Elevations in the townsite range from 278 to 266 m and the area of catchment that drains through the townsite is 600 ha. The terminus for surface drainage is the salt lake 4.5 km north-north-west of the town (Figure 2-2).

The catchment is predominantly cleared with small remnants of native vegetation on rocky outcrop areas around the southern catchment divide.
2.2 Geology

Carnamah lies about 3 km east of the Darling Fault on the edge of the Yilgarn Craton. While the hills to the east and west are composed of Archaean granitic rocks, the townsite overlies a trough of Proterozoic meta-sediments of the Coomberdale Subgroup. The depth of the trough is unknown but probably exceeds 200 m (Aoukar, N. 1993, pers. comm.).

The meta-sediments in the Carnamah area are predominantly Noondine Chert and Noingara Siltstone (Baxter and Lipple 1985) and are intruded by a number of large northerly-striking dolerite dykes.
2.3 Climate

Most rain in Carnamah falls in winter and summers are hot and dry. Carnamah receives an annual average rainfall of 390 mm, 78 per cent of which falls from April to September inclusive (Bureau of Meteorology 2000). However, summer rainfall events can be significant. The highest recorded daily rainfall was 153 mm in March 1971.

2.4 Drainage

Two main surface drainage systems run through Carnamah. One from the south coincides approximately with the Midlands Road (Figure 2-2). The other is from the south-east and has been diverted from its natural course at the south-eastern edge of the town and directed along an open drain to the east of the shire offices and sports ground.

2.5 Hydrogeology

An airborne geophysical survey was flown over the Carnamah area in 1992 to assess the use of airborne geophysics for catchment management (Speed, R., unpublished data). Carnamah appears to overlie a groundwater system which extends throughout the basin of meta-sediments, bound to the east and west by granitic basement. Information from the geophysical survey indicates that groundwater below Carnamah is isolated from the Yarra Yarra Lakes to the west by a granitic ridge.

Five groundwater monitoring sites were installed in the basin in 1993 as part of 'ground-truthing' the geophysical survey (Speed, R., unpublished data). Two of these sites, CA15 and CA16, are directly down gradient of Carnamah townsite (Figure 2-2). Site CA15 is adjacent to the creek which drains water from the townsite and CA16 is near a lake. At site CA15, drilling intersected 20 m of unconsolidated sediments over chert basement. At site CA16, drilling intersected 11.5 m of clayey profile over white siltstone. The siltstone was more competent with depth and by 24 m was too hard for the rig to penetrate.

At each site, both a piezometer (labelled 'D') and an observation bore (labelled 'OB') were installed. Groundwater has been monitored regularly at both sites since November 1993. The piezometer hydrographs (Figure 2-2 and 2-4) show groundwater levels fluctuate in response to seasonal rainfall but no longer term trend is apparent (Speed, R., unpublished data).
Figure 2-2. Hydrograph for piezometer CA15D and daily rainfall bar chart

Figure 2-3. Hydrograph for piezometer CA16D and daily rainfall bar chart
3. Groundwater investigation

Author: Russell Speed, Catchment Hydrology Group, Agriculture Western Australia

3.1 Introduction

The groundwater investigation aimed to establish current groundwater levels and to provide a groundwater monitoring network so that any risk of salinity could be assessed. This section describes the drilling program and the monitoring network that was established to address the aim and presents preliminary monitoring results. It also summarises the lithologies encountered during drilling and provides an interpretation of the hydrogeology of the area.

3.2 Method

The following information for the Carnamah townsite was used during drill site selection and to assist geology and hydrogeology interpretations:

- geological map at scale 1:250,000 with explanatory notes (Baxter and Lipple 1985);
- aerial photography taken in 1996 at nominal scale of 1:25,000 (obtained from Department of Land Administration);
- rectified satellite imagery from 1996 at scale of 1:100,000 (Department of Land Administration);
- 2-metre elevation contours generated from digital elevation models (produced by Spatial Resource Information Group, Agriculture Western Australia);
- cadastre (obtained from Department of Land Administration);
- airborne geophysical survey data: QUESTEM electromagnetics and magnetics acquired at 200-metre line spacing, 120-metre flying height, images displayed at 1:25,000 scale (Speed, R., unpublished data);
- drill hole data from seven sites acquired in 1993 in support of the airborne geophysical survey (Speed, R., unpublished data);
- time-series groundwater data from two sites from November 1993 (Speed, R., unpublished data).

3.2.1 Drill site selection

Four drill sites were selected along current surface drainage systems through the townsite. One site was located in the central part of the town adjacent to the shire offices as a 'Community Bore' (site 00CA04).
3.2.2 Drilling methods

The bores were drilled by contractor Drilling and Grouting Services Pty Ltd using reverse circulation air-core methods with a 141 mm-diameter bit. Cores up to 10 cm long were recovered from some indurated sections of the profile.

3.2.3 Piezometer and observation bore construction

Piezometers (00CA01D to 00CA05D) were installed at five sites and an observation bore (00CA02OB) was also installed at one of the sites during May 2000.

Piezometers and the observation bore were constructed with 50 mm-diameter class 12 PVC casing. The intake section was machine-slotted.

Piezometers were screened over the bottom 2 metres (except 00CA02D which had a 4-metre screened interval). The annulus around the intake section was packed with graded gravel (grade '8x16', about 1.2 to 2.4 mm diameter). Bentonite pellets were used to seal the annulus above the screened interval. The annulus was then back-filled to ground surface with the graded gravel. Headworks were completed with a lockable steel collar set in cement.

The observation bore was screened over the bottom 4 metres and the annulus back-filled to the surface with graded gravel. A spirit level was used to ensure that the top of the casing was at the same elevation as that of the adjacent piezometer so that groundwater level depths could be compared. Headworks were completed with a galvanised steel collar, with threaded end-cap, set in cement.

Only two piezometers (00CA2D and 00CA5D) warranted development using compressed air at the completion of construction. Groundwater yields were estimated by timing how long it took to fill a bucket of known volume from water discharged from the constructed piezometer by 'air-lifting'.

3.2.4 Drill sample analyses

Drill samples were collected and described over 1-metre intervals. They were oven-dried at 60°C. Descriptive logs were recorded and are available at: <http://www.agric.wa.gov.au/environment/links/RMtechreports/>.

Duplicate chip trays were prepared for all profiles. One set of chip trays is stored at the Geraldton office of Agriculture Western Australia; the other set was presented to the Shire of Carnamah.

3.2.5 Groundwater monitoring and sample analyses

Groundwater samples were collected as part of routine monitoring. Samples were analysed for electrical conductivity at Agriculture Western Australia laboratories in South Perth. Results are stored on the Agriculture Western Australia AgBores database.
3.2.6 Surveying

Surveying was carried out by contractors Warren King and Co. using a dual frequency global positioning system (GPS). The tops of the casings of the observation bores at sites CA15, CA16 and 00CA02 had been constructed to be at the same elevations as those of the adjacent piezometers (a spirit level was used on each occasion) and so the tops of the observation bores were considered to be at the same elevations as the adjacent piezometers. Warren King and Co. quoted the accuracy to be ±30 mm horizontally and ±40 mm vertically for the towns they surveyed for the Community Bores Project.

Two transects along the main surface drainage directions were profiled with an automatic level, staff and measuring wheel. The transect through 00CA02 and 00CA05 was joined to a previously profiled transect from CA15 to CA16 using elevations derived from the digital elevation model.

3.3 Results

3.3.1 Profile descriptions


The profiles appeared to be intensely weathered meta-sediments. Ironstone bands were a common feature. In the upper 20 m the ironstone displayed some pisolite development. Below 20 m, much of the ironstone appeared to be banded iron formation (BIF), often inter-layered with chert (BIF crops out about 13 km north-east of the townsite).

The top 2 metres of the profiles were brown gritty loams. This soil horizon may be a geologically recent transported cover. However, the underlying profiles were considered to be in situ weathered Proterozoic sediments.

Crystalline basement was intersected at one site only, 00CA01, at a depth of 34 m. It is likely to be an intrusive feature, or the metamorphosed margin of an intrusive dolerite dyke.

3.3.2 Groundwater data

Some of the site, drilling, piezometer, observation bore and groundwater details are listed in Table 3-1 and the changes in groundwater levels and salinities across the townsite are illustrated in Figure 3-1. The shallowest groundwater was measured on the north-western edge of the town in piezometer 00CA05D.
Figure 3-1. Groundwater level depths (metres below ground) on 8 June 2000 and salinities (milliSiemens per metre) on 27 July 2000 for piezometers and observation bores, and locations of the cross-sections in Figures 3-2 and 3-3.
Table 3-1. Site, drilling, construction and groundwater details of the piezometers and observation bores (groundwater levels were measured on 8 June 2000; groundwater samples were taken on 27 July 2000)

<table>
<thead>
<tr>
<th>Drill hole name</th>
<th>Easting (m)</th>
<th>Northing (m)</th>
<th>Ground elevation above AHD (m)</th>
<th>Depth drilled (m)</th>
<th>Screened interval elevation above AHD (m)</th>
<th>Groundwater level depth below ground level (m)</th>
<th>Groundwater level elevation above AHD (m)</th>
<th>Electrical conductivity (mS/m)</th>
<th>Estimated yield (m³/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA15D</td>
<td>391044.3</td>
<td>6717168.1</td>
<td>254.5</td>
<td>19.8</td>
<td>236.2—238.2</td>
<td>4.33</td>
<td>250.2</td>
<td>5,120</td>
<td>H</td>
</tr>
<tr>
<td>CA15OB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>nd</td>
<td></td>
</tr>
<tr>
<td>CA16D</td>
<td>390964.7</td>
<td>6718581.3</td>
<td>248.6</td>
<td>24.1</td>
<td>225.1—227.1</td>
<td>1.44</td>
<td>247.2</td>
<td>5,100</td>
<td>nd</td>
</tr>
<tr>
<td>CA16OB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>nd</td>
<td></td>
</tr>
<tr>
<td>00CA01D</td>
<td>392437.7</td>
<td>6715306.9</td>
<td>269.7</td>
<td>34</td>
<td>236.1—238.1</td>
<td>14.33</td>
<td>255.4</td>
<td>491</td>
<td>N</td>
</tr>
<tr>
<td>00CA02D</td>
<td>392024.9</td>
<td>6714897.9</td>
<td>267.0</td>
<td>37</td>
<td>230.7—34.7</td>
<td>11.85</td>
<td>255.2</td>
<td>1,990</td>
<td>100</td>
</tr>
<tr>
<td>00CA02OB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>dry</td>
<td>dry</td>
</tr>
<tr>
<td>00CA03D</td>
<td>392550.0</td>
<td>6714980.2</td>
<td>271.2</td>
<td>30</td>
<td>241.3—243.3</td>
<td>14.85</td>
<td>256.3</td>
<td>956</td>
<td>N</td>
</tr>
<tr>
<td>00CA04D</td>
<td>392385.7</td>
<td>6715194.1</td>
<td>269.3</td>
<td>24</td>
<td>245.6—247.6</td>
<td>13.56</td>
<td>255.8</td>
<td>135</td>
<td>N</td>
</tr>
<tr>
<td>00CA05D</td>
<td>391872.7</td>
<td>6715182.1</td>
<td>265.6</td>
<td>36</td>
<td>229.8—231.8</td>
<td>10.29</td>
<td>255.3</td>
<td>817</td>
<td>70</td>
</tr>
</tbody>
</table>

Note: AHD – Australian Height Datum;  H – high flow, not measured;  nd – no data;  N – negligible flow
3.3.3 Groundwater systems description

At sites within the town, groundwater depth ranged from 10.29 to 14.85 m below the surface on 8 June 2000 (see Figure 3-1). The shallowest groundwater was measured on the north-western edge of the town in piezometer 00CA05D.

Estimated yields were highly variable ranging from negligible to about 100 m$^3$/day.

Below the townsite, groundwater salinities ranged from 135 to 1,990 mS/m on 27 July 2000 (Figure 3-1). However, only one measurement exceeded 1,000 mS/m and the average salinity was 880 mS/m.

3.4 Interpretation and discussion

A cross-section along (and crossing) the open drain which directs surface water from the south-eastern edge of the town to the east of the shire offices is presented in Figure 3-2. The watertable gradient (less than 0.3 per cent) is flatter than the topographic gradient (about 0.4 per cent). Extrapolating the profiles intersected by drilling indicated an apparent northerly dip in a sequence of BIF, chert and clays.

![Cross-section along open surface drain through Carnamah townsite](image)

Figure 3-2. Cross-section along open surface drain through Carnamah townsite (see Figure 3-1 for location).

A cross-section along the main drainage direction through the townsite extending to the eastern edge of the salt lake 4.5 km north-north-west of Carnamah is presented in Figure 3-3.

The lowest groundwater elevation in the townsite (00CA02) does not coincide with the lowest surface elevation (00CA05). As shown in Figure 3-3, the apparent groundwater gradient between 00CA02 and 00CA05 is southward, which is reverse to the northward topographic gradient. However, from 00CA05 to CA15, both the
Groundwater and topographic gradients are northward. The groundwater gradient (about 0.25 per cent) is around half the topographic gradient (about 0.5 per cent).

Groundwater salinity increases markedly toward the salt lake, consistent with a general northerly groundwater flow direction from Carnamah townsite toward the salt lake.

There is currently no information on recharge below the townsite, but investigations in other towns in the Community Bores Project have indicated that there is substantial recharge below townsites. Therefore, by analogy, the Carnamah townsite is also assumed to be a zone of elevated recharge. Long-term, frequent and regular monitoring of the piezometer and bore network will show whether this is so, and whether townsite recharge is causing a long-term groundwater level rise.

Figure 3-3. Cross-section along the main drainage direction through the townsite extending to the eastern edge of the salt lake north-north-west of Carnamah (electrical conductivity values on 27 July 2000, see Figure 3-1)
4. Conclusions

Below the town of Carnamah, the watertable is between about 10 and 15 m deep. The available records for locations downslope of the townsite (CA15 and CA16) imply that the groundwater outflow balances the inflow from year to year. However, it is not known whether this is representative of the long-term behaviour, nor whether the situation below the town of Carnamah is similar.

5. Recommendations

It is recommended that the groundwater levels of the monitoring network be measured regularly and frequently for a long period to confirm that inflow and outflow are in balance beneath the town.
6. Acknowledgments

Dick Kelly, Ed Solin and Jim Prince helped collect the information for the hydrogeological investigation and John Simons helped to drill the two pre-existing monitoring sites (CA15 and CA16).

7. References


Borehole **00CA01**

**RURAL TOWNS PROJECT**

- **UTM E**: 392437.65
- **UTM N**: 6715306.9
- **UTM RL**: 269.7
- **UTM Grid**: 

**Hydrologist/Supervisor**: RUSSELL SPEED  
**Date Drilled**: 25/05/2000

**Town**: CARNAMAH  
**Hole Depth (m)**: 34

**Drill Method**: RC  
**Hole Diameter**: 141

**Driller**:  
**Notes/Location**: Flats, Adjacent Drainage Ditch, Next to Oval, Northside of Town

---

### Geology

<table>
<thead>
<tr>
<th>From m</th>
<th>To m</th>
<th>Moisture</th>
<th>Water Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>Soil/Landfill</td>
<td>gravely Light brown loam</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>Soil/Landfill</td>
<td>Light brown silty loam</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>Silcrete</td>
<td>Hard silcrete cemented pisoliths (10mm) and quartz grits (2-3mm)</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Silcrete</td>
<td>Hard silcrete cemented quartz grits (2-3mm)</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>Silcrete</td>
<td>Silcrete (?) - cemented quartz grits (1-3mm)</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>Silcrete</td>
<td>Silcrete with pisoliths (8-12mm) and quartz grits (2-3mm)</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>Sediments</td>
<td>Quartz grits (1-3mm) cemented in a fine grained matrix - silty sandstone (?)</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>Laterite</td>
<td>Ironstone - immature pisolith development</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>Laterite</td>
<td>Laterite with band/s of light grey silcrete</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>Laterite</td>
<td>Laterite</td>
</tr>
<tr>
<td>10</td>
<td>11</td>
<td>Laterite</td>
<td>Laterite with massive quartz fragments (vein or chert ?)</td>
</tr>
<tr>
<td>11</td>
<td>12</td>
<td>Laterite</td>
<td>Mixture of laterite and massive quartz fragments</td>
</tr>
<tr>
<td>12</td>
<td>13</td>
<td>Banded Iron Formation</td>
<td>Banded iron formation plus chert</td>
</tr>
<tr>
<td>13</td>
<td>14</td>
<td>Banded Iron Formation</td>
<td>Grading to chert</td>
</tr>
<tr>
<td>14</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>34</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Casing Data

- **Casing Type**: CLASS 12, 50MM PVC
- **AGL**: 00CA01D
- **Screen**: 28-16 Gravel, Bentonite Seal
- **Material Screened**: 8-16 Gravel, Bentonite Seal
- **Est. Yield**: 0
- **SWL (m)**: 16.66
- **SWL 2 (m)**: 0

---

Page 1 of 2
Borehole 00CA01

RURAL TOWNS PROJECT

Borehole Information:
- UTM E: 392437.65
- UTM N: 6715306.9
- UTM RL: 269.7
- Hydrologist/Supervisor: RUSSELL SPEED
- Date Drilled: 25/05/2000
- Town: CARNAMAH
- Hole Depth: 34
- Drill Method: RC
- Driller: __________

Notes/Location:
- Flats, Adjacent Drainage
- Ditch, Next to Oval, Northside of Town

Stratigraphy:

- 29.30: Banded Iron Formation
  - Banded iron formation with white and yellow/brown clay.

- 30.31: Banded Iron Formation
  - Banded iron formation with yellow/brown clay.

- 31.33.9: Banded Iron Formation
  - Banded iron formation fragments with golden brown clay.

- 33.9: Crystalline Bedrock
  - Crystalline basement - quartz mixed with a dark green mineral and minor mafic minerals.

Casing Type Information:

<table>
<thead>
<tr>
<th>Hole</th>
<th>Casing Type</th>
<th>Casing AGL</th>
<th>Screen</th>
<th>Material Screened</th>
<th>Est. Yield</th>
<th>SWL (m)</th>
<th>SWL 2 (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>00CA01D</td>
<td>CLASS 12, 50MM PVC</td>
<td>34.3</td>
<td>0.7</td>
<td>8-16 Gravel, Bentonite Seal</td>
<td>0</td>
<td>16.66</td>
<td></td>
</tr>
</tbody>
</table>
Borehole 00CA02

RURAL TOWNS PROJECT

Hydrologist/Supervisor: RUSSELL SPEED
Town: CARNAMAH
Notes/Location: Drainage Depression. Westrail Reserve, Adjacent Main Road

Date Drilled: 25/05/2000
Hole Depth (m): 37
Drill Method: RC
Hole Diameter: 141
Driller:

<table>
<thead>
<tr>
<th>From m</th>
<th>To m</th>
<th>Geology</th>
<th>Moisture</th>
<th>Water Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>Landfill/Soil</td>
<td>Compact red/brown gravelly/gritty loam - ironstone + quartz.</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>Soil/Landfill</td>
<td>Brown gravelly loam - ironstone + quartz.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>Soil/Landfill</td>
<td>Hard, Yellow/brown grits.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Soil/Laterite</td>
<td>Grey and brown gritty clay (grits - 1-2mm)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>Soil/Laterite</td>
<td>Red/brown indurated gritty clay.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>6.5</td>
<td>Soil/Laterite</td>
<td>Ironstone/ferricrete - weakly pisolithic.</td>
<td></td>
</tr>
<tr>
<td>6.5</td>
<td>8</td>
<td>Altered Metasediments</td>
<td>Soft, Pale greeny/yellow fine gritty clay (grits - &lt;1mm).</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>13</td>
<td>Altered Metasediments</td>
<td>Greeny yellow brown fine gritty clay (grits - &lt;1mm).</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>20</td>
<td>Altered Metasediments</td>
<td>Greeny yellow brown fine gritty clay with light grey fine gritty clay harder bands.</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>21</td>
<td>Altered Metasediments</td>
<td>Greeny yellow brown fine gritty clay with ironstone bands.</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>28</td>
<td>Altered Metasediments</td>
<td>Green yellow brown fine gritty clay - harder fragments (partial core) has a granular appearance with - 15-20% mafic minerals.</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>29</td>
<td>Altered Metasediments</td>
<td>Ironstone grits with greeny dark brown clay.</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>30</td>
<td>Altered Metasediments</td>
<td>Ironstone grits with greeny brown clay.</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>31</td>
<td>Altered Metasediments</td>
<td>Ironstone grits in greeny brown clayey return.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hole</th>
<th>Casing Type</th>
<th>Casing AGL (m)</th>
<th>Screen (m)</th>
<th>Material Screened</th>
<th>Est. Yield (m³/d)</th>
<th>SWL (m)</th>
<th>SWL 2 (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>00CA02D</td>
<td>CLASS 12, 50MM PVC</td>
<td>37.03</td>
<td>0.7</td>
<td>8-16 Gravel, Bentonite Seal</td>
<td>95</td>
<td>12.68</td>
<td></td>
</tr>
<tr>
<td>00CA02B</td>
<td>CLASS 12, 50MM PVC</td>
<td>10.64</td>
<td>0.62</td>
<td>8-16 Gravel</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Page 1 of 2
Borehole 00CA02

Hydrologist/Supervisor: RUSSELL SPEED
Date Drilled: 25/05/2000
Town: CARNAMAH
Hole Depth (m): 37
Drill Method: RC
Driller:

Notes/Location:
Drainage Depression.
Westrail Reserve, Adjacent Main Road

<table>
<thead>
<tr>
<th>Hole</th>
<th>Casing Type</th>
<th>Casing AGL</th>
<th>Screen</th>
<th>Material Screened</th>
<th>Est. Yield</th>
<th>SWL (m)</th>
<th>SWL 2 (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>00CA02D</td>
<td>CLASS 12, 50MM PVC</td>
<td>37.03</td>
<td>0.7</td>
<td>8-16 Gravel, Bentonite Seal</td>
<td>95</td>
<td>26/05/2000</td>
<td>12.68</td>
</tr>
<tr>
<td>00CA02B</td>
<td>CLASS 12, 50MM PVC</td>
<td>10.64</td>
<td>0.62</td>
<td>8-16 Gravel</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **31** 32 Altered Metasediments
  - Silicified ironstone - almost geode structures.

- **32** 33 Altered Metasediments
  - Silicified ironstone girts in dark green brown return.

- **33** 34 Altered Metasediments
  - Laminated silica and ironstone (laminar - 2-3mm thick).

- **34** 35 Altered Metasediments
  - Ironstone in dark brown/black return.

- **35** 36 Altered Metasediments
  - Ironstone in dark green/brown return. At 36m while drilling, est yield - 108m3/day.

- **36** 37 Altered Metasediments
  - Weathered (altered) very fine grained metasediment. Granular structure apparent but soft and scrapes away as brown clay. Evidence of vein fractures - feldspar - altered to kaolin. Non-water bearing. Decide to end hole. Pull out and screen with 4m of slots

- **37** 38 Altered Metasediments
  - Weathered (altered) very fine grained metasediment. Granular structure apparent but soft and scrapes away as brown clay. Evidence of vein fractures - feldspar - altered to kaolin. Non-water bearing. Decide to end hole. Pull out and screen with 4m of slots
## Geology

<table>
<thead>
<tr>
<th>From m</th>
<th>To m</th>
<th>Moisture</th>
<th>Water Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>Gritty Loam</td>
<td>Loamy grits (1-2m)</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>Gritty Loam</td>
<td>Light brown gritty loam (grits-1-2mm)</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>Hard Set Gritty Loam Pisolitic</td>
<td>Hardset Light brown gritty silty clay (grits-1-2mm). Some larger fragments of quartz and pisolithic ironstone.</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>Gritty Clay</td>
<td>Weakly indurated light brown gritty silty clay (grits-&lt;1-2mm)</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>Indurated Gritty Clay</td>
<td>Indurated light brown and orange silty/clayey grits (grits-&lt;1-2mm)</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>Indurated Gritty Clay</td>
<td>Indurated gritty white silty clay grading to white very gritty indurated clay (grits-&lt;=1mm)</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>Indurated Gritty Clay</td>
<td>Gritty, pinky brown mottled indurated clay (grits-&lt;=1mm)</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>Indurated Gritty Clay</td>
<td>Orange/red mottled gritty indurated clay</td>
</tr>
<tr>
<td>10</td>
<td>12</td>
<td>Indurated Gritty Clay</td>
<td>White and light brown fine gritty indurated clay (grits-&lt;1mm)</td>
</tr>
<tr>
<td>12</td>
<td>14</td>
<td>Indurated Gritty Clay</td>
<td>Orange/brown fine gritty indurated clay (grits-&lt;1mm)</td>
</tr>
<tr>
<td>14</td>
<td>18</td>
<td>Clay Chert</td>
<td>Golden brown fine gritty clay (grits-&lt;1mm). Some larger chert fragments (~20-40mm). Bands of chert (I massive fragment). From 17-18m some large (50-70mm) ironstone concretions - bands of ironstone?</td>
</tr>
<tr>
<td>23</td>
<td>28</td>
<td>Clay Ironstone</td>
<td>Light brown clay with massive chert and ironstone fragments.</td>
</tr>
<tr>
<td>28</td>
<td>29</td>
<td>Clay Ironstone</td>
<td>Predominantly ironstone with light brown clay.</td>
</tr>
</tbody>
</table>

## Casing Details

<table>
<thead>
<tr>
<th>Hole</th>
<th>Casing Type</th>
<th>Casing AGL (m)</th>
<th>Screen AGL (m)</th>
<th>Screen Material</th>
<th>Est. Yield</th>
<th>SWL (m)</th>
<th>SWL 2 (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>00CA03D</td>
<td>CLASS 12, 50MM PVC</td>
<td>30.55</td>
<td>0.7</td>
<td>8-16 Gravel, Bentonite Seal</td>
<td></td>
<td></td>
<td>15.55</td>
</tr>
<tr>
<td>Hole</td>
<td>Casing Type</td>
<td>Casing AGL (m)</td>
<td>Screen (m)</td>
<td>Material Screened</td>
<td>Est. Yield</td>
<td>SWL (m)</td>
<td>SWL 2 (m)</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------</td>
<td>----------------</td>
<td>------------</td>
<td>------------------------</td>
<td>------------</td>
<td>---------</td>
<td>-----------</td>
</tr>
<tr>
<td>00CA03D</td>
<td>CLASS 12, 50MM PVC</td>
<td>30.55</td>
<td>0.7</td>
<td>8-16 Gravel, Bentonite Seal</td>
<td></td>
<td>15.55</td>
<td></td>
</tr>
</tbody>
</table>

Date Drilled: 26/05/2000
Hole Depth (m): 30
Drill Method: RC
Driller: Clay Ironstone
Light brown clay with ironstone grits.
From m | To m | Geology | Moisture | Water Level
---|---|---|---|---
0 | 1 | Gritty Loam | Grits (-1-2mm). | |
1 | 2 | Gritty Loam | Brown gritty grey loam. (Grits-1-2mm). | |
2 | 3 | Cemented Gritty Clay | Brown silty grits (-1-2mm) grading to cemented grits. | |
3 | 4 | Cemented Gritty Clay | Hard cemented/indurated grits (-1-2mm) band of brown gritty clay. | |
4 | 5 | Indurated Grits Pisolites | Indurated (silified?) grits (-1-2mm) and pisoliths (-8-12m). | |
5 | 6 | Indurated Gritty Clay | Indurated (silcrete?) brown and white fine gritty silt (grits-<1mm) | |
6 | 20 | Indurated Gritty Clay | Indurated (silicified?) orange and red mottled gritty clay (grits-1mm). | 08/06/2000 |
20 | 21 | Clay Ironstone | Indurated, mottled gritty clay then ironstone bands in golden brown clay. | |
21 | 23 | Clay Ironstone | Thin bands of ironstone and chert in golden yellow brown clay. | |

Hole 00CA04D | Casing Type CLASS 12, 50MM PVC | Casing AGL 24.42 | Screen 0.7 | Material Screened 8-16 Gravel, Bentonite Seal | Est. Yield | SWL (m) 14.25 | SWL 2 (m) 08/06/2000
<table>
<thead>
<tr>
<th>From m</th>
<th>To m</th>
<th>Geology</th>
<th>Moisture</th>
<th>Water Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>Gritty Loam</td>
<td>Light brown gritty loam (grits - 1-2mm)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>Hardset Gritty Loam</td>
<td>Hardset, light brown fine gritty loam.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>Hardset Gritty Loam Pisolites</td>
<td>Hardset gritty grey clay (grits - 1-2mm) with ironstone fragments and a few pisolioliths (-10mm).</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>Indurated Gritty Clay</td>
<td>Indurated fine gritty grey clay (some yellow/brown mottling). From 3-5m, grits - &lt;=1mm. From 5-6m, grits - 1-2mm.</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>18</td>
<td>Indurated Gritty Clay</td>
<td>Indurated red and yellow mottled (stain/coloured) gritty clay (grits - 1-2mm) from 14-16m - very hard excellent core recovery - grits - 2-3mm.</td>
<td>08/06/2000</td>
</tr>
<tr>
<td>18</td>
<td>19</td>
<td>Clay Ironstone</td>
<td>Indurated red and white fine gritty clay - some ironstone formation.</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>21</td>
<td>Clay Ironstone</td>
<td>Golden brown clay with bands of ironstone.</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>24</td>
<td>Green Clay</td>
<td>Bright green clay.</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>26</td>
<td>Clay</td>
<td>Light grey clay grading to golden brown clay.</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>30</td>
<td>Clay Ironstone</td>
<td>Golden brown clay - hard ironstone band at 30m.</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>31</td>
<td>Clay</td>
<td>Golden brown clay - with harder bands (of clay).</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>32</td>
<td>Clay</td>
<td>Red/brown clay with hard resistive bands.</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>34</td>
<td>Clay</td>
<td>Golden brown clay with more resistive bands.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hole</th>
<th>Casing Type</th>
<th>Casing AGL</th>
<th>Screen m</th>
<th>Material Screened</th>
<th>Est. Yield m³/d</th>
<th>SWL (m)</th>
<th>SWL 2 (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>00CA05D</td>
<td>CLASS 12, 50MM PVC</td>
<td>36.52</td>
<td>0.7</td>
<td>18-16 Gravel, Bentonite Seal</td>
<td>72</td>
<td>10.99</td>
<td></td>
</tr>
</tbody>
</table>
**Borehole**: 00CA05

**UTM E**: 391872.7 | **UTM N**: 6715182.1 | **UTM RL**: 265.59 | **UTM Grid**:  

**Hydrologist/Supervisor**: RUSSELL SPEED  
**Town**: CARNAMAH  
**Date Drilled**: 26/05/2000  
**Hole Depth (m)**: 36  
**Drill Method**: RC  
**Hole Diameter**: 141  
**Driller**:  

**Notes/Location**: Exit Point for Surface Drainage from Townsite. Northside of Town.  

<table>
<thead>
<tr>
<th>34</th>
<th>35</th>
<th>35</th>
<th>36</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Green Clay</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Greany golden brown clay with more resistive bands. Fragments of which have a granular appearance similar to 21-28m interval in 00CA02. |  
| **Green Clay** |  
Greeny brown clay with resistive fragments displaying granular texture. Yielding some water! |  

**Casing Type**  
**Hole Casing**  
**m AGL**  
**Screen**  
**Material Screened**  
**Est. Yield**  
**m3/d**  
**SWL (m)**  
**SWL 2 (m)**  

<table>
<thead>
<tr>
<th>Hole</th>
<th>Casing Type</th>
<th>Casing AGL</th>
<th>Screen</th>
<th>Material Screened</th>
<th>Est. Yield</th>
<th>SWL (m)</th>
<th>SWL 2 (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>00CA05D</td>
<td>CLASS 12, 50MM PVC</td>
<td>36.52</td>
<td>0.7</td>
<td>18-16 Gravel, Bentonite Seal</td>
<td>72</td>
<td></td>
<td>10.99</td>
</tr>
</tbody>
</table>