Isotope sampling in the VRD
FIGURES

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Introduction
As part of a regional study of the water resources of the Victoria River District, groundwaters, springs, rivers and rain waters were sampled and tested for Deuterium ($^2$H) and Oxygen 18 ($^{18}$O) isotopes. In addition selected groundwaters were submitted for carbon dating. The aim was to gain some insight into sources and mechanisms of groundwater recharge. The work was carried out in conjunction with standard chemical and physical studies of the aquifer systems.

Observations
Details of sites sampled and the results are listed in Tables 1 and 2. The deuterium / oxygen data has been plotted as graphs in Figures 1 to 4 to determine if any trends are present. A local meteoric line, shown on figure 1 was obtained from isotope data from previously collected from Top End rain and rivers (International Atomic Energy Agency data and Water Resources Division unpublished data). Some of the main observations made from these plots include:

- The VRD deuterium / oxygen data lie close to the local meteoric line, with ground waters slightly below it (Figure 1).
- Detailed deuterium / oxygen data from Darwin indicate that rainfall at the height of the wet season (January / February) tends to be isotopically lighter than events at the beginning and end of the Wet (Figure 2). The VRD rainfall data is sparse but seems to conform to the same trend. Most fall within the range of the isotopically lighter rains at the peak of the wet season (Figure 1).
- River waters show a similar isotopic range to all but the lightest groundwaters (Figure 1).
- Shallow groundwaters tend to be isotopically heavy (Figure 3). Deeper ones show a cluster which is isotopically light but the rest of the samples cover a similar range to the shallow waters.
- Groundwaters with a TDS below 400 mg/l tend to be isotopically light (Figure 4). Above that value there is no obvious trend. Groundwaters less than about 800mg/l TDS show a positive relationship between TDS and $^{18}$O (Figure 5).
- Groundwaters from shallow basalt aquifers (<30m) are isotopically heavy (Figure 6). Those from deeper basalt aquifers vary over a wider range but tend to be lighter.
- Spring waters fall within the range of the deeper basalt groundwaters (Figure 6).
- All groundwaters yielded relatively young $^{14}$C ages (Figure 3). The oldest is 3125 years BP and four are less than 50 years old. The youngest waters are isotopically heaviest. The oldest waters tend to be from aquifers deeper than 50 metres.

Discussion
The low TDS of most groundwaters, together with the fact that the deuterium / oxygen data plots close to the local meteoric line, suggests that recharge waters have only undergone a relatively small amount of evaporation prior to infiltration into the aquifer. The deviation beneath the meteoric line reflects slight secondary fractionation due to
evaporation. The positive relationship between TDS and the isotopes is also indicative of some evaporative concentration.

The main source of recharge is rainfall, either infiltrating directly where it falls or as stream bed infiltration. The isotopic signature of the groundwaters matches that of the river waters and of the heavier rainfall events which occur at the peak of the Wet, commonly in January and February. All the groundwaters are lighter than the early and late wet season rains (Darwin data). The young age of the groundwaters indicates that residence times are short and that recharge is regular.

One aspect of the data which is difficult to explain is the observation that the shallow groundwaters are isotopically heavier than deeper ones. This indicates that the shallow groundwaters have been subject to more evaporation prior to entry below the depth of evaporative influence. A possible explanation for the difference may be that there are different recharge mechanisms involved. For example deeper aquifers may be recharged mainly from direct downward infiltration which bypasses the shallower aquifers, leaving little time for evaporation. Most shallow aquifers and some deep ones on the other hand also have a contribution from stream bed infiltration, which tends to be isotopically heavier as evaporation progresses.
Fig. 1 Oxygen 18 Vs Deuterium plot, showing sample types

- VRD (Groundwater)
- Rivers
- Rainwater

Oxygen 18

Deuterium
Fig. 2 Oxygen 18 Vs Deuterium plot of Darwin rainfall showing amount and date

- Oxygen 18 range: 3.00 to 66.00
- Deuterium range: -100.00 to 40.00
- Rainfall amount (mm):
  - 3.00 to 66.00
  - 66.00 to 157.00
  - 157.00 to 278.00
  - 278.00 to 676.10
Fig. 3 Oxygen 18 Vs Deuterium plot of groundwaters, showing sample depths

Slot depth (metres)

- Open circles: 10 - 50 metres
- Solid circles: 50 - 250 metres
Fig. 4 Oxygen 18 Vs Groundwater TDS

![Graph showing the relationship between Oxygen 18 and Groundwater TDS.](image)
Fig. 5

GROUNDWATERS
OXYGEN 18 Vs TDS
Fig. 6 Oxygen 18 Vs Deuterium plot of groundwaters, showing rock type and depth.
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<td>Basalt deep</td>
<td>7.9</td>
<td>35.7 - 103.4 OH</td>
</tr>
<tr>
<td>ST10</td>
<td>31/10/96</td>
<td>525860</td>
<td>8159971</td>
<td>-5.21</td>
<td>-35.6</td>
<td>Waterlool 28907</td>
<td>Homestead</td>
<td>Basalt shallow</td>
<td>5.9</td>
<td>22 - 28</td>
</tr>
<tr>
<td>ST14</td>
<td>11-04-96</td>
<td>532000</td>
<td>8046350</td>
<td>-6.44</td>
<td>-48.2</td>
<td>Kirkland 6900</td>
<td>Moonee Moonee</td>
<td>Basalt/Ptz sst contact</td>
<td>0.25</td>
<td>30.6</td>
</tr>
<tr>
<td>ST12</td>
<td>31/10/96</td>
<td>535900</td>
<td>8256000</td>
<td>-7.91</td>
<td>-51.2</td>
<td>Newry 28905</td>
<td>Bubble Bubble</td>
<td>Ptz tillite</td>
<td>32.7</td>
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* Basalt is Cambrian age
* OH...Open Hole
* Ptz denotes Proterozoic age
Table 2  Carbon 14 results

<table>
<thead>
<tr>
<th>Bore No.</th>
<th>Modern carbon% (pMC+/-)</th>
<th>Years before present (+/-)</th>
<th>Years before present (uncorrected)</th>
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<tr>
<td>27025</td>
<td>94.1(2.9)</td>
<td>490(250)</td>
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<tr>
<td>28736</td>
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<tr>
<td>28737</td>
<td>Not enough carbon</td>
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<td></td>
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<tr>
<td>28901</td>
<td>107.8(3.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28902</td>
<td>115.0(3.4)</td>
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<tr>
<td>28905</td>
<td>121.2(3.5)</td>
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<tr>
<td>28906</td>
<td>87.3(3.5)</td>
<td>1090(330)</td>
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<tr>
<td>28907</td>
<td>114.6(4.9)</td>
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<td>25442</td>
<td>65.1(1.2)</td>
<td>3125</td>
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<td>25204</td>
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<tr>
<td>21993</td>
<td>87.1(1.4)</td>
<td>720</td>
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<td>6631</td>
<td>102.4(1.5)</td>
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<td>27041</td>
<td>92.3(1.4)</td>
<td>240</td>
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<td>21709</td>
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<td>29260</td>
<td>70.0(1.5)</td>
<td>2520</td>
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<td>30600</td>
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<td>27283</td>
<td>97.5(1.5)</td>
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<tr>
<td>23863</td>
<td>107.5(1.5)</td>
<td>&lt;50</td>
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</tbody>
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