NORTHERN TERRITORY OF AUSTRALIA
DEPARTMENT OF TRANSPORT & WORKS
WATER DIVISION

TENNANT CREEK
WATER SUPPLY
1977–1978 investigation

MARCH, 1980.
ABSTRACT

A groundwater investigation to augment the Tennant Creek water supply was conducted during 1977 - 1978. A new area 40 to 50 km west-south-west of Tennant Creek, known as the Tennant Creek West area, was investigated. The findings of this investigation led to an assessment of regional geology and a reassessment of the hydrogeology of the present borefields.

A new borefield is to be established at Tennant Creek West to supply water for industry and agriculture. The present borefields are to be fully developed for town water supply. Monitoring programs and further investigations are outlined and recommended to make full use of surface water and groundwater resources. A comprehensive management policy for the Tennant Creek water resources cannot be formulated until the recommended program for 1979 - 1980 is completed.
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<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>AHD</td>
<td>Australian Height Datum</td>
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<tr>
<td>AMG</td>
<td>Australian Map Grid</td>
</tr>
<tr>
<td>km</td>
<td>kilometre</td>
</tr>
<tr>
<td>$ls^{-1}$</td>
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<tr>
<td>$mgl^{-1}$</td>
<td>milligrams per litre</td>
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<tr>
<td>$r$</td>
<td>distance (variable) from pumped bore</td>
</tr>
<tr>
<td>$s$</td>
<td>drawdown at distance 'r' from pumped bore</td>
</tr>
<tr>
<td>$\Delta s'$</td>
<td>slope of distance-drawdown plot per log cycle</td>
</tr>
<tr>
<td>$S$</td>
<td>Storage coefficient</td>
</tr>
<tr>
<td>SAR</td>
<td>Sodium Adsorption Ratio</td>
</tr>
<tr>
<td>SWL</td>
<td>Standing Water Level</td>
</tr>
<tr>
<td>$t$</td>
<td>time since pumping commenced</td>
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<tr>
<td>$T$</td>
<td>Transmissivity</td>
</tr>
<tr>
<td>TDS</td>
<td>Total Dissolved Solids</td>
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CONCLUSIONS

1. **Tennant Creek West Hydrogeology**

1.1 Wiso Basin sediments of Cambrian age overlying Pre-Cambrian acid igneous rocks and sediments of the Lower Proterozoic were encountered in the Tennant Creek West area 40 to 50 km west-south-west of Tennant Creek.

1.2 Three major aquifers were defined, within:

(i) friable white sandstone (middle unit) of the Point Wakefield Beds;

(ii) dolomite of the Montejinni Limestone; and

(iii) reddish-purple sandstone of pre-Montejinni Limestone age.

Minor aquifers are contained within the dolomitic siltstone of the Hooker Creek Formation, the sandy siltstone sequences of the Point Wakefield Beds, and pre-Cambrian bedrock.

1.3 Major aquifer bore yields exceed 10 ls⁻¹.

1.4 Water from the two sandstone aquifers is of low to medium salinity but because it contains marginally excessive concentrations of nitrate and fluoride it is unsuitable for human consumption. However, the water is suitable for agricultural use. Water from the dolomite aquifer is unsuitable both for human consumption and for agricultural use.

1.5 The Point Wakefield Beds white sandstone is very friable. The aquifer has an average transmissivity value of 200m²d⁻¹. It is semi-confined and has a storage coefficient value of 5 x 10⁻⁴. Standing water level is approximately 5m.

Underflow is approximately 1000m³d⁻¹. The safe yield cannot be assessed because of insufficient information, but a lower bound value is 1000 m³d⁻¹. The volume of water in storage which can be utilised is 4.8 x 10⁶m³ for a section of aquifer measuring 8 km x 1 km in plan and fully saturated. With drainage from the overlying siltstone storage is 9.6 x 10⁶m³.

1.6 The reddish-purple sandstone is more stable than the overlying white sandstone. Little is known of this aquifer area, but for the one bore tested transmissivity was 250m²d⁻¹ and storage coefficient was 1 x 10⁻³. The aquifer is semi-confined and the standing water level is approximately 5m.
1.7 Recharge to aquifers in this area is probably a combination of:

(i) groundwater underflow from the south-east and from Kelly Well West; and,

(ii) surface water recharge from the floodout during periods of high rainfall such as that experienced in the mid 1970’s.

2. Regional Hydrogeology

2.1 The Wiso Basin sediments of Cambrian age found at Tennant Creek West have also been identified in investigation holes in the Kelly Well and Kelly Well West area 20 km south of Tennant Creek, in the South-West Warrego area 50 km west-north-west of Tennant Creek, in the Eastern Wiso and Green Swamp Well area 70 km west-north-west of Tennant Creek, and in the Point Wakefield area 75 km south-west of Tennant Creek.

2.2 The formations and aquifers encountered at Tennant Creek West cover an extensive area west of the meridian of longitude 134° 00’.

2.3 From available knowledge large supplies of water are held in storage west of Tennant Creek West but this water is of poorer quality than that at Tennant Creek West.

3. Present Borefields Hydrogeology

3.1 Aquifer characteristics are re-assessed. Regional values of transmissivity and storage coefficient in the Kelly Well - Kelly Well West area are 400 m²d⁻¹ and 0.03 respectively.

3.2 Total underflow for Cabbage Gum and Kelly Well is 2500 m³d⁻¹.

3.3 The volume of water in Kelly Well and Kelly Well West able to be utilised for human consumption is 4 x 10⁷ m³ which is approximately 50 times the 1977/78 annual consumption for Tennant Creek. Deeper bores need to be constructed to enable extraction of water from the sandstone aquifer underlying the presently utilised siltstone aquifer.

3.4 Since the commencement of pumping in 1968 there has been a net increase of the volume of water held in storage. Water levels reflect surface recharge which has occurred as a result of high rainfalls in the mid 1970’s. The total volume added to storage to September 1978 is 11.7 x 10⁶ m³. As the volume extracted to that date was 5.1 x 10⁶ m³, the net increase in volume is 6.6 x 10⁶ m³ representing a 17%
increase of volume held in storage. Surface water recharge is more important than previously thought.

3.5 A crude estimate of safe yield for the present borefields is $3200m^3d^{-1}$. To place this in perspective current daily extraction is approximately $2300m^3d^{-1}$.

4. **Future Water Supply**

4.1 A new borefield will be established at Tennant Creek West. It will be operational in July 1981, supplying the abattoir, other industries and farms.

4.2 The present borefields of Cabbage Gum, Kelly Well and Kelly Well West are to supply domestic requirements. At the present rate of increase, demand will exceed safe yield in 1989. Another estimate fixes this date as early as 1984.

4.3 A comprehensive management policy is required for the Tennant Creek water resources. This policy can only be formulated once the studies and field investigations recommended for 1979/80 have been conducted.
RECOMMENDATIONS

1. TENNANT CREEK WEST BOREFIELD

1.1 A groundwater investigation in 1979 is recommended to further define the reddish-purple sandstone.

1.2 It is recommended that the current program of monitoring bore water levels in the 29 bores listed in Chapter 8 (8.2.4) be continued. Bores RN 11597, RN 11598, RN 11626 and RN 11637 should be equipped with continuous water level recorders in August 1979. The recorders should be maintained for at least one complete water year.

2. PRESENT BOREFIELDS

2.1 A groundwater investigation in 1979 is recommended to define the areal extent and thickness of aquifers, particularly south of Kelly Well West.

2.2 The current program of monitoring bore water levels in the 16 bores listed in Chapter 8 (8.2.3) should be continued.

2.3 It is recommended that the value of safe yield be re-assessed.

2.4 It is recommended that artificial improvement of surface water recharge be investigated during 1979/80.

3. CONNECTION BETWEEN THE PRESENT BOREFIELDS AND TENNANT CREEK WEST

3.1 A small groundwater investigation in 1979 is recommended to define the areal extent and thickness of aquifers connecting the Tennant Creek West and Kelly Well West areas.

3.2 A low-priority long term groundwater investigation should be conducted in the area of the Edinburgh Creeks floodout south of Kelly Well West.
CHAPTER 1  INTRODUCTION

1.1 Background

Tennant Creek township currently obtains its water supply from production bores in the Cabbage Gum, Kelly Well and Kelly Well West areas (Figures 1 and 2). Rose (1973) calculated that future increased demand would exceed the safe yield of the aquifers in these areas, and recommended that alternative sources of groundwater be investigated "without delay to ensure an additional water supply to Tennant Creek is operative by 1981".

The surface water and groundwater resources of the Tennant Creek surrounds were considered. The first investigation, conducted at Gosse River in 1975 (Verhoeven, 1976), proved unsuccessful in locating an additional water supply.

Although high rainfalls in the mid 1970's eased the pressure to have an additional supply operative by 1981 (by lowering consumer demand and by recharging the aquifers), investigation continued. A field investigation to assess the groundwater potential in the Tennant Creek West area was programmed for 1977/78. The results of the investigation, together with information from other areas in the south-east corner of the Wiso Basin, are presented and analysed in this report, yielding both local and revised regional interpretations of the hydrogeology, revised safe yield and storage values for the present borefields, the site for the next borefield, and a program for continued monitoring and surface water and groundwater investigation.

1.2 Orientation

The 1977/78 field investigation area lies within a larger region in which groundwater and surface water hydrology are evaluated. The region is bounded by the parallels of latitude 19° 15' south and 20° 15' south, and the meridians of longitude 133° 15' east and 134° 15' east. Within the region it is convenient to examine geographical areas defined by groupings of bores, each area having been the focus of a particular investigation by the former Water Resources Branch, the Department of Transport and Works, the Department of Mines and Energy or private mining and exploration companies:

(i) Cabbage Gum
(ii) Kelly Well
(iii) Kelly Well West
(iv) Tennant Creek West
(v) Eastern Wiso and Green Swamp Well
(vi) South-west Warrego
(vii) Point Wakefield

The extent of each of these areas, and the location of bores are shown in Figures 1, 2 and 3.
CHAPTER 2  OBJECTIVES

The objectives of the investigation are twofold:

(i) Locate a supply of water adequate in quantity and quality, and within 'economic' pumping distance of Tennant Creek township, to augment the town's water supply.

(ii) Produce a report recommending, if possible, an area for future water supply development and any further work required in the area, and considering the economic aspects of such a development.
CHAPTER 3  PRELIMINARY STUDY

A preliminary study, considering both surface water and groundwater potential, was carried out in May 1977 (Verhoeven, 1977). Constraints were listed and outlined: finance, time for field investigation, area of investigation, water quality and quantity, field crews and equipment, availability of project staff, and climate.

Areas which offer or have offered the potential for investigation are briefly discussed in this section. As the capital cost of pipeline and the operating cost of pumping are a function of the location of a water source with respect to Tennant Creek, each area is listed and examined in the order of its radial distance from the town (Figure 1).

3.1 Areas Within 30 km of Tennant Creek

3.1.1 Catchment and Floodout of Tennant Creek
(10 km north to 25 km north east)

This area is not suitable for surface water development. With regard to groundwater, production bores (for the Telegraph Station), investigation bores and stock bores have penetrated aquifers in Cainozoic sediments, Warramunga Group siltstones, schists and granites, and Gum Ridge Formation limestone and chert. These aquifers have low permeability and generally contain water having quality unsuitable for human consumption.

3.1.2 Cabbage Gum, Kelly Well and Kelly Well West
(15 km to 25 km south)

The production bores for Tennant Creek are located in these areas.

Prior to 1965 the only major investigation work that had been undertaken was in the Cabbage Gum area for water supply for Tennant Creek. (Bracewell, Crohn and Hays, 1962). Earlier drilling around the town had shown limited supplies of poor quality water in the Warramunga Group sediments and the granitic basement rocks. The result of the Cabbage Gum investigation was the delineation of a small sedimentary basin of uncertain age (but believed to be Cainozoic) underlain by Proterozoic sediments and granites. Within the basin, moderate supplies of potable water were found in a 30m maximum thickness sequence of siltstones, sandstones and grits, the main aquifer being a vugular siltstone having high transmissivity (100 to 300m²d⁻¹) and a low storage coefficient. The dominant feature of the basin was a north-east to south-west shatter belt that formed the north-west boundary of the basin and controlled the hydrology. The safe yield of the basin was estimated to be about 500m³d⁻¹.
In 1965 as a result of increased water demand for Tennant Creek the area south of Cabbage Gum was investigated. Initial drilling in the south of this area (called the Kelly Well area) revealed a sediment filled valley containing large quantities of potable water in a sandstone aquifer (Faulks, 1965). Due to distance from the Cabbage Gum pipeline the main investigation was carried out north-west of this initial area and proved the extension in a north-west direction of this major valley (Ride, 1966). Up to 60m of sediments of uncertain age were found to overlie a granitic bedrock. Large quantities of potable water were found in a vugular siltstone aquifer (local transmissivity 700m²d⁻¹). A deeper sandstone aquifer was also intersected but was not fully investigated.

Further work was done to the west of the Kelly Well area by the Water Resources Branch of the Department of Northern Territory in 1971 in an attempt to delineate the extension of the buried valley located in the Kelly Well area (Rose and Willis, 1973). The results of the Kelly Well West investigation proved somewhat disappointing with no large area of good quality water being intersected. Throughflow of the area was low (400 m³d⁻¹) and did not reflect the combined throughflow of the Kelly Well and Cabbage Gum areas calculated by Rose (1973) to be 1700 m³d⁻¹. Rose believed that an over estimation had been made of the throughflow in the Kelly Well area.

The hydrogeology of these areas is re-interpreted in Chapter 5 and safe yield, recharge and storage are reappraised in Chapter 6.

3.1.3 Flynn's Monument
(20 km to 25 km north)

The many investigation bores drilled to locate a potable supply for Three Ways Roadhouse, and stock bores which have been drilled have encountered Lower Proterozoic rock aquifers of low permeability containing water of quality unsuitable for human consumption.

3.2 Areas Within 60 km of Tennant Creek

3.2.1 Upper Gosse River-Channingum Creek
(30 km to 40 km east-south-east)

The area was subjected to an intensive groundwater investigation in 1975 (Verhoeven 1976). Seepage water was encountered in shallow alluvial aquifers. Aquifers within the Hatches Creek Group and Warramunga Group have low permeability and contain water of quality unsuitable for human consumption. The area is not suitable for surface water development.

3.2.2 Gosse River Floodout
(40 km to 60 km east-north-east)
Groundwater potential has been assessed by a small groundwater investigation conducted in 1971, and by an examination of stock bores. The deep Gum Ridge Formation aquifers are of low permeability and contain poor quality water.

3.2.3 South-West Warrego
(50 km west-north-west)

In 1969 Peko Mines NL carried out a groundwater investigation program in two areas close to Warrego Mine (Ride, 1970). The first area, initially considered to be a possible embayment of the Wiso Basin, was 16 km south-west of Warrego. Two holes (RN 6856, RN 6857) were drilled in this area, intersecting a friable white sandstone aquifer yielding good supplies of moderate quality water. Pump test results, however, suggested an aquifer of limited storage and no further investigation was carried out as the area was believed to be a small alluvial basin of Cainozoic age.

3.2.4 Tennant Creek West
(30 km to 50 km west-south-west)

The area lies on a flat floodout draining in a north-westerly direction from creeks as far south as Wycliffe Creek. Although there are no suitable locations for large surface water storages, the floodout is a potential source of surface water recharge to any aquifers that may underlie it. (Verhoeven, 1977).

Prior to 1977, a number of stock bores and mineral exploration diamond drill holes had been drilled. In 1975 and 1977 BMR diamond drilling (Figures 2 and 3) intersected sandstones containing potable water overlying Pre-Cambrian basement rocks (Howard, 1979). These sandstones were identified as being of Cambrian age, and the present Tennant Creek West investigation was a continuation of this discovery.

Although the aquifers had not been recorded during drilling, the TDS concentration of water from holes which intersected the sandstone was acceptable for human consumption while that from the other holes was not acceptable. Between 1975 and 1977, the water level rose 2 metres in hole RN 10929, indicating recharge.

3.2.5 Edinburgh Floodouts
(45 km south)

The area does not contain sites suitable for large surface water storages.
Negligible supplies of water were obtained from Cainozoic sediments in two stock bores (RN 2715 and RN 2786). The underlying Lower Proterozoic sediments and granite contain limited supplies of poor quality water. The groundwater gradient parallels that of surface drainage to the north-west. The Cainozoic sediments in the floodout west of the Stuart Highway may yield good quality water in large supply if the area receives sufficient recharge from Edinburgh and Little Edinburgh Creeks.

3.2.6. **Phillip Creek Catchment and Floodout** (40 km north)

Many of the stock bores have encountered poor quality water in Cainozoic aquifers of low permeability, and in underlying Gum Ridge Formation and Lower Proterozoic aquifers. A more detailed hydrogeological assessment is required.

3.2.7. **Gibson, Hayward and Attack Creeks** (50 km to 70 km north)

The area may contain suitable sites for large surface water storages in the hilly upper catchments. The floodouts of these creeks could provide a potential source of groundwater, but more detailed hydrogeological assessment is necessary.

3.2.8 **Eastern Wiso and Green Swamp Well**

In 1969 Peko Mines NL conducted a groundwater investigation in an area 30 km west of Warrego on the eastern side of the Wiso Basin. Large supplies of moderate to good quality water were obtained from the Montejinni Limestone, this aquifer having a transmissivity value in excess of 150 m²d⁻¹.

The BMR drilled five stratigraphic holes across the Green Swamp Well area of the Wiso Basin (Randal, 1973; Kennewell, 1977). All the holes intersected Cambrian sediments. Water of quality suitable for stock was located in the Montejinni Limestone in the eastern-most bore (RN 4952). Water of saline quality was located in the Lothari Hill Sandstone in bores RN 4955 and RN 10783.

3.3 **1977/78 Investigation: Selection of Area and Investigation Strategy**

It has been established from the many groundwater investigations within the Tennant Creek region that an aquifer must receive regular (preferably annual) surface water recharge and be of post-Lower Proterozoic age.
before it can be considered suitable for investigation. Within aquifers in the older rocks of Lower Proterozoic age water quality is unsuitable for human consumption and porosity and permeability are generally low.

The Tennant Creek West area was selected for groundwater investigation for a number of reasons:

(i) The possibility of aquifers within the Cambrian beds and the location of this formation further eastward than previously thought.

(ii) The chemical quality of water from the Cambrian beds as indicated by BMR diamond drilling holes was acceptable for human consumption.

(iii) Potentially large volumes of surface water recharge from the floodout in years of high rainfall and resulting flooding.

(iv) The proximity of this area to Tennant Creek, should a suitable water supply be located.

The field investigation comprised two stages. In Stage One, two lines of drill holes were planned, one across and the other along the axis of the floodout (Figure 4). It was presumed that good quality water could be found in Cambrian sandstone and/or Cainozoic sediments, and that poor quality water was contained within the underlying Lower Proterozoic and Archaean rocks. The results of the preliminary drilling would dictate the direction of Stage Two of the investigation.

Should the initial reconnaissance yield encouraging results, Stage Two would commence with a program of surveying comprising bore location and levelling, and the laying of traverse lines. This would be followed by geophysical surveying, both surface and bore hole logging. Information from Stage One drilling, the above surveys and water quality analyses would indicate where further drilling was required. These later holes would in turn provide more geophysical control, geological and water quality data, water level measuring points and more suitable bores for pump testing.
CHAPTER 4 INVESTIGATION PROGRAM: TENNANT CREEK WEST AREA

Field operations were held reasonably close to the programmed timetable except where major mechanical breakdowns (drilling rig and geophysics vehicles) interrupted work. Drilling and pump test operations were curtailed after 19 November 1977 with the onset of heavy and persistent rainfall. These operations were completed during May-June 1978, as was a brief program of geophysical bore logging. Report writing greatly exceeded the programmed time because of the inclusion of a regional hydrogeological evaluation.

4.1 Drilling and Bore Completion

Drilling Rig. No. 21 of the Water Division was used in both stages of the investigation. This Portadrill rotary drilling rig, when coupled with a Holman compressor (20m³ min⁻¹ capacity at 1720 kPa), proved sufficiently versatile to handle a variety of drilling conditions.

Thirty holes (Figure 3) were drilled into a number of formations and aquifers. Drilling was terminated due to one or a combination of the following:

(i) Basement encountered. Bores RN 11597, RN 11599.

(ii) Hard rock drilling with little or no bit penetration. Bores RN 11598, RN 11638, RN 11640, RN 11641.

(iii) Instability of hole sides caused by swelling clay or formation material (generally sand) falling into the hole. Bores RN 11609, RN 11639.

(iv) Inability to maintain drilling fluid circulation. Bores RN 11626, RN 11682, RN 11746.

(v) Intersection of zones of very friable sandstone, resulting in sand entering the hole. Bores RN 11600, RN 11601, RN 11602, RN 11606, RN 11626, RN 11682. Attempts to drill through this sandstone using mud drilling techniques proved unsuccessful. Bores RN 11622, RN 11682.

(vi) Intersection of a large supply of water. Bores RN 11600, RN 11601, RN 11602, RN 11606, RN 11683 etc.

(vii) Target depth of observation bore. Bores RN 11666, RN 11687, RN 11690, RN 11692, RN 11745.
With the exception of observation bores, all bores were constructed with 203.2mm and/or 152.4mm diameter casing so that geophysical logging tools could be run, and to allow for pump testing. Opposite the major water bearing zones, the bores were either left uncased or lined with perforated casing. This practice did not prove satisfactory for most pump tests. Most bores pumped clay and silt intermittently or continuously during testing. Bores completed in the friable sandstone pumped sand during testing. Bore screens having an aperture size of 0.25mm would be required to restrict entry into the bore of this fine-grained uniform sized sand. However this screen size would be too fine for the bore to be efficient.

After logging and pump testing, 152.4mm or 203.3mm diameter casing was left in the bores listed in Table 1 to provide for continuous water level recording points in the designated aquifers. Each pump test observation hole was backfilled and marked with a steel star picket set in concrete. In the remaining bores the casing was replaced by 50mm diameter ID galvanised water pipe. These bores will serve as long-term level monitoring points. Each bore was securely capped, tagged with its name and RN, and surrounded by a concrete block.

**TABLE 1. BORES SUITABLE FOR EQUIPPING WITH CONTINUOUS WATER LEVEL RECORDERS.**

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<th>BORE</th>
<th>AQUIFER</th>
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<td>RN 11597</td>
<td>Point Wakefield Beds sandy siltstone</td>
</tr>
<tr>
<td>RN 11598</td>
<td>Archaean schist (bedrock)</td>
</tr>
<tr>
<td>RN 11626</td>
<td>Point Wakefield Beds white sandstone</td>
</tr>
<tr>
<td>RN 11637</td>
<td>Montejinni Limestone dolomite</td>
</tr>
</tbody>
</table>

4.2 **Survey**

The survey program was commenced in September with the laying of traverse lines and the pegging of geophysics potential drop ratio (PDR) points on these lines. During Stage Two of the investigation Water Division and Department of Mines and Energy holes were located to AMG co-ordinates, as they were key points on the traverse grid. AHD bench marks were established 20m from each bore or group of bores. The bores and the lake surface were levelled in.

4.3 **Geological Logging**

Strata samples collected at 3m intervals in each hole were logged regularly by Hydrogeologists Knott and Read.
4.4 Geophysics

Geophysics comprised a surface survey after Stage One drilling, and well logging of selected bores in May 1978. This phase of the investigation has been documented by Braybrook (1979).

4.4.1 Surface methods

The major surface technique adopted was Potential Drop Ratio resistivity depth probing because:

(i) the technique has previously been used successfully in the nearby Kelly Well West area, which has similar geology;

(ii) the lines of investigation and diamond drill holes should provide good stratigraphic control; and

(iii) the technique is rapid to apply (6 sites each to a depth of 150m can be probed per day) and not as costly as other techniques such as seismic surveying.

PDR was carried out at 119 stations on Lines 1 to 6 inclusive (Figure 2) and on the line of BMR diamond drill holes at 1 km intervals and adjacent to investigation holes. The depth to fresh bedrock granite or schist was generally available from the PDR profiles (see Section 5.1.2). However the method was unable to differentiate between water saturated sands, silty sands, and clays that are present in the thick Cambrian succession, and the weathered layer of bedrock.

A magnetometer survey totalling 21.2km was conducted on line 1 from the eastern end of the line to bore RN 11606, and on the line of BMR diamond drill holes between lines 1 and 4. The survey was carried out at 100m intervals using a Proton Precession Magnetometer. The results of this survey were inconclusive.

4.4.2 Down-hole logging

Gamma ray logging of all investigation holes that remained open was conducted to aid with formation identification and correlation. Twenty six bores in the Tennant Creek West area, twelve bores in the Kelly Well area, and BMR Bore Green Swamp Well No. 1 (RN 4952) were logged. Due to hole cave-in and only partially cased bores it was not possible to log to the completed depth in most bores. Use of the logs is discussed in Section 5.1.2.
4.5 Pump Test

The pump test program was commenced on 19 October 1977, curtailed after 19 November, and completed during May-June 1978. Two field crews and a variety of pumps and motors were utilised. Bore diameter limited the size of pump test equipment which in turn restricted the maximum pumping rate to 10 l/s⁻¹.

Preliminary and constant discharge tests were conducted. The constant discharge tests were of up to four days duration and were concluded with two increases in discharge, at steps of 100 minutes duration.

Although the Stage One holes were drilled primarily for geological reconnaissance and as such were not constructed to production bore standard, it was considered a bonus if they could be pump tested, to:

(i) determine the value of transmissivity for each aquifer.

(ii) note the behaviour of each bore with pumping; and

(iii) note whether or not water quality varied with pumping.

Stage Two bores were drilled with a view to evaluating various aquifer hydraulic characteristics. The proximity of at least one observation hole to each pumped bore enabled the evaluation of aquifer transmissivity and storage coefficient values.

4.6 Water Sampling

Water samples representative of each aquifer encountered in each bore were analysed to ascertain the chemical quality and suitability for human consumption. Variations in ionic concentration areally, with depth and with aquifer sampled have been used to define the directions of groundwater movement and possible areas of recharge.

Investigation holes were sampled:

(i) during drilling, at each increase in supply; and

(ii) at various intervals in time during each pump test, but from a constant depth.

The diamond drill holes were sampled some time after drilling. It is not known of which aquifer(s) the water sample is representative.
4.7 Water Level Monitoring

Water levels were first measured in the area in 1975, in the diamond drill holes.

In the current investigation, water levels were measured as each bore was completed, and are now measured at three-monthly intervals. As the bores have been levelled to AHD, contours on the potentiometric surface for each aquifer can be interpolated from the reduced water levels. Areal and temporal variations of the potentiometric surface will be useful in identification of areas of recharge and in determination of groundwater flow gradients.
CHAPTER 5 -- DATA INTERPRETATION

5.1 Geology

5.1.1 Regional geology

Pre-Cambrian acid igneous rocks and sediments of the Lower Proterozoic Warramunga Group form the Tennant Creek Block, and Wiso Basin sediments of Cambrian age occur under Cainozoic covered plains to the south-west (refer to Figures 5 and 6 and Table 2). The eastern boundary of the Wiso Basin is ill-defined and a possible eastern extension of Cambrian sedimentation is shown in Figure 5.

Archaean

Only minor outcrops of Archaean schists occur in the area. These are confined to an area close to the eastern edge of the present investigation. When intersected in drill holes this schist is composed dominantly of quartz, feldspar and mica.

Proterozoic

The Warramunga Group sediments of Lower Proterozoic age consist dominantly of phyllites and greywackes which are khaki to red-brown in the oxidized zone, and bluish-grey to greenish-grey below this. Dips are generally steep, and minor zones of shearing and silicification are common. The group outcrops to the north and east of the area of investigation forming the topography and subcrops at depth to the south.

A suite of acid igneous rocks of Post Warramunga age underlies most of the area, and outcrops to the north and east of the Cabbage Gum and Kelly Well areas. In composition these rocks consist of porphyritic granite, granitic gneiss, augen gneiss, biotite adamellite and porphyritic adamellite.

Dolerite of post-Warramunga age occurs as dykes in the area, and minor quartz veins, often associated with faulting, are common.

The Hatches Creek Group unconformably overlies the Warramunga Group. It outcrops in prominent strike ridges as in the south-eastern part of the area. Coarse to medium grain silicified quartz sandstone, sub-rounded, thick and medium bedded, cross bedded, ripple marked together with feldspathic sandstone with a minor pebble based conglomerate forms the ridges, whilst softer
sandstone, greywacke, shale, siltstone and lavas outcrop between the ridges. Basic lavas predominate (strongly epidotised basalt and meta basalt) but acid lavas also occur (Smith, 1961; Stewart and Smith, 1961). The Hatches Creek Group is believed to form basement for the Lander Trough and to unconformably overlie the Warramunga Group at depth on its northern flank. The age of the group is believed to be Lower Proterozoic - Carpentarian (McDougall et al, 1965).

The Tomkinson Creek Beds outcrop in the north of the area forming the edge of the Wiso Basin in the Eastern Wiso area. It is believed that they underlie most of the north-eastern part of the Wiso Basin in this area.

Light brown silicified quartz sandstone, typically coarse grained, well rounded and cross bedded, generally forms the outcrop with feldspathic sandstone, siltstone, shale, dolomite and volcanics not exposed. The thickness of the Tomkinson Creek Beds are estimated at approximately 15 000 metres (Randal and Brown, 1979).

Their age is Lower Proterozoic to Carpentarian, and believed to correlate with the Hatches Creek Group in the south. The Tomkinson Creek Beds are younger than the Warramunga Group, although their exact relationship to this group is not clear.

Cambrian

Cambrian sediments in this area were initially assigned to the Middle Cambrian and the Merrina Beds (Milligan et al, 1966). They were correlated in part to the Montejinni Limestone of the Northern Wiso Basin, the Tindall Limestone of the Daly Basin, and the Gum Ridge Formation, a marginal unit of both the Georgina and Wiso Basins.

Milligan subdivided the Merrina Beds into three lithological units, based on the BMR drilling in the Green Swamp Well area. The uppermost, or Sandstone unit, 100m thick, consisted of white and grey sandstones, often friable red-brown quartz sandstone, partly dolomitic with interbedded brown siltstone and dolomite. This unit was underlain by a siltstone member, 75m thick, comprising interbedded dark brown siltstone and claystone, partly dolomitic, with thin interbedded microcrystalline dolomite. The lower, Dolomite Unit, 50m thick minimum, consisted of brown-grey to dark grey dolomite, partly argillaceous and partly calcareous, with chert fragments.

Kennewell and Huleatt (1979 in prep) in their recent work on the Wiso Basin dropped the term Merrina Beds and correlated the lower dolomite unit with the Montejinni...
<table>
<thead>
<tr>
<th>Age</th>
<th>Rock Unit &amp; Symbol</th>
<th>Est. Max. Thickness</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cainozoic</td>
<td>(C)</td>
<td>10 - 80m</td>
<td>Unconsolidated sand, laterite, clay travertine.</td>
</tr>
<tr>
<td></td>
<td>Lake Surprise Sandstone (K1)</td>
<td>350m</td>
<td>Well sorted, well rounded, medium to coarse grained sandstone.</td>
</tr>
<tr>
<td>Ordovician</td>
<td>Hanson River Beds (Oh)</td>
<td>300m</td>
<td>Fine to coarse grained sandstone, well to poorly sorted, claystone dolomite.</td>
</tr>
<tr>
<td>(Templetonian)</td>
<td>Point Wakefield Beds (Gwl)</td>
<td>100m</td>
<td>Calcareous siltstone, sandstone, siltstone.</td>
</tr>
<tr>
<td></td>
<td>Lothari Hill Sandstone (Gml)</td>
<td>100m</td>
<td>Fine grained, sub-rounded to sub-angular silty, quartz sandstone, occasionally dolomite.</td>
</tr>
<tr>
<td>Middle Cambrian (Ordian)</td>
<td>Hooker Creek Formation (Gmh)</td>
<td>170m</td>
<td>Red brown laminated dolomitic siltstone, siltstone and silty dolomite.</td>
</tr>
<tr>
<td></td>
<td>Montejinni Limestone (Gmm)</td>
<td>200m</td>
<td>Grey fine to medium crystalline dolomitic siltstone, siltstone, gypsum veins.</td>
</tr>
<tr>
<td>(Age uncertain)</td>
<td>Gum Ridge Formation (Gmg)</td>
<td></td>
<td>Sandy limestone, chert, siliceous shale and sandstone.</td>
</tr>
<tr>
<td>Lower Proterozoic (?)</td>
<td>Tomkinson Creek Group (Ptg)</td>
<td>Several thousand</td>
<td>Quartzite, sandstone, siltstone and dolomite.</td>
</tr>
<tr>
<td></td>
<td>Hatches Creek Group (Plh)</td>
<td></td>
<td>Quartzite, sandstone, siltstone, lavas.</td>
</tr>
<tr>
<td></td>
<td>Granite (Pg)</td>
<td></td>
<td>Granite, granite-gneiss, adamellite.</td>
</tr>
<tr>
<td></td>
<td>Warramunga Group (Pw)</td>
<td></td>
<td>Greywacke, volcanics</td>
</tr>
<tr>
<td>Archaean</td>
<td></td>
<td></td>
<td>Schist</td>
</tr>
</tbody>
</table>
Limestone which they describe as a grey, medium to finely crystalline dolomite with interbeds of red-grey and green dolomitic siltstone and silstone. Minimum thickness is stated as 157m, and the unit does not outcrop.

Overlying the Montejinni Limestone, and partially correlated to the middle unit of the Merrina Beds, are a series of red-brown laminated dolomitic siltstone called the Booker Creek Formation, which grade into beds of siltstone and dolomite up to 10m thick. Minimum thickness is stated as 162m and the unit does not outcrop.

The upper sandstone unit of the Merrina Beds may correlate with the Lothari Hill Sandstone and consists of white, fine grained, quartzose sandstone, sub-rounded, to sub-angular, silty and dolomitic in parts. The sandstone weathers brown. Sparse beds of white soft friable silty claystone and rare beds of grey cryptocrystalline chert and white microcrystalline dolomite are also present. Minimum thickness is stated as 94m and the unit does not outcrop.

The Point Wakefield Beds outcrop in the Green Swamp Well and Point Wakefield areas and are generally a red to white, fine grained, angular, well sorted sandstone, interbedded with red-brown or white micaceous silty claystone. In some areas the unit is represented by a white calcareous claystone, silty or chalcedonic in parts. The age of this unit is uncertain; it lies between middle Cambrian and Ordovician (Middle Arenigian). The total thickness of the unit probably does not exceed 100m.

Throughout this report reference will be made to both Milligan's subdivision and Kennewell and Huleatt's subdivision of the Cambrian.

The Gum Ridge Formation forms low rubble covered mounds outcropping around the edge of the sedimentary basin. The formation consists of impure sandy limestone, chert, siliceous shale and sandstone, and is of unknown thickness. The upper part of the unit has been removed by erosion in this area. The Gum Ridge formation is believed to be a facies variant of the Merrina Beds representing the edge of deposition.

Cainozoic

The post-laterisation deposits consist mainly of poorly-sorted unconsolidated sands and gravels, clays and calcrete, the latter forming small ridges in the area.

5.1.2 Geology of the Tennant Creek West Area

The cross section of Line 1 is representative of the geology of the Tennant Creek West Area (Figure 9).
Consolidated sediments of Cambrian age overlie pre-Cambrian bedrock. About 15m of Cainozoic sediments cover the whole area. Cross sections of Lines 2 to 6 are shown in Figures 10 to 14. PDR profiles have been used in drawing up the cross sections, notably the depth to bedrock granite or schist.

A sequence of sandstones and siltstones unconformably overlie the Hooker Creek Formation and the Montejinni Limestone in a threefold division. The upper unit, minimum thickness 60m, consists of light coloured, poorly indurated siltstones, often grey, brown, yellow or purple, and often arenaceous. In places they grade into poorly sorted silty sandstones. The middle unit is a 15 to 20m thick friable white well-sorted medium grained lightly cemented quartz sandstone. The lower unit is a brown micaceous siltstone, which weathers to a white or yellow soft micaceous siltstone. In places this siltstone grades into a fine grained micaceous sandstone. This sequence of sandstone and siltstones is correlated with the Point Wakefield Beds. Between bores RN 11607 and RN 11597 a minor flexure has preserved the upper unit in a shallow synclinal structure. East of RN 11606 the upper units have been eroded away (Figure 9). A cross section through Tennant Creek West (Figure 16) shows the correlation from hole to hole using gamma logs whilst Figure 17 shows a composite gamma log section through the Point Wakefield Beds that has been compiled from these Tennant Creek West bores. Reasonable correlation can be seen to exist from bore to bore, and the friable white sandstone unit is clearly defined on the gamma profile.

The Montejinni Limestone is a grey brown crystalline hard dolomite and was intersected in the bores at the western end of Line 1, and also at the western end of Line 6. Conformable above the Montejinni Limestone lies the Hooker Creek Formation which is present in Bores RN 11637 and RN 11607 and consists of red-brown mottled siltstone and grey dolomitic siltstones.

Three bores on Line 1 and one on Line 4 intersected a reddish-purple sandstone with good interstitial porosity at the bottom of the bores. No bore completely penetrated this sandstone; a maximum of 26m was intersected in RN 11665. Some degree of silicification was present at the top of this sandstone. The age and relationship of this member is not certain. Further investigation is required to determine the age (Chapter 8).

5.2 Correlation of Other Areas with Tennant Creek West

5.2.1 Eastern Miso and Green Swamp Well (Figure 7)

Siltstones of the Point Wakefield Beds unconformably overlie the Montejinni Limestone in the easternmost Green Swamp Well investigation bore (RN 4952). The bore bottoms in reddish purple sandstone after intersecting 5m of dolomite. The 1969 Geopoko investigation bores to the east...
passed from siltstone of the Point Wakefield Beds into cavernous dolomite (Montejinni Limestone) and three of these bores bottomed in reddish-purple sandstone. The ridge of Lower Proterozoic Tomkinson Creek Group sediments occurring some 23 km west of Warrego Mine marks the eastern edge of the Wiso Basin sediments in this area. Outcrops of Cambrian Gum Ridge Formation occur east of this ridge and to within about 9 km of Warrego.

5.2.2 **South-West Warrego**

The two holes (RN 6856, RN 6857) drilled by Geopeko in this area (1969 investigation) both bottomed in a friable white sandstone, from which moderate supplies of fair quality water was obtained. Geopeko concluded from the pump test carried out on one of the bores that the area was a small alluvial basin of Cainozoic age. However this recent Tennant Creek investigation indicates that the friable white sandstone may belong to the Point Wakefield Beds and that the area could be part of the major Wiso Basin. The limited extent of the basin is attributed to minor flexuring within the white sandstone unit of the Point Wakefield Beds, similar to that occurring on Line 1 in Tennant Creek West.

5.2.3 **Point Wakefield** (Figure 8)

Results from Geopeko mineral exploration holes drilled in the south-west have shown a sequence of Cambrian sediments overlying the Warramunga Group. Fine grained ferruginous sandstones with minor interbeds of dolomite and siltstone, and in excess of 105m, occur at the top of the sequence and are correlated with the Lothari Hill Sandstone of Kennewell and Huleatt. These are underlain by a 70 to 90m thick sequence of dolomitic siltstone with three distinct beds of dolomite, 6 to 14m thick, one of which is algal dolomite. This unit is assigned to the Hooker Creek Formation. Below this unit, in excess of 70m of dolomite with minor siltstone interbeds occur (Montejinni Limestone).

5.2.4 **Kelly Well and Kelly Well West**

A friable white sandstone has been noted in both the driller's logs and geologist's logs in the Kelly Well and Kelly Well West areas. The initial drilling of the Kelly Well area in 1965 revealed a friable white to grey sandstone at depth yielding large supplies of potable water (bores RN 4875 and RN 4911). In the main area of investigation in Kelly Well a friable white sandstone was noted beneath the vugular siltstone aquifer in most of the deeper bores, and recognised as such by both Woolley (1966) and Faulks (1965) as only existing in the deeper parts of the basin.
In the Kelly Well West area a review of the driller's logs and the gamma-ray profiles together with the geologist's logs shows that the following succession occurs over a large area (Figure 18):

- Top soil
- Light brown silty sandstone
- Chalcedony
- Brown silty sandstone
- Siltstone, often tubular
- White/light grey sandstone
- Granite bedrock

Contrary to the previously held idea that the only major aquifer was the tubular siltstone, the sandstone units both above and below the chalcedony act as aquifers, as does the white sandstone below the siltstone. In some cases water has been attributed to the siltstone due to the incorrect belief that it was the major aquifer, whereas closer inspection of the driller's logs reveals that the supply came from the sandstone units. It is also believed that increases in supply noted in bores penetrating the siltstone unit may, in some cases, represent an increase in flow from the overlying sandstone due to bore development during drilling. However, the siltstone unit is the major aquifer in many of the bores.

Comparison of the gamma ray logs run in bores in the Kelly Well and Kelly Well West areas with those run in Tennant Creek West show some similarity (Figure 19). The low amplitude of the gamma-ray log occurring against the white/light-grey sandstone unit and beneath the higher amplitude of the siltstones correlates with the upper unit of the Point Wakefield Beds in the Tennant Creek West area. This implies that the friable white sandstone and the overlying silicified and tubular siltstones occurring in the Kelly Well and Kelly Well West area are of Cambrian age. The development of laterite above the siltstone in some bores in the area signifies a Cainozoic age for the post-siltstone sequence. Hays (1971) indicates a late Cretaceous to early Tertiary age for development of laterite in this area which tends to support a pre-Cainozoic age for the siltstones and underlying sandstones.

5.3 Surface Water Hydrology

The predominant landform within the study region is a plain having very gentle gradient to the north-west (Figure 4). This plain is bounded by Short Range to the north, Murchison Range to the east and Davenport Range to the south-east. There are no sites suitable for large reliable surface water storage in proximity to Tennant Creek.

The ranges provide the main surface water resource for the region. Storm run-off is concentrated into numerous streams which flood out on the plain (Figure 4), resulting in infiltration and percolation to groundwater aquifers.
Flows are generally of short duration, occurring as a result of summer rainfalls. The stream of importance to the present borefields is Kelly Creek which provides recharge both directly at the borefields and to groundwater underflow originating south-east of the borefields.

In years of extremely high rainfall such as those experienced in the mid 1970's, streams including Gilbert, McLaren and Sonney Creeks and others from as far south as Wycliffe Creek flow out onto the plain and combine to form one large floodout draining to the northwest. The extent of the floodout in February 1974, obtained from a LANDSAT image print, is shown on Figure 4. The area inundated was 15 km wide and extended for more than 100 km before ending in the Tennant Creek West area.

This large volume of water would have provided potentially high recharge to the aquifers underlying the plain.

5.4 Groundwater Hydrology

5.4.1 Aquifers

(1) Definition

Three major aquifers and three minor aquifers have been defined in the Tennant Creek West area. Of the major aquifers the youngest is a friable white sandstone, about 20m thick, occurring in the middle unit of the Point Wakefield Beds. This aquifer is approximately 10 km wide from bore RN 11603 to bore RN 11606 on Line 1. It is also intersected in bores RN 11689 and RN 11690 (Line 2) and RN 11744 and RN 11745 (Line 4). It forms a minor synclinal structure probably trending north-west with a maximum depth of 40m beneath the Cainozoic cover, indicating dips of less than 10° on the flanks of the syncline. Permeability in this aquifer is intergranular and primary.

The dolomite of the Montejinni Limestone is a major aquifer occurring in the west of the Tennant Creek West area on Line 1 (bores RN 11609, RN 11637) and Line 6 (bore RN 11691). Permeability is due to solution joints and cavities.

Believed to be underlying most of the central and eastern part of the area at a depth greater than 60m is the third major aquifer. This is a reddish-purple sandstone of uncertain age that has only been intersected in bores RN 11665 (Line 1), RN 11609 (Line 1) and RN 11638 (Line 4). Intergranular primary permeability occurs in this aquifer.
The dolomitic siltstone of the Hooker Creek Formation contains minor aquifers in fractures in bores RN 11607 and RN 11637 (Line 1). Other minor aquifers occur in the sandy siltstone sequences of the Point Wakefield Beds over most of the area, and in bedrock. In these minor aquifers fracture permeability is dominant.

Table 3 lists all the major water supplies encountered in drilling the bores in Tennant Creek West, together with a summary of the chemical characteristics (TDS, nitrate, fluoride, bicarbonate-chloride ratio, and SAR).

(ii) Pump Test and Aquifer Characteristics

The pump test procedure is outlined in Chapter 4. All size aquifers described in the previous section were tested. Yields from bores in the major aquifers are listed in Table 3 and shown in Figure 21. Minor aquifer bore yields ranged from 0.5 to 10 ls⁻¹ with the majority being less than 5 ls⁻¹.

Only five of the bores drilled into the Point Wakefield Beds white sandstone aquifer yielded information on aquifer characteristics. Transmissivity values vary from 70 m²d⁻¹ to 600 m²d⁻¹ with an average of 200 m²d⁻¹. The aquifer is semi-confined and has a short term storage coefficient value of 5 x 10⁻⁴. In these bores (RN 11600, RN 11602, RN 11606, RN 11689 and RN 11744) fine sand and silt were pumped in suspension either continuously or in short cloudy bursts. At the completion of testing each bore was found to have been back-filled with five to eight metres of aquifer material. Bores RN 11601, RN 11603 and RN 11682 developed throughout testing and no aquifer characteristic values could be determined. If this aquifer is to be developed for water supply, construction of production bores will require bore screens, artificial gravel pack material and development.

Of the three bores drilled into the Montejinni Limestone dolomite aquifer only two (RN 11637 and RN 11681) were successfully tested. Transmissivity values range from 100 m²d⁻¹ to 200 m²d⁻¹. The aquifer is semi-confined. Fine sand, silt and clay were pumped in suspension during testing.

Three bores were drilled into the red-purple sandstone aquifer but only bore RN 11665 was successfully tested. Bore RN 11609 collapsed during drilling and RN 11638 failed to develop with pumping. Using observation bores RN 11602 and RN 11666 the value of transmissivity was calculated as 250 m²d⁻¹. The aquifer is semi-confined and has a short term storage coefficient value of 1 x 10⁻³.
with the three minor aquifers tested. The only bore (RN 11607) tested in the Hooker Creek Formation dolomitic siltstone aquifer gave a transmissivity value of 100 m² d⁻¹. Bores tested in the Point Wakefield Beds sandy siltstone aquifer yielded values of transmissivity ranging from 20 m² d⁻¹ to 480 m² d⁻¹ with an average of 100 m² d⁻¹. Storage coefficient values for these aquifers were not determined.

Bore RN 11683 in bedrock yielded an aquifer transmissivity value of 100 m² d⁻¹ and a short term storage coefficient value of 4 x 10⁻⁴.

Values of transmissivity for the major aquifers in the Tennant Creek West area and in the areas of the present borefields are summarised in Figure 20.

(iii) Water Quality

Figure 30 shows a Piper analysis of the water chemistry of Tennant Creek West.

Waters from the dolomite aquifer are generally of moderate to poor quality (TDS 1000 to 3000 mg l⁻¹) and are essentially sodium chloride waters with low bicarbonate-chloride ratios. These waters would be totally unsuitable for domestic supplies without prior treatment, and are also generally unsuitable for agriculture.

The white sandstone aquifer yields water of low to medium salinity (TDS 370 to 1120 mg l⁻¹). However, nitrate (43 to 65 mg l⁻¹) and fluoride (1.4 to 2.2 mg l⁻¹) are above the permissible levels for human consumption (45 mg l⁻¹ and 1.5 mg l⁻¹ respectively: WHO, 1971). The lower salinity supplies are ideally suited for agriculture because of their low SAR.

Analyses of waters from the red sandstone aquifer plot out in the same field on the Piper diagram as those from the white sandstone, indicating close chemical similarity of the two waters. These waters exhibit low SAR values indicating their suitability for agriculture.

Water from this unit is also marginally suitable for human consumption having TDS concentration ranging from 700 to 780 mg l⁻¹, a nitrate concentration of 48 mg l⁻¹ and fluoride concentrations of 1.1 and 2.4 mg l⁻¹.

Bores RN 11607 and RN 11608 obtain large supplies from a sequence of siltstones. The water chemistry of Bore RN 11607 is very similar to that of neighbouring bore RN 11606 (white sandstone aquifer), and it is suggested that the aquifer is contained in a major fracture (possibly a fault) within the Hooker Creek formation, with good hydraulic continuity with the white sandstone aquifer (refer to the geological interpretation in Figure 9). Water quality in bore RN 11607 (see Table 3) is suitable for both human consumption and agricultural use. The water from Bore RN 11608 has
### TABLE 3

**MAJOR WATER SUPPLIES - TENNANT CREEK WEST**

<table>
<thead>
<tr>
<th>RN</th>
<th>Yield (l s⁻¹)</th>
<th>Aquifer Type</th>
<th>Depth (m)</th>
<th>TDS</th>
<th>NO₃</th>
<th>F</th>
<th>HCO₃/Cl</th>
<th>SAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>11600</td>
<td>10</td>
<td>White Sandstone</td>
<td>53</td>
<td>1120</td>
<td>56</td>
<td>1.7</td>
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<td>900</td>
<td>47</td>
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<td>4</td>
<td>White Sandstone</td>
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<td>710</td>
<td>52</td>
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<td></td>
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<td>Red Sandstone</td>
<td>81</td>
<td>710</td>
<td>48</td>
<td>1.6</td>
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<td>8</td>
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<td>11626</td>
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<td>33</td>
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<td>6</td>
<td>White Sandstone</td>
<td>44</td>
<td>800</td>
<td>52</td>
<td>1.8</td>
<td>1.9</td>
<td>4.4</td>
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<td></td>
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<td>48</td>
<td></td>
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<td>11744</td>
<td>4</td>
<td>White Sandstone</td>
<td>21</td>
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<tr>
<td></td>
<td>5</td>
<td>White Sandstone</td>
<td>26</td>
<td>760</td>
<td>63</td>
<td>1.6</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Bedrock (Weathered Granite)</td>
<td>57</td>
<td>720</td>
<td>26</td>
<td>1.6</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>tested supply</td>
<td></td>
<td>740</td>
<td>66</td>
<td>1.8</td>
<td>2.9</td>
<td>2.7</td>
</tr>
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<td>11745</td>
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<td>White Sandstone</td>
<td>26</td>
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</tr>
<tr>
<td>11746</td>
<td>8</td>
<td>White Sandstone</td>
<td>53</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>10</td>
<td>Red Sandstone/Siltstone Interface</td>
<td>67</td>
<td>780</td>
<td>47</td>
<td>1.1</td>
<td>2.2</td>
<td></td>
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<tr>
<td>11638</td>
<td>4</td>
<td>Red Sandstone</td>
<td>65</td>
<td>710</td>
<td>52</td>
<td>2.4</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>11665</td>
<td>10</td>
<td>Red Sandstone</td>
<td>72</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Red Sandstone</td>
<td>95</td>
<td>700</td>
<td>47</td>
<td>1.6</td>
<td>2.1</td>
<td>3.8</td>
</tr>
<tr>
<td>RN</td>
<td>Yield (Ls⁻¹)</td>
<td>Aquifer Type</td>
<td>Depth (m)</td>
<td>TDS</td>
<td>No₃</td>
<td>F</td>
<td>HCO₃/Cl</td>
<td>SAR</td>
</tr>
<tr>
<td>------</td>
<td>--------------</td>
<td>-----------------------</td>
<td>-----------</td>
<td>------</td>
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</tr>
<tr>
<td>11609</td>
<td>4</td>
<td>Dolomite</td>
<td>82</td>
<td>1060</td>
<td>51</td>
<td>2.9</td>
<td>1.5</td>
<td>15.5</td>
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<tr>
<td>11637</td>
<td>10 to 12</td>
<td>Dolomite</td>
<td>99 to 116</td>
<td>2940</td>
<td>47</td>
<td>1.8</td>
<td>0.4</td>
<td>17.4</td>
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<tr>
<td>11691</td>
<td>5</td>
<td>Dolomite</td>
<td>71</td>
<td>2560</td>
<td>149</td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Dolomite</td>
<td>79</td>
<td>1160</td>
<td>56</td>
<td>1.4</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>tested supply</td>
<td>1360</td>
<td>64</td>
<td>1.8</td>
<td>1.1</td>
<td>8.6</td>
<td></td>
</tr>
<tr>
<td>11607</td>
<td>10</td>
<td>Siltstone (6m)</td>
<td>93</td>
<td>430</td>
<td>38</td>
<td>1.3</td>
<td>6.8</td>
<td>1.7</td>
</tr>
<tr>
<td>11608</td>
<td>8 to 15</td>
<td>Siltstone (base)</td>
<td>67</td>
<td>870</td>
<td>55</td>
<td>1.8</td>
<td>2.2</td>
<td>5.7</td>
</tr>
<tr>
<td>11683</td>
<td>7</td>
<td>Bedrock (Weathered diorite)</td>
<td>81</td>
<td>700</td>
<td>41</td>
<td>1.8</td>
<td>2.2</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Bedrock (Fractured diorite)</td>
<td>98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
groundwater chemistry similar to that in the white sandstone aquifer, and this aquifer is also interpreted as being a fracture within the siltstone. Water quality from this bore is marginal for human consumption but suitable for agricultural use.

Bores RN 11683 and RN 11744 obtain major supplies from both the weathered and fractured zones of the bedrock. Water quality is similar to that from the white sandstone aquifer. Water quality from both bores is good (TDS 700 to 740 mg/l), marginally suitable for human consumption due to slight excess of nitrate and fluoride, but ideally suitable for agriculture.

High values of dissolved silica are associated with the white sandstone aquifer (63 to 79 mg/l) and the bedrock aquifers (82 to 100 mg/l). This high concentration reflects the granitic rock type from which these waters were derived. By contrast waters of the dolomite aquifer contain more normal values of silica (18 to 30 mg/l). Unlike the Kelly Well West area where Rose and Willis (1973) found a strong correlation between high silica concentrations and chalcedony, the Tennant Creek West area shows no development of chalcedony, nor are the high silica concentrations associated with bores in the main underflow channel, as was the case in Kelly Well West.

5.4.2 Recharge and groundwater movement

Figures 21 to 29 show contours of yield, TDS concentration, bicarbonate-chloride ratio, nitrate concentration and fluoride concentration for the Tennant Creek West - Kelly Well - Cabbage Gum area, and for the regional area. The bicarbonate-chloride ratio, an indicator of recharge, has its highest values at bores RN 11606, RN 11607, RN 11626 and RN 11682. This area is also a topographic low in the floodout. The high bicarbonate-chloride ratio is accompanied by low concentrations of TDS, nitrate and fluoride indicating recent surface water recharge.

Bedrock contours for the Kelly Well, Kelly Well West and Tennant Creek West areas are shown in Figure 15. The north-west to south-east trending channel through Kelly Well joins a smaller channel from the Cabbage Gum area.

This channel divides in the vicinity of Production Bores 6 and 7 (RN 10622 and RN 10624 respectively). One channel turns south-west and the other carries on in a north-west direction through Kelly Well West entering Tennant Creek West in the vicinity of Bore RN 11683. The south-west trending channel is postulated mainly on circumstantial evidence:
(i) The major shatter belt bounding the north-west side of the Cabbage Gum basin would, if extended, pass along the postulated channel and be a controlling factor in the lineation of this channel.

(ii) The bedrock contour map shows a slight restriction in the north-east channel width to the west of Production Bore 7.

(iii) Underflow through Kelly Well West was calculated by Rose (1973) to be significantly less than that expected from the combined underflow of Kelly Well and Cabbage Gum (refer to Chapter 3, 3.1.2).

(iv) Water quality tends to deteriorate in Kelly Well West from south-east to north-west, and neither the TDS contours (Figure 22) nor the bicarbonate-chloride ratio contours (Figure 23) follow the bedrock contours in this area. This is not in accord with the previously understood major groundwater movement.

The above suggest that the bedrock low through Kelly Well West is a minor channel, with the major channel trending south-west.

The direction of groundwater movement is along these channels from south-east to west or north-west (Figure 31 shows the potentiometric surface for November 1978). The lake west of Kelly Well West is a 'window on the water table'. In Tennant Creek West the regional groundwater gradient is west-north-west in the bedrock and Montejinni Limestone aquifers. This gradient is disrupted within the Point Wakefield Beds white sandstone aquifer. It is hypothesised that a large groundwater throughflow component originating south-south-west of the area influences the groundwater gradient, diverting it north-north-west and raising water levels within this aquifer.

5.4.3 Underflow, safe yield and storage

With current knowledge, of the three major aquifers in the Tennant Creek West area only that within the Point Wakefield Beds white sandstone horizon is a potential future borefield. While the water from this aquifer is of marginal quality for human consumption it is suitable for agricultural and industrial uses and is of better quality than water from the Montejinni Limestone dolomite aquifer (Table 2). As the red-purple sandstone the third major aquifer has not been investigated over an extensive area its borefield potential cannot be assessed.
However, underflow and storage in this aquifer are possibly of the same order of magnitude as that of the Point Wakefield Beds white sandstone aquifer. Investigation of the red-purple sandstone is recommended (see Chapter 8).

Underflow and storage are assessed below for the Point Wakefield Beds white sandstone aquifer and its safe yield is discussed.

In the assessment of underflow a uniform aquifer thickness of 20m is adopted. The aquifer trends south-south-east to the north-north-west. Although it is 10 km wide (Figure 9) the eastern most 2 km is thinner and is less permeable than the remainder, and so is not included in the under flow calculation. Underflow is calculated by using the equation below and the potentiometric surface in Figure 31.

\[ Q = \frac{T \Delta h}{\Delta l} w \]

Where
- \( Q \) = Underflow
- \( T \) = Average aquifer transmissivity of 200 m² d⁻¹
- \( \Delta h \) = Height difference between four equipotential contours (6m)
- \( \Delta l \) = Distance between four equipotential contours (10,000m)
- \( w \) = Aquifer width of 8,000m

The underflow is approximately 1,000 m³ d⁻¹.

The safe yield for this aquifer cannot be assessed because no surface water measurements and only limited bore water level measurements are available. A lower bound value for safe yield is given by the underflow value of 1000 m³ d⁻¹.

Storage which can be utilised is calculated for a block of white sandstone aquifer 8 km wide and 1 km long. The entire aquifer thickness of 20m is saturated. A value for specific yield of 0.03 is assumed; this value has been used for the aquifer in the Kelly Well area (Chapter 6, 6.1.3). Storage per kilometre length of aquifer is given by the term:

\[ \text{Storage (utilised)} = A l S \]

Where
- \( A \) = cross-sectional area = 160,000 m²
\[ l = \text{aquifer length} = 1000 \text{ m} \]
\[ S = \text{specific yield} = 0.03 \]

The storage is \( 4.8 \times 10^6 \text{ m}^3 \) per kilometre length of aquifer.

Storage in the minor siltstone aquifer overlying this sandstone aquifer can also be utilised, even if the siltstone is not pumped directly. The thickness of saturated siltstone is 40m, and for an assumed specific yield of 0.015 storage is \( 4.8 \times 10^6 \text{ m}^3 \) per kilometre length of aquifer.

The total volume of storage which can be utilised in both the siltstone and sandstone aquifers is \( 9.6 \times 10^6 \text{ m}^3 \) per kilometre length of aquifer. This volume is one quarter that of the storage present in the Kelly Well - Kelly Well West borefields. These calculations have assumed complete de-watering of the aquifers.
CHAPTER 6

PRESENT TOWN WATER SUPPLY

6.1 Re-assessment of Aquifer Characteristics, Storage, Underflow and Safe Yield in Existing Borefields: Cabbage Gum, Kelly Well and Kelly Well West

Since the previous report written on this subject (Rose, 1973), marked variations in annual recharge and extraction volumes and additional hydrogeological information have necessitated re-assessment of aquifer characteristics, storage, underflow and safe yield in the existing borefields.

Prior to 1972/73 pumping of production bores in the Kelly Well and Kelly Well West areas resulted in a continuous lowering of water levels within these areas. Any annual surface water recharge was negligible and masked by the effect of groundwater extraction (Figure 32).

Rainfall in 1972/73 was of sufficient volume to alter the rate of water level decline and the total annual volume of groundwater extracted was less than in the previous year (Figure 34). It cannot be ascertained whether the higher than expected water levels were due solely to the decrease in pumping, or to a combination of decreased pumping and surface water recharge.

High rainfall from 1973/74 to the present has resulted in marked water level rises (Figure 32). These rises are due to surface water recharge and increased groundwater inflow from the south-east (note the two marked rises in water level of 1m and 2m in bore RN 10761 at the time of summer rainfalls). The effect of these high rainfall events had been to recharge the aquifers to a point where they now contain more water in storage than when pumping first commenced in the mid 1960's.

6.1.1 Aquifer characteristics (Kelly Well and Kelly Well West)

Regional values of aquifer characteristics are used in the evaluation of underflow, storage and safe yield. The following assumptions are adopted;

(i) The regional values of aquifer characteristics calculated for the Kelly Well area also apply in the Kelly Well West area.
(ii) Pumping in Kelly Well is from a point source (bore RN 5701 (Production 2) is then taken as the centre of pumping).

(iii) Aquifer properties are homogeneous.

(iv) As the aquifer characteristics are only evaluated for pre 1973/74, surface water recharge is negligible.

(v) The straightline approximation is valid when analysing distance draw-down relationships.

The decline in water levels since the commencement of pumping in September 1968 is plotted against the distance of each observation bore from the centre of pumping. The distance-drawdown semi-log plots for August 1969, August 1971 and August 1973 (Figure 35) approximate the average drawdown cone of depression for the borefield at the end of each water year. The greater the distance from the centre of pumping the better the fit to the straight line as local variations around the production bores are smoothed out regionally.

Values of regional transmissivity and storage coefficient are obtained using the equations (Hazel 1975):

\[
T = \frac{-2.3Q}{2m\Delta s'}
\]

\[
S = \frac{2.25Tt}{r^{2.10}(-2s/\Delta s')}
\]

Where \( Q \) = Average daily extraction rate since pumping began.

Values of quantities are listed in Table 4.
TABLE 4 QUANTITIES USED IN CALCULATION OF REGIONAL AQUIFER CHARACTERISTICS FOR KELLY WELL AREA

<table>
<thead>
<tr>
<th>Quantity</th>
<th>August 1969</th>
<th>August 1971</th>
<th>August 1973</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Q$ $(m^3 d^{-1})$</td>
<td>964</td>
<td>1011</td>
<td>1187</td>
</tr>
<tr>
<td>$\Delta s'$ $(m)$</td>
<td>-0.85</td>
<td>-1.70</td>
<td>-2.25</td>
</tr>
<tr>
<td>$t$ (days)</td>
<td>365</td>
<td>1095</td>
<td>1825</td>
</tr>
<tr>
<td>$r$ $(m)$</td>
<td>900</td>
<td>540</td>
<td>340</td>
</tr>
<tr>
<td>$s$ $(m)$</td>
<td>0.45</td>
<td>1.50</td>
<td>2.75</td>
</tr>
<tr>
<td>$T$ $(m^2 d^{-1})$</td>
<td>415</td>
<td>218</td>
<td>193</td>
</tr>
<tr>
<td>$S$</td>
<td>0.035</td>
<td>0.032</td>
<td>0.025</td>
</tr>
</tbody>
</table>

The aquifer characteristics can be summarised:

(i) Up to August 1969, $T = 400 m^2 d^{-1}$.

(ii) Between 1969 and 1971 the radius of influence intersected a barrier boundary and the value of apparent transmissivity was halved. For August 1971 and 1973, $T = 200 m^2 d^{-1}$. This value compares favourably with that obtained by Rose (1973) for his distance-drawdown analysis for June 1971 and June 1973 ($190 m^2 d^{-1}$). However, the value is about twice that obtained by Rose (1973) for his drawdown-time analysis.

(iii) The value of storage coefficient decreases with time. A constant regional value of $3 \times 10^{-2}$ is used. This value is twice that calculated by Rose (1973) because the value of transmissivity used to calculate storage coefficient is double that used by Rose.
6.1.2 Underflow (Kelly Well and Kelly Well West)

Underflow is calculated for the pre-pumping case using the potentiometric surface of November 1968 (not included in this report) for the four idealised cross-sections in the Kelly Well and Kelly Well West areas (Figures 3, 33A and 33B)

The calculations:

(i) Utilise only that portion of the saturated aquifer which is greater than 10m thick.

(ii) Do not include underflow which may be present in the underlying weathered granite. Underflow only in the Cambrian and Cainozoic sediments is calculated.

(iii) Utilise a similar northern boundary to that proposed by Rose (1973) but assume that saturated sediments extend to a greater depth to the south-west.

Underflow is calculated in Table 5 using the equation:

\[ Q = T i w \]

Where

\[ Q \] = Daily underflow

\[ T \] = Value of regional transmissivity of 400 m² d⁻¹.

\[ i \] = Hydraulic gradient taken over four equipotential lines centres on each cross section.

\[ i = \frac{\Delta h}{\Delta l} \]

\[ w \] = width of cross section. This is a corrected value, as the cross-sections of Figures 333A and 33B are not necessarily parallel to the equipotential lines.
TABLE 5 QUANTITIES USED IN CALCULATION OF UNDERFLOW IN KELLY WELL AND KELLY WELL WEST AREAS

<table>
<thead>
<tr>
<th>Component</th>
<th>AA'</th>
<th>BB'</th>
<th>CC'</th>
<th>DD'</th>
</tr>
</thead>
<tbody>
<tr>
<td>(w_{\text{corrected}}(m))</td>
<td>3000</td>
<td>3000</td>
<td>7000</td>
<td>6000</td>
</tr>
<tr>
<td>(\Delta h (m))</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>(\Delta l(m))</td>
<td>2800</td>
<td>2000</td>
<td>2000</td>
<td>2500</td>
</tr>
<tr>
<td>(i)</td>
<td>(1.07 \times 10^{-3})</td>
<td>(1.50 \times 10^{-3})</td>
<td>(1.00 \times 10^{-3})</td>
<td>(1.20 \times 10^{-3})</td>
</tr>
<tr>
<td>(Q(m^3 d^{-1}))</td>
<td>1284</td>
<td>1800</td>
<td>2800</td>
<td>2800</td>
</tr>
</tbody>
</table>

Value for \(Q\) obtained by:

Rose (1973)

1205

409

The value for underflow at Sections AA' and BB' is of the same order as that obtained by Rose (1973) between Sections AA' and BB'. The large discrepancy between underflow values at Section DD' is due to the size of cross-sectional area assumed. Section DD' is only just within the Kelly Well West area and so is not truly representative of that area. North-west of Section DD' the channel cross-sectional area decreases.

To summarise and round-off:

Underflow for Cabbage Gum area is 500 \(m^3 d^{-1}\) (Eggington 1965, Binch, 1966)

Underflow for Kelly Well area is 2000 \(m^3 d^{-1}\)

Total underflow is 2500 \(m^3 d^{-1}\)

6.1.3 Storage (Kelly Well and Kelly Well West)

The volume of water suitable for human consumption and able to be utilised between Sections AA' and DD' (Figure 2) is calculated below. These calculations neglect water held in storage in weathered granite and consider only that held in Cambrian and Cainozoic sediments. It is assumed that:

(i) Deeper bores would be constructed to enable extraction of water from the Cambrian sand/sandstone aquifer underlying the siltstone aquifer.

(ii) Aquifers are semi-confined to unconfined and the regional value for specific yield is 0.03.
(iii) Because of bore location and the shape of the cone of depression, only half of the water held in storage and able to be extracted by gravity discharge can be utilised.

From the shape and position of the potentiometric surface of 1968, the volume of useable water held in storage is given by:

\[
V_s = \frac{S}{2} \left[ \sum_{AA'} \left( \frac{\text{Area}_{AA'} + \text{Area}_{BB'}}{2} \right) \times \text{Surface length}_{ij} \right]
\]

Where \( V_s \) = Volume of useable water held in storage (\( m^3 \)).

\( S \) = Specific yield

\( \text{Area}_{AA'} \) = Cross-sectional area at Section\( ii \) (\( m^2 \))

\( \text{Surface Length}_{ij} \) = Average plan distance between Section\( ii \) and Section\( jj \) (m)

From Figures 33A and 33B:
\[
\begin{align*}
\text{Area AA'} &= 90500m^2 \\
\text{Area BB'} &= 75000m^2 \\
\text{Area CC'} &= 23100m^2 \\
\text{Area DD'} &= 43000m^2
\end{align*}
\]

From Figure 2:
\[
\begin{align*}
\text{Surface Length}_{AB} &= 4000m \\
\text{Surface Length}_{BC} &= 2000m \\
\text{Surface Length}_{CD} &= 6000m
\end{align*}
\]

Then \( V \) is \( 4 \times 10^7 m^3 \), or approximately 50 times the 1977/78 annual consumption for Tennant Creek. This is approximately three times the volume \( 1.4 \times 10^7 m^3 \) calculated by Rose (1973). Rose assumed smaller cross sectional areas and had neglected the sediments underlying the main siltstone aquifer.
6.1.4 Volume added to storage between 1968 and 1978

Data is insufficient to carry out an annual water balance, but a crude estimate of the volume added to storage can be made. Assume that the annual volume added to storage in a water year is given by the summation of the net increase in volume (measured from SWLs) and the amount extracted from Kelly Well and Kelly Well West borefields.

The net increase in volume between Sections AA' and DD' is given by:

\[ V_{NI} = \left[ \sum_{ij}^{DD} (Surface \ Area_{ij} \times \Delta h_{ij}) \right] \]

Where

- \( V_{NI} \) = Net increase in volume (m³)
- \( S \) = Specific yield (3 x 10⁻²)

Surface area\(_{ij}\) = Plan area of surface between Sections ii and jj (m²).

\( h_{ij} \) = Weighted average water level rise in aquifer between Sections ii and jj (m).

From Figure 2:

- Surface area\(_{AB}\) = 1.204 x 10⁷ m²
- Surface area\(_{BC}\) = 1.265 x 10⁷ m²
- Surface area\(_{CD}\) = 4.515 x 10⁷ m²

The annual variations in water level \( \Delta h_{ij} \) are obtained by weighing the annual change in water level \( \Delta h \) for each bore (Figure 32). Annual net increases in volume are listed in Table 6. When the annual extraction is added, the total volume added to storage can be computed.
TABLE 6 ANNUAL PRECIPITATION AND ANNUAL VOLUME ADDED TO STORAGE IN KELLY WELL AND KELLY WELL WEST AREAS.

<table>
<thead>
<tr>
<th>Water Year</th>
<th>Net Increase in Volume (m$^3 \times 10^3$)</th>
<th>Volume Extracted to Storage (m$^3 \times 10^3$)</th>
<th>Volume added to Storage (m$^3 \times 10^3$)</th>
<th>Precipitation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1968/69</td>
<td>- 303</td>
<td>297</td>
<td>- 6</td>
<td>207</td>
</tr>
<tr>
<td>1969/70</td>
<td>- 294</td>
<td>337</td>
<td>+ 43</td>
<td>218</td>
</tr>
<tr>
<td>1970/71</td>
<td>- 347</td>
<td>418</td>
<td>+ 71</td>
<td>226</td>
</tr>
<tr>
<td>1971/72</td>
<td>- 228</td>
<td>571</td>
<td>+ 343</td>
<td>393</td>
</tr>
<tr>
<td>1972/73</td>
<td>- 311</td>
<td>488</td>
<td>+ 177</td>
<td>316</td>
</tr>
<tr>
<td>1973/74</td>
<td>+ 230</td>
<td>428</td>
<td>+ 658</td>
<td>751</td>
</tr>
<tr>
<td>1974/75</td>
<td>+ 16</td>
<td>529</td>
<td>+ 545</td>
<td>434</td>
</tr>
<tr>
<td>1975/76</td>
<td>+ 742</td>
<td>626</td>
<td>+ 1366</td>
<td>661</td>
</tr>
<tr>
<td>1976/77</td>
<td>+ 4894</td>
<td>665</td>
<td>+ 5559</td>
<td>671</td>
</tr>
<tr>
<td>1977/78</td>
<td>+ 2171</td>
<td>728</td>
<td>+ 2899</td>
<td>591</td>
</tr>
<tr>
<td>SUMMATION</td>
<td>+ 6568</td>
<td>5087</td>
<td>+ 11656</td>
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</tr>
</tbody>
</table>

Between September 1968 and August 1978 water levels first declined and then rose to heights above the pre-pumping potentiometric surface. There was a net increase to the volume held in storage. The total volume added to storage is $1.7 \times 10^6$ m$^3$, this being added by a combination of direct surface water recharge and groundwater inflow from the south-east. The total volume held in storage in September 1978 is 17% greater than that held before pumping began.

6.1.5 Safe yield and aquifer exploitation (Cabbage Gum, Kelly Well, Kelly Well West)

The safe yield of Cabbage Gum has been evaluated independently by Eggington (1965) and Binch (1966) and is 500 m$^3$ d$^{-1}$. This was being utilised until pumping from the Kelly Well commenced in 1968, when the volume extracted from the Cabbage Gum area was reduced (Figure 34). At present half the safe yield is being extracted from Cabbage Gum. Pumping should be increased to utilise the available safe yield from this area.

The safe yield for the Kelly Well and Kelly Well West areas is difficult to assess because hydrogeological data is incomplete. A conservative value for safe yield can be obtained by considering annual underflow and a recharge component. Underflow for the pre-pumping situation has been calculated as 2000 m$^3$ d$^{-1}$ through the Kelly Well area. A crude linear relationship
between annual precipitation and annual total volume added to storage (Table 6) is:

\[ V = -400 + 2P \]

Where \( V \) = Annual total volume added to storage
\( (m^3 \times 10^3) \)

\( P \) = Annual precipitation (mm)

The relationship does not hold for 1976/77 and 1977/78, indicating that recharge is probably dependent on rainfall in previous years as well as in the current year. This has not been considered. Derivation of such a relationship requires more detailed investigation (discussed later in this chapter).

Based on an expected (median) annual rainfall of 336mm, the expected volume added to storage by recharge is 272 x 10^3 m^3 annually or in excess of 700 m^3 d^-1. Safe yield for the Kelly Well and Kelly Well West areas is then 2 700 m^3 d^-1.

The combined safe yield for the three extraction areas is 3 200 m^3 d^-1 (2 700 + 500), an average daily pumping rate which is yet to be surpassed. This value is almost twice that calculated by Rose (1973) who calculated a value of 1 700 m^3 d^-1 using a smaller aquifer width without considering recharge.

Neither the above calculation of safe yield nor those of Rose make allowance for recharge of magnitudes which have occurred since 1972/73. A more refined value of safe yield requires:

(i) development of a relationship between rainfall and recharge;

(ii) consideration of the aquifer system as a reservoir; and,

(iii) storage-yield analysis of the aquifer-reservoir, using a number of sequences of generated rainfalls having the same statistical properties as the recorded rainfall sequence for Tennant Creek. This analysis assumes a stochastic model for the system rather than the more frequently used deterministic models of groundwater systems.

The statistically derived value of safe yield is expected to be higher than that calculated in this report.
Ambroggi (1978) points out that to fully utilise an aquifer, exploitation must be carried out beyond the value of underflow. Two or more years of unusually heavy rainfall which can be expected at least once in 15 years, will replenish an aquifer that has been drawn down during previous years (as has been shown). The benefits of exploitation beyond the value of underflow are twofold:

(i) An increased volume of water which can be extracted annually.

(ii) Long term improvement of water quality (discussed later in this chapter).

6.2 Recharge to Present Borefields

High rainfall and flooding events since 1972/73 have resulted in recharge to aquifers in the Cabbage Gum, Kelly Well and Kelly Well West areas. If recharge can be managed and increased, the safe yield of the aquifers in the present borefields can be increased.

A Water Division project is planned to examine natural and artificial recharge in the Kelly Well area. The infiltration project aims to (a) determine the areas most favourable to recharge, by a combination of studies including past records and photographs, field tests using auger holes, soils and vegetation, and (b) proceed to a design of conjunctive use surface/groundwater source.

Without anticipating the project results, recharge could be artificially improved by (Macqueen, 1977):

(i) containing surface water within the desired area of recharge;

and,

(ii) maximising the depth of surface water by concentration, using furrows and/or weirs.

6.3 Treatment of Marginal Supplies

There are a number of marginal groundwater supplies in areas which are closer to Tennant Creek than the Tennant Creek West area. These supplies could be utilised but they require treatment to reduce the concentration of various chemical ions.

Groundwater quality within aquifers in the Catchment of Tennant Creek, Flynn's Monument and Gosse River
areas varies, with TDS ranging from acceptable for human consumption to 10000mg/l. However, the high cost of desalination, low volume of supply and many kilometres of pipeline required make the use of these supplies comparatively uneconomic.

Supplies of marginal quality water also exist on the fringes of Cabbage Gum, Kelly Well and Kelly Well West areas, adjacent to supplies of better quality. If future management policy decides that all water in these areas is to be used, pumping of both good and poor quality waters and mixing to acceptable quality standards prior to introducing into the reticulation system would involve lower expenditure than treating of the poor quality water. As the poorer quality marginal water is removed, recharge water of improved quality will migrate into these areas, leading to a long term improvement of the quality of town water supply.
CHAPTER 7 . FUTURE WATER DEMAND AND SUPPLY

It has been found (Brisbane City Council, 1969) that predictions of future demand trends:

(i) are invariably wrong;

(ii) are almost invariably low; and

(iii) assume a steady state condition at some time in the future, which state has never been observed except by the imposition of restrictions.

The task for Tennant Creek is further complicated by incomplete per capita consumption statistics. Prediction of demand is based on past consumption trends, with allowance for decreased demand resulting from high rainfall.

7.1 Steady Water Demand Increase

Prior to November 1978 two water demand curves had been projected to 1989/90 (Figure 34).

(i) Rose (1973) projection. The cumulative groundwater extraction to meet demand between 1977/78 and 1989/90 is $1.3 \times 10^7 \text{m}^3$. The revised safe yield is surpassed in the mid 1990's.

(ii) Alternative projection. The cumulative groundwater extraction to meet demand between 1977/78 and 1989/90 is $1.5 \times 10^7 \text{m}^3$. The revised safe yield is surpassed in 1983/84.

The existing borefields could have met short and medium term demand provided that demand did not increase above projected values.

7.2 Effect of Establishment of an Abattoir or Other High Water Use Industry

The N.T. Government decided in February 1979 to support the establishment and operation of an abattoir at Tennant Creek. The '100 000 gallon per day' size abattoir was to have an annual killing season of 40 weeks, and be operational in 1980. Water requirements, spread over 365 days, include:
Abattoir requirements  \(350 \text{ m}^3\text{d}^{-1}\)

Additional population
(abattoir workers, allied
industry workers and their
families)  \(200 \text{ m}^3\text{d}^{-1}\)

Landscaping around abattoir  \(85 \text{ m}^3\text{d}^{-1}\)

**TOTAL**  \(635 \text{ m}^3\text{d}^{-1}\)

This is equivalent to an annual requirement of \(230 \times 10^3 \text{ m}^3\)

The major effect of the abattoir will first be observed in 1979/80 (Figure 34). As the abattoir will be in operation for two thirds of that water year, total annual demand will exceed Rose's projection by \(154 \times 10^3 \text{ m}^3\). In the following years total annual demand will exceed Rose's projection by \(230 \times 10^3 \text{ m}^3\). The new projected demand will first exceed the revised safe yield of the present borefields in 1982. From then on extraction from storage will increase annually.

The establishment of other higher water industries or 'hobby farms' would have a similar effect on the annual demand. For example, the annual water demand for ten farms each of 2 hectares with half the area of each being irrigated at any time is \(200 \times 10^3 \text{ m}^3\). This demand is of the same order of magnitude as that of the abattoir.

7.3 **Tennant Creek West Borefield**

In view of the problem of the effect of a high water use industry on the present borefields, in February 1979 the N.T. Government accepted the need to commit $3.2 million for an additional water supply. A borefield, to be developed at Tennant Creek West (see Figure 2 for location of proposed borefield), will be operational by July 1981 (Verhoeven, 1979).

The Point Wakefield Beds white sandstone aquifer meets the quality and quantity requirements. Investigation of the underlying red sandstone aquifer in 1979 may result in an increased water source from which to pump. The water, having a chemical quality marginally unsuitable for human consumption, will be used to meet industrial (including the abattoir) and agricultural requirements.

After July 1981 two separate water supply systems will be operational:
(i) The present Cabbage Gum, Kelly Well and Kelly Well West Borefields supplying domestic requirements.

(ii) The Tennant Creek West Borefield supplying industry and farms. The advantage of using this borefield for industrial agricultural uses is the saving of water from the present borefields for human consumption.

The effect of total demand on the present borefields is shown on Figure 34. In 1981/82 the total annual demand falls to $73 \times 10^3 \text{ m}^3$ above Rose's projection, this added demand being the domestic requirements of the workers and their families. In following years annual demand on the present borefields remains at $73 \times 10^3 \text{ m}^3$ above Rose's projection. The revised annual safe yield is exceeded in 1989.
CHAPTER 8 MONITORING AND FURTHER INVESTIGATION

The results of this investigation highlight the need for further investigation, both of the surface water and groundwater resources. Analysis has shown the inter-relationship of aquifers previously thought separate and the importance of surface water in a system which has been exploited in the past for its groundwater potential. Now that the system parameters and variables have been identified, further investigation is required to assign quantitative values to these. The results would then be formulated into a comprehensive management policy for the Tennant Creek water resources.

8.1 Objectives of Monitoring and Further Investigation

The objectives of monitoring programs are outlined below, in order of priority. As the design for the Tennant Creek West production bores and borefields is required in December 1979, investigation work required for this design has highest priority.

(i) In the Tennant Creek West area define the areal extent, thickness and aquifer characteristics of the red sandstone aquifer which underlies the Point Wakefield Beds white sandstone aquifer. A successful outcome to this investigation will result in utilisation of both aquifers as water sources.

(ii) Define the areal extent and total thickness of aquifers in the present borefields, particularly south of Kelly Well West. Full utilisation of the present borefields is the objective.

(iii) Review and refine the estimates of safe yield for the present borefields. Determine and implement means of improving natural recharge in the Kelly Well area.

(iv) Determine a value for safe yield for the Tennant Creek West Borefield.

(v) Define the areal extent and thickness of aquifers connecting the present borefields with Tennant Creek West.
8.2 Outline of Investigations

8.2.1 Tennant Creek West - Groundwater

Up to six investigation bores, each of 150m depth and located on Lines 2, 4 and 6 are to be drilled, logged and tested. Five observation bores adjacent to future production bore sites are to be drilled, logged and tested to aid in production bore design.

8.2.2 Present Borefields - Groundwater

Surface geophysics techniques of PDR and seismic survey will be used on a 10 km long traverse line. Up to ten investigation and geological control holes, each of up to 100m depth are to be drilled, logged and tested.

8.2.3 Safe Yield - Present Borefields

The results of basin management and groundwater investigations are required.

(i) The investigation outlined in 8.2.2 above will provide additional necessary parameter values.

(ii) The current program of monitoring bore water levels in the present borefields - bores RN 5338, RN 5363, RN 6355, RN 6356, RN 6357, RN 6358, RN 6360, RN 6528, RN 6529, RN 10139, RN 10144, RN 10181, RN 10564, RN 10761, RN 10762, RN 10763 - should be continued at intervals of three months. After the investigation outlined in 8.2.2 more bores may be added to this list, and some of the above deleted.

(iii) Examination and analysis of past water level, stream flow and rainfall data should enable the determination of a rainfall recharge relationship. By using this relationship with a number of generated rainfall sequences a series of storage-yield analyses of the aquifer system can be conducted to determine a refined value of safe yield.

(iv) Examine soil types, infiltration rates and topography in the area of the present borefields. Conduct field tests with the objective of increasing recharge to the aquifers in this area.
8.2.4 **Safe yield - Tennant Creek West**

(i) The investigation outlined in 8.2.1 will provide the additional parameter values for the red sandstone aquifer.

(ii) The current program of monitoring bore water levels in the following bores at intervals of three months and commenced in 1978 should be continued. The number of bores monitored can be reduced in three or four years time once the steady-state shape of the potentiometric surface has been confirmed. The bores are RN 10760, RN 10926, RN 10927, RN 10928, RN 10932, RN 10933, RN 11556, RN 11559, RN 11597, RN 11598, RN 11599, RN 11600, RN 11601, RN 11602, RN 11603, RN 11606, RN 11607, RN 11608, RN 11609, RN 11637, RN 11638, RN 11639, RN 11640, RN 11641, RN 11683, RN 11688, RN 11689, RN 11691, RN 11744. More bores may be added to this list after the investigation outlined in 8.2.1.

(iii) Bores RN 11597, RN 11598, RN 11626 and RN 11637 should be equipped with continuous water level recorders in August 1979. These recorders should be maintained for at least one complete water year to study surface water recharge to the aquifer system.

8.2.5 **Connection between the present borefields and Tennant Creek West - Groundwater**

The degree of connection between the two areas will determine the extent to which each area can be developed.

Two connecting zones are hypothesised:

(i) A north-west extension of the channel in Kelly Well West.

(ii) A westward trending channel underlying the Edinburgh creeks floodout. This channel originates south-west of Production Bores 6 and 7 in Kelly Well West.

Connection between the two areas beneath the Edinburgh creeks floodout, should it exist, would allow for expansion of the present borefield in the long term future.
To investigate the connection between Kelly Well West and Tennant Creek West surface geophysics techniques of PDR and seismic survey will be used on a 10 km long traverse line. Up to four geological control holes, each of up to 100m depth are to be drilled, logged and tested.

The Edinburgh creeks floodout investigation is a low-priority long term groundwater investigation and will not be detailed in this report.

8.3 Status of Investigations

(i) The program of monitoring water levels at three-month intervals advocated in 8.2.3 and 8.2.4 is already in progress. The equipping of four bores in Tennant Creek West with continuous water level recorders should be carried out before or during August 1979.

(ii) The groundwater investigations outlined in 8.2.1, 8.2.2 and 8.2.5(i) have been grouped into Water Division Project 91 entitled TENNANT CREEK WEST - GROUNDWATER. The project will be conducted during 1979/80.

(iii) The infiltration and recharge study outlined in 8.2.3 is contained in Water Division Project 11 entitled KELLY WELL INFILTRATION STUDY. This will be carried out by the Water Management Section, Alice Springs, during 1979/80.

(iv) The groundwater investigation outlined in 8.2.5 (ii) is not programmed for the foreseeable future.
CHAPTER 9 REFERENCES


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VERHOEVEN, T.J. (1979) Timetable for Establishment of Tennant Creek West Borefield. Department of Transport and Works, Water Investigation Unit, Internal Minute. March 1979


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APPENDIX 1    FIGURES
In Good and RN
Investigation hole and name
(geological information)

‡
Bore and windmill

Sealed road

Dirt road or track

Lake

Groundwater investigation area boundary

Pastoral lease boundary

Kilometres

0 10 20 30

HORIZONTAL DATUM: AUSTRALIAN MAP GRID
Tennant Creek Local Environs
Investigation & Production Bore

LEGEND
- Investigation or observation bore
- Production bore
- Bore equipped with windmill

TENNANT CREEK LOCAL ENVIRONS
INVESTIGATION & PRODUCTION BORES

FIG. 3
Intermittent stream

Extent of floodouts on 14 February 1974
(from LANDSAT image print)

Swamp
Surface contours at 50 m intervals
(from NATMAP Sheet SE 53-14)
Bore

REGIONAL SURFACE HYDROLOGY

FIG. 4
Lake Surprise Sandstone (Pz1)
Hansen River Beds (Oh)
Point Wakefield Beds (Cmp)
Gum Ridge Formation (Cmrg)
Tomkinson Creek Group (Ptk)
Hatches Creek Group (Plh)
Lower Proterozoic Granite (Bg)
Warramunga Group (Pw)

**REGIONAL GEOLOGY**

FIG. 5
For geological symbols see Figure 5.
Cainozoic Cover omitted.

Emp Point Wakefield Beds

Emh Hooker Creek Formation

Emm Montejinni Limestone

P Red Sandstone Unit

Ptg Tomkinson Creek Group

Topography is shown where survey information exists.
**Cainozoic Cover ommitted.**

- **£mp**: Point Wakefield Beds
- **£ml**: Lothari Hill Sandstone
- **£mh**: Hooker Creek Formation
- **Pw**: Warramunga Group

Topography is assumed flat.

**Fig. 8**

**Tennant Creek West**

**Geological Cross Section**

**Point Wakefield Area**

Horizontal Scale: 1:200,000

Vertical Scale: 1:2,000

Vertical Exaggeration: 100:1
C. Cainozoic sand and clay

Emp<sub>3</sub> Point Wakefield Beds — upper siltstone

Emp<sub>2</sub> — white sandstone

Emp<sub>1</sub> — lower siltstone

Emh Hooker Creek Formation — dolomitic sandstone

Emm Montijinni Limestone — dolomite

P Red sandstone unit

Pg Lower Proterozoic Granite

A Archaean schist

Basement profile extrapolated from geophysical data.

TENNANT CREEK WEST GEOLOGICAL CROSS SECTION

LINE 1

FIG. 9
C Cainozoic sand and clay
-£mp3 Point Wakefield Beds — upper siltstone
---£mp2 — white sandstone
-£mp1 — lower siltstone
Pg Lower Proterozoic granite

Basement profile extrapolated from geophysical data.
C. Cainozoic sand and gravel

Cmp1. Point Wakefield Beds — lower siltstone

Pg. Lower Proterozoic granite

A. Archaean schist

Horizontal Scale: 1:100 000
Vertical Scale: 1:2 000
Vertical Exaggeration: 50:1
Vertical Datum: A.H.D.
C. Cainozoic sand and gravel
$
\$\text{Emp}_2$, Point Wakefield Beds — upper siltstone
$\$\text{Em}_p$, white sandstone
$\$\text{Emp}_1$, lower siltstone
$\$\text{Pg}$, Lower Proterozoic granite
A. Archaean schist

Basement profile extrapolated from geophysical data.

Horizontal Scale: 1:100 000
Vertical Scale: 1:2 000
Vertical Exaggeration: 50:1
Vertical Datum: A.H.D.
C - Cenozoic sand and clay

\( \text{\textcopyright} \) Point Wakefield Beds - lower siltstone

\( \text{\textcopyright} \) Hooker Creek Formation - dolomite siltstone

\( \text{\textcopyright} \) Montejinni Limestone - dolomite

P - Red sandstone unit

Pg - Lower Proterozoic granite

\begin{align*}
\text{Horizontal Scale: } & 1:100,000 \\
\text{Vertical Scale: } & 1:2,000 \\
\text{Vertical Exaggeration: } & 50:1 \\
\text{Vertical Datum: } & \text{A.H.D.}
\end{align*}
C Cainozoic sand and clay
$\text{Emp}_2$ Point Wakefield Beds — white sandstone
$\text{Emp}_1$ — lower siltstone
$\text{Emm}$ Montejinni Limestone — dolomite
Pg Lower Proterozoic granites

Horizontal Scale: 1:100,000
Vertical Scale: 1:2,000
Vertical Exaggeration: 50:1
Vertical Datum: A.H.D.
NOTE: Correlation between bores was based on strato samples and gamma logs.
Gamma log characteristics

- Sensitivity: 250 cps/cm
- Time Constant: 2
- Range: 4
- Logging Speed: 12 m/min
- Instrument: LM 444 B LMG 15

GAMMA LOG COMPOSITE
POINT WAKEFIELD BEDS

FIG. 17
Gamma log characteristics

- Sensitivity: 50 cps/cm
- Time Constant: 2
- Range: 4

Vertical Scale: 1:200

FIG. 19
TOTAL DISSOLVED SOLIDS CONCENTRATION (mg/l)
LOCAL ENVIRONS

FIG. 22
Tennant Creek

FIG. 23

BICARBONATE - CHLORIDE RATIO LOCAL ENVIRONS

HORIZONTAL DATUM: AUSTRALIAN MAP GRID

Kilometres 0 5 10

WATER DIVISION REF ORG: 1693-4-208
NOTE

Nitrate concentration greater than 45 mg L\(^{-1}\) is not recommended for drinking water. (W.H.O. 1971)
Tennant Creek

FLUORIDE CONCENTRATION (mg l⁻¹)
LOCAL ENVIRONS

FIG. 25

HORIZONTAL DATUM: AUSTRALIAN MAP GRID

WATER DIVISION REFF: 1695-4-20
In this area values are generally less than 1500 mg/l.
In this area values are generally greater than unity.
In this area values are generally less than 70 mg l⁻¹.
In this area values are generally less than 2.0 mg l⁻¹.

FLUORIDE CONCENTRATION (mg l⁻¹) REGIONAL ENVIRONS

FIG. 29
While sandstone aquifer - Point Wokefield Beds (Em2)
- Dolomitic siltstone aquifer - Hooker Creek Fm (Cnh)
- Dolomitic aquifer - Montejin limestone (Cmn)
- Red sandstone aquifer - Blāruck aquifer

TENNANT CREEK WEST
PIPER TRILINEAR DIAGRAM

FIG. 30
TENNANT CREEK MONTHLY RAINFALLS & BORE WATER LEVELS IN THE PRESENT BOREFIELDS 1968 - 1978

FIG. 32
IDEALISED CROSS SECTIONS
KELLY WELL & KELLY WELL WEST AREAS

FIG. 33A
IDEALISED CROSS SECTIONS
KELLY WELL & KELLY WELL WEST AREAS

FIG. 33B
Annual Safe Yield, Cabbage Gum and Kelly areas (Verhoeven 1978)

Pumping rate at which storage in Cabbage Gum and Kelly areas will be exhausted by 1992 (Rose 1973)

Annual Safe Yield: Cabbage Gum and Kelly areas (Rose, 1973)

TENNANT CREEK WATER SUPPLY. ANNUAL EXTRACTION, PROJECTED WATER DEMAND AND SAFE YIELD.

NOTE: Water also supplied to Peko Mines in 1971 and 1972.

FIG. 34
DISTANCE - DRAWDOWN - TIME - RELATIONSHIP
IN THE KELLY WELL AREA

FIG. 35