THE OCCURRENCE OF GROUNDWATER ON
WILLOWRA STATION, NORTHERN TERRITORY

BY

T. QUINLAN and D. WOOLLEY.

CONTENTS

SUMMARY 1
INTRODUCTION 1
GEOLOGY 2
(1) Precambrian Igneous and Metamorphic Rocks 1
(ii) Upper Proterozoic Sedimentary Rocks 2
(iii) Tertiary Sediments 2
(iv) Tertiary Deep Weathering Profile 2
(v) Quaternary Sediments 3
HYDROLOGY 5
Availability of Groundwater 5
The Piezometric Surface 6
Recharge and Loss of Groundwater 6
Quality of Groundwater 7
Suitability of Groundwater for Irrigation 9
RECOMMENDATIONS 10
REFERENCES 11

WATER LIBRARY DARWIN

CLASS NO. 641 DATE
Rocks and unconsolidated sediments of Tertiary and Quaternary age, overlying a basement of Pre-cambrian rocks, occur in the vicinity of Willowra Homestead. The Tertiary sediments do not crop out; the maximum thickness indicated by results of previous drilling is 60 feet. The maximum known thickness of Quaternary sediments is 115 feet.

Water is available in sufficient quantities for use in irrigated agriculture from the Tertiary and some of the Quaternary sediments. Insufficient data is available to assess the maximum safe yield of the basin.

The quality of groundwater from a small area in the immediate vicinity of Willowra homestead is suitable for agricultural purposes. Quality of groundwater from the remainder of the basin is marginal or unsuitable.

A drilling programme to estimate the quantity of groundwater available in the area is recommended.
INTRODUCTION.

The information available regarding the occurrence of groundwater on Willowra Station has been compiled at the request of the Agriculture Adviser of the Reserve Bank of Australia and the Director of the Water Resources Branch, N.T. Administration. This information is required to assess the possibility of irrigated agriculture and to design a programme of test drilling to determine the groundwater resources of the area.

Twenty two bores and wells have been sunk on the area of pastoral leases no. 594 and 491 shown on Plate 1. Adequate quantities of suitable quality groundwater for domestic and pastoral use have been obtained from 10 of the bores and 5 of the wells.

GEOLoGY

Quaternary alluvial sand and red earth soil cover a large part of the area. There are small outcrops of igneous and metamorphic rocks of Precambrian age and silicified quartz sandstone of Upper Proterozoic age. Fossilitic and ferruginous horizons of the deep weathering profile, crop out in an area south of Willowra Homestead. Calcrete and kankar crop out in a drainage depression 24 miles south-west of the homestead and along Ingallana Creek.

The rocks which crop out and which occur below the surface of the ground on Willowra Station have been arbitrarily assigned to the Precambrian and to the Upper Proterozoic, Tertiary and Quaternary periods. (Plate 1). The criteria used to assign these ages are the principle of superposition and the relationship of the rocks to the surface of Tertiary deep weathering. The sediments assigned to the Tertiary period are correlated with sediments near Alice Springs which contain Tertiary spores (Evans unpublished data).

1) Precambrian Igneous and Metamorphic Rocks.

These are the oldest rocks in the area.
The metamorphic rocks consist of tightly folded and faulted schists and gneisses which have been intruded by granite and quartz reefs. Because of insufficient field work and because the areas of outcrop are small, no attempt has been made to sub-divide them or to assign relative ages to them. These rocks are intruded by quartz reefs which comprises the main outcrop areas of the Precambrian.

(ii) Upper Proterozoic Sedimentary Rocks.

Sandstone and silicified sandstone of this group crop out at Mt. Barkly and Mt. Leichardt.

Lithologically the sedimentary rocks consist of a sequence of interbedded medium grained kaolinitic and micaceous quartz sandstones and hard white massive quartzite. This sequence overlies a sequence of black shale with thin interbeds of quartzite and silty sandstone. The total thickness of the sedimentary rocks is not known.

The sedimentary rocks are strongly jointed and sheared and they have been infolded and faulted into the Precambrian rocks.

(iii) Tertiary Sediments

These rocks do not crop out on Willowra and their lithology is inferred from samples collected by drillers. They consist of fawn and mottled brown and yellow fine grained sandy clay and fine to medium and coarse grained sand and sandstone. The sandstone is cemented by colloidal silica. The maximum thickness of these sediments intersected in bore holes is 80 feet.

The sediments rest unconformably on deeply weathered schists of Precambrian age and they occur stratigraphically below the surface of Tertiary deep weathering. The depth to the contact of the sediments and the Precambrian schists is difficult to determine from the drillers samples because of the effects of the deep weathering. The original textures of the sediments and of the metamorphic rocks have been destroyed over intervals of up to 100 feet (bore FS3/5 - 24 Plate 1 and Fig 1). A Tertiary age is inferred for these sediments by correlation with Tertiary sediments at Alice Springs (Evans 1962).

(iv) Tertiary Deep Weathering Profile

The chemical composition and texture of the
rocks of Precambrian, Upper Proterozoic and Tertiary ages have been altered by the processes of deep weathering. An examination of the samples from bores which have been drilled through the profile suggests that there are three zones in a complete profile. They are, in descending order, a ferruginous zone, a mottled zone and a pallid zone. The zones are characterised by typical textures and chemical composition.

The ferruginous zone is black and it has a massive texture which may become nodular at the top. The original texture has been obliterated by the deposition of iron oxide; generally as hematite.

The mottled zone has an amorphous texture formed by the contemporaneous deposition and leaching of chemical ions. The rock may be broken by irregular fractures, presumably formed by alternative hydration and dessication. The surfaces of the fractures are coated with colloidal silica and/or iron oxide. The rock is irregularly coloured or mottled yellow, red or brown, and white or fawn. The white colour may be either the original colour of the sediment or due to the leaching of the original pigments. The red and blue colour is due to concentrations of iron oxide in forms of varying hydration.

The original texture of the parent is frequently preserved in the pallid zone. Typically the pigments in the parent have been leached out and deposited in either the mottled or ferruginous zones.

The concentration of aluminium within the profile has not been considered, because its oxides are not distinctive and their presence can only be determined satisfactorily by chemical analysis.

(v) Quaternary Sediments

Quaternary sediments cover a large portion of the area of Willowra Station. They have been assigned to two main groups: Pleistocene to Recent and Recent (Quinlan 1962). The absolute ages of the two groups are not yet known.

The Pleistocene to Recent sediments which have been distinguished are:

1. Terrace gravels - on the northern flank of Mt. Leichart and Mt. Dennison a thin deposit of gravel lies on a bevelled surface which abuts the hills. They have been examined at Mt. Dennison where the boulders and cobbles are of quartzite, and they rest
unconformably on the black shales of Upper Proterozoic
age. The gravels are correlated with those which
crop out in the Reynolds and Mac Donnell Ranges
(Quinlan) 1962.

2. Aeolian Sand - Redistributed aeolian
sand covers a large area of Willowra. It is thought
that the sand has been redistributed from ancient
dune fields in the area. These deposits, as soils,
are probably related to the Harwietoama soil family
of Jackson (1962).

3. Kunkar, Calcrete, and Alluvium -
Rocks of this lithological type occur along the valley
of Ingallana Creek. Calcium carbonates have been
deposited as large concretionary masses within the alluvium
to form kunkar, and as a calcareous cement in
the alluvium, to form calcrete. It is thought that
the carbonate has been deposited from circulating
groundwater and soil moisture. On the margins of
the deposit the kunkar rests unconformably on weathered biotite - feldspar schists of Precambrian
age. This is illustrated in the logs of limestone Wall
(F53/5 - 6) and Possum Well (F53/5 - 10) on Fig 1.

Similar deposits of calcrete and kunkar
occur in a drainage depression 20 miles south west of
Willowra Homestead.

The sediments of Recent age which have
been mapped are:

4. Alluvium - Deposits of alluvial sand
and gravel have been mapped along the present course
of Lander River and Ingallana Creek. Similar sediments
are associated with old channels of the Lander River, which have now been abandoned. The
maximum thickness of alluvium is 115 feet, as shown
by the log of bore number F53/5 - 74.

5. Piedmont deposits - deposits of silt,
sand, and gravel have been deposited in the alluvial
fans which have been built up against Mt. Leichhardt.
The known maximum thickness of these sediments is
213 feet, in Koononyeri Bore (F53/5 - 18). The
basal portion of sediments of this type may be
Pleistocene age.

6. Red earth soil - the outcrop areas of
this soil are covered with mulga (Acacia aneura).
The texture of the soil is of a very silty sand. The
red earth soil may be related to the Bond Springs and
and Yambah soils families of Jackson (1962).

HYDROLOGY

Availability of Groundwater

The results of previous drilling will be used to outline the availability of groundwater from aquifers within the profile of Deep Weathering and the 6 lithological units outlined above.

(1) Precambrian Metamorphic and igneous rocks - Five bores have been drilled to the base of the deep weathering profile developed on the metamorphic and igneous rocks. Small supplies of good to poor quality water obtained within the mottled and pallid zones and in one case (bore F53/5 - 48) an adequate supply of salt water was obtained from the base of the profile.

(2) Upper Proterozoic sedimentary rocks - No bores have been drilled in these rocks, but it is expected that they would yield moderate supplies of groundwater.

(3) Tertiary sediments - Good supplies of good to moderate quality groundwater have been obtained from beds of sand and sandstones of Tertiary age. These beds are aquifers in Syphon, and Easy Bores, and possibly in Wailbru and 8 mile wells. The specific capacity of Easy Bore is approximately 1000 gallons per hour per foot drawdown, with an aquifer thickness of 60 feet. The maximum yields of the other three bores are not known, but they are probably low, because the available drawdown is limited. The overlying beds of sandy clay and silt are aquicludes where they occur below the water table. The permeability of the Tertiary sediments does not appear to have been reduced significantly by the processes of deep weathering.

(4) Pleistocene to Recent Terrace Gravels - These sediments do not occur below the piezometric surface.

(5) Pleistocene to Recent Aeolian Sand - The aeolian sand is not known to occur below the piezometric surface.

(6) Pleistocene to Recent Eukar, Calcrete and Alluvium - The bores and wells which have been
sunk along Ingallana Creek have obtained good to moderate supplies of variable quality water from rocks of this type, at shallow depths.

(7) Recent Alluvium - Five bores and wells have been drilled in these sediments (Barkly, Island, Stockyard and Koonyerdi bores and the Homestead Well). Good to moderate supplies of good quality groundwater are available with sufficient available drawdown.

(8) Recent Red Earth Soil - This lithological unit does not occur below the water table.

The Piezometric Surface

The form of the piezometric surface is not known as surface levels are not available. The depth to the piezometric surface varies between 30 and 130 feet, and it is shallowest near Willowra Homestead. A seasonal fluctuation of 44 feet in the water level has been recorded in the Homestead Well.

Recharge and Loss of Groundwater. Recharge of groundwater to the aquifer system about Willowra Homestead occurs during and for short periods following flow of water in the Lander River and Ingallana Creek.

The catchment of the Lander River consists of an area of 950 square miles with outcrop of mountains and hills of igneous and metamorphic rocks of Precambrian age. It can be assumed that the ratio of runoff to rainfall is high.

The area of the catchment of Ingallana Creek is 1310 square miles of which igneous and metamorphic rocks crop out in an area of 70 square miles. The remainder of the catchment consists of undulating plains of low relief which are covered with alluvium and aeolian sand. It can be assumed that the ratio of runoff to rainfall will be lower than that for that for the Lander catchment.

It is expected that recharge to the various aquifers will occur where the channel sands of the Lander River are in contact with the aquifers. Recharge probably occurs in this way in the area about Willowra Homestead.

The path followed by the recharge water which comes from Ingallana Creek is not known. Groundwater
is lost by both flow to the north of water within the system of aquifers, and by withdrawal.

**Quality of Groundwater.**

The quality of the groundwater which is available is variable. The content of total dissolved solids varies from 400 parts per million at Mt. Barkly to 3300 parts per million in Mud Hut Well. (Conductivities 620 and 5200 micromhos/cm respectively).

The controlling factors are the lithology of the aquifer, the degree of interconnection of the various aquifers and relationship of the aquifer to areas of groundwater recharge and loss. A qualitative assessment of these factors is given below.

(i) Precambrian Metamorphic and Igneous rocks - Aquifers in these rocks generally yield water of moderate to poor quality. The samples of water from Limestone Well and from bore E53/5 - 48 contained 3522 parts per million and 9937 parts per million of total dissolved solids respectively (Conductivities 5400 and 15000 micromhos/cm respectively).

(ii) Sediments of Tertiary and Quaternary age - Aquifers in the rocks of Tertiary and Quaternary age contain good to moderate quality water. There is a considerable overlap in quality between the two groups, and it is only possible to distinguish between them by examining the type of water associated with each group of aquifers.

On the basis of the logs of seven bores, five are thought to obtain water from Quaternary deposits, and two from Tertiary sediments, as shown below:

<table>
<thead>
<tr>
<th>Quaternary aquifers</th>
<th>Tertiary aquifers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barkly</td>
<td>Easy</td>
</tr>
<tr>
<td>Pilooman</td>
<td>Syphon</td>
</tr>
<tr>
<td>Island</td>
<td></td>
</tr>
<tr>
<td>Homestead</td>
<td></td>
</tr>
<tr>
<td>Stockyard</td>
<td></td>
</tr>
</tbody>
</table>

Other wells in other areas, for which only inadequate logs are available, are Sandford, Mud Hut, Wallbrl and 8 mile wells. The aquifers in these could be either Tertiary or Quaternary.

Water samples from the bores and wells have been analysed by the Animal Industry Branch, N.T. Administration.
Percentage reacting values, calculated from analyses, have been plotted on a triangular diagram (Fig 2). There is a wide variation in the relative proportion of the anions, but two groups may be distinguished on a basis of the percentage of calcium plus magnesium ions of the total anion concentration. The first group contains approximately 20% of the total anion concentration as calcium and magnesium and the second 13%.

The first group contains analyses from all the bores which are considered to obtain groundwater from aquifers of Quaternary age and the second group contains analyses from aquifers of Tertiary age. On this basis it would be inferred that the aquifers in Mud Hut and Sandfords well are of Quaternary age and that those in Wailbri and 8 mile well are of Tertiary age.

The triangular plot of the percentage reacting values of the cations indicates that if the Quaternary and Tertiary aquifers form a continuous system then the quality of the water deteriorates with increasing distance from the recharge area.

The dissolved solids in water from Quaternary aquifers is less than 1000 parts per million (conductivity 1500 microhms/cm) in all cases except Piloman Bore, (2274 parts per million), (conductivity 3400 microhms/cm) and the high salinity of this water is presumably due to the distance (8 miles) from a recharge source. The other bores and wells in this group are all close to the Lander River. The salinity of some of these bores varies with time since a river flow (e.g. Homestead Bore).

The total dissolved solids in water from Tertiary aquifers varies between 1000 and 2000 parts per million (conductivities 1500 to 3100 microhms/cm). The proportion of sulphate plus chloride plus nitrate in the water from these bores increases in the order Easy bore - 8 mile well - Wailbri Well - Syphon Bore, and this corresponds fairly closely to the order of increasing distance from a recharge source.

The nitrate content of all the bores and wells in the area is less than 50 parts per million.
FIG 3 DISTRIBUTION OF CONDUCTIVITY AND SAR IN GROUNDWATER, WILLOURA AREA

LEGEND

Existing bore showing conductivity and SAR
- Boundary of saturated sediments
- Conductivity contour
- SAR contour
- Boundary of water type

Resident Geographer's Office
Alice Springs September 1982
Suitability of the groundwater for irrigation.

The suitability of groundwater for irrigation purposes can be assessed on the basis of Sodium absorption ratio (SAR) and conductivity. Classes based on these factors have been established by the United States Department of Agriculture (Richards 1954). Four divisions (S1, S2, S3 and S4) are used to indicate low, medium, high and very high sodium water, and four divisions (C1, C2, C3 and C4) are used to indicate low, medium high and very high salinity water. A low salinity high sodium water would be classed as C1 - S3.

In figure 3, the conductivity and SAR of water obtained from bores penetrating saturated sediments in the Willowra area have been plotted, and the area contoured with respect to each of these variables assuming a continuous aquifer system. Approximate boundaries for each class of water represented are also shown. It is clear from this diagram that the best quality water occurs in a small area in the vicinity of Willowra Homestead, as a result of direct recharge from the Lander River to the sediments. The groundwater in this area is classed as C3 - S3; that is, it has a high salinity and low sodium hazard. Irrigation with water of this class would require adequate drainage, and special management for salinity control may be required (Richards 1954).

Water classed as C3 - S2 occurs in a belt extending north from the homestead area, and southeast from Easy Bore. This type of water is suitable only for irrigation of coarse textured soils having good permeability.

The remainder of the water in the area is included in classes C4 - S2 and C4 - S3. This water is only suitable for irrigation under very special conditions.

The salinity distribution outlined above is based on a small number of observation points only, and must therefore be regarded as preliminary.
RECOMMENDATIONS.

1. A drilling programme to estimate the quality of groundwater available in the area should establish:

   (a) the stratigraphy of the Tertiary and Quaternary sediments, and their aerial distribution. This would include a delineation of the aquifers.
   
   (b) the limit of saturated sediments (in area and depth)
   
   (c) the shape of the piezometric surface.
   
   (d) the distribution and variation of salinity of the groundwater. In particular if a salt water interface exists between Sandfords Well and Willowra Homestead.

2. It is recommended that investigation holes be drilled on a rectangular one mile (or 5000 foot) grid. Two initial lines of holes AA’ and BB’ as shown on the map (Plate 1) should be drilled to commence the programme.

3. All investigation holes should be drilled to bedrock. A water sample should be obtained, and a measurement of standing water level made, at each hole, and preferably for each aquifer encountered. Cuttings from each hole should be examined by a geologist. Holes should be completed in such a way as to allow for continuing measurements of water levels.

T. Quinlan.

D. Woolley.
# REFERENCES

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Title</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evans, P.H.</td>
<td>1962</td>
<td>Bore WRR/ZG, Alice Springs Farm Area</td>
<td>(unpub. data)</td>
</tr>
</tbody>
</table>