DEPARTMENT OF LANDS PLANNING AND ENVIRONMENT
WATER RESOURCES DIVISION

WATER RESOURCES SURVEY OF THE WESTERN VICTORIA RIVER DISTRICT

LIMBUNYA

REPORT 10/1997D
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Darwin
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WATER RESOURCES SURVEY OF LIMBUNYA STATION
NORTHERN TERRITORY

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Water Resources of Limbunya
LIST OF ABBREVIATIONS

- km  - kilometre
- L/s - litres per second
- m  - metre
- m$^3$ - cubic metre
- mg/L - milligrams per litre
- ML - megalitre (one million litres)
- mm - millimetre
- μS/cm - microsiemens per centimetre
- pH - acidity and alkalinity index
- TDS - total dissolved solids

LIST OF CONVERSIONS

1 mm (millimetre) = .04 inches (4 points)
1 m (metre) = 3.3 feet
1 km (kilometre) = 0.6 miles
1 L (litre) = 0.22 gallons
1 ML (megalitre) = 220,000 gallons
1 L/s (litre per second) = 800 gallons per hour

Water Resources of Limbunya
SUMMARY
The accompanying Water Resources Development maps can be used as a guide to determine
the type of water supply most appropriate to specific areas of the station. Moderate supplies
of groundwater are generally available in areas underlain by sandstone aquifers. In situations
where surface water flows and soil types are suitable, excavated tanks may be an alternative
option to bores. Few areas are likely to have sufficient depth of clay soil to enable the
construction of tanks with enough storage to last most of the dry season. Sites could be found
however for shallower tanks which could supply water at least for the early part of the Dry.

1. INTRODUCTION
This project was started by the Victoria River District Conservation Association (VRDCA). Its
aim is to provide station managers with up to date information on water resources, so that they
can make more informed decisions about water and land management. It is funded by the
Northern Territory Government and the National Landcare Program with a contribution by the
VRDCA. A total of 20 properties will be studied between July 1993 and June 1998.

Limbutuya station covers an area of 6094 km² and is located some 200 kilometres southeast
from Kununurra, the closest major town. Road access is via the Buchanan Highway. During
the wet season both the highway and many station tracks may be impassable.

The availability of stock water is a major influence on stock management. Nearly all of the
annual rainfall, which averages approximately 611 mm, occurs in the short hot monsoonal wet
season between December and March (Table 1). Little rainfall is experienced during the
remainder of the year. Recharge to groundwater aquifers occurs at this time. Evaporation
rates of water bodies such as dams or waterholes are between 4.5 and 8.8 millimetres per day
(average about 6.9 mm per day or 2.5 metres per year). This ensures that water levels in creeks,
dams and tanks decline rapidly. Air temperatures are high throughout the year. The average
monthly maxima range from about 27.8 degrees in June to 38.2 degrees in December. The
corresponding average monthly minima are 10.8 and 24.0 degrees.

Current stock management is based on water availability. At present the station carries about
14,000 head of cattle. Bores supply approximately 80% of the water need, the remainder
coming mainly from springs and waterholes. Eight bores are used, normally in conjunction
with steel or cement tanks which act as temporary storages. During the Wet and the early Dry,
most of the available surface water that is accessible is used, but as the Dry progresses, these
sources become depleted and more reliance is placed on groundwater and permanent spring
fed waterholes. There is only one excavated tank on the station and it usually runs dry by July.

Water Resources of Limbutuya
TABLE 1

CLIMATIC AVERAGES - LIMBUNYA STATION

<table>
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<th></th>
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<th>DAILY MIN. TEMP (°C)</th>
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Note: Temperatures are from Wave Hill Station

Water Resources of Limbunya
2. WATER SUPPLY DEVELOPMENT

An attempt has been made to classify the station according to the type of water resource developments considered most appropriate for particular areas. The results are shown on the accompanying Water Resources Development Map of Limbunya. The map was made by combining information on existing features (waterholes, dams, bores etc.) with information on groundwater occurrence, topography and soil types. Local conditions, such as soil types can vary considerably, so the maps should not be taken as a definitive guide to cover every situation. Rather they are broad scale maps which are intended to give an overall picture of possible development options. Detailed on-ground investigations are recommended when considering specific developments.

For an explanation of the colours on the main map refer to the legends entitled "Water Resources Development Options". Four categories of "preferred options" have been mapped:

- areas which are unsuitable for surface water storages or bores (option 1)
- areas in which surface water is the best option (option 2).
- areas in which groundwater is the best option and where moderate yields can be expected (option 3).
- areas in which surface water and groundwater may both be viable options (option 4).

Some of the main features of the maps are:

- a large proportion of the station is relatively inaccessible and so unsuitable for most water supply developments
- groundwater is available in moderate amounts over most of the developed areas of the station.
- areas suitable for the construction of excavated tanks include those on black soil plains north of the homestead and those on alluvial soils adjacent to watercourses. The thin clay soils overlying basalt, north of the homestead are only suitable for excavated tanks of limited storage capacity.

3. GROUNDWATER

Groundwater conditions across the station have been assessed using geological information, satellite images, aerial photos and information from existing boreholes. The results are presented as the Groundwater Resources Map, a small side maps on the accompanying map of Limbunya station.

Technical information on water bores is shown in Appendix 1. Further details on individual bores are held on the Water Resources Division's files and are available on request. Chemical analyses of groundwaters and recommended limits for common uses are listed in Appendix 2 and 3, while the results of the pump testing program are presented in Appendix 4.

Groundwater is stored in and moves through minute spaces in rocks caused by fractures (cracks), the spaces between sand grains or spaces where minerals have dissolved away. If economically viable quantities of water can be extracted, the water bearing horizon is termed an aquifer. The zones of groundwater yield shown on the maps are meant to give an
indication of the most likely yield which could be expected. Natural variations in the properties of rocks means that variation also occurs in groundwater yields. For example in a zone mapped as 0.5 to 5.0 L/s a certain percentage of bores may obtain higher yields and some may be lower but most will fall within the range. At a specific site, yield is often highly dependent on the number of water bearing fractures intersected. There are generally too few existing bores to determine the likely yields with statistical certainty. Rather they are based on a combination of geological knowledge and known yields. The groundwater map is therefore intended to identify the prospectivity of broad areas only. When selecting specific bore sites it is useful to observe local rock types and to study aerial photographs and topographic maps for signs of linear features which may indicate the presence of fractures.

A paddock holding 1000 head of cattle (each consuming 50 litres per day) requires a bore capable of pumping between 0.5 and 1 L/s continuously. Bores yielding less than 0.5 L/s are generally regarded as being uneconomic.

Stock water is presently obtained from about fifteen bores. Water drilling has been moderately successful with only eleven of the thirty four bores drilled on the station being recorded as abandoned due to insufficient yield. Most of the unsuccessful bores were drilled into dolomite and siltstone, rocks now known to be poor aquifers in the VRD. The actual number of “dud” bores is probably higher because the area was first drilled more than sixty years ago and duds were unlikely to have been recorded until recent times.

Water quality is suitable for stock in all bores tested. It is also suitable for human consumption.

The three zones shown on the groundwater map are now described:

3.1 Areas with yields 0 to 0.5 L/sec, dolomite and siltstone

The main rock types in these areas are siltstone, dolomite and shale, fairly impermeable rocks which generally contain only small supplies of water. Drilling in these areas is likely to be unsuccessful. There are some indications however that dolomite can be locally water bearing. Several bores drilled in an excision area near Swan Yard encountered good supplies in cavernous dolomite at depths of less than twenty metres (eg RN 28479 and 28732). Another favourable indicator is the presence of substantial springs originating in dolomite. These include Black, Campbell and Fraynes Camp Springs.

3.2 Areas with yields 0.5 to 5.0 L/sec, basalt

Basalt, a black volcanic rock covers a large part of the developed areas of the station. It forms a flat sheet which sits on top of the other main rock types such as sandstone, siltstone etc (see the cross-section on the map). In order for it to form an aquifer it has to be at least thirty metres thick, so that there is sufficient depth of it below the watertable, otherwise the rock will be dry. In most parts of the station water levels are lower than the base of the basalt, so it only forms aquifers in restricted areas such as in the extreme west and possibly in the northeast part of No 22 paddock. Elsewhere it will be necessary to drill through the basalt into the underlying rock, in order to locate a water supply.

Water Resources of Limbunya
Where basalt is below the watertable groundwater occurs where the rock is fractured such as in the vicinity of faults and in the horizontal partings between individual lava flows. Yields of up to 1.0 L/sec are typical of basalt but aquifers can be sparse and difficult to locate. None of the stations production bores tap basalt aquifers although on neighbouring properties it is often the main aquifer.

3.3 Areas with yields 0.5 to 5.0 L/sec, sandstone and minor dolomite

The majority of the existing production bores tap sandstone aquifers. They tend to be more extensive than the other aquifers so the success rate with drilling is usually higher. Only two bores out of nineteen reported as drilled into sandstone had yields less than 0.5 L/sec. Airlift yields range up to 12 L/sec but are more typically 2 L/sec or less. Aquifer depths range from 40 to 160 metres but average 80 metres. A particularly prospective target is the upper ten metres of sandstone directly beneath the basalt. This represents an ancient land surface buried by the flows of basalt. The upper section of sandstone was deeply weathered causing many fractures to be open and thus water bearing. No I bore is good examples of bores which tap this zone.

4. SURFACEWATER

Surface water flow in the creeks and on the floodplains is largely confined to the wet season. Some creek flows and replenishment of waterholes during the Dry are due to spring flows. An effective annual evaporation rate of about 2.5 metres is responsible for the subsequent rapid loss of stored water from excavated tank and waterholes. During the average Wet, flow of the Negri River, Stirling Creek, and minor streams are sometimes accompanied by sheet flow over the adjacent floodplains. After the Wet, all drainages deplete to form unconnected waterholes, the majority of which are dry by about July. Surface water studies have been directed at designing structures to conserve enough of the wet season flow to provide reliable stock supplies for the duration of the Dry or at least part of the Dry. An example of typical storage requirements would be 3.8 megalitres (million litres) for a paddock holding 500 head (50 litres/head/day) after allowance is made for evaporation losses. That would ensure a 5 month daily stockwater supply from April.

For its stock water supplies from surface water the station is dependent on waterholes, springs, and an excavated tank. Details of the station’s key surface water storages and an assessment of their capabilities are given in Appendix 5. About 20% of the stock water demand on Limbunya is supplied from natural and artificial surface water sources. The station has only one excavated tank, it is shallow with bunds made from the excavated material and open on the upstream side. It is about 2 metres deep, but with a maximum excavated depth of less than 1.5 metres.

The region has been divided into five zones showing the suitability for surface water development for stock watering. They are based on soil type, geology, topography and runoff characteristics. The results are presented as the Surface Water Resources Map, one of the two small side maps accompanying the Water Resources Development Map.

**Water Resources of Limbunya**
4.1 Surface Water Storage Types

Three types of excavated tanks are suitable for the flat to gently sloping country with black and grey soil, onstream tanks, offstream tanks, and drainage-line tanks (Figure 1). An onstream tank is one dug in a well defined stream channel. Offstream tanks are constructed away from the main channel but are connected to it by an excavated inlet channel. The third type, the drainage-line tank is the preferred option and is one which is sited along a broad poorly defined watercourse.

The onstream excavated tank requires a high standard of design and construction and is prone to erosion or silting because of its location in a fast flowing main stream channel. The offstream design (Figure 2) reduces these problems by using a man-made channel to divert water from the stream to the tank. This is an improvement on the onstream design, but has excessive excavation costs because to take advantage of short lived stream flows, the tank level must be below that of the natural stream bed.

The drainage-line tank (Figure 3) is an excavated tank constructed in flat to moderately sloping areas where there are no clearly defined incised creek systems. The tank itself is of the same design as the offstream one, but without an inlet channel. Sheet flow on the plains, with its low silt load, may be harvested using catch drains or wing walls.

Another type of dam, the gully dam is suited to gently undulating to hilly country and consists of an embankment built across a drainage line. It should be noted that structural failures are high amongst gully dams, as they require a high standard of design, construction and management. Construction of these dams in much of the low hilly country on Limbunya may not be economically feasible due to the thin permeable soils and underlying hard basalt bedrock. Areas where soils are clayey may be locally suitable for gully dams. The minimum average depth of the dam should be 4.5 metres in order to compensate for the high evaporation, and to maintain a high reliability. All excess runoff has to be taken through a by-wash or spill. Constructing a gully dam at an appropriate location in the region would involve high costs in coping with the foundation condition and flood flows. It is recommended to consult a Civil Engineer before planning to construct these dams on rock foundation. Embankments more than 3 metres high need licensing from the Water Resources Division.

Generally excavated tanks in the VRD experience the following problems if they are not constructed properly:

- rill erosion of the bund if the bund is not compacted properly.
- silting of tanks
- silting of catch drains and inlet channels

Regular maintenance is required before the next Wet to correct damage due to these problems. The current design does not give sufficient storage capacity for cattle requirements, due mainly to high evaporation losses. The depth of excavated tanks should be more than 3 metres, depending on subsoil types, if they are to supply till the end of the Dry. As the depth increases beyond 3 metres, the tank's reliability increases.

**Water Resources of Limbunya**
Figure 1. Types of tanks and dams

*Water Resources of Limbunya*
Figure 2 Typical offstream excavated tank
Figure 3 Typical drainage-line excavated tank

Water Resources of Limbunya
4.2 Selection of Sites for Excavated Tanks

The selection of a site for an excavated tank is determined by the availability of runoff and the water holding capacity of the ground. A drainage-line tank is best located on flat or gently sloping ground. Excavation will be minimised where the tank site has some slope, say about 1%, to allow bunds constructed from excavated material to add to the storage volume of the tank. On areas mapped as "flat to gently undulating country with black and grey clay soils" on the Surface Water Resources Map, clays soils may extend in places to depths of up to 2.5 metres and will be suitable for excavated tanks. However it should be noted that over most of that area it is likely that there will be insufficient depth of suitable soil for tank construction. The most favourable areas are the black soil plains north of the homestead. Areas mapped as "alluvial plains" may also be suitable, however places with sandier soils should be avoided. Drainage-line tanks may be feasible in areas immediately adjacent to the low hilly country if clayey soils with sufficient depth are present. Areas suitable for consideration are also summarised on the Water Resources Development Map. Following selection of a general area, more detailed investigation is required (Appendix 6) and may require the input of a geotechnical consultant.

For drainage-line storages a minimum catchment area of 1.5 km$^2$ is required. Other types of excavated tanks require a minimum catchment area of 4 km$^2$. Cracking clay soils are suitable for holding water. Remedial work such as installing a clay liner, or reselection of the site will be necessary where dispersive or sandy soils, or high permeability zones are encountered.

4.3 Design and Construction of Excavated Tanks

Design dimensions for an excavated tank are determined by the number of stock to be watered. This is also dependent on the carrying capacity of the paddock, typically varying between 200 and 1000 head. At a consumption of 50 litres per head per day the corresponding water requirement is between 1.5 and 7.5 megalitres over a period of five months. The amount of runoff that can be captured by a tank increases with catchment area.

A drainage-line tank of the design shown in Figure 3 and with a catchment area of 2 km$^2$, would supply 300 head of stock, over a period of four months on a daily basis with just less than 90% reliability (ie. for 9 years out of 10). This same tank with a catchment area of 1.5 km$^2$, will supply the same number of stock over the same period with a lesser reliability of 84% during the Dry. Tank sizes of 80 x 80 x 2.5 or 100 x 80 x 3.0 metres could supply stock water on a daily basis for 400 to 500 head with a reliability of 90% over a period of six months.

An offstream tank of the design shown in Figure 2 and with a catchment area of 4 km$^2$ should supply 400 head of cattle, with 90% reliability over a period of five months. The same tank with a catchment area of 8 km$^2$ would cater 600 head over a five month period with 88% reliability. Due to the region’s relatively low rainfall, a reliability as low as 85% might be considered satisfactory. An Offstream tank of size 100 x 80 x 3m and with a catchment area of 4km$^2$ could cater for 500 head of stock on a daily basis over a six month period with 92% reliability.

Water Resources of Limbunya
The design of excavated tanks is covered in more detail in the internal Water Resources Division Report No 03/1997D, entitled "Surface Water Storage Potential - Limbunya Station". The proposed design is relatively simple. Excavated spoil can be dumped to waste or used to build a bund on three sides of the tank. A bund and wing walls will increase the storage capacity of a drainage-line tank where there is a moderate slope on the natural ground surface. Excavated volumes are large for the proposed design dimensions (approximately 14,000 m$^3$) so construction costs will be high. Cost will also be influenced by ground conditions. Tank construction is described in more detail in Appendix 7.

4.4 Waterholes and Springs

Natural waterholes are present during the Dry, in major and medium creeks. Some are spring fed and never dry even though they are shallow. The available capacity of some waterholes may be increased by excavation of the base (Appendix 7), but only where the site is underlain by clay or a ripaple and impermeable rock such as shale. The widespread occurrence of shallow hard rock makes this an unlikely option on Limbunya. The storage capacity of a well confined waterhole with high banks could be increased by construction of a bund at its downstream end. The bund would need to be designed and constructed to withstand flood flows.

Springs usually occur on hill slopes and in stream beds. Some of the main springs in Limbunya are Unidait, Beasley, Black and Campbell Springs. Flows range up to 4L/sec and only the larger ones last till the end of the Dry. The springs in the station are not protected, and cattle have direct access to them. A spring with a flow of more than 2 litres per second at the end of Dry, should be able to supply a turkey nest designed to store three days supply of stock water for 500 head of cattle. Piping water from springs to areas where groundwater or surface water are not available may be an option in some situations.

4.5 Piping of Surface Water

On some stations surface water has been piped from borrow pits into turkey nests and this practice could be utilised as an alternative low cost water supply option where possible. Pumping direct to turkey nests is the preferred option because of the smaller volumes of water lost to evaporation.

Fifty millimetre polythene pipe, buried where possible, can be used to pipe water up to four kilometres in flat country. The distance can be increased by using larger diameter pipes and higher capacity pumps. It is desirable to bury polythene pipe to protect it from physical damage (eg. grass fires or stock trampling) and because its strength is reduced if subjected to elevated daytime temperatures.

4.6 Supply of Stock Water from Tanks

Turkey nests are required as a balancing reservoir between the tank and stock watering troughs. Dimensions for turkey nests providing three days water for various stocking rates are

**Water Resources of Limbunya**
given in Appendix 7. The basic equipment to transfer water from an excavated storage tank to a turkey nest is a pump, with a choice of three energy sources, diesel, wind or solar. The initial cost of a windmill or solar powered pump is high but running costs are low. The low cost and availability of a relatively cheap diesel motor and centrifugal pump makes diesel the preferred option even though running costs are high. The advantages are mobility and ease of maintenance.

5. RECOMMENDATIONS

- The water resources development map can be used to determine the type of water supply most appropriate to a specific area on the Station. In areas where alternative options are available economics will normally determine the final development type selected.
- Moderate amounts of groundwater are available in most areas except in those underlain by dolomite or siltstone.
- In situations where surface water flows and soil types are suitable, excavated tanks away from clearly defined drainages, and sited to harvest sheet flow are an alternative option or a supplement to bores.
- The provision of reliable water supplies with a maximum grazing radius of six kilometres should be a priority, in order to reduce over-grazing and soil erosion.
- Advice should be sought from geotechnical engineering consultants when considering the construction of larger excavated tanks.

Specific recommendations are considered under three headings: distribution, groundwater, and surface water.

5.1 Water Supply Distribution

In many parts of the V.R.D. over-grazing has resulted in a reduction of ground cover and in places, in soil erosion. Another unwarned result is degradation of pasture quality by allowing unbeneﬁcial species and weeds to become dominant. Apart from the number of cattle present, the distribution of watering points is a major factor affecting grazing pressure. A rule of thumb commonly adopted for planning the location of watering points is that they should be located so that cattle can graze the whole paddock without having to walk more than six kilometres for water. Where possible, tanks or bores should be located to give a maximum spacing of twelve kilometres between watering points. Otherwise the water can be piped to turkey nests or directly to troughs in appropriate locations. The piping of water away from supplies sited in the corners of paddocks may decrease the grazing pressure by keeping the cattle spread over a greater area. (Figure 4).

5.2 Groundwater

Careful site selection can improve the chances of successful drilling. Sandstone constitutes the most prospective aquifer with typical yields of 2 L/sec and a high success rate.

*Water Resources of Limbunya*
Figure 4 Sketch showing improved size of grazing area due to piping away from a reliable bore or tank

Water Resources of Limbunya
5.3 Surface Water

Drainage-line and offstream type excavated tanks are recommended for areas with black or gray clay soils at least 2.5 metres deep. The supply however would only be sufficient for up to 6 months in the dry. Excavated tanks could also be constructed where there is as little as 2.0 metres of soil but the reliability would be 80% or less and the supply would be limited to less than four months in the Dry. Selection of sites depends on the presence of suitable sub-soils. Deepening or enlarging the surface area of existing surface water storages should be subject to satisfactory sub-soil investigations. Site investigations are an essential prerequisite for any construction work. All existing and planned surface water storages (excavated tanks, waterholes, springs etc.) should be fenced and stock watering infrastructure such as troughs, windmills, turkey nests or on-ground fabricated tanks should be provided.

6. ACKNOWLEDGMENTS

The authors would like to thank Michael Fox, former manager and Michael Stanley, the present manager of Limbunya Station for their assistance during the study. The guidance of Mr Peter Jolly, and Mr. Fred Barlow throughout the survey has been much appreciated, as has the efforts of the drafting and GIS staff, Lynton Fritz and Jeff Fong, who produced the maps and figures for the report. Thanks also to Technical Assistants Roger Farrow and Rob Roos who carried out the GPS surveys. The staff of the Pastoral Branch of the Department of Lands and Housing also provided much assistance in the form of pastoral maps, inspection reports and general advice.

Water Resources of Limbunya
APPENDIX 1

STATION BORES

The following table is a list of bores drilled on the station together with selected details about their location, construction and groundwater intersections. More detailed information on many bores is available on request from the Water Resources Division in Darwin. Some of the headings on the table are explained below:

- **BORE RN** A registered number assigned to each bore by the Water Resources Division.

- **AMG EASTING** The east-west coordinates of the bore in metres. It refers to the grid lines on the map.

- **AMG NORTING** The north-south coordinates of the bore in metres. It refers to the grid lines on the map.

- **DEPTH DRILLED** The total depth of the bore in metres below ground level.

- **CASING** The length of casing in the hole in metres and its internal diameter in millimetres.

- **WATER STRUCK** The depth in metres below ground level at which the main water bearing zone was encountered.

- **YIELD** The amount of water obtained in litres per second by airlifting, usually during drilling of the hole.

- **SWL** Standing water level, the depth below ground level that water rises to in the bore.

- **SLOTS** The depths in metres below ground level between which the bore casing is slotted.
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<th>Casing Point (m)</th>
<th>WATER PROD (m)</th>
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<td>21/6/98</td>
<td>676900 811149</td>
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<td>18.4 -22.6 8.0 11.4 18.3-22.6</td>
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</tr>
<tr>
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<td>1/2/93</td>
<td>607200 608140</td>
<td>27.3 17.9 X 156</td>
<td>11.4 27.3 3.5 11.1 17.9 -22</td>
<td>CAPPED</td>
<td></td>
<td></td>
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</table>
APPENDIX 2

CHEMICAL ANALYSES OF GROUNDWATERS

The following table lists chemical analyses performed on groundwaters on Limbunya. See Appendix 3 for an explanation of the main factors which limit water use for stock and domestic consumption.
| FN  | 28730 | 0.9 | 28732 | 5  | 21  | 28  | 441  | 1  | 0.3  | 0.1  | 26  | 407  | 421  | 0.1  | 0.1  | 12345  | 341  |
|-----|--------|-----|--------|----|----|----|--------|---|----|-----|----|----|----|--------|---|----|--------|-----|
|     | 28730  | 0.2 | 45    | 552  | 0.2 | 45  | 552  |    |    |     |    |    |    |        |   |    |        |     |
| 609 | 22/8/89 | 850 | 520   | 7.8 | 90  | 4   | 34    | 57  | 26  | 6    | 627  | 6    | 0.1  | 0.1  | 41 514  | 380  |
|     | 20/10/1 | 820 | 820   | 7.7 | 127 | 4   | 57    | 87  | 26  | 6    | 675  | 6    | 0.4  | 0.4  | 84 716  | 540  |
| 609 | 22/8/89 | 850 | 520   | 7.8 | 90  | 0.1  | 0.1  | 12345  | 341  |
|   |       |    |       |    |    |    |     |     |    |    |     |     |    |    |        |   |    |        |     |
| 609 | 22/8/89 | 850 | 520   | 7.8 | 90  | 4   | 34    | 57  | 26  | 6    | 627  | 6    | 0.1  | 0.1  | 41 514  | 380  |
|     | 20/10/1 | 820 | 820   | 7.7 | 127 | 4   | 57    | 87  | 26  | 6    | 675  | 6    | 0.4  | 0.4  | 84 716  | 540  |
| 609 | 22/8/89 | 850 | 520   | 7.8 | 90  | 0.1  | 0.1  | 12345  | 341  |
|   |       |    |       |    |    |    |     |     |    |    |     |     |    |    |        |   |    |        |     |
| 609 | 22/8/89 | 850 | 520   | 7.8 | 90  | 4   | 34    | 57  | 26  | 6    | 627  | 6    | 0.1  | 0.1  | 41 514  | 380  |
|     | 20/10/1 | 820 | 820   | 7.7 | 127 | 4   | 57    | 87  | 26  | 6    | 675  | 6    | 0.4  | 0.4  | 84 716  | 540  |
| 609 | 22/8/89 | 850 | 520   | 7.8 | 90  | 0.1  | 0.1  | 12345  | 341  |
|   |       |    |       |    |    |    |     |     |    |    |     |     |    |    |        |   |    |        |     |
### APPENDIX 3

**WATER QUALITY REQUIREMENTS FOR STOCK AND DOMESTIC WATER**

#### 1. WATER QUALITY STANDARDS FOR STOCK USE

<table>
<thead>
<tr>
<th>SUBSTANCE</th>
<th>GUIDELINE VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH range</td>
<td>5.5 - 9.0</td>
</tr>
<tr>
<td>Total dissolved solids</td>
<td>8000 mg/L</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>Not more than 75% when total dissolved solids near limit.</td>
</tr>
<tr>
<td>Sulphate</td>
<td>2000 mg/L</td>
</tr>
<tr>
<td>Nitrate</td>
<td>400 mg/L</td>
</tr>
<tr>
<td>Fluoride</td>
<td>5.0 mg/L</td>
</tr>
<tr>
<td>Magnesium</td>
<td>300 mg/L</td>
</tr>
</tbody>
</table>

The composition of mineral supplements to stock feed must be considered when stock waters are near to the guideline limits, especially for fluoride and sulphate. Further information is available from the Chief Veterinary Officer, Northern Territory Department of Primary Industry and Fisheries.

#### 2. WATER QUALITY STANDARDS FOR DOMESTIC USE (NATIONAL HEALTH AND MEDICAL RESEARCH COUNCIL, AUSTRALIAN DRINKING WATER GUIDELINES 1996)

Analyses of water intended for human consumption should lie within the guidelines listed below. Discussion relating to the quality of domestic water should be addressed to the Northern Territory Department of Health and Community Services.

<table>
<thead>
<tr>
<th>SUBSTANCE</th>
<th>GUIDELINE VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH range</td>
<td>6.5 - 8.5*</td>
</tr>
<tr>
<td>Total dissolved solids</td>
<td>500 mg/L**</td>
</tr>
<tr>
<td>Chloride</td>
<td>250 mg/L**</td>
</tr>
<tr>
<td>Sulphate</td>
<td>250 mg/L**</td>
</tr>
<tr>
<td>Nitrate</td>
<td>50 mg/L***</td>
</tr>
<tr>
<td>Fluoride</td>
<td>1.5 mg/L</td>
</tr>
<tr>
<td>Hardness (as Calcium Carbonate)</td>
<td>200 mg/L*</td>
</tr>
<tr>
<td>Sodium</td>
<td>180 mg/L*</td>
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</table>

(*): Values outside of the guidelines for pH and hardness may result in either build-up of scale in pipes or corrosion of pipes but they do not pose a health problem.

(**): Above these limits the taste may be unacceptable but they do not pose a health problem.

(***): For nitrate a limit of 50 mg/L is recommended for babies less than 3 months old, 100 mg/L is the guideline for older children and adults.

*Water Resources of Limbunya*
The results of pumping tests carried out on bores on Limbunya are summarised in the following table. More detailed information is available from the Water Resources Division in Darwin.

<table>
<thead>
<tr>
<th>RN</th>
<th>BORE NAME</th>
<th>PUMP RATE (L/s)</th>
<th>PUMP SETTING (m)</th>
<th>BORE DIAMETER (mm)</th>
<th>SWL (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28479</td>
<td>Swan Yard</td>
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<td>14</td>
<td>113</td>
<td>11.4</td>
</tr>
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<td>28732</td>
<td>Swan Yard</td>
<td>5.2</td>
<td>13</td>
<td>152</td>
<td>11.1</td>
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</table>

- PUMP RATE: The recommended pump rate in litres per second
- PUMP SETTING: The recommended depth below ground level at which the pump intake should be set
- BORE DIAMETER: The minimum internal bore diameter in millimetres
- SWL: The standing water level in the bore, in metres below ground level, measured immediately prior to the test
APPENDIX 5

WATERHOLES DAMS AND SPRINGS

1. Racecourse Dam:
This is a small shallow offstream excavated tank located on black soil. It supplies a holding paddock. Though it fills every year, it only lasts till June. Runoff analysis indicates that it could provide a daily water supply for 100 head of cattle for three months from April with 88% reliability. It is recommended that soil investigations be carried out before any deepening the tank is carried out.

2. Racecourse Waterhole:
Located on a minor creek near Racecourse Dam this is a small and shallow waterhole enlarged by a bund built across the creek. It can supply daily water to 100 head of cattle over a period of two months. It is recommended that investigations be carried out to locate an offstream tank in the vicinity.

3. Old Station Waterhole:
This is a relatively deep waterhole located in a small gorge. Access for cattle is difficult because it is situated among steep outcrops. It serves 300 head till the end of Dry. It is recommended that water be pumped and stored in a ground tank or turkey nest nearby to improve access.

4. Longhole Waterhole:
Located on Kunja Creek this waterhole is long and relatively deep. It should be capable of supplying 350 head of cattle for nine months from April with a reliability of 88%. Access is difficult, and therefore it is recommended that water be pumped into a ground tank or turkey nest.

5. Uindait Spring:
There are a few waterholes along Uindait Creek, and some are spring fed. The waterhole that was inspected in August 1996 was very long, and had a flow of 3.3 L/sec. About 1000 head of cattle depend on it and it is said to be permanent due to spring flows.

6. Swan Creek Waterhole:
Also permanent and spring fed it is a relatively deep, narrow, and long waterhole. It is capable of supplying 500 head on a daily basis throughout the Dry. In August 1996, the flow was found to be more than 3 L's.

7. Murray Waterhole:
It is capable of supplying 500 head over a period of six months with 80% reliability. It is situated in a siltstone area, so it may have the potential to be deepened, provided the rock is rippable.

Water Resources of Limbunya
APPENDIX 6

SITE INVESTIGATIONS

Having determined a catchment capable of supplying stock quality water for the required stock numbers, site investigations must be undertaken to confirm that the proposed tank site is suitable. The site investigation guidelines presented here are based on a very useful booklet entitled "Design and Construction of Small Earth Dams" (Nelson, 1985, Inkarta Press, Melbourne). The key investigation method is to auger a series of investigation holes. In an excavated tank situation this helps to:

- determine the extent of impermeable soils and the presence of any layers which are likely to have leakage problems
- show if there is any impermeable and soft rock present, such as rippable shale
- ascertain whether shallow groundwater is present, and if so, is it suitable for stock
- provide information on the soils to ensure the tank sides will be stable

If an onstream tank is proposed then spillway conditions will also require investigation. If it is too sandy it will erode and wash away or if it is in rock, excavation could be very expensive.

A hand operated 100 mm earth auger capable of drilling to between 5 and 6 metres is the basic tool for the subsurface investigations. Auger holes are sunk in soil to one metre deeper than the tank design depth, with minimum 500 gram samples taken wherever there is a change in soil. A plan of the soil changes down each hole should be kept to compare variations from hole to hole. Excavated tanks require a minimum five test holes, one in the centre and the other 4 positioned at the mid point of each corner slope of the proposed tank (Figure 5). For the modification of an existing waterhole, auger holes are sunk at 50 metres apart along the centre of the bed, and 100 metres apart along the edges of the bed.

The site for proposed excavation must fulfil three main conditions:

- the loss by seepage must be relatively low
- the sides must be stable
- siltting must not be excessive

1. Seepage Loss

In most areas of the plains country the watertable will be deeper than the proposed 4 to 4.5 metre tank depth. Hence leakage of stored water through the sides and base of the tank is possible. A simple permeability test can give an indication of potential leakage from the tank using the series of auger holes used for soil sampling. The following procedure is proposed but is only indicative:

1. Pre-soak each hole for at least 1 hour before starting the test by filling the hole to exactly 0.5 metres below ground level and maintaining it at this level by addition of water.
2. The test involves maintaining this water level (0.5 metres below ground level). The amount of water added to keep the water level is recorded. Continue the test for one day.

If the water added exceeds 30 litres per hour, then the site is too permeable for an excavated tank.
Figure 5  Test hole plan for an excavated tank

*Water Resources of Limbunya*
tank. If it is between 3 and 30 litres per hour then the area should be considered as doubtful and should only be accepted with professional advice. Rates less than 3 litres per hour indicate that leakage will not be a serious problem.

2. Tests on Soil Samples

Soils commonly consist of particles which may range in size from coarse gravels, through sands and silts, to very fine clays. Gravels and sands can be readily identified by appearance and feel and unless they are mixed with finer silts and clays will be prone to leakage. Clays and silts are indistinguishable when dry. While clay is one of the most useful soils in dam building, silt, when wet, is the most troublesome. It tends to be unstable in the presence of water, often collapsing when saturated.

Generally a favourable site investigation result will confirm the presence of non-dispersive clays that bind together any coarser particles to create a water holding material. Accurate classifications of soil types can be undertaken by sending at least 100 gram of sample to the Land Conservation Branch, Department of Lands Planning and Environment and these provide a very good indication of soil suitability. However simple field tests can give a good feel for the likely behaviour of the soils.

1. A simple test to differentiate clay from silt is to moisten the sample and feel it. Clay should be sticky. Pinch a sample between the thumb and forefinger; if it is clay it should be possible to form a flexible ribbon about 1.5 mm thick and at least 40 mm long.

2. If the presence of clay is established then the water holding potential of the soil can be tested using the "bottle test". The bottom of a 1.25 ml plastic drink bottle is cut off. The bottle is inverted and one-third filled with the soil to be tested. The bottle is filled with water. If no water seeps through the soil in 24 hours, it has good water-holding properties.

3. All clays should be tested for dispersion. Some clays break down in water to form a suspension of clay particles throughout the water. This is dispersion and has been the cause of many dam failures. To test for dispersion take 5 to 10 grams of air dried soil crumbs and drop them into 100 ml of distilled water in a cup. Allow it to stand for at least one hour without shaking. If the water appears cloudy then dispersion has occurred and special care will be needed if building tanks in these materials. The presence of deep erosion gullies suggests markedly dispersive soils and these sites should be avoided.

If site investigations show that there is likely to be problems with any of these factors then professional advice should be sought, and remedial measures may be possible. However it may be necessary to abandon the proposed site.

Water Resources of Limbunya
CONSTRUCTION DETAILS OF EXCAVATED TANKS, TURKEY NESTS AND MODIFIED WATERHOLES

Assuming preliminary investigations (Appendix 5) have shown the suitability of a site for a specific structure then construction can be begin. No matter how good the design, poor construction methods can lead to a less than perfect structure.

1. Excavated Tanks

The site is first cleared of vegetation and the planned tank laid out on the ground using marker pegs. Excavation is commonly carried out using scrapers or bulldozers. If the tank is in an area with some slope (say greater than 1 in 100) excavated material can be used to construct bunds around three sides of the excavation to increase its storage capacity. The bund should have a minimum berm width of 5 metres (Figure 3). Topsoil with potential for leakage must be removed down to an impervious layer before the bund is built, and compaction should be undertaken using the available machinery. The ideal time to achieve optimum compaction is early in the Dry when soils are still slightly moist.

Three sides of the tank are excavated with a slope of 1 in 3, and flow enters the tank through the side with a mild slope, as low as of 1 in 10. The inflow side may be rubble packed to prevent erosion. Where the excavation is in rock, with little chance of erosion, the inlet batter may be increased to 1 in 4, to decrease the volume of material to be removed. The recommended slopes allow for machinery to enter the tank, excavate, turn and exit with ease. For offstream excavated tanks catch drains can be constructed, eg. using a tilted grader blade, to direct an increased volume of sheet flow towards the tank.

2. Modifying Waterholes

Modifying a waterhole usually means constructing a narrow excavated tank within the waterhole to increase its storage capacity. Site investigations are critical. If the subsoil is impermeable, non-dispersive, and there is no rock within two metres depth then excavation should be possible using a scraper. The presence of rock will usually require the use of rippers for excavation. The longitudinal batter could be 1 in 3 or less, while the cross sectional batter should not be more than 1 in 2.

3. Turkey Nests

The current design and construction techniques for turkey nests are adequate although special attention should be paid to:
- removal of leaky topsoil from the base before construction;
- the selection of a non-dispersive soil construction material (Appendix 5);
- compaction at optimum moisture content. This can be achieved if construction is undertaken early in the Dry when soil is still moist. Every 100 mm layer of loose soil should be compacted.

Water Resources of Limbunya
For three days water supply from a turkey nest the following dimensions are recommended:

<table>
<thead>
<tr>
<th>NUMBER OF CATTLE</th>
<th>INNER DIAMETER AT BASE (metres)</th>
<th>INNER DIAMETER AT TOP (metres)</th>
<th>HEIGHT (metres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>6</td>
<td>13</td>
<td>1.1</td>
</tr>
<tr>
<td>500</td>
<td>8</td>
<td>16</td>
<td>1.5</td>
</tr>
</tbody>
</table>

These figures are based on sides with a 1 in 2.5 slope.
### APPENDIX 8

#### GLOSSARY

<table>
<thead>
<tr>
<th>Word</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AQUIFER</td>
<td>A body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities to bores and springs.</td>
</tr>
<tr>
<td>BATTER</td>
<td>Slope expressed as a ratio of horizontal to vertical distance.</td>
</tr>
<tr>
<td>BERM</td>
<td>Flat area between excavated area of tank and bund.</td>
</tr>
<tr>
<td>BORE</td>
<td>Small diameter hole constructed with a drilling rig, and down which a pump is lowered to extract groundwater.</td>
</tr>
<tr>
<td>BUND</td>
<td>Bank, constructed of compacted fill, used to contain water.</td>
</tr>
<tr>
<td>DEMAND</td>
<td>The volumetric flow rate required for stock watering, therefore the rate at which water would be supplied if available.</td>
</tr>
<tr>
<td>DRAINAGE-LINE TANK</td>
<td>Excavated tank built in an area which does not have a defined creek.</td>
</tr>
<tr>
<td>GROUNDWATER</td>
<td>Water contained in rock below the water table.</td>
</tr>
<tr>
<td>OFFSTREAM TANK</td>
<td>Excavated tanks built near creeks, and connected to the creek by a channel to tap the creek flow.</td>
</tr>
<tr>
<td>ONSTREAM TANK</td>
<td>Excavated tanks built across a well defined stream.</td>
</tr>
<tr>
<td>RELIABILITY</td>
<td>The frequency at which a tank would be able to supply the annual stock water demand, eg. 90% reliability means that the tank should be able to supply annual stock demand for on average every nine years out of ten.</td>
</tr>
<tr>
<td>SPILLWAY</td>
<td>A structure designed to overflow excess water out of a dam.</td>
</tr>
</tbody>
</table>

*Water Resources of Limbunya*
SPILL TAIL CHANNEL
A channel built downstream of the spillway to direct excess water back into the creek.

STANDING WATER LEVEL (SWL)
The level, below the ground surface, to which groundwater will rise in a bore or well.

STORAGE CAPACITY
The volume of water that can be stored in a tank up to its full supply level.

TOTAL DISSOLVED SOLIDS (TDS)
A measure of water salinity based on the quantity of solids left after evaporation of a litre of the sample.

WATERTABLE
The surface resulting when the standing water levels in adjacent bores in the same aquifer are connected.

Water Resources of Limbunya