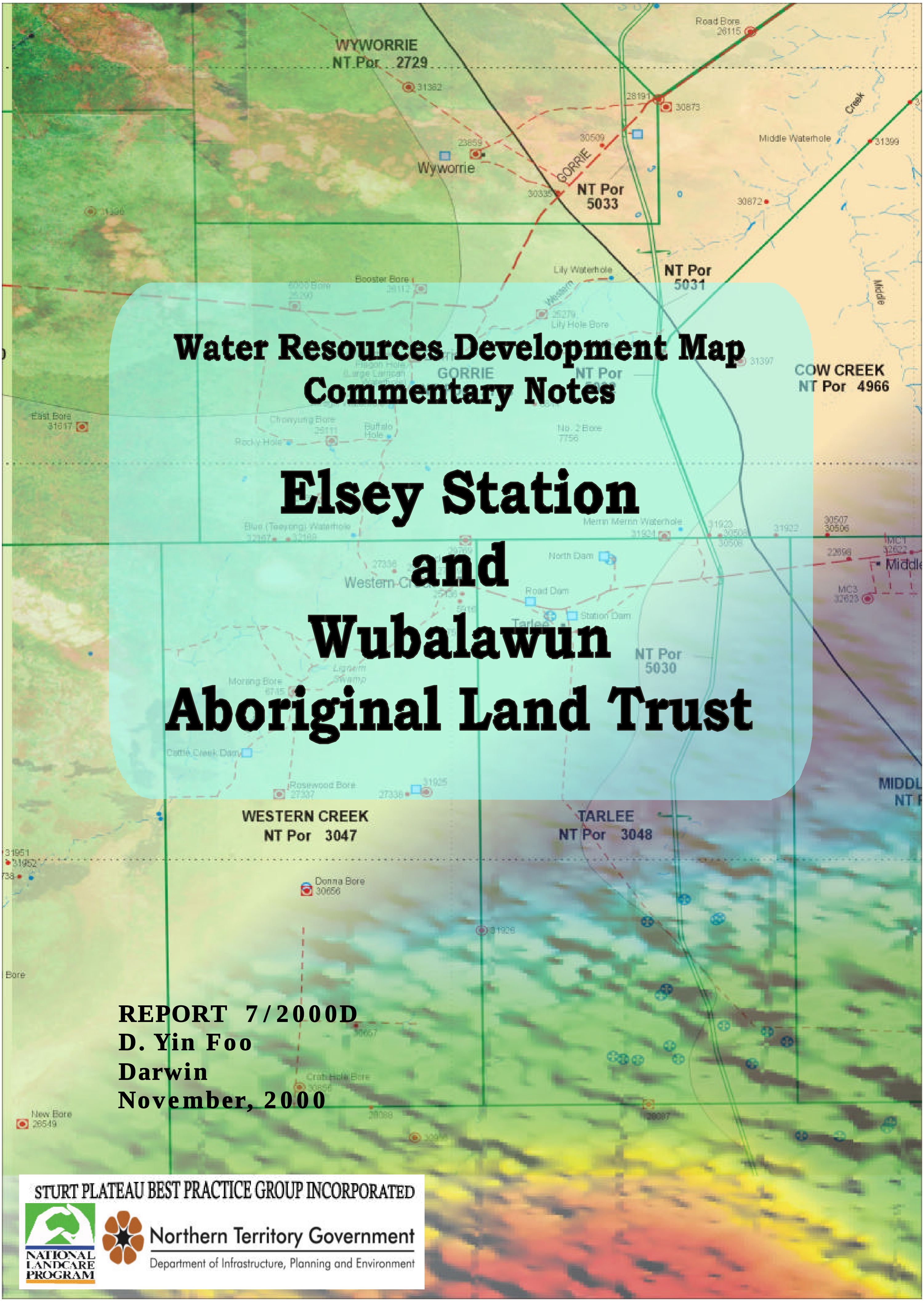

Water Resources Development Map
Commentary Notes

Elsey Station and Wubalawun Aboriginal Land Trust

REPORT 7/2000D

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Darwin

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STURT PLATEAU BEST PRACTICE GROUP INCORPORATED
NATIONAL LANDCARE PROGRAM
Northern Territory Government
Department of Infrastructure, Planning and Environment

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LIST OF ABBREVIATIONS

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

LIST OF CONVERSIONS

1 mm (millimetre)	=	0.04 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

PLATES

SUMMARY

This Water Resources Development map is designed as a guide in determining the most appropriate type of water supply for an area.

Groundwater within this map region is derived from a number of aquifer types. These include sandstone, siltstone and limestone. Prospects range from excellent, particularly from limestone aquifers in the central parts, to poor in the basalts of the south-western corner.

Surface water development options within the map region are mostly good, though patchy in the eastern part of Elsey Station. However, in developing the surface water potential of the area, it is useful to draw on experiences with dams elsewhere in the Top End. An effective dam must resist flood damage, have viable capacity and harvest adequate sheet and/or stream flow from the catchment.

Dam and tank construction on the Sturt Plateau is limited by difficulties associated with flat topography and low runoff potential. However, there is usually sufficient clay in the soil for viable dam construction. Evaporation is high and deeper dams with adequate storage to persist through the dry season may not always be an option. In such instances, shallower tanks or dams are still viable and will permit a greater area of pasture to be used for at least the early part of the dry season.

1.0 INTRODUCTION

This map and accompanying notes represent one in a series of four covering the Sturt Plateau region. The intention was to provide station managers with a map tool containing up to date information on water resources. In conjunction with other natural resources maps, planning and management at property scale will be feasible.

Joint funding of this project involving the Northern Territory Government and the National Landcare Program has made this work possible. Study of the water resources in the Sturt Plateau region, comprising 23 properties and land trust areas, was conducted between May 1997 and June 2000.

The Sturt Plateau region covers approximately 30000 km^2 and defines an area which extends between Mataranka in the north and Dunmarra in the south. The eastern boundary is featured by an upland area parallelling the Stuart Highway. It is bounded to the west by the Buntine Highway. Road access is good throughout the region. During the wet season, the main roads are generally accessible by light vehicles, although 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 about 800mm, occurs in the short hot monsoonal wet season between December and March. Recharge to groundwater systems occurs during this time. Little rainfall is experienced during the remainder of the year. Evaporation rates of water bodies such as dams or waterholes are between 5 and 11 millimetres per day (average about 8 mm per day or 2.8 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 29 degrees in June to 37 degrees in December. The corresponding average monthly minima are 13 and 24 degrees. Climatic data for Larrimah, at the centre of the Sturt Plateau, are presented in Table 1.

Plate 1 - Elsey Creek at the Roper River confluence

Plate 2 - 'Daylight's bore' on Elsey Station

Where development has occurred in this map sector of the Sturt Plateau, bores - with steel tanks as temporary storages, supply the vast majority of stock water needs. On Elsey Station, the Roper River represents a permanent surface water supply not found elsewhere on the Sturt Plateau. However, bores are still used to provide a conjunctive water supply. During the wet and the early dry season, most of the surface water that is accessible in the region is used, but as the dry season progresses, these sources become depleted. A few waterholes within the Elsey Creek system (eg. Longreach Waterhole) persist throughout the year.

TABLE 1

CLIMATIC AVERAGES for LARRIMAH

	Rainfall (mm)	Rain Days	Daily Min. Temp (°C)	Daily Max. Temp (°C)	Daily Evap. (mm)
January	201	15	24.0	35.5	10.4
February	191	15	23.6	34.3	7.9
March	154	11	22.5	33.7	7.5
April	33	3	19.6	33.8	8.6
May	14	1	16.2	31.4	6.1
June	5	1	12.8	29.2	5.0
July	4	1	12.0	29.0	6.0
August	0	0	14.7	32.1	7.2
September	5	1	17.9	34.7	6.9
October	27	3	21.6	37.0	8.6
November	65	7	24.1	37.7	11.4
December	113	10	24.3	36.9	8.3
Total	812	67			

2.0 WATER SUPPLY DEVELOPMENT

The accompanying Water Resources Development Map gives a broad view of the most likely and suitable development options for stock watering. The map classifications are based on a combination of information on groundwater occurrence, soil types and topography. Local conditions, such as soil types can vary considerably, so the maps should not be taken as a definitive guide to cover every situation. Detailed on-ground investigations are recommended when considering specific developments.

Water supply for domestic use is best sourced from groundwater as this option usually precludes the need for treatment and is the most reliable.

For an explanation of the colour codes on the main map, refer to the legend entitled “Water Resources Development Options”. Four categories of “preferred options” have been mapped:

OPTION 1 - Where natural waterholes exist, piping from these features is the most appropriate development option. Man made surface water developments are not suitable and the area is not likely to produce adequate stock supplies from bores.

OPTION 2 - Within this area, surface water development, particularly dams or excavated tank constructions, are viable and the area is not likely to produce adequate stock supplies from bores.

OPTION 3 - Groundwater is a viable option within this area. Surface water development is not suitable.

OPTION 4 - Water supply development is viable using either groundwater or surface water sources.

Some of the main features of the development map are:

- groundwater availability is good for the majority of the map. In some areas, geophysical information will aid site selection.

- there is a significant area which is suitable for surface water development in the central region. The construction of drainage-line excavated tanks are preferred due to the flat nature of the landscape.

- the south-eastern sector of Elsey Station is featured by uplands comprising sandstone ridges and escarpment country. Man-made surface water development options are not prospective mainly due to sandy soils, shallow rock and generally inaccessible terrain.

- The central to western half of the map features a deepening of the limestone basin. While this represents an area with potential for individual high yielding bores suitable for large scale irrigation, evaluation of the sustainable yield of the resource needs to be undertaken to prove the long term viability of such projects.

3.0 GROUNDWATER

Groundwater prospects across the area have been assessed using information on geology, ground and airborne geophysical surveys and from existing boreholes. Assessment of this data has enabled a more detailed side map entitled the 'Groundwater Resources Map', to be produced. 'The Thickness of Limestone Below the Water Table' and 'The Depth to Water Table' side maps should be used as guides to minimum bore depths and indicative pumping depths and are applicable to areas within the limestone basin.

Technical information on bores in the area is held on the Natural Resources Division's files and is available on request. Chemical analyses of groundwaters from all bores and guideline limits for common uses are listed in Appendix 2 and Appendix 3 respectively.

Plate 3 - Karstic weathering

Most bores on the map area are concentrated in the established part of Elsey Station and these provide water supplies to paddocks adjacent to the Roper Highway and Roper River. Groundwater supplies are sourced from a number of different aquifer types across this part of the station. Sandstone, siltstone and shale formations of this area are highly weathered and aquifers have developed in localised fractures and weathering features. Bores in these aquifers usually produce adequate yields of stock water. Other bores have intersected basalt or dolerite above or within the sandstone formation and have had moderate success.

The most extensive groundwater resource exists within a limestone formation in the region. This resource parallels the Stuart Highway in the western part of Elsey Station and is largely undeveloped. This system is described as karstic - a term which describes a landscape resulting from dissolution and weathering of limestone, and is usually noted for cavern development. An aquifer thus formed comprises a myriad of interconnected cavities and fractures developed within the horizon of the host rock, which allows movement of groundwater through it. Successful bores intersect submerged cavities, voids and fractures in the formation. This resource sustains the many springs in the reach of the Roper River approximately between Mataranka and Elsey homesteads.

Three descriptors of likely success are referred on the Groundwater Resources Map – poor, moderate and high. Success is gauged in terms of the stock watering capacity of bores. Bores yielding above 0.5 L/s are regarded as successful.

Plate 4 - Drilling on the Sturt Plateau

Consider a typical case of a paddock holding 1000 head of cattle (each consuming 50 litres per day). Adequate stock watering is represented by a pumping regime yielding a minimum of 0.5 L/s continuously. This equates to a bore yielding 1 L/s to run two days out of four. A bore yielding more than 2 L/s to top up storages intermittently would provide a safe margin.

The likelihood of success is considered poor if yields of less than 0.5 L/s are expected. A moderate likelihood is applicable to areas where bores may be expected to yield between 0.5 L/s and 5 L/s, and high if greater than 5 L/s. The delineation of these areas is based mainly on experience in the type of aquifers and geological knowledge, and also the success rate of other bores drilled in the same formation.

Water quality from most aquifers across this region of the Sturt Plateau is suitable for stock. Some bores in the vicinity of Djilkminggan provide water which is marginal for human consumption. High salinity has only been reported from one bore RN 31168, drilled on Elsey Station. Appendix 2 tabulates the available water analyses from bores in the area.

Five different groundwater environments are depicted on the Groundwater Resources map. These are categorised in terms of the prospect of success of bore sites (ie. poor, moderate, high). The cross-section A-B presents a schematic representation of these environments.

3.1 Areas of Poor Likelihood of Success

In the south-western corner of this map sheet, occupied mainly by the Wubalawun Aboriginal Land Trust area, shallow subcropping basalt represents a zone of low prospectivity for groundwater. Obtaining successful bores will depend on locating fractures in the rock and these may be difficult to locate as they are masked by a thin cover of other sediments. Bores intersecting the weathered horizon of the basalt occasionally yield about 0.3 L/s. This supply could be considered adequate if intended for homestead use only. Bores intersecting fractured rocks may yield 1 to 2 L/s.

This area is not recommended for artificial water supply development (refer Development map). However, if bore supplies are required (eg. for stock water development), geophysical surveys should be considered as this currently presents the most cost-effective option in locating potential bore sites within this zone. An appropriately designed geophysical investigation should aim to locate fractures in the rock, which can then be targeted with drilling. Costs will mainly depend on the technique used.
The basalt aquifers usually occur as isolated and independent aquifers and hence the water quality from different bores vary. However, the water quality is expected to be satisfactory for stock with hardness levels bearing a general similarity to the limestone waters. That is, hard to very hard and scale forming.

Other aquifers which exist in the uplands area to the east of Elsey Station are those in basalt, dolerite, siltstone, shale and greywacke rock types. These rock types are sometimes ‘mixed’ with or within the sandstone beds of the area. While some consistency in locating successful bore sites in weathered sandstone, shale and siltstone beds is noted (RN’s 4495, 5557 and 7323), the other rock types are generally not favourable unless associated with faulting. Bores RN 3545 (No. 5 bore) and RN 5047 (Mt. Sir James bore) have been successful in locating a supply *beneath* a layer of basalt. Therefore, this area is considered to be of moderate to poor prospect for successful bores and some assistance, such as geophysics or aerial photograph interpretation, is recommended to enhance the likelihood of success.

Water quality does not appear to be an issue. A measure of salinity, known as total dissolved solids (TDS), is considered the primary indicator of water quality.
The desirable limit for human consumption is 500mg/L, although up to 1500mg/L is acceptable. Cattle will tolerate a TDS of up to 10000mg/L. The water quality of bores in shale vary significantly, however, TDS values range to a maximum of 1000mg/L.

3.2 Areas of Moderate Likelihood of Success

The Groundwater Resources side map identifies two environments in which there is a moderate likelihood of success. These aquifer types are the sandstone and the limestone aquifers.

Sandstone outcropping as ridges and low hills forms the upland country extending along the eastern flank of Elsey Station and is noted for difficult access to some parts. Aquifers occur in weathering features and fractured areas associated with faulting. Most station bores drilled in this area obtain adequate stock supplies from this aquifer type. Site selection for stock bores does not appear to be critical.

The second aquifer type is within the limestone formation found mainly in the central region of the map. This aquifer is high yielding, except on its eastern margins where the formation thins out. This area is represented as a narrow band on the map. Here, the amount of submergence, described as the thickness of limestone below the water table, diminishes. Correspondingly, the likelihood of success also diminishes. Bore yields will be highly variable and can be expected to range from 0.5 L/s to more than 5 L/s, depending on submergence.

Groundwater quality, from all aquifers in the region appear to be suitable for stock. The sandstone bores in the region typically produce water with a TDS of less than 500mg/L.

Major variations in water quality are present within the limestone aquifer, which produces water with a TDS typically ranging from 1000mg/L to 2000mg/L. Notably, the higher values appear to be associated with the aquifer in the region of Djilkminggan, and are possibly influenced locally by the catchments of Salt Creek and the lower reaches of Elsey Creek. High salinities result from a combination of carbonates, and sulphate and sodium chloride salts.

Generally, the limestone waters are very hard (total hardness greater than 500mg/L) and scale forming. Measures can be taken to minimise the occurrence of scale development on elements of the reticulation. These include control of thermal variation of the reticulated water and limiting the aeration of the water.

3.3 Areas of High Likelihood of Success

Within the map region, this area lies east of Birdum Creek, parallelling the Stuart Highway. Here, the limestone formation is at its thickest (see Cross-Section A-B), diminishing towards the east. Mapping of the eastern boundary of this zone is based on aquifer submergence exceeding 20m.

In this area, there is only a very low risk of failure for stock bores. Bores usually yield in excess of 5 L/s from limestone. Up to 35m of clays and sandy sediments overlie the limestone.

It is important to note that although the aquifer in this area may produce high yielding bores, there is currently a low level of information available on which to assess the sustainability of the resource. Issues of resource sustainability, environmental impact and allocation need to be addressed in these areas if large scale water usage (eg. for horticulture) is considered.

4.0 SURFACE WATER

Few man made surface water storage constructions exist throughout the Sturt Plateau region. The flat topography, low runoff potential and high evaporation rates may make excavated tank and dam construction unattractive as primary water source options. However, regardless of the difficulties that these factors pose, surface water development options do exist for most areas and formal and purposeful design will provide these options. Even if preferred as secondary options, shallow tanks or dams will permit a greater area of pasture to be used for at least the early part of the dry season.

The Roper River in the northern part of this map represents the only permanently flowing surface water supply on the Sturt Plateau. The availability of permanent water made possible the establishment of Elsey Station, its subsequent development along the river and the Roper Stock Route. The many springs in the Mataranka area, and in the reach of the river as far as Elsey Homestead, are due to the discharges of the regional limestone aquifer. The springs are natural outflow points for groundwater, occurring where the water table has been incised by the river bed. The result is that the flow in the Roper River is maintained throughout the year.

Plate 5 - Warloch Ponds looking downstream from the Stuart Highway road bridge (March, 2000)

The major drainage systems in the map area include the Strangways River, Cattle Creek and Elsey Creek - each draining into the Roper River, but representing different catchment types. The Strangways River and Cattle Creek drain the ridge and rocky, sometimes sandy, undulating and dissected country of the uplands area on the eastern part of Elsey Station. Although runoff from this area is good, the generally difficult nature of the terrain and presence of shallow rock makes it unsuitable for cost-effective tank excavation and dam construction.

In contrast, Elsey Creek captures a large part of the flows from the flat Sturt Plateau region, which includes the Western Creek and Birdum Creek systems. Flow records exist for Elsey Creek, which indicate that only a small percentage of rainfall (less than 10%) eventually contributes to sheet flows over the catchment. Flow only occurs during the wet season after the catchment has been adequately wet or following significant rainfall events. Initial wetting of the catchment may account for up to 40% of the total seasonal rainfall each year. See map side graphs for Elsey rainfall (at Elsey Homestead) and Elsey Creek flow data (at Warloch Ponds).

Typically, the drainage systems deplete to form isolated pools in the rivers and waterholes. The majority of these are dry by August or September. Longreach waterhole, downstream of Warloch Ponds, is a permanent waterhole and considered to be maintained by a shallow water table in the groundwater system of the area.

The region's suitability for surface water development has been assessed by broadly adapting the land systems classifications and supplementing this information with field testing. The Land Systems Classifications (Reference 1), which integrate factors including topography, soil and vegetation types provide an approximation of relative runoff characteristics. Field investigation at a number of localities has allowed assessment of site suitability in terms of depth and clay content and enabled comment on the water retention characteristics of various soils. The results are presented as the Surface Water Resources Map, one of the side maps accompanying the Water Resources Development Map. However, it should be noted that the broad scale of this map is primarily for planning purposes and does not preclude the need for site specific investigations.

4.1 Surface Water Storage Types

By its nature, monsoonal rainfall in the Top End gives rise to discrete, sometimes significant flow events in local drainage systems. Dam construction types, which are sympathetic to this regime but enable effective and adequate harvest of surface water, are limited. The general lack of defined drainage courses on the Sturt Plateau further limit options.

Three types of excavated tanks are suitable for the generally flat to gently sloping plains of this map region. They are on-stream tanks, off-stream tanks, and drainage-line tanks (see Figure 1). An on-stream tank is one dug in a well defined stream channel. Off-stream 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 on-stream excavated tank requires a high standard of design and construction and is prone to erosion and silting because of its location in a fast flowing main stream channel. The off-stream design (see 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 on-stream design, but has high excavation costs as to take advantage of short duration stream flows, the tank level must be below that of the natural stream bed.

The drainage-line tank or hillside storage is constructed in flat to moderately sloping areas where there are no clearly defined incised creeks. This type of construction is considered the most suited to this area. The tank itself is of the same design as the off-stream one, but without an inlet channel (see Figure 3). Sheet flow on the plains, with its low silt load, is then harvested. Catch drains or wing walls directing flow towards the dam may be used to enhance interception capacity.

Some common problems experienced with excavated tanks include:
- inadequate spilltail channels do not direct water away from bunding
- erosion of wing walls
- silting of catch drains

Regular maintenance is required before the wet season to correct these problems.

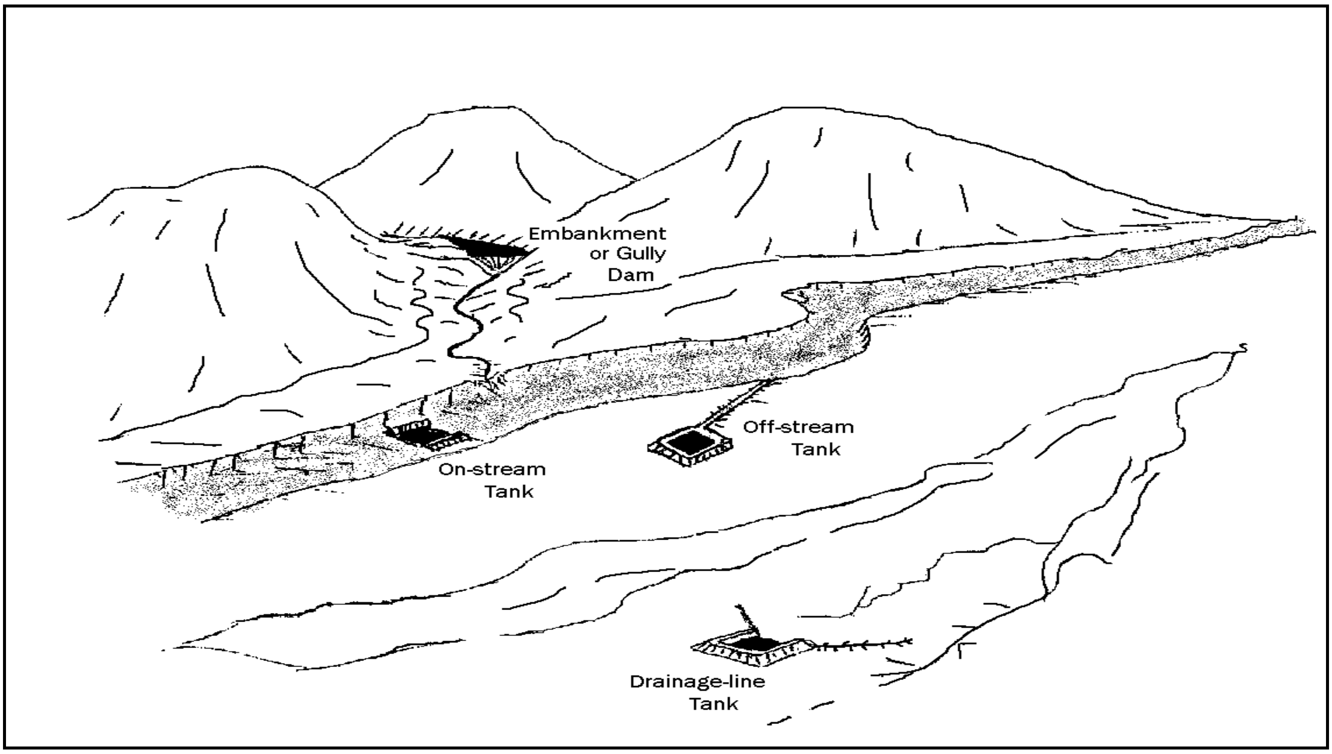

Figure 1. Types of Dams and Embankments

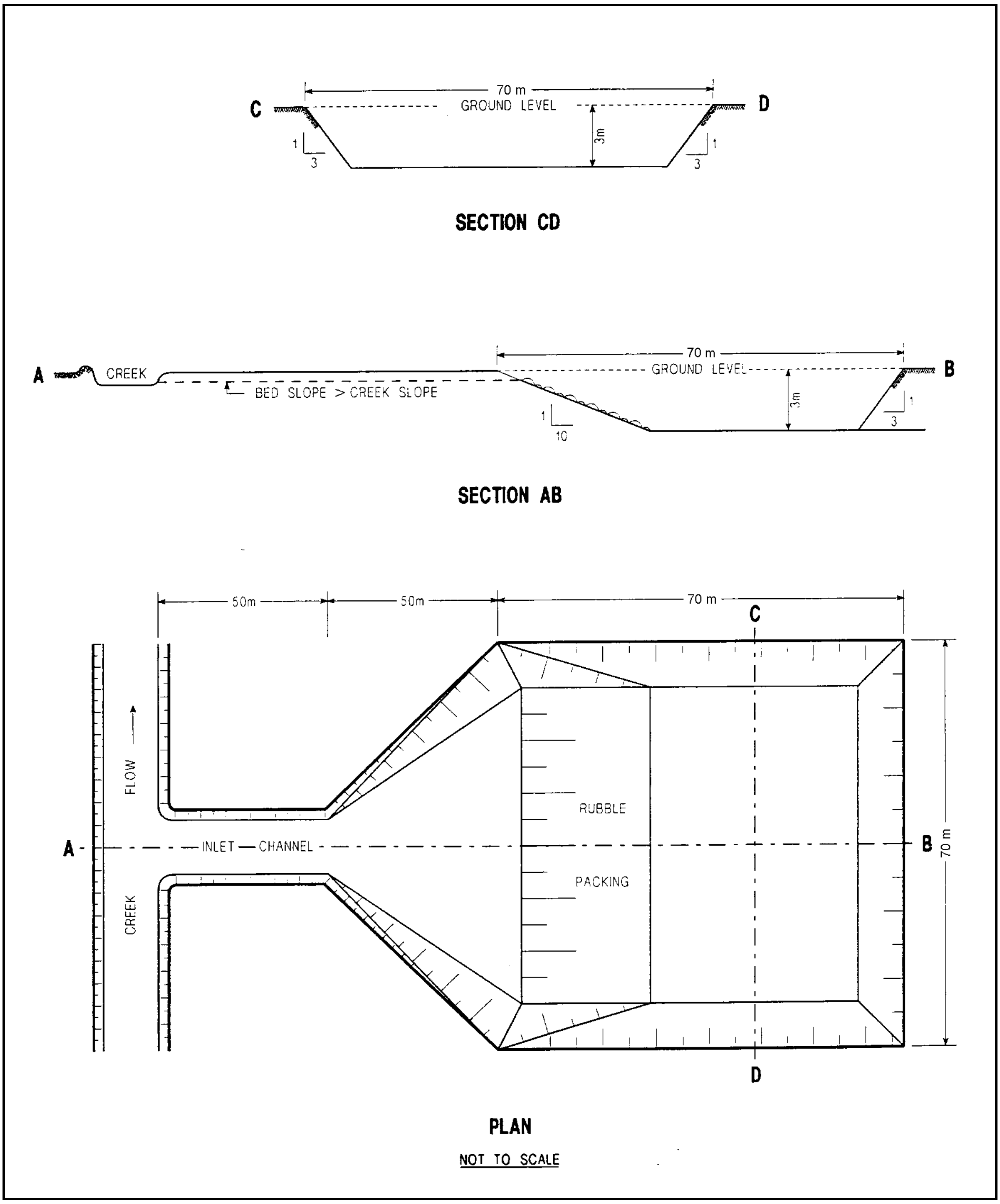

Figure 2 Typical Off-Stream Excavated Tank

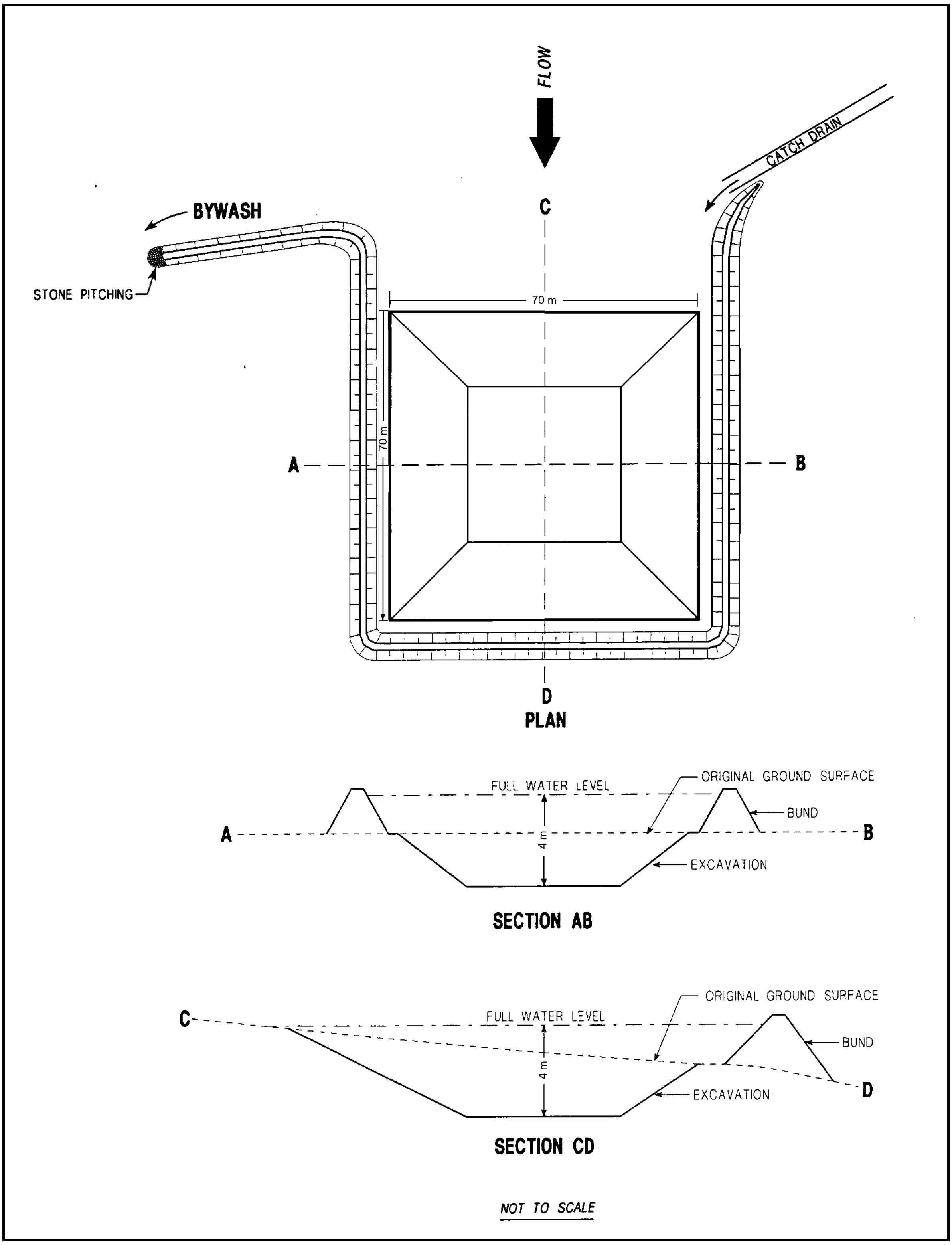

Figure 3 Typical Drainage Line Excavated Tank

Another type of dam, the gully or embankment dam, is suited for 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 gully dams involves potential high costs in dealing with the foundation and mitigation of flood flows with diversion through an adequate by-wash or spill. It is recommended that appropriate planning and design be undertaken, particularly for construction on rock foundations.

The "Earth Movers Training Course" booklets 9 and 10 (Reference 2), provides an excellent background guide to dam building and design. However, it is important that the information be considered in conjunction with local knowledge as many of the dam types are only applicable to the less extreme conditions experienced in southern climates.

4.2 Selection of Sites for Excavated Tanks

Plate 6 - Soil sampling with a small auger rig

The availability of runoff and depth of impermeable soil are usually the determining factors in site selection for excavated tank construction. The Surface Water Resources side map indicates that most of the area suited to excavations and dam construction lies in the western half of Elsey Station and part of the Wubalawun Aboriginal Land Trust area. Here, the soil appears to have sufficient clay content and rainfall runoff conditions are adequate.

A drainage-line tank is best suited to this country where there is flat or gently sloping ground. Excavation will be minimised where the tank site has some slope, say about 1:100, to allow bunds constructed from excavated material to add to the storage volume of the tank. Drainage-line tanks may also be feasible in areas immediately adjacent to the low hilly country on rippable laterite horizons if there is sufficient depth of clayey soils.

A few areas have been mapped indicating where ferricrete is predominant on the surface. This rock, in its 'in-situ' form is highly permeable and would appear to be non-prospective as a foundation for shallow dam or tank construction.

However, Avago and Hidden Valley have conducted informal trials in such areas using small holding dams, and report that success has been achieved over a short period of time, simply by allowing animals to 'work' the soil in the dams. After the soil is 'pugged in', a seal is effected. A number of landholders, through personal communication, report a similar result is commonly noted in sinkholes, where once freely draining 'holes' are 'pugged' when animals are allowed access into them.

Areas mapped with variable soils are minor, but they may also be suitable for excavated tanks. In these areas, there is a likelihood of encountering dispersive or sandy profiles, or high permeability zones and these should be avoided. Remedial work such as installing a clay liner brings added expense, but would be necessary.

4.3 Design and Construction of Excavated Tanks

In this section, empirical calculations are used for example purposes only. However, it serves to demonstrate typical dimensions which may be encountered on the Sturt Plateau.

The design dimensions for an excavated tank are determined by the number of stock in the paddock to be watered. This is often governed by the carrying capacity of the country and grazing radius. On the Sturt Plateau, this would be typically between 400 and 800 head. Based on a consumption of 50 litres per head per day, the corresponding water requirement is between 6 ML and 12 ML for the 9 month period from April through to December. With a depth of about 4m, which is the minimum preferred for good reliability and 1:3 batters, the larger tank would measure approximately 70m square at the top.

Following from this example, a storage of 12 ML (if neglecting evaporation and leakage losses) as a drainage-line dam would need a minimum catchment area of about 1 km^2 for the typical environment. This figure assumes an average annual rainfall of 700mm, a runoff threshold of 60% of rainfall and a runoff coefficient of 5%. For tank sizes of larger or smaller storage capacity, the required catchment area would need to be varied correspondingly to capture the required amount of runoff.

The proposed design is indicated in Figure 3 and is relatively simple. Excavated soil can be dumped to waste or used to build a bund on three sides of the tank. 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. The excavated volume in this example is large for the proposed design dimensions (approximately 10,000 m^3) so construction costs will be high (usually in the order of $\$1/m^{3}$). The cost will also be influenced by ground conditions. Tank construction is described in more detail in Appendix 5.

An off-stream tank shown in Figure 2 is similar and with 12ML capacity. However, its 'filling' capability is controlled by the elevation of the inlet channel in relation to the creek bed and the nature and frequency of flow in the creek. The hydrology of the creek would therefore need to be examined to enable a viable tank to be designed.

4.4 Waterholes

In the dry season, natural waterholes are found in depressions in streambeds and floodplains. Most are shallow and become dry a few months after the end of the wet season. The available capacity of some waterholes may be increased by excavation of the base (Appendix 5), but only where clay or a rippable and impermeable rock underlies the site. 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.

4.5 Piping of Surface Water

Surface water may be piped from borrow pits into turkey nests and this practice is effective as an alternative low cost option where possible. The use of turkey nests is a good option as losses to evaporation can be minimised. 50mm polythene pipe, buried where possible, can be used to pipe water to about 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.

Piping is a recommended stock water development option for a large portion of the Wubalawun Aboriginal Land Trust where there is shallow basement rock or the veneer of surface soil is sandy. Water may exist in shallow natural waterholes immediately following the wet season and piping to turkey nests should be considered.

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

Plate 7 - 'No. 1 bore' on Elsey Station

rates are given in Appendix 5. 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 main advantages are mobility and ease of maintenance.

5.0 RECOMMENDATIONS

- The water resources development map should be used during the conceptual planning stage to determine the type of water supply most appropriate to the development of specific areas of the property. In areas where a number of options are available, economics will normally determine the final development type selected.
- Groundwater is available over much of the region.
- 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 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

Over-grazing will severely reduce ground cover and eventually, initiate soil erosion. A major adverse effect is the degradation of pasture quality by allowing non-beneficial 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 steel tanks / 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 cattle spread over a greater area. Figure 4 is an example layout showing the potential increase in the size of the grazing area due to improved water reticulation from a bore or tank.

5.2 Groundwater

The prospect for obtaining a groundwater supply in the map area is generally good. Adequate stock water supplies may be obtained from aquifers in the limestone and sandstone formations underlying most of the region. Such areas are indicated on the 'Groundwater Resources' side map. 'The Depth to Water Table' and 'Thickness of Limestone Below the Water Table' side maps should be used to indicate likely pumping depths and maximum drilling depths.

Bore siting is critical in some areas. Where groundwater prospects are mapped as poor, water supplies are usually only available in basalt, dolerite, siltstone or shale aquifers. If groundwater options are to be pursued in these areas, geophysical or other aids should be utilised to locate specific targets for drilling.

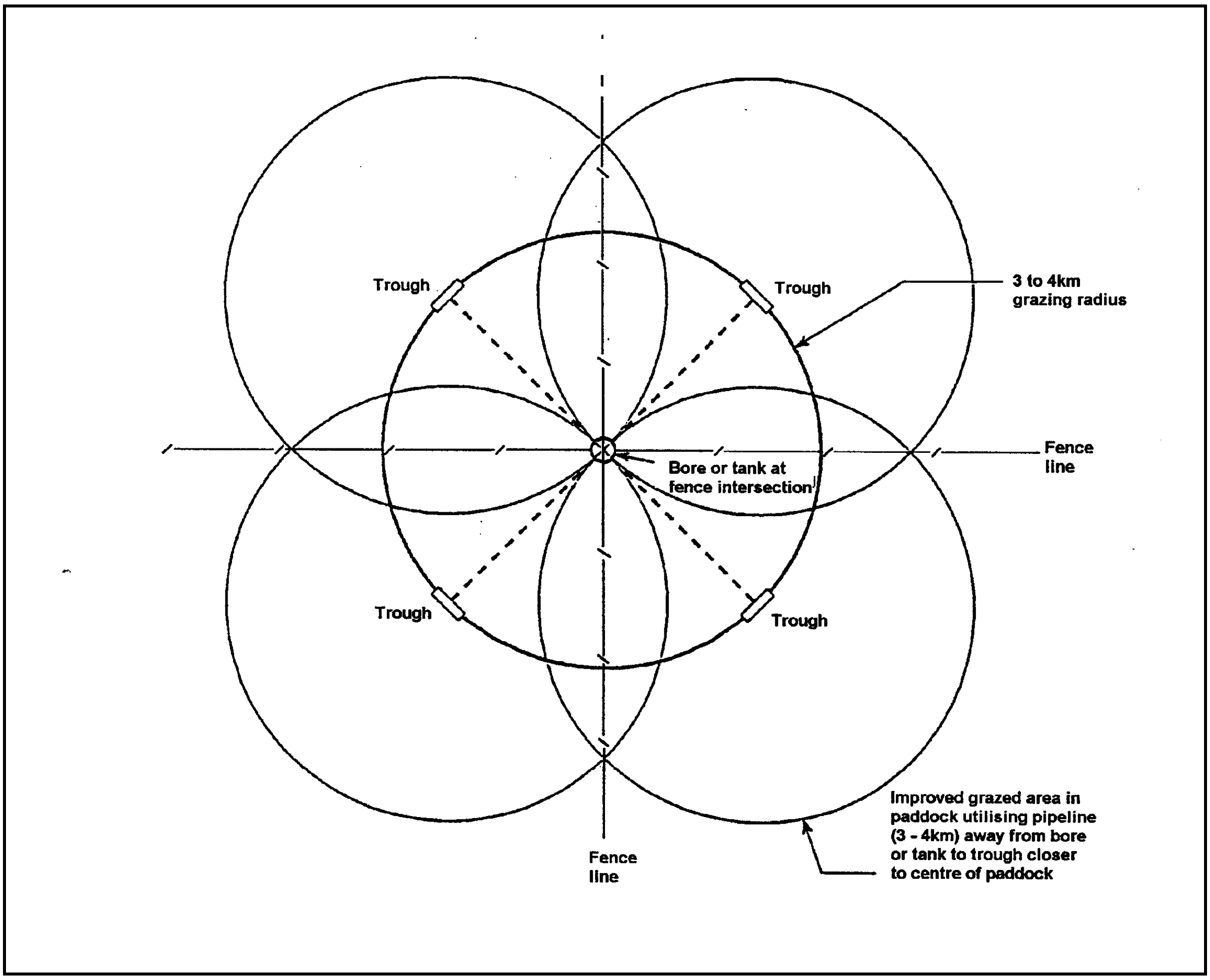

Figure 4 Sketch showing increased size of grazing area due to improved water reticulation from bore or tank

5.3 Surface Water

The 'Surface Water Resources' side map accompanying the main map provides an indication of the potential for dam and excavated tank construction over the area. However, this is based on broad scale mapping and intended for planning purposes only. Site specific investigations will need to be conducted to ascertain the viability of particular sites.

Drainage-line and off-stream type excavated tanks are recommended for areas suited to development. These construction types are less susceptible to washout during seasonal flooding, and more effective in harvesting the low runoff available from the catchments on the Sturt Plateau.

In areas where clayey soils are shallow or there is underlying shallow rock, small capacity excavated tanks may still be considered. The supply may not be sustained throughout the year, however, a greater spread of grazing will be possible for the initial part of the dry season.

6.0 ACKNOWLEDGMENTS

The author would like to thank the managers, families and staff of all stations involved for their time, assistance and fruitful discussions during the study.

The work of Anthony Knapton contributed largely to the outcomes of this project. His assessment and analysis of the geophysical components, particularly airborne magnetics, laid the cornerstone for the current understanding of the basement structure.

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Acknowledgment and thanks is also extended to Paul Schober who assisted in the geophysical and ground surveys, Jeff Fong of the GIS unit who drafted the maps and figures for the report, and the drilling and bore testing crews of the Technical Services Group.

7.0 REFERENCES

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8.0 GLOSSARY

AMG EASTING	The east-west coordinates of the bore in metres from the grid's origin. It refers to the grid lines on the map.
AMG NORTHING	The north-south coordinates of the bore in metres from the grid's origin. It refers to the grid lines on the map.
AQUIFER	A body of rock that is sufficiently permeable to transmit groundwater and to yield economically significant quantities to bores and springs.
BATTER	Slope expressed as a ratio of horizontal to vertical distance.
BERM	Flat area between excavated area of tank and bund.
BORE	Lined hole constructed with a drilling rig and which is used to extract groundwater.
BORE DIAMETER	The minimum internal bore diameter in millimetres
BORE REGISTERED NUMBER (RN)	A number assigned by the Natural Resources Division to each registered bore.
BUND	Bank constructed of compacted fill used to contain water.
CASING	Tubing used to line boreholes. The length of casing in the hole is expressed in metres and its internal diameter in millimetres.
DEMAND	The volumetric flow rate required for stock watering therefore the rate at which water would be supplied if available.
DEPTH DRILLED	The total depth of the bore in metres below ground level.
DISSOLUTION	The process where rock has been dissolved by water and the component parts are carried in solution.
GROUNDWATER	Water contained in rock below the water table.
KARSTIC	Term which denotes the characteristic scenery of a limestone region.

OFF-STREAM TANK	Excavated tank built near creeks and connected to the creek by a channel to tap the creek flow.
ON-STREAM TANK	Excavated tank built in the bed of a well defined stream.
PERENNIAL	Lasting throughout the year, or through many years.
PUMPING RATE	The recommended pumping rate in litres per second.
PUMP SETTING	The recommended depth below ground level at which the pump intake should be set.
SLOTS	The apertures located in the casing adjacent to the aquifer. An interval over which they exist is usually expressed between depths in metres below ground level.
SPILLWAY	A structure designed to overflow excess water out of a dam.
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.
WATER TABLE	The surface resulting when the standing water levels in adjacent bores in the same aquifer are connected.
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.

APPENDIX 1

BORE TEST REPORTS

Test reports for bores within the region are included in this Appendix. Further details of the bore tests and other bore information is available from the Natural Resources Division in Darwin.

1. General Recommendations for Finishing, Operating and Protecting Groundwater Bores.

Attention to the following points will prolong the life of the bore supply and help prevent pollution of the groundwater resources.

a. Construct a concrete apron around the borehead to prevent surface flow and any spillage from entering the bore.

b. Seal the space between casing and pump equipment to prevent entry of small animals, insects, dirt and pollutants.

c. Maintain pumping equipment in good order to prevent pollution. Avoid spillage of fuel and oil on the ground around the bore.

d. Keep stock away from the bore head. Discourage domestic activity at the bore and store fertiliser and other chemicals at least 50 metres distant.

e. Pumping the bore at higher than recommended rates may cause sand intrusion and lead to instability or pump problems. Seek advice from this office or other qualified source.

f. When bore is not equipped or no longer required it should be securely capped. If the bore is to be abandoned, the casing may need to be removed, the bore backfilled and cement plugs placed.
NB. This requires the services of a registered driller

Please ensure that the BORE IDENTIFICATION TAG is retained securely at all times. The registered bore number, RN, is the Natural Resources Division's only reference to the scientific and engineering data on this bore and hence important to this Division’s records for advice to bore owners.

LANDS PLANNING ENVIRONMENT
Northern Territory Government

NATURAL RESOURCES DIVISION
TEST REPORT – RN 31953

Bore Location. Elsey Station
Map: GORRIE 1:100,000 Sheet: 5567
Grid Reference: 031000 - 8318850

Client: Natural Resources
Purpose: Stock

****

RECOMMENDATIONS: Pumping Rate 4 L/s **Pump Setting: 35m**

For alternative pumping rates or settings contact:
General recommendations are on reverse side.
In all correspondence please quote **RN 31953**

Natural Resources Goyder Centre
25 Chung Wah Terrace
Palmerston NT 0831

Bore Data:

Finished depth: 85.37 m Completion date: 8.9.98
Standing Water Level: 27.03 m on 18.8.99
Construction Details:

Test Date: 18.8.99
Test Rate: up to 5 L/s
Test Duration: 8.5 hours

Interval	Description
0 - 57.50 m	**152 mm ID steel casing**
57.5 - 89.39 m	**150 mm open hole**

Notes: 1. Top of casing when tested was 0.5 m above ground.
2. All depths are measured from natural ground level.
3. Test rates do not necessarily indicate a sustainable yield for production pumping.

WARNING: MINIMUM INTERNAL BORE DIAMETER IS 150 mm.
MINIMUM INTERNAL BORE DIAMETER TO RECOMMENDED PUMP SETTING IS 150 mm.

****

COMMENTS:

1. The above recommendations are based on multi-rate tests to 5 L/s and assume that hydrological conditions remain constant.

2. Provision to monitor water levels and obtain water samples while pumping should be incorporated when bore is equipped.

3. Pumping rate limited to 4 L/s due to ingress of fine sand. This will clear with continual pumping.

4. Higher rates may be possible from this bore, further testing would be required.

****

WATER ANALYSIS: 1053

Prepared by: D Hill 14/10/99

Checked by: B Thatcher 14/10/99

APPENDIX 2

CHEMICAL ANALYSES OF GROUNDWATERS

The following table lists chemical analyses of bores sampled in this region. See Appendix 3 for quality guideline limits for stock and domestic consumption.

Table 2 Water Quality Data

Bore RN	Sample Date	Conductivity (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarbonate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magnesium (mg/L)	Nitrate (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Sulphate (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Silica (mg/L)	Sampling Data
550	11/11/55				681	540	1322	116	200		61		12	127	123	1.86			
550	03/10/68	1900	7.7	354	216	445	810	53	180		53		14	135	119	0.7	0.1		
550	10/05/90	1680	6.8	514	627	573	1015	136	182	300	57		17	141	145	0.3	10.1		
550	08/11/94	1650	7	514	627	604	1000	156	185	305	52	3	18	143	147	0.2	0.1	43	
550	12/02/97	1648	7.5	103	126	682.8	969	55	186	306	133	3	10	127	164	0.5	9.2	26	1.2L/s, 38m, pumped
2326	15/10/68	1600	7.4	416	254	580	1010	65	200		78		7	160	201	0.6	0.1		
2379	15/10/68	395	7.3	222	135	218	200	50	6		5		2	3	2	0.1	0.3		
3545	15/10/68	430	7.9	220	134	190	250	27	16		28		5	22	2	0.4	6.1		
4142	15/10/68	530	7.9	276	168	72	310	14	14	23	8		7	105	2	0.2	0.2		
4495	14/10/68	690	7.8	342	209	286	360	43	16	26	44		4	39	17	0.6	0.4		
5149	02/10/65	1900	8.1	362	192	620	1039	36	218		127		21.5	249	96		0.1		
5152	15/10/68	800	7.5	216	132	222	490	37	108		32		9	95	54	0.6	1.4		
5557	01/09/66	758	7.8	320	195	280	422	26	56	99	52		8	60	5		0.6		
5557	15/10/68	700	8.1	326	199	292	390	43	60	100	43		7	55	4	0.5	0.3		
7323	05/11/70	1100	8.3	551	672	268	650	7	67		61		18	170	22	1.1	4.4		6L/s, 61m
8149	21/07/73	690	7.4	12	15	43	380	7	140	231	6	1	1	116	87	0.9	14	25	1.9L/s, 67m, airlift
8241	14/11/73	1010	6.9	122	148	243	650	48	141		30	3	1	120	198	0.3		12	3L/s, 60m, airlift
8361	18/07/74	2860	7.3	508	619	1000			470	775									19L/s, pumped

Table 2 Water Quality Data (continued)

Bore RN	Sample Date	Conductivity (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarbonate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magnesium (mg/L)	Nitrate (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Sulphate (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Silica (mg/L)	Sampling Data
8361	18/07/74	2570	7.3	513	625	930			442	728									19L/s, pumped
8361	19/07/74	2650	7.3	510	622	940	1810	184	413	681	117	3	26	245	415	0.8	0.1	44	19L/s, pumped
8362	20/07/74	2560	7.3	511	623	940			403	664									24L/s, pumped
8362	20/07/74	2660	7.3	510	622	980			442	728									24L/s, pumped
8362	21/07/74	2570	7.3	518	631	912	1785	176	394	649	115	3	28	242	415	0.8	0.1	45	24L/s, pumped
20745	15/04/81	1260	7.7	423	516	398	950	46	130	214	69		25	161	182	1	16		6L/s, 9m, airlift
20745	23/05/81	600	7.5	215	262	276	380	76	50	80	21		4	13	11	0.1	0.6		1.5L/s, 8m, pumped
20746	15/04/81	2420	7.5	436	531	707	1490	86	340	560	120		35	272	413	0.8			6L/s, 16m, airlift
20746	22/05/81	2740	7.5	533	650	815			387	638									4L/s, 12.3m, pumped
20746	22/05/81	2710	7.2	531	647	808	1700	120	378	620	124		38	290	430	0.8	4.4		4L/s, 12.3m, pumped
20747	16/04/81	2400	7.6	421	513	678	1490	86	342	564	113	2	34	274	415	0.9		52	6L/s, 13.5m, airlift
20747	23/05/81	2720	7.3	531	647	831	1690	124	390	644	127	1	37	290	423	0.8	0.8	53	6L/s, 9.1m, pumped
20747	28/09/93	1880	7.3	546	666	682	1160	138	211	348	82	1	22	164	228	0.5	0.4	52	pumped as equipped
20747	24/04/97	3050	7.5	543	662	861	2048	90	500	824	155	2	32	345	508	0.5	0.1	56	3L/s, 30m, pumped
25437	10/05/90	1680	6.8	514	627	573	1015	136	182	300	57	3	17	141	145	0.3		45	pumped as equipped
29012	11/01/94	1740	7.2	504	615	603	1080	149	190	313	56	4	28	164	175	0.4	0.2	42	18L/s, 76m, pumped
29012	28/11/97	1730	6.7	498	607	536	1060	126	211	348	54	4	24	155	190	0.1	0.2	39	1L/s, 45m, pumped
31953	18/08/99	1580	7.3	445	543	553	952	121	178	293	61	3	22	137	200	0.5	0.2	40	pumped
32448	28/11/99	2450	8.0	371	452	621	1540	58	376	620	116	1	32	306	400	0.6		57	12m, airlift
32448	28/11/99	2470	7.9	447	545	651	1540	57	344	567	124	1	31	311	400	0.4		56	30 m, airlift
32448	29/11/99	2600	7.9	411	501	692	1650	70	399	658	126	1	32	300	430	0.4		54	66m, airlift

APPENDIX 3

WATER QUALITY STANDARDS FOR STOCK AND DOMESTIC USE

1. WATER QUALITY STANDARDS FOR STOCK USE

SUBSTANCE	GUIDELINE VALUE
pH range	6.5 - 8.5
Total dissolved solids	10000mg/L
Sodium chloride	Not more than 75% when total dissolved solids near limit
Sulphate	2000mg/L
Nitrate	400mg/L
Fluoride	2.0mg/L
Magnesium	300mg/L

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.

SUBSTANCE	GUIDELINE VALUE	
pH range	6.5 - 8.5	*
Total dissolved solids	500mg/L	#
Chloride	250mg/L	#
Sulphate	250mg/L	#
Nitrate	50mg/L	+
Fluoride	1.5mg/L	
Hardness (as Calcium Carbonate)	200mg/L	*
Sodium	180mg/L	*

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

APPENDIX 4

EXCAVATED TANK 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 booklet entitled "Design and Construction of Small Earth Dams" (Reference 4). 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 present leakage problems
- show if there is any impermeable and soft rock present, such as rippable hard clays or laterite
- 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 on-stream 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 sub-surface 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
- silting must not be excessive

1. Seepage Loss

In most areas, the water table will be deeper than the proposed 3 to 4 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.

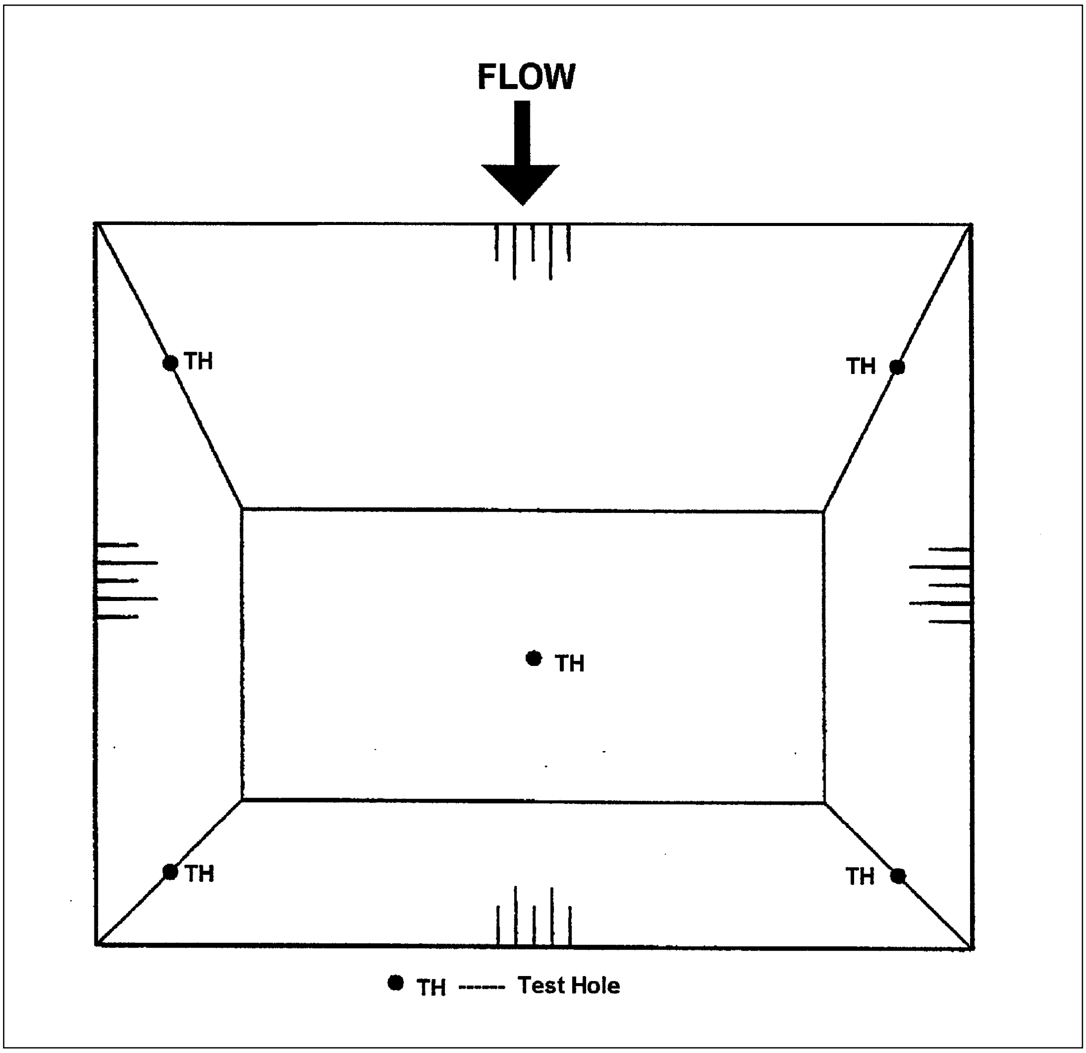

Figure 5 Test hole plan for an excavated tank

The following procedure is proposed but is only indicative:

- 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. Maintain the water at this level by topping up as necessary.
- The test is a measurement of the amount of water needed to maintain the water level at 0.5 metres below ground level for one day. Once the test is commenced, the amount of water added is recorded. This should continue for one day.

If the water added exceeds 30 litres per hour, then the site is too permeable for an excavated tank. If it is between 3 and 30 litres per hour then the site is considered doubtful. Some work would be needed to limit the water loss rate or to increase the sealing capacity of the tank floor (eg. use plastic liner or clays). Seepage 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 ranging 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 a soil laboratory to provide confirmation of soil suitability. However, simple field tests can give a good indication for the likely behaviour of the soils.

- 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.

- 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 one litre 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.

- 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 that 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 also be necessary to abandon the proposed site.

APPENDIX 5

CONSTRUCTION DETAILS OF EXCAVATED TANKS, TURKEY NESTS AND MODIFIED WATERHOLES

Assume preliminary investigations (Appendix 4) have been conducted and indicate that suitable conditions exist for the proposed construction. The integrity of the structure now hinges on the construction methods utilised.

1. Drainage-Line 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 the 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 may be undertaken using the available machinery. The ideal time to achieve optimum compaction is early in the dry season 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.

Catch drains can also be constructed (eg. using a tilted grader blade) to effectively increase the interception capacity 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 quite sound although special attention should be paid to:

- removal of leaky topsoil from the base before construction
- the selection of a non-dispersive soil as the construction material
- compaction at optimum moisture content. This can be achieved if construction is undertaken early in the dry season while the soil is still moist. Every 100 mm layer of loose soil should be compacted.

The table below gives examples of recommended dimensions, sized for turkey nests of a three day water supply capacity.

Number of Cattle	Inner Diameter At Base (m)	Inner Diameter at Top (m)	Total Height of Turkey Nest (m)	Draught (m)
250	4	13	1.8	0.8
400	6	15	1.8	0.8
600	6	16	2.0	1
1000	6	18.5	2.5	1.5

These figures are based a slope of 1 in 2.5 for the inner sides. The capacity of the tank (in terms of number of cattle) allows for leakage, the overflow standpipe to be 0.5m below the top of the tank and the outlet pipe supported 0.5m above its base. The draught is the depth of available water in the tank and is effectively the tank's storage capacity.