POWER AND WATER AUTHORITY
WATER RESOURCES DIVISION

WATER RESOURCES SURVEY OF THE
WESTERN VICTORIA RIVER DISTRICT

BRADSHAW STATION

REPORT 35/1995D
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WATER RESOURCES SURVEY OF BRADSHAW STATION NORTHERN TERRITORY

APPENDICES

TABLES

FIGURES

MAPS

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

SUMMARY

The accompanying Water Resources Development Map can be used as a guide to determine the type of water supply most appropriate to specific areas of the station. On the inland plains (the main grazing area) the best option for future water supply developments is considered to be excavated tanks, sited to capture wet season sheet floods. The reliability of existing tanks can be improved in many cases by deepening where appropriate. An alternative to excavated tanks is to pipe water from waterholes, springs, and bores situated adjacent to the plains. All existing and planned surface water storages including excavated tanks, waterholes and springs should be fenced and stock watering infrastructure provided. Adequate groundwater supplies in accessible areas are limited to the southeastern margin of the Angalarri River valley.

1. INTRODUCTION

This project was initiated by the Victoria River District Conservation Association (VRDCA). The 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.

Bradshaw station covers an area of 10,000 km^2 and is located between the lower reaches of the Victoria and Fitzmaurice Rivers. Road access is from the Stuart Highway via Claravale, Dorisvale and Wombungi Stations or from Timber Creek via Auvergne Station and a barge crossing across the Victoria River (Figure 1). During much of the wet season the roads are impassable and the homestead can only be reached by air.

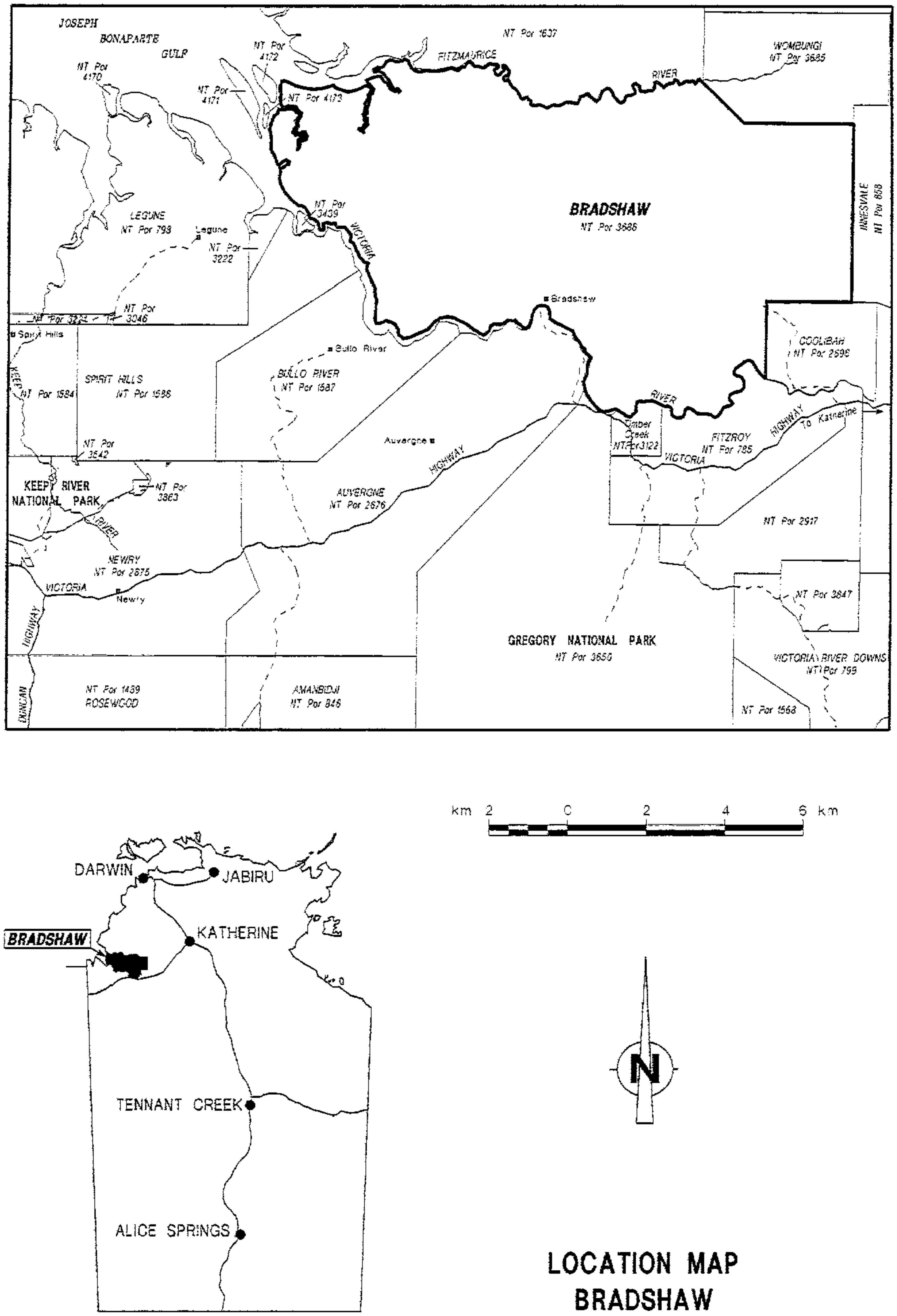
The availability of stock water is the major influence on stock management. Nearly all of the annual rainfall, which averages 854 mm, occurs in the short hot monsoonal wet season between December and March (Table 1). Little rainfall is experienced during the remainder of the year when temperatures are warm. During the Wet, when the streams flow, much of the low lying country is inundated. Recharge to groundwater aquifers occurs at this time. During the Dry, evaporation rates of water bodies such as dams or lakes are between 5 and 9 millimetres per day (average about 7 mm per day or 2.6 metres per year). This ensure that water levels in creeks, dams and tanks decline rapidly. Air temperatures are high throughout the year. The average monthly maxima range from about 30.3 degrees in July to 38.5 degrees in November. The corresponding average monthly minima are 12.9 and 25.3 degrees.

Current stock management is based on water availability. At present the station carries about 10,000 head of cattle. Two bores supply approximately 5% of their water needs, the remainder coming from springs, dams and waterholes. Surface water is the major water source, particularly in the Dry. Few man made storages normally last until the end of the Dry. At the time of inspection there were nine dams on the station including drainage-line and offstream excavated tanks and excavated waterholes. There are two waterholes, and three springs which are being successfully exploited.

The station can be classed into three broad landform types, rugged hills and ranges, coastal plains and inland plains (Figure 2). Most pastoral development is undertaken in the latter area because they support better pasture and are more accessible.

The ranges include the greater part of the station. They rise abruptly out of the plains to a maximum elevation of approximately 300 metres above sea level and are steep and rocky. Dissected plateaus formed on near horizontal sandstone beds are a common feature in many areas. Numerous short streams dissect the ranges, with many deep valleys and gorges. Soils are thin and stony supporting low open woodland and low woodland.

The inland plains have formed where rivers have preferentially cut down into a relatively soft rock formation, the Angalarri Siltstone. The rocks mostly dip at low angles to the northwest and tributaries of the Victoria River such as the Angalarri River and the Laingang Creek have eroded parallel to the



LOCATION MAP
BRADSHAW

Fig. 1

trend of the bedding, removing resistant sandstone capping and forming northeast-southwest trending valleys. The Angalarri River plains have loamy and clayey soils which support low woodlands. Paperbarks are dominant in the flood prone areas while eucalypts are dominant elsewhere. Whirlwind Plains at the mouth of the Angalarri River valley has cracking clay soil with a cover of grassland.

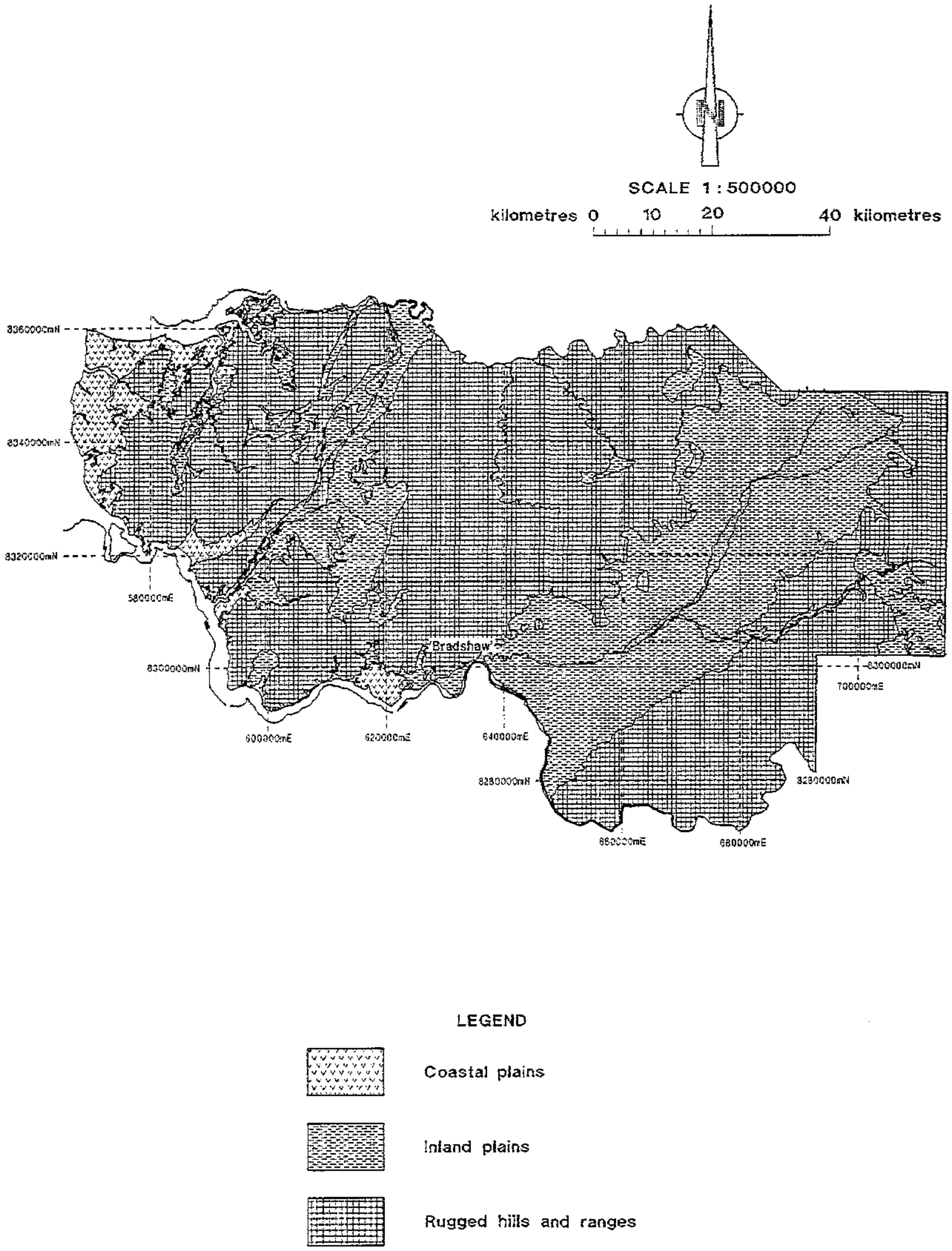
Patches of coastal plain occur along the lower reaches of the Victoria and Fitzmaurice Rivers. They are subject to tidal inundation and are either bare mudflats or support patches of salt tolerant shrubs and grasses.

TABLE 1

CLIMATIC AVERAGES - BRADSHAW STATION

	RAINFALL (mm)	RAIN DAYS	DAILY MINIMUM TEMPERATURE (°C)	DAILY MAXIMUM TEMPERATURE (°C)
JANUARY	209.5	13	24.7	35.6
FEBRUARY	192.7	11	24.5	34.3
MARCH	134.9	8	23.7	34.8
APRIL	23	2	20.3	34.9
MAY	3.9	0	17.2	32.6
JUNE	2.4	0	13.5	30.3
JULY	2.3	0	12.9	30.3
AUGUST	0.4	1	15.3	32.7
SEPTEMBER	8.8	2	19.6	35.6
OCTOBER	21.1	7	24.1	37.6
NOVEMBER	89.6	7	25.3	38.5
DECEMBER	164.3	10	24.8	36.9
TOTAL	854.6	57		

NOTE: *: Temperatures noted are from Auvergne Homestead.



LANDFORM MAP OF BRADSHAW STATION

Figure 2

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 Bradshaw station. The map was made by combining information on existing developments (dams, bores etc.) with information on groundwater occurrence, topography and soil types. Local conditions, such as soil types can vary considerably, so the map should not be taken as a definitive guide to cover every situation. Rather it is a broad scale map which is 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 map refer to the legend entitled "Water Resources Development Options". The various "preferred options" listed there fall into four types:

- -areas which are unsuitable for artificial water supplies such as surface water storages or bores (options 1, 2 and 3)
- -areas in which surface water storages are the best option (options 4, 5 and 6).
- -areas in which groundwater is the best option (option 7).
- -areas in which surfacewater and groundwater may both be viable options (option 8).

Some of the main features of the map are:

- -the areas used most for grazing, the inland plains flanking the Angalarri River and the Kollendong Valley , are mainly suitable for the development of surfacewater supplies in the form of excavated tanks and natural waterholes. Usable supplies of groundwater in those areas are generally lacking, except along the south eastern margin of the Angalarri River valley where moderate supplies could be expected at selected sites. Piping of groundwater from those areas out onto the plains is also an option
- -large areas of the station are unsuitable for water supply developments either due to rugged terrain or because of periodic tidal inundation.

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**, one of the two small side maps on the accompanying map of Bradshaw 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.

Stock water is presently obtained from only two bores on Bradshaw, River bore and Paperbark bore. Numerous unsuccessful bores have also been drilled over the years. Failures have been due to either an insufficient supply of water or because the groundwater was too salty.

Rock type is the main factor which determines groundwater availability and the three yield zones shown on the map (0 to 0.5, 0.5 to 5 and more than 5 litres per second) reflect different rock formations. 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 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 obtain lower yields. 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.
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 unsatisfactory for the scale of the present day pastoral operations.

High salinity waters, unsuitable for stock, occur under the Whirlwind Plains and other low lying areas adjacent to the tidal sections of the rivers. The salt water originates from inflows of seawater along tidal sections of the rivers and creeks and from marine sediments.

Each of the three yield zones on the groundwater map are now described:

3.1 <u>Areas with yields 0 to 0.5 L/sec</u>

This zone comprises much of the inland plains which are underlain by a rock formation known as the Angalarri Siltstone. Of the ten bores drilled on the station all intersected Angalarri Siltstone, but only two, RN7277 and RN7280 encountered significant quantities of water. On neighbouring Auvergne station many more holes have been drilled into the same formation with equally poor results. Minor locally developed aquifers have been found there in the weathered zone of the siltstone, generally shallower than 50 metres. The maximum thickness of the siltstone drilled on Auvergne is 325 metres.

Only saline groundwaters have been encountered in this formation on Bradshaw, although all the bores have been drilled relatively close to the Victoria River, which is tidal in that area. On Auvergne, patches of saline water have also been found in areas remote from the river.

Another area with similarly poor prospects for groundwater is in the southeastern corner of the station flanking the Victoria River. That area is underlain by dolomite and dolomitic siltstone of the Skull Creek Formation. A considerable amount of drilling in this formation on neighbouring Fitzroy station has failed to locate usable supplies.

The northwestern section of the station, bounded by the Victoria River Fault is also relatively poorly prospective for groundwater. Largely rugged and inaccessible the area is underlain by hard sandstone and siltstone. Based on drilling in similar rocks on Legune station, minor aquifers associated with local fractures are probably present. Only low yields could be expected on average but chances can be improved by siting bores along major fractures identified on aerial photographs or satellite images. Valleys cutting into the hills may also indicate the presence of water bearing fracture zones.

Prospects for obtaining supplies of more than 0.5 L/sec in this zone are low and other sources of water supply should be investigated before drilling.

3.2 Areas with yields 0.5 to 5.0 L/s

Moderate groundwater yields can be expected from the southwestern and northeastern margins of the Angalarri River valley. The aquifer there is a fractured sandstone formation known as the Jasper Gorge Sandstone . It outcrops in hills flanking the southeastern side of the valley but most of that country is inaccessible due to rugged terrain.

The sandstone is overlain by the Angalarri Siltstone and slopes to the northwest. As a result the depth required to hit the aquifer increases progressively to the northwest (see cross-section C-D on the Groundwater Resources Map). The Jasper Gorge Sandstone is present beneath much of the Angalarri River valley but it is mostly located at considerable depth. A narrow strip extending northeast from River bore and along the Ikymbon River represents the main area which is accessible and in which the aquifer is present at reasonably shallow depths. The chances of obtaining a stock supply in this area are good and can be improved by siting bores along fractures visible on aerial photographs.

A line showing where the aquifer is deeper than 150 metres is shown on the Groundwater Resources Map. Drilling for stock supplies at depths greater than about 150 metres is considered to be uneconomic, especially when alternative water sources may be present. Furthermore drilling on Auvergne Station has shown that the chances of success decrease considerably where a thick cover of Angalarri Siltstone is present. Drilling for groundwater in the Jasper Gorge Sandstone, beneath the greater part of the Angalarri River valley is therefore not recommended.

Fractured sandstone aquifers which overlie the Angalarri Siltstone are extensively developed in the rugged and largely inaccessible plateau country of the Yambarran Range. Several springs issue from the heads of small valleys on the southeastern side of the range. Soubon Spring is located on a prominent fracture zone and the water is channelled mainly along the contact between sandstone and the underlying Angalarri Siltstone. The other springs probably also owe their existence to similar geological circumstances. Many more springs are likely to be present on the northwestern side of the range because the sandstone beds slope in that direction and the main groundwater flow could be expected to be in that direction.

3.3 Areas with yields more than 5 L/s

High yielding aquifers are restricted to isolated areas flanking the Victoria River. At the mouth of the river the coastal plain is underlain by soft porous sandstone capable of producing high yields. The groundwater in this aquifer however is almost certainly highly saline .

Further upstream patches of unconsolidated river sediments are present. These are known to contain water bearing gravels which may be capable of producing high yields. Downstream of Timber Creek they only contain saline water. Drilling on the river flats on neighbouring Fitzroy station has proven moderate yields of fresh water in river gravels down to depths of 30 metres.

4. SURFACEWATER

Surface water flow in the creeks, rivers, and the floodplains is largely confined to the wet season. However replenishment of some waterholes and some creek flows during the Dry are due to spring flows. An effective annual evaporation rate of about 2.6 metres is responsible for the subsequent rapid loss of stored water from tanks and waterholes. During the average Wet, flow of the Ikymbon River, Angalarri River, Victoria River, and their tributaries are often accompanied by sheet flow over much of the low lying inland plains country. After the Wet, all drainages above the tidal influence deplete to form unconnected waterholes, the majority of which are dry by about October. 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. In a paddock holding 500 head the requirement is to hold 9.2 megalitres (million litres) of water for stock supply (50 litres/day/head) after allowance is made for evaporation losses.

For it's stock water supply from surface water, Bradshaw Station is largely dependent on excavated tanks, dams, temporary waterholes and billabongs. About 95% of the stock water demand in the station is supplied from natural and artificial surface water storages.

The region has been divided into seven zones showing suitability for surface water development for stock watering. They are based on soil type , 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 of Bradshaw.

4.1 Surface Water Storage Types

Three types of excavated tanks are suitable for the plains, onstream tanks, offstream tanks, and drainage-line tanks, the latter being the preferred option. On Bradshaw the depth of excavated tanks should be 3 to 3.5 metres, depending on subsoil types. As the depth of the tank increases beyond three metres, it's reliability increases. Details of the station's key surface water storages(dams and waterholes) and an assessment of their capabilities are given in Appendix 4. Since a field inspection was made in August 1994 five new excavated tanks have been constructed in Widgeman and Gavin's Paddocks and these are not included in the appendix .

The majority of the existing man made reservoirs are shallow excavated tanks with a surrounding bund on three sides, made from the excavated material and open on the upstream side. Some are of the drainage line type with small catchment areas. There are also two offstream excavated tanks which are about 3 to 4 m deep from the top of the bunds, but with a maximum excavated depth of only 1.5 to 2.0 metres The existing design and construction of the station's excavated tanks has resulted in the following problems:

(1) rill erosion of the bund and silting of the tanks .

(2) inadequate spilltail channels do not direct water away from bund walls prompting further erosion .

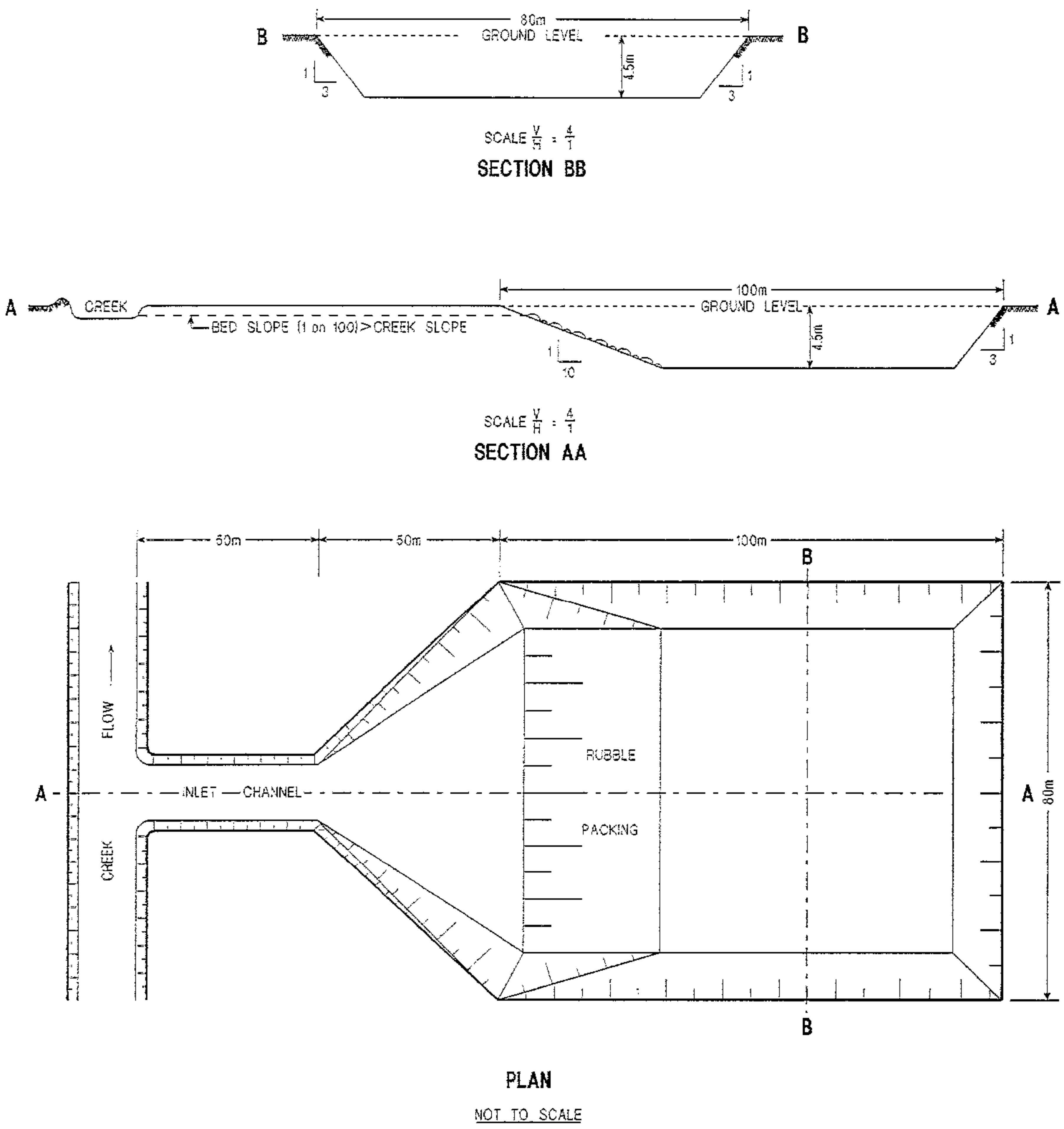
(3) ineffective sediment traps, resulting in silting of tanks

Regular maintenance is required before the next Wet to correct damage due to these problems. The current excavated tank design does not give sufficient storage capacity for cattle requirements, due mainly to evaporation losses and to a lesser extent leakage.

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 3) reduces these problems by using a man-made channel to divert water from a natural stream to the tank. This is an improvement on the onstream design, but has excessive excavation costs since to take advantage of short lived stream flows, the tank level must be below that of the natural stream bed.

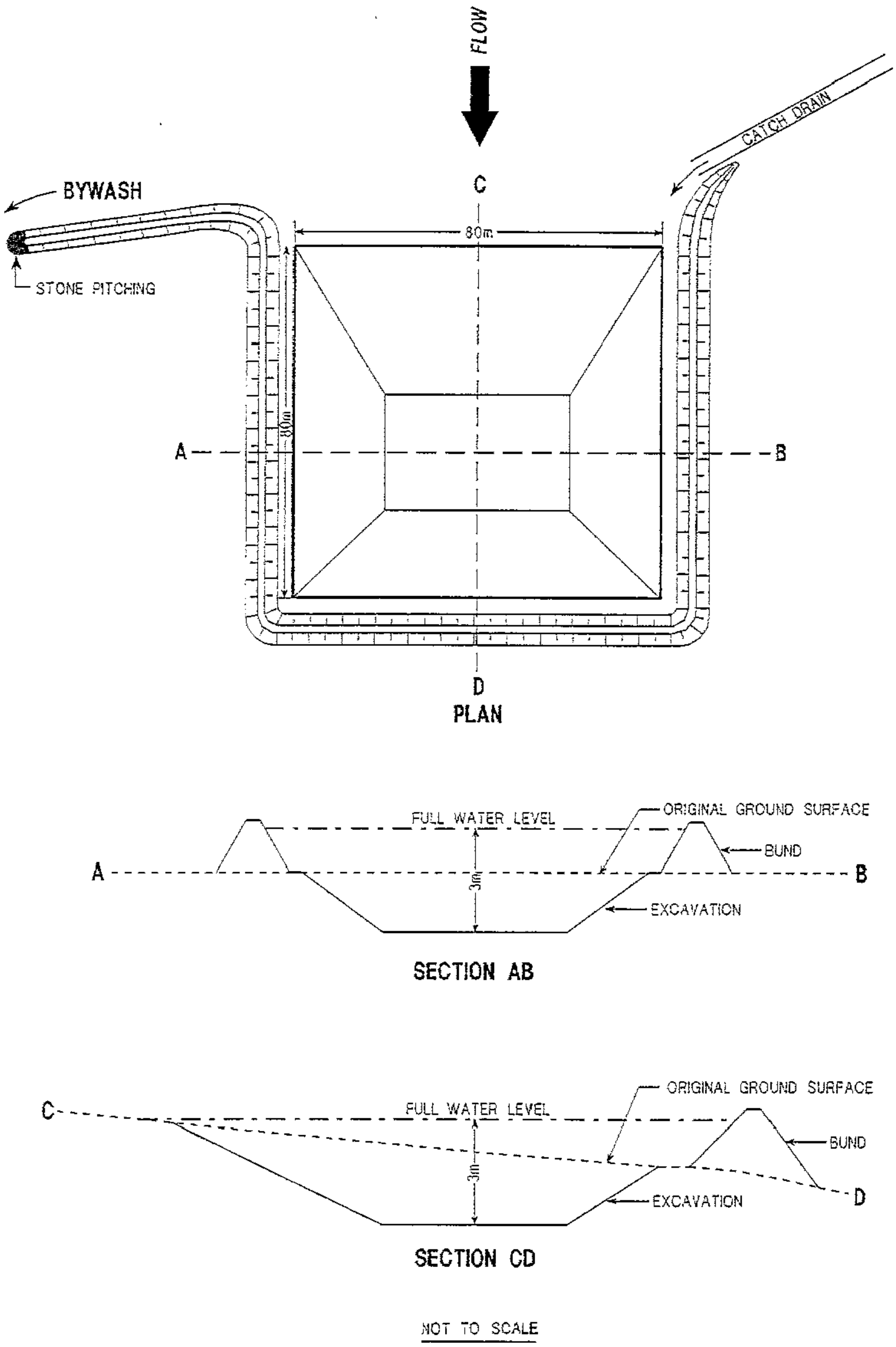
The drainage-line tank (Figure 4) is an excavated tank constructed in flat to moderately sloping areas where there are no clearly defined creek systems. Burkies dam is an examples of this type. The tank itself is of the same design as the offstream one, but without an inlet channel. It is excavated in a drainage area which does not have a defined creek system and water may be directed towards it using catch drains or wing walls. Sheet flow on the plains, with its low silt load, may be harvested in this manner. This design is most suitable for Bradshaw and has been used successfully on Auvergne Station in the same situation.

Another type of dam, the gully dam, is suited to gently undulating 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 hilly country on Bradshaw may not be possible due to the thin permeable soils and permeable sandstone bedrock. Areas where soils are clayey, and underlain by shale may be locally suitable for gully dams. The minimum average depth of the dam should be 3 metres in order to compensate for the high evaporation. 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



TYPICAL OFFSTREAM EXCAVATED TANK

Fig. 3



TYPICAL DRAINAGE-LINE EXCAVATED TANK

Fig 4

foundation. Embankments more than 3 metres high need licensing from the Water Resources Division.

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 tightness of the ground. A drainage-line tank is best located on flat or gently sloping alluvial floodplains underlain by shale. 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 alluvial plains on the **Surface Water Resources Map** cracking clays extend to a depth of up to 3 metres in some areas and are suitable for excavated tanks. Areas mapped as gently undulating 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 hilly country if clayey soils 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 5) and may require the input of an geotechnical consultant. For drainage-line storages a minimum catchment area of 0.5 km^2 is required. Other types of excavated tanks require a minimum catchment area of 1.5 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 the excavated tank are determined by the stock numbers to be watered for a whole year (stock numbers will be higher if the tank is utilised for only part of the year). This in turn is dependent on the cattle carrying capacity of the paddock, usually varying between 400 and 1000 head (ie. a requirement of between 7.3 and 18.3 megalitres per year when based on 50 litres per head per day).

The larger the catchment, the more runoff that can be expected to be captured by a tank. As for drainage-line tanks, catchment sizes between 0.5 km^2 and 2 km^2 should supply between 425 and 950 head respectively, with 90% reliability (ie. for 9 years out of 10), using the proposed drainage-line storage design. An offstream tank with a catchment size range of between 1.5 and 2.5 km^2 is designed to supply between 325 and 1000 head of cattle, with 90% reliability.

The basic design for a typical drainage-line tank is shown in Figure 4. Dimensions of 60 x 60 x 4 metres are recommended for stock numbers up to 450. A design dimension of 80 x 80 x 3 metres for a drainage-line tank with 0.5 km^2 of catchment can supply up to 350 head with a reliability of 90%. Dimensions of 100 x 80 x 4 metres are required for stock numbers up to 800, depending on the area of the catchment. A minimum tank depth of 3 to 4 metres is required to allow for an annual 2.6 metres water loss due to evaporation. The basic design for a typical offstream tank is shown in Figure 3 and dimensions of 100 x 80 x 4.5 metres are required for stock numbers up to approximately 1000. The design of excavated tanks are covered in more detail in the internal Water Resources Division Report No 23/1995D, entitled " Surface Water Storage Potential - Bradshaw Station".

Construction is covered in more detail in Appendix 6. 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 an drainage-line tank where there is a moderate slope on the natural ground surface (as at Burkies Dam). Excavated volumes are large for the proposed design dimensions (approximately 10,000 m^3 for the smaller tank, and 20,000 m^3 for the large) so construction costs will be high. Cost will also be influenced by ground conditions.

4.4 Waterholes

Natural waterholes are present during the Dry, in depressions in stream and riverbeds. Some of the waterholes , such as Barramundi waterhole never dries. The available capacity of the waterholes could be increased by excavation of the base (Appendix 6), but only where site investigation proves that this will not result in leakage. A shale base could be excavated without fear of leakage, however the region underlain largely by sandstone is not water tight. Waterholes in the hilly country may be deepened, provided the excavation is confined to cracking clay soils. The storage capacity of a well confined waterhole with high banks could be increased by construction of an appropriate bund at its downstream end.

4.5 Springs and Piping of Surface Water

Springs usually occur on hill slopes and in river valleys. Piping water from springs to areas where groundwater or surface water are not available has been a success on the station. Perennial springs such as Camballin, Soubon, and Buffalo Springs are being exploited for stock and also for domestic purposes. Each spring is connected to pipe system which discharges under gravity into a turkey nest, overhead tank or ground tank. The spring flow varies from spring to spring and also seasonally. At the time of inspection spring flows varied from 0.5 to 3 l/s. Polythene pipe has been mainly used in the pipe system with some PVC and steel, especially at the initial reaches. Details of spring systems are noted in Appendix 7. If a spring is found to have more than 2 litres per second flow at the end of Dry, it should be more than sufficient to supply a turkey nest designed to store three days supply of stock water for 500 head of cattle.

Pumping direct to turkey nests is the preferred option because of the smaller volumes of water lost to evaporation. Fifty millimetre 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 pipes to protect them from physical damage (eg.

grass fires or accidental ploughing) and because their strength is reduced if subjected to elevated daytime temperatures. Burial, to protect from fire, stock trampling, etc., is easy where surficial materials allow excavation using a tilted grader blade, but is not possible in areas of exposed rock.

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 given in Appendix 6.

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

1. The water resources development map should 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.
2. Excavated tanks away from clearly defined drainages, and sited to harvest sheet flow are considered the best option for new sources of stock water for most of the plains area. Piping of water from reliable supplies (bores, waterholes and springs) in adjacent areas is also an option.
3. The provision of reliable water supplies with a maximum grazing radius of six kilometres throughout the good pasture of the plains should be a priority, in order to reduce over-grazing and soil erosion.
4. Advice should be sought from geotechnical engineering consultants when considering the construction of larger excavated tanks, or from groundwater consultants or the Water Resources Division for detailed bore siting information.

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 unwanted 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 5). This would also enable several watering points to be established in a single paddock. Bradshaw has a reasonably good distribution of watering points, particularly in the southwestern end of the Angalarri River valley. Areas more remote from the homestead have fewer watering points and may be appropriate sites for creating new watering points by piping from new or existing sources.

5.2 Groundwater

The potential for developing new groundwater supplies is limited to a narrow strip on the southeastern side of the Angalarri River valley extending northeast along the Ikymbon River. Bores in this area should each be capable of supplying several remote watering points located closer to the centre of the valley.

5.3 Surface Water

Drainage-line and offstream type excavated tanks are recommended for areas with black clay soils. Selection of sites depends on the presence of suitable sub-soils. Gully dams may be locally suitable in undulating country but site investigations and proper design and construction methods are essential. Deepening or enlarging the surface area of existing surface water storages should be subject to satisfactory sub-soil investigations. The pipe system should be complete with air release valve, wash out valves etc for efficient usage of the system. 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

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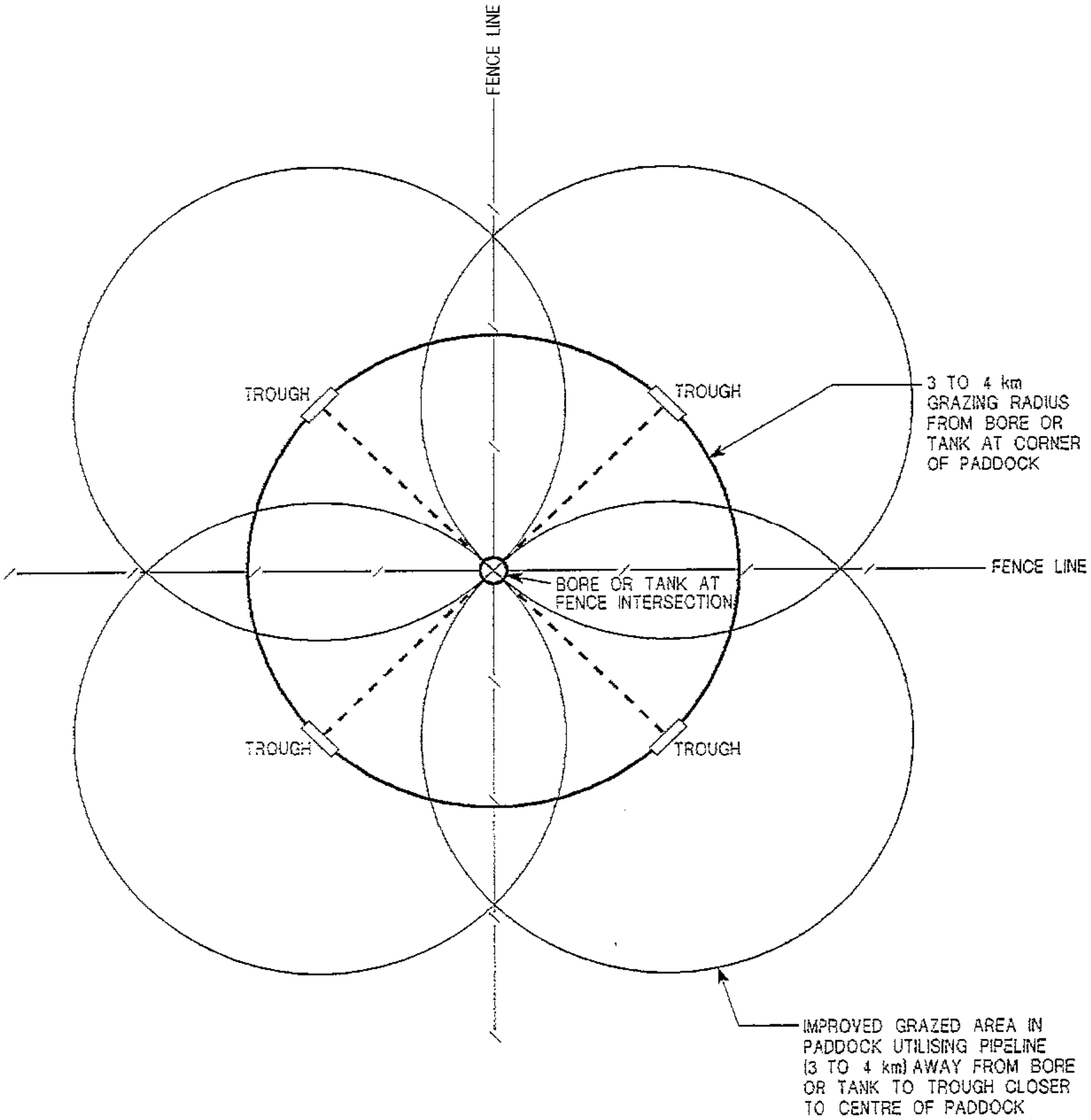


SKETCH SHOWING IMPROVED SIZE OF GRAZING AREA DUE TO PIPING AWAY FROM RELIABLE BORE OR TANK

Fig. 5

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.

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

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

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

-CASING The length of casing in the hole in metres and it's internal diameter in millimetres .

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

-AIRLIFT 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.

APPENDIX 1 STATION BORES BRADSHAW

BORE NO.	LOCAL NAME	STATUS	EASTING	NORTHING	COMPLETION DATE	DEPTH(M)	CASING depth(m)xdiam(mm)	Depth struck(m)	AIRLIFT YIELD	SWL
RN6217		Abandoned	643800	8306300	Aug-68	213		210.3	0.3	7.6
RN6218		Abandoned	646300	8301500	5/9/68	274		15.2	0.1	7.6
RN7277		Abandoned	655200	8298000	2/10/70	38.1		38.1	1	12.1
RN7278		Abandoned	620200	8299000	16/9/70	30.5			0	
RN7279		Abandoned	655400	8307200	18/9/70	121.9			0	
RN7280		Capped	647600	8289800	26/09/70	183	21x150	155.5	1.3	10.7
RN7281	PAPERBARK BORE	Equipped	651800	8285800	29/9/70	91.4	21x150	77.7	1	9.8
RN8759	RIVER BORE	Equipped	640500	8282300	6/9/75	57	40x175	48	2.5	6
RN8760	GREEN SWAMP BORE	Capped	556400	8289500	8/9/75	101	40x150	96	2.3	12
RN8761		Abandoned	658500	8295200	14/9/75	188	1x200	70	0.3	24

APPENDIX 2

CHEMICAL ANALYSES OF GROUNDWATERS AND SPRING WATERS

The following table lists chemical analyses performed on groundwaters on Bradshaw. See Appendix 3 for an explanation of the main factors which limit water use for stock and domestic consumption.

APPENDIX 2 CHEMICAL ANALYSES OF GROUNDWATERS AND SPRING WATERS BRADSHAW STATION

BORE RN	BORE NAME	DATE	CONDUCTIVITY	T.D.S.	pH	SODIUM	POTASSIUM	CALCIUM	MAGNESIUM	CHLORIDE	SULPHATE	BICARBONATE	NITRATE	FLUORIDE	IRON	SILICA	ALKALINITY	HARDNESS
			uS/Cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
6217		19/8/68	10000		6.6	2350	60	159	54	3300		88		1.1	2.4		144	2500
6217		19/8/68	10500		7.9	2600	60	159	55	3800	825	89		1	6.6		146	2800
6217		20/8/68	11500	7527	5.8	2850	70	114	26	4100	935	77		1	3.5		126	700
6217		20/8/68	11500	7666	6.9	2950	70	123	27	4200	785	107		0.8	7.2		176	1000
6218		5/9/68	"Good"															
7280		10/3/71	36420							15200		163					134	5000
7281	PAPERBARK BORE	29/9/70	"Fair"															
8759	RIVER BORE	20/12/76	650	360	8.5	61	21	22	26	62	20	220		3.9	0.8		212	162
8759	RIVER BORE	4/8/94	629	344	8.0	48	20	47	23	46	21	296	<1	3.2	0.1	17	243	212
8760	GREEN SWAMP BORE	27/6/75	15260		6.7					5145		109					89	1000
8760	GREEN SWAMP BORE	20/12/76	15260		7.9					4949		146					120	1800
8760	GREEN SWAMP BORE	18/7/77	14880							4900								
8761		14/9/75	"Good"															
	SOURON SPRINGS	19/7/94	26	46	6.1	3	2	<1	1	6	3	8	<1	<.01	0.1	28	7	4
	BUFFALO SPRINGS	26/6/62	110		6.8					14							20	10
	CAMBARLAN SPRINGS	27/6/62	68		6.5					15							10	3
	CAMBARLAN SPRINGS	7/7/94	37	54	6.0	3	3	<1	1	7	5	17	<1	<.01	0.1	33	14	4

APPENDIX 3

WATER QUALITY REQUIREMENTS FOR STOCK AND DOMESTIC WATER

1. WATER QUALITY STANDARDS FOR STOCK USE

SUBSTANCE	GUIDELINE VALUE
pH range	5.5 - 9.0
Total dissolved solids	8000 mg/L
Sodium chloride	Not more than 75% when total dissolved solids near limit.
Sulphate	2000 mg/L
Nitrate	400 mg/L
Fluoride	5.0 mg/L
Magnesium	300 mg/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, AND AUSTRALIAN WATER RESOURCES COUNCIL CRITERIA)

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	1000 mg/L
Chloride	400 mg/L
Sulphate	400 mg/L
Nitrate	45 mg/L
Fluoride	0.5 - 1.7 mg/L
Hardness (as Calcium Carbonate)	500 mg/L
Sodium	300 mg/L

APPENDIX 4

DAMS AND WATERHOLES ON BRADSHAW

1. JOCKEY CREEK DAM:

This is an excavated waterhole in the Angalarri channels. It's maximum depth is about 2.2 metres and it is said to never run dry. It can supply water throughout the year for 200 head of cattle with 90% reliability. It is being used intermittently for a holding paddock with an average cattle strength of 300. Further deepening is recommended subject to subsoil suitability.

2. GUMMIES DAM:

This is an excavated tank which is silted and has a maximum depth of about 2.4 metres. At present 350 cattle are watered there, and it dries by end of October. About 250 head of cattle can be supplied with 90% reliability. If deepened to 3.5 metres (subject to subsoil suitability), it could cater for 400 cattle with 90% reliability. The dam should be desilted but deep excavation should not be carried out.

3. TI TREE DAM:

This is an excavated water hole in the Angalarri channels. It's maximum depth is about 2.2 metres and it is said to never run dry. It is being used intermittently for a holding paddock with an average cattle strength of 150. It has insufficient capacity to supply stock water throughout the year on a continuous basis. Further deepening is recommended subject to subsoil suitability. The improperly compacted bunds on either sides of the dam continue to erode and silt. It may need desilting.

4. HALFWAY DAM:

Halfway Dam is a drainage line excavated tank, with a capacity to water 125 cattle over a year with 90% reliability. It is recommended that it be expanded to a design dimension as noted in Figure 4, subject to subsoil suitability. Rill erosion is occurring in the bunds and is an indicator of improper and/or insufficient compaction.

5. BOSON GATE DAM:

This is an off-creek excavated tank with a capacity to water 110 head of cattle over a year with 90% reliability. The silt trap is not effective and does not effect the functioning of the dam.

6. MIDDLE BOSON DAM:

This is a drainage line excavated tank in Boson paddock with a capacity to supply 150 head of cattle over a year with 90% reliability. Deepening may be feasible if subsoil conditions are suitable.

7. DEATH CORNER DAM:

This is an off-stream excavated tank with a silt trap which is ineffective. It's present capacity can supply 625 head of cattle over an year with 90% reliability. Cattle water directly from the dam but there is a fence across it, allowing it to be used by two paddocks. The water was turbid at the time of inspection.

8. SALTY BORE DAM:

This is a drainage-line excavated tank with a capacity to water 200 head of cattle over a year with 90% reliability. It can be deepened if subsoil conditions are favourable. Cattle water directly from the tank and the water is turbid. It is submerged under major floods and in such a wet it could cater for 250 head of cattle.

9. KING BILLABONG:

Located adjacent to the Victoria River this natural waterhole gets flooded almost every year. It supplies water to an 8500 gallon overhead tank and is used to cater for the holding paddock. Present usage is only intermittent, however if it was to be used on a daily basis it could supply 325 head of cattle over a year with 90% reliability. There are sand pockets beneath the bed and detailed investigations should be made before any deepening is carried out.

10. HICKEY DAM:

This is a drainage line excavated tank which is fenced and equipped with a windmill that pumps to a turkey nest. There is a silt trap at the entrance to the tank, but it does not appear to serve its purpose. The tank could supply daily stock water over a year for 520 head of cattle with 90% reliability. In an average year, the tank is not used in January and February and so it has the capacity to supply 600 cattle.

11. BARAMMUNDI WATERHOLE:

The waterhole is a permanent, filled by both spring flow and runoff. With the watershed runoff alone, it has a capacity to water 225 head of cattle over a year with 90% reliability. It presently caters for 1000 head of cattle and therefore the spring flow contributes most of the water requirement. Water is pumped from the waterhole to a steel ground tank and toTomb's Turkey Nest. The flow into the turkey nest at the time of inspection was 0.2 L/s.

12. BURKIES DAM:

This is a drainage line storage (hillside storage variety) with a capacity to water 450 head of cattle over a year with 90% reliability. It was built last year and is yet to be used.

13. ANGLE POINT SHALE TANK:

This is a drainage line tank just downstream of the excavated waterhole (Ti Tree Shale tank), and in most years it lasts till the end of the Dry. The tank is small but deep and can serve 250 head of cattle with 90% reliability over a year.

14. TI TREE SHALE TANK:

This is an excavated shallow waterhole which usually lasts till end of dry. It can provide water to 100 head of cattle with 90% reliability over a year.

APPENDIX 5

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.

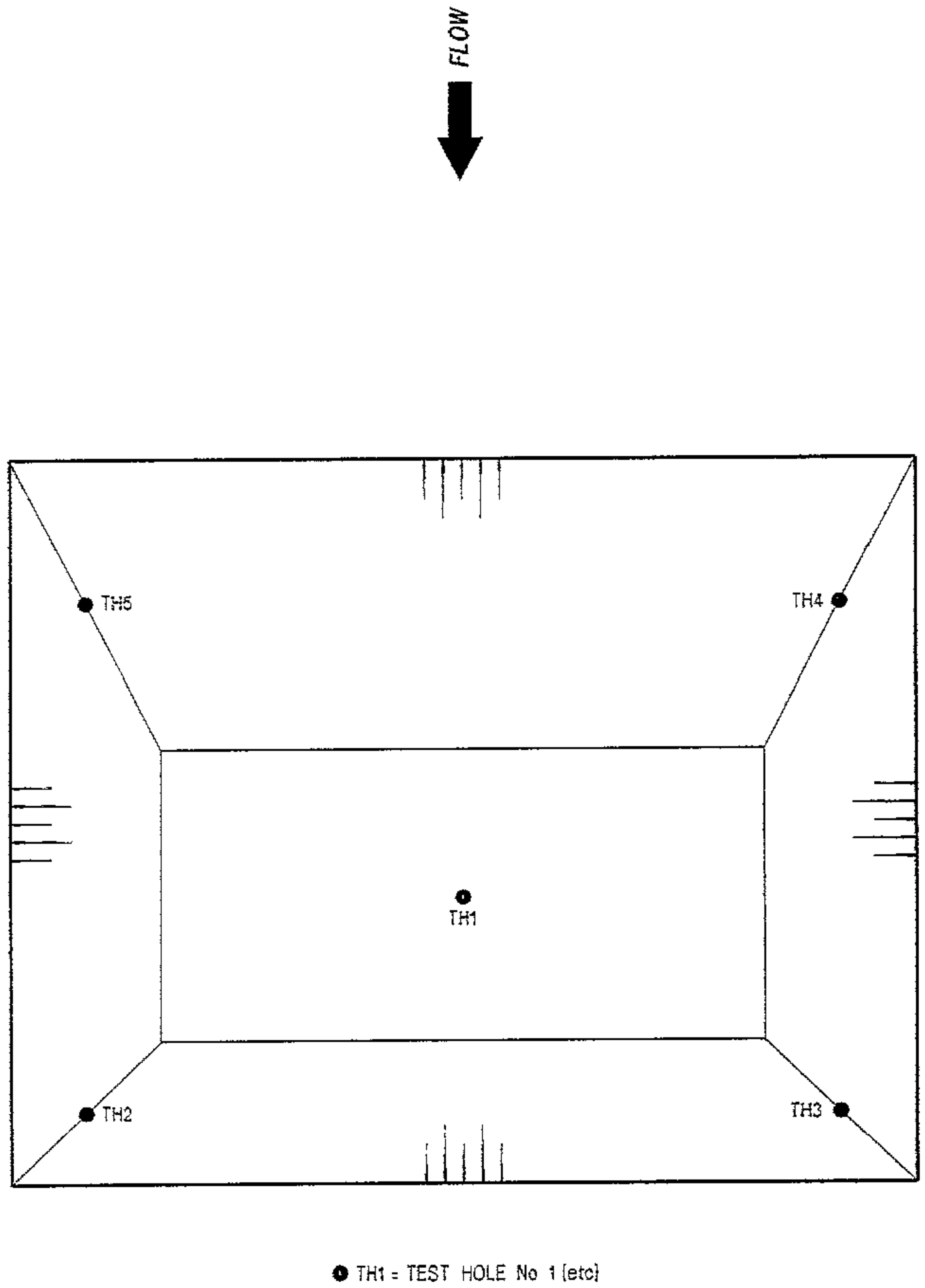
A hand operated 100 mm earth auger capable of drilling to between 5 and 6 metres is the basic tool for the subsurface investigations. Auger holes are sunk in soil to one metre deeper than the tank design depth, with minimum 500 gram samples taken wherever there is a change in soil. A plan of the soil 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 6). 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 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.



TEST HOLE PLAN FOR
AN EXCAVATED TANK

Fig 6

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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. 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 Conservation Commission of the Northern Territory 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

APPENDIX 6

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 it's storage capacity. The bund should have a minimum berm width of 5 metres (Figure 4). 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. 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 while soil is still moist. Every 100 mm layer of loose soil should be compacted.

For three days water supply from a turkey nest the following dimensions are recommended:

NUMBER OF CATTLE	INNER DIAMETER AT BASE (metres)	INNER DIAMETER AT TOP (metres)	HEIGHT (metres)
200	6	13	1.1
500	8	16	1.5

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

3. 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.

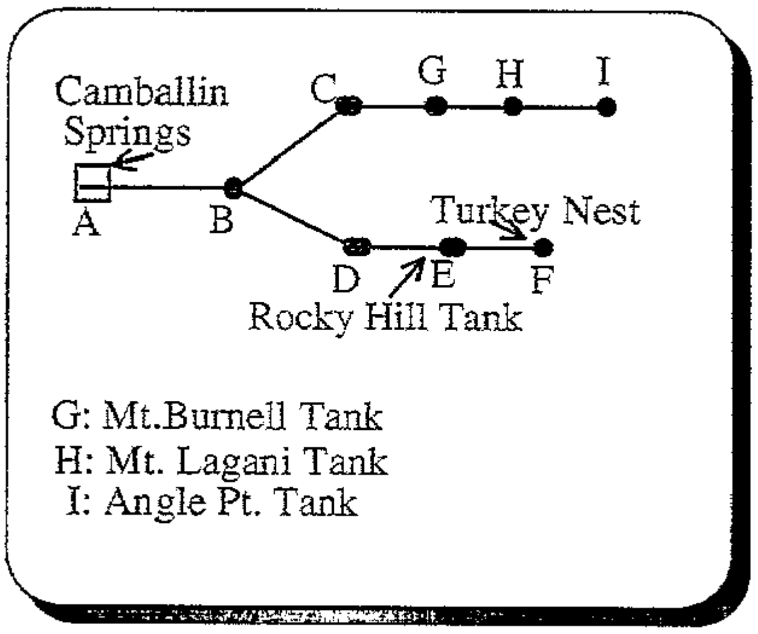
APPENDIX 7

RETICULATION SYSTEMS ON SPRINGS IN BRADSHAW STATION

Camballin Spring System:

A schematic diagram of the Camballin spring system is shown in below. There are air release valves in reaches GH and HI. The approximate, length, type, size and reach are given in the table below. At the time of inspection the flow into tank G was 1 l/s, and the other two tanks were full. The turkey nest and the Rocky Hill tank (Tank E) were also full. The tanks G,H, I, and E have stopvalves to stop the flow when they are full. The flow into the turkey nest was only 0.1 l/s, because the flow into line BF was reduced at B, allowing more flow into line BI. Water flows in the entire pipe system under gravity. Leaks were found mostly in the joints. In most places pipes are not buried or covered with soil.

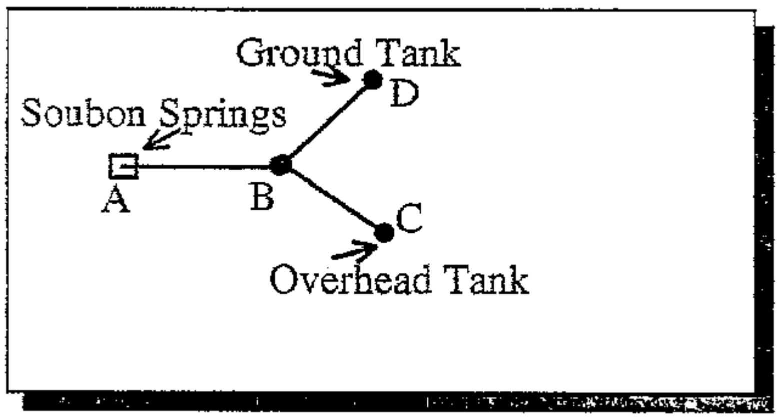
REACH	PIPE DIAMETER	TYPE	LENGTH (km)
AB	3 inch(80mm)	Steel + PVC	2.3
BD	2.5 inch(65mm)	Steel + PVC	1
DE	2.5 inch(65mm)	Poly	3
BC	2.5inch(65mm)	Steel	2
CG	2 inch(50mm)	Poly	2
GH	2 inch(50mm)	Poly	6
HI	2 inch(50mm)	Poly	6
EF	1.5 inch(40mm)	Poly	6



Soubon Spring System:

Soubon spring serves one ground tank for stock watering and one overhead tank for domestic purposes. The system has two washout valves, and one air release valve. The schematic diagram of the spring system is shown below. The spring flow at the weir could not be measured because it was overflowing and leaking. However it was much more than 1 l/s. The flow in the entire pipe system is under gravity.

REACH	PIPE DIAMETER	TYPE	LENGTH (km)
AB	2.5inch(65mm)	Poly	1.3
BC	2 inch(50mm)	Poly	1
BD	2 inch(50mm)	Poly	1.2



Buffalo Spring System:

Water flows from the spring through a 50mm poly pipe over a length of 0.8km to a ground tank. At the time of inspection the tank was full and therefore flow could not be measured.

APPENDIX 8

GLOSSARY

AQUIFER A body of rock that is sufficiently permeable to conduct 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 Small diameter hole constructed with a drilling rig, and down which a pump is lowered to extract groundwater.

BUND Bank, constructed of compacted fill, used to contain water.

DEMAND The volumetric flow rate required for stock watering, therefore the rate at which water would be supplied if available.

DRAINAGE -LINE TANK Excavated tank built in an area which does not have a defined creek.

GROUNDWATER Water contained in rock below the water table.

HILLSIDE STORAGE A variety of drainage-line tank located at the base of a hill which has no well defined depressions.

OFFSTREAM TANK Excavated tanks built near creeks, and connected to the creek by a channel to tap the creek flow.

ONSTREAM TANK Excavated tanks built across a well defined stream.

RELIABILITY 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.

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.

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