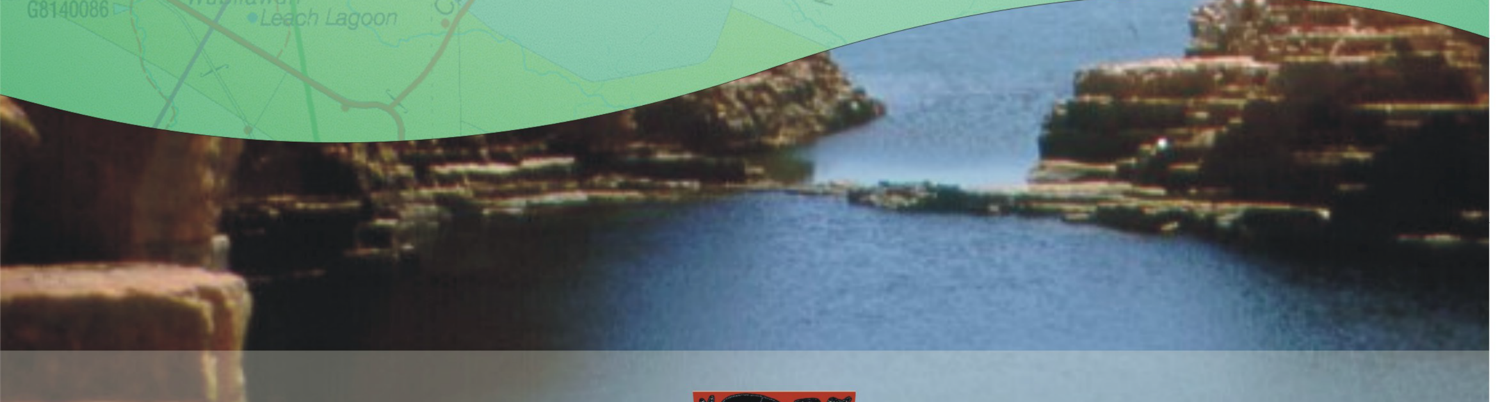
# Water Resources of the Katherine Region and South West Arnhem Land



NATIONAL LANDCARE PROGRAM

JAWOYN ASSOCIATION

LANDS PLANNING ENVIRONMENT
Northern Territory Government
NATURAL RESOURCES

DEPARTMENT OF LANDS, PLANNING AND ENVIRONMENT

NATURAL RESOURCES DIVISION

# WATER RESOURCES OF THE KATHERINE REGION AND SOUTH WEST ARNHEM LAND

Nitmiluk (Katherine Gorge)

REPORT NUMBER 28/2001D

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DARWIN NT

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## ABBREVIATIONS

| | |
|---|---|
| ADWG | Australian Drinking Water Guidelines |
| AHD | Australian Height Datum |
| $CaCO_3$ | Calcium Carbonate |
| DLPE | Department of Lands Planning and Environmnent |
| EC | Electrical Conductivity |
| GIS | Geographical Information System |
| km | kilometres |
| L/s | litres per second |
| m | metres |
| $m^3$ | cubic metres (1 $m^3$ = 1000 litres) |
| mg/l | milligrams per litre |
| mm | millimetres |
| NLC | Northern Land Council |
| NLP | National Landcare Program |
| NRD | Natural Resources Division (formerly Water Resources) |
| NT | Northern Territory |
| RN | Registered Number (referring to bore) |
| TDS | Total dissolved solids (in mg/l) |
| µS/cm | microSeimens per centimetre (units of EC) |

**NOTE:**

Words in *italics* are defined in the GLOSSARY OF TERMS at the end of the report.

## SUMMARY

The aim of this study is to provide an information resource that will help landowners and land managers incorporate water resources aspects in their planning processes. This report provides an explanation of the groundwater and surface water resources in the Katherine and South West Arnhem Land region, as depicted on the accompanying Water Resource Map.

The partners in this study were DLPE, NLP and the Jawoyn Association, who were also the primary client.

A Water Resource Map was produced at a scale of 1:250 000. The groundwater resource has been classified according to the supply potential into the following categories:

- Cretaceous aquifer - Lots of water / moderate supply
- Dolomitic aquifers - Lots of water / large supply
- Locally developed aquifers - Small supplies possible
- Minor groundwater resources - Little chance of water

Most groundwater in the study area is fit for human consumption. The major aquifers occur in limestone, dolomite and poorly *consolidated* sandstones.

All Dry season flows in the river systems are maintained through *groundwater discharge*. The major aquifers maintain the flow in the major rivers such as the Katherine River and Mary River. River flow has been classified according to the minimum flow recorded, estimated or documented at the end of the Dry season. There are four categories that describe river flow; from rivers which are *ephemeral*, to rivers with a flow of more than 100 L/s at the end of the Dry Season.

Knowing how the groundwater and river systems respond to rainfall allows predictions to be made of their future behaviour. A study was made of the low flow characteristics of the Katherine River, which allows Dry season flows to be predicted using daily rainfall information. This work outlines the variability in Dry season flow in the Katherine River.

Other products produced from the study include a GIS, regional base maps (based on satellite imagery), Technical Data reports, Appendices and a photographic collection. The entire information resource aims to provide regional planners and land owners with a good starting point in the development of water resource management plans for the region.

## 1.0 INTRODUCTION

Previously existing information sources are insufficient in content and in form to enable water resources issues to be adequately included in land management planning. This project has produced an information set, which includes maps, interpretive reports, technical data and a photographic collection. This forms a set of decision making tools which will allow the Jawoyn Association, community councils and government departments to readily include water resource considerations in their decision processes regarding future land management and development.

The partners in this three-year project were:

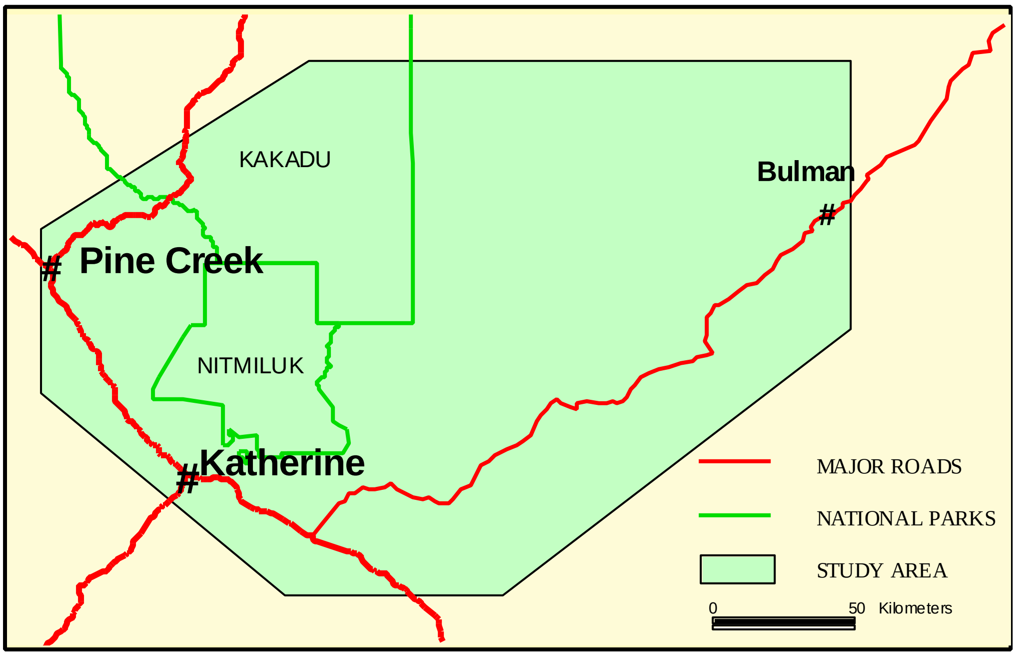
- Natural Resources Division, Northern Territory Department of Lands Planning & Environment – NRD of DLPE
- National Landcare Program – NLP
- Jawoyn Association

The study area covers approximately 41000km$^2$, and includes Aboriginal Land, National Parks and parts of Pastoral Leases, with a corresponding range of land uses. The study area is shown in Figure 1. Katherine is the major population centre in the region. Other communities include Barunga, Wugularr, Manyallaluk and Bulman, with several smaller communities and outstations also in the study area.

The Water Resources Map is an interpretation of the region's *geology*, *topography*, bore data, stream flows and vegetation patterns. To produce the map, satellite images and aerial photographs were studied, and field programs including investigation drilling, *geophysical* surveys, test pumping, water sampling and stream gauging were undertaken. The contribution from Traditional Owners, in particular their knowledge of the waterways, has been vital to this mapping exercise, particularly in areas where access was difficult. The maps show the generalised *groundwater* and surface water characteristics of the region, and present other information pertaining to water resources such as bore location and stream gauging and rainfall stations.

In order to make the map products more accessible to the Aboriginal landowners and managers, language placenames have been included where possible. Jawoyn language names have been collected from a number of sources, with consent, and their inclusion is a valuable aspect of the project. (Refer to Section 7.0 for details)

All data referred to in this report is held by the NRD at their offices in Darwin. Most is on public record and is easily accessible. (Refer to Section 8.0 for details regarding data format, location and availability)



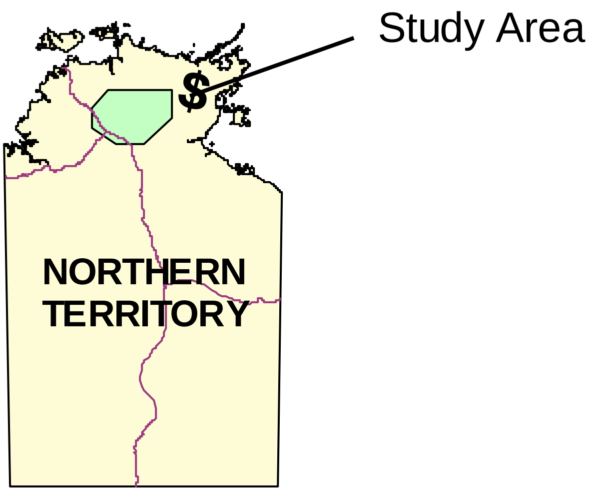




**Figure 1** Location maps for Katherine Region and South West Arnhem Land

## 1.1 Climate

The region lies in the "Wet/Dry" monsoonal tropics, with a long Dry season between April and October, and a Wet season from November to March. The mean annual rainfall for Katherine is 972mm, with the majority of rain falling between December and March. Average monthly rainfall and annual rainfall is shown in Figures 2 and 3. Temperatures range from a mean annual maximum of 34°C to a mean annual minimum of 20°C. Highest temperatures are recorded in October and November, when the mean daily maximum approaches 38°C. Evaporation is high, averaging 2279mm per year, with monthly evaporation exceeding monthly rainfall throughout the year. There is high variability in annual rainfall, with a documented range from 364mm in 1951/52 to almost 2000mm in 1897/98. The influence of the variable climate on the regions water resources is discussed in later chapters.

## 1.2 Geology

Rock type and geological structure are some of the main factors influencing groundwater occurrence and the location of springs. The study area is covered by the 1:250,000 geological map sheets KATHERINE, MOUNT MARUMBA, URAPUNGA and MOUNT EVELYN, and several more detailed special edition 1:100,000 map sheets (listed in References).

The area contains rocks from three major units which are known as the Pine Creek Geosyncline, the McArthur Basin and the Daly Basin. The oldest rocks are shales, siltstones and *cherts*, found in the South Alligator Valley and Barnjarn. Granites were then intruded (injected) into these sediments, and examples can be seen in the southeast of Nitmiluk as the Grace Creek and Yeuralba Granites. Kombolgie Sandstone was deposited on top of these older rocks, and today forms the Arnhem Land Plateau that dominates the landscape of the region. To the west, basalts and limestones were deposited in the Daly Basin, forming today's Tindall Limestone.

Much younger subhorizontal Cretaceous sandstones overlie all of these units, forming small flat topped mesas and more extensive plateaus (eg the Murruwal Plateau). These sediments were deposited when much of the area was drowned by rising sea levels, leaving only the higher parts of the Arnhem Land Plateau above sea level. The sea level has since fallen, and intense weathering has removed much of the Cretaceous sediments, and led to the development of iron-rich cappings on many surfaces, known as *laterite* or ironstone. The formation of the laterite has reduced the rate of erosion.

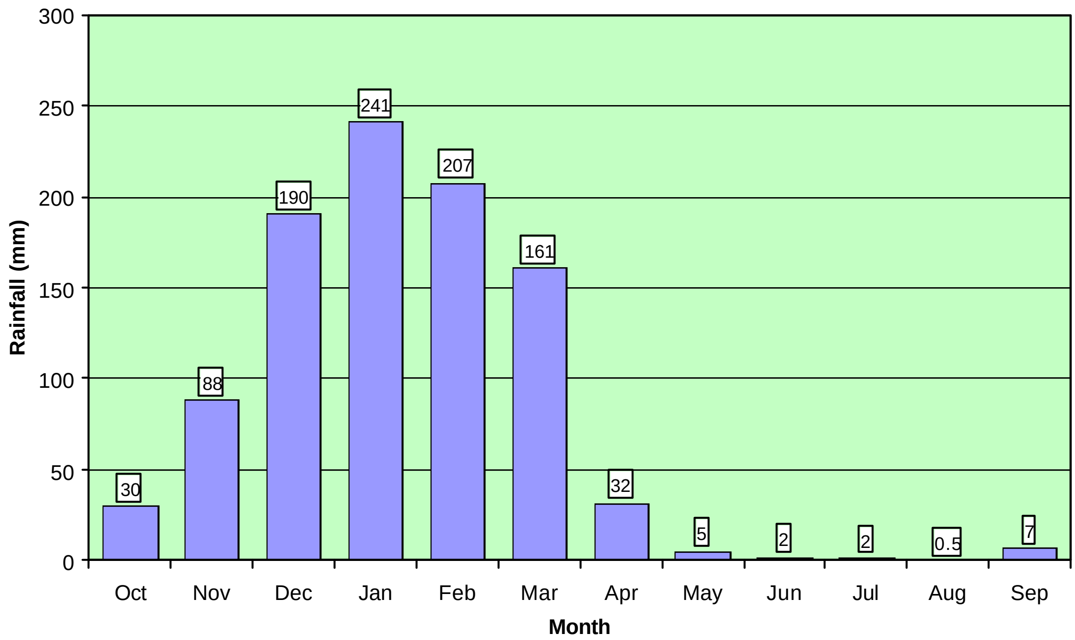



**Figure 2** Average monthly rainfall – Katherine

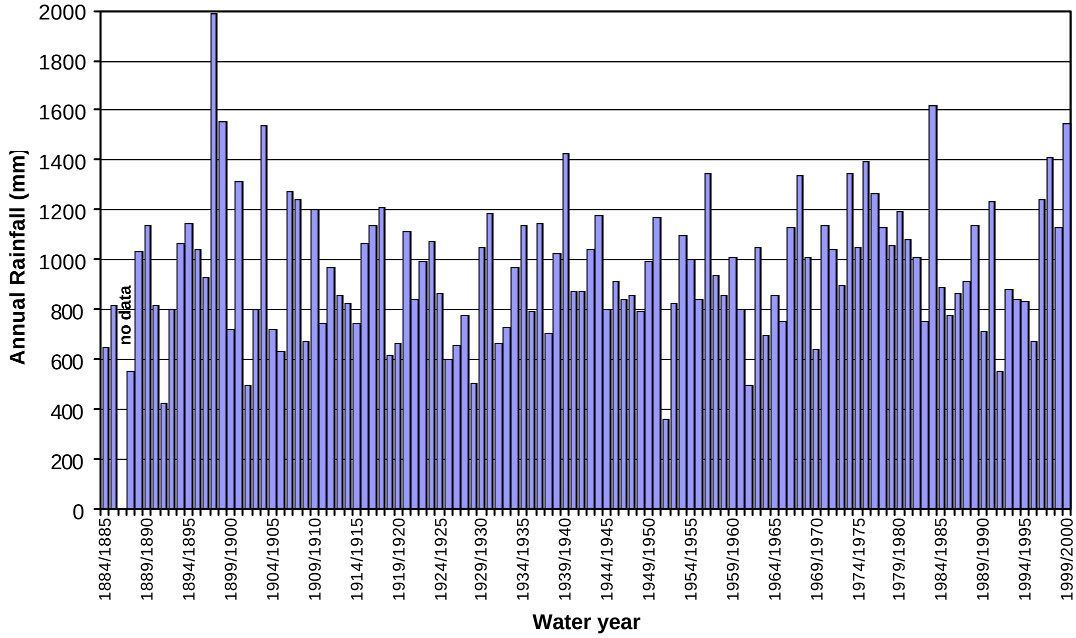



**Figure 3** Annual rainfall for Katherine (*water year* October – September)

### 1.3 Landform and drainage

The landforms and environment of this region have evolved through the interaction of geology and climate over many millions of years. The different landforms and soils are related to the underlying rocks, and to the effects of weathering and erosion.

Prominent mesas or plateaux are formed by the flat lying Cretaceous sediments, which rest on top of older Proterozoic bedrock. The two major examples of this are the Murruwal Plateau and the area between Banatjarl, Barunga and Manyallaluk. Tall open eucalypt forest usually grows on top of these plateaux. The edges of the plateaux are often abrupt, with steep slopes or cliffs which have allowed the formation of monsoon rainforest pockets, for example close to Banatjarl. Seasonal billabongs occur on top of the plateaux, and springs are a common feature of the margins. An example of the plateau edge can be clearly seen from the road, to the north of the highway, just a few kilometres west of Barunga.

Undulating sandy areas with rounded boulders characterise the granite country, as seen to the north of Manyallaluk and also between the Stuart Highway and Werenbun. Surface water is rarely seen in these areas as water quickly infiltrates into the sandy soils.

Much of the study area is characterised by rocky pavements with sparse vegetation and a criss-cross pattern of vertical fractures or joints, the "Stone Country". This is the outcropping Kombolgie Sandstone, which forms the Arnhem Land Plateau, as seen at Nitmiluk and the Escarpment in Kakadu. The sandstone cliffs of the Arnhem Land escarpment were formed by the undermining effect of wave erosion at their base during a period of high ocean levels.

Headwaters of seven major Top End drainage basins are included in the study area, as shown in Figure 4. Of these, the Roper, Daly (ie Katherine, Edith and Fergusson Rivers), Mary, South Alligator and the Mann Rivers have permanent Dry season flow supplied by *aquifers* within the study area.

The major drainage patterns are based on ancient river systems which were re-instated once more recent sedimentary deposits were removed by erosion. Katherine Gorge is a good example of re-juvination of a pre-existing gorge.

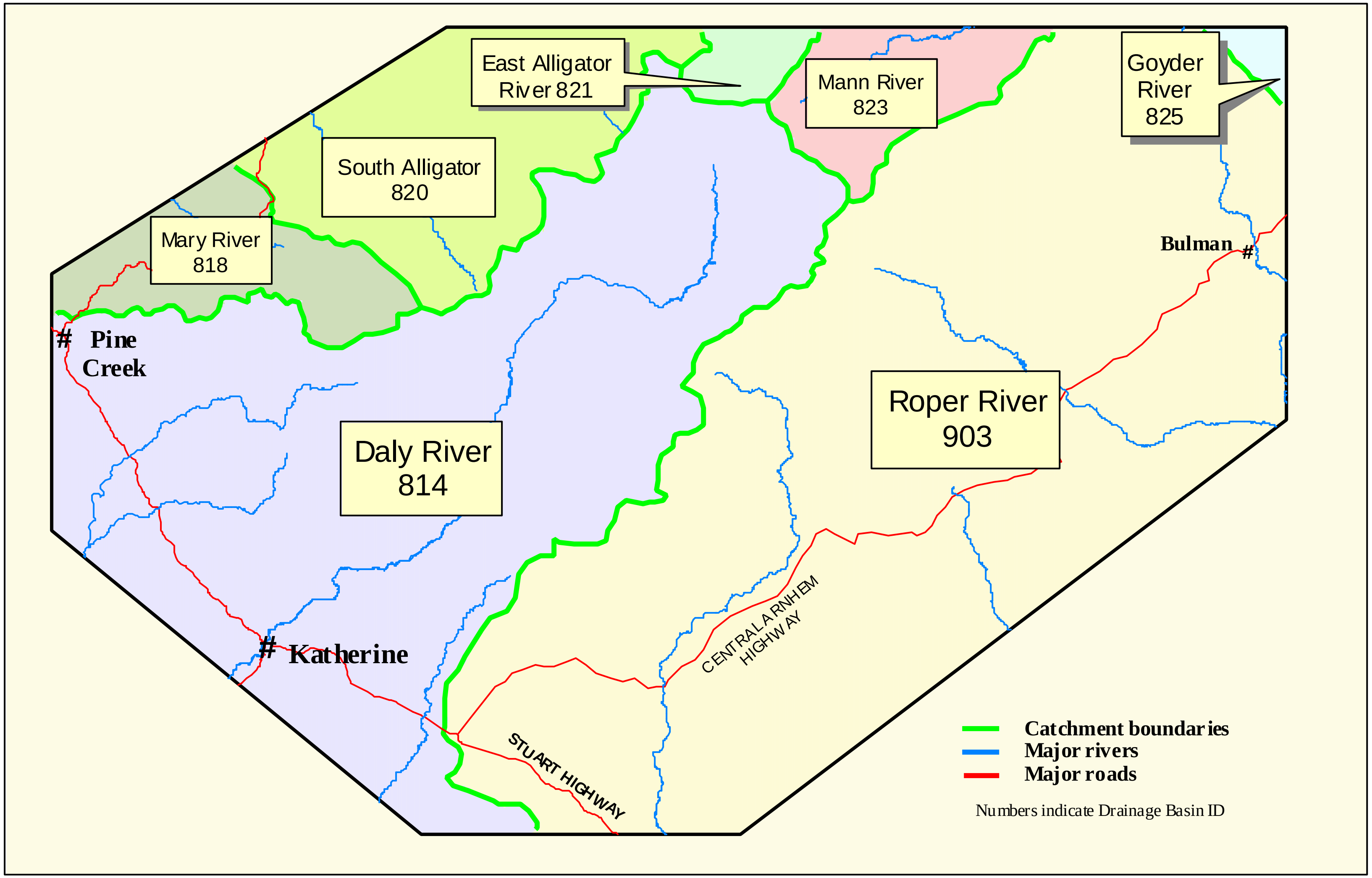



**Figure 4** Major river catchments

### 1.4 Current water usage

Katherine town water supply is drawn from the Katherine River at Donkey Camp, and is occasionally supplemented by bore water.

Traditionally, communities and outstations all obtained their water supply from surface water, such as billabongs or creeks, or from springs. Bore water is now used throughout, with the exception of Mount Catt, which continues to abstract water from a spring in the absence of a successful bore, and Barunga where spring water supplements the bore water supply.

Groundwater is also abstracted for domestic, agricultural and horticultural irrigation supply and light industrial use in the Katherine region.

**Plate 1** Mount Catt Spring and water supply

## 2.0 GROUNDWATER

### 2.1 The Groundwater System

To understand the groundwater system, it helps to have an understanding of the water cycle (see Figure 5). When rainfall hits the ground, some of it runs off into streams and creeks (surface runoff), some of it evaporates and some of it seeps into the ground (infiltration). The amount of water that infiltrates depends on many factors, including the soil and rock type, the slope and the intensity and duration of rainfall. Of the water that infiltrates, some will evaporate or be taken up by the soil and used by vegetation (evapotranspiration), and the rest will move downwards until it reaches the watertable to become groundwater. The process of adding water to the groundwater system is called *recharge*. *Porous* rocks and soil allow the groundwater to slowly move from high areas to low areas, usually discharging to the surface at some point. If a useful amount of water can be extracted from a rock unit, then it is referred to as an *aquifer*.

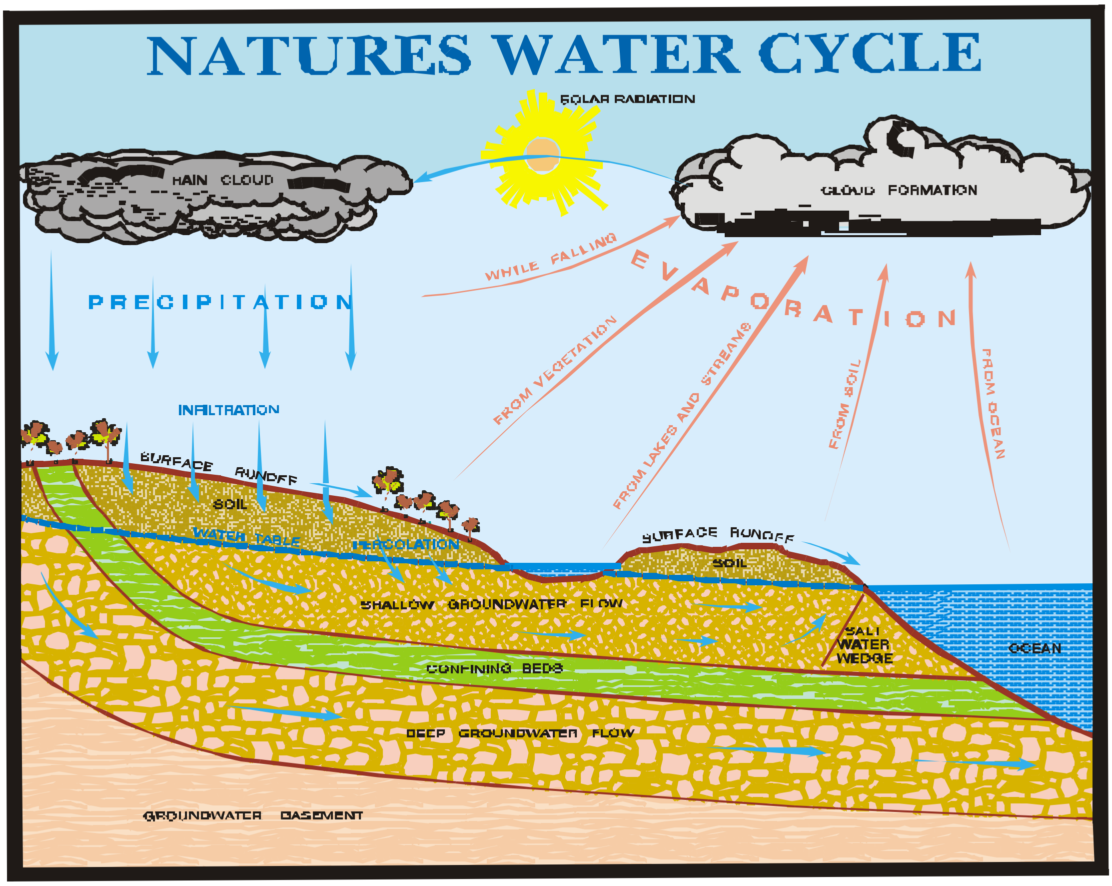



**Figure 5** The Water Cycle

*Recharge* occurs only in the Wet season when rainfall intensity and duration is sufficient. Groundwater levels rise, while in the Dry season the levels fall. The amount and rate at which the groundwater levels rise and fall depends on the type, size and other physical properties of the aquifer as well as the amount of recharge. NRD monitors the change in groundwater levels in many aquifers throughout the Northern Territory, and has many years of record. This is done by measuring the depth of *water* in observation bores, which are generally bores that were primarily drilled for this purpose.

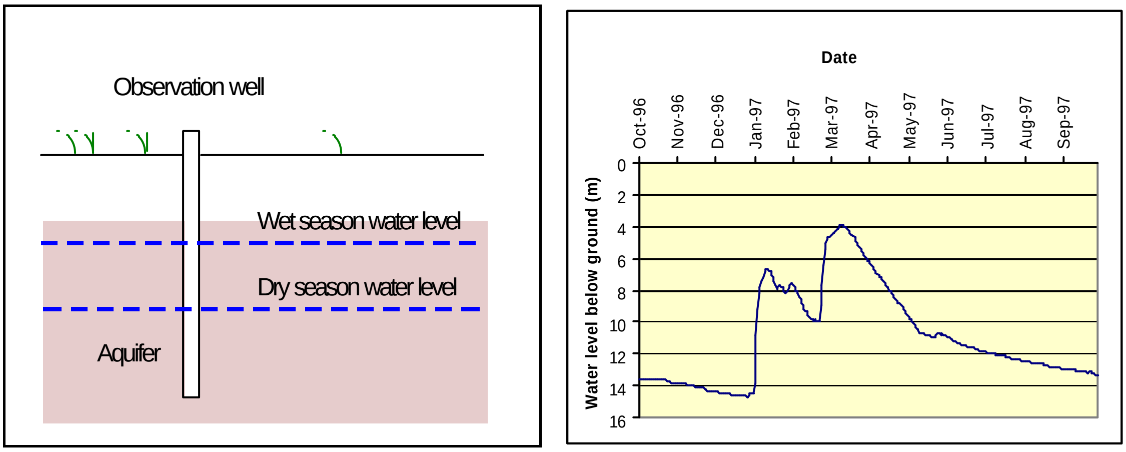



**Figure 6** Variation in Groundwater Levels in observation bore RN21689 at Wugularr

Knowing how an aquifer responds to recharge and Dry season water level changes can help us determine how much groundwater is available for abstraction from a bore, and how the water levels will change in response to pumping.

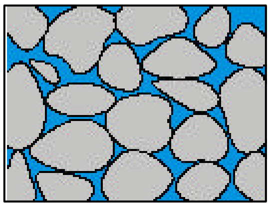
## 2.2 Aquifer type

The different aquifers found in the Katherine region and South West Arnhem Land have been grouped according to the expected bore *yield* and water quality of the groundwater found in them. Each of the groundwater groupings is discussed below, and their sustainability is discussed in Section 5. Geological units have been grouped together based on their relevant properties.

The bore yields stated represent typical yields that could be expected from bores sited using geological and local knowledge. Natural variation in the properties of the aquifers means that variation in bore yield within a groundwater grouping will occur. As such, a percentage of bores within a particular grouping may have a lower or higher yield than described, but most will fall within the nominated limits. The amount of water that can be safely pumped from a bore over a long period is less than that which can be pumped over a short period. Therefore it is recommended that bores are pumped at a lower rate than the yield produced by *airlifting* whilst drilling is taking place.

### *2.2.1 Explanation of Aquifer Type as shown on the Water Resource Map*

CRETACEOUS AQUIFERS



This aquifer type is coloured blue on the map. These zones represent areas of upland and plateaus that are formed by Cretaceous aged clays and sandstones, which form major aquifers in this region. The groundwater is stored in the spaces between the grains. Poorly *consolidated* sandstones underlie claystones and the lateritic surface. These aquifers naturally discharge large volumes of groundwater throughout the year, and are responsible for the *baseflow* of many of the larger rivers and creeks in the region.

The Murruwal Plateau and the uplands between Banatjarl, Barunga and Manyallaluk are the major occurrences of this type of aquifer. Surface water flow in Seventeen Mile Creek (which often provides most of the dry season flow into Katherine's water supply at Donkey Camp) is maintained by groundwater discharge from a number of springs and seeps at the base of the Murruwal Plateau. For example Crystal Falls and Biddlecombe Cascades are sourced from a number of seeps upstream.

This aquifer type has a high storage of groundwater (ie *porosity*), but high permeability is limited to the sandstone unit of variable thickness which occurs at its base. This aquifer has the capacity to supply significant amounts of water, however individual bore yields will depend upon the depth and thickness of sandstone intersected. Bores have been successfully completed within this aquifer that yield up to 20 L/s, although a more typical yield is 2 L/s to 10 L/s. This type of aquifer provides water to Manyalluluk and Banatjarl, and several high yielding bores have been drilled close to Barunga. Bore depths required range from 25 to 50 metres.

As groundwater discharge from these aquifers provides Dry season flows in many springs, creeks and rivers, the volume of water extracted by bores must be carefully managed to avoid any impact. This is discussed in further detail in Section 5.0.

DOLOMITIC AQUIFERS

This aquifer type is coloured green on the map. It can be subdivided into three different aquifers based on geology, as shown in Figure 7. Groundwater occurs in networks of cavities or fractures in the rock caused by water slowly dissolving the rock over many years. This is known as a *karstic* aquifer.

***Dook Creek Formation***

One aquifer has formed in dolomitic rocks of the Dook Creek Formation, which occurs in two locations, one close to Wugularr, and the other a much larger area extending from Flying Fox Creek through to Bulman. Groundwater discharge from this aquifer type provides the Dry season flow in Flying Fox Creek, Mainoru River and some of the Wilton River. The water supplies for Bulman and it's neighbouring outstations is sourced from bores drilled into this aquifer. Several large springs emanate from this aquifer, for example at Weemol. Two bores located in the small isolated aquifer to the east of Wugularr has provided the community water supply since 1982. Where extensive, this aquifer type has the potential to supply quite large amounts of water. Individual bore yields of up to 10 L/s are expected, although bores can be unsuccessful if cavities are not intersected. Drilling depths may be up to 80 metres, depending on the local occurrence of suitable cavities.

Sinkholes are a common feature of this aquifer, and spectacular examples occur on Mainoru Station, approximately 7 km north of the Central Arnhem Highway crossing of the Mainoru River (Plate 1). Smaller examples can be seen approximately 6km east of Wugularr (for example at grid reference 0302250 8393200).

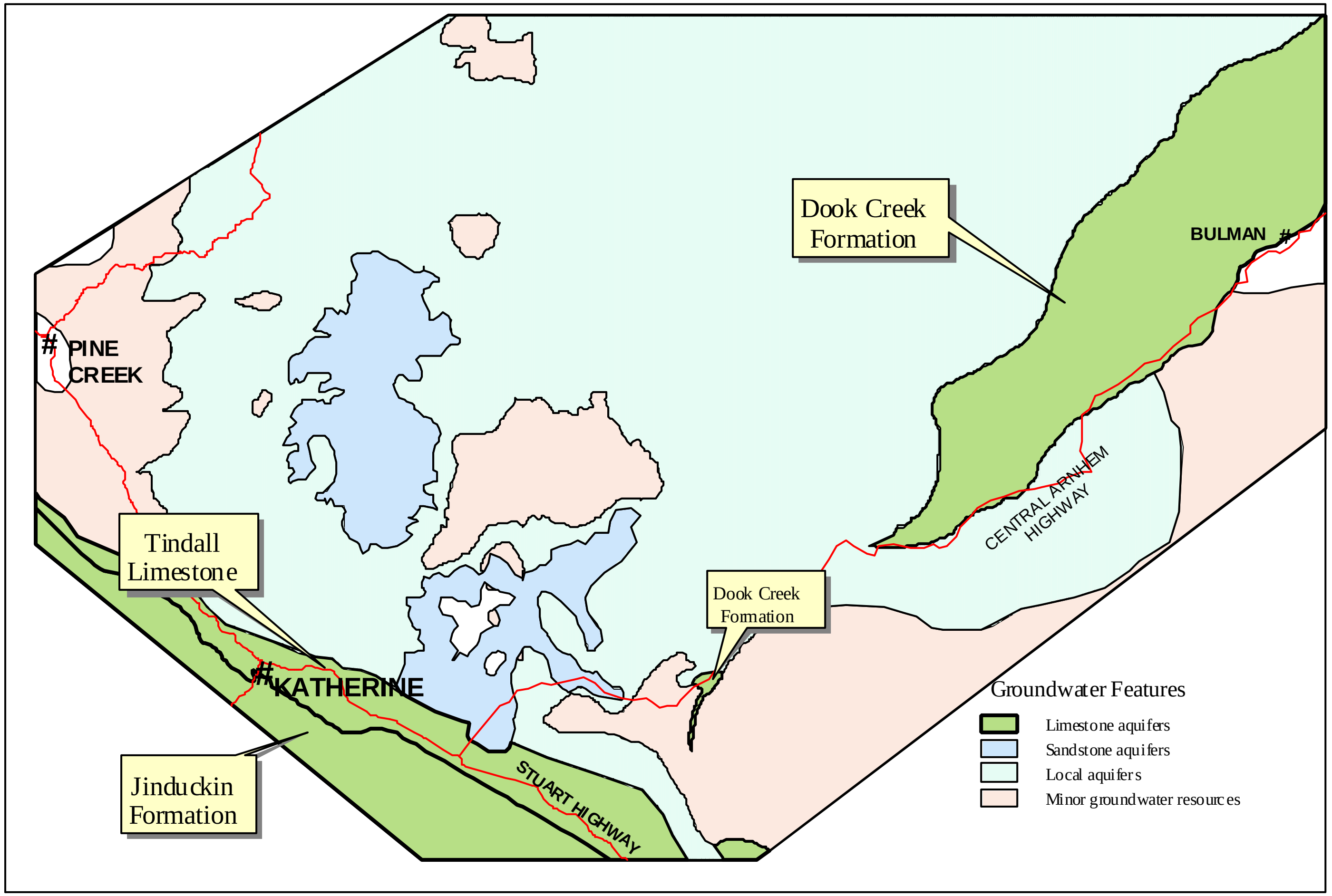



**Figure 7** Occurrence of aquifer types

**Plate 2** Sinkhole on Mainoru Station as viewed from the air

***Tindall Limestone***

The Tindall Limestone is an important regional aquifer in the Katherine area. It provides a substantial and reliable groundwater resource that is currently utilised for irrigation, and both private and municipal water supplies. It is a highly *permeable* dolomitic aquifer, and groundwater occurs in cavities and fractures. The area shown is the *unconfined* portion of the aquifer, which has the highest yield potential. Individual bore yields are typically 2-20 L/s, and yields of up to 60 L/s are known from bores located in favourable aquifer conditions. Drilling depths range from 60 to 150 metres, and success depends on the intersection of suitable cavities. Sinkholes are a common surface feature, and act as points of recharge to, and occasionally discharge from, the aquifer.

Water from this aquifer is used for irrigation of horticulture in this region. An example of this is the Venn horticultural area to the south-east of Katherine, where several large scale irrigation systems, including centre-point irrigation, utilise high producing bores.

This aquifer also provides the Dry season baseflow for the Katherine, Fergusson, Douglas and Roper Rivers. Availability of groundwater for abstraction is based primarily on maintaining river baseflows (known as *environmental flows*). Notwithstanding this, aquifer hydraulic characteristics are such that developments requiring large quantities of water appear feasible. Much of the Tindall aquifer in this area lies within the Katherine Water Control District, and therefore licences are required for bore drilling and abstraction.

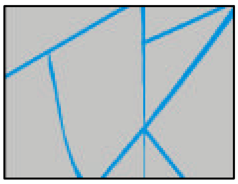
***Jinduckin Formation***

This aquifer is coloured lighter green on the maps, and represents where the Tindall Limestone is overlain by the limestone, siltstone and shale of the Jinduckin Formation. The Jinduckin Formation is an *unconfined* aquifer of low yield potential, suitable for domestic, pastoral and small scale horticultural development.

Bore yields are typically 0-5 L/s, although higher yielding bores (up to 10 L/s) have been constructed where there are favourable aquifer conditions. Bores drilled in this aquifer are up to 50 metres deep. Water quality is of sometimes marginal, and is discussed in the following section. The availability of groundwater is based primarily on sustaining rural production.

A second aquifer underlies the Jinduckin. This is the *confined* portion of the Tindall Limestone. Here, it is of low yield potential due to its location and depth, but is suitable for domestic, pastoral and small scale horticultural developments. Bore yields can be up to 30 L/s, although due to its confined nature, less water is available for abstraction than for the *unconfined* part of the aquifer. The availability of groundwater is based primarily on maintaining pressure heads in the aquifer.

LOCALLY DEVELOPED AQUIFERS



This group is coloured light blue-green on the map, and covers the largest portion of the region. In these aquifers, groundwater occurs in networks of fractures or cracks, and can occur in a range of rock types such as hard sandstone, basalt and cherts. The aquifers tend to be in areas where fracturing is more intense, such as faults zones, but can also occur where there has been a significant weathering of the surface rock.

Some of the most heavily fractured zones are shown on the map by cross-hatching. Outside of these areas, bores need to be sited in areas where there is a good chance of intersecting cracks and fissures in the rock at depth. Faults and fracture zones may be identified on aerial photographs and/or satellite imagery by *hydrogeologist*s, and bores can then be sited on the most promising features. *Geophysical* surveys can also be used to identify potential bore sites.

The effects of fracturing and weathering generally decreases with depth, and therefore drilling depths are seldom more than 60 metres. Bore yields from these aquifers tend to be low, up to 5 L/s with correct siting and careful construction. The nature of these aquifers makes it very difficult to predict the quantity of water available, and even bores drilled close together can have very different yields. Sustainability of supplies from these aquifers is described in Section 5. Heavy fracturing is often associated with mineralisation of the rocks, and so enhanced groundwater availability may be found in mining areas such as the Moline and Mount Todd area.

MINOR GROUNDWATER RESOURCES

This group is coloured orange on the maps. These areas are mostly underlain by granite or shales, claystones and cherts. These rocks are poor aquifers, with only small, isolated supplies available. Most bores drilled in these areas are dry.

If drilling is proposed, then it should be targeted at fractured and weathered portions. Hydrogeologists should be consulted prior to drilling as careful site selection will increase the likelihood of obtaining a useable supply.

### 2.3 Water quality

The quality of groundwater depends upon factors such as the type of rock that constitutes the aquifer, and the amount of time that the water has been moving through the aquifer. In order to describe the quality of water and its suitability for drinking or other use, a number of parameters can be measured in the field and in the laboratory. The Australian Drinking Water Guidelines (ADWG, 1996) define good quality drinking water from the perspective of health and aesthetics. They do not provide mandatory standards, but represent a framework for identifying acceptable water quality through community consultation. The full guidelines are included on the accompanying project CD-ROM.

Water samples were taken from a number of springs, creeks and bores during this project in order to characterise the water quality and chemistry for the region. Comprehensive chemical analyses of the various groundwaters in this region are presented in Tables 3 and 6 in the accompanying Technical Data volume. This includes results of water sampling from previous studies and work in the region. Specialised water sampling has been undertaken in several areas: the AUSRIVAS initiative included biological and macroinvertebrate sampling in the Katherine and Mary River systems; the Environmental Research Institute of the Supervising Scientist (*eriss*) conducted macroinvertebrate sampling in the upper reaches of the Mann and Katherine Rivers and full trace element sampling was carried out in springs and creeks in the upper reaches of the Mann and Katherine Rivers as part of this project. This provides baseline chemistry data of this near pristine environment before any changes in land use (such as mining) have any impact. Results and locations of this sampling are given in Table 6 of the Technical Data Volume.

A more direct way of describing water quality is simply by measuring the two parameters of *Total Dissolved Solids* (TDS) and pH. These two parameters can be easily measured in the field, and give an immediate indication of water quality and suitability.

TDS is a measure of the saltiness of water. It is a measure of the amount of salt in milligrammes per litre of water (mg/L). The ADWG states that good drinking water has a TDS of less than 500 mg/L, and that a TDS of 500 – 1000 mg/L is acceptable according to taste. Greater than 1000 mg/L may be associated with excessive scaling, corrosion and unsatisfactory taste. Water can also be described as being 'hard' or 'soft', a measure of the amount of calcium and magnesium present. 'Hard' water requires more soap to produce suds than 'soft' water, and is generally associated with groundwaters occurring in limestone and dolomite aquifers. Water having more than 150 mg/l *hardness* can deposit scale in pipes and water heaters.

A simple way of estimating TDS in the field is by measuring the water's electrical conductivity, EC. Salt present in the water makes it more conductive for an electrical current. This can be easily measured with a small field probe and is measured in microSeimens per centimetre, µS/cm. At a temperature of 30 Celsius, water with a TDS of 1000 mg/L will have an EC of approximately 1600 µS/cm. Figure 8 below shows the approximate relationship between TDS and the EC as measured in the field.

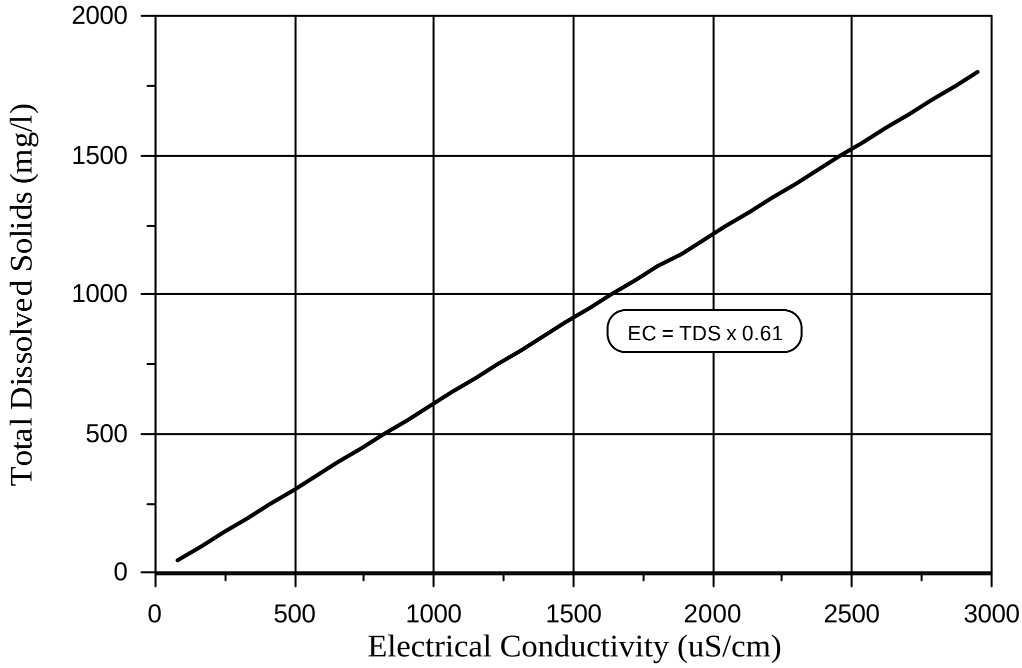



**Figure 8** Approximate comparison between Electrical Conductivity and Total Dissolved Solids

pH is a measure of the hydrogen ion concentration. Water is said to be either acidic or alkaline, depending on the relative concentration of hydrogen ions. A pH of 7 indicates neutrality, whereas a pH of less than 7 indicates an acidic water, and a pH of greater than 7 indicates an alkaline water (although temperature does have a small effect). The pH of most groundwaters results from the balance between dissolved carbon dioxide derived from the atmosphere, and the dissolved carbonates from the aquifer material. An acidic water generally indicates that recharge is recent and has occurred rapidly. Acidic water is corrosive to metal bore casing and pipes, but is still suitable for consumption if plastic or PVC bore casing and pipes are used to distribute the water. Alternatively, the water can be treated by aeration, which allows the dissolved carbon dioxide to be released to the atmosphere, causing the pH to increase. Alkaline water is generally associated with limestone or dolomite aquifers, and is a good indicator of the aquifer rock type. Recommendations for local water treatment can be obtained from the DLPE Advisory Service in Darwin (contact details in Section 6.0).

Measurement of pH in the field is important, as during sampling, storage and transportation to a laboratory, there may be changes in pH due to chemical reactions. Field measurement is easy, and generally done by using a small probe which can give excellent results if regularly calibrated.

**Plate 3** Taking chemistry measurements in the field

### *2.3.1 Relationship between Water Quality and Aquifer Type*

CRETACEOUS AQUIFERS

The water quality from this sandstone aquifer is consistent, with a low TDS, typically less than 50 mg/l, a pH of around 5, and can be classed as very soft (ie generally less than 10 mg/l of calcium carbonate, $CaCO_3$). This water is corrosive to metal bore casing and pumps, but is still suitable for consumption if PVC casing and pipes are used, or if treated by aeration. Aeration can also be used to treat the high iron content that, although not a constraint on *potability*, can be high enough to discolour the water.

DOLOMITIC AQUIFERS

***Dook Creek Formation***

Bore and spring water sourced from this aquifer generally has a TDS ranging from 200 to 500 mg/L, and is slightly alkaline with a pH of 7 to 8. The water can be described as 'hard', with $CaCO_3$ concentrations of up to 350 mg/L. Hard water requires more soap to produce suds.

This water may be associated with excessive scaling of water heaters, jugs and pipework. Otherwise, this water is suitable for all uses.

***Tindall Limestone***

Water chemistry in the Tindall aquifer is fairly uniform and of reasonable quality. It is a typical limestone water , with its most notable feature being *hardness* (250 to 500 mg/L $CaCO_3$). TDS ranges from 200 to 500 mg/l and pH is generally between 7 and 8. Any variation in water quality is due to localised differences in rock type and the age of the groundwater. The water from this aquifer is suitable for most uses. Katherine Town water supply is occasionally supplemented with water from bores in this aquifer.

***Jinduckin Formation***

Bores in this aquifer often yield supplies with excessive *salinity*, particularly in the form of calcium sulphate. This generally renders the water intolerably hard and unsuitable for human consumption. Fluoride levels can also be too high for human consumption. Potable water is sometimes encountered, generally at shallow depths, although it is unlikely that these better quality supplies would sustain major development. However, high sulphate water has been successfully used for irrigation of fodder crops at Tipperary, and at the Manbulloo Mango Farm. Cattle seem to become tolerant to the water, although if fluoride levels are high, the correct salt licks must be used.

Bores drilled into the Tindall Limestone at depth, through the overlying Jinduckin Formation, have encountered water of good quality, with a chemistry similar to that of the *unconfined* portion of the Tindall aquifer.

LOCALLY DEVELOPED AQUIFERS

and

MINOR GROUNDWATER RESOURCES

These smaller localised aquifers are in many different types of rocks, which can often have a direct effect on groundwater quality. In general however, groundwater will be of good quality, with low to moderate TDS and a low pH. There are cases where water intersected at depth is slightly salty (eg Moline area). Water chemistry from bores drilled into these aquifers can be found in Table 3 of the Technical Data report.

## 3.0 SURFACE WATER

Surface water occurs as billabongs, river pools, rivers and springs, and can be characterised into two main sources: directly from rainfall and rainfall *runoff*; or from groundwater discharge or *baseflow*.

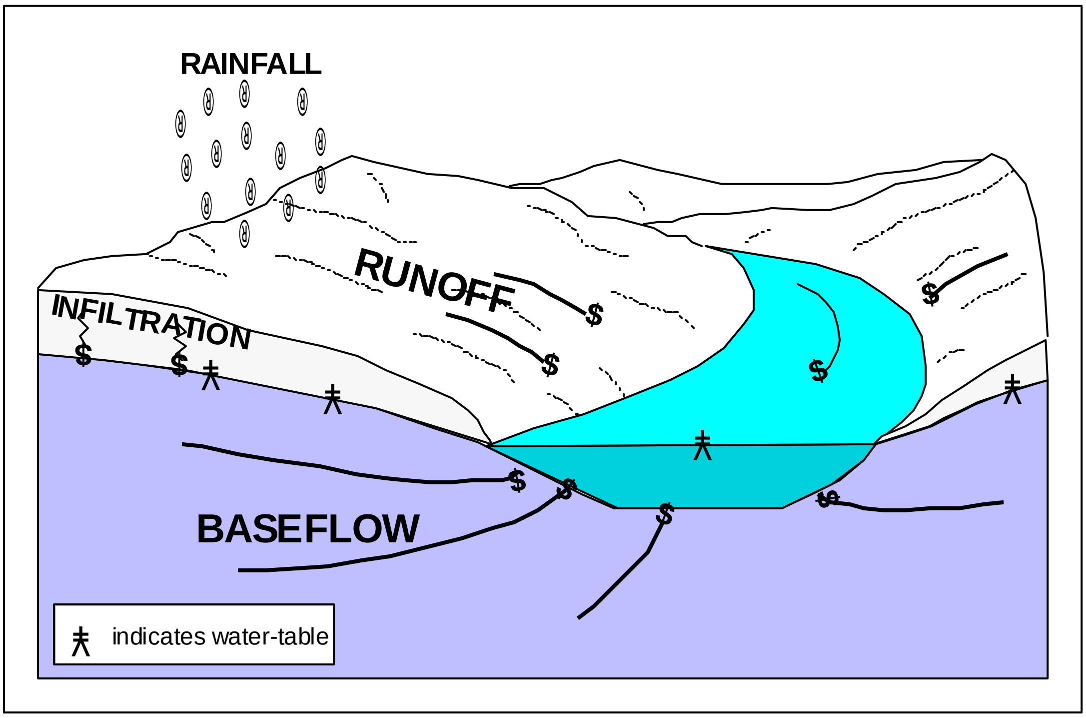



**Figure 9** Runoff and Baseflow components of surface water

When examining surface water occurrence it is important to distinguish between these two sources. Surface water derived from rainfall and runoff occurs in the Wet season, and will only persist if storage is high enough to last through the Dry season. It is the baseflow component that keeps rivers and creeks flowing through the long Dry season.

A third category of temporary baseflow may occur, providing apparently permanent baseflow to springs and creeks, but only after an extended period of above average Wet seasons. An example of this is Dook Creek near Wugularr, normally sourced from springs and seeps in the Cretaceous sandstones. During this project, the creek continued to flow significantly throughout the Dry season, although it is known that it will often dry up at the road crossing near the community in average to below average rainfall periods. This is due to the higher than average rainfall period raising the water table in the underlying sandstone aquifer, to the point where the creek bed intersects the raised groundwater system.

Flow in a river is often presented as a *hydrograph*, which usually shows daily or monthly variations in water flow or height. Figure 10 depicts the variation in flow for Seventeen Mile Creek between October 1980 and May 1982. The two components of baseflow and runoff are easily distinguished.

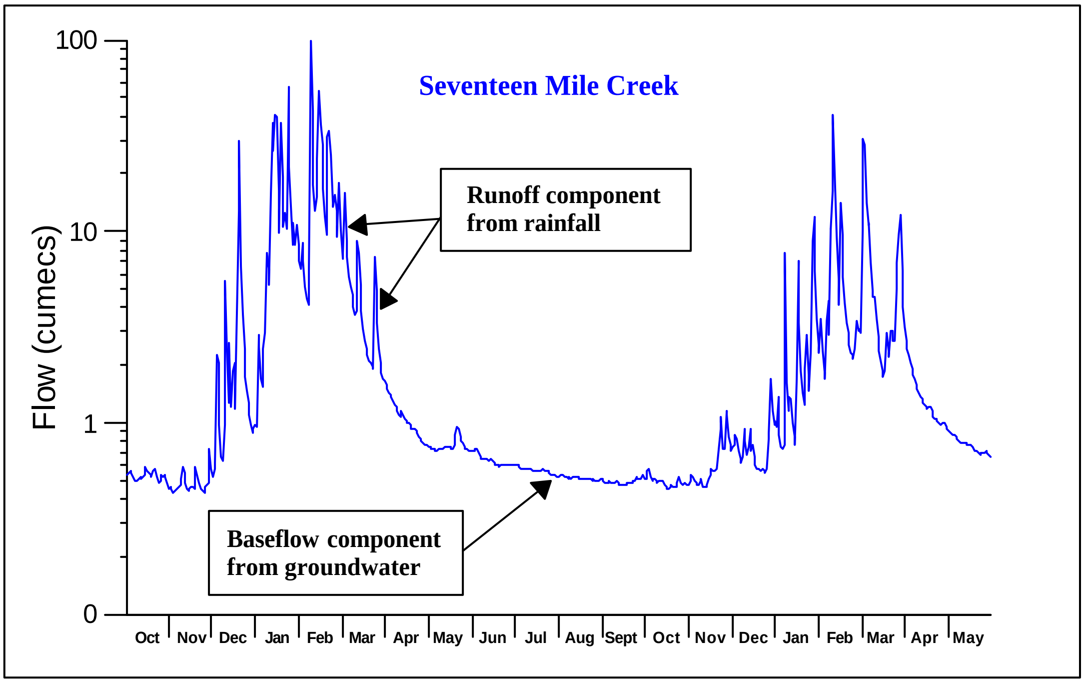



**Figure 10** Flow in Seventeen Mile Creek from October 1980 to May 1982. Flow record from NRD's gauging station G8140159

NRD records the variation in river height and flow at a number of sites (*gauging stations*) in the region. Currently monitored sites (open) and previously monitored sites (closed) are shown on the Water Resources Map and listed in Tables 4 and 5 of the Technical Data report. This is done by continuously monitoring river height using a recording device (logger), with regular calibration by manual flow measurements (gaugings). The records from these gauging stations have been used to correlate river flows with variation in groundwater levels and rainfall.

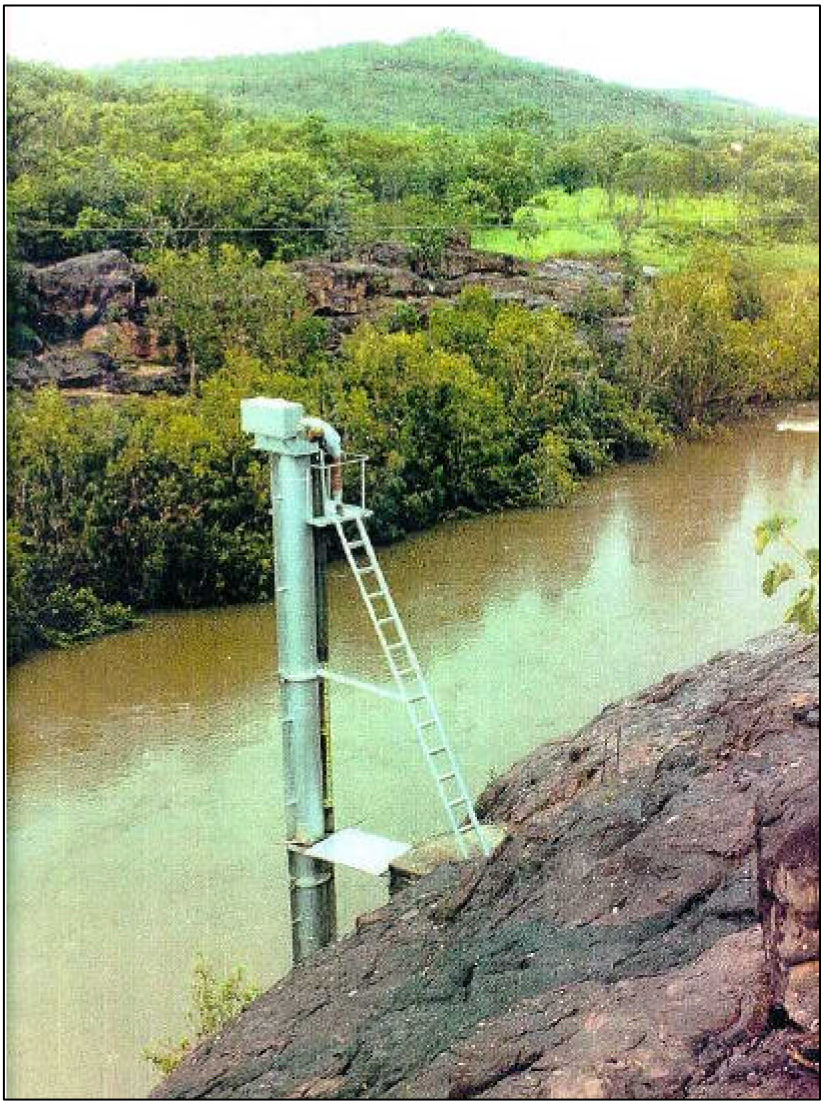


**Plate 4** Photo of gauging station
South Alligator River at El Sherana - G8200045

### 3.1 Minimum Flows

In order to know what quantity of water can be sustainably pumped from a river, it is necessary to know what the minimum flow is, and how much variability there is. Figure 11 shows the flow at Seventeen Mile Creek since 1966. It can be seen that the minimum Dry season flow in 1972 was 0.2 cumecs (200 L/s), whereas the minimum flow in 1976 was 0.6 cumecs. This variation is due to variations in annual rainfall. Analysis of the rainfall records for the region, shows that there is a complex relationship, depending on the combined impact of several years of rainfall.

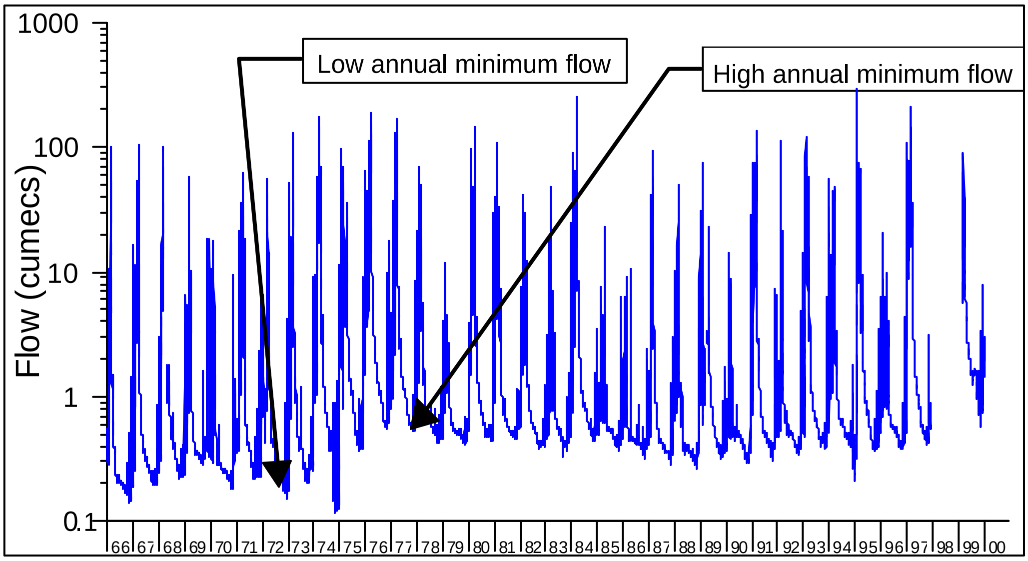



**Figure 11** Flow at Seventeen Mile Creek from 1966 to 2000.
Recorded at NRD's gauging station G8140159

### *3.1.1 Baseflow in the Katherine River*

The Katherine River has the longest and most complete record of all of the rivers in this region. A relationship between rainfall and river baseflow at the Low Level Crossing has been established using computer modelling. This has allowed the production of a baseflow hydrograph, which depicts the groundwater baseflow contribution to river flow for a period covering the entire rainfall record (1885 to present). A summary of this work is given in the Appendices. Analysis such as this gives a good indication of the variability in river baseflows that occurs in this region. It can be seen that there have been several periods historically during which the river baseflow has dropped below 600 L/s, compared with the period between 1977 and 1982 when the flow never dropped below 1500 L/s. Baseflow in the Katherine River comes from both the Cretaceous aquifers via Seventeen Mile Creek, and from the Tindall Limestone aquifer between Knott's Crossing and Galloping Jack's.

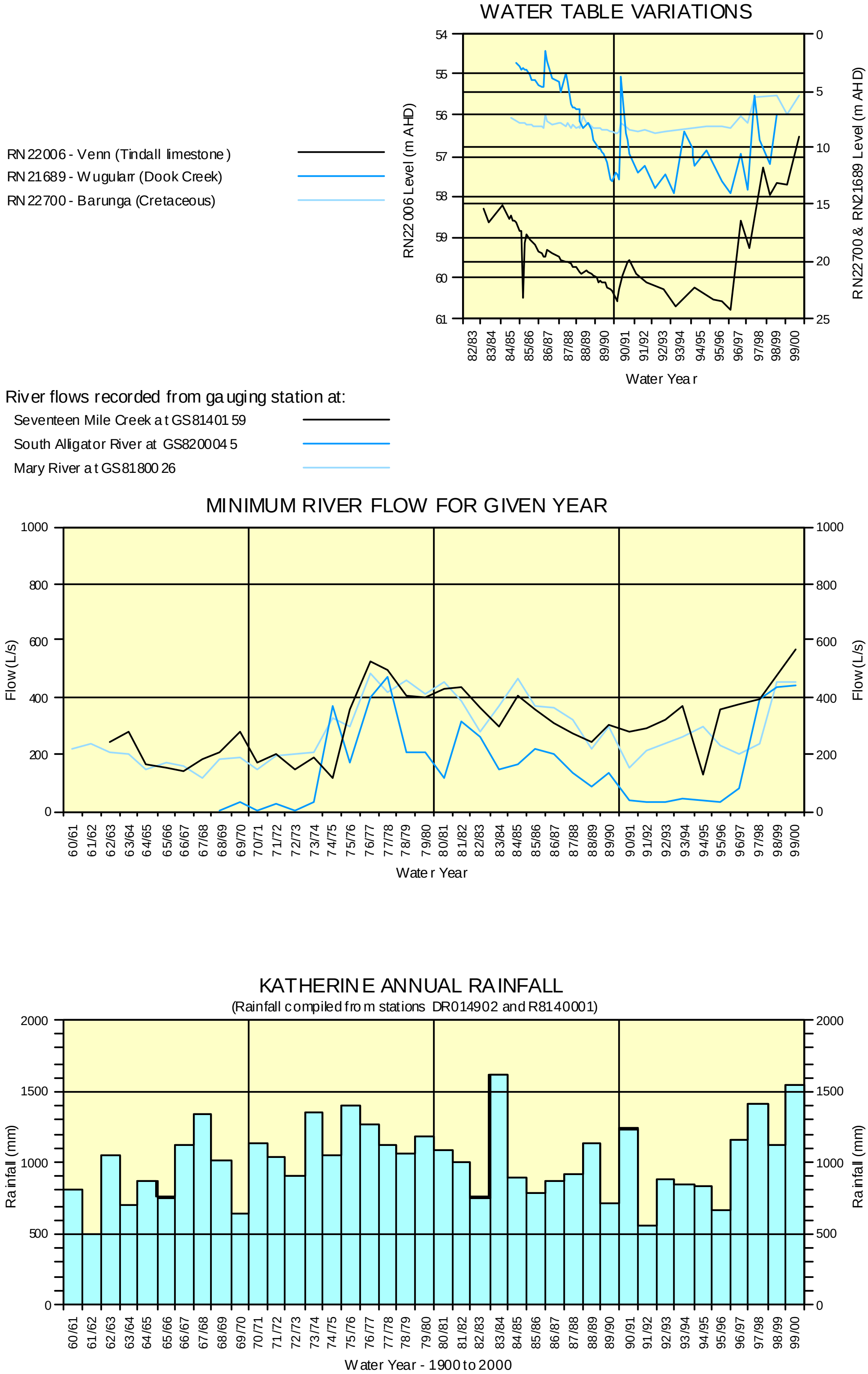



**Figure 12** Correlation between rainfall, water table level and river flow

### 3.2 Mapping minimum flows

River and creek flow on the Water Resource Map was plotted according to its minimum expected flow. Some of the river systems have been gauged and monitored for many years, and the long term variation in flow was taken into account when establishing minimum flows. In cases where no long term record exists, site visits, gaugings and local knowledge were used to determine flows. This project was conducted during a time of above average rainfall and consequently higher than minimum flows were observed in most river systems. This has been taken into account, and minimum expected flows have been estimated using Traditional Knowledge and scientific analysis.

The categories of some rivers have been estimated from anecdotal evidence or scientific interpretation, as some areas were inaccessible during the project duration.

There are four categories of minimum flow shown on the Water Resource Map as follows:

River with a flow of more than 100 L/s at the end of the Dry season.

These rivers can provide a large water supply. The Katherine River downstream of Seventeen Mile Creek, and the Mary River, are the only rivers in this region that will always flow in excess of 100 L/s along any significant length. Katherine's town water is supplied by water from Seventeen Mile Creek and the Katherine River.

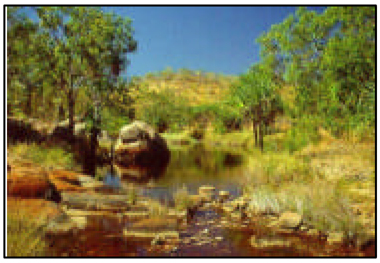
**Plate 5** Katherine River

River with a flow of between 10 L/s and 100 L/s at the end of the Dry season.

This category could provide a supply for a small community. The upper parts of the South Alligator River, and Flying Fox Creek are examples of this category. The South Alligator River provides Gimbats water supply.

**Plate 6** South Alligator River

River with permanent waterholes and flows up to 10 L/s at the end of the Dry season.



This category indicates a potential water supply for outstations. It includes rivers which cease to flow on the surface, but maintain permanent waterholes which could supply an outstation through the Dry season. Historically, most communities, homesteads and outstations in the region were supplied by rivers in this category. The upper reaches of the King River are an example of this category.

**Plate 7** King River

River which is dry at the end of the Dry season.

These rivers are not suited to supply water throughout the year. Many rivers and creeks will continue to flow throughout the Dry season after average and above average wet periods, but will cease to flow during drier times. Much of the Waterhouse River is in this category.

**Plate 8** Waterhouse River

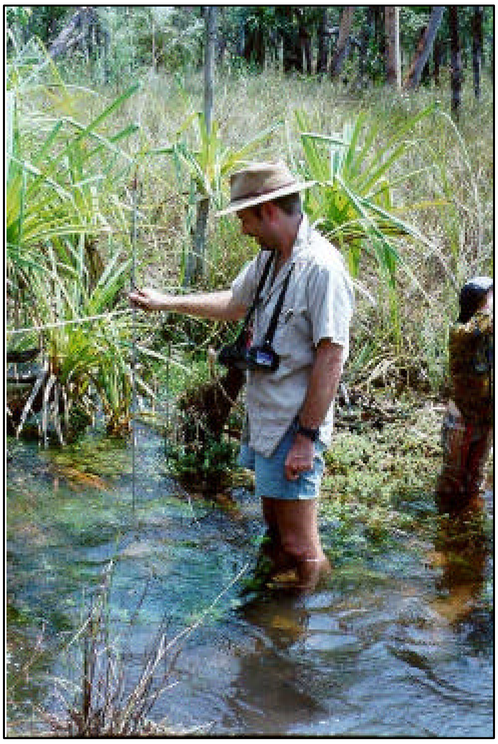


**Plate 9** Undertaking a flow gauging
Upper Katherine River

### 3.3 Wet Season Flows

In the Wet season, river flows increase due to rainfall runoff. The increase in flow at a point along the river is dependent upon the rain that has fallen in the *catchment* upstream from that point. The larger the catchment, the bigger the increase in flow due to rainfall. Major catchment boundaries are shown on the Water Resource Map. Major and minor catchments are also included in the GIS. The variation in river flow over the year is graphed for a number of rivers on the Water Resource Map.

A good example of the relationship of runoff to catchment size is shown in Figures 13 and 14. The catchment area above the gauging stations G8140159 (Seventeen Mile Creek) and G8140019 (Katherine Gorge – now closed, replaced by G8140023) are shown, and it can be seen that the Katherine River catchment is almost ten times the size of Seventeen Mile Creek's catchment. Figure 14 shows the Average Monthly Flow for these two gauging stations for the period 1963 to 1986. During the Wet season, average flow in the Katherine River is up to twenty times that of Seventeen Mile Creek, whereas during the Dry season, the flow in Seventeen Mile Creek is the greater. Groundwater discharge from the Cretaceous sediments of the Murruwal Plateau maintains the Dry season flow in Seventeen Mile Creek, whereas there are no major groundwater discharge sources into the Katherine River upstream of Nitmiluk Gorge.

Catchment boundaries are useful for relating Wet season flows and water quality at different points within a catchment. For example, an increase in *turbidity* in a stream could be due to eroding soils from a rough track in its vicinity, or perhaps due to feral animals damaging the river banks and allowing the soil to wash into the creek with the rain. Turbidity can destroy otherwise healthy habitats. Plate 9 shows the impact that feral buffalo and pigs have had on water quality in the most upstream parts of the Mann River.

**Plate 10** Feral buffalo damage – Upper Mann River

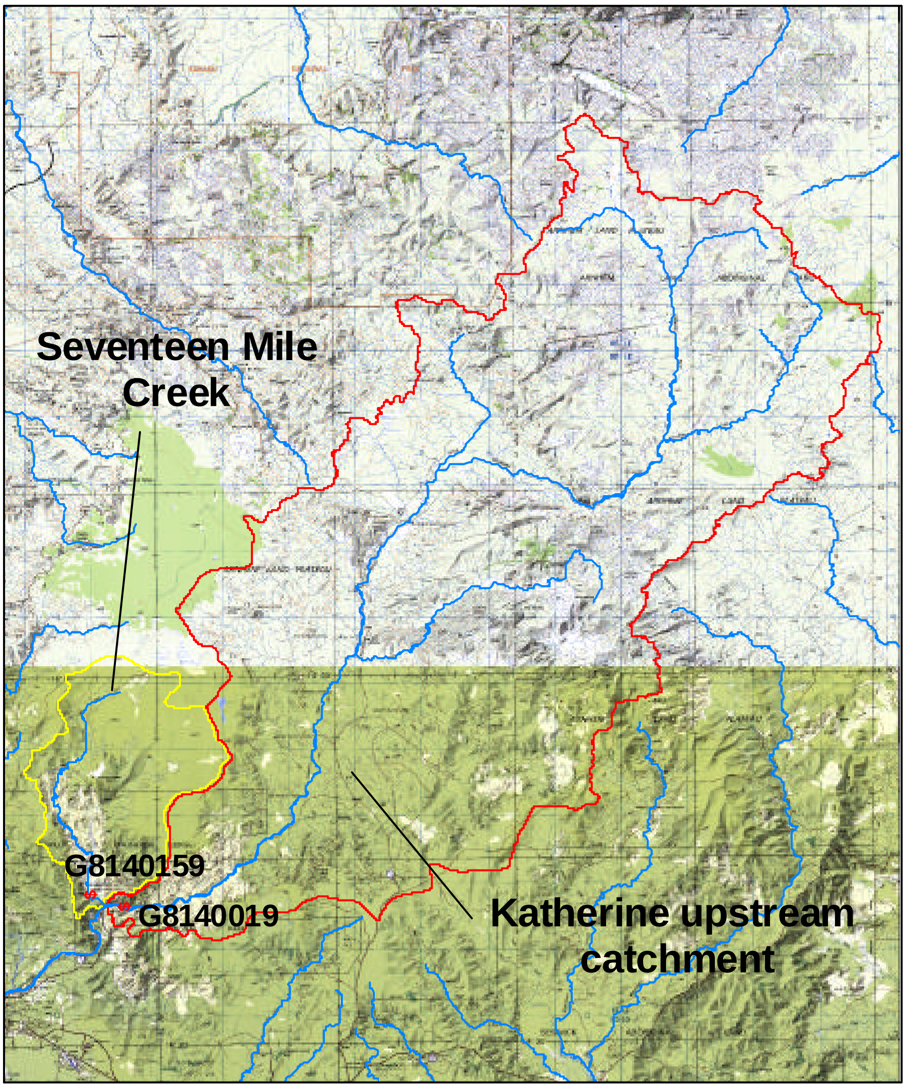



**Figure 13** Comparison of surface water catchment area.
Katherine River vs Seventeen Mile Creek

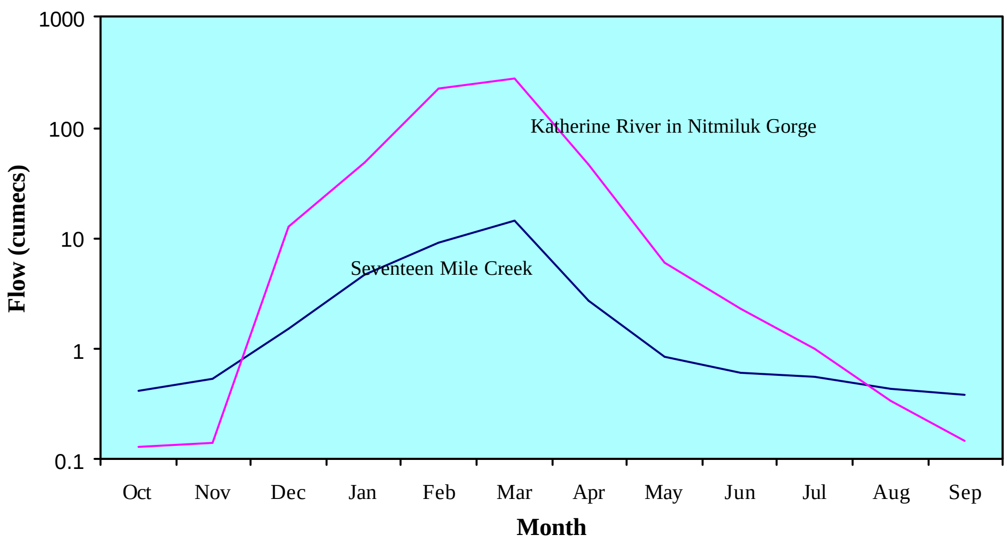



**Figure 14** Comparison of mean monthly flows for Katherine River and Seventeen Mile Creek

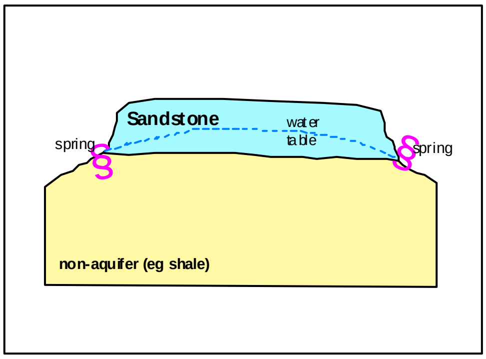
# 4.0 INTERACTION OF SURFACE WATER AND GROUNDWATER

Interaction between groundwater and surface water takes place in the form of groundwater discharges, either as discrete individual springs or as a diffuse flow into creeks and rivers. It can also take place in reverse, as surface water from rainfall runoff can recharge aquifers through streambeds and sinkholes.

Springs are natural outflow points for groundwater. They occur where the watertable is at or above the ground surface, and can be permanent (*perennial*) or seasonal (*ephemeral*), depending on the fluctuations in the local watertable.

## 4.1 Spring types

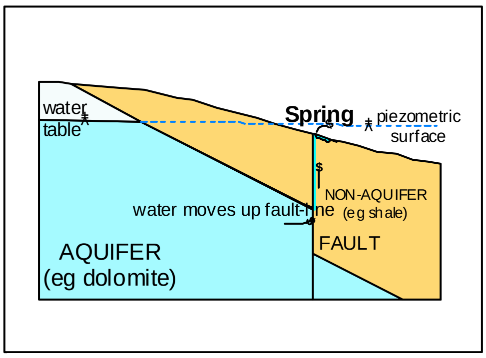
The location of springs is determined by a combination of rock type, aquifer location and topography. There are many different occurrences of springs in this region, a few of these are described below.




Spring type 1

SPRING TYPE 1

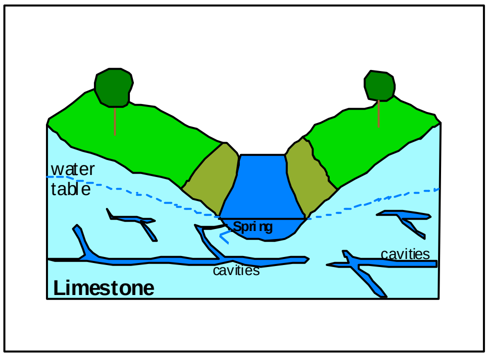
This is the most common type of spring in the region. It occurs where a layer of *porous* and permeable sandstone overlies a low permeability rock such as shale or granite. Water stored in the upper layer seeps out at the contact between the two rock types. This is generally in the form of a seepage zone or swampy area at the contact. Seepage over an area will eventually coalesce to form a creek (eg upper parts of the King River). Occasionally there will be a discrete spring or permanent waterhole, such as at Barunga Spring.




Spring type 2

SPRING TYPE 2

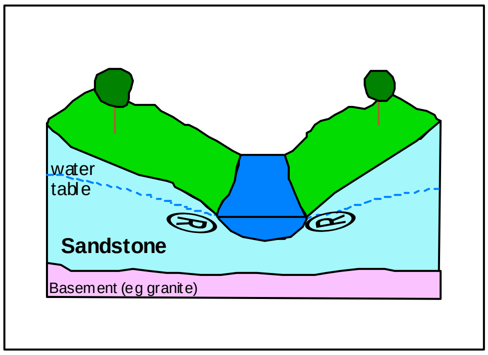
This type of spring occurs when a geological fracture or fault provides a pathway to allow groundwater to rise to the surface, in areas where it is normally confined beneath a low permeability rock. A good example of this is at Mount Catt, where a large spring provides the community water supply. Smaller springs and seeps of this type may occur in fractured rock areas.




Spring type 3

SPRING TYPE 3

The Katherine River in the town area obtains most of its baseflow from points along the river valley, where fractures and cavities in the underlying Tindall Limestone aquifer are intersected.




Spring type 4

SPRING TYPE 4

Seeps and springs occur in areas of *unconsolidated* sand aquifers when the local groundwater table is high enough to be intersected by the drainage lines and creek beds. This can be a temporary feature after periods of above average rainfall, such as the period from 1997 to present, as seen at Dook Creek.

The location of many springs is indicated on the Water Resource Map. The springs shown are a combination of those visited during fieldwork, identified on satellite imagery and aerial photographs, and several located remotely using local Traditional Knowledge and maps. All of these springs are thought to be permanent features, providing some groundwater discharge even during periods of below average rainfall. During the period of fieldwork for this study there were many additional springs and seeps located, but remote sensing, geology, topography and local knowledge has helped to identify many of these as *ephemeral.* Most of the springs are small features, with flows up to 10 or 20 L/s sourced from a seepage zone or swamp. However, some of the springs, particularly those occurring in the dolomitic aquifers, have a discrete source with considerable flows, and are important local water supply features. For example the spring at Mount Catt has a recorded permanent discharge of approximately 180 L/s.

All springs are important for maintaining Dry season flow in creeks and rivers, and most of them sustain small rainforest or pandanus/paperbark swamp pockets. This is covered in more detail in Section 5.0. Many of the springs indicated on the Water Resource Maps appear in areas of apparently low groundwater availability. Such springs are sourced from relatively small areas of sandstone or *unconsolidated* sand, which store a certain volume of groundwater, but are unsuitable for groundwater abstraction.

### 4.2 Water quality

The water quality of groundwater discharges are directly related to the geology of the aquifer supplying that particular spring. Most springs are sourced from sandstone or *unconsolidated* sand, and consequently have a TDS of less than 50 mg/L, and are acidic with a pH of less than 7. Springs sourced from other aquifer types are easily identified by their chemistry.

Most springs in the eastern region are sourced from the Dook Creek Aquifer, a dolomitic aquifer with TDS values in excess of 200 mg/L. Consequently, the water quality of the creeks and rivers in the eastern region, for example Flying Fox Creek, Mainoru River and the Wilton River, changes through the year. Runoff water (basically rainwater) has very low TDS and is slightly acidic. As the Wet season runoff component of flow into the rivers decreases, the relative proportion of groundwater discharge into the rivers increases, reaching 100% by the mid to late Dry season. The water chemistry therefore becomes higher in TDS and pH as the Dry season progresses.

### 4.3 Sinkholes

Sinkholes are a common surface feature of limestone or karstic aquifer systems. They are widespread in the Tindall Limestone and Dook Creek Formation aquifers. A sinkhole is a localised sinking of the land surface caused by the dissolution of the underlying rocks. They can form as depressions or more dramatically as cavern systems. Sinkholes are a natural feature, but many collapses can be induced by changes of land use causing changes in the water table or drainage system. Many examples of rapid sinkhole development have been documented in the Tindall Limestone in the Katherine town area. The sinkholes are currently being studied in another NHT funded project entitled “Land Degradation By Sinkholes”. Sinkholes can act as a pathway for rapid recharge to the underlying aquifer.

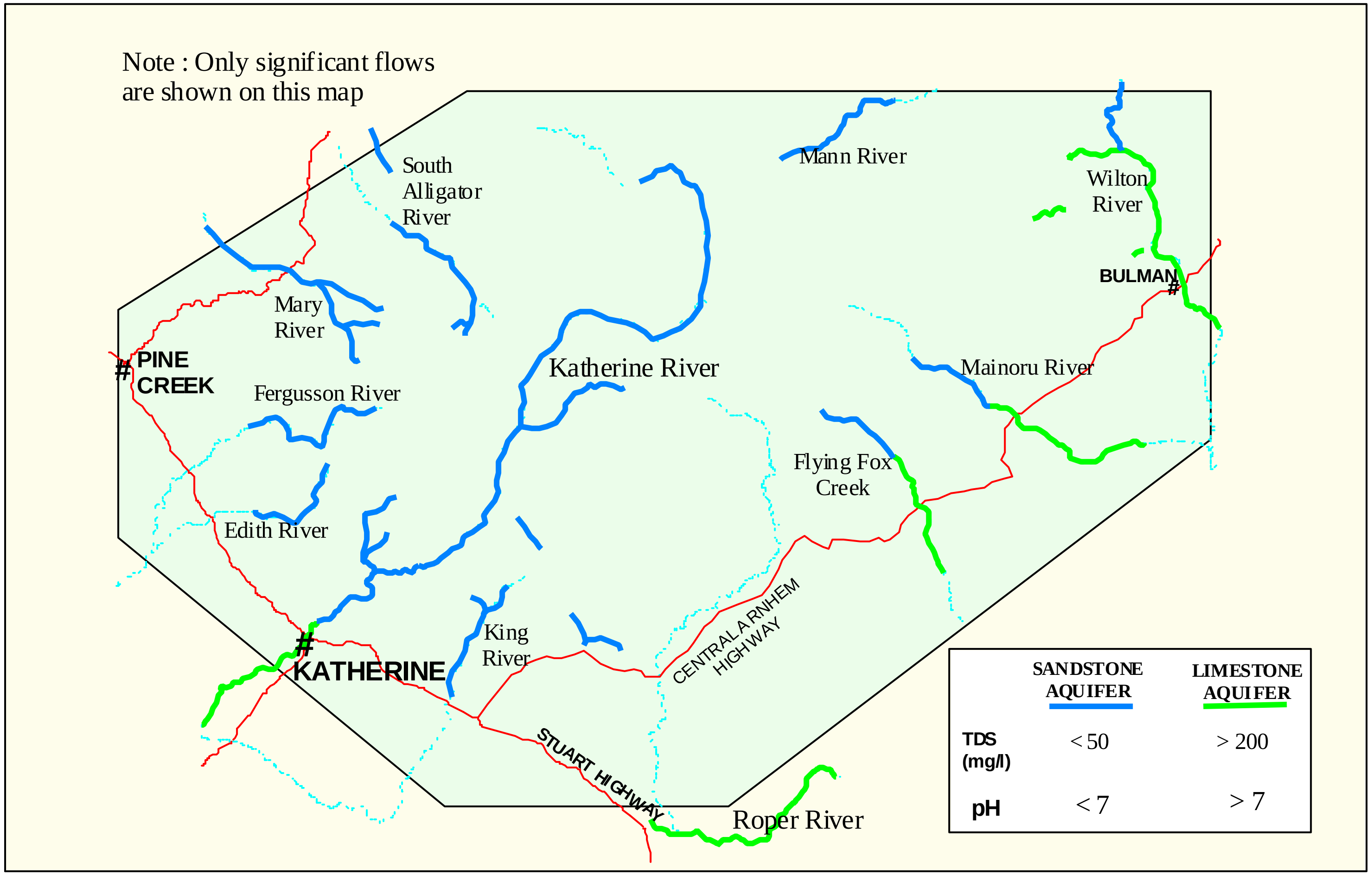



**Figure 15** Chemistry of dry season river flows

# 5.0 SUSTAINABILITY OF WATER SYSTEMS

Water levels in bores, springflows and baseflows in rivers are all directly related to the recharge of the groundwater system. In this region, rainfall is quite variable, with a pattern of wet and dry periods being normal. Recharge amounts vary with rainfall, hence a knowledge of past climatic variations is essential in determining the variability in water levels and baseflows, and therefore determining what usage from bores and river baseflows can be maintained.

The term Sustainable Yield is used to describe the amount of water which can be extracted from a resource without a long term adverse effect on the environment or the resource. Section 6.0 gives further information on the allocation of water and its control.

## 5.1 Sustainability of aquifer systems

CRETACEOUS AQUIFERS

This aquifer type presently provides direct water supplies for Manyallaluk, Barunga and Banatjarl. In addition, springflows from the Murruwal Plateau supply Dry season flow in Seventeen Mile Creek, which in turn provides much of the Dry season flow into Katherine's water supply at Donkey Camp.

The Murruwal Plateau sandstone aquifer lies almost entirely within the two National Parks and there is presently no development of the available groundwater resources. It is largely inaccessible by motor vehicle and occurs as a mostly thin veneer of sandstone on top of older less permeable rocks. It may be difficult to abstract large quantities of groundwater from this aquifer by drilled bores due to the limited thickness of the aquifer, except by targeting zones of greater thickness aided by *geophysical* investigations. No investigation bores have been drilled on this plateau.

The other main occurrence of this aquifer type, between Barunga, Manyallaluk and Banatjarl has been drilled a number of times since the 1980's. Many of these bores have yielded significant amounts of water from depths of up to 30 metres below ground level. This aquifer has considerable storage of groundwater, and available water level records suggest that it receives recharge in all but the driest of years. These records also show that closer to the margins of the aquifer, water levels drop considerably through the Dry season as the aquifer drains freely to the springs around its perimeter. Abstraction bores should therefore be located away from the margins to avoid impacting on these springs and seeps.

DOLOMITIC AQUIFERS

***Dook Creek Formation***

Water level records suggest that the small aquifer that supplies Wugularr community water supply has reached, or is close to, its sustainable yield. Any increase in abstraction from this aquifer would not be sustainable during dry periods, as experienced between 1992 and 1996.

The more extensive area of this aquifer type, in the north east of the region, is largely undeveloped, and from a water resources aspect, appears to have great potential for groundwater abstraction and development. There is no long term water level record from bores drilled into this aquifer. However, several rivers and springs receive continuous baseflow from this aquifer, and appear to be sustained during dry periods, suggesting a large volume of groundwater in storage in the aquifer. Water supplies at Bulman and the surrounding outstations are sourced from this aquifer, and there is no evidence of any local impact on water table levels due to abstraction.

***Tindall Limestone and Jinduckin Formation***

Studies are ongoing to quantify the sustainable yield of these aquifers using relationships between rainfall, water table levels and river baseflows. A sustainable yield will be decided that is acceptable in terms of Beneficial Uses of the community and environment (see Section 6.0). Because of the demand on the groundwater resources of these aquifers, licensing and allocation regulations are being put in place.

LOCALLY DEVELOPED AQUIFERS

and

MINOR GROUNDWATER RESOURCES

All other areas outside of the main 'large supply' aquifer types have limited resources available. Some of the aquifers may have large amounts of groundwater in storage, but the low permeability of the aquifer means that bore abstraction rates are low, and pumping drawdowns may be large.  Overpumping may lead to bore failure and even damage the aquifer.

Other aquifers may have higher permeability, but their limited extent means that there is little water in storage, and bores tend to fail by the end of each Dry season.  If the aquifer is able to recharge during the subsequent Wet season, bore performance returns to normal.

Conservation values must be carefully considered before planning any significant development based on groundwater availability.  Inappropriate bore locations and pumping rates have the potential to seriously impact upon natural groundwater discharges such as springs and creek flows.  There are many examples of groundwater dependant ecosystems in this region, such as rainforest pockets and perennial waterholes.  Some of these are within the National Parks, but several others occur on Aboriginal land such as Banatjarl, Barnjarn and Manyallaluk Land Trusts.  Many of these could be impacted by inappropriate siting of bores, for example those located too close to the margins of the Cretaceous aquifer, or by overabstraction of groundwater.

## 6.0 ABORIGINAL KNOWLEDGE

The aims of this study were not only to provide a scientific assessment of groundwater and surface water in the region, but also to include traditional Aboriginal knowledge about water occurrence and significance.

During the course of the study, many Aboriginal people from the communities and outstations provided extensive help with locating water sites such as springs, and also invaluable knowledge about their historical behaviour.

In order to make the map as accessible as possible to local people as well as land managers, many language placenames and country names were documented. Where appropriate, these have been included on the map and other products, in addition to language names previously documented by other researchers.

This information remains the intellectual property of the Jawoyn people, and has only been reproduced with their permission.

### 6.1 How information was gathered

On most field trips, NRD officers were accompanied by Traditional Owners or their representatives, who imparted their knowledge on water resources and placenames, either during site visits, or during group discussions. Discussions and visits were aided by the use of reference material such as satellite imagery, aerial photographs and topographic maps. Information was recorded in written notes and occasional audio and videotape recordings. Placename locations were recorded onto working maps directly, or with the use of GPS (Global Positioning System). At all times when collecting names and data, it was made clear that this information would be public, so culturally sensitive information was not recorded.

### 6.2 Where the information is recorded

An appendix to this report contains lists of all Aboriginal knowledge collected during the course of this study, as well as referring to data collected previously. This consists mostly of placenames and their location. Some of these placenames, where appropriate, have been recorded on the Water Resource Map, and a greater number are also included in the GIS version of the map.

# 7.0 WATER RESOURCE DATA – FORMAT, LOCATION AND AVAILABILITY

The Water Resource Map that accompanies this report was produced by the NRD, and is stored in digital form as a MicroStation "Design File". This can be reprinted at any time, and is available to interested parties.

The original data was developed as ESRI Shapefiles, and was produced using the GIS package ArcView. The Jawoyn Association has been supplied with a complete version of these shapefiles to be incorporated into their GIS. Simplified versions of the shapefiles have also been produced that can be viewed with the program ArcExplorer, a free software package which has been included with the data. This forms a simple GIS, allowing the user to view and manipulate individual components of the map. This data is available on CD-ROM.

A report has also been compiled titled 'Water Resources of the Katherine Region and South West Arnhem Land – Technical Data'. This provides a bibliography of all NRD reports relevant to this area, a summary of all bores, water quality data, and information on surface water sites such as gauging and rainfall stations. The data is also available in digital format on CD-ROM.

A photographic collection was built up during this project. All photographs have been scanned, and are available digitally on CD-ROM.

All reports and maps are also available digitally in **.pdf** format, to be read by Adobe Acrobat Reader.

Copies of bore reports are held by NRD in Darwin in both digital and paper form, and are available on request by quoting the RN (registration number). This data, along with digital versions of many of the NRD's reports will be available via the Internet by late 2001.

Detailed information on NRD gauging and rainfall stations is kept on the 'HYDSYS' database. This includes river height, flow data and water quality data, and is available on request.

# 8.0 ACKNOWLEDGEMENTS

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I would also like to thank the following; the Community Councils at Wugularr and Barunga; Nick Di Candillo from Manyallaluk, the staff at Jawoyn Association, in particular Jo Fox and Mel Sheppard; PWCNT Rangers and staff from Nitmiluk National Park, in particular Kerri Watkins and Andrew Hartwig; Kakadu National Park Rangers Steve Heggie, Cathy Wilson, Greg Ryan and Lyndel; Andrew Edwards from the Bushfires Council and Peter Sherman (Gulin Gulin).

This work would not have been possible without the assistance and knowledge of the many Traditional Owners and their families who were involved throughout the project. In particular I would like to thank Margaret Katherine and Nikibini, Eddie, Anthony, Andre and David Oenpelli, Phyllis Wiynjorroc, Esther, Victor Hood, Long John, John Dalywater, Brian Manyita, Mike Redford, Peter Bolgi and of course Reggie.

## 9.0 FURTHER WORK

This project has compiled existing data and new data to give an overview of the water resources of the Katherine and South West Arnhem Land Region. It is not to be used as a final detailed water resources study for potential developments, but as an information source to allow land managers to take water resources into consideration during initial land management planning.

Water resources availability estimates are being constantly updated by the NRD as more data is collected each year. The following further work is recommended in order to refine these calculations and more comprehensively understand the resource and its dynamics.

Improved low flow ratings for the major river gauging stations

Total water balances for aquifer systems

Establishing Environmental Flows for all rivers and springs, incorporating conservation values

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## 11.0 GLOSSARY OF TERMS

**Airlift Yield:** The rate at which water is extracted from a bore with compressed air as drilling takes place.

**Aquifer:** A body of rock which is sufficiently permeable to conduct groundwater and to yield useable quantities of groundwater to bores and springs

**Baseflow:** The groundwater contribution to a stream. Baseflow often maintains the flow in a stream over the Dry season.

**Catchment:** Area in which rainfall collects to form the supply of a river.

**Chert:** Very hard and brittle rock that is often fractured. Associated with quartz.

**Confined aquifer:** An aquifer that occurs beneath an impermeable layer. The amount of water available for abstraction from this type of aquifer is lower than an unconfined aquifer.

**Consolidated:** Any process whereby soft or loose earth materials become firm, for example the cementation of sand or the compaction of mud.

**Cretaceous:** A geological time period from 65 to 144 million years ago. This is the age of the rocks that form one of the major sandstone aquifers

**Current meter:** A device for measuring water velocity, consisting of a propeller that turns at a rate dependent on the water's velocity.

**Drawdown**: The lowering of the water level of a well as a result of the withdrawal of water.

**EC:** Electrical conductivity, the ability of water to conduct electricity. It is directly related to the salt content of the water. EC is measured in microseimens per centimetre, µS/cm.

**Environmental Flow:** The minimum flow required in a river or stream that is required to sustain the native flora and fauna.

**Ephemeral:** A creek or river that dries up in the Dry season.

**Gauging station:** Site on a stream where direct observation of water velocities, heights and volumes are made and recorded. *Pictured – gauging station recording river height.*

**Geology:** science of earth's crust, rocks, strata etc

**Geographical Information System (GIS):** A computer system that allows the storage of data so that it can be viewed and accessed using a computerised map.

**Geophysics:** The use of specialised surveys to give an indication of underlying rock type. Techniques such as *magnetics, gravity, elctro-magnetics,* and *seismics* can be used on the earth's surface in order to indicate geology.

**Groundwater:** Subsurface water contained in aquifers.

**Groundwater Discharge:** The release of groundwater to the surface by seepage, evaporation or transpiration (from plants).

**Hardness:** A measurement of the level of calcium carbonate in water. Results in increased quantities of soaps necessary to produce suds.

**Hydrogeologist**: A geologist who studies the relationship between geology, groundwater and surface water.

**Hydrograph**: A graph that shows water levels or flow in a stream, or the watertable level in a bore.

**Impermeable:** An impermeable soil, rock or sediment is that in which fluid (water) is unable to pass through.

**Karst:** A network of caves and fissures that form in a limestone or dolomite rock.

**Laterite:** A residual rocky material formed through prolonged weathering, probably under warm, wet conditions.

**Monitoring/Observation bore:** A bore used for measuring groundwater levels.

**Perennial:** A stream, lake or waterhole which retains water throughout the year.

**Permeability/Permeable:** The ability of water to move through soil or rock.

**pdf:** A file format that allows reports and maps to be viewed using the software package Adobe Acrobat

**pH:** A measure of acidity (low pH) or alkalinity (high pH). A pH of 7 indicates neutrality - non corrosive to metal.

**Potable:** Water that is fit for human consumption

**Porosity:** The total amount of pore space in a soil or rock.

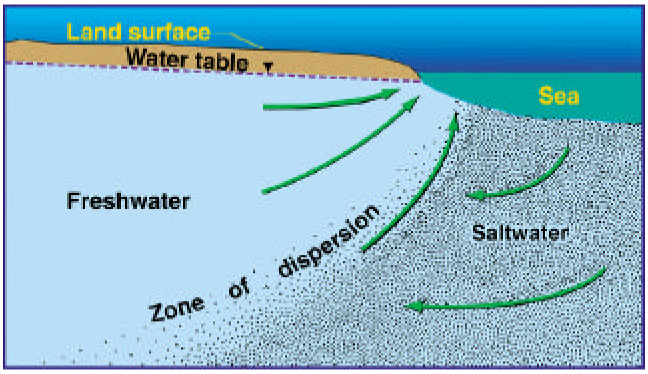
**Porous:** Containing pores and able to absorb water, air or other fluids.

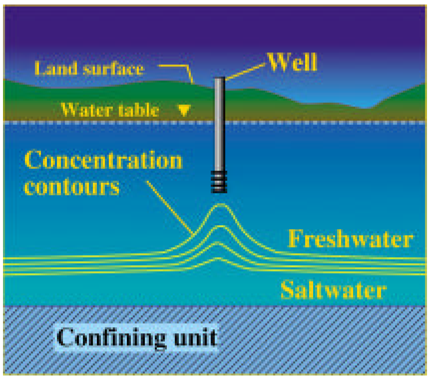
**Recharge:** Addition of surface water to an aquifer to become groundwater.

**Runoff:** Rainwater that leaves an area as surface flow.

**Salinity:** The degree to which water contains dissolved salts.

**Saltwater intrusion:** movement of salt water into fresh water aquifers.




Diagrams from: http://water.usgs.gov/ogw/gwrp/saltwater/salt.html http://water.usgs.gov/ogw/gwrp/saltwater/fig4.html

**Satellite Imagery:** Digital 'photographs' taken from satellites orbiting the Earth in space.

**Spring:** Outflow points for groundwater where the watertable is near or above the ground surface.

**Standing Water Level:** The level below ground surface, to which groundwater rises in a bore.

**Sustainable:** maintain (without adverse effect)

**Topography:** The shape and height of the land surface.

**Turbidity:** Relative measure of the clarity of the water. The greater the turbidity, the murkier (muddier) the water.

**Total Dissolved Solids (TDS):** A measure of the salinity of water, the amount of salt dissolved in the water, usually expressed as milligrams per litre.

**Water table:** Level of the surface of the groundwater. It is often measured in observation bores.

**Water quality:** Physical, chemical and biological characteristics of water and how they relate to it for a particular use.

**Water Year**: In the NT, the water year splits the year from October of one year to September of the next year. This is so that the total Wet season rainfall is accounted for.

**Wetland:** Land which remains wet for a large part of the year.

**Yield:** Amount of water which can be supplied by an aquifer or pumped from a bore over a certain time period.