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Gulf Water Study

Robinson and Calvert Rivers Region

Australian Government
Water Smart Australia

Front cover:

Frank Shadforth, owner of Seven Emu Station at the Calvert River

Water Monitor on the Calvert River

Tufa dams on Coconut Spring Creek

GULF WATER STUDY

Robinson River

WATER RESOURCES OF THE ROBINSON & CALVERT RIVERS REGION

REPORT 18/2009D

U. ZAAR

DARWIN NT

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This project was co-funded through the Australian Government's Water Smart Australia Program and the Northern Territory Government Department of Natural Resources, Environment the Arts and Sport.

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I am very much indebted to the local people in the region. There is little recorded surface water data in the region and given the large fluctuations in spring and river discharges over the years the information provided by locals has been vital to the project. I thank the station owners and managers and the people of Robinson River Community who were generous with their time and were very hospitable; John and David Keighran, Frank Shadforth, Owen Davies, Stuart Zlotkowski, Alex Chopple, Paul, Ian, Bill South, Larry Hoosan, Stella, Ronnie Whitehead, Kathleen Shadforth, Doreen George, Hazel Godfrey, Russell Ellis, Bindy Noble, Reggie Dickson, Tony Jack and Russell L'Arrington from North Australian Helicopters who was also very helpful with his knowledge of the region.

Indigenous people with links to the region provided not only excellent field guidance but also a cultural perspective. The memory of some of the older people has been extraordinary. I thank Albert Charlie, Jack Green, Jack Hogan, Les Hogan, Norman Kingsley, Kelly Martin, Dulcie Mawson, Katie Baker and Daphne Mawson for her transcriptions.

I would like to thank the Northern Land Council who provided liaison assistance with indigenous knowledge and drilling clearances.

I humbly thank all these people as it has been no less than fascinating to learn about water in the Gulf.

Lynton Fritz

Technical working group

Larry Hoosan and Ursula Zaar

SUMMARY

This report provides details of the groundwater and Dry season surface water resources of the Robinson and Calvert Rivers region of the Gulf as depicted on the accompanying water resource map. It is one of five regions which make up the mapping area of the Gulf Water Study (Figure 1.1). The study was co-funded by the Australian Government Water Smart Australia Program and the Northern Territory Department of Natural Resources, Environment, the Arts and Sport.

The purpose of this work is to provide readily accessible and easily understandable information products on water resources in the region. The project was undertaken with the dual perspective of western science and indigenous knowledge and both are represented in the products of this study. It is hoped that common understandings will develop between indigenous people and land managers about water in the region. The key aim is to provide a fundamental data set to guide sustainable development of water resources maintaining social values, healthy groundwater systems and rivers as well as the ecosystems which depend upon them.

Five cattle stations are situated in the study region. One of these properties, Pungalina Station, which is owned by the Australian Wildlife Conservancy is considered to be one of the region's last strongholds for wildlife. The other land tenement in the area is the Garawa Aboriginal Land Trust on which lies the Robinson River community with a population of approximately 200 people. Domestic supplies are sourced from groundwater, river water and rainwater. Cattle are watered by groundwater, natural waterholes and dams.

The groundwater resource has been classified into six aquifer types:

• Fractured and Karstic Rocks	(yields up to 10 L/s)
• Fractured and Weathered Rocks – carbonate rocks	(yields 0.5 – 10 L/s)
• Fractured and Weathered Rocks – carbonate rocks	(yields 0.5 – 5 L/s)
• Fractured and Weathered Rocks	(yields 0.5 – 5 L/s)
• Fractured and Weathered Rocks with minor groundwater resources	(yields 0 - 0.5 L/s)
• Sedimentary Rocks with some intergranular porosity	(yields 1.0 – 10 L/s)

The Fractured and Karstic aquifer has not been drilled. However, the weathered nature of the rock would suggest that yields of 10 L/s or more can be expected from individual bores. The aquifer is situated on Pungalina Station and provides baseflow to the Calvert River. A widespread carbonate Fractured and Weathered Rock aquifer is a key target for water supplies in the region supplying adequate yields generally up to 10 L/s. This aquifer lies within the Karns Dolomite. Good yields (up to 10 L/s) have also been confirmed from a porous rock aquifer situated on southern Calvert Hills Station. These are the better yielding aquifers which all contain good quality water. Lower yields can be attained from other Fractured and Weathered Rock aquifers but fractures would need to be targeted. This aquifer type exists around the Robinson River community where poor water quality has been encountered. This particular

area should not be targeted for water supply. Salty groundwater has also been intercepted in coastal areas. The extent of these areas has been indicated on the map.

Across the study region small groundwater discharges host dependent ecosystems often marked by lush vegetation pockets.

River flow has been classified according to the minimum flow recorded or observed at the end of the Dry season during a low rainfall period. There are three categories that describe river flow;

- River with a minimum flow of between 10 and 100L/s at the end of the Dry season
- River with permanent waterholes and minimum flows up to 10 L/s at the end of the Dry season
- River which is dry at the end of the Dry season

Only 2 rivers, Coconut Spring Creek and Karns Creek (tributaries of the Calvert River) draining the Fractured and Karstic Rock aquifer and 3 rivers draining a sandstone aquifer are listed under the first category. All these rivers are situated in the north-east of the map. The Calvert and Robinson Rivers belong to the second category with most other rivers belonging to the last category.

Baseflow in the Calvert and Robinson Rivers are largely sourced from groundwater discharging from the Karns Dolomite. This project was begun during a historically extremely wet period. Rainfall recorded at Calvert Hills station showed that over the last 7 years (to 2007) the average rainfall was 1088mm compared with the long term 117 year average of 661 mm. With such high rainfall, aquifers were well recharged which in turn resulted in observed high baseflows in rivers. This allowed for good data collection for an extremely wet period. Rainfall in 2007 and 2008 was average to mediocre which resulted in an extended baseflow recession in the rivers. For example, baseflow at the most downstream site on the Calvert River dropped from 3.6 to 1.2 cumecs over one year. With little recorded historical data available on the rivers, and a project being undertaken during an extremely wet period, anecdotal data was paramount to the mapping exercise which entailed mapping rivers in the driest times. For that lower Calvert River site, local knowledge taught us that the river could be completely dry here with only isolated waterholes remaining. This shows the area can be very dynamic in terms of water resources.

Indigenous knowledge on specific sites has been provided by traditional owners and is documented in this report. Many of the sites are shown on the map. To provide a background to this knowledge an overview on how indigenous people in the region view land and water is discussed. Indigenous people believe that the Spirit Ancestors created their environment as well as a charter that is the Law for existence and through this law all land, water, plants, animals, natural phenomena, people and the Spirit Ancestors (Dreamings) are inextricably connected. It is through these intricate connections that indigenous people relate to water and everything else. Water sites not only have a physical entity and a purpose in the connected environment but also social, emotional, cultural and spiritual significance. Effective management of land and water therefore involves consideration of all these realms. Much can be learnt from their holistic view as it engenders responsible land and water management.

Aside from the map and this report other products from the Gulf Water Study include a GIS, posters and photographic and video collection which are all available on DVD.

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Abbreviations:

L/s = litres per second

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1. INTRODUCTION

This report provides details of the groundwater and Dry season surface water resources of the Robinson and Calvert River regions of the Gulf of Carpentaria as depicted on the accompanying water resource map. It is one of five regions which make up the mapping area of the Gulf Water Study (Figure 1.1). The study was co-funded by the Australian Government Water Smart Australia Program and the Department of Natural Resources, Environment, the Arts and Sport of the Northern Territory Government.

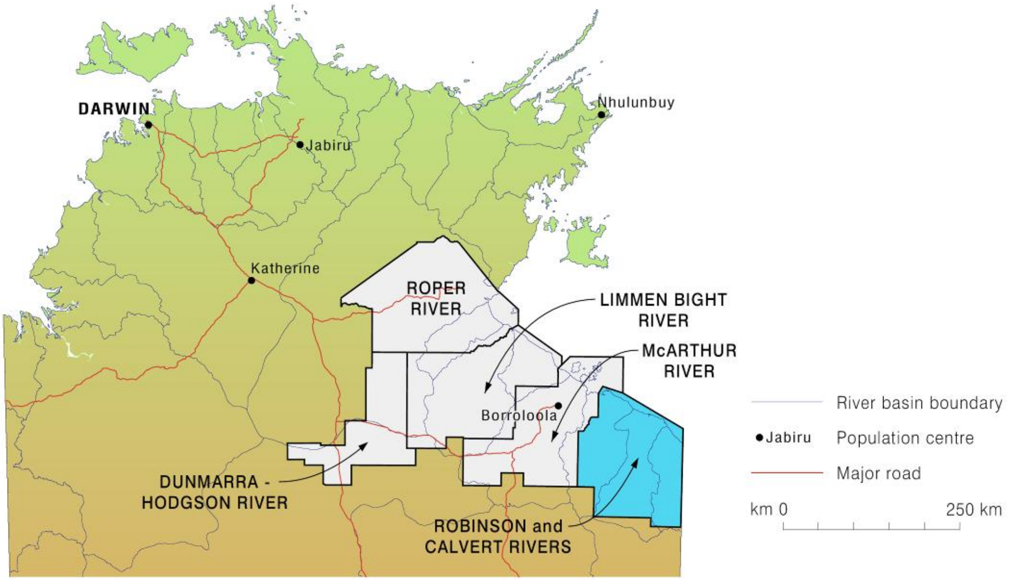


Figure 1.1 Study Regions

Ancillary to this report and map are posters, geographic information system (GIS) and a spatial photographic and video collection. All products from the study are available on a DVD (digital video disc) data disc.

The purpose of this work is to provide readily accessible, easily understandable and user friendly information products on water resources in the region. The project was undertaken with the dual perspective of western science and indigenous knowledge and both are represented in the products of this study. It has been targeted to inform all stakeholders from station managers, traditional owners and land developers through to water allocators and government bureaucrats. The key aim is to provide a fundamental data set to guide development of water resources in the region maintaining healthy groundwater and rivers.

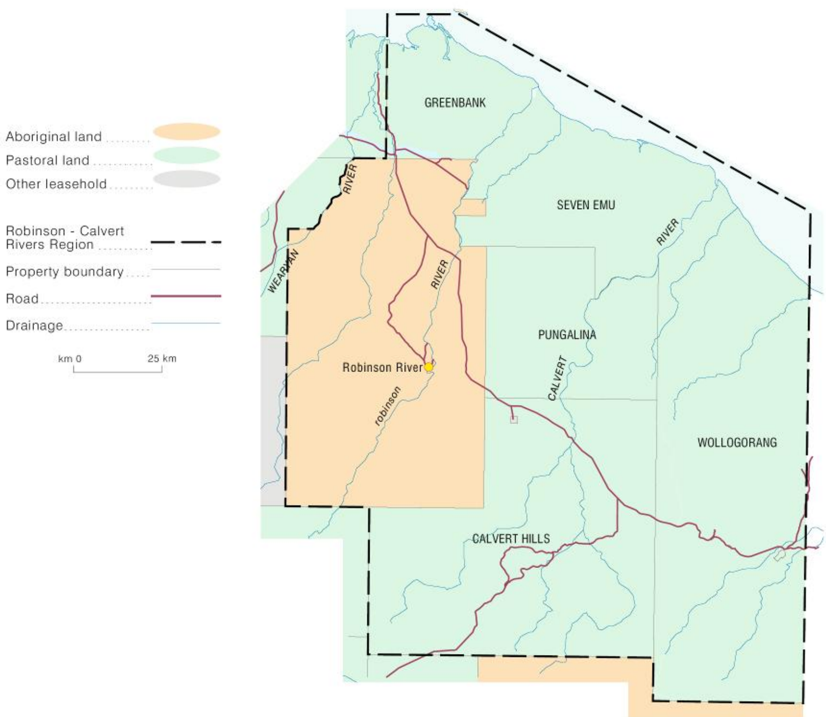
The water resources map is an interpretation of the regions geology, topography, bore data, stream flows and vegetation patterns. Where data was lacking investigations were carried out including drilling, geophysical surveys, water quality sampling and stream gauging. The contribution from local people, in particular their knowledge of the waterways has been vital to this mapping exercise, especially in areas where access was difficult and scientific information scant.

2. LOCATION

The map region is dominated by 5 cattle stations two of which are indigenous owned – Greenbank and Seven Emu. Of interest is Pungalina Station which was purchased in 2008 by the Australian Wildlife Conservancy (AWC) who consider it one of the region's last strongholds for wildlife. Similarly AWC have subleased 110,000 hectares from Seven Emu Station for conservation. (www.awc.org.au)

Aside from the cattle stations is the Garawa Aboriginal Land Trust within which lies one major community, Robinson River, which has a population of approximately 250 people. Mungoorbada Aboriginal Corporation services the community as well as a number of outstations which lie not only on the Garawa Aboriginal Land Trust but on excisions on neighbouring cattle stations. There is one operational mine in the area – Redbank Mine which mines copper. It is situated on Wollogorang Station.

Access to the region is by the unsealed Wollogorang Road, also known as Highway 1, which travels in a south-easterly direction from Borroloola to the Queensland border. Wollogorang Station lies along the Queensland border. Another unsealed road, namely the Calvert Road provides a connection from the Tablelands Highway (outside the map region) to the Wollogorang Road through Calvert Hills Station. Robinson River community is located 120 km south east of Borroloola and the travel time is approximately 2.5 hours.



The two major rivers in the region are the Robinson and Calvert Rivers which run from south to roughly north through the map sheet. A section of the Calvert River is listed on the Register of the National Estate with 'indicative property' status. (www.environment.gov.au/heritage/ahdb)

Figure 2.1 Land use in the Robinson and Calvert Rivers Region

3. CLIMATE

The map region lies in the Wet/Dry tropics. With 6 months of negligible rain in the Dry season most streams cease to flow unless they are groundwater fed. Annual evaporation exceeds rainfall. The last 7 years has been the wettest for the period of record that is 117 years.

The map region has a tropical savanna climate with a marked Wet season from November to April and Dry season from May to October (Figure 3.1). Most of the map region has an average annual rainfall of between 800 - 1000mm whereas the north-eastern coastal strip receives between 1000 - 1200mm. (Figure 3.2). Annual rainfall has varied widely over the last century (Figure 3.3).

The long term record is represented in Figure 3.3 for the rainfall recorder site DR014705 on Calvert Hills Station and consists of recorded and interpolated data obtained from SILO Data Drill (www.longpaddock.qld.gov.au/silo). Also shown in the figure is the recorded data from the site for comparison, and indeed an excellent fit is obtained which provides confidence in the data. DR014705 data was used as it has the longest recorded period of record in the map area. A listing of rainfall recorder sites is provided in Appendix K. Figure 3.3 clearly shows the large fluctuations in rainfall and how the latter 7 years have been exceptionally wet with an average rainfall of 1088 mm compared with the long term average of 661mm. The higher average has resulted in unusually high Dry season river flows which have been observed during the course of this study.

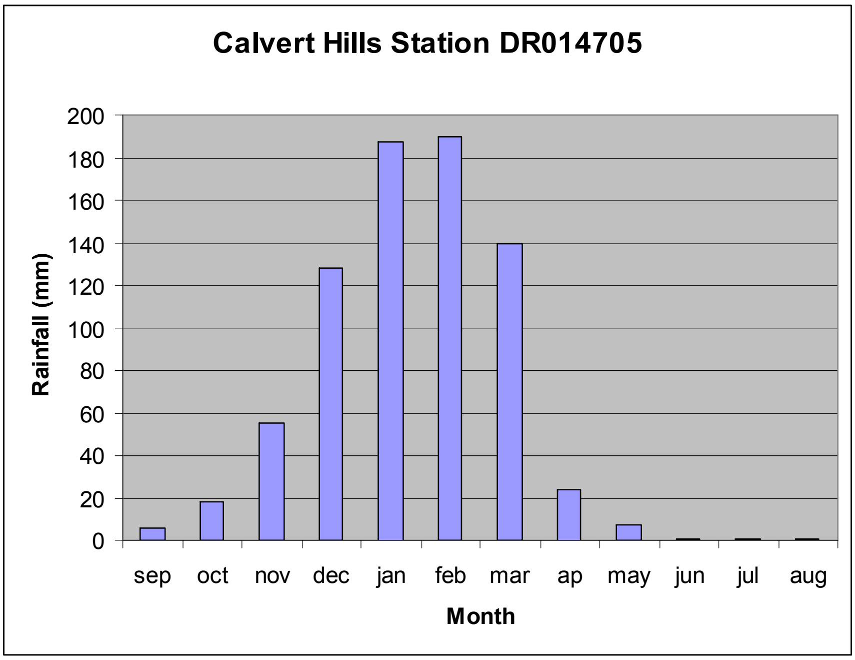


Figure 3.1 Average monthly rainfall for Calvert Hills (Station Number DR014705)
(From Bureau of Meteorology web site: www.bom.gov.au/climate/averages)

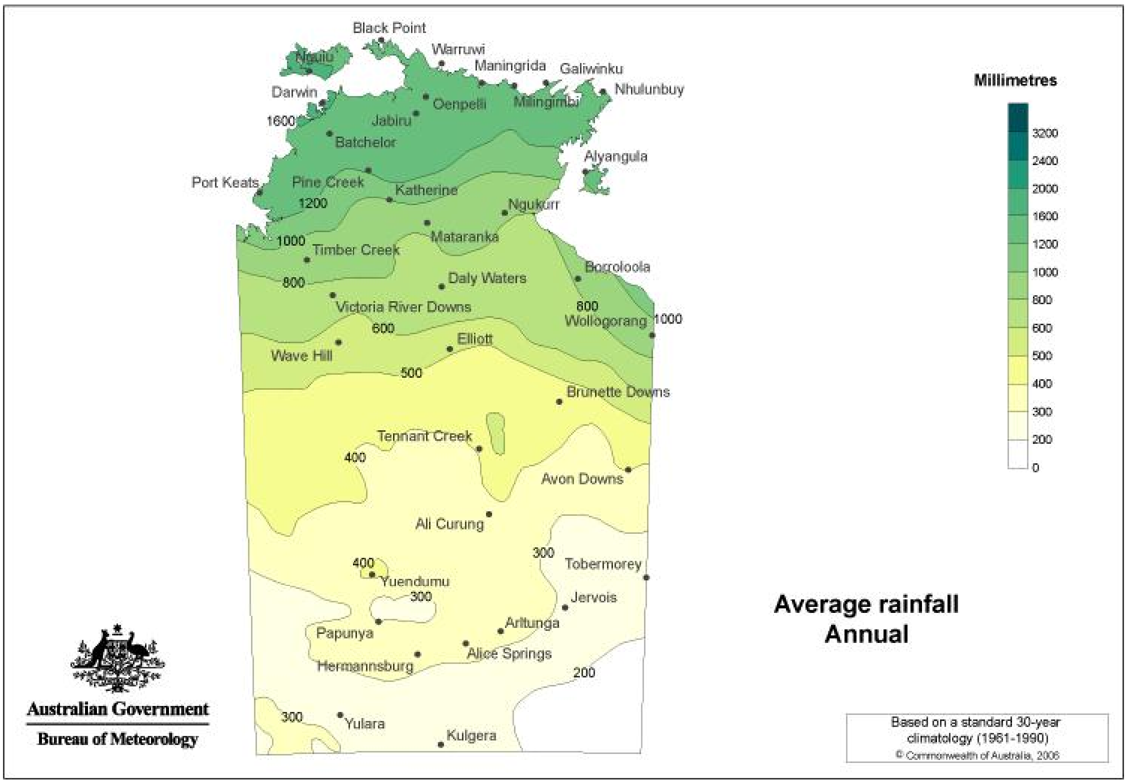


Figure 3.2 Average annual rainfall for the Northern Territory
(From BOM website: www.bom.gov.au/jsp/ncc/climate_averages/rainfall)

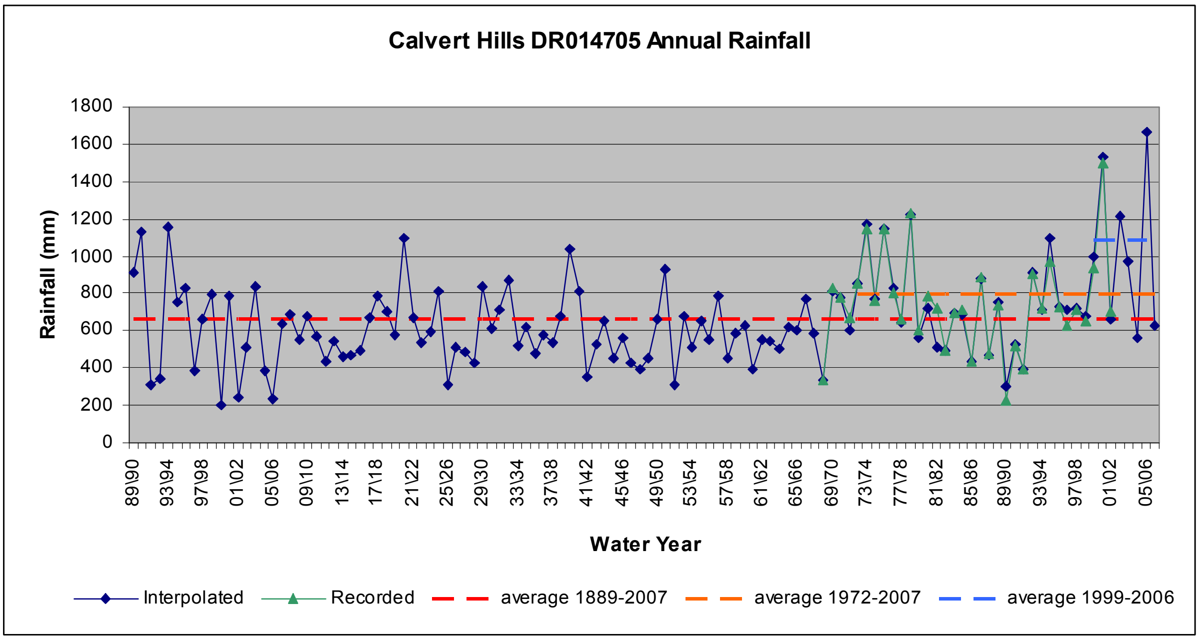
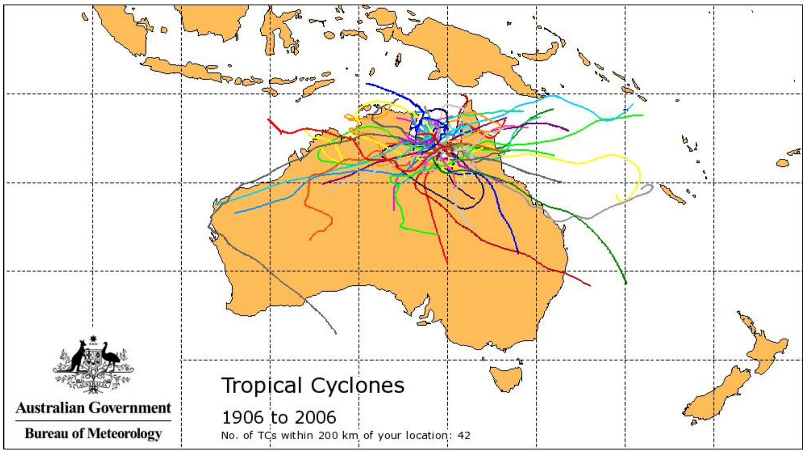


Figure 3.3 Calvert Hills annual rainfall at DR014705.

Calculated over the Water year = September to August of the following year. (Interpolated data obtained from SILO Data Drill data made available by the State of Queensland through the Department of Natural Resources)

Average daily minimum temperature varies from 12 to 25°C and average daily maximum from 29 – 37°C. Average annual evaporation is about 3000 mm for the region which exceeds the annual rainfall in even the wettest of years. Three pm humidity varies from 26 – 64 percent.

The Wet/Dry season contrast has significant implications for water resources. The monsoon brings wet season rainfall but cyclones, and the lows before and after cyclones, bring large rainfall events. These events cause major flooding and can provide good recharge to aquifers. In Figure 3.4 we can see that for the period available 1906-2006 there have been 42 cyclones within 200 km of DR014705 and 7 between 1999-2006 showing that in these latter years there has been frequent cyclone activity. This has brought exceptional rainfall to this region which has provided significant recharge and caused unprecedented high dry season flows.



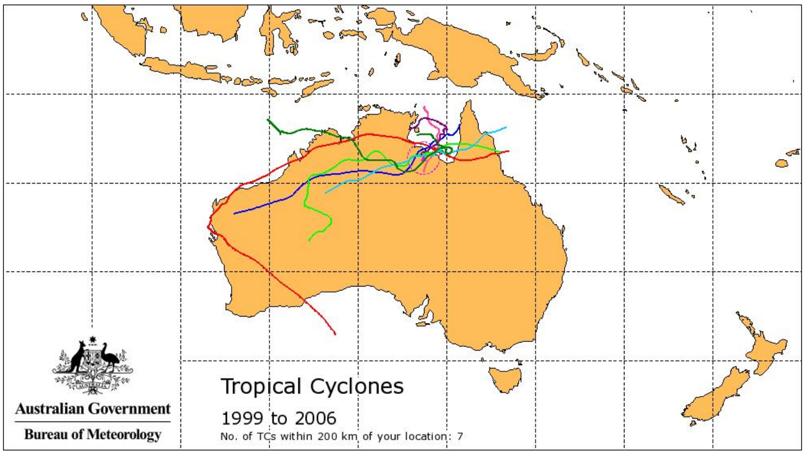


Figure 3.4 Tropical cyclones between 1973 – 2006 and 1999 – 2006 in the map region

(From BOM website: www.bom.gov.au/cgi-bin/silo/cyclones.cgi)

Although the Wet season brings significant rainfall over a short period, the ensuing Dry, with months of negligible rain, results in most rivers in the region ceasing to flow unless they are groundwater fed, such as reaches of the Karns Creek, Coconut Spring Creek, Running Creek and Sandy Creek. .

4. CURRENT WATER USAGE

The level of water usage in the region is low, with groundwater (bores), rainwater (tanks and dams), natural waterholes and rivers providing water for domestic usage and cattle grazing.

Groundwater is used for domestic supplies wherever possible. The Robinson River Community sources its water from one bore and an adjacent large waterhole of the Robinson River (Plate 4.1, 4.2). Securing an adequate groundwater source has proven difficult for the community due to either poor yields in the bores or poor water quality. The water level in the water hole has been known to drop significantly and is open to contamination particularly as the community runs parallel to it. Outstations use bores and rainwater and some use river water for their domestic water supply.

The cattle stations use bores, rainwater tanks or river water for their domestic supply aside from Greenbank station which also uses a lagoon. (Table 4.1). Cattle are watered through bores, dams, river water, springs and water holes. Cattle stations have reported dams drying up late in the Dry season due to the months of no rain and high evaporation rates. The main industry in the area is cattle grazing.

Plate 4.1 & 4.2 Waterhole at Robinson River community and pipe infrastructure to pump water from the waterhole.

Table 4.1 Current water use in the Robinson and Calvert Rivers Region.

Location	Water Supply	Water supply to cattle
Robinson River Community	Bore and waterhole of the Robinson River	
Calvert Hills Station	Bore	Rivers, springs, bores, dam
Wollogorang Station	Bore, rainwater	Dams, waterholes, rivers
Seven Emu Station	Robinson River	Dam, rivers, waterholes
Greenbank Station	Lagoon	Waterholes, river, dam.
Pungalina Station	Calvert River, rainwater	
Jangalina Outstation	Bore, rainwater	
Yangulinyina Outstation	Bore, rainwater	
Mimina Outstation	Bore, rainwater	
Meera Outstation	Bore, rainwater	
Wundigalla Outstation	Bore, rainwater	
Wulaburri Outstation	Foelsche River, rainwater	
Bujan Outstation	Bore, rainwater	
Doolgarina Outstation	Robinson River, rainwater	
Redbank Mine	Bore	

Plate 4.3 Calf on Calvert Hills Station. Grazing is the main industry in the area.

5. INDIGENOUS KNOWLEDGE

To indigenous people water sites not only have a physical entity and a purpose in the connected environment, but also social, emotional, cultural and spiritual significance. Effective management of land and water therefore involves consideration of all these realms.

'… nothing is without meaning, because to have no meaning would be to have no Law, if something has no Law it has no place and this cannot be for Indigenous plants and animals, (and land and water) all have ngalki, they have essence or substance that relates them to all other living things including humans.' (Bradley et al. 2006)

Western science provides a view of water resources in terms of its physical characteristics. On the water resource map rivers are classified according to their minimal flow, groundwater classified according to aquifer type and waterholes depicted as to whether they are permanent or intermittent. Aboriginal people however view and classify the natural environment differently and kinship plays a major role. Just as any scientific based management of water requires an understanding of scientific principles and classification, likewise indigenous environmental management requires an understanding of indigenous views and classification of the environment.

To begin to comprehend the indigenous perspective is no easy task when coming from a Western European perspective. '*Many cross-cultural differences exist in relation to environmental perceptions, knowledge of scientific practices, spirituality and language. Bradley notes that it was only after he had become quite fluent in Yanyuwa that he began to really understand how the Yanyuwa view their environment.*' (Bradley et al. 2006) Bradley is an anthropologist who has worked with the Yanyuwa people since 1980. The work of Bradley and others is presented following as it gives a clear overview of how one language group, the Yanyuwa view the environment, thus providing an example of indigenous perspectives in the Gulf region. The Yanyuwa people are one of several language groups situated in the Gulf Region. Other groups include Alawa, Marra, Warndarrang, Mangarrayi, Ngalakan, Garawa, and Gudanji as well as others. Cultural differences exist between the language groups but the underlying world view remains the same. Yanyuwa traditional country is situated north-east of Borroloola and encompasses the Sir Edward Pellew Group of islands.

The following overview has been heavily resourced and quoted from Bradley et al. 2003 and Bradley et al. 2006 and is denoted by the grey font. The information presented is the result of years of research by Bradley.

For Yanyuwa people the environment is both a physical, spiritual and cultural landscape. To begin to understand their interconnected view of the environment it is necessary to explain their view on how life and land came into being.

The Yanyuwa believe all was created by the Spirit Ancestors, commonly called Dreamings or in Yanyuwa *Yijan* '*who rose up from the earth or travelled from distant places, and created and /or changed geographical features and placed different plants and animals on the earth'*.

'*The Spirit Ancestors also created a charter that is the Law for existence. … The Law is the reason why things are as they are, or are done in a particular fashion*'. *As 'the Spirit Ancestors set out the forms of Law, and established the natural order and shape of the landscape they also left their creative potency. At some point in time, most of the Spirit Ancestors changed into a number of forms. Some became life forms or phenomena, as we know them today, such as certain species of plant and animal, celestial bodies, winds and tides. Others transformed themselves into rocks, trees and watercourses, and their power became localized at certain sites'.*

'*The Yanyuwa believe that these Spirit Ancestors and their power still exist in the land. They also believe that their power is still active and that through ceremony, song and certain forms of ritual action, they can be contacted. It is because of this that the country is said to be able to 'hear', that a rock for example, can make certain things happen, and that places when visited can be describes as being happy, sad, generous or ungiving'*.

The land and water is '*criss-crossed with the tracks or paths of these Spirit Ancestors, and these tracks are marked with places where the Spirit Ancestors danced, ate, fought, slept, urinated and so on. All of these places are seen to be repositories of power and the consciousness of the Spirit Ancestors. Thus the whole landscape is seen as a vast network of interconnected meaning'*. An example is provided in Figure 5.1 which provides a listing of the Spirit Ancestors and shows their tracks in the Foelsche and Wearyan Rivers area (south-eastern Gulf). Figure 5.2 shows the place names associated with these Spirit Ancestors for the same area. Figure 5.3 provides part of one of the dreaming stories for this area, namely that of Walalu, the Stranger Rainbow Serpent. This area forms part of the Law that comes from the Mainland.

The tracks that the Spirit Ancestors took 'are also the song cycles, kujika, which are sung during ceremonial performances. The song cycles for the travelling Spirit Ancestors follow a particular track and have offshoots that diverge from the main track to bring into the song all the stationary Spirit Ancestors that may be associated with a particular tract of land. Both the songs and the creatures can be called kujika, as they play a creative role.' It is believed that 'the songs are still moving through country even if no one is singing them, it is like they have a life of their own. People who know the Kujika can join in and sing, and once they start singing it is like the country is singing through that person.' The Spirit Ancestors and their songs are inseparable from each other and from the sites that they created through the action of singing. Thus, the Spirit Ancestors are the creators, the singers of songs, which sang the Yanyuwa environment into being. Everything they did is recorded in these songs: the names of country, fauna, flora, events and names of people and places are all recorded'. 'The Kujika is said to preserve the way the country was in the Dreaming and how it still is, and how the

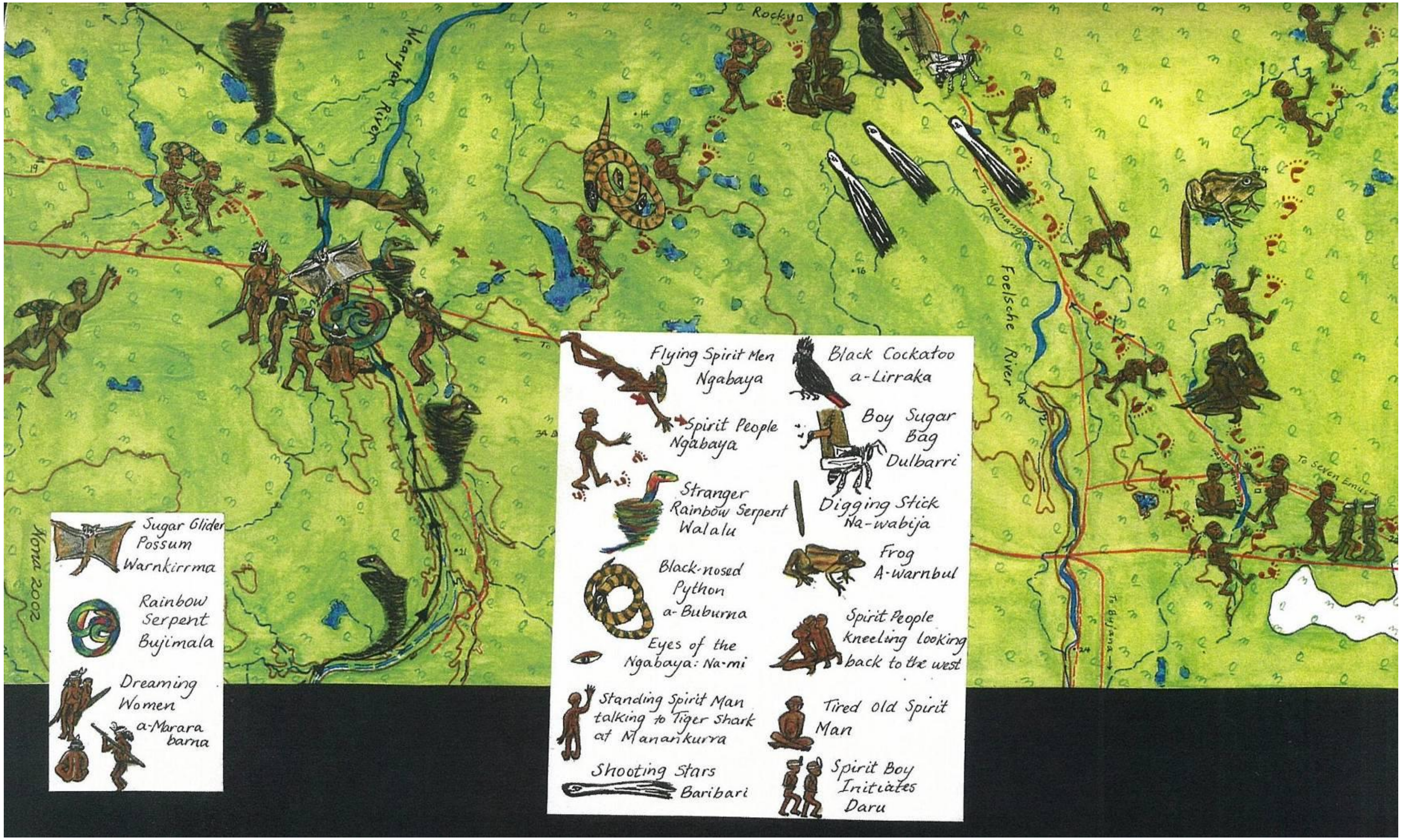


Figure 5.1 **Spirit Ancestors and their tracks in the Foelsche and Wearyan Rivers area**. (From Bradley et al, 2003)

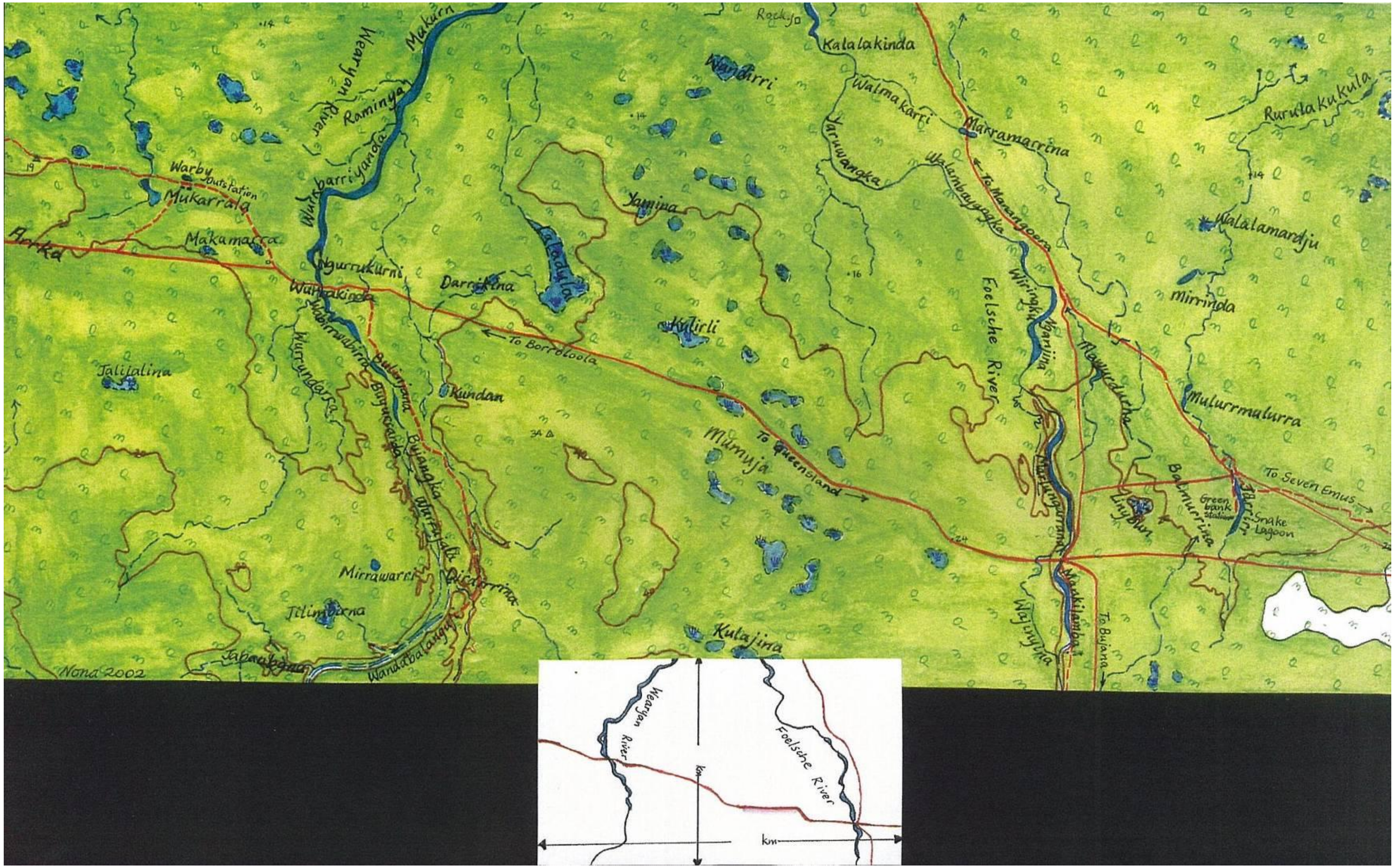


Figure 5.2 Place names associated with the Spirit Ancestors and their tracks in the Foelsche and Wearyan Rivers area.
(From Bradley et al, 2003)

Other Stories:

1.The story of the Walalu, Stranger rainbow Serpent is very important and very sacred. The Walalu is really important to the a-Kunabibi ceremony and the story of his journey and the things he did are really sacred. His *kujika* is also very important and very sacred. The stories told here are all outside versions of his travels. The Walalu is sometimes called *Yankarra* which is Yanyuwa for "the Stranger", he is called this because he came from such a long way away and, once he moves through Garrwa and Yanyuwa country he keeps moving all the way into Marra country, he moves through Alawa and Mangarrayi country, and finishes his journey at the Mataranka hot springs which is far to the west. The Walalu has many other different names that are sung in his *kujika* but these names are only known to men. Some of the Walalu's journey is sung in the public *kujika* used in the a-Marndiwa initiation ceremonies. (see *Wandayarra a-yabala* and the Mambaliya *kujika* in particular)

2.The *ma-jabanda* forked pole is seen by men, women and children at the end of the a-Kunabibi ceremony. It is stood up on the women's ceremony ground.

3.Wabirrwabirra is the Yanyuwa name for this important rock hole, in Garrwa this place is called Wabirrwabirrnyina. Some places have two names like this when they are near places where one language takes over from another language. The Wearyan River is a place where in the old days Yanyuwa and Garrwa people were always moving together.

4.The Walalu is an important figure in the a-Kunabibi ceremony, but this ceremony does not just belong to the Yanyuwa people. When this ceremony is being held on Yanyuwa country people from many other communities have to be asked to attend. Garrwa people come from Doomadgee and Robinson River, Marra and Alawa people come from Roper River, Nunggubuyu people come from Rose River and Gudanji people from the Tablelands. It is not just men that have to come because women too, have their own very important ceremonies that belong to a-Kunabibi. Today these people travel by car, plane and motor boat to come to this ceremony, in the old days they travelled by foot and dugout canoe. Once this ceremony starts all of these different people have to come, this ceremony has a lot of power and is very sacred. In Yanyuwa the words for power are *wurrama* which is like "authority" and *wirrimalaru* which is like "spiritual power".

MAP: Foelsche and Wearyan Rivers
DREAMING: Walalu, Stranger Rainbow Serpent
CLAN: Mambaliya

The Walalu, Stranger Rainbow Serpent came far from the east, from Mangkabarra which is in the sea near Massacre Inlet in Queensland. He travelled from the east, as a whirlwind, passing over the Calvert, Robinson, Foelsche, Wearyan and McArthur Rivers.1. Just to the east of the Foelsche River is the large long lake called Kalajangku, it is not far from the Manangoora turn off. The Walalu created that lagoon and then came to the Foelsche River at Bujana where the outstation is now located. He then headed southwest and came to the Wearyan River. He arrived at the Wearyan River at Bulukwanja and then began going down stream and came to Jabanbana where he left behind a sacred ma-jabanda forked pole.2. He then passed through Dirdirrina, Wurrujala, Bujangka, Buyurranda, Bulinjana and then came to Wabirrwabirra.3.
At Wabirrwabirra he met up with a lot of Dreaming Women [a-Mararabarna], which had also come up out of the sea at Mangkabarra, but they had been trying to keep away from the Walalu Stranger Rainbow Serpent because they were brother and sister and they should have been avoiding each other. At Wabirrwabirra they danced together very important dances from the a-Kunabibi ceremony. The Sugar Glider Possum [warnkirrma] is also a Dreaming at this place. Today there is a very large rock hole at Wabirrwabirra and there is a Rainbow Serpent Dreaming there that was left behind by the Walalu. The Walalu kept going downstream and came to the Wurrakinda where the road now crosses the Wearyan River, he then came to a small creek on the west bank of the Wearyan River called Wurrbarriyanda and this is where he left the Wearyan River and continued to travel west, heading towards Kawurrukuma near Marrinybul.4. (see Map Fletcher and McPherson Creek.)

Figure 5.3 Dreaming story. (From Bradley et al, 2003). Right: one of the dreaming stories relating to the Foelsche and Wearyan Rivers area. Left: other stories associated with that Dreaming, Walalu. This story in particular has been presented here because, as detailed under 'Other Stories 1' the story of Walalu travels right across the Gulf region and ends at Bitter Springs at Mataranka, thereby traversing several language groups and providing an example of how the stories link people from different language groups.

old people would like it to stay.' The songs are also about power and the sound of the song creates power that can make things happen. For example, Stephen Roberts, a senior elder living at Minyeri, in talking to Zaar about the rain dreaming at Mambilila spring, located south of Ngukurr, explained:

"If the heavy storm come, you can stop that rain (by) singing, … (sings song). That's how you stop that rain, he wont come rough. You sing … backwards. (sings song) You sing like that. You stop that rain, never come. That cloud will go right back Minimeer, that's all. (Stephen Roberts, pers. comm.)

An example of part of a *Kujika* is provided in Figure 5.4. These are the final verses from a *kujika* which has in it Walalu, the Stranger Whirlwind Rainbow Serpent Dreaming amongst others. The *kujika* starts at *Marrinybul* rockhole.

Bradley explains that '*every kujika has its own Ngalki'. 'Ngalki is a very complex word that identifies and gives distinction to its owner or owners. It is often translated as 'essence', 'skin' or 'sweat'. For example the ngalki of a flower is its smell; of food, its taste and a songs' ngalki is its tune. The Yanyuwa believe that the Spirit Ancestors were imbued with ngalki, which was also a classifying agent that divided all things into one of four clans*[1]'. As the Spirit Ancestors called and named places, animals, plants and other environmental features they also classified them, with a *ngalki*, which places them within the Yanyuwa clan system. The names of these four clans are:

- Wurdaliya,
- Wuyaliya,
- Rrumburriya and
- Mambaliya-Wawukarriya.

The interrelationship between *Kujika, Ngalki*, Dreaming and clans is portrayed in the following example: *'the kujika starting at Manankurra belongs to the Tiger Shark Dreaming and the Tiger Shark Dreaming is Rrumburriya. Rrumburriya is the name of the ngalki, it is also the name of the clan that owns the Manankurra Kujika.'*

The map in Figure 5.5 shows Yanyuwa clan areas and Table 5.1 provides a listing of plants and animals according to the clan classification. This clan classification is not restricted to the Yanyuwa, and other language groups in the Gulf identify with it. An example is provided by the Aboriginal land trust named 'Mambaliya Rrumburriya Wuyaliya Aboriginal Land Trust' which is situated on the McArthur River and is connected with a number of language groups. The trust has used clan names rather than language group names for identification. The four clans can be called different names in different languages. When Zaar undertook field work with indigenous people from differing language groups, they often referred to land and water areas in terms of the four clan names.

1 Baker (1999) describes the social groups of the Yanyuwa as consisting of two moieties which each have two semi-moieties. The semi moiety groups are equivalent to the clan groups noted by Bradley et al. (2006)

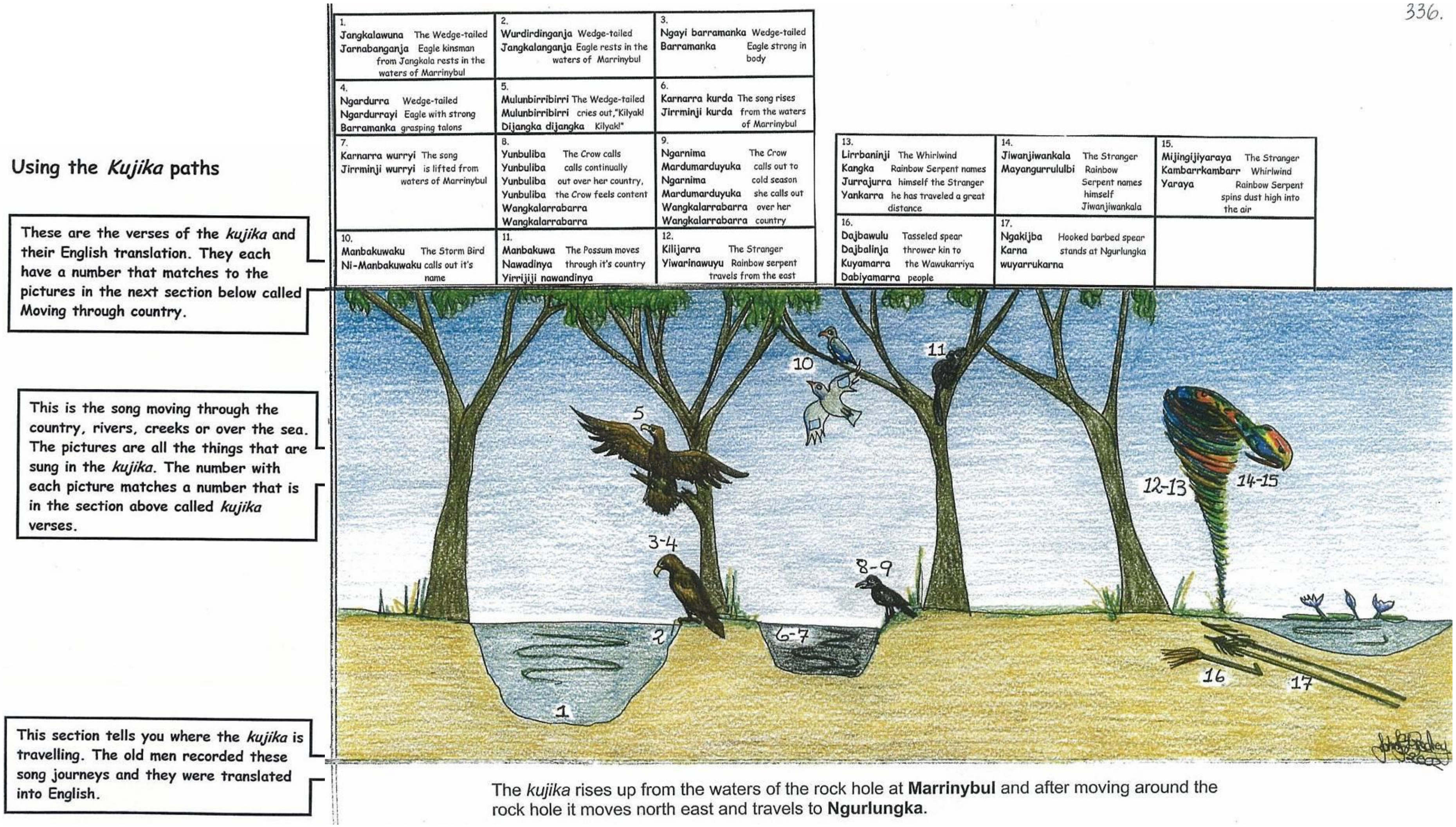
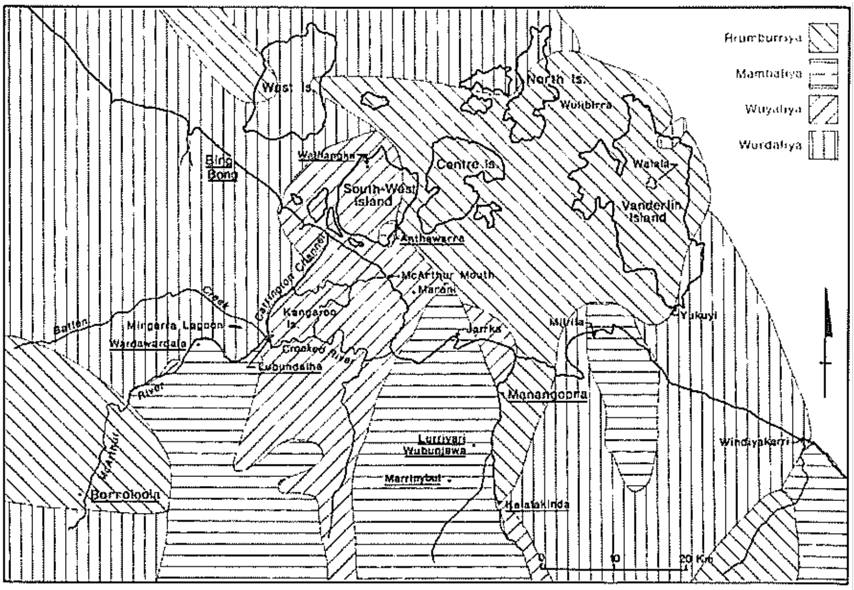


Figure 5.4 The beginning versus of the Mambaliya-Wawukarriya Kujika. It travels from Marrinybul rockhole to Jarrka.



Rrumburriya
Mambaliya-Wawukarriya
Wuyaliya
Wurdaliya

Figure 5.5 Clan areas in the Borroloola area. (Baker, 1999)

Table 5.1 Examples of Yanyuwa clan classification (Bradley et al., 2006, p12)

Rrumburriya	Mambaliya-Wawukarriya	Wurdaliya	Wuyaliya
li-maramaranja dugong hunters	*murndangu* long necked turtle	*malurrba* green turtle	*wardali* dingo
warriyangalayawu hammerhead shark	*kurdarrku* brolga	*karrubu* hawksbill turtle	*a-kuridi* groper
ngurdungurdu tiger shark	*a-kilyarrkilyarr* wedge-tailed eagle	*a-wurrkayny* large bodied mosquito	*kirdil* sandfly
ma-arnbaka cycad palm	*kinybutha* little read flying fox	*ngabaya* spirit man	*li-jakarambirri* blue ringed octopus
a-warranyuka black flying fox	*wakuwaku* cyprus pine	*balubalu* pelican	*ma-lhalhaki* northern kurrajong tree

People also carry *ngalki.* A person follows the *ngalki* of their father and father's father. There are *four terminological lines of descent, which are distinguished at a grandparental level* and which can be matched to a clan. These are:

- *Father's father*
- *Mother's father*
- *Father's mother's (brother)*
- *Mother's mother's (brother)*

This is the basis of Yanyuwa kinship. *'The clans are categories that codify relationships of importance in ritual activity and in daily life.'* For example '*the Yanyuwa are ngimarringki for their father's country and jungkayi for their mother's country. The former is usually translated into English as 'owner' and the latter term is translated by the Yanyuwa into English as 'manager'.* (Baker, 1999) People relate to country after the relatives that come from it; if, for example they were Rrumburriya, and they were referring to land that was Rrumburriya, they would call it 'country of my father's father'.

As mentioned earlier, the Spirit Ancestors set out the Law and the Law that belongs to country provides the rules for how people should interact with their environment and with others. It also determines how ceremonies are to be performed and what each person's role is in a ceremony. This again is interrelated to a person's clan. For example *'the secret and sacred a-Kunabibi ceremony is for the Mambaliy-Wawukarriya and Rrumburriya clans and they are ngimarringki while the Wuyaliya and Wurdaliya clans are jungkayi'.* Each has particular responsibilities in the ceremony. Hence '*everyone is dependent on others to carry out the life-sustaining ceremonies associated with the land'* (Baker, 1999). This was noted by Zaar when in conversation with Donald Blitner, a Marra man from Ngukurr who said:

"I am the last child from my uncle and father who taught me the Willy Wagtail ceremony and song. If it's a dry time, my old people used to sing the rain song and my uncle and brother in law would sing at the cold weather time for rain. The Jungayi, that is, the Joshua family for the area have passed away so no ceremony is done anymore. That's the way it goes. My eldest brother knew more than me but he has passed away". (Donald Blitner, pers. com.)

Because people, land, animals, plants and other natural phenomena all belong to a clan, a person belonging to one clan will know how to relate to everything else in their natural environment. Hence the existence of an intricate web of spiritual, cultural and social relationships between people and their environment. For example: '*The Brolga is Mambaliya-Wawukarriya so people from this clan are ngimarringki for the brolga and call it father's father, while people from the Wuyaliya and Wurdaliya clans will be jungkayi for it because it is either their mother or father's mother. Rrumburriya people call the brolga, mother's mother'*.

Aside from the spiritual and social way in which Yanyuwa view their environment they also view it in terms of the *'physical landscape and the habitat an organism occupies'*. They have developed habitat classifications; birds for example are classified into many habitats including mangroves, freshwater and lagoons amongst others. They have divided the '*physical landscape into distinctive 'land units' reflecting topography, soil and vegetation.*' One of these units is presented in Figure 5.6. In it freshwater is associated with riparian vegetation such as river pandanus and paperbark trees which is a familiar association also in Western science. The Yanyuwa are aware of how their seasons and animal and food resources all interact with the land units and habitats. They are acutely aware of environmental changes and the causes.

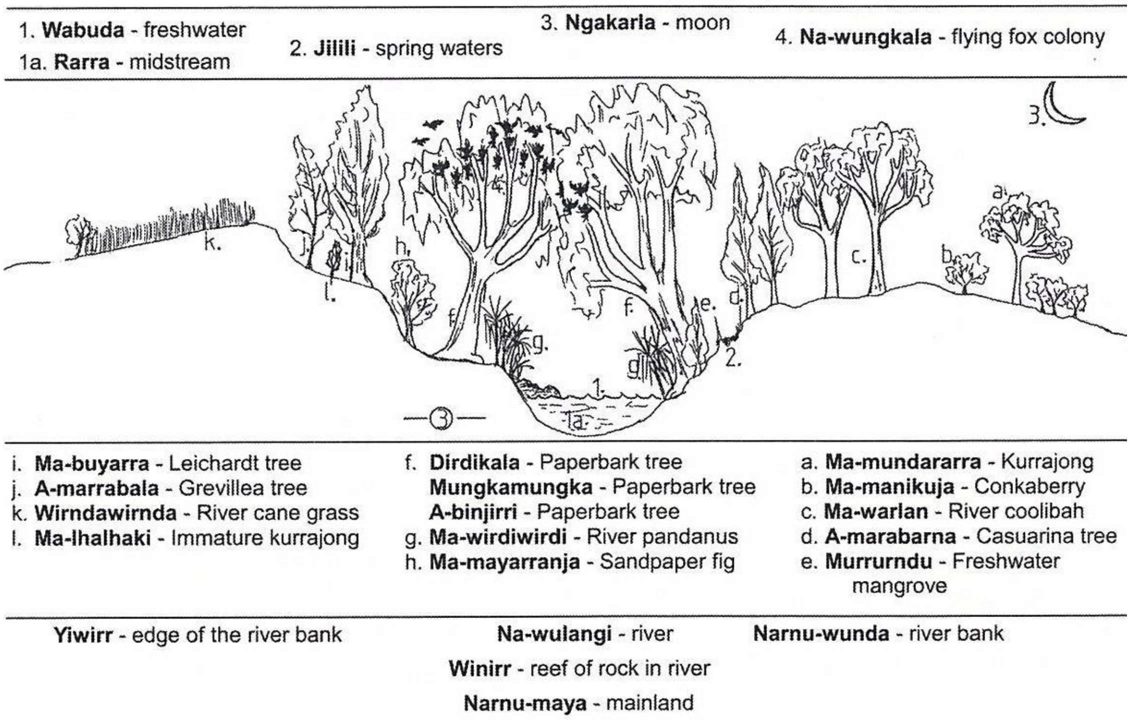


Figure 5.6 Some of the land units associated with the mainland as identified by Yanyuwa. (Bradley et al., 2006) The land unit is listed at the bottom of the diagram ie *Yiwirr*, environmental detail is listed above this, and other environmental detail is provided at the top.

- There is total prohibition on some species and, typically, these are attributed with the power to preserve particular resources. For example, the survival of the 'quiet' water snake is thought to maintain waterholes. (Baker, 1993)
- Permission from the ngimarringki is required to hunt in areas. These rights are jealously guarded in areas of plentiful resources, such as small islands rich with bird or turtle eggs. (Baker, 1999)
- Undertaking log coffin funeral practices to return spirits to the land and revitalize the country. This practice has ceased amongst the Yanyuwa and hence people say the 'lands's getting weak, (because) no people, no spirit come back now'. (Baker, 1999)

Now let's look specifically at water in relation to the above dissertation on the indigenous perspective of the environment. Let's take the example of a waterhole, any waterhole. Each waterhole has been named and created by a Spirit Ancestor as it travelled on its path. The waterhole would be named in one or more songs which would have a particular tune. The songs would explain what events occurred at the waterhole. The waterhole would have its unique *Ngalki* or essence. The waterhole would be part of land belonging to a clan. There would be owners and managers for the waterhole. Each of these people would carry responsibilities in relation to caring for the waterhole. Ceremonies may take place at the waterhole. There may be a particular way in which people must interact with the waterhole as determined by the law. The waterhole forms part of a land unit, a habitat that is used by flora, fauna and people. The waterhole has a purpose. The waterhole would be managed in a sustainable way because it has a role to play in the interconnected spiritual, social and physical realm of the indigenous people. In fact management of the waterhole includes all these aspects.

Les Hogan Warramurru a Garawa elder from Borroloola had similar words to say when interviewed by Zaar:

"Every waterhole has a story of how it was created. It got story that one. Every lagoon, every waterhole, all the way down (the river) all that story, that one. We know (the story). We show our children when we go there. We tell them. This is the country that dreaming been say, he's here somewhere, something like that. We show them the right waterhole, the dreaming there. Some places all right (to visit), when that dreaming been talk, he's all right, they still can fish or catch turtle. (When going to a waterhole we talk to the dreaming) I'm here, I'm the boss for this country, you got to talk yourself. You tell the old people (the ancestors), they belong to there, they are there somewhere but you can't see them." (Les Hogan, pers. com.)

Plate 5.1 Les Hogan Warramurru

The West has in recent decades become more aware of interconnections of water and the environment through such fields as hydroecology; it recognises the beneficial uses of water which include cultural and environmental uses and it realises people have to be responsible in managing the environment. There has been this awareness by indigenous people for thousands of years only their world view takes one step further – that of the spiritual. Their holistic view engenders responsible land and water management.

As a means of presenting indigenous knowledge on water, indigenous waterhole names collected as part of this study are marked on the water resource maps and information pertaining to the waterholes and who provided that information is given in Appendix A. This information, which has often been provided by elders, provides a little insight into the significance of water to indigenous people in this map area. It presents a fragment of the indigenous knowledge of the vast Gulf region that has been passed on through generations by word of mouth, song, dance, painting and ceremonies. It is hoped that this introduction which has very much simplified what is really an interconnected complex system, has provided enough background so that the information in Appendix A can be put into perspective.

Ancillary to this report, indigenous knowledge has also been documented through photographs and video and is available on The Gulf Water Study DVD.

6. GROUNDWATER

6.1 The Water Cycle

To understand the groundwater system, it helps to have an understanding of the water cycle (Figure 6.1). 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 of the land and the intensity and duration of rainfall. As the water infiltrates it wets up the soil and moves down. Some of this water will be evaporated or used by plants, 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.

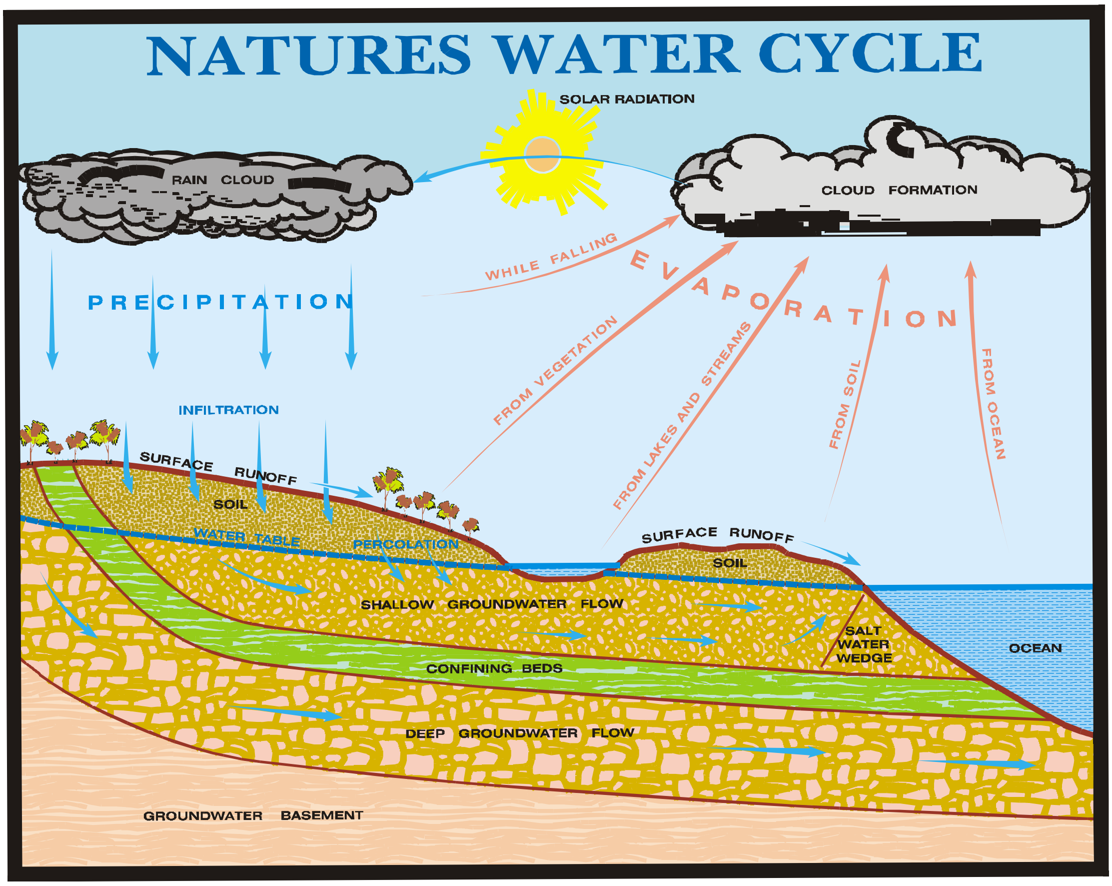


Figure 6.1 The Water Cycle

6.2 Geology

Geology is the science of rocks and its characteristics. Rock type and geological structure are some of the main factors influencing groundwater occurrence and the location of springs.

6.2.1 Rock Formations

Rock formations are made up of one or several rock types. These are shown on geology maps. The groundwater potential of each formation is assessed and those with similar aquifer characteristics are grouped together and mapped under one of the aquifer types shown on the water resources map.

Rocks are classified into rock formations as characterised by their physical and chemical features. Rock formations can consist of one or several rock types i.e. sandstone, dolomite. When a number of rock formations have common characteristics, they are grouped together to form a rock group. The age of the rock is categorized by a geologic time frame. Table 6.1 provides a broad outline of the rock groups and formations of the region and their ages.

Table 6.1 Rock groups, formations and their ages.

GROUP	ROCK FORMATION	AGE: IN MILLIONS OF YEARS	GEOLOGIC TIME FRAME
	Undivided Cenozoic (alluvial, colluvial, eluvial deposits)	0 - 65	(Youngest) Cenozoic
	Undivided Cretaceous (sandstone and claystone)	65 - 145	Cretaceous
	Bukalara Sandstone	488 - 542	Cambrian
Roper	Limmen Sandstone Mantangula Formation	542 - 2500	Proterozoic
McArthur	Karns Dolomite Lower Karns Dolomite		
Tawallah	Echo Sandstone Pungalina Member Hobblechain Rhyolite Packsaddle Microgranite Gold Creek Volcanics Wollogorang Formation Settlement Creek Dolerite Aquarium Formation Sly Creek Sandstone Mc Dermott Formation Seigal Volcanics Westmorland Conglomerate		(oldest)

The extent of each rock formation is depicted on geology maps. The map region is covered by the following 1:250000 scale geology maps:

- PELLEW
- ROBINSON RIVER
- CALVERT HILLS

A number of the rock formations noted in Table 6.1 will be referred to in this report. The groundwater potential of each formation has been assessed and formations with similar aquifer characteristics are grouped together under one of the aquifer types. The geology maps, which show the area covered by each formation, are used to map out the area of each aquifer type shown on the water resource map (Figure 6.2). Put simply, formations with similar aquifer characteristics are mapped together under one of the aquifer types. Aquifer type delineates the groundwater resources on the water resource map.

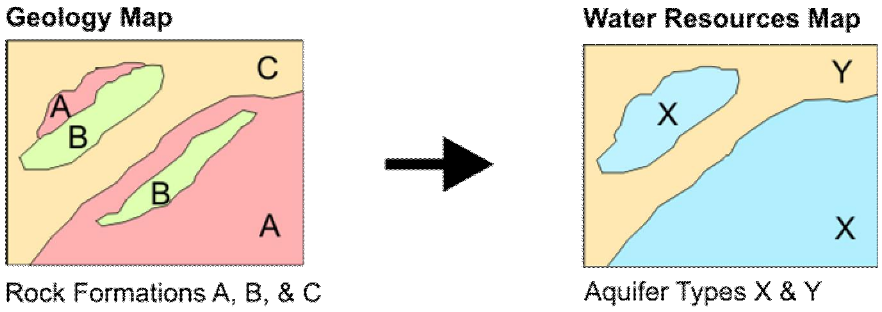


Figure 6.2 Example of grouping of rock formations into aquifer type. Here formations A and B have similar aquifer characteristics whereas formation C is different.

6.2.2 Geologic Structure and depositional history

The region contains rocks primarily from the McArthur Basin which include the Roper, McArthur and Tawallah Groups. These are old rocks from the Proterozoic eon (Table 6.1). The McArthur Basin is the name given to a sequence of rocks which roughly form the shape of a basin as they overlay each other.

The oldest rocks lie at the bottom of the basin. These rocks are from the Tawallah group. They outcrop at the edge of the basin in the south, east and north-east of the map. They also outcrop around Robinson River Community.

The most extensive rock formations in the region from this basin are the Echo Sandstone and the overlying Karns Dolomite. The Echo Sandstone is observed as a hard pinkish sandstone that forms rocky hills and escarpments. It can be seen along the highway around Surprise Creek. The Karns Dolomite holds the major aquifer in the region and consists of dolostone, siltstone and sandstone.

The Bukalara Sandstone, a younger rock from the Georgina Basin, is dominant in the south west of the map area where it forms a plateau and overlies the Karns Dolomite.

Overlying part of the Bukalara Sandstone and some of the older rocks in the southern area of the map, is a much younger sandstone from the Cretaceous. The most recent deposits are from the Cenozoic primarily consisting of sands and clays. They are dominant along the coast and may only be several metres thick but mask the underlying rocks.

There is little deformation in the map area. Faults run in a north-westerly direction. Notable are the Karns Fault which is situated near Karns Creek and the Calvert Fault which lies in the southern area of the map. Faults and fractures can increase the permeability of rocks and hence bore yield.

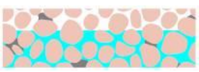
Topographically the region extends from plateau country in the south, to dissected hills, to coastal plain in the north. Drainage is therefore from the higher plateau region in the south towards the coast in the north.

6.3 Aquifer Type

An Aquifer is a body of rock that contains water and releases it in useable quantities. The rock contains water-filled pore spaces that are sufficiently connected to allow the water to flow through the rock. The pores can develop from fractures, rock dissolution or occur naturally due to voids between the grains in the case of sandstone. Aquifers are classified according to the type of pore spaces.

When assessing the groundwater resource potential of a rock formation, bore yields, springs, water quality, sinkholes and importantly rock type and the nature of the spaces in the rock is taken into account. The latter delineates aquifer type. The properties of the spaces determine how extensive an aquifer is, how easily water moves through it, and how much water can be stored in it. Aquifer type is related to rock type. There are three basic aquifer types (Table 6.2). Aquifers can consist of combinations of the main aquifer types.

Table 6.2 Basic aquifer types and their characteristics. (Adapted from Tickell, 2008)

Aquifer type	**Description**	**Rock type that contains this aquifer type**
Fractured 	Networks of fractures in the rock provide space for water to collect and move through. The degree of fracturing can vary greatly. Fractures are normally very small, less than a millimetre, but if there are enough of them an aquifer can exist. Where fracturing is extensive and interconnected throughout a formation a widespread aquifer results. Localised fracturing results in a localised aquifer which is usually not very productive.	All rock types. It is the main aquifer type for hard, impermeable rocks such as granite, schist, dolerite and silicified sandstone.
Fractured & Karstic 	This aquifer is created by the dissolution of the rock by water passing through it. It forms in carbonate rocks – limestone or dolomite. Over geological time frames these rocks are slightly soluble in water. As water moves through fractures, it gradually enlarges them as the rock is slowly dissolved. The process can form caverns but more commonly openings of millimetre to centimetre in scale.	Carbonate rocks – Limestone and dolomite 
Sedimentary Porous rock 	This aquifer occurs in sands and sandstone. Pore spaces between the grains provide storage and a flow path for water. Not all sandstones have suffic-ient intergranular porosity to form an aquifer. Also over time, minerals may fill or partially fill the pore spaces hence the younger the sandstone the more likely it is to have its intergranular porosity intact.	Sands and sandstones 

The effects of weathering can increase aquifer development and therefore has been included in the description of aquifer type. Weathering is the physical disintegration and chemical decomposition of rock. Physical weathering occurs from the alternate expansion and contraction due to temperature changes, and chemical weathering produces new minerals. Weathering can cause the formation of new fractures or increase existing fractures, resulting in better aquifers. Weathering can also cause the narrowing of fractures reducing aquifer development. Typically weathering can affect rock to a maximum depth of 80m. The most productive aquifers commonly occur near the base of the weathered rock.

Weathering can be triggered or enhanced by fracturing. When rock is fractured, open spaces develop in the rock mass, and water collects in the spaces. Aquifers can exist in rocks due to fracturing alone. Fracturing can occur in all rock types but the degree of fracturing can vary greatly. Faults and fractures are marked on geology maps but the degree of fracturing is not indicated. Fractures can be targeted for potential water supplies but specialist scientific advice is advised.

6.3.1 Flow system description of aquifers

Aquifers can be described according to the distance groundwater moves through the aquifer, from where it enters the ground (recharge areas) to where it discharges to the surface (discharge areas) (Figure 6.3). The distance it flows depends on the extent of the aquifer. It can vary from hundreds of kilometres to less than a kilometre. The scale of groundwater flow has been categorized by Coram and others (2000). These are termed groundwater flow systems (Table 6.3) and are used to describe the aquifers on the water resource map.

The rate at which groundwater flows is usually very slow compared to river flows. It can vary from a few millimetres to several metres per year. Karstic aquifers are an exception where water can flow almost like a river through caverns when they exist. Depending on the size and type of an aquifer, it can take days to thousands of years for rainwater to complete its journey through an aquifer from when it infiltrates into the ground to when it discharges. The water we drink from some springs could be very old indeed.

Table 6.3 Aquifer flow systems (Coram et al, 2000)

Groundwater flow system	Flow path distance of groundwater	Example
Local	< 5 km	Fractured rock aquifers in granite often have a short flow path because the aquifer is only as extensive as the group of fractures.
Intermediate	5 to 50 km	Carbonate rocks that extend for tens of kilometres can have longer flow paths as provided by the interconnected caverns.
Regional	> 50 km	In large sedimentary basins, like the Great Artesian Basin, the flow path is long because the sediments have been deposited over a very large area and remain connected. These aquifers usually have high transmissivity.

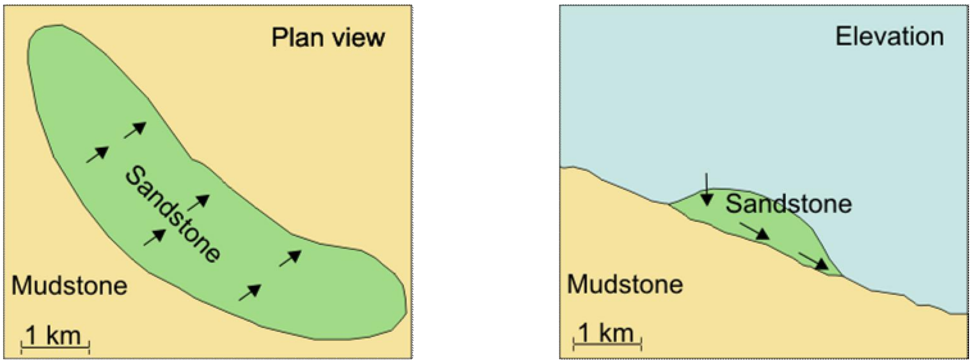
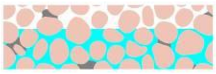
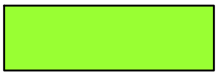
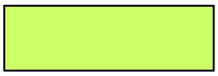
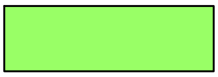


Figure 6.3 Flow path of water in a fractured rock aquifer. This is a local system.

6.3.2 Mapped aquifers / Groundwater Resources

In the map region six aquifer categories have been identified and drawn on the water resource map (Table 6.4). Each aquifer category has been determined by its aquifer type, flow system, typical bore yield and whether or not it consists of carbonate rock. Carbonate rocks impart a particular water quality to groundwater.

Table 6.4 Aquifer categories in the map region represented on the water resource map.

Representative colour on the map	Diagram of aquifer type	Aquifer Type	Flow system	Typical bore yield
		Sedimentary rocks with intergranular porosity	Local to intermediate scale	0.5 – 5 L/s
		Fractured and karstic rocks – carbonate rocks	Local to intermediate scale	Up to 10 L/s may be encountered
 		Fractured and weathered rocks – Carbonate rocks	Local to intermediate scale	0.5 – 10 L/s (2 categories) 0.5 – 5 L/s
		Fractured and weathered rocks	Local scale	0.5 – 5 L/s
		Fractured and weathered rocks with minor groundwater resources	Local scale	0 – 2 L/s

The occurrence and characteristics of each of these aquifers is detailed below. The extent of each of the aquifers has been determined by use of the geological maps and grouping together rock formations that contain the same aquifer type. Drilling information is used to confirm the interpretation of aquifer type and its extent. All water bores drilled in the Northern Territory are identified by a Registration Number (RN) and these are plotted on the water resource map. Details of each bore are provided in Appendix G and H.

Aquifer areas are plotted according to the most productive aquifer type that would be encountered to a depth of 100m. For example if there is a higher yielding aquifer, situated at 70 m depth, that lies below a lower yielding aquifer, then the higher yielding aquifer will be plotted on the map.

Sedimentary rocks with intergranular porosity

On the map the aquifers listed under this category are local to intermediate in scale. Yields have shown to vary from 1 – 10 L/s. The aquifers exist in the interconnected pore spaces between the sand grains or particles. The aquifer often occurs in younger sedimentary rocks as is the case here. This aquifer category is located in three areas of the map; the north, the north-east and the south. In the north supplies can be attained from a shallow aquifer or a deeper sandstone aquifer which lies beneath a clay confining bed. A shallow sandstone aquifer exists in the south. Each aquifer is discussed separately. Details of bores drilled into these aquifers are provided in Appendix E.

The north

Sedimentary rocks lie along the north coast of the map area. Here there are two identified aquifers separated by a clay confining layer. The top aquifer occurs in sediments consisting of poorly consolidated alluvium, sand, clays and gravels. Mutton (2006) considered the sediments to be of Cretaceous age or younger, belonging to the Carpentaria Basin. The sediments were intersected in RN28349, RN28470 (near Wonmurri), RN35922 and RN35923 as well as in drill holes from mining companies that explored on Seven Emu, Greenbank and Manangoora stations (See Mutton 2006, Poltock et al. 1993) for mineral exploration bore information). Not all bores drilled into the sediments yielded water. In RN28349 3 L/s was airlifted from this aquifer. The aquifer was generally encountered above 40 m. Although the shallow aquifer was not productive in RN35922 and RN35923 (Figure 6.4) mineral exploration bores indicate that supplies have been intercepted in the area and hence the aquifer has been mapped here.

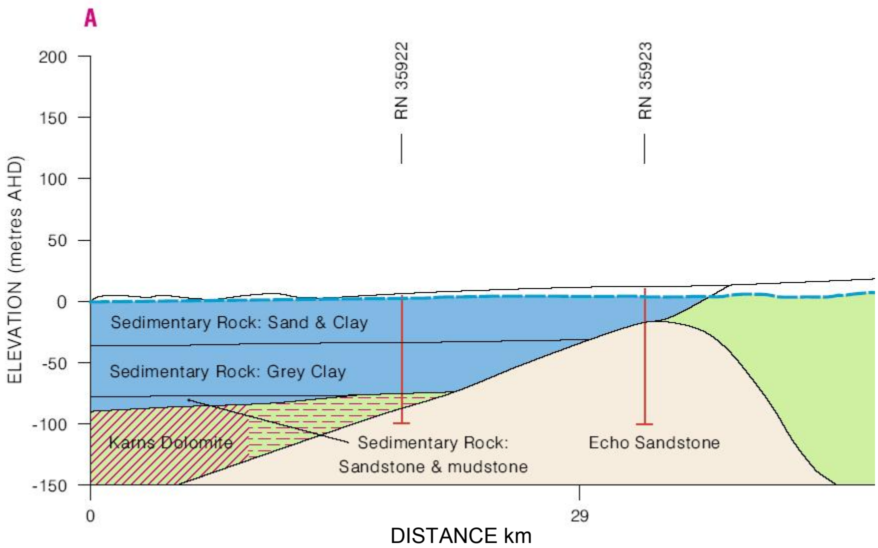


Figure 6.4 Cross section from coast through investigation bores showing sedimentary sequences.

Below the shallow aquifer a Cretaceous grey mudstone was encountered in a number of the bores. The mudstone varied in thickness from about 10 m in the bores near Wonmurri (RN28349, RN28470) to 45 m in RN35922 (Figure 6.4). Below the mudstone a deeper aquifer in soft, possibly Cretaceous, sandstone was intercepted in the Wonmurri bores around 50 m depth and was high yielding (airlifting 10 L/s). This reflects known sequences in the Carpentaria basin where sandstone was deposited by fluvial deposition in the Jurassic to Early Cretaceous followed by mudstone in a marginal and shallow marine setting in the middle Cretaceous (Mutton 2006). RN35922 did not intercept this sandstone but rather dolomite (at 78 m depth) and then a firm sandstone, probably the Proterozoic Echo Sandstone which also airlifted 10 L/s. This is a fractured and weathered rock aquifer. RN35923 intercepted fractured, firm and soft sandstone horizons from 39 m. It is uncertain if this sandstone was Cretaceous or Proterozoic but has been interpreted as the latter.

In summary the sedimentary rocks in the north contain a shallow low yielding aquifer underlain by a confining bed of grey clay. Below the clay exists another higher yielding aquifer consisting of either a Cretaceous soft sandstone or a fractured and weathered Proterozoic sandstone or dolomite (which is a different aquifer category).

Poltock et al. (1993) offers a completely different interpretation to the shallow sedimentary rock discussed and suggests that they are in part weathered Karns Dolomite. He noted difficulty in 'differentiating between unconsolidated cover sediments and weathered Proterozoic lithologies' and interpreted 'clays and interlayered friable sandstones to represent dolomites and dolomitic sandstone' in mineral exploration drill holes on Southern Greenbank Station. No matter what the origin, what is for certain is that these sediments generally provide yields of about 2 L/s with moderate success rate.

Bores RN28349 and RN35922 were initially drilled with air but once water was encountered problems arose with clays collapsing into the hole. This problem also arose in mineral exploration holes. Drilling with mud is therefore advised.

The North east

In the north-east previous exploratory drilling from CRA Exploration (Mackay 1995) intersected Carpentaria Basin sediments including a confining bed of Cretaceous grey clay beneath which lay a porous sandstone, albeit only 2 m thick but which was interpreted as the basal unit of the Carpentaria Basin. This parallels the findings in the north discussed above. The porous sandstone was targeted in our drilling program with RN35868. This bore encountered a similar sequence to the CRA drilling but only minor fine sandstone was intercepted beneath the grey clay and this was not water bearing. Water was encountered in the bore just above the grey clay at 29 m in a shallow aquifer but was found to be salty. Further investigations may prove the existence of a freshwater sandstone aquifer lying beneath the clay confining layer in this region. Budget and access constraints limited our drilling investigations on this occasion.

In the north and north-east areas lie old Proterozoic rocks; primarily the Karns Dolomite and Echo Sandstone adjacent to and underneath the Cretaceous sediments. Extensive Cenozoic deposits, which may be only a few metres thick, overlay both the cretaceous and proterozoic sediments thereby masking the extent of each. Information from bore holes drilled by Water Resources and mining companies has therefore been critical in determining the coverage of each aquifer type.

The south

In the south an aquifer consisting of a pale brown to white unconsolidated sandstone was intercepted in investigation bore RN35869 and yielded 10 L/s reflecting the clean low clay content sandstone (Plate 6.1 & 6.2). The aquifer was located at a depth of 35 m. RN27834, drilled in 1989, also intercepted loose sandstone at a depth of 30 m although it only yielded 2.5 L/s. Gamma logs for the two bores are very similar confirming the aquifer was intercepted in both bores and that it may reasonably wide spread. These are the only bores in this southern aquifer. The sandstone is interpreted as the basal unit of the Cretaceous aged Mullaman Beds. These beds consist of sandstone and conglomerate near the base overlain by clayey sandstone and siltstone. The formation can be up 70 m thick.(Ahmad et al 1989) The basal sandstone is not always present and hence the extent of the aquifer has been mapped conservatively. The aquifer may be more widespread but further drilling would be required to determine its extent.


Plate 6.1 and 6.2 Sandstone drill cuttings from RN35869. Samples are taken every 3 m. Steve Tickell comparing drill cutting with rock outcrop of the same strata.

Fractured and Karstic Rocks – carbonate rocks

This aquifer type is located on the eastern side of Pungalina Station and is situated in the Karns Dolomite. In this area the Karns Dolomite forms an isolated basin surrounded and underlain by the

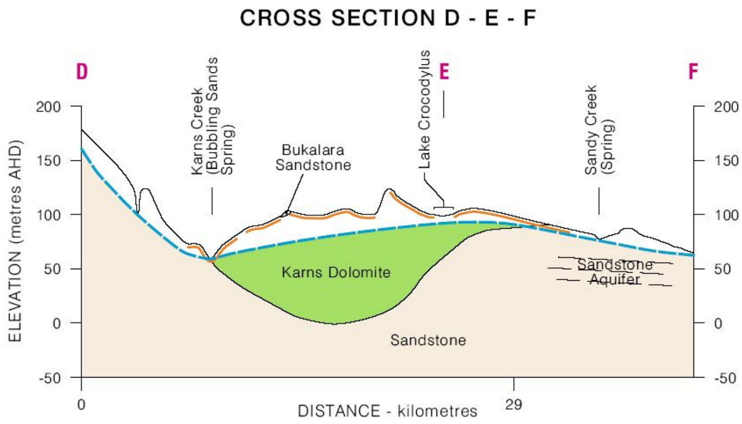


Figure 6.5 Excerpts from the water resource map showing the extent of the karstic aquifer and a cross section through the aquifer showing its basin shape.

Echo Sandstone. The Echo Sandstone in the area is observed as a hard silicified rock.
A cross section showing the basin structure is provided in Figure 6.5. Overlying the Dolomite are pockets of Bukalara Sandstone. Most of the Dolomite here is covered by Cenozoic unconsolidated sands which are only a few metres thick but makes access difficult. This isolated area of Karns Dolomite has developed karst features of sinkholes, caves and currently large localised springs. (Plate 6.3, 6.4 & 6.5) This is the only area in the region where these features in the Karns Dolomite are known to occur and it is the only carbonate rock area on the map that has permanent springs discharging more than 10 L/s in the driest periods.

Plate 6.3, 6.4, 6.5 Karst features of the Karns Dolomite – sinkholes, caves and large localised springs

Aquifer potential depends on the presence of cavities or fracturing in the rock. Occasionally this is absent and a dry hole is drilled. This is the nature of Karst. When interconnected fractures have been enlarged by the dissolution of the dolomite forming extensive cavities then good yields are possible.

The cave system in the area appears extensive with surveyed lengths up to 500 m and 10 m high (Brooker, 2005) and there are many sinkholes. On inspection of one of the caves, strata consisting of a fragile rock with extensive dissolution cavities was found: the type of material that would form a highly transmissive aquifer. A sample of the strata is shown in Plate 6.6.

Plate 6.6 Dissolution cavities in Karns Dolomite

No bores have been drilled into this karstic aquifer and drilling investigations were not possible due to access difficulties. However, the weathered nature of the rock would suggest that yields up to 10 L/s or more are possible from individual bores. Rotary percussion drilling using air is normally used in these aquifers because formations are generally hard and holes stable. Problems are often encountered when cavities are intersected and drilling circulation is lost. Cuttings and groundwater may not be returned to the surface, so information about the formations and water intersections is lost. Running casing as drilling progresses is a technique used to avoid this problem.

Owen’s story (boxed text) provides insight into the dynamic nature of this karstic aquifer, particularly in the last decade where there has been exceptional rainfall.

Discussion on Owens Story

The extraordinary wet season of 2000-2001 provided exceptional recharge to the karstic aquifer. Sinkholes throughout the area would have provided an efficient recharge mechanism. The depression west of Lake Crocodlyus is most likely a broad sinkhole through which water is able to quickly infiltrate to the underlying aquifer.

Good recharge continued in following years with continued good wet seasons. (See Figure 3.3 for the rainfall record) The resulting high water level in the aquifer resulted in high spring discharges providing exceptional flow in Karns Creek and the Calvert River. (See Section 7). The long term interpolated rainfall record (Figure 3.3) shows that the 2000-2001 wet season had the highest rainfall for over a hundred years. This is confirmed by dating of a dead tree from the lake which was shown to be at least 98 years old.

Indigenous people in the region, in particular Frank Shadforth whose father previously owned Pungalina Station, agreed with Owens observations of the area in 1999 and confirmed that the main permanent flowing spring is Coconut Spring Creek which has the indigenous name Guwallana. Of interest is that Bubbling Sands spring was not considered as a spring of significance by the indigenous people. This supports the idea that the high discharge from this spring only occurs rarely.

Owen's story

Owen Davies was the manager of Pungalina Station during most of the project. He arrived at the station in 1999. He has been very observant of the changes in water resources on the station during his time there. Following is a documentation of his observations. They tell a most incredible story of changes in water resources due to the karstic aquifer.

<u>In 1999 - 2000</u>

In October 1999 the Calvert River upstream of the Karns Creek confluence had reduced to a trickle of water, but downstream from Karns Creek the flow picked up. More water flowed into the river from Coconut Spring creek further downstream. In fact there was more flow in Coconut Spring Creek than Karns Creek at the time.

In October 2000 we estimated about 33L/s was flowing down Coconut Spring Creek. Karns Creek was barely trickling and there was only a bit of water discharging out of Bubbling Sands Spring. Bubbling Sands spring and Bandicoot spring were really just muddy holes.

Lake Crocodylus was dry in late 1999.

<u>In the big wet of 2000 – 2001</u>

During this big wet season Lake Crocodylus filled to overflowing and spilled into a neighbouring depression to the west which subsequently filled with water. Within 6 weeks the water in this depression had totally disappeared however water remained in Lake Crocodylus.

<u>After 2000</u>

After the big wet of 2000-2001 there were great changes in the flows of all these springs. Bubbling Sands spring in particular has become the largest spring on the station and has not stopped flowing at around its current rate since then. (See Appendix I for flow gaugings)

To this day (2009) there remains water in Lake Crocodylus. This has caused trees in the lake to die from waterlogging.

There are caves on Pungalina Station. Some of the caves have water in them. The water level is now (2007) dropping however. Sinkholes have opened up in this area over the last two years. There are a lot of sinkholes.

The reason Coconut Spring is the largest permanent localised spring draining this aquifer is because it cuts into the aquifer at a lower point than Bubbling Sands or Bandicoot Spring. When groundwater levels are high in the aquifer good discharges are observed at all the springs but when water levels are low then discharges to the springs situated higher up in the aquifer will be most effected.

Fractured and weathered rocks – carbonate rocks (Yields 0.5-10L/s)

Carbonate rocks under the fractured and weathered rocks aquifer category have been identified separately because they impart a very distinct water quality to the rocks. The carbonate is present in the form of dolomite.

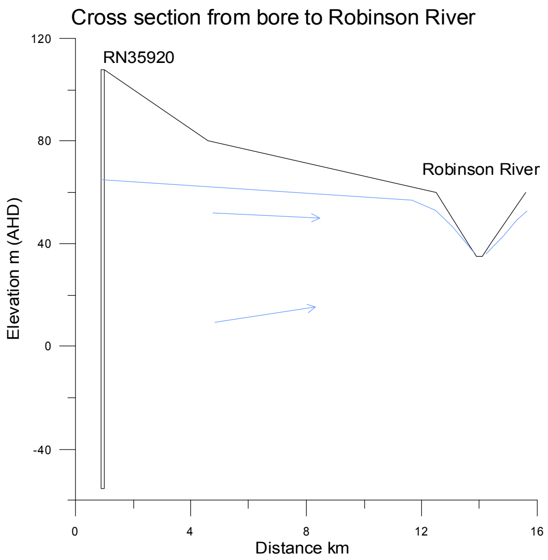
Two formations are mapped under this category; the Karns Dolomite, which is the most extensive, and the McDermott Formation which contains dolostone. Carbonate rocks have the potential to be karstic and there is an area of the Karns Dolomite that is karstic as previously discussed, however aside from this area, the Karns Dolomite does not display karstic features. Hence it has been mapped under this category. Some dissolution of the rock is likely to have occurred in places, such as enlarging fractures, but broadscale interconnected cavity development has not taken place.

18 bores have been drilled into the Karns Dolomite of which 3 did not yield water (Appendix B). This is a good success rate. A number of the bores have not been sited on fractures and yet been successful indicating weathering and fracturing is widespread within the formation. Yields have varied up to 25 l/s but 3 l/s appears most common. In some of the bores higher yields may have been obtained if drilling had continued. Aquifers have usually been intercepted within the first 60 m of drilling. The deepest bore drilled was RN35920 (163 m) which also had the highest airlift yield at 25 L/s (Plate 6.7). This bore intersected a variety of strata sequences including dolomitic siltstone, chert, dolomitic sandstone and dolomite reflecting the sedimentary origins of the rock. The yield in the bore increased with increasing depth as aquifers were encountered in fractured and weathered sections.

Plate 6.7 Airlifting 25L/s at RN35920

Only two bores have been drilled in the Mc Dermott Formation, both yielding around 1 l/s (Appendix B). The Mc Dermott Formation has similar characteristics to that of the Karns Dolomite. The formation is not widespread on the map sheet and lies in the southern area.

The flow systems in this aquifer type are local to intermediate in scale. This is outlined in Figure 6.6. The Karns Dolomite provides the source of baseflow to the major rivers in the region; the Robinson and the Calvert. In an average rainfall period the total baseflow measured in these streams in August is approximately 400 and 500 L/s respectively. In a dry period the rivers will stop flowing but will maintain large waterholes.



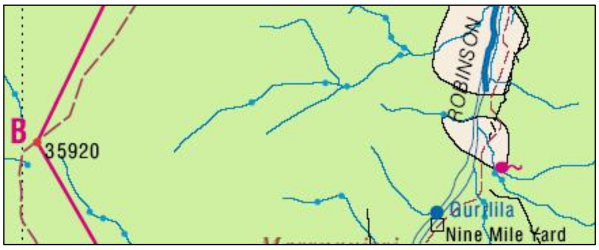


Figure 6.6 Flow path of water in Karns Dolomite from bore RN35920 located at the top of the divide to the Robinson River.
(Excerpt from the water resource map)

Rotary percussion drilling using air is best technique for these aquifers as the formations are generally hard resulting in a stable borehole. Problems were encountered however with the deepest bore RN35920 as the casing was not able to be lowered any further than 76 m due to collapse of the formation. Loosing circulation of the drilling fluids into cavernous formations can sometimes be encountered.

Fractured and weathered rocks – carbonate rocks (Yields 0.5-5L/s)

The Wollogorang Formation and the Aquarium Formation (Table 6.1) fall under this aquifer category. They contain dolomitic siltstone. These rocks are largely reliant on fracturing for aquifer development. They are identified as lower yielding and faults and fractures should be targeted. Appendix C provides a list of bores drilled into these formations within the map area. Of the 9 bores drilled, 3 were dud, 3 are recommended to be pumped at 0.5 L/s and one at 2 L/s. This latter bore was sited by a hydrogeolgist on a fault and hence the better yield. The flow system for this aquifer category is local.

Fractured and weathered rocks (Yields 0.5-5L/s)

This aquifer type occurs in the Bukalara Sandstone which lies in the south-west of the map area. The effects of weathering have provided permeability to the rock allowing aquifer development. The formation has not been extensively drilled and no bores have been drilled into this formation within the map area. West of the map area, however, airlift yields of up to 7 L/s have been obtained and there have been no duds (dry bores).

Fractured and weathered rocks with minor groundwater resources

A large part of the map area is covered by proterozoic rock formations consisting of siltstone, mudstone, sandstone, volcanic rocks, conglomerate and granite. These are all old rocks that have hardened over millions of years. Fracturing and faulting is the most common source of aquifer development in these rocks. Airlift yields can vary considerably dependent on the degree of fracturing. Long term sustainability however is usually limited to small supplies less than 2. L/s. The aquifer flow system is local. Rotary percussion drilling using air is the most common technique used in these aquifers. The rock formations are generally hard resulting in stable boreholes. Appendix D provides details of all the bores that have intersected aquifers under this category. Key formations are detailed following.

Settlement Creek Dolerite/Volcanics

This formation has been extensively drilled at Robinson River community. The formation has proven not only to be poor in yield but also to contain poor quality groundwater unsuitable for human consumption. (Appendix D). This is most probably due to sparse fracturing in the rock causing poor recharge and concentrating salts. The one successful bore is located next to the Robinson River and the aquifer it lies in is probably being recharged by good quality water from a large waterhole in the river. It is very unfortunate that the community is located over this rock type. This formation is an unlikely target for water supply. The extent of this formation in the Robinson River area is clearly indicated on the map sheet by shading indicating brackish water.

Westmorland Conglomerate

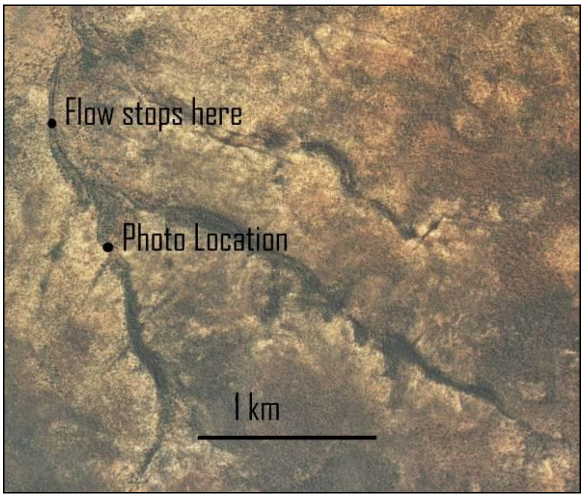
A conglomerate is a rock that contains rounded pebbles which have been cemented together by finer particles or minerals. The Westmorland Conglomerate lies in the very south-eastern corner of the map sheet and is one of the oldest rocks in the map area. Three bores have been drilled into the conglomerate and each has had a high airlift yield for this rock type (Appendix D). This is because the bores have been drilled along a fault which contains extensive fracturing.

Echo Sandstone also known as the Masterton Sandstone and Gold Creek Volcanics

A number of bores have been drilled into these formations at Redbank Mine. Most of the bores airlifted around 2 L/s however there were a few with higher yields. This is most likely due to interception of well fractured zones in the rock. Mineralisation tends to occur in fracture zones so it is not surprising that some higher yields occurred in bores on a mine site.

Plate 6.8, 6.9, 6.10 Echo Sandstone Springs

Left: Frank Shadforth at perennial spring sourced from sandstone, flowing at 2 l/s.
Below left Aerial photo of creek in the sandstone country. Flow is maintained for 1 km even in the driest year.
Below: Extract from geology map showing fractures as marked by the small black lines.
Can you match the fractures with the aerial photo?



The Echo Sandstone is the most widespread formation listed under this aquifer category dominating the central and north-eastern areas. It is mostly observed as a hard, silicified sandstone reliant on fracturing for aquifer development. Many of the escarpment springs and seeps noted on the map are supplied from localised aquifers developed in fracture zones. These springs often stop flowing in the late dry season, but, if perennial, would usually have a minimum discharge less than 10 L/s (Plate 6.8, 6.9, 6.10).

A notable exception to this lies in the Eastern Pungalina region where significant perennial spring discharge occurs; up to 100 l/s in Sandy Creek and Running Creek. Although masked by Cenozoic sands these springs appear to discharge from the Echo Sandstone. The water quality of the spring water indicates that the water is likely to be sourced from a sandstone. There are a number of possible sources for this flow:

a. It is possible that the Echo Sandstone in this region is particularly well fractured forming a more extensive aquifer
b. Or the region could be covered with Cretaceous sandstone sediments providing a porous rock aquifer. These sediments are not marked on the geology map as the rocks in the areas around the springs are masked by the surficial Cainozoic sediments.

c. Or there are softer horizons in the Echo Sandstone which could have high storage capacity and host a higher yielding (porous rock) aquifer.

Rawlings (2006) provides good evidence that 'c' is the likely source of the flow. In his analysis of the Echo Sandstone at the headwaters of Running Creek he identifies the characteristic silicified Echo Sandstone beneath a veneer of Karns Dolomite but about 40 m below the top of the Sandstone he notes a 'white to grey, friable, coarse- to very coarse-grained … sandstone'. The thickness of the friable unit is about 15 m. This is the likely aquifer that supplies water to the perennial rivers draining to the north east. These are the largest known springs that discharge from the Echo Sandstone. Further field work would be required to confirm the springs are sourced from this aquifer and to ascertain if the friable unit in the sandstone is widespread or if it is a localised feature.

The springs have made us aware of the variable nature of the Echo Sandstone. It raises the possibility that it may harbour an extensive higher yielding aquifer situated in its highly weathered or porous horizons.

Other groundwater supplies

Alluvial deposits and sand dunes can also provide minor groundwater supplies. These unconsolidated sediments belong to the sedimentary rock aquifer type. They are limited in extent and are not shown on the map. Bores generally yield 0.5 L/s or less.

Aquifers can be found in alluvial deposits built up along rivers or on floodplains, particularly where sediments consist of well rounded gravels and are well sorted (of similar size). Bores drilled in alluvial deposits have a low success rate because of their limited extent, variability in thickness and gravel, silt and sand content (making construction difficult).

Small supplies can be attained from aquifers in sand dunes. Although sand dunes exist within the map sheet they have not been drilled for water supply. Infiltration galleries rather than bores are recommended for extracting water from sand dunes to ensure water quality is maintained.

6.4 Groundwater Quality

Groundwater quality is affected by evapotranspiration of rainfall and rock type.

Rainwater contains salts. As rainwater moves down through the soil to the water table evapotranspiration concentrates the salts. Salts are made up of ions. For example table salt (Sodium Chloride) is made up of the ions Sodium and Chloride. Common ions used to describe water quality are listed in Appendix H. If recharge is low then the salts can become so concentrated that the water becomes unsuitable for human consumption. Low recharge can be due to low rainfall but it is also related to rock type. A fine sandstone for example would have lower recharge than a coarse sandstone because the small particle size of the rock allows little water through.

Rock type affects water quality because, as water moves through them, it picks up (dissolves) salts from the surrounding rock. This process is particularly evident in limestone and dolomite because they contain high amounts of calcium or magnesium carbonate which dissolves in acidic conditions (Plate 6.11) and our rainfall is naturally acidic. When these rocks dissolve, calcium, magnesium and bicarbonate ions are released into the water. Hence groundwater rich in these ions is likely to have come from a limestone or dolomite formation.

Plate 6.11 A drop of acid dissolving limestone as shown by the fizz. This is a common field test for carbonate rocks.

6.4.1 Water quality measurements

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. One of these parameters is Total Dissolved Solids (TDS) which is a measure of the saltiness of the water. It is usually described in terms of the number of milligrams of salt in a litre of water (mg/L).

The Australian Drinking Water Guidelines (ADWG, 2004) define good quality drinking water human consumption from the perspective of health and aesthetics. The guidelines state that good drinking water has a TDS of less than 500 mg/L, and that a TDS of 500 – 800 mg/L is fair. A TDS of greater than 1000 mg/L is considered unacceptable. High TDS may be associated with excessive scaling and unsatisfactory taste. A simple way of estimating TDS in the field is by measuring the water's electrical conductivity (EC). Salt present in the water will make it more conductive for an electrical current, which can be easily measured with a small field probe (Plate 6.12). EC is measured in microSeimens per centimetre, μS/cm. TDS is approximately equivalent to 0.6 x EC.

Plate 6.12 Ursula Zaar measuring the EC with an EC meter.

Water can also be described as being 'hard' or 'soft'. 'Hard' water requires more soap to produce suds than 'soft' water, and is generally associated with groundwater occurring in limestone and dolomite aquifers. These aquifers contain calcium or magnesium rich waters. Water having more than 150 mg/L calcium carbonate can deposit scale in pipes and water heaters under favourable conditions.

Another parameter which can be easily measured in the field, and give an immediate indication of water quality and suitability is pH. 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, a pH of less than 7 indicates an acidic water, and a pH of greater than 7 indicates an alkaline water (Table 6.5). A low pH can be caused by high levels of dissolved carbon dioxide. 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. High alkaline waters can also be treated to lower pH. It should be noted that pH measurements taken from airlifted water during the drilling process may not give a true indication of the pH.

Table 6.5 pH and water quality characteristics observed in the map region

Acidic	**Neutral**	**Alkaline**
pH < 7 Often due to high levels of dissolved carbon dioxide	pH = 7	Ph > 7 Can be due to high carbonate content sourced from dolomite or limestone
Generally EC < 150 μS/cm indicating low mineral content in the water. The surrounding rocks may be inert or recharge may be high.		Generally EC > 300 μS/cm indicating that the water may contain dissolved minerals from the surrounding rock.

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.

Besides undertaking field measurements of water quality parameters, water samples were also taken from a number of springs, creeks and bores prior to and during this project. These samples were then analysed in a laboratory where the quantity of common ions in the water was determined. These results are detailed in Appendices H and J. The water quality could then be characterised for a stream or an aquifer.

Most of the bores which have supplied salty water have been drilled close to the sea, estuary or mangrove and swamp areas. Near the coastline or tidal streams, fresh water in aquifers can become mixed with sea water. This can happen naturally on a seasonal basis, or when water is pumped from an aquifer close to the ocean. These waters can be distinguished by high TDS, sodium and chloride concentrations.

6.4.2 Water Quality and Aquifer Type

Below is a basic description of water quality for each of the aquifer types denoted on the water resource map.

Sedimentary rocks with intergranular porosity

The water quality of this aquifer type, which is located in 3 areas, is discussed for each area and water quality analysis details for bores are provided in Table 6.6.

Northern aquifer

Only 2 water bores intercepted this aquifer: RN28349 and RN28470. Both are located at Wonmurri, which is close to the coast and likely to be affected by salt water. The bores had a marginal TDS and one of the bores, RN28349 was also tested for Arsenic and the results showed that the guideline value for health was exceeded.

Only one water quality reading is available for the shallow aquifer, namely at RN28349. It had a TDS of 1143[2] mg/L which is considered unacceptable in taste. However, the water quality from seeps from the shallow aquifer indicated that the water quality can be good at locations further inland from the coast: the seep at G9085066 discharging from the edge of the bank of the Robinson River had a TDS of 27mg/L (calculated from Ec).

North eastern aquifer

Only a shallow aquifer was intercepted in investigation bore RN35868 and the water quality was salty. Because this bore was approximately 30 km inland from the coast, it indicates that the entire aquifer may be saline and this has been marked on the water resources map. Further investigations are required to confirm this inference.

Southern aquifer

The water quality in the southern sandstone aquifer as sampled from investigation bore RN35869 was good with a low TDS. This water quality was reflected in other bores in this aquifer.

Table 6.6 Water quality of sedimentary rock aquifers.
Aside from pH, measurements are in mg/L.

Spring site	TDS	pH	Bicarbonate	Calcium	Magnesium	Sodium	Chloride	Sulphate	Potassium
RN28349 Lower aquifer	884	7.4	333	39	39	248	331	51	15
RN28349 Shallow aquifer	1143[2]	6.49							
RN35868	9800	7.7	353	341	471	2140	4830	818	55
RN35869	30	7.3	11	0.4	1	6.3	10.4	2.3	2.5

[2] As calculated from Ec.

Fractured and karstic rocks – carbonate rocks

No water bores have been drilled in this aquifer in the Karns Dolomite, however spring discharges from the aquifer provide a good indication of the water quality in the aquifer. The water quality is typical of a dolomitic aquifer. An outline is provided in Table 6.7 with further details of the sample available in Appendix H. Further details on groundwater quality in the Karns Dolomite aquifer is provided in the next section.

Table 6.7 Water quality of fractured and karstic aquifer.
Aside from pH, measurements are in mg/L.

Spring site	TDS	pH	Bicarbonate	Calcium	Magnesium	Sodium	Chloride	Sulphate	Potassium
G9095070 Bubbling Sands Spring	220*	8.2	227	31	34	5	8	<.1	3

*TDS of the spring has varied between 220 – 372 based on Ec measurements

Fractured and weathered rocks - carbonate rocks (Yields 0.5-10L/s)

A good overview of water quality in the Karns Dolomite is provided by the bores drilled into the formation as shown in Table 6.8. Water quality analysis has been undertaken for only one bore in the McDermott Formation represented by RN23247. The water quality is reflective of acidic rainwater dissolving the calcium - magnesium carbonate from the dolomite as it moves through the formation. The water quality lies within drinking water health limits however a TDS<500 mg is preferred for taste considerations (See Appendix H for further details).

Table 6.8 Water quality of aquifer in Karns Dolomite and Mc Dermott Formation.
Aside from pH, measurements are in mg/L.

BoreRN	TDS	pH	Bicarbonate	Calcium	Magnesium	Sodium	Chloride	Sulphate	Potassium
RN023245	560	7.3	594	70	77	34	46	8	5
RN023247	390	7.3	429	67	48	8	12	3	4
RN026067	240	7.1	271	42	29	5	8	6	3
RN026068	260	7.8	264	38	27	13	18	8	3
RN026068	145	7.6	156	19	20	5	9	6	3
RN027842	305	7.9	322	37	41	16	14	9	3
RN027843	310	7.5	345	44	42	18	12	10	3
RN030350	297	7.8	365	45	39	11	5	19	3
RN030351	283	7.9	341	45	35	9	13	12	2
RN035920	290	8	290	34	45	7	12	2	4
RN035921	260	8	217	38	31	10	25	4	5
RN035924	200	8.2	180	30	25	5	7	0	4

Fractured and weathered rocks – carbonate rocks (Yields 0.5-5L/s)

The water quality of this aquifer is similar to that of the carbonate rock aquifers above. TDS and dissolved salts, particularly chloride, are high in some of the samples, most likely reflecting the low recharge rate of the aquifer. A TDS greater than 1000 mg/L is generally associated with unsatisfactory taste but there is no health guideline limit. The aesthetic guideline for Chloride is 250 mg/L but again no health based guideline is considered necessary. See Appendix H for further details on water quality of these bores.

Table 6.9 Water quality in Fractured and Weathered Rocks – Carbonate Rocks
Aside from pH, measurements are in mg/L.

BoreRN	TDS	pH	Bicarbonate	Calcium	Magnesium	Sodium	Chloride	Sulphate	Potassium
RN001889	1125	7	378	62	66	190	315	94	19
RN001889	701	8	217	50	84		45	80	26
RN001889	940	7.5	622	92	130	43	152	20	6
RN023246	580	7.4	545	75	71	40	64	6	14
RN026071	350	8	376	40	38	40	13	26	8
RN028674	267	8.6	287	45	31	9	8	18	8
RN028675	294	7.4	352	62	34	6	9	14	6

Fractured and weathered rocks

There are no bores in the Bukalara Sandstone in this map area however water quality parameters are available from the adjoining map area. Table 6.10 provides an outline. The TDS is low which is typical for groundwater sourced from sandstone. This is good drinking water.

Table 6.10 Water quality in Fractured and Weathered Rocks – Bukalara Sandstone
Aside from pH, measurements are in mg/L.

BoreRN	TDS	pH	Bicarbonate	Calcium	Magnesium	Sodium	Chloride	Sulphate	Potassium
RN030332	82	7.3	27	2	1	8	10	5	7
RN030334	81	7.7	18	1	1	8	10	7	7

Fractured and weathered rocks with minor groundwater resources

The water quality in these aquifers has a very wide variation. It is not unusual for the TDS to be very low or exceed the aesthetic guideline value, with rock type and poor recharge being the likely causes. Each formation will be discussed separately.

Settlement Creek Dolerite/Volcanics

As noted earlier this formation has poor groundwater quality considered unsuitable for human consumption due to the high salt content which is likely to be due to a combination of rock type and poor recharge. An overview is provided in Table 6.11. Brackish water has been indicated on the map over the extent of this formation because of the poor results around Robinson River community. This formation is an unlikely target for water supply.

Table 6.11 Water quality in bores in the Settlement Creek Dolerite.
Aside from pH, measurements are in mg/L.

BoreRN	TDS	pH	Bicarbonate	Calcium	Magnesium	Sodium	Chloride	Sulphate	Potassium
RN027845	3570	7.8	152	294	149	689	1150	1010	21
RN031748	3570	8.3	224	62	101	923	1920	15	85
RN032158	3173	8.4	215	87	54	945	1742	10	60
RN032158	2152	7.6	319	64	79	528	1080	10	37
RN032800	4390	8.1	236	113	65	1060	2120	15	118
RN032801	2510	8.1	344	87	95	514	1160	22	61

Westmoreland Conglomerate

Limited water quality parameters are available for bores drilled into the Conglomerate however the low TDS indicates a generally low salt content. The pH however is acidic and hence the water would be corrosive to metal pipes as mentioned in Section 6.4.1 so care should be taken with reticulation pipes, otherwise this is good drinking water.

Table 6.12 Water quality in bores in the Westmoreland Conglomerate
Aside from pH, measurements are in mg/L.

BoreRN	Ec	TDS	pH	Bicarbonate	Calcium	Chloride
RN009277	86	51	6.7	27	10	16
RN009278	51	30	6	6	5	8
RN009279	160	96	4.1		10	16

Echo Sandstone also known as the Masterton Sandstone, and the Gold Creek Volcanics

Bores drilled into these formations are located at Redbank mine on Wollogorang Station. The tabled water quality parameters fall within guideline values however iron is above the aesthetic guideline value of 0.3 mg/L. There is no guideline value based on health considerations for iron due to insufficient data. High iron concentrations stain laundry and fittings. The mine is situated in a localised zone of mineralisation so it is not surprising that the iron levels are high. Iron bacteria which stems from iron can cause blockages, odour and corrosion but is not caused by high iron levels.

Table 6.13 Water quality in bores situated in Echo Sandstone and Gold Creek Volcanics
Aside from pH, measurements are in mg/L.

BoreRN	TDS	pH	Bicarbonate	Calcium	Magnesium	Sodium	Chloride	Sulphate	Potassium	Iron
RN027472	215	7.8	231	30	23	8	5	10	9	0.8
RN027473	225	8.2	232	27	26	7	5	12	9	0.6
RN027474	230	7.7	225	27	26	7	5	16	9	
RN028420	177	5.7	14	5	8	12	7	64	14	
RN028421	150	7.1	34	6	10	5	6	43	10	
RN028422	179	7.7	201	24	25	5	6	10	7	9.9
RN028424	197	7.9	216	30	23	7	8	11	7	2.1
RN028426	195	7.9	224	30	226	6	7	11	7	4.4
RN028427	210	7.5	181	28	24	7	9	34	9	5.9
RN028428	31	5.4	2	1	1	3	6	1	1	
RN029526	53	5.9	3	1	1	3	8	5	4	37
RN029527	223	8.3	233	27	17	5	7	13	8	5
RN029528	219	8.2	225	23	18	6	7	16	7	15.4
RN029530	132	8.2	117	18	10	4	6	6	16	1.3

Low TDS (<100) and low pH has been recorded from springs discharging from the Echo Sandstone and hence the water quality from RN028428 and RN029526 suggests that these bores may be situated only within the Echo Sandstone. The volcanics are likely to be imparting the higher TDS to the water. The low pH in the two bores means it is corrosive and hence inert materials, such as PVC piping, should be used for water reticulation.

6.5 Recharge

Recharge is where water is added to an aquifer. Recharge can be observed by monitoring water levels in bores. It is important to carefully manage areas where recharge occurs to ensure groundwater quality is maintained.

Recharge is where water is added to an aquifer. It occurs during the wet season. Recharge amounts vary with rainfall, soil and geology. It occurs through three main mechanisms; diffuse, point source and stream bed. Diffuse recharge is the widespread downward seepage of rainwater, point source recharge occurs through an opening in the ground such as a sinkhole allowing direct drainage to the aquifer, and stream bed recharge is where water drains from a stream to an aquifer (the water level of the aquifer must be lower than river level for this to occur).

High rainfall usually results in greater recharge. Recharge is indicated by the rise of groundwater levels and can be observed in bores which are monitored. Currently there are no bores being monitored in the map region however during the course of this study water levels were monitored in a number of bores. The results are shown in Figure 6.8.

Note how the water levels have increased in the existing bores from the first record, obtained from when they were drilled, to when monitoring started in 2006. This reflects the good recharge attained from high rainfall from 2000 to 2006 (See Figure 3.3 for rainfall record). In Figure 6.7 the black vertical lines denote December 2006, 2007 and 2008. You can see how the water level slowly recedes over the dry season in the bores from about July to December each year. Note also how the water level between December 2006 and December 2008 has lowered. This is due to poor recharge over these years, causing a continued decline in water levels, because of poor rainfall. Long term trends in rainfall can result in large variations in groundwater level. Such variation is indicated by RN30350 which has an 8 m difference between its highest and lowest record for the data available.

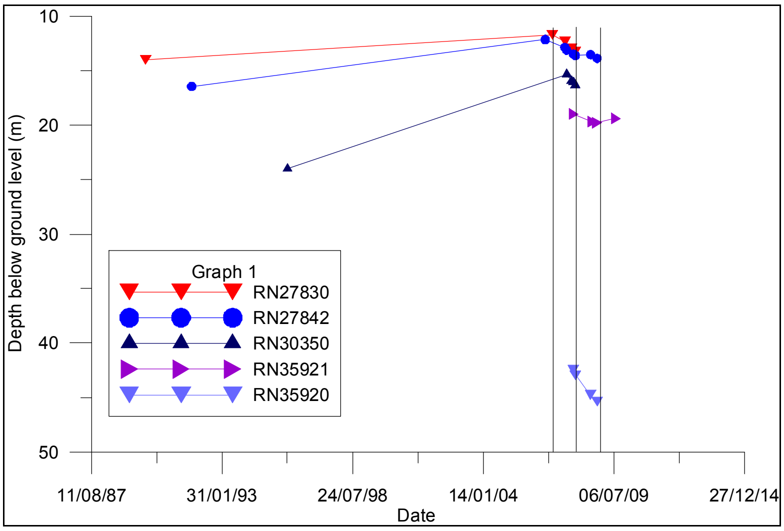


Figure 6.7 Recorded water levels (from local ground level) in bores in the Karns Dolomite.

Recharge is affected by geology or rock type and soil type. The amount of water that reaches an aquifer is dependent on the rock types or soils that overly the aquifer as well as in the rocks that make up the aquifer. Water moves through some rocks and soils better than others, that is, they have a better permeability. Permeability is affected by the size and shape of the voids in the rock and how well the voids are interconnected. A coarse sand, for instance, has a high permeability whereas a mudstone or a poorly fractured granite has a low permeability. If a sand is overlain by a mudstone or clay, then it will be poorly recharged, but if it is unconfined it will be better recharged (Figure 6.8). When an aquifer is confined the recharge area can be restricted to the area where the rock is in outcrop (Figure 6.8). Recharge areas should be managed to ensure water quality is maintained. For example, sewage works should not be located over recharge areas. Recharge is often described as the amount of rainfall entering an aquifer in mm/year or by the rise in water level in an aquifer in metres. Between 0-20% of annual rainfall results in groundwater recharge.

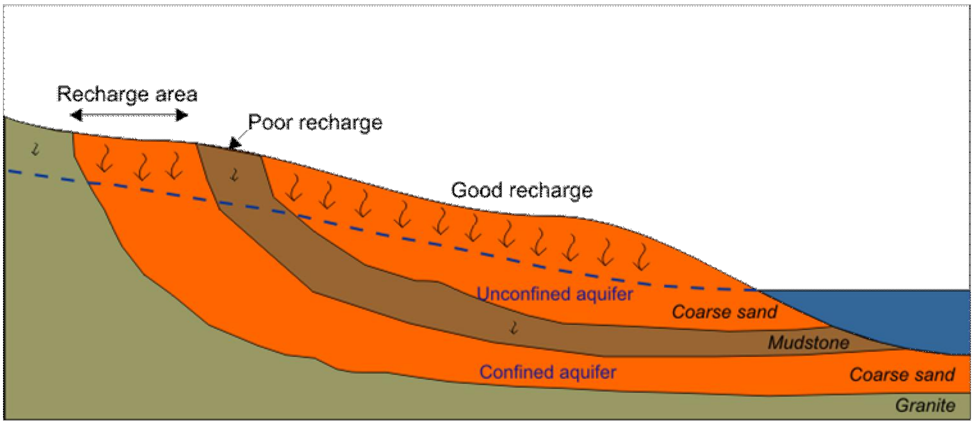


Figure 6.8 Recharge to a confined and unconfined aquifer.

The sustainable yield of an aquifer can be considered as that amount that can be extracted from an aquifer without adversely affecting the environment and reducing the average groundwater level in that aquifer. In other words the extraction rate should be less than the average recharge rate. Hence the importance of determining recharge rates. When detailed water resource investigations are carried out recharge and permeability values are determined.

6.6 Groundwater discharge and dependent ecosystems

All isolated springs in the map area maintain lush vegetation pockets which are refuges for wildlife. These are groundwater dependent ecosystems.

One way groundwater discharges is through springs and seeps. These are marked on the water resource map. Bubbling Sands, Bandicoot and Coconut spring located on Pungalina Station are localised springs as they discharge from one point, but groundwater can also discharge as diffuse flow along a river bed. Diffuse or streambed seepage is where a stream cuts through an aquifer allowing water to drain into the stream. The area of drainage forms the discharge zone, which is marked by a gradual increase in river flow. Another less obvious way in which groundwater discharges is through evapotranspiration. Plants can tap into groundwater when it is shallow enough and similarly groundwater can be directly evaporated through the soil when it is within metres of the surface.

Springs occur where the water table is at or above the ground surface. They can be permanent (perennial) or periodic (ephemeral) due to fluctuations in the local water table. Invariably denser vegetation communities (ie rainforests) occur at these springs. Such communities are dependent on groundwater. Riparian (riverbank) vegetation can also be reliant on groundwater although it may not be situated in a spring area.

OGrady et al. (2002) in their study along the Daly River found Silver-leaved Tea Tree (Melaleuca argentea) and Freshwater Mangrove (Barringtonia acutangula) were associated with river banks with shallow water tables and were shown to be reliant on groundwater. O'Grady et al.(2002) state that 'further work is required to fully assess the level of groundwater dependency and the environmental flow requirements of riparian vegetation'.

Rainforest vegetation communities associated with riparian (river bank) zones and springs have been mapped throughout the Top End by Russell-Smith (1991) and his work is shown on the Water Resource maps. These are likely groundwater dependent ecosystems.

Various types of springs have been recognised in the mapped region and an overview is provided below.

Depression Springs

This type of spring results when the water table is intersected by a low point (a depression) in the landscape such as a valley or escarpment, allowing drainage to occur from the surrounding rock. (Figure 6.9) The rock could be a porous rock or a fractured and weathered rock. Sometimes the low point in the landscape is resultant of a fracture or fault and the aquifer can be very localised to that feature. Some springs can be a temporary feature occurring only when the water table reaches the surface after periods of good rainfall.

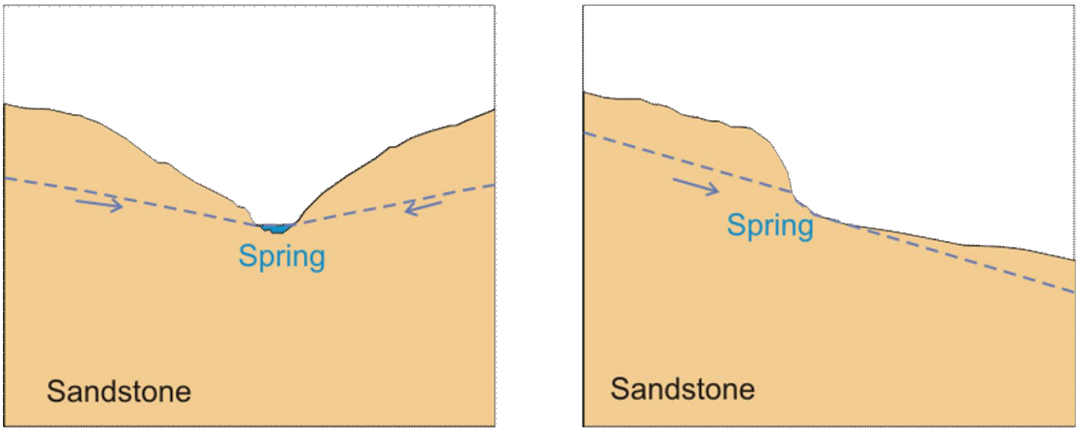


Figure 6.9 Depression spring in a valley and at an escarpment

There are many small depression springs and seeps in the map area, usually associated with escarpment country. Most of these springs discharge less than 10 L/s. These springs are often seen at the base of escarpments and provide water to lush vegetation pockets (Plate 6.13, 6.14). When the water table drops below the land surface the spring stops flowing. At times the groundwater in sandstone escarpments does not break out in the form of a spring but comes close to the surface. These areas are often marked with lush vegetation as tree roots find their way to the watertable. Such vegetation can effectively be considered a groundwater dependent ecosystem.


Plate 6.13 & 6.14 Rainforest pocket in escarpment valley and seep within the rainforest on Wollogorang Station.

Depression springs also occur in sand dune country. Groundwater within the sand dunes discharges to low points which often maintain swamp environs like that at Shark Creek on Seven Emu Station (Plate 6.15, 6.16)


Plate 6.15 & 16 Sand dunes and swamp situated next to sand dunes.

Some of the largest depression springs occur in the north-east of the map on Johnson, Sandy and Running Creeks (Plate 6.17, 6.18). In some sections of these rivers spring discharge is diffuse and in other areas localised (Plate 6.19, 6.20). During the project the flow at Running and Sandy Creeks was measured on several occasions as shown in Figure 6.10. In the Figure you can see how the discharge decreases as the Dry season progresses. This is because as water is drained from the aquifer the water table level decreases.


Plate 6.17 & 6.18 Running Creek and Sandy Creek


Plate 6.19 & 6.20 Broad seepage zone (diffuse flow) flanking Running Creek and localised spring forming tributary of Running Creek

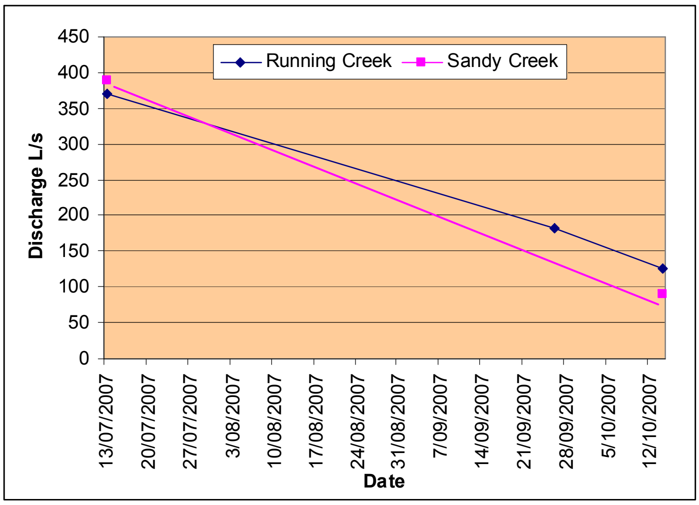


Figure 6.10 Flow gaugings at Running and Sandy Creeks in 2007.

Sinkhole and contact spring

In karstic aquifers groundwater can move through fractures and connected cavities in the rock. Springs emerge where cavities intersect with the land surface (Figure 6.11). Often these low points are situated in sinkholes and Bubbling Sands Spring provides a good example (Plate 6.21). Discharges from such springs can be large and localised because water has coalesced into conduits. These springs are found along the edge of the fractured and karstic aquifer located on Pungalina Station. But not all of the springs discharge from sinkholes from this aquifer. The fractured and karstic aquifer in the Karns Dolomite is situated above the Echo Sandstone which is a less permeable rock (Plate 6.22, 6.23). Water discharges from the Dolomite at the contact between the rock types because it is unable to penetrate into the Sandstone (Figure 6.11). Bubbling Sands Spring is therefore also a contact spring as are all of the springs emerging from the fractured and karstic aquifer as they are all situated along the contact between the two rocks. The contact largely coincides with reaches of Karns Creek and the Calvert River. Some of the contact springs are situated in and along the bed of these rivers and hence could be labelled streambed seepage.

Plate 6.21 Bubbling Sands Spring.
Note the typical circular form of this sinkhole spring.

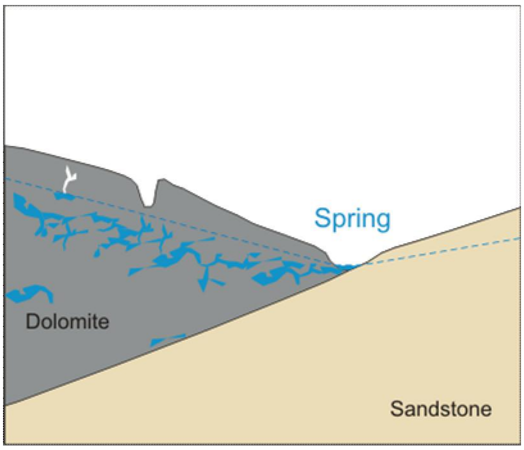


Figure 6.11 Sinkhole and contact spring. **Plate 6.22 & 6.23 Dolomite and Sandstone**

7. SURFACE WATER

The major surface water resources in the region are the Robinson and Calvert Rivers and some tributaries where baseflow is sourced from the Karns Dolomite and Sandy and Running Creeks where baseflow is sourced from a sandstone aquifer. Most of the other rivers dry out or cease to flow by the end of the Dry season limiting supplies to waterholes.

Surface water occurs as rivers, springs, lakes and billabongs and can be characterised into two main sources: directly from rainfall and rainfall runoff; or from groundwater discharge which provides baseflow to many rivers in the Top End (Figure 7.1).

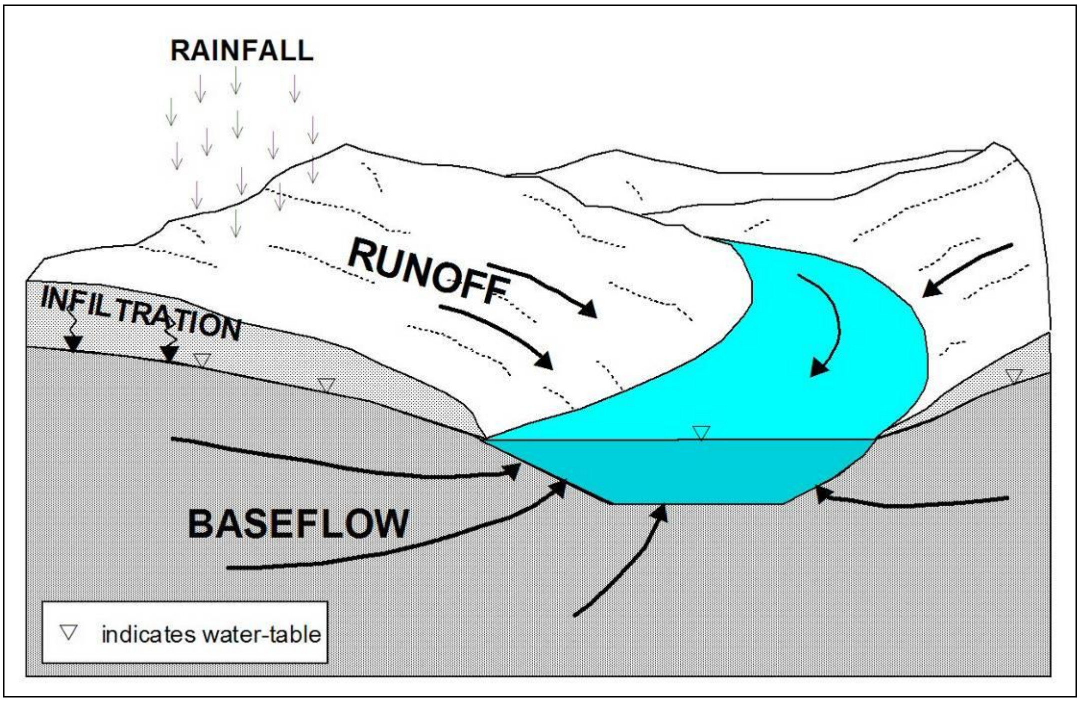


Figure 7.1 Runoff and Baseflow Components of Surface Water

When examining surface water occurrence it is important to distinguish between these two sources. Surface water derived only from wet season rainfall and runoff will only persist if storage is adequate to last through the Dry season: waterholes, lakes, dams all need to be deep enough to account for the high evaporation rate and months of negligible rain. It is the baseflow component that keeps rivers and creeks flowing through the long Dry season.

Flow in a river is often presented as a hydrograph, which usually shows daily or monthly variations in water flow or height. Figure 7.2 depicts the variation in flow for the Wearyan River in 1977. The two components of baseflow and runoff are easily distinguished.

The baseflow component of flow slowly diminishes as the Dry season progresses. This is because less groundwater discharges to the river due to the lowering of the water table (Figure 7.3). If the water table falls below the river bed then no groundwater is able to discharge to the river and it would cease to flow or may even dry out.

One way a river can be classified is by whether it gains water as it flows downstream, which is called a gaining stream or loses water as it flows downstream which is called a losing stream. Rivers on this map have reaches which are gaining and other reaches which are losing. For example in upper Running Creek the creek is a gaining stream as springs discharge to the river but once the spring discharges stop the creek becomes a losing stream. The loss in flow is likely due to evapotranspiration.

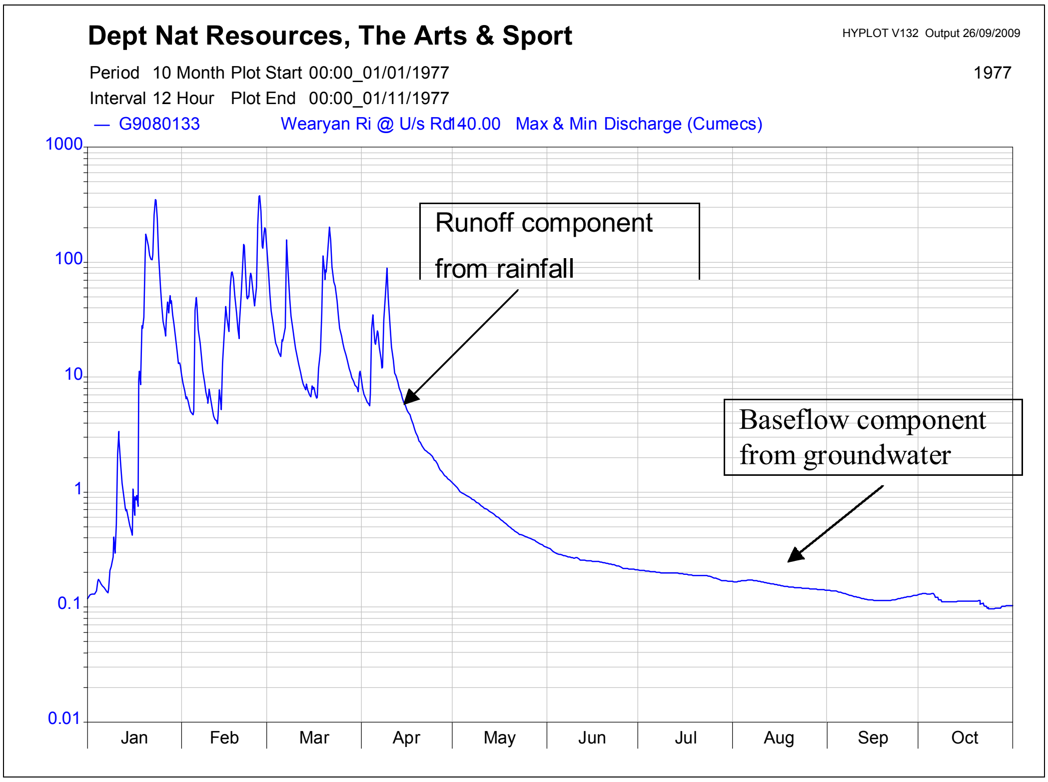
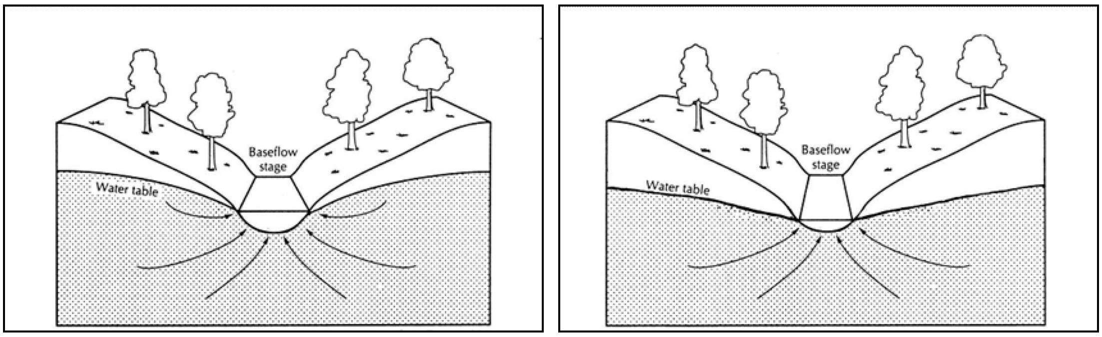


Figure 7.2 **Discharge hydrograph in the Wearyan River at G9030250 in 1977.**



High water table = large flow in river **Low water table = low flow in river**

Figure 7.3 **Effect of Water Table Level on River Flow** (Adapted from Fetter, 1994)

7.1 How surface water sites are recorded

All NRETAS surface water sites have a unique 'gauge station', 'G' number and name eg. G9080133 Wearyan River at upstream road crossing. A listing of all the NRETAS surface water sites within the mapped area is provided in Appendix I. The amount of data collected at each site can vary greatly:

from a single water quality record to detailed water quality and water level records over several decades.

The surface water sites marked with a 'G' number on the map include:

- Gauging stations where river height has been continuously recorded and flow measurements made. (See Glossary)
- Gauge sites where a number of flow measurements have been made
- Springs where water quality and flow measurements have been made
- Permanent waterholes where water quality measurements have been made.

The continuous height record generally spans from 1968 to 1986 (See Appendix I for details). There are currently no sites in the map area where river level is still continuously recorded.

7.2 River Catchments

The Robinson and the Calvert River catchments dominate the map. Other rivers on the map include the Wearyan and the Foelsche Rivers in the north-west and Sandy Creek, Running Creek and settlement Creek located on Wollogorang Station in the east. Before the advent of this project there was very little recorded surface water information for the area aside from 3 gauging stations and a baseflow survey undertaken for the Calvert and Robinson Rivers in 1984. The information suggested there was little in the way of permanent flowing rivers and so it was a great surprise when field survey teams found significant stream discharges in the area. There were two main reasons for the discrepancy;

i) The gauging stations were located on river reaches upstream of significant spring discharges and
ii) This project was undertaken during an extremely wet period resulting in record spring discharges.

Each of the river catchments and the findings of the field work are discussed in detail below.

7.2.1 Robinson River

Flow variation at the gauging station

One gauging station G9080122 recorded water level at the community waterhole from 1969 to 1986, (Plate 7.1) (Appendix I). The data shows that the river ceased to flow in most years however during the high rainfall period in the 1970's (Figure 3.3) the river did not cease to flow for 4 years. This is because during this period the Karns Dolomite aquifer, which provides baseflow to the river and is situated upstream of the gauging station, was well recharged and the water table remained high enough to maintain sufficient spring discharges to the river and keep it flowing. Similarly in 2006 the river also maintained its flow at the site for the same reason. However in 2007 and 2008 the river ceased to flow following average to poor annual rainfall, (Plate 7.2). In these years the aquifer was not well recharged and the water table continued to decline resulting in little to no flow in the river. This is of concern to the community as it draws water from a large waterhole in the river just upstream from this crossing (Plate 7.2). The flow records and observations show that river baseflow at this location is only sustained through the Dry during high rainfall periods.

Plate 7.1 River gauging station G9080122 on the Robinson River at the community.

Plate 7.2 a,b,c Flow at the Robinson River crossing at the community.
December 06 Flow =168 L/s September 07 No flow July 08 Completely dry crossing
The crossing is about 150 m downstream of the gauging station.

Flow variation along the Robinson River

Baseflow surveys along the Robinson River were conducted in August 1984, November 2006 and October 2007. The results (Figure 7.4) show that even when there is no flow at G9080122 (located at 100 km from the river mouth) there can be good discharges further downstream. The river is a gaining stream due to groundwater discharging from the Karns Dolomite to the river. Note on the water resources map that the river downstream of G9080122 is situated on the Karns Dolomite. The most downstream point in Figure 7.4, located at 39 km from the river mouth, is the Wollogorang road crossing. In drier periods the river here can also cease to flow.

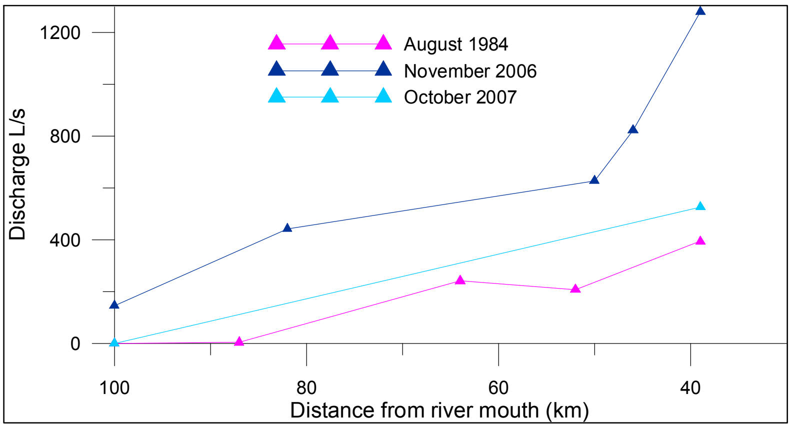


Figure 7.4 Baseflow measurements along the Robinson River.
From Robinson River community located at 100 km to Wollogorang Road at 39 km from the river mouth.

7.2.1 Calvert River

Baseflow variation at the gauging stations

Two gauging stations G9090248 and G9090249 located upstream of the Wollogorang Road crossing recorded water level on the Little Calvert River and the Calvert River respectively from 1968 until 1986 (Plate 7.3, 7.4). As per the Robinson River site, these gauging stations were situated upstream of any significant spring discharges and hence the rivers here cease to flow almost every year (Appendix I). From the available record it was only in 1979 that G9090249 continued flowing (Appendix I). Flow gaugings made at G9090249 during the project period showed a similar trend to that observed at Robinson River G9080122 with flow observed (20 L/s estimated) in December 2006 and less than 1 L/s in October 2007.



Plate 7.3, 7.4, 7.5 G9090249, G9090248 and no flow at G9090248 in December 2006.

Flow variation along the Calvert River

Baseflow surveys along the Calvert River were conducted in August 1984, and during the project period from 2006 to 2008. The surveys confirm that flow significantly increases downstream from the junction with Karns Creek (Figure 7.5). This spring flow is sourced from the Fractured and Karstic aquifer situated on Pungalina Station.

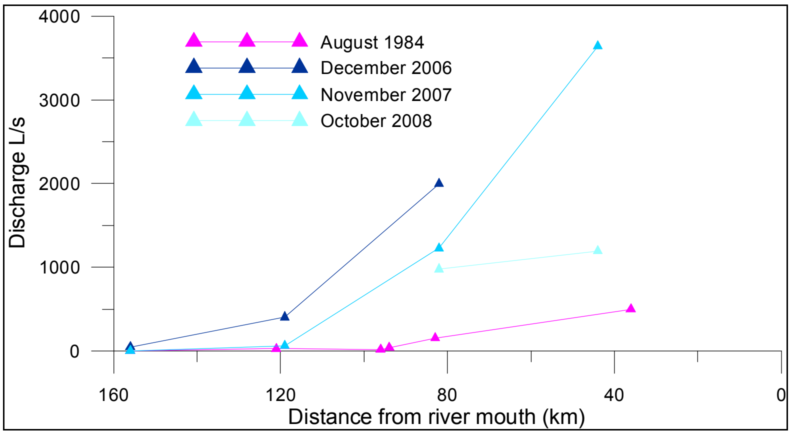


Figure 7.5 Baseflow measurements along the Calvert River
G9090249 at 156 km, Wollogorang Rd crossing at 119 km, Pungalina Homestead at 82 km, Old Coast Rd at 44 km.

An overview of spring discharge to the river in this region is provided in Figure 7.6. Flow measurements made in November 2007 are represented. Large localised springs observed are Coconut Spring, Bubbling Sands Spring and Bandicoot Spring. The total discharge from all these springs and river flow is measured at the site G9095038 Calvert River at Pungalina Homestead which was 1230 L/s. Only one other measurement was undertaken on the Calvert River downstream of this site, G9095083, and that came to 3643 L/s. This is a three fold increase in flow yet there are no other observed large springs between the two sites. This suggests that spring discharge occurs in the river bed. Large groundwater discharges are likely to be located along the edge of the Karns Dolomite where it meets with the river. These sites are downstream of Pungalina Homestead, around Bluff Waterhole and around the Bath Tub Spring area. This can be confirmed by further stream flow gauging.

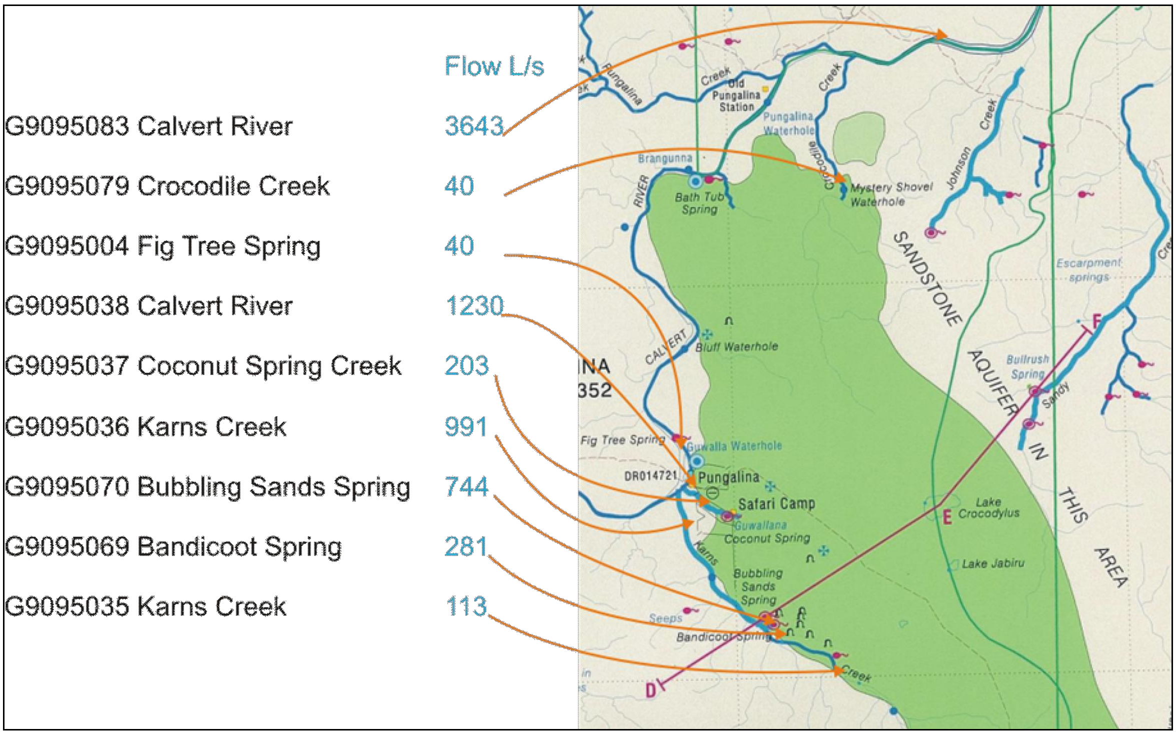


Figure 7.6 Excerpt from the water resources map showing spring discharges in 2007

In the years following the 2005/06 exceptional wet season, rainfall has been mediocre resulting in an extended recession in baseflow. Figure 7.7 clearly depicts the declining discharges at sites measured late in the Dry season in these years (2006 – 2008). The recession in baseflow will continue unless good rainfalls occur. A glimpse of how the river can change in drier periods is provided by Frank Shadforth's story on Bill Jackson (See boxed text).

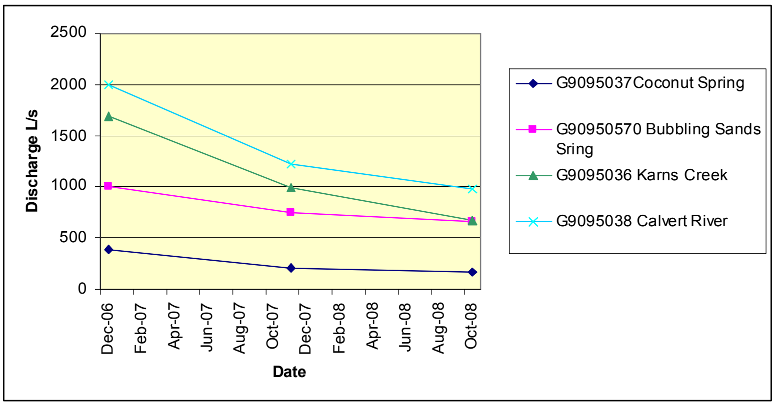


Figure 7.7 Declining discharges at gauge sites.

Crocodile hunting on the Calvert River at Pungalina

'Bill Jackson had a grazing lease at Pungalina. Willy Shadforth, my father, used to go and hunt freshwater crocodiles on the Calvert River in the early 60's. At that time the Calvert River on Pungalina had stopped running and the men would travel over dry stretches of river between waterholes. My dad travelled by horse and used pack horses for the skins. However mad Bill Jackson used a bonnet from an old dodge truck to carry his skins. He dragged it from the road crossing on the Calvert River east of the old Pungalina Homestead (G9095083) up and down the river shooting and collecting crocodile skins. He had to drag the bonnet across dry creek beds. Sometimes it would take him two days to drag his bonnet boat between waterholes. Hunting for crocs was done at night. After shooting the croc it would sink to the bottom so the hunters would dive in with a torch and get it'. (Frank Shadforth, personal communication)

This story provides a historic account of how dry the Calvert River has been in the past. It is hard to imagine considering that for the duration of this study, 2006-2009, the flow in the same stretch of river discussed has not dropped below 1000L/s.

7.2.1 Wearyan River

Like the Robinson and Calvert Rivers the Wearyan River also drains the Karns Dolomite, however it is only in its lower reaches, from Doolgarina downstream, that it meets with the Dolomite. Upstream of Doolgarina the Wearyan stops flowing each Dry season. Springs are located at Doolgarina. A gauging station G9080133 (Plate 7.6, 7.7)is situated approximately 7 km downstream from Doolgarina, near the Wollogorang Road. Within 2 kilometres downstream of the Wollogorang Road the river becomes tidal. Although the gauging station is located on the adjacent water resource map (Water Resources of the McArthur River Region) it is discussed below because it is the most downstream site that recorded discharge from the Karns Dolomite.

Plate 7.6, 7.7, 7.8 Gauging Station on the Wearyan River, Gauge boards and the Wollogorang Road Crossing just downstream from the gauging station.

Baseflow variation at the gauging station

Unlike the other gauging stations discussed, this station is sited downstream of a spring area where flow ceases only during low rainfall periods (A graph in Appendix I shows the flow record for the station). Annual minimum flows from the recorded data are shown in Figure 7.8. To gain a perspective on how minimum flow may have varied over a longer period, recorded annual minimum flow was correlated with the 2 year moving average annual rainfall (at the Calvert Hills recorder site DR014705[3]), (Figure 7.8) and regression analysis undertaken. The correlation coefficient was 0.71. From the correlation equation, predicted annual minimum flows were calculated for the period of the rainfall record (1891 – 2007). The results show that the high baseflows experienced in the Wearyan River at G9080133, since 2001 are a result of extremely high rainfall which occurred for the first time in over 100 years.

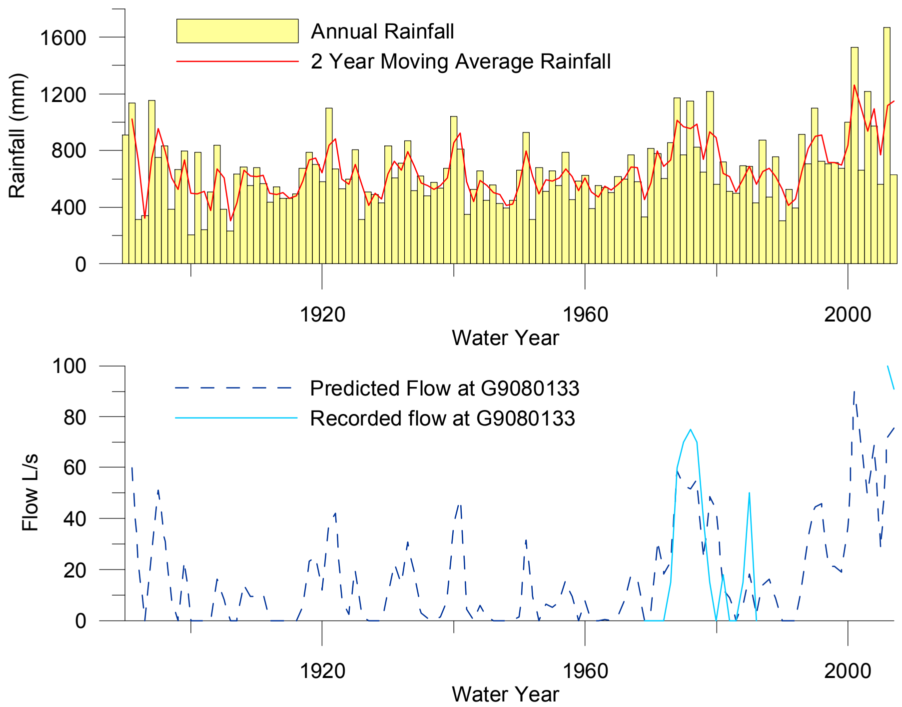


Figure 7.8 Annual rainfall at Calvert Hills and minimum flow at G9080133
Calvert Hills annual rainfall at the DR014705 rainfall recorder site and the 2 year moving average of annual rainfall. Calculated over the Water year = September to August of the following year. This is interpolated data obtained from SILO Data Drill made available by the State of Queensland through the Department of Natural Resources. Correlation coefficient between rainfall and recorded minimum flow = 0.71.

7.2.1 Johnson, Sandy and Running Creek

As explained in section 6.6 baseflow in these rivers is sourced from a sandstone aquifer. No data had previously been collected on these rivers. Flow measurements made during this project are shown in Figure 6.11 and listed in Appendix I. Although the discharge from these rivers is small compared to the Calvert and the Robinson, Frank Shadforth confirmed that these rivers are perennial in their upper reaches.

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[3] Interpolated rainfall was used for the site at DR014705. Data was sourced from SILO Data Drill made available by the State of Queensland through the Department of Natural Resources.

7.3 Availability of river water

7.3.1 Mapping minimum baseflows

To provide an overview of water availability all rivers on the Water Resources map have been plotted according to their minimum flow, thereby reflecting the environment at its driest. It is intended to raise awareness of how supplies from these rivers can be limited. In cases where there was little recorded data, site visits, flow gaugings and local knowledge were used to determine minimum flows. Local knowledge proved vital to this task as this project was conducted during a period of above average rainfall and higher than minimum flows were observed in most rivers. The minimum flow categories of some rivers have been estimated from anecdotal evidence or scientific interpretation, as not all sites could be visited during the project duration. There are three categories of minimum flow shown on the water resource map:

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

Plate 7.9 Coconut Spring Creek

Coconut Spring Creek, the lower Karns Creek, a reach of the Calvert River, Johnston Creek, Sandy Creek and Running Creek are marked under this category.

River with permanent waterholes or a minimum flow up to 10 L/s at the end of the Dry season

Plate 7.10 Calvert River near Goanna Yard

This category includes rivers which cease to flow, but maintain permanent waterholes which can provide a supply throughout the year. Some of the waterholes can be small but others such as the one pictured can be long and deep. Reaches of the Calvert and the Robinson Rivers fall into this category.

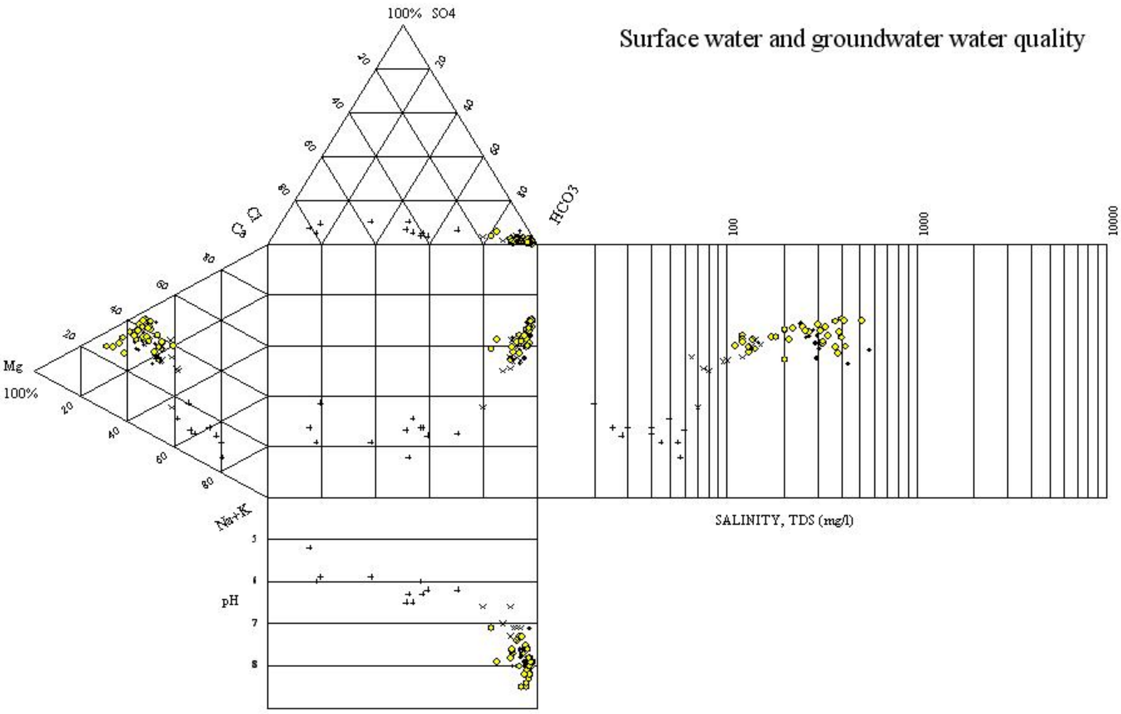
River which is dry at the end of the Dry season

These rivers are not suited to supply water reliably throughout the year. Although most of the rivers in this category are dry by the end of the Dry season some of them may continue to flow throughout the year after periods of average and above average rainfall, but will dry out in drier times. Rivers which can have long stretches of dry riverbed with only the occasional waterhole are also marked under this category. Where possible these isolated permanent waterholes are marked on the map

Plate 7.11 Tributary of Branch Creek

7.3.2 Baseflow Water Quality

Baseflow water quality in the Lower Wearyan, the Foelsche, Robinson and Calvert Rivers reflect their origin from aquifers in the Karns Dolomite. This is clearly shown in the Durov diagram below which groups waters of similar composition. Note in the diagram how water quality parameters from these rivers coincide with that from bores drilled into the Karns Dolomite. Details of river water quality are provided in Appendix J. Baseflow water quality readings are those undertaken in the Dry season.



● Bores drilled in Karns Dolomite
+ Baseflow sourced from sandstone
X Baseflow sourced from sandstone and Karns Dolomite
O Baseflow sourced from Karns Dolomite

Figure 7.9 Durov diagram of river baseflow water quality and water quality of bores

Baseflow of rivers sourced from sandstone aquifers have a low pH and salt content as reflected by the low Ec. The water quality of these rivers has also been plotted in Figure 7.9. In the figure you can see the distinct difference in water quality between water sourced from sandstone compared with dolomite. Some baseflow water quality sites show to have a water quality between that of a sandstone and a dolomite type water and hence are probably a mixture of the two (Figure 7.9).

It is notable that in the 1984 Baseflow survey (Field et al., 1988) Ec, bicarbonate, magnesium and calcium decreased in Robinson River with distance downstream (Figure 7.10) but the discharge increased. The trend in Ec was replicated in the 2007 survey. A similar trend was also observed in the Calvert River. It is an interesting phenomena and may indicate that the increasing discharge may be partially derived from a dolomitic aquifer with a lower carbonate content or a sandstone.

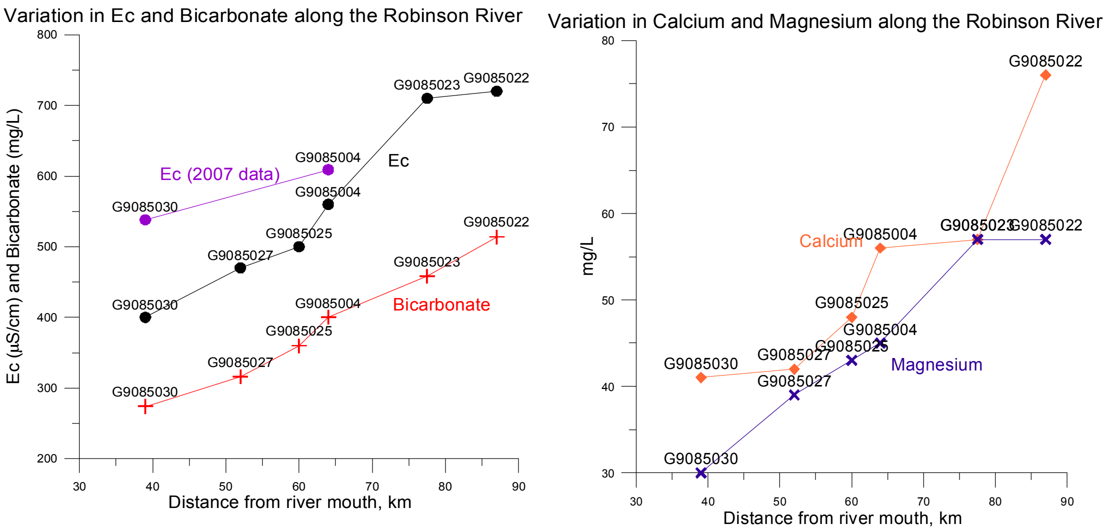


Figure 7.10 Variations in water quality along the Robinson River.

An interesting feature in the area related to the carbonate waters is tufa. Tufa is a type of limestone. It forms when evaporation causes spring water to become super-saturated with calcium carbonate. The mineral precipitates out of solution when triggered by turbulence. Hence tufa deposits are often seen at cascades and rock bars often forming tufa dams. These can be quite spectacular sights and one along the Calvert River is without a doubt a wonder of the territory (Plate 7.12a & b). Tufa deposits have been marked on the water resource map.

Plate 7.12a & b Tufa dams adjacent to the Calvert River

Given the large discharge at Bubbling Sands Spring the survey team took the opportunity to undertake stygofauna sampling. Stygofauna are small aquatic invertebrates that live in aquifers and caves. The samples showed to be Asellota Protojaniridae which was first collected quite recently from Gregory National Park. This is evidence of life in groundwater at Pungalina.


Plate 7.13 a & b Collecting Stygofauna at Bubbling Sands Spring

River water quality in the map region is good however water quality has been compromised in the Settlement Creek catchment by mining activities. Acid leachate containing high copper concentrations from one of the ponds from the mine permeated into a shallow transmissive zone in the surrounding rock and entered into the adjoining creek, Hanrahans Creek and travelled downstream. This has caused environmental damage. The problem is being addressed through a water management plan and waste discharge licensing. Mitigation works have been undertaken.

7.4 Wet Season Flows

In the Wet season, river flows increase due to rainfall runoff. Figure 7.11 provides an example showing how flow in the Calvert River at G9090249 increases with rainfall events at Calvert Hills DR014705. 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. For the same amount of rainfall, larger catchments have larger flows. Major catchment boundaries are shown on the Water Resource Map. Appendix I provides plots of the flow record for the gauging stations. Note the large variations in maximum flow over the years. Large quantities of rainfall runoff can discharge along the Robinson and Calvert Rivers. This presents a substantial resource.

For further information on rainfall runoff The CSIRO North Australia Sustainable Yields (NASY) project is best referenced. (www.csiro.au/science/NASY-Gulf-of-Carpentaria.html) It assesses surface water and groundwater resources in the region under varying scenarios including the historical, recent (last 10 years) and future (2030) climates.

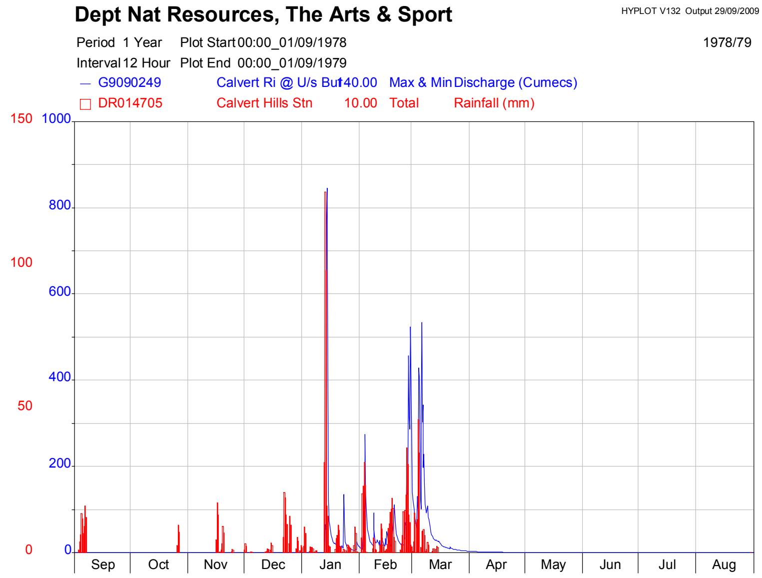


Figure 7.11 Flow increases in the Calvert River in response to rainfall.

7.2.1 Effects of high rainfall

The extreme high rainfall conditions experienced in the area since 2000 have had the effect of providing good recharge to aquifers in the Karns Dolomite resulting in unprecedented high baseflows in rivers. Another effect however has been felt by vegetation communities. As noted in 'Owen's Story' (section 6) Lake Crocodylus filled to overflowing during the wet season of 2000-2001 and to this day water remains in the lake. This has caused trees in the lake to die from prolonged inundation. Dating of one of the dead trees showed it to be at least 98 years old. It follows that such a rainfall event and indeed a period of prolonged high rainfall, has not occurred for at least 98 years. This agrees with the long term rainfall record (Figure 3.3) which shows the 2000-2001 rainfall was the highest on record since recording started in 1890. Historical aerial photography also showed that the lake usually dries by the end of the Dry season. A poster has been produced examining this occurrence called 'A case for too much water'.

Plate 7.14 Lake Crocodylus in 2007

Plate 7.15 Aerial photo of dry lake in 1981

8. WATER RESOURCE DATA AND AVAILABILITY

The Water Resource Map that accompanies this report was produced by NRETAS. It can be reprinted at any time and made available to interested parties.

NRETAS reports pertaining to this map area are listed in Appendix F and many are available in digital format.

All products produced for the Gulf Water Study are available in digital format on DVD. The DVD titled 'The Gulf Water Study' contains the following products:

- This report and the reports for the other regions of the study
- Posters pertaining to the study area
- A GIS which uses the program Arc Explorer
- A photographic and video database which is geo referenced

The DVD is available through the Natural Resources Division of NRETAS.

All detailed information on surface water sites is kept on the NRETAS 'Hydstra' database. Requests for such data can be made to: Spatial Data and Mapping Branch, NRETAS Phone (08) 8999446, Email: DataRequests.NRETA@nt.gov.au

All bore reports are available through the internet site www.nt.gov.au/nretamaps. These are regularly updated.

Plate 8.1, 8.2, 8.3 Scientific data collection: Patrick Gray measuring flow at Pungalina Station, Anthony Knapton undertaking a gamma log on Greenbank Station, drilling on Greenbank Station.

9. GLOSSARY

Airlift Yield: The rate at which water is extracted from a bore using compressed air downhole.

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 flow in a river.

Confined aquifer: A confined aquifer occurs where an aquifer is overlain by a confining bed. The confining bed prevents upward movement of the groundwater. Such aquifers are usually completely saturated with water which is commonly under pressure. Therefore when a bore intersects the aquifer, water rises up the bore. If the pressure is sufficient to drive the groundwater above the ground level, the bore is called artesian.

Carbonate rock: A rock such as limestone or dolomite, consisting largely of the carbonate minerals; calcium carbonate or calcium magnesium carbonate.

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

Dhuwa and Yirritja: These are the two moiety names often used in Arnhem Land. Everyone and everything is either Dhuwa or Yirritja. This is one of the fundamentals of Aboriginal culture.

Dolomite: A sedimentary rock composed mainly of the mineral dolomite (calcium magnesium carbonate)

Electrical conductivity, **EC**: The measure of the ability of water to conduct electrical current. The magnitude is directly related to the dissolved mineral content of the water. EC is measured in microseimens per centimetre, μS/cm.

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

Evaporation: The process whereby liquid water turns to vapour. It accounts for the movement of water to the air from sources such as the soil, canopy interception, and waterbodies.

Evapotranspiration: The sum of evaporation and plant transpiration from the Earth's surface to the atmosphere. Transpiration accounts for the loss of water from plants as vapour through its leaves.

Fractured: A fractured rock is one that is broken by joints, cracks or faults.

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

Geology: Science of earth's composition, crust, rocks, origin, structures, historical changes and processes.

Geographic Information System (GIS): A computer system that captures, stores, analyses, manages and presents data that is linked to location. Data 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, electro-magnetics, and seismics can be used on the earth's surface in order to indicate geology.

Groundwater: Water beneath the surface of the earth that is in the saturated zone.

Groundwater dependent ecosystems: A community of plants and animals that rely partially or completely on groundwater for its existence.

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.

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.

Jungkayi: People who have responsibilities to their mother's clan, ritual managers of one's mother's country. The term can be translated in English as 'manager', 'caretaker' or 'policeman'.

Karst: A term describing typical geologic/topographic attributes of limestone or dolomite resulting from mineral solution such as caves and sinkholes.

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

Ngimarringki: Yanyuwa term for traditional land owners.

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

Perennial flow: Flow that is retained throughout the year.

Permeability/Permeable: The capability of sediments and rocks to allow water to move through them.

pH: A measure of acidity (low pH) or alkalinity (high pH). A pH of 7 indicates neutrality whereas lower pH levels indicate acidity.

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

Primary porosity: Voids in a rock formed when the rock was deposited. The spaces between sand grains are an example of primary porosity.

Recession: The part of the hydrograph where the water level or flow diminishes.

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

Runoff: Rainwater that leaves an area as surface flow.

Sandstone: A sedimentary rock composed of sand grains cemented together.

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

Secondary porosity: Voids in a rock formed after the rock has been deposited; not formed when the rock was formed, but later due to other processes.

Silicification Is where pore spaces and cavities are filled with the silica mineral resulting in a hard rock with poor permeability.

Siltstone: A sedimentary rock composed of silt sized particles.

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

Surface Water: Water that is on the earth's surface, such as a stream, river, lake or reservoir.

Sustainable: maintain (without adverse effect)

Topography: The shape and height of the land surface.

Total Dissolved Solids (TDS): The amount of dissolved material in water, usually expressed as milligrams per litre (mg/L).

Unconsolidated: A sedimentary deposit in which the particles are not cemented together.

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

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

Water Year: The water year splits the year from September of one year to August of the next year. Hence 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.

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APPENDIX A: INDIGENOUS KNOWLEDGE

All cultural perspectives need to be recognised when undertaking land and water management and development. In effort to present the indigenous cultural perspective pertaining to water, care has been taken to present indigenous place names on the maps and detail cultural information relevant to the places in this report. All indigenous place names relate to the people, their ancestors and the country. It is hoped that aside from producing a cross-cultural user friendly map, non-indigenous readers can begin to appreciate the rich heritage of the indigenous people of this region.

The following information was collected during field trips when indigenous people were interviewed or accompanied field workers and guided them to water sites. At all times when collecting indigenous knowledge, it was made clear that the information would be public, so culturally sensitive information was not recorded. Where possible, the language of the place name was recorded. Efforts were made to transcribe the names correctly.

Where substantial information has been supplied it is presented in alphabetical name order of the individual or group who supplied the information. A photo of the individual is shown where possible and this is followed by detailed information and photos of some sites. A table is provided with location and transcription details of all sites discussed. Information from other individuals is presented in tabular form at the end of the Appendix. In the tables it is noted if the site was visited or the location only estimated by use of maps and through discussion. A draft 1:250000 water resource map was used to identify locations. Eastings and Northings were then approximated using 1:50000 topographic maps. Where there is too much uncertainty on location, no co-ordinates were supplied. Some of the locality names are non-indigenous but are none the less recorded here.

Indigenous and non-indigenous people provided information on water resources and their dynamics that has helped with mapping and scientific understandings. This information such as spring locations and whether or not waterholes are permanent or intermittent is knowledge gained through experience and observation. Such information has been invaluable, particularly as such a vast area was covered and access difficult.

Ancillary to this report, indigenous knowledge has also been documented through photographs and video and is available on the Gulf Water Study DVD.

Albert Charlie, Jack Green, Jack Hogan, Les Hogan, Norman Kingsley, Kelly Martin

The meeting with these Traditional Owners was kindly organised by the Northern Land Council.

Table A1 Indigenous place names and details supplied by Albert Charlie, Jack Green, Jack Hogan, Les Hogan, Norman Kingsley, Kelly Martin.

Indigenous name	Site	Comment	Easting	Northing	Transcribed
Badurrula /Badurruna	River waterhole, permanent	Spear waterhole on Settlement Creek	786700 As per topo map	8076900	Ursula Zaar
Banmurrina	Waterhole, permanent	Snake Lagoon, a permanent waterhole	704500 As per topo map	8207600	Ursula Zaar
Blangyalina	River waterhole	Settlement Creek	807000 As per topo map	8089300	Already noted on 50K topo map
Damundju	Spring	Spring at the old station Foelsche R. Upstream are rock holes and gorge country. Cattle cant climb up there.	674200 Location estimated	8146000	Ursula Zaar
Djangalina	River waterhole, permanent	On Branch Creek	816500 As per topo map	8092400	Already noted on 50K topo map
Djiwalnguna	River waterhole, permanent	On Settlement Creek	813500 As per topo map	8095000	Already noted on 50K topo map
Djiwarrlilli	Spring in river	500m south from Jilarrli. There is a spring. Boiling water always. On Robinson River.	613900 Location estimated	8168000	Ursula Zaar
Galadjarngu	Waterhole, permanent	Lily Lagoon, permanent waterhole	701800 Location estimated	8200500	Ursula Zaar
Gallalargina	River waterhole, permanent	1 km further down from Watermelon Bend on the Foelsche River. Devil dreaming place. Freshwater.	700100 Location estimated	8213000	Ursula Zaar
Galwalyina	River waterhole	On Settlement Creek	804800 As per topo map	8088500	Already noted on 50K topo map
Gundinyirra	River name	Running creek. Rainbow serpent came through from Queensland side and created springs and gave them names and kept going.	790000 Location estimated	8142500	Ursula Zaar
Gundiridji	River waterhole, permanent	Permanent waterhole on Foelsche River.	675500 Location estimated	8147300	Ursula Zaar
Gunjurrina	River waterhole, permanent	Permanent waterhole on the Foelsche River	690800 Location estimated	8160000	Ursula Zaar
Gunninmidji (Kunninmidji)	Area along the river.	Is Mannigan yard, old stock yard.	700500 Location estimated	819700	Ursula Zaar
Gurnang	Area	Kelly Gap	689500 Location estimated	8159000	Ursula Zaar
Gurrlila	River, waterhole	Nine mile yard on Robinson R. waterhole. Same as Goylerrla noted by Kathleen Shadforth.	712800 Location estimated	8163000	Ursula Zaar
Guyalina	Spring	Permanent spring. On Wollogorang.	801700 Location estimated	8060600	Ursula Zaar
Guyulana	River	Karns Creek			Ursula Zaar

Indigenous name	Site	Comment	Easting	Northing	Transcribed
Jilarrli	River waterhole, permanent.	At Mc Queen yard. Can stop running but permanent water	714500 Location estimated	8170000	Ursula Zaar
Jillinmudu	River waterhole, intermittent	This part of the Foelsche River can dry out.	694700 Location estimated	8161600	Ursula Zaar
Judijina	River area with permanent water.	Bluey Creek between the highway and Bluey Waterhole. It is always running here. Similarly noted by Kathleen Shadforth.	750600 Location estimated	8125000	Ursula Zaar
Koerannga	River waterhole, permanent	Permanent waterhole on the Foelsche River.	694800 Location estimated	8166700	Ursula Zaar
Kunnalarngandja	River waterhole permanent	Permanent waterhole on Foelsche River.	694500 Location estimated	8163000	Ursula Zaar
Lagarranga	River waterhole, intermittent.	Watermelon bend on the Foelsche River. Dries. Greenbank station.	700600 Location estimated	8212600	Ursula Zaar
Mangulamba	River waterhole, intermittent	On the Foelsche river at the highway crossing. Dries completely.	701300	8206600	Ursula Zaar
Marleburrinna	River waterhole, permanent	About 5 km from Yinmurlunna. Permanent water on the Foelsche River.	692200 Location estimated	8173000	Ursula Zaar
Marrunyirri	Rock	stone near Yirringanna	711300 Location estimated	8161100	Ursula Zaar
Maurra	Hill	Hill at the gap - Kelly gap			Ursula Zaar
Milbunji	River	12 mile creek. On wollogorang.			Ursula Zaar
Pilanjarri	River	5 mile creek. On wollogorang.			Ursula Zaar
Renburrnunga	River waterhole.	About 500 m from Gallalargina, Foelsche River.			Ursula Zaar
Uranyina	River waterhole	On Branch Creek	814500 As per topo map	8088300	Already noted on 50K topo map
Walaburri	Outstation	Outstation on Foelsche River. Steven Rory lived there. No-one there now.	696600 As per topo map	8185300	Ursula Zaar
Winmereena	River waterhole	Little Calvert River at homestead.	748000 Location estimated	8093300	Ursula Zaar
Winmerrina	River junction.	Calvert River where karns Creek joins.	757200 Location estimated	8149600	Ursula Zaar
Yalagunji	River waterhole permanent	Permanent waterhole on Quaker creek	694000 Location estimated	8133700	Ursula Zaar
Yinmurlunna	River waterhole, permanent	Buffalo yard. On Foelsche River. (Les Hogan)	692300 Location estimated	8177500	Ursula Zaar
Yirringanna	River, junction	Junction between Hobblestrap and Robinson river	711600 Location estimated	8161300	Ursula Zaar
Yuwindinna	River	Little creek. Just south of Manangoora outstation.	697000 Location estimated	8228400	Ursula Zaar

Galadjarngu. Permanent billabong of the Foelsche River.

Katie Baker, Les Hogan Warramurru, Dulcie Mawson, Daphne Mawson

The following place names were recorded at a meeting attended by these people. Daphne, who teaches indigenous culture in Garrwa at the Borroloola school, transcribed the names which are in Garrwa.

Table A2 Indigenous place names and details supplied by Katie Baker, Les Hogan Warramurru and Dulcie Mawson.

Indigenous name	Site	Comment	Easting	Northing	Transcribed
Dunmanjina	Spring	Washing springs on an upper Foelsche River tributary. Sandstone water. Runs about 1 km.	673900 As noted on 50K topo map	8118600	Daphne Mawson
Gunanda	River waterhole, permanent	Located along the Wearyan River. Get emu there.	677600 Location estimated	8185200	Daphne Mawson
Dingalina	Waterhole intermittent	Near Wearyan River	688600 Location estimated	8202000	Daphne Mawson

Les Hogan Warramurru and Jack Wangurrli (Means black crow)

Les Hogan.

The meeting with these men was kindly organised by the Northern Land Council.

Table A3 Indigenous place names and details supplied by Les Hogan Warramurru and Jack Wangurrli. Initially transcribed by Ursula Zaar and later cross checked by Daphne Mawson

Indigenous name	Site	Comment	Easting	Northing	Transcribed
Badakullabah	River	Branch Creek. Creek stops running every year but waterholes keep water. River dries a fair bit.			Daphe Mawson, Ursula Zaar
Billibillibi	River waterhole	Waterhole on Foelsche River	680000 Location estimated	8150900	Daphe Mawson, Ursula Zaar
Buluka (Beoyerlukgu)	River waterhole	Waterhole with salt water crocodile on Robinson River.	711000 Location estimated	8142500	Daphe Mawson, Ursula Zaar
Bundall		Word for river in Garawa language like Manangarr			Daphe Mawson, Ursula Zaar
Djangalina	River waterhole, permanent	Permanent waterhole. On Branch Creek.	816500 Location estimated	8092400	Already noted on 50K topo map
Djangalla	River junction	Junction at Quaker creek junction	702300 Location estimated	8136400	Daphe Mawson, Ursula Zaar
Djarrmendi	Area	On tributary to the Wearyan River	669500 Location estimated	8159200	Daphe Mawson, Ursula Zaar
Djiwalnguna	River waterhole, permanent.	Main settlement Creek crossing at Wollogorang.	812400 Written on topo map	8194300	Already noted on 50K topo map
Dudduji	Area	Horse pocket, limestone country with springs around here.	692000 Location estimated	8109000	Daphe Mawson, Ursula Zaar
Ganbanganna	River waterhole	Waterhole and hill on Robinson River	711700 Location estimated	8144800	Daphe Mawson, Ursula Zaar
Gandjarrinjarri	Hill	Mt Gnome. It is at the head of the Robinson River. Area name.			Daphe Mawson, Ursula Zaar

Indigenous name	Site	Comment	Easting	Northing	Transcribed
Gillidjalki area	River waterhole	Barramundi yard on Foelsche River	677300 Location estimated	8148100	Daphe Mawson, Ursula Zaar
Gunjulinna	Area	Area at Hobblestrap creek, means red paint	693400 Location estimated	8151500	Daphe Mawson, Ursula Zaar
Guyuganna	River waterhole	Permanent waterhole on Quaker Creek.	678700 Location estimated	8129800	Daphe Mawson, Ursula Zaar
Kabullanudji	River waterhole, intermittent	Area at road crossing Foelsche River dries out here	683400 Location estimated	8152700	Daphe Mawson, Ursula Zaar
Kunninmidji	Waterhole	Waterhole at Donald yard, Foelsche River.	685800 Location estimated	8156200	Daphe Mawson, Ursula Zaar
Kuwayaludji	River waterhole, permanent	Large waterhole – with salt water crocodiles. On the Robinson River.	706400 Location estimated	8137300	Daphe Mawson, Ursula Zaar
Labalabanna	Hill	Hill at Robinson River community	710300 Location estimated	8145400	Daphe Mawson, Ursula Zaar
Langawuna	Area	Grey Horse pocket east of Robinson River. This name was confirmed by Roy Dixon.	698500 Location estimated	8114000	Daphe Mawson, Ursula Zaar
Ligirri	Area	Area. George Butchers old station	679200 Location estimated	8148500	Daphe Mawson, Ursula Zaar
Manangarr		Is the Garawa word for large river			Daphe Mawson, Ursula Zaar
Mannbu	Country name	Country name. Mambaliya people own Mannbu.	683000 Location estimated	8128000	Daphe Mawson, Ursula Zaar
Meera	River waterhole, intermittent	Waterhole that does go dry on Hobblestrap creek	698500 Location estimated	8154100	Daphe Mawson, Ursula Zaar
Mukularrungu (Mugalarramu)	River	Name of river at Robinson River community.	711500 Location estimated	8145700	Daphne Mawson
Munkilumba (Mangarlamba)	River	Foelshe River			Daphe Mawson, Ursula Zaar
Najjagurrunnu	River waterhole, permanent	Small creek running into Hobblestrap. At the headwaters – perennial. Hobblestrap creek dries out but for this small creek.	684300 Location estimated	8136900	Daphe Mawson, Ursula Zaar
Udoorrli	River waterhole, permanent	Deadmans creek, permanent waterhole here	705800 Location estimated	8135300	Daphe Mawson, Ursula Zaar
Wadjulippi	River	Is the crossing area at Calvert River - Also name of river			Daphe Mawson, Ursula Zaar
Wanbullananna	River waterhole, intermittent	At main road crossing hobblestrap Creek. Water dries out late there. Horses scratch for water – a bit of seepage	702300 Location estimated	8155800	Daphe Mawson, Ursula Zaar
		Cow Creek	670000 Location estimated	8161500	Daphe Mawson, Ursula Zaar
		Emu Creek	669500 Location estimated	8143400	

Indigenous name	Site	Comment	Easting	Northing	Transcribed
		Robinson River at Seven Emu crossing does stop flowing.			
		Spring at hobblestrap stops in a really bad year			

Larry Hoosan

Larry Hoosan

Larry's youth on the stations

Ronnie Whitehead and I were born on Calvert Hills Station. We learnt to work and ride there. That was 'tea leaf and sugar' days. That was when you worked for beef and bread. Then we transferred to Robinson River Station. I worked all through the Gulf region from Wollogorang through to Borroloola. I have seen all the changes in the rivers.

As kids we used to leave Calvert Hills station in the morning and hunt for a feed all day. People were in country and it was alive. We had no clothes. When we had clothes we thought what's this for? And took it off.

Now the country looks sad because people don't go out on country anymore. They stay in community and drink and smoke. Doreen and Kathleen brought us up at Calvert Hills. They worked for tucker – no money. That was the old days. We used to catch bull. We travelled with 12 pack horse to muster all the top end area to places where no vehicle could go. We'd be gone 3 months.

Cultural considerations

Some waterholes are proper sacred. Some people, their grandfather lived in that country and they have dreaming in that country. They know the sacred places and waterholes in that country. You can't go to that country until you get the right mob of people to get permission to go to that country. If they're not there then you have to wait till they come back.

When you damage country you can hear people, the ancestors, crying in the night. They are crying because the country is being damaged. You can't grade and bulldoze places now until you ask those people. All those years ago people didn't touch or damage country.

When you do something to country you need to ask the Traditional Owner and Jungayi. The Jungayi is like the lawyer for the country, the person who looks after that country. There can be many Jungayi and Traditional Owners for an area of land. The law has been here before you people came.

Drilling a bore along the road to Robinson River community

When you drilled the bore you needed to consult Stella, my wife and I to ensure you drilled in an area where you didn't destroy sites. The plum tree is sacred in that area and you cannot damage them. Stella is the Traditional Owner and Jungayi for that area. The plum tree there relates to a dreamtime story. The dreamtime story is about a child who was buried beside the plum tree because they were bitten by a snake and killed. They were playing and put their hand in a log and were bitten. They were playing under a plum tree. You don't pull plum down from the tree. Now the country looks sad. Not as much fruit. Before the country then looked alive. It was alive. Now there is no family there. It looks sad. Now there's motorcars so people don't walk country anymore.

Historical dry periods

There are more cyclones now than before and it has made a difference to the water resources in this region. In the past, in the 60's the water tasted pure and now the water is more limey. There are new springs in this country that weren't there before.

Donald yard area on the Foelsche River went dry in 1968 and 1969. Waterholes were dry all the way to Buffalo Yard. The next permanent waterhole from Buffalo Yard upstream was at old Willy Shadforths station near the rocky country. The dry time started in about 1964 and lasted to 1969. Barramundi Yard got its name because the river went dry and the barramundi died.

1968-1969 were very dry years and the Robinson River at the community dropped to a very low level resulting in poor water quality.

Table A4 Indigenous and local place names and details supplied by Larry Hoosan. Initially transcribed by Ursula Zaar and later cross checked by Daphne Mawson. Indigenous place names are in the table are in the Garrwa language.

Indigenous name	Site	Comment	Easting	Northing	Transcribed
Bidida	Country name	Kevin yard area (surprise, deadmans, nippers)	708000 Location estimated	8122000	Daphne Mawson Ursula Zaar
Buluka (Boeyerlukgu)	River waterhole	Waterhole with salt water crocodile on Robinson River	711000 Location estimated	8142500	Daphne Mawson Ursula Zaar
Djarladjarla	River waterhole, permanent	Waterhole on Kangaroo ck	725200 Location estimated	8143500	Daphne Mawson Ursula Zaar
Dudujina	Country name	Country name for Horse Pocket and Pony pocket. Similarly noted by Les and Jack.	692000 Location estimated	8109000	Daphne Mawson Ursula Zaar
Ganbanganna	River waterhole	Waterhole and hill on Robinson River	711700 Location estimated	8144800	Daphne Mawson Ursula Zaar
Jilarli	River waterhole, permanent	Moon dreaming, big waterhole on Robinson River.	714700 Location estimated	817070	Daphne Mawson Ursula Zaar
Kujulurru (Gudjulurru)	Country name	Means wild turnip. Creek called Limestone creek.	712295 Location estimated	8158427	Daphne Mawson Ursula Zaar
Kuwayaludji	River waterhole, permanent	Old camp (Also noted by Jack Wangurrli)	706400 Location estimated	8137300	Daphne Mawson Ursula Zaar
Labalabanna	Hill	Hill at Robinson River community	710300 Location estimated	8145400	Daphne Mawson Ursula Zaar
Mugarlarlarngu	River waterhole, permanent	The large waterhole at Robinson River Station.			Daphne Mawson Ursula Zaar
Mungubarda Mungoorbada	Area	Hill at Robinson River community			Daphne Mawson Ursula Zaar
Udoorli	River waterhole, permanent	Upstream of Udoorli deadmans creek dries up. Udoorli is on the Robinson River. It is the larges waterhole on the river. Les and Jack gave this a slightly different location.	704500 Location estimated	8136800	Daphne Mawson Ursula Zaar
	Bloodwood creek	And Bloodwood yard. The water is limy around here.	696000 Location estimated	8129500	
	Area, yard	Bloodwood yard. Waterhole near there is permanent. Then the river is dry on Quaker creek till you get to the waterhole near Quaker yard.	692000 Location estimated	8130000	
	Permanent waterhole	Cave yard creek	699500 Location estimated	8116500	
	Kevin yard		721500 Location estimated	8131000	
	Pony Pocket creek	Permanent waterhole	696800 Location estimated	8116700	
	Sting ray swamp	Dried in 60's	720200 Location estimated	8137600	
	Cattle Creek		681300	8128200	

Indigenous name	Site	Comment	Easting	Northing	Transcribed
			Location estimated		
	River waterhole, permament	At Quaker yard	688700 Location estimated	8132700	
	River waterhole, permament	South of Buffalo Yard on the Foelsche River			

Frank Shadforth

Frank Shadforth. Owner of Seven Emu Station

The Welfare Settlement on the Robinson River

In around 1950 Borroloola went dry. Some time later people were moved to an area on Seven Emu Station along the Robinson River, the 'Old Welfare Settlement'. There is permanent water there. They only stayed a couple of years however. One of the reasons was that two old ladies died which spooked the people and they returned to Borroloola.

Dry times on the Foelsche River

In around 1968 the Foelsche River went dry all the way along. The crocodiles were concentrated in one waterhole so the people got the crocodiles out of it and took them to the Robinson River where there was more water.

Foelsche River at Wollogorang Road crossing in 2007.

Crocodile hunting on the Calvert River at Pungalina

Bill Jackson had a grazing lease at Pungalina. Willy Shadforth (Franks father) used to go and hunt freshwater crocodiles on the Calvert River in the early 60's. At that time the Calvert River on Pungalina had stopped running and they would travel over dry stretches of river between waterholes. Willy travelled by horse and used pack horses for skins. However mad Bill Jackson used a bonnet from an old dodge truck to carry his skins. He dragged it from the road crossing on the Calvert River east of the old Pungalina Homestead up and down the river shooting and collecting crocodile skins. He had to drag the bonnet across dry creek beds. Sometimes it would take him two days to drag his bonnet boat between waterholes. Hunting for crocs was done at night. After shooting the croc it would sink to the bottom so the hunters would dive in with a torch and get it.

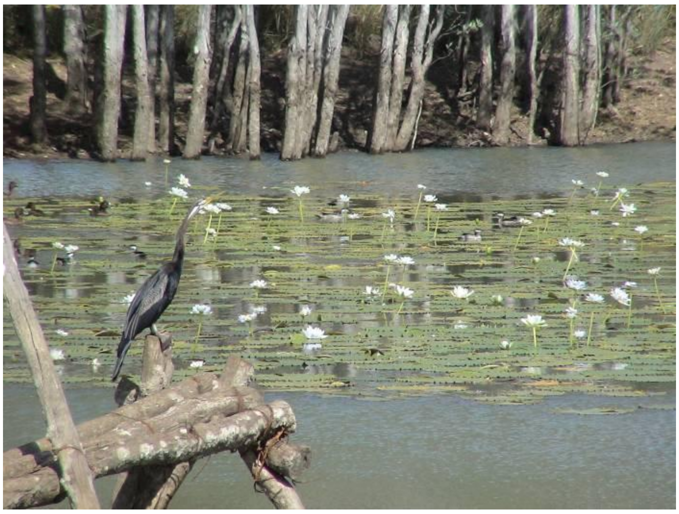
The only creeks in this region that haven't stopped running in really dry times are Coconut spring creek, Running Creek and Johnston Creek.

Comety hole, a waterhole on Pungalina in the Calvert River, was so called because of all the sinkholes in the area. The sinkholes were thought to have been caused by comets impacting on the ground. This is the only place where there are so many sinkholes in the one place.

The springs at Karns Creek – Bubbling Sands spring and Bandicoot spring are permanent but Karns Creek can stop flowing further downstream from these springs.

Late in the dry the cattle congregate at permanent waterholes and rivers so we know where to find them to muster.

Changes to Baker Waterhole



Baker Waterhole

In 1970 in September Willy and Morgan Rory, Eric Shadforth, Ned Shed, Ray brothers and myself went to Baker waterhole and got all the long neck turtle we could. There were around 40-50 and we loaded them up on the landrover and brought them back to the station. Since then I have seen the waterhole go dry and never seen a turtle in it. However in the waterhole next to Baker waterhole, where pigs have been seen, there are turtles.

Changes in the Robinson River

Frank at the islands area on the Robinson River.

Just downstream from the Seven Emu Homestead there is an island of sand. It is an island when the water level is high. Seven years ago the island started to get washed away. It disappeared (was totally submerged) two years ago due to big floods; the biggest one I ever saw in all my life. In the last ten years the water in the rivers here is coming down faster in the wet. The water rises faster. There is more water around now than in the past but give it a few years and the water levels will drop and the rivers will go back to flowing like they used to. Some people may be surprised in the future when they see the water levels drop and how dry this area can be.

Changes due to cattle

When people have small paddocks and rotate cattle through the paddocks, the paddocks get flogged. They leave the cattle there longer by use of licks. This causes the grass to almost disappear and the soil becomes bare and when the rain hits it, it runs off quickly because the grass is not there to hold and trap the water. Too much burning can also cause this. This results in more water running to the creeks faster and rivers rising faster which causes more damage. People should run their cattle on big paddocks. If cattle cannot survive on country as it is then the cattle shouldn't be there.

Rainbow Serpent Rockhole

The old people say that this is where the rainbow serpent came up from the ground leaving this rock hole behind. At this rock hole a particular grass grows. There is a story about the grass.(See 'The curlew and the moon') There are other rockholes towards Woollogorang Station where that Rainbow Serpent also came up – one of them is called screwdriver

Frank at the Rainbow Serpent rockhole.

The Curlew and the Moon

The curlew hid the baby boy and the baby girl in the clump of grass. The moon and the curlew had a fight, so the moon snatched the girl and wanted the boy as well. It could not find the boy because he was hidden in the grass. So the moon took off with the girl and that's why when you look at the moon it's smiling down at you and why boys have whiskers because the boy was hidden in the grass. This grass grows at the rainbow serpent rockhole.

Gurralgurral hill

Rocky hill which is related to the stormbird dreaming. That's where the stormbird is supposed to make the rain.

Gurralgurral hill

Vegetation and water

Broad leafed Bloodwood

The broad leafed bloodwood indicates where water is. This tree is situated next to a small creek.

Tundarra swamp

Frank at Tundaburra swamp

This swamp dries up most years.

Waterholes

Indigenous people have a name for every waterhole. Every waterhole has a meaning.

Table A5 Indigenous and local place names and details supplied by Frank Shadforth. Initially transcribed by Ursula Zaar and later cross checked by Daphne Mawson. Indigenous place names are in the table are in the Garrwa language.

Indigenous name	Site	Comment	Easting	Northing	Transcribed
Brangunna	Waterhole	Waterhole on Calvert	757961	8165570	Daphne Mawson Ursula Zaar
Djarrnarda	River	4-mile creek. Dries out in most years	733600	8196100	Daphne Mawson Ursula Zaar
Dulbudulbu	Waterhole, intermittent	Franks father said that fish hide in the ground at this waterhole	768000	8197300	Daphne Mawson Ursula Zaar
Gurralgurral	Hill	Rocky hill which is related to the stormbird dreaming. That's where the stormbird is supposed to make the rain.	774000	8179700	Daphne Mawson Ursula Zaar
Guwalla	Waterhole	Waterhole on the Calvert River	757000	8152300	Daphne Mawson Ursula Zaar
Kumbi	Waterhole	Waterhole. Dries in bad year, lies further downstream to this GPS location	736560	8201930	Daphne Mawson Ursula Zaar
Tundaburra	Waterhole	Swamp that dries	732000	8196400	Daphne Mawson Ursula Zaar
Wadjalibi	River	Calvert River at the Old stock crossing. Many years ago there was an old canteen here. This is the freshwater-saltwater boundary of the river and there is a rock bar here. It can stop running here.	776400	8177800	Daphne Mawson Ursula Zaar
Yumbarra	River waterhole	Waterhole on Seven Emu ck	744700	8210400	Daphne Mawson Ursula Zaar
	River	Charlie Adam Creek, flows into Pungalina creek			
	Waterhole,	Crocodile waterhole. On Karns Creek	758700	8145500	
	River	Grey Horse pocket Creek. Flows into Pungalina Creek			
	River	Karns Creek Flows all the time. Frank says it stops in a bad year.			
	River	Kieghran Spring creek flows into Pungalina Creek			
	River waterhole, intermittent	Dave's yard waterhole. Dries out in a bad year. Goes so brackish that you cannot drink it	748525	8214106	
	Waterhole, intermittent	Dave Yard swamp. This dries in most years.	748385	8215751	
	River	Koolfella Creek has stopped flowing about three times in the last 40 years.	719300 visited	8189250	
	River waterhole, intermittent	The waterhole at Old Seven Emu station dries in some years. In dried in the 1980's.			
	River waterhole, permanent	Rainbow serpent rockhole	729600	8192900	
	Waterhole, intermittent	Tickly Flat	727000	8195400	
	Waterhole, intermittent	Greenhide Waterhole. Dries in most years.	736200	8218200	

Indigenous name	Site	Comment	Easting	Northing	Transcribed
	Spring	Bullock Paddock Spring. It is only in a very dry year that this will dry.	742728 Visited	8221195	
	Spring	Shark Creek spring. This will dry only in a very bad year.	744667 Visited	8220553	
	River waterhole, permanent	Onion Waterhole maintains water which is always fresh enough to drink.	747158 Visited	8211379	
	River waterhole, permanent	Emu waterhole. In dry years the cattle come here to drink.	745937 Visited	8210956	
	River	Bindy Eye Crossing or Bindy Eye Bend is the only part of the Calvert River on Pungalina that will maintain flow.	755600	8163700	
	River, intermittent	8-mile creek	737300	8196100	
	River, intermittent	12-mile creek	741100	8196100	
	River, intermittent	Morgan Creek	750600	8196000	
	River, intermittent	Dinner Camp Creek	751700	8196000	
	River, intermittent	Stony Creek	752300	8195900	
	River, intermittent	Trench Creek	760000	8195700	
	River, intermittent	Robert Creek	768200	8188200	
	River, intermittent	Sandy Creek	770200	8188200	
	River, intermittent	Spring Creek	772300	8188000	
	River, intermittent	John Henry Creek	774200	8187700	
	Waterhole, intermittent	Brumby Waterhole	781700	8194200	
	Waterhole, permanent	Little Stinking Lagoon	782000	8185000	
	Waterhole, permanent	Bertle Swamp	784700	8181600	

Kathleen Shadforth, Doreen George, and Hazel Godfrey

These ladies live at Robinson River Community and kindly provided much information on waterholes in the region.

Garjarlinna

The whitefella shot the blackfella at Garjarlinna.

Garjarlinna, Blackfella spring.

Table A6 Indigenous and local place names and details supplied by Kathleen Shadforth, Doreen George and Hazel Godfrey. Place names were transcribed by Ursula Zaar and later checked by Phyllis. Indigenous place names in the table are in the Garrwa language.

Indigenous name	Site	Comment	Easting	Northing	Transcribed
Bauwanandjarnnga	River waterhole, permanent	Swamp at duck hole yard on the upper Little Calvert River. There are birds and turtles.	743500 Location estimated	8074400	Ursula Zaar
Buganjarrlina	River waterhole, permanent	Bloodwood yard, on Calvert River.	755600 Location estimated	8075700	Ursula Zaar
Djabbabinga	River junction	Junction of surprise and southern cross creek. Stn cross creek dries. Nippers keeps running.	724700 Location estimated	8117600	Ursula Zaar
Djagarlarnna	River	Karns creek at the highway	770900 Location estimated	8104800	Ursula Zaar
Djanbirrbina	River waterhole	Waterhole on Bluey creek where it meets with Jacks creek.	739300 Location estimated	8103500	Ursula Zaar
Djuluwanna	River waterhole, permanent	6 mile yard. Permanent waterhole on Six Mile Creek.	754200 Location estimated	8088100	Ursula Zaar
Djumbarranna	River waterhole	Lake. From the lake it is dry upstream on Bluey Ck.	716000 Location estimated	8073400	Ursula Zaar
Gajalaguya	River	Always flowing water, but not limestone water. On Surprise Creek.	731700 Location estimated	8125300	Ursula Zaar
Ganbeedabuya	River waterhole	Waterhole on Karns creek	773400 Location estimated	8109250	Ursula Zaar
Garbulbulrinna	River waterhole	Bluey waterhole on Bluey Ck. At old hwy crossing	746200 Location estimated	8118300	Ursula Zaar
Gangarlanna	Waterhole / spring	Cattle creek yard area. Waterhole or spring at cattle creek yard	729800 Location estimated	8094500	Ursula Zaar
Garjarlinna / Gajalina	Spring	Blackfella spring. Whitefella shot the blackfella there. There was a camp and stockyard there. This name was confirmed by Roy Dixon.	719500 Location estimated	8084000	Ursula Zaar
Girriwa	Spring	This is otherwise known as Nun Spring	714826	8149432	Ursula Zaar
Goylerrla	River waterhole	Waterhole on the Robinson River at nine mile yard. Saltwater crocs there.	712500 Location estimated	8162500	Ursula Zaar
Gudjillina	River junction	Junction of Bluey creek and Calvert River	751100 Location estimated	8125500	Ursula Zaar
Gumundjurru	Waterhole permanent	On Seven Emu station. The rainbow serpent rockhole.	729600	8192900	Ursula Zaar
Guwallanna	Spring	Coconut spring. The Calvert river between coconut spring and old Pungalina always flows.	759700 Location estimated	8148300	Ursula Zaar
Guwarrlanna / Guwarnlanna	Spring	Perennial spring on Jacks creek. Not limestone water. From the spring to the Bluey creek there is always water.	742900 Location estimated	8102500	Ursula Zaar
Guyulana	River name	Karns creek			Ursula Zaar
Lugulugurlu	River waterhole, permanent	Gorge country. Permanent water. On Bluey Ck.	742500 Location estimated	8116600	Ursula Zaar
Judijina	River	First waterhole on Bluey	750600	8125000	Ursula Zaar

Indigenous name	Site	Comment	Easting	Northing	Transcribed
	waterhole, permanent	Creek upstream from highway crossing. There are water lilies on it. There are lots of fish and turtle. It is close to the junction.	Location estimated		
Margulunna	River area, area name	Calvert river at photo yard. Area name	752700 Location estimated	8117500	Ursula Zaar
Mermalewya	River waterhole, permanent	Waterhole in gorge on Little Calvert River.	743400 Location estimated	8087800	Ursula Zaar
Mudjirra	River waterhole	Tanners yard, Bluey creek waterhole	738800 Location estimated	8108800	Ursula Zaar
Mugularrangu /Mugalarramu	River	Robinson river name.			Ursula Zaar
Munmunna	River waterhole, permanent	Near Crocodile yard on the Little Calvert River.	745700 Location estimated	8083300	Ursula Zaar
Munnayinna	River waterhole, permanent	Waterhole at old cattle yard on Karns Creek.	775300 Location estimated	8114800	Ursula Zaar
Murnmurndjarldi / Murnmurndjurldi	River waterhole	Waterhole on Bluey creek. Waterholes are getting smaller now.	732500 Location estimated	8101400	Ursula Zaar
Nanngaoona	River waterhole	Waterhole on Bluey Creek.	716800 Location estimated	8076400	Ursula Zaar
Nangarrina	River waterhole, permanent.	Permanent waterhole on Calvert River.	755700 Location estimated	8099900	Ursula Zaar
Noorbireena	River waterhole, permanent	On Horse Creek near Shadforth yard. Big waterhole on the creek.	733500 Location estimated	8081500	Ursula Zaar
Nunidji	Spring	Photo yard spring. It is permanent. From here the Calvert river has a perennial flow.	755800 Location estimated	8117700	Ursula Zaar
	Spring Piker Springs	Piker springs has perennial spring flow			Ursula Zaar
Undoorburinna / Undurburrina	River waterhole, permanent	Permanent waterhole on the Calvert River at turntable yard.	764000 Location estimated	8072300	Ursula Zaar
Wallabunyinna	River waterhole	Waterhole on Bluey ck. Permanent. Spring country. Springs on the river bank.	721000 Location estimated	8096800	Ursula Zaar
Wandburralingga	River waterhole	Waterhole on Bluey ck. Permanent.	722400 Location estimated	8097700	Ursula Zaar
Warlilligurli	River waterhole, permanent.River junction	Junction of the little Calvert and Calvert Rivers. From here downstream is permanent water.	755400 Location estimated	8100800	Ursula Zaar
Yirrgaganna	River waterhole	Waterhole downstream of quaker (?)			Ursula Zaar
Wandarbarlinga	River junction	Junction cattle creek and Bluey creek	728600 Location estimated	8099100	Ursula Zaar

Indigenous and local place names and details supplied by other people

Table A7 Indigenous and local place names and details supplied by others.

Indigenous name	Site	Comment	Easting	Northing	Transcribed
Gillidjalki	River	Waterhole on the Foelsche River. Also known as Barramundi Yard. Informed by Russell Ellis.	679091	8147710	Ursula Zaar
Meera	River waterhole	The outstation at Hobblestrap Creek is called Meera. Informed by Bindy Noble.	702973	8155963	Ursula Zaar
	Spring	Watermelon Bend Spring. Informed by David and John Keighan. Located on the Foelsche River.	700770	8212216	
	Waterhole, intermittent	Guitar Lagoon. Named due to its shape being like a guitar. Informed by David and John Keighan. This dries out.	700995	8207866	
	Spring	Reggie Dickson explained that Nun Spring is named after old Jack Nun who used to live there.	714826	8149432	
	Waterhole, intermittent	Sting Ray swamp. Informed by Reggie Dickson.	720119	8137636	

Reggie Dickson at Nan Spring area.

Bindy Noble at Hobblestrap Creek, Meera

Russell Ellis on the Foelsche River near Gillidjalki.

John Dymock

Many of the indigenous place names on Wollogorang Station are not listed herein but are presented on the Water Resource Map. They have been obtained from the 1:50 000 topographic maps for the area. These names were collected by John Dymock on behalf of the Place Names Committee of the Northern Territory (Dymock, 1999). Dymock undertook extensive liaison with indigenous people with ties to this region.

APPENDIX B: BORES DRILLED INTO THE KARNS DOLOMITE AND MC DERMOTT FORMATION

Registered Number	Location	Depth drilled	Aquifer depth	Airlift Yield l/s	Ec	date	swl	Comment	Formation
RN023244	Hwy 1 turnoff Calvert Hills Station	78.3	No info	2.25	NA	28.8.74 11.12.06	 17.42	Lack of info on this bore Obstruction at 25.8 m so pump test not completed. Called Goanna bore No 1	Karns Dolomite Inferred from nearby bore & geology map
RN023245	Karns Ck Calvert Hills Station	62.4	No info	0.9	970	27.11.84 11.12.06	8.5 6.275	Pump test 0.65 l/s No 2 Karns bore Near RN027828, Rn027829	Karns Dolomite Inferred from nearby bores.
RN026067	Yangulina outstation	64.6	27 - 30	10	430	7.11.88	8.58	27-32 fractured dolomite and chert. Pump test 8 l/s. Sited on geological lineament	Karns Dolomite
RN026068	Bujana Outstation, Lily Lagoon	52.4	28 - 34	4	435	22.10.88	10.4	Supply from broken dolomite / chert Pump test 2 l/s for 8 hours	Karns Dolomite
RN027828	Karns ck Calvert Hills Station	100	-	-	-	20.11.89	-	Dud 20 – 100 dolomite and chert	Karns Dolomite
RN027829	Karns ck Calvert Hills Station	100	-	-	-	21.11.89	-	Dud 20 – 100 dolomite and chert	Karns Dolomite
RN027830 Roads bore	Hwy 1 Calvert Hills Station	30	18 - ?	3 10 hrs	NA	18.11.89	14	18 – 30 Sandstone with dolomite bands	Karns Dolomite
RN027832 Roads bore	Hwy 1 Garawa Land Trust	100	30 - 60	1	NA	15.11.86	30	Struck at 30 m in sandstone dolomite Pumped 10 hrs 1 l/s no change in water level	Karns Dolomite
RN027842	Greenbank Station	70.8	34 64 - 66	0.5 3	 500	1.10.91 24.10.91	 16.45	5 – 70.8 Dolomitic silitstone /chert 64 – 66 m fractured cherty dolomite Pump test 3 l/s	Karns Dolomite
RN027843	Greenbank Station	70.8	43 - 44	2.1	495	2.10.91 26.10.91	 15.1	15 – 70.8 Dolomitic siltstone/ chert 45 – 50m fractured cherty dolomite Pump test 3 l/s	Karns Dolomite
RN029955	Garawa Land Trust	72	26 - 42	0.2	725	28.5.95	10.4	Dolomite at 12 m but aquifer in mostly sandstone (dolomitic).	Karns Dolomite
RN030350 Roads bore	Hwy 1 Garawa Land Trust	30	24 - 28	2+	562	1.11.95	24	From 2 m limestone encountered (dolomite)	Karns Dolomite
RN030351 Roads bore	Hwy 1 Garawa Land Trust	26	15 - 26	3	511	3.11.95	8	15 – 26 fine sand with limestone bands (dolomite)	Karns Dolomite
RN035465	Wundigalla Outstation	60	dud	dud	-	22.11.07	-	Drilled into dolomitic sandstone	Karns Dolomite
RN035466	Wundigalla	18	9 - 10	2.5	NA	23.11.06	1.5	Aquifer is dolomitic sandstone	Karns Dolomite

Registered Number	Location	Depth drilled	Aquifer depth	Airlift Yield l/s	Ec	date	swl	Comment	Formation
	Outstation							0 – 12 sandstone and clay bands	
RN035920	Garawa Land Trust	163	60.9 65 – 67 73 74.5 – 76 109 145.7 163	.04 0.6 1.0 3.0 5.0 15-20 20-25	67 94 340 680 690	24.10.07	42.5	60.9 chert 65 – 67 chert, siltstone 73 chert, siltstone,silicous rock 74.5–76 as above 109 chert 145.7 dolomitic sandstone 163 dolomite	Karns Dolomite
RN035921	Seven Emu Station	67	20.5 – 24 26	0.2 1.8	650 458	30.10.07	18.98	20.5 – 24 gravels, chert, clay 26 quartz, 27 dolomite	Karns Dolomite
RN035924 In adjoining map area	Wearyan River	61.2	15.7–18.5 24.6 36.8	3.5 1.5 2	410 400 400	12.11.07	9.85	15.7–18 dolomite, chert,clay 24.6 dolomite 36.8 fractured dolomite	Karns Dolomite (not in study region E)
RN023247	Calvert Hills station	86	NA	1.5	660	7.9.74	9.2	No 3 Valley bore 1.3 l/s pump test	Mc Dermott Formation
RN027833	Calvert Hills station	93	37	1.2	NA	4.12.89	37	Bore called Buffalo Springs 0 – 60 siltsone & chert 60 – 93 sandstone	Mc Dermott Formation

Swl = Standing water level in metres.

APPENDIX C: BORES DRILLED INTO FRACTURED AND WEATHERED ROCKS – CARBONATE ROCKS

Registered Number	Location	Depth drilled	Casing depth	Probable Formation drilled	Strata details	Supply depth m	Airlift Yield l/s	Ec	Date drilled	Swl m	comment
RN001889	Wollogorang	76		Ptq	0 - 9 sandstone 9 - 21 sandy clay 21 – 76 shale, siltstone,clay	18	0.5	1490 1350 1200	11.9.59	15.2	Police bore pH 7, 7.65, 7.5, 8
RN023246	Calvert Hills	54.8	52	Pto	No data	Pump test 0.5 l/s	3	1010 1140	26.8.74	8.9 m 4.12.84 9.48 m 11.12.06	Station Bore. Ec and geological location indicate formation. Pump test 0.5 L/s
RN026069	Mimina	70.7		Pto/Pte	0 – 16 topsoil, sandstone, siltstone 16 - 55 siltstone 55 – 70.7 dolerite		dud	-	24.10.88	-	
RN026070	Mimina	100		Pto/Pte	3 – 15 sandstone 15 – 25 sandstone, siltsone 25 - 55 siltstone 55 – 100 dolerite		dud	-	25.10.88	-	
RN026071	Mimina	52	47	Pto or Pk	3 – 30 dolomite & siltstone 30 – 52 Dolomitic sandstone	45 - 47 m fractured	10	640	26.10.88	1.75 on 8.11.88	Sited at intersection of faults Pump test 2 l/s
RN028673	Wollogorang Jangalina	100		Ptq/Ptl	3 - 16 sandstone, clays, gravel 16 – 19 siltstone 19 - 100 sandstone	-	dud	-	5.7.93	-	
RN028674	Wollogorang Jangalina	102	97	Ptq	0 – 13 sandstone, shale 13 – 64 siltstone 64 – 78 sandstone & siltstone bands	85, 91	1.5	540, 650	9.7.93	4.5	Jangalina outstation bore. pH 8.76 Rcommended pump rate 0.5 L/s
RN028675	Wollogorang Jangalina	128.8	82	Ptq	Siltstone and sandstone bands	108, 122	1.0	550	16.7.93	1.8	Jangalina outstation bore pH 8.2. Pump test 0.5 L/s
RN036050	Calvert Hills	>30 m		Ptq	N/A			530			Mineral exploration bore cased in pvc and left flowing at <0.5 L/s

Formation refers to the geological formation noted on maps Robinson River and Calvert hills (Rawlings, 2002). Note that the letter P at the start of each formation abbreviation refers to the age of the rock as Proterozoic.

Ptq	Aquarium Formation
Pto	Wollogorang Formation
Pte	Settlement Creek Dolerite
Pk	Karns Dolomite
Ptl	Sly Creek Sandstone

APPENDIX D: BORES DRILLED INTO FRACTURED AND WEATHERED ROCKS

Registered Number	Location	Depth drilled	Casing depth	Probable Formation drilled	Strata details	Supply depth m	Airlift Yield L/s	Ec	Date drilled	Swl m	comment
RN009277	Wollogorang	150		Ptw	0.3 - 45.7 sandstone	38, 110	5	86	24.10.77	NA	Bore name PDH1, pH 6.7 Bore located near fault. See mines for more info
RN009278	Wollogorang	94.5		Ptw	0 - 29 sandstone	40, 46, 70	28	51	1.11.77	NA	Bore name PDH2, pH 6 Bore located near fault. See mines for more info
RN009279	Wollogorang	136.6		Ptw	0 - 136.6 sandstone. Westmoreland conglomerate	24, 110	12.5	160	4.11.77	NA	Bore name PDH1, pH 4.1 Bore located near fault. See mines for more info
RN024295	Wollogorang	37	37	Pte/Ptq	0 - 15 sandy loam 15 - 26 shale, volcanics 26 - 37 shale	18,26	0.5, 2	NA	24.10.85	NA	Station bore
RN026476	Robinson River community	46.5	47	Pte	12-21 sandstone To 46.5 Basalt	12 @0.5 l/s, 38 @1.5 l/s, 42 @ 1.5 l/s	3.0	974	20.5.90	18	Supply bore to community
RN027472	Redbank Mine	42	36	Pms/Ptg	0 - 18 sandstone 18 – 42 volcanics	8	2.5	375	11.12.90	8.5	pH 7.8
RN027473	Redbank Mine	42	38	Pms/Ptg	0 - 8 sandstone 8 - 42 volcanics	8	2	375	10.12.90	8.5	pH 8.2
RN027474	Redbank Mine	42	37	Pms/Ptg	0 - 8 sandstone 8 - 42 volcanics	8	2	375	3.12.90	8.5	pH 7.7
RN027827	Wollogorang station along hwy	47	40	Ptc or Kl?	0 – 12 sand & boulders 12 – 30 soft black soil 30 - 47 loose sandstone	22	1.5	NA	24.11.89	22	
RN027831	Wollogorang hwy	98.5		Ptc or Kl? /Pte	0 - 20 sandstone & boulders 20 – 98 basalt & sandstone		dud	-	2.12.89	-	dud
RN027844	Robinson River community	65		Qa/Pte/Pto	12 sandstone 15 gravel 40 Basalt 65 Siltstone		dud	-	3.10.91	-	
RN027845	Robinson River community	46.3	47	Pte	12 clays 30 weathered basalt 46.3 Basalt	Struck at 28 m	2.2	5620	4.10.91	18	
RN028233	Robinson River community	42	42	Pte	0 - 36 Basalt 36 - 42 Siltstone	20 – 36	1.5		8.10.93	8	Water quality noted as good
RN028420	Redbank Mine	90	89	Pms/Ptg	0 - 12 sandstone 12 - 18 Kaoleen 18 - 42 volcanics 42 - 90 breccia	18-24	2.5	190	10.5.93	10	pH 5.7

Registered Number	Location	Depth drilled	Casing depth	Probable Formation drilled	Strata details	Supply depth m	Airlift Yield L/s	Ec	Date drilled	Swl m	comment
RN028421	Redbank Mine	54	54	Pms/Ptg	0 - 12 sandstone 12 - 24 Kaolin 24 - 42 volcanics 42 - 54 breccia	18 and 24	2 & 0.5	190	11.5.93	12.5	pH 7.1
RN028422	Redbank Mine	60	60	Pms/Ptg	3 – 18 sandstone 18 - 24 quartzite 24 - 60 volcanics	18,30,42,54	5	350	12.5.93	9.8	pH7.7
RN028423	Redbank Mine	36	3	Pms/Ptg	2 - 12 sandstone 12 - 36 volcanics	30	seepa ge	NA	12.5.93	9.8	
RN028424	Redbank Mine	72	72	Pms/Ptg	0 - 21 sandstone 21 - 24 quartzite 24 - 72 volcanics	33, 60	3.5	350	13.5.93	8.5	pH 7.9
RN028425	Redbank Mine	54	54	Pms/Ptg	3 - 18 sandstone 18 - 54 volcanics	25	seepa ge	390	13.5.93	9.5	
RN028426	Redbank Mine	78	78	Pms/Ptg	3 - 18 sandstone 18 - 24 quartz 24 - 78 volcanics	24,40,72	5	370	14.5.93	10.1	pH 7.9
RN028427	Redbank Mine	78	78	Pms/Ptg	3 - 18 sandstone 18 - 24 quartz 24 - 78 volcanics	36,48,.60	2.5	365	15.5.93	11.1	pH 7.5
RN028428	Redbank Mine	30	30	Pms	6 - 18 sands, gravel 18 - 30 sandstone	10, 18	2	23	15.5.93	5.1	pH 5.4
RN029526	Redbank Mine	64	64	Pms	0 – 30 sandstone & clay 30 - 57 sandstone & siltstone 57 - 64 siltstone	24,33,53	1.4	149	16.9.94	13.5	pH 5.9
RN029527	Redbank Mine	72	72	Pms/Ptg?	0 – 12 sandstone & clay 0 - 72 sandstone	42,53,57,60	10	383	18.9.94	16.5	pH 8.3
RN029528	Redbank Mine	72	72	Pms/Ptg?	0 – 15 Laterite & clay 15 - 72 sandstone	49	2	394	24.9.94	18	pH 8.2
RN029529	Redbank Mine	72		Pms/Ptg	3 - 15 sandstone & clay 15 - 72 sandstone & volcanics	-	dud	-	24.9.94	-	-
RN029530	Redbank Mine	66	60	Pms/Ptg?	12 – 24 laterite & clay 24 - 66 sandstone & siltstone	15, 48-57	10	218	25.9.94	13	pH 8.2
RN031747	Robinson River community	54		Pte	0 – 15 silty clays 15 – 39 Basalt 39 – 43 siltstone 45 – 54 basalt		dud	-	16.9.98	-	
RN031748	Robinson River community	75	6	Pte	0 – 15 silty clays 15 – 42 Basalt 42 – 51 siltstone 51 – 75 basalt	67 in basalt	3.5	1730 6220	17.9.98	18.5	pH 7.6, 8.3 Water quality noted as bad
RN032158	Robinson River community	54	6	Pte	0 – 15.3 clays, gravel 15.3 - 54 Basalt	49 – 49.3	2	5620	3.6.99	27.2	pH 8.4
RN032159	Robinson River community	70	9	Pte	0 – 13.5 sand & gravel 13.5 – 70 Basalt and siltstone layers	52	0.8	-	5.6.99	-	

Registered Number	Location	Depth drilled	Casing depth	Probable Formation drilled	Strata details	Supply depth m	Airlift Yield L/s	Ec	Date drilled	Swl m	comment
RN032800	Robinson River community	67		Pte	0 – 17 clay & gravels 17 – 39 Basalt 39 – 49 siltstone 49 – 67 basalt	27 - 30	0.1	7100	14.10.00	NA	pH 8.1
RN032801	Robinson River community	67	16	Pte	0 – 16.3 soil & gravels 16 – 67 Basalt	15 - 16	0.5	4290	15.10.00	12	

Bores highlighted in violet are those which have intersected Pte – Settlement Creek Dolerite

Formation refers to the geological formation noted on maps Robinson River and Calvert hills (Rawlings, 2002). Note that the letter P at the start of each formation abbreviation refers to the age of the rock as Proterozoic.

Ptq Aquarium Formation
Pto1 Lower Wollogorang Formation
Pto Wollogorang Formation
Pte Settlement Creek Dolerite
Pms Masterton Sandstone (This is equivalent to the Echo Sandstone Ptc)
Ptg Gold Creek Volcanics
Ptc Echo Sandstone
Kl Cretaceous sediments
Ptw Westmoreland conglomerate

Swl = Standing water level.

APPENDIX E: BORES DRILLED INTO SEDIMENTARY ROCKS

Registered Number	Location	Depth drilled m	Aquifer thickness m	Airlift Yield l/s	Ec	date	Swl m	comment	Age / Aquifer type Cretaceous = sedimentary Proterozoic = fractured & weathered.
North Western area									
RN028349	Wonmurri Outstation	56.8	21 – 27 48 - 52	3 15	1905 1500	2.12.92	 6.2	21-27 gravels, sand, clay 40 - 48 grey mudstone 48-52 sandstone	Tertiary/Cretaceous Cretaceous
RN028470	Wonmurri Outstation	60.6	 49 - 53	 10	 1500	5.12.92	 6.2	1 – 38 clay and gravels 38 – 49 grey mudstone 49 – 52 soft sandstone 52 – 60 clay and sand Pump test recommended 2 l/s	 Cretaceous Cretaceous
RN035922	Greenbank Station	103	 78 – 84 86 - 92	 1.7 8.3	 3600 3870	5.11.07	 6.3	0 – 31 Bands of soft sandstone & clay but no water 31 – 78 Grey clay (stone) 78 – chert, dolomite, grey clay 86 - Sandstone	Cretaceous Cretaceous Proterozoic?/Cretaceous? Proterozoic?/Cretaceous?
RN35923	Greenbank Station	116	 Aquifer bands from 38 - 116	 7	 850	8.11.07	 10.6	0 – 20 clay, sand, gravels, chert quartz 20 – 116 sandstone, various colours, soft and firm bands	Cretaceous Proterozoic?/Cretaceous?
North Eastern area									
RN035868	Wollogorang Station	146	27 - 29	2.5	14600	17.10.07	12.9	27 – 29 quartz, clay 29 – 138 grey clay, black shale 138 – 139 sandstone, siltstone	Cretaceous
Southern area									
RN027834 Roads bore	Calvert Hills station	48	30 – 48	2.5	NA	5.12.89	37	Sandstone	Cretaceous sandstone
RN035869	Calvert Hills Station	60.7	35 – 45+	10	56	20.10.08	17.8	Sandstone	Cretaceous sandstone

Swl = Standing water level.

APPENDIX F: DEPARTMENTAL WATER RESOURCES REPORTS

These reports are available from NRETAS. They pertain to this study region and are listed in alphabetical order of area. Scanned reports are available in digital format. Reports can be viewed and downloaded at www.nt.gov.au/landwater/index.jsp.

Scan No:	NRD No:	Title	Type	Area	Author
WRD03023	23/03D	Water Resource Mapping of the Barkly Tabelands	GW	Barkly Region*	S Tickell
WRD89057	57/89D	Bore completion Report - Bore 26068 Bujana outstation	GW	Bujana	R Sanders
WRD92019	19/92D	Bore Completion Report - Bores 27842 & 27843 Crab Hole Outstation	GW	Crab Hole	R Sanders
WRD93054	54/93D	Bore Completion Report, Wollogorang Outstation	GW	Jangalina	A Moser
WRD89059	59/89D	Bore Completion Report - Bore 26071 Donalds Yard (Mamina) Outstation	GW	Mamina	R Sanders
WRD88007	07/88D	Baseflow water quality surveys in rivers in the NT Vol 9 Robinson & Calvert Rivers	SW & GW	Robinson and Calvert Rivers	D F Field, S M Taylor
WRD02047	47/02D	Robinson River Review of Water Supply Source Options	GW	Robinson River	P Jolly
WRD89069	69/89D	Bore completion Report – Bore 26067 Surprise Creek outstation (Calvert Hills)	GW	Yangulinyina	R Sanders

*The Barkly Region abuts this study area to the south.

GW = Groundwater

SW = Surface Water

APPENDIX G: SUMMARY OF BORE INFORMATION

There are no bores in this map region which have been or are currently monitored by NRETAS.

The following bore summary data is provided in alphabetical order of land parcel name.

Calvert Hills

Site	Site Name	Zone	Easting	Northing	Start Date	Drill Depth	Casing Depth	Standing water level	Yield L/s
RN023244	NO.1 GOANNA BORE CALVERT HILLS STN	53	763985	8109168	28/08/1974	78	NA	NA	2.25
RN023245	NO. 2 KARN'S BORE CALVERT HILLS STN.	53	771045	8104158	27/09/1984	78	78	8.52	0.9
RN023246	NO.4 HOMESTEAD ADV.101\09273 CALVERT HILLS STN.	53	747875	8093548	26/08/1984	54.8	52	8.9	3
RN023247	NO. 3 VALLEY BORE ADV.102/73 CALVERT HILLS STN.	53	738725	8086668	7/09/1974	86	86	9.2	1.5
RN026067	DCD SUPRISE CREEK=NICHOLSON RIVER	53	735125	8130868	20/10/1988	64.6	44	18	10
RN027828	WOLLOGORANG RD-206.15K WOLLOGORANG	53	771025	8104068	19/11/1989	100	none		dry
RN027829	WOLLOGORANG RD-206.5K WOLLOGORANG	53	771325	8104118	20/11/1989	100	none		dry
RN027830	WOLLOGORANG RD-193.7K CALVERT HILLS	53	761275	8110918	16/11/1989	30	21	14	3
RN027833	CALVERT HILLS RD-58.2K CALVERT HILLS	53	732375	8082468	2/12/1989	93	58	37	1.2
RN027834	CALVERT HILLS RD-83.15K CALVERT HILLS	53	717775	8065568	4/12/1989	48	48	37	2.5
RN035869	CALVERT HILLS STOCK BORE	53	723942	8070834	20/10/2008	60.7	42	17.8	10
RN036050	Mineral exploration flowing bore CY1 CR1982-0088	53	746355	8088157	3/06/1905	510	NA	flowing	NA

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Site	Site Name	Zone	Easting	Northing	Start Date	Drill Depth	Casing Depth	Standing water level	Yield L/s
RN026068	DCD BUJANA=FOELSCHE RIVER	53	700325	8200767	22/10/1988	52.4	48	10.4	4
RN026069	DCD MAMINA	53	694025	8141167	24/10/1988	70.7	none	dud	dud
RN026070	DCD MAMINA	53	694325	8141067	25/10/1988	100	none	dud	dud
RN026071	DCD MAMINA	53	695125	8141367	25/10/1988	52	47	1.75	10
RN026476	GC 90/1 HOMESTEAD ROBINSON RIVER	53	711975	8145767	18/05/1990	46.5	47	18	2.5
RN027832	WOLLOGORANG RD-127.1K ROBINSON RIVER	53	720725	8158967	13/11/1989	100	58	30	1
RN027844	GC 91/1 ROBINSON RIVER ROBINSON RIVER	53	711075	8146317	3/10/1991	65	none	dud	dud
RN027845	HOMESTEAD NO.2 ROBINSON RIVER	53	711075	8146317	4/10/1991	46.3	46.8	18	2.2
RN028233	MUNGOORBADA ABORIGINAL CORP 1/93 BORE ROBINSON RIVER	53	710325	8147367	8/10/1993	42	42	8	1.5
RN029955	MUNGOORBADA ABORIGINAL CORP 1/95 ROBINSON RIVER	53	706625	8151667	27/05/1995	72	60	10.4	0.2
RN030350	WOLLOGORANG RD-85.9K ROBINSON RIVER	53	705313	8191999	1/11/1995	30	28	24	2
RN030351	WOLLOGORANG RD-77.6K ROBINSON RIVER	53	701961	8201707	3/11/1995	26	24	8	3
RN031747	SITE NO 1	53	711625	8145467	16/09/1998	54	none	dud	dud
RN031748	SITE NO.2 ROBINSON RIVER STATION	53	710664	8145842	17/09/1998	75	6	18.5	3.5
RN032158	SITE A	53	710951	8145558	3/06/1999	54	6	27.2	2
RN032159	SITE B	53	711746	8146161	4/06/1999	70	9	NA	0.8
RN032800	NO 1	53	709674	8147043	12/10/2000	67	none	NA	0.1
RN032801	NO 2	53	709674	8147041	14/10/2000	67	16	12	0.5
RN035465	ROBINSON RIVER WUNDIGALLA OUTSTATION	53	718128	8177293	22/11/2006	60	none	dud	dud

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Site	Site Name	Zone	Easting	Northing	Start Date	Drill Depth	Casing Depth	Standing water level	Yield L/s
RN035466	ROBINSON RIVER WUNDIGALLA OUTSTATION	53	717715	8177447	23/11/2006	18	18	1.5	2.5
RN035920	Robinson River Aboriginal Land Trust monitoring bore	53	700450	8164460	20/10/2007	163	76	42.47	25

Greenbank

Site	Site Name	Zone	Easting	Northing	Start Date	Drill Depth	Casing Depth	Standing water level	Yield L/s
RN027842	GC 91/1 CRAB HOLE ROBINSON RIVER	53	706395	8227167	30/09/1991	70.8	69	16.45	3
RN027843	GC 91/2 CRAB HOLE ROBINSON RIVER	53	706385	8226167	1/10/1991	70.8	52.6	15.1	2.1
RN028349	MANANGOORA STATION 1/92 MANANGOORA STATION	53	699325	8224467	27/11/1992	56.8	55	6.2	15
RN028470	MANANGOORA 2/92 MANANGOORA STATION	53	699406	8224528	2/12/1992	60.6	54	6.2	10
RN035922	GREENBANK STATION INVESTIGATION BORE	53	727974	8220018	5/09/2007	103	5	6.28	15
RN035923	GREENBANK STATION INVESTIGATION BORE	53	723320	8211356	8/11/2007	116	71	10.6	5

Seven Emu

Site	Site Name	Zone	Easting	Northing	Start Date	Drill Depth	Casing Depth	Standing water level	Yield L/s
RN035921	Seven Emu Station stock bore	53	722981	8196939	30/10/2007	67	20.4	18.98	2

Wollogorang

Site	Site Name	Zone	Easting	Northing	Start Date	Drill Depth	Casing Depth	Standing water level	Yield L/s
RN001889	POLICE BORE WOLLOGORANG	53	813815	8093328	11/09/1959	76	NA	15.2	0.5
RN005455	HOMESTEAD WELL WOLLOGORANG	53	813615	8094878	18/10/1967?	20.7	10	12.9	NA
RN009083	POLICE BORE 1/77 WOLLOGORANG	53	813815	8093328	17/06/1977	20.3	20	NA	2.5
RN009277	PDH 1 (RESTRICTED INFO) WOLLOGORANG STN.	53	802115	8059948	24/10/1977	150	NA	NA	5
RN009278	PDH 2 (RESTRICTED INFO) WOLLOGORANG STN.	53	802115	8059948	1/11/1977	94.5	NA	NA	28
RN009279	PDH 3 (RESTRICTED INFO) WOLLOGORANG STN.	53	802115	8059948	4/11/1977	136.6	NA	NA	12.5
RN024295	ZLOTKOWSKY P WOOLOGORANG STN	53	813425	8094768	24/10/1985	37	37	8.9	2
RN027472	REDBANK MINE-ACCESS RD NO.1 WOOLOGORANG	53	792525	8097968	11/12/1990	42	36	8.5	2.5
RN027473	REDBANK MINE-SANDY FLAT NO.2 WOOLOGORANG	53	791425	8097068	4/12/1990	42	38	8.5	2
RN027474	REDBANK MINE-SANDY FLAT NO.1 WOOLOGORANG	53	791425	8097068	30/11/1990	42	37	8.5	2
RN027827	WOLLOGORANG RD-214.75K WOLLOGORANG	53	778725	8102068	22/11/1989	47	40	22	1.5
RN027831	WOLLOGORANG RD-240K WOLLOGORANG	53	800325	8093168	1/12/1989	98.5	none	dud	dud
RN028420	AMALG SYNDICATE 1/93 REDBANK MINE WOLLOGORANG	53	793415	8098657	9/05/1993	90	89	10	2.5
RN028421	AMALG SYNDICATE 2/93 REDBANK MINE WOLLOGORANG	53	794215	8099188	10/05/1993	54	54	12.5	2
RN028422	AMALG SYNDICATE 3/93 REDBANK MINE WOLLOGORANG	53	793119	8098968	11/05/1993	60	60	9.8	5
RN028423	AMALG SYNDICATE 4/93 REDBANK MINE WOLLOGORANG	53	793325	8098880	12/05/1993	36	3	9.8	seepage
RN028424	AMALG SYNDICATE 5/93 REDBANK MINE WOLLOGORANG	53	793045	8098978	12/05/1993	72	72	8.5	3.5
RN028425	AMALG SYNDICATE 6/93 REDBANK MINE WOLLOGORANG	53	793333	8098882	13/05/1993	54	54	9.5	seepage
RN028426	AMALG SYNDICATE 7/93 REDBANK MINE WOLLOGORANG	53	793331	8098877	13/05/1993	78	78	10.1	5

Wollogorang

Site	Site Name	Zone	Easting	Northing	Start Date	Drill Depth	Casing Depth	Standing water level	Yield L/s
RN028427	AMALG SYNDICATE 8/93 REDBANK MINE WOLLOGORANG	53	792925	8098578	14/05/1993	78	78	11.1	2.5
RN028428	AMALG SYNDICATE 9/93 REDBANK MINE WOLLOGORANG	53	793025	8098868	15/05/1993	30	30	5.1	2
RN028673	WOLLOGORANG WOLLOGORANG STATION	53	817645	8093758	1/07/1993	100	NA	dud	dud
RN028674	WOLLOGORANG WOLLOGORANG STATION	53	817525	8093468	5/07/1993	102	97	4.5	1.5
RN028675	WOLLOGORANG WOLLOGORANG STATION	53	817525	8093498	9/07/1993	128.8	82	1.8	1
RN029526	ALAMEDA PTY LTD REDBANK MINE 1/94	53	792625	8099568	16/09/1994	64	64	13.5	1.4
RN029527	ALAMEDA PTY LTD REDBANK MINE 2/94	53	793225	8098968	17/09/1994	72	72	16.5	10
RN029528	ALAMEDA PTY LTD REDBANK MINE 3/94	53	792825	8098568	23/09/1994	72	72	18	2
RN029529	ALAMEDA PTY LTD REDBANK MINE 4/94	53	793225	8098668	24/09/1994	72	none	dud	dud
RN029530	ALAMEDA PTY LTD REDBANK MINE 5/94	53	792625	8099568	24/09/1994	66	60	13	10
RN035868	WOLLOGORANG STATION STOCK BORE	53	819177	8138656	17/10/2008	146	35	12.8	2

APPENDIX H: BORE WATER CHEMISTRY

All groundwater contains various kinds of dissolved salts (minerals). Small quantities of many of these salts are essential to good health. Excessive concentrations however, can limit the uses of the water. Following is some information to help you interpret the water quality represented on the following pages. The information has been summarised from NRETAS technical fact sheets @ www.nt.gov.au/nreta/publications/natres/waterfactsheets.html. More information is available from this site.

Source of dissolves salts:

Salts in the water originate from minute quantities dissolved in rain water and from the chemical breakdown of rocks. Nitrate is also produced in the soil by natural biological activity. Over long periods of time evaporation concentrates them to varying degrees.

Guideline Values:

The maximum recommended values listed beside each salt are guidelines rather than strict limits. The reason for this is because there are often many factors governing how a particular salt affects the user. These can include a person's age and the total volume of water consumed. The guidelines given below are conservatively chosen in order to cover most situations. (Guideline values for stock noted in brown)

Fluoride 1.5 mg/L **(Stock 2 mg/L)**	This limit is based on health considerations. Excess fluoride can be removed by water treatment.
Hardness 200 mg/L (Aesthetic guideline only)	Hardness is a measure of the amount of calcium and magnesium in the water. Hard waters can cause the build up of scale in hot water pipes and fittings. They also require more soap to obtain a lather.
Iron 0.3 mg/L	Above this limit, taste may be unacceptable but it does not pose a health problem. High iron concentrations give water a rust brown appearance resulting in staining of laundry, pipe encrustation and odour problems. A common way to remove iron is to aerate the water by cascading it into a tank and allowing the iron to floc or settle.
Nitrate 50 mg/L **(Stock 400 mg/L)**	Based on health considerations a limit of 50mg/L is recommended for babies less than three months old and 100mg/L for older children and adults. Nitrate levels can be reduced if necessary by water treatment.
pH 6.5 - 8.5 **(Stock 5.5 – 9.0)**	This is a measure of the acidity or alkalinity. Values less than 6.5 indicate acidic water and can results in corrosion of pipes and fittings. When pH is more than 7.5, the water is alkaline and encrustation of pipes with calcium carbonate can occur. pH can be treated.
Total Dissolved Solids (TDS) 500 mg/L **(Stock 10 000 mg/L)** **Chloride 250 mg/L** **Sulphate 250 mg/L** **(Stock 2000 mg/L)** **Sodium 180 mg/L**	Above these limits for TDS, chloride, sulphate and sodium, taste may be unacceptable but it does not pose a health problem. (Aesthetic guideline only) TDS is approximately equal to 0.6 x EC

The following bore water chemistry data is provided in alphabetical order of land parcel name.

Calvert Hills

BoreRN	Sample Date	Sample No:	EC (uS/cm)	pH	Total Alkalinity	Bicarb-onate	Total Hardness	TDS	Calcium	Chloride	NaCl	Magn-esium	Nitrate	Potass-ium	Sodium	Sulp-hate	Flou-ride	Iron	Silica	Other Analysis
RN023245	27/11/1984	45210	970	7.3	488	594	491	560	70	46	74	77	1	5	34	8	0.6	2.6	22	
RN023246	4/12/1984	45211	1010	7.4	447	545	479	580	75	64	105	71	17	14	40	6	0.6	0.1	45	
RN023247	30/11/1984	45212	660	8	349	426	349	400	64	12	20	46	1	4	9	27	0.2	3.8	29	
RN023247	1/12/1984	45213	670	7.3	351	429	365	390	67	12	20	48	1	4	8	3	0.2	0.2	29	
RN026067	21/10/1988	49672	430	7.8	223	272	216	245	42	12	20	27	1	4	5	6	0.2	9.7	25	
RN026067	7/11/1988	49673	430	7.1	222	271	224	240	42	8	13	29	1	3	5	6	0.1	0.5	25	Heavy Metals
RN035869	20/10/2007	EL09256	56	7.3	11	11	5.1	30	0.4	10.4		1	0.1	2.5	6.3	2.3	0.1	0.94	16.2	Heavy Metals
RN036050	20/10/2007	EL09256	208	10	79	18	61.9	110	12	17.3		7.7	0.02	9.3	11.5	3.1	0.1	0.12	0.2	Heavy Metals

Garawa Land Trust / Robinson River

BoreRN	Sample Date	Sample No:	EC (uS/cm)	pH	Total Alkalinity	Bicarb-onate	Total Hardness	TDS	Calcium	Chloride	NaCl	Magn-esium	Nitrate	Potass-ium	Sodium	Sulp-hate	Flou-ride	Iron	Silica	Other Analysis
RN026068	22/10/1988	49675	435	7.8	217	264	206	260	38	18	30	27	1	3	13	8	0.2		43	Heavy Metals
RN026068	11/11/1988	49676	440	7.6	218	266	217	270	39	14	23	29	1	3	12	6	0.1	0.4	42	Heavy Metals
RN026068	11/11/1988	49677																		Heavy Metals
RN026068	14/07/1989	49678	265	7.6	128	156	130	145	19	9	15	20	2	3	5	6	0.1	0.3	12	Heavy Metals
RN026071	26/10/1988	49679	610	8	308	376	256	350	40	13	21	38	1	8	40	26	0.3	16.2	20	Heavy Metals
RN026071	9/11/1988	49680	640	7.5	320	390	273	365	42	11	18	41	1	8	44	26	0.4	0.4	21	Heavy Metals
RN026071	9/11/1988	49681																		Heavy Metals
RN026476	29/10/1996	158359	967	7.2	481	587	520	490	44	53	87	100	8	4	21	26	0.9	0.1	1	
RN026476	29/10/1996	155239	967	7.2	481	587	520	490	44	53	87	100	8	4	21	26	0.9	0.1	1	
RN026476	29/04/1998	159466	922	6.6	452	551	473	513	40	47	77	91	9	4	21	30	1	0.1	32	
RN026476	17/12/1999	163960	910	7.3	424	517	410	515	13	49	81	92	10	4	26	25	1.1	0.1	32	
RN027844	29/04/1998	159464	1026	6.6	529	645	550	587	46	46	76	106	1	4	19	38	1	0.7	32	
RN027844	29/04/1998	159465	1021	6.5	531	647	543	594	45	46	76	105	1	4	19	38	1	0.4	32	
RN027845	4/10/1991	51054	5620	7.8	125	152	1350	3570	294	1150	1900	149	52	21	689	1010	1.7		29	
RN029955	28/05/1995	143010	725	7.6	359	438	253	432	37	20	33	39	1	16	24	48	0.4		14	
RN031748	17/09/1998	161564	6120	8.3	184	224	569	3570	62	1920	3164	101	1	85	923	15	1.2	28	12	
RN032158	4/06/1999	163801	5620	8.4	188	215	439	3173	87	1742	2871	54	1	60	945	10	1.8	0.6	11	

Garawa Land Trust / Robinson River

BoreRN	Sample Date	Sample No:	EC (uS/cm)	pH	Total Alkalinity	Bicarb-onate	Total Hardness	TDS	Calcium	Chloride	NaCl	Magn-esium	Nitrate	Potass-ium	Sodium	Sulp-hate	Flou-ride	Iron	Silica	Other Analysis
RN032158	20/11/1999	163981	5190	8.1	230	281	380	3086	78	1584	2610	45	1	66	875	18	1.9	1.2	11	
RN032158	17/12/1999	164161	5350	7.9	239	291	482	3046	60	1643	2708	81	1	70	870	1	1.9	0.8	14	
RN032158	25/01/2000	412	3760	7.6	262	319	484	2152	64	1080	1780	79	1	37	528	10	1.7	0.2	30	
RN032800	10/01/2001	32800	7100	8.1	194	236	549	4390	113	2120	3490	65	1	118	1060	15	1.5	1.1	5	
RN032801	10/02/2001	63	4290	8.1	282	344	607	2510	87	1160	1910	95	1	61	514	22	1		19	
RN035920	24/10/2007	EL09256 sample 8	515	8	290	290	269	290	33.8	12		44.8	0.44	3.9	7.3	1.6	0.2	0.78	30.2	Heavy Metals
RN035920	24/10/2007	EL09998 sample 1	67	7.3	29	29	6		0.1	8.8		1.3	0.32	15.8	7.1	4.5	0.4		41.6	
RN035920	24/10/2007	EL09998 sample 3	94	7.5	43	43	26		3.4	6.9		4.3	0.34	4.9	7.3	0.8	0.2		20.8	
RN035920	24/10/2007	EL09998 sample 5	237	8.2	117	117	112	140	11.3	7.9		20.4	0.02	5.8	6.7	0.7	0.2		25.6	

Greenbank

BoreRN	Sample Date	Sample No:	EC (uS/cm)	pH	Total Alkalinity	Bicarb-onate	Total Hardness	TDS	Calcium	Chloride	NaCl	Magn-esium	Nitrate	Potass-ium	Sodium	Sulp-hate	Flou-ride	Iron	Silica	Other Analysis
RN027842	1/10/1991	51050	500	7.9	264	322	245	305	37	14	23	41	1	3	16	9	0.2	0.9	26	
RN027842	25/10/1991	51051	545	7.5	283	345	266	305	46	14	23	37	1	3	20	9	0.2	0.1	26	
RN027843	2/10/1991	51052	495	7.9	258	315	232	295	37	16	26	34	1	3	27	10	0.2	1	24	
RN027843	28/10/1991	51053	540	7.5	283	345	282	310	44	12	20	42	1	3	18	10	0.2	0.1	24	
RN028349	1/12/1992	51370	1550	7.2	249	304	229	823	39	323	532	32	2	15	225	49		1.2	23	
RN028349	11/02/1993	51371	1690	7.5	377	460	310	926	63	314	517	37	1	16	225	27	0.4	2.6	33	
RN028349	17/06/1993	51372																		Arsenic
RN028349	17/06/1993	51373																		Arsenic
RN028349	17/06/1993	51374							40			43						0.58		Heavy Metals
RN028349	18/06/1993	51375	1630	7.4	273	333	258	884	39	331	545	39	1	15	248	51	0.3	0.7	20	
RN028349	18/06/1993	51376																		Arsenic
RN028349	15/07/1993	51377																		Arsenic
RN028349	15/07/1993	51378																		Arsenic
RN028349	15/07/1993	51379																0.05		Arsenic
RN028470	4/12/1992	51463	1690	7.6	246	300	246	908	36	353	582	38	1	15	241	69	0.3	1	20	
RN028470	21/06/1993	51464	1785	7.4	247	301	278	981	37	389	641	45	1	15	266	70	0.3	0.6	18	
RN035922	5/11/2007	EL09256 sample 1	3450	8.1	142	142	526	1940	41.5	1070		103	0.02	15.6	469	81.5	0.2		15.2	Heavy Metals
RN035922	5/11/2007	EL09256 sample 2	2660	8.1	219	219	487	1500	53.5	746		85.7	0.02	11.3	340	75.7	0.3		19.4	Heavy Metals

Greenbank

BoreRN	Sample Date	Sample No:	EC (uS/cm)	pH	Total Alkalinity	Bicarb- onate	Total Hardness	TDS	Calcium	Chloride	NaCl	Magn- esium	Nitrate	Potass- ium	Sodium	Sulp- hate	Flou- ride	Iron	Silica	Other Analysis
RN035923	8/11/2007	EL09256	806	8.3	254	254	224	470	28.6	111		37.1	0.12	6.3	82.9	22.8	0.2	.02	31.8	Heavy Metals

Seven Emu

BoreRN	Sample Date	Sample No:	EC (uS/cm)	pH	Total Alkalinity	Bicarb- onate	Total Hardness	TDS	Calcium	Chloride	NaCl	Magn- esium	Nitrate	Potass- ium	Sodium	Sulp- hate	Flou- ride	Iron	Silica	Other Analysis
RN035921	30/10/2007	EL09256	458	8	217	217	221	260	38.4	24.6		30.5	0.02	5	10.4	3.8	0.1	0.3	39.6	Heavy Metals

Wollogorang

BoreRN	Sample Date	Sample No:	EC (uS/cm)	pH	Total Alkalinity	Bicarb-onate	Total Hardness	TDS	Calcium	Chloride	NaCl	Magn-esium	Nitrate	Potass-ium	Sodium	Sulp-hate	Flou-ride	Iron	Silica	Other Analysis
RN001889	10/09/1959	2928		7		378	428	1125	62	315		66		19	190	94	0.6			
RN001889	27/09/1967	2929	1200	8	356	217	365	701	50	45		84		26		80	1	0.1		
RN001889	5/05/1977	2930	1350	7.5	510	622	783	940	92	152	250	130	157	6	43	20	0.9	0.2	72	
RN005455	27/09/1967	9232	700	7.5	356	217	362	400	3	6		85	2.6	5	20		0.7	0.1		
RN009083	15/06/1977	18887	950	7.8	395	482	456	530	56	74	122	77	24	7	32	20	1.7	0.5	47	
RN009083	22/06/1977	18888	1100	8	448	546	530	632	66	88	145	89	44	8	35	14	0.7	0.2	53	
RN009083	23/06/1977	18889	1120	7.1	460	561	543	510	68	83	136	91	48	7	35	20	0.6	0.2	57	
RN009277	24/10/1977	20025	86	6.7	22	27	9			10	16									Arsenic
RN009278	1/11/1977	20026	51	6	5	6	9			5	8									Arsenic
RN009279	4/11/1977	20027	160	4.1			12			10	16									Arsenic
RN027472	13/12/1990	50778	375	7.8	189	231	169	215	30	5	8	23	1	9	8	10	0.2	0.8	26	
RN027473	10/12/1990	50779	375	8.2	190	232	175	225	27	5	8	26	1	9	7	12	0.1	0.6	30	
RN027474	3/12/1990	50780	375	7.7	185	225	175	230	27	5	8	26	3	9	7	16	0.1		28	
RN028420	10/05/1993	51442	211	5.7	11	14	45	177	5	7	12	8	1	14	12	64	0.5		45	
RN028421	11/05/1993	51443	162	7.1	28	34	56	150	6	6	10	10	1	10	5	43	1.1		51	
RN028422	12/05/1993	51444	319	7.7	165	201	163	179	24	6	10	25	1	7	5	10	0.4	9.9	31	
RN028424	13/05/1993	51445	348	7.9	177	216	170	197	30	8	13	23	1	7	7	11	0.2	2.1	28	
RN028426	14/05/1993	51446	354	7.9	184	224	182	195	30	7	12	226	1	7	6	11	0.2	4.4	30	
RN028427	15/05/1993	51447	353	7.5	148	181	169	210	28	9	15	24	1	9	7	34	0.2	5.9	20	
RN028428	15/05/1993	51448	23	5.4	2	2	4	31	1	6	10	1	1	1	3	1	0.1		16	

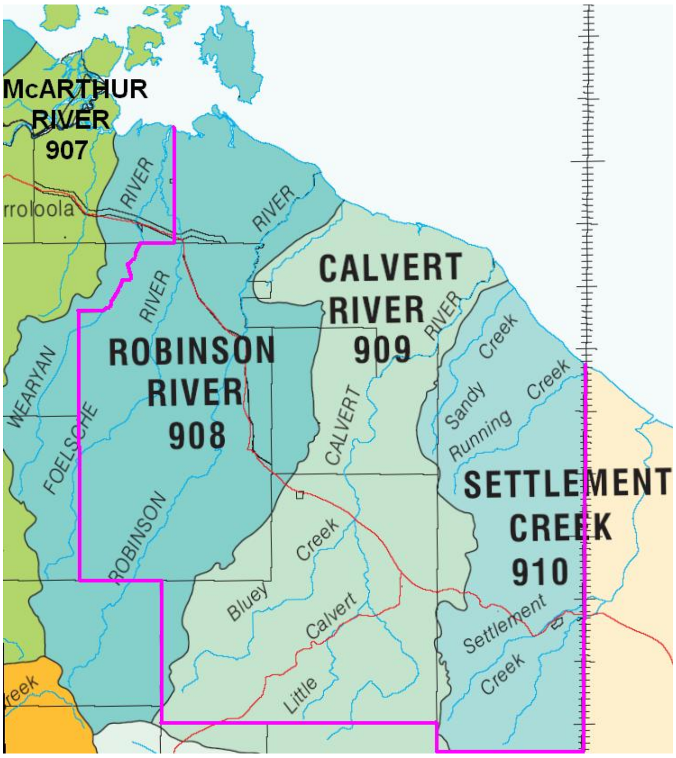
Wollogorang

BoreRN	Sample Date	Sample No:	EC (uS/cm)	pH	Total Alkalinity	Bicarb-onate	Total Hardness	TDS	Calcium	Chloride	NaCl	Magn-esium	Nitrate	Potass-ium	Sodium	Sulp-hate	Flou-ride	Iron	Silica	Other Analysis
RN028674	9/07/1993	51527	469	8.6	245	287	240	267	45	8	13	31	1	8	9	18	0.1		16	
RN028674	10/08/1993	51528	512	7.4	267	325	270	271	57	8	13	31	1	7	7	17	0.1	0.6	18	
RN028674	10/08/1993	51529							53			32						0.47		Heavy Metals
RN028675	16/07/1993	51530	481	8.5	259	303	255	272	46	7	12	34	1	7	8	15	0.1	5.9	21	
RN028675	12/08/1993	51531	543	7.4	289	352	295	294	62	9	15	34	1	6	6	14	0.1	0.2	21	
RN028675	12/08/1993	51532							58			34						0.21		Heavy Metals
RN029526	16/09/1994	142054	24	5.9	2	3	1	53	1	8	13	1	1	4	3	5	0.1	37	24	
RN029527	18/09/1994	142037	370	8.3	191	233	137	223	27	7	12	17	1	8	5	13	0.1	5	31	
RN029528	24/09/1994	142038	368	8.2	185	225	132	219	23	7	12	18	1	7	6	16	0.3	15.4	29	
RN029530	25/09/1994	140412	197	8.2	96	117	86	132	18	6	10	10	1	16	4	6	0.1	1.3	24	
RN035868	17/10/2007	EL09256	14600	7.7	353	353	2790	9800	341	4830		471	0.02	54.7	2140	818	0.6		38.8	Heavy Metals

APPENDIX I: SURFACE WATER SITES

Surface water sites include:

- Sites along a river
- Waterholes
- Springs



River basins across the Robinson and Calvert Rivers map region

All NRETAS surface water sites have a unique 'gauge site', 'G' number and name eg. G9085000 Koolfella Creek At spring. Sites are numbered according to which basin (catchment) they lie within. The first 3 digits of the 'G' number refer to the basin number and the following digits identify the site. The following surface water site tables are provided in numerical order of basin (catchment) number.

Basins represented in the Robinson and Calvert Rivers Region are shown in the figure to the left. These are:

- 908 Robinson River Basin
- 909 Calvert River Basin
- 910 Settlement Creek Basin

Only those sites within the map sheet are listed.

In each of these basins data is listed in order of:

- River gauging stations with a continuous height record (and flow measurements)
- Water quality sites (Some of these sites have river flow measured)

For the river gauging stations that have a continuous height record and flow measurements, plots of river height and discharge for the period of record are provided. These are:

- G9080122
- G9080133 (Outside of, but close to the study region and of interest as baseflow is sourced from the Karns Dolomite)
- G9090248
- G9090249

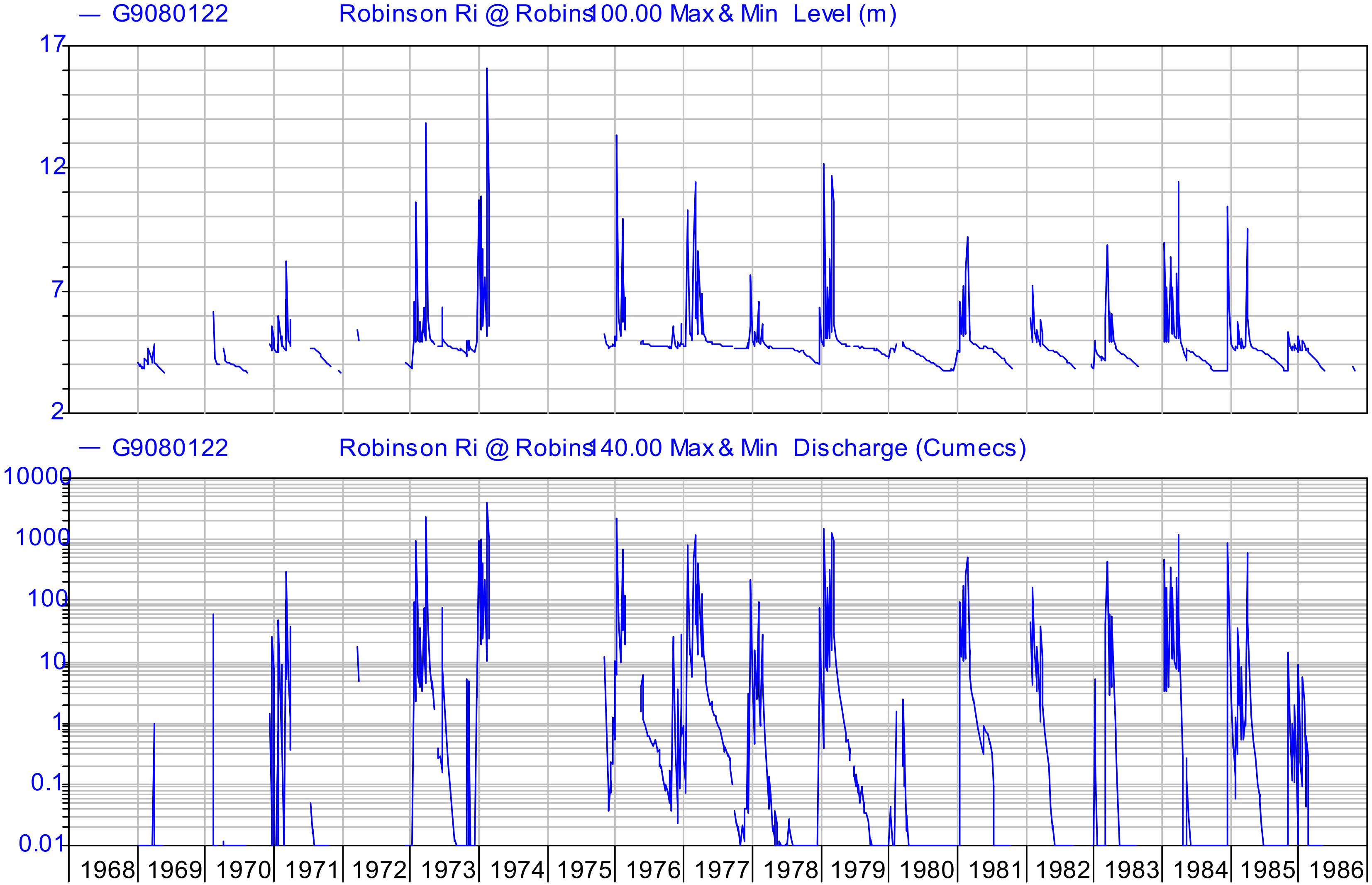
There are no gauging stations in this study region currently recording river level.

Dept Nat Resources, The Arts & Sport

HYPLOT V132 Output 18/09/2009

Period 19 Year Plot Start 00:00_01/01/1968 1968-87

Interval 10 Day Plot End 00:00_01/01/1987



Dept Nat Resources, The Arts & Sport

HYPLOT V132 Output 27/09/2009

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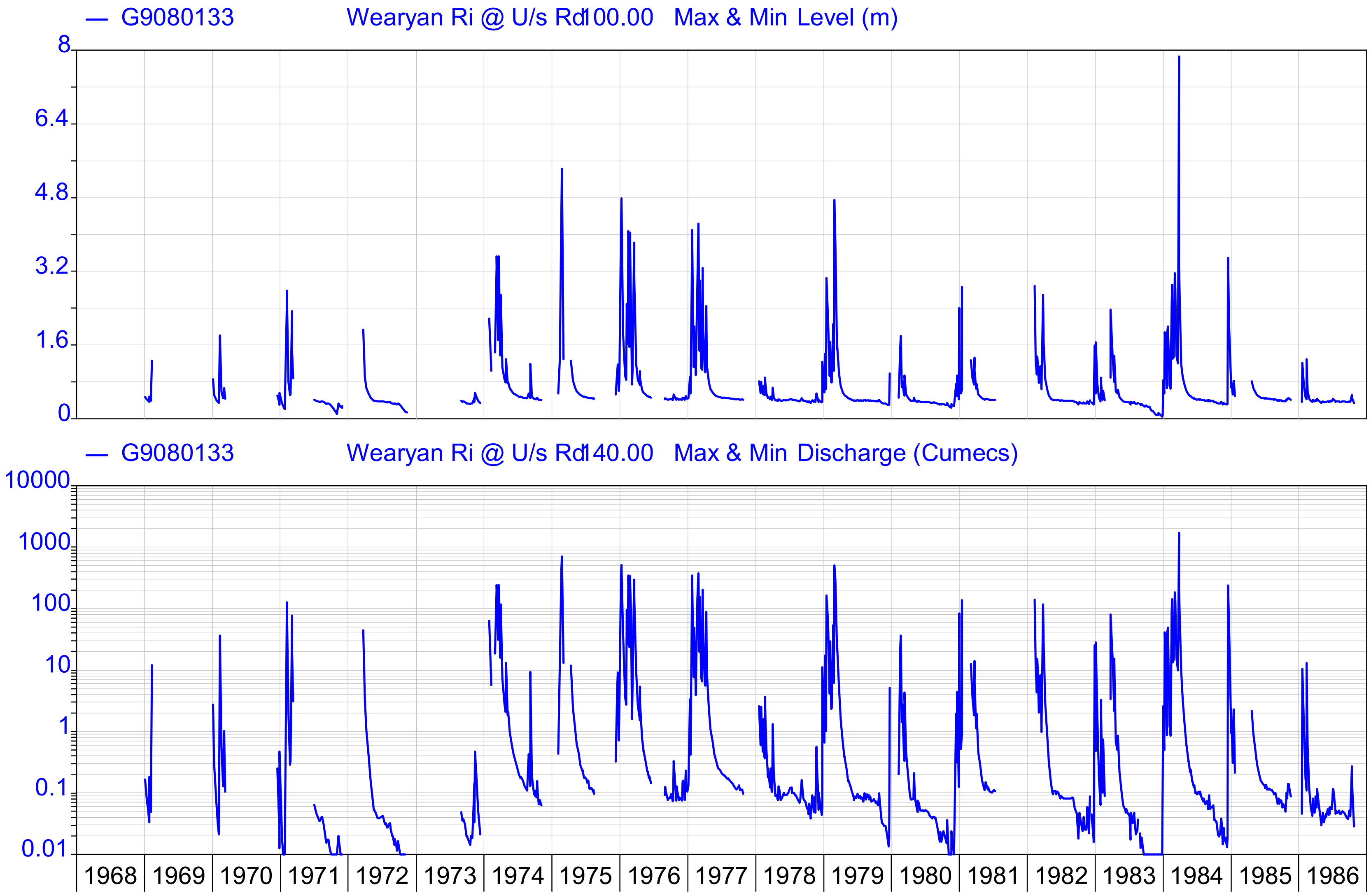
Interval 10 Day Plot End 00:00_01/01/1987



Dept Nat Resources, The Arts & Sport

HYPLOT V132 Output 18/09/2009

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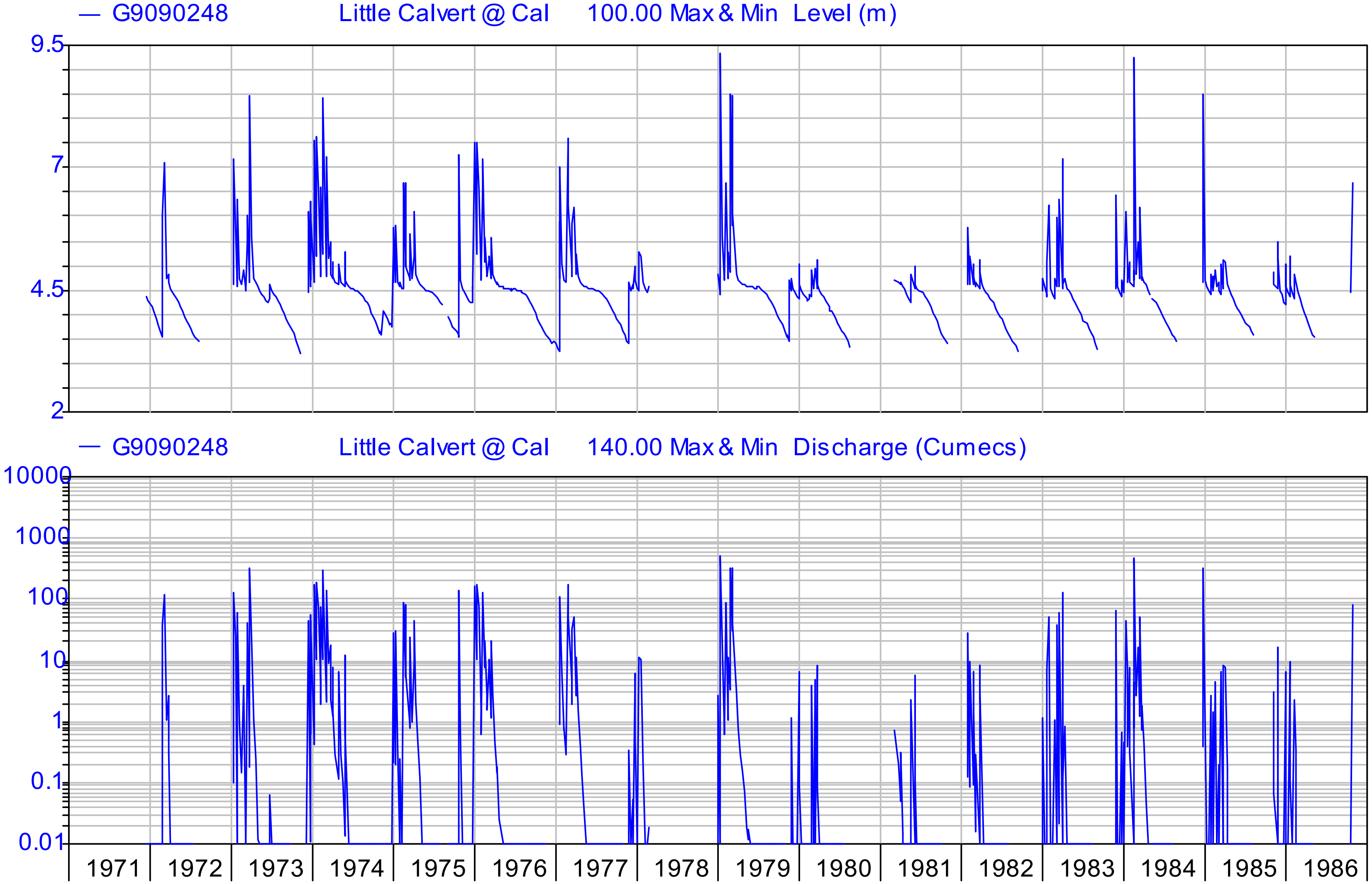
Interval 10 Day Plot End 00:00_01/01/1987

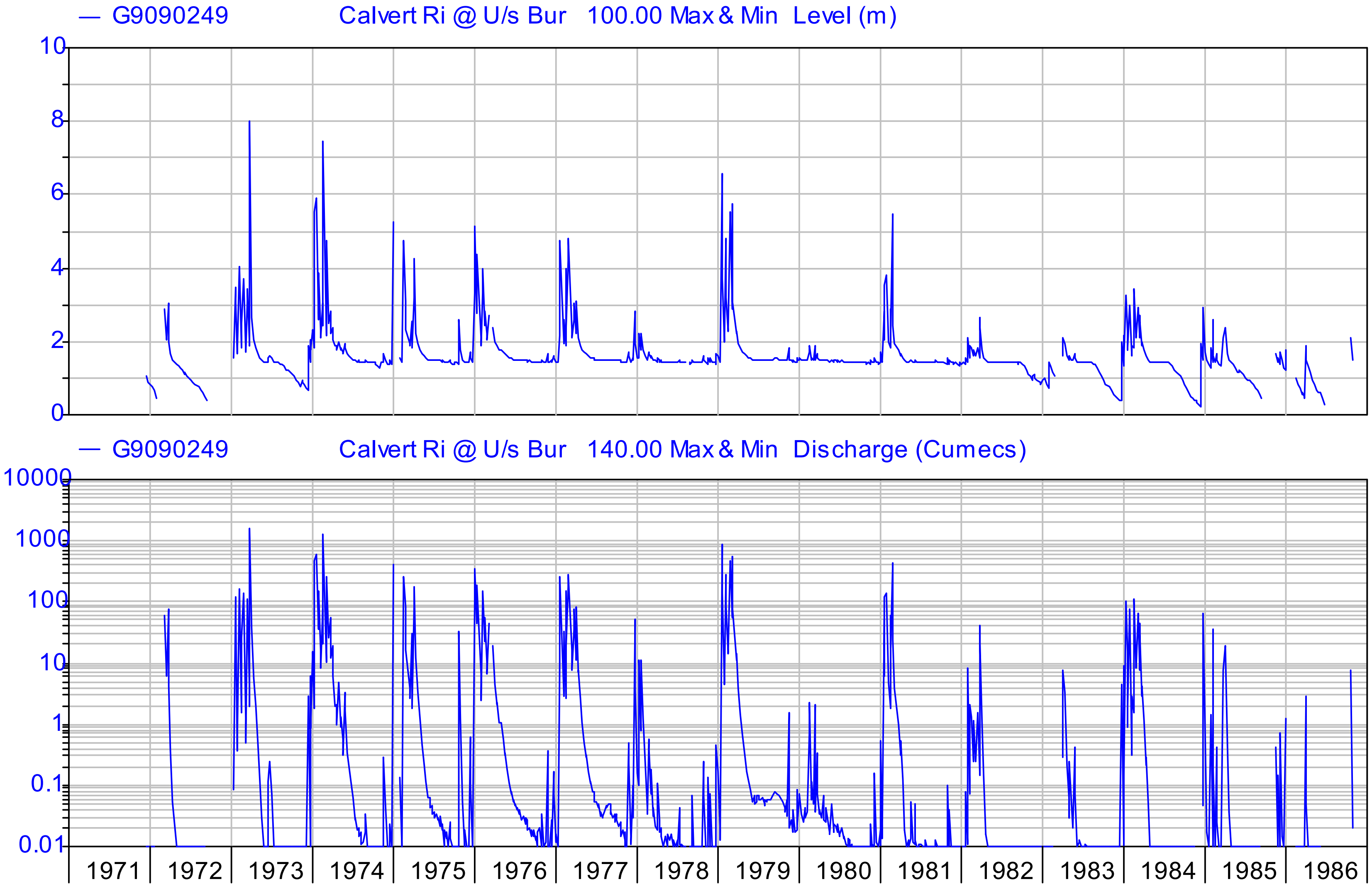


Dept Nat Resources, The Arts & Sport

HYPLOT V132 Output 18/09/2009

Period 16 Year Plot Start 00:00_01/01/1971 1971-87

Interval 10 Day Plot End 00:00_01/01/1987



908 ROBINSON RIVER

STATION	STATION NAME	EASTING	NORTHING	COMMENCE	CEASE	NUMBER OF FLOW RECORDS
Gauging stations with a continuous height record and flow measurements						
G9080122	Robinson River At Robinson Homestead	713328	8147188	15/08/1960	29/10/1986	28

STATION	STATION NAME	EASTING	NORTHING	DATE OF FLOW RECORD	FLOW L/s	SITE TYPE	COMMENT
Water quality sites, some have river flow measured							
G9080140	Foelsche River At Downstream Buffalo Yards	700497	8200809	14/07/1973	399	River	
				28/08/1973	60		
G9080143	Robinson River At Koolafella	719103	8190484	15/08/1962	18	River	
				22/04/1961	14		
				23/04/1961	32		
				5/05/1962	49		
				6/05/1962	46		
				7/05/1962	41		
				24/06/1963	80		
G9085000	Koolfella Creek At Spring	722605	8183067	4/08/1984	31	River	
G9085001	Robinson River At Spring	710425	8140867	3/08/1984	24 est	Spring	In river
G9085003	Robinson River At Spring	704025	8136867	2/08/1984	.1 est	Spring	
G9085004	Robinson River Billabong At Woolagorang Road Crossing	721995	8177867	6/08/1984	242	River	
G9085005	Robinson River At Spring	742355	8221867	4/08/1984	Seepage	Spring	
G9085006	Hobble Strap Creek At Spring	710125	8160567	3/08/1984	3 est	Spring	In river
G9085008	Kangaroo Creek At Spring	735325	8152367		N/A	River	
G9085009	Robinson River At Spring	710625	8155967		N/A	Spring	
G9085011	Mc Craggans Yard Billabong At 30m From Stockyard	724115	8140957		N/A	River	
G9085012	Green Bank Station At Scrutton Lagoon	721875	8206267		N/A	Waterhole	
G9085015	Robinson Station Billabong At Foelsche River Road Cross	701425	8206967	16/06/2007	612	River	
				12/07/2007	562		
				25/09/2007	278		
				27/10/2007	284		

STATION	STATION NAME	EASTING	NORTHING	DATE OF FLOW RECORD	FLOW L/s	SITE TYPE	COMMENT
				26/11/2007	211		
				22/10/2008	120 est		
G9085016	Lily Lagoon At 30m R/h Side Of Road	702115	8201157		N/A	Waterhole	Permanent
G9085017	Snake Lagoon At 16m R/h Side Of Road	704565	8207667		N/A	Waterhole	Permanent
G9085018	Marmarina Lagoon At 36.5m East Of Road	699625	8214667		N/A	Waterhole	
G9085019	Robinson River At Point A	694325	8121868		N/A	River	
G9085020	Robinson River At Point B	697625	8128367		N/A	River	
G9085021	Robinson River At Point C	710425	8140867	3/08/1984	0.1 est	Spring	
G9085022	Robinson River At Point D	710625	8155967	3/08/1984	4 est	River	
G9085023	Robinson River At Point E	713525	8164567	3/08/1984	3 est	River	
G9085024	Robinson River At Point F,Creek near Wundigalla	717912	8177367	3/08/1984	3 est	River	
				27/10/2007	2 est		
G9085025	Robinson River At Point G	722125	8181167		N/A	River	
G9085026	Kangaroo Creek At Point H, 1km u/s Robinson River.	722195	8180667	4/08/1984	0.4	River	
				14/12/2006	60 est		
				27/10/2007	CTF		
G9085027	Robinson River At Point I	721995	8188767	4/08/1984	208	River	
G9085029	Koolfella Creek At Point K	722045	8189167	8/08/1984	15	River	
				16/08/2006	100 est		
				12/12/2006	25 est		
				17/06/2007	5 est		
G9085030	Robinson River At Point L	722405	8199567	4/08/1984	394	River, tidal	
G9085031	Robinson River At Point M	722565	8205867		N/A	River, tidal	
G9085032	Robinson River At Point N	723345	8213567		N/A	River, tidal	
G9085033	Robinson River At Point O	723895	8218967		N/A	River, tidal	
G9085034	Robinson River At Point P	724325	8225767		N/A	River, tidal	
G9085035	Robinson River At Point Aj	687725	8111668		N/A	River	
G9085037	Robinson River At Point Al	687425	8113868		N/A	River	
G9085038	QUAKER CREEK	689329	8133367		N/A	River	
G9085040	Robinson River outlet channel from Community Waterhole	711886	8146009	3/11/2006	146	River	
				13/12/2006	168		
G9085041	Robinson River app. 9 km D/S Robinson Community W/hole	710941	8152903	3/11/2006	76	River	
G9085042	Tributary to Robinson River 15km D/S Robinson Community	712320	8158500	3/11/2006	15	River	
				22/11/2007	5 est		
G9085043	Robinson River @ 18km D/S Robinson Community Water hole	711730	8161633	3/11/2006	442	River	

STATION	STATION NAME	EASTING	NORTHING	DATE OF FLOW RECORD	FLOW L/s	SITE TYPE	COMMENT
G9085044	Hobblestrap Creek 100m U/S Robinson R confluence	711499	8161284	2/11/2006	188	River	
				21/06/2007	140		
G9085045	Robinson River 7.2km U/S Wollogorang Road crossing	715391	8171504	4/11/2006	823	River	
G9085046	Robinson River 11km U/S Wollogorang Road crossing	713921	8167994	4/11/2006	627	River	
G9085047	Quaker Creek Tributary @ 1.3km NE Quaker Stock Yard	678496	8129751	8/11/2006	N/A	River	
G9085048	Quaker Creek Tributary @ 3.5km NE Quaker Stock Yard	679431	8131847	8/11/2006	N/A	River	
G9085049	Quaker Creek Tributary 3.8km NE of Quaker Stock Yard	679669	8131961	8/11/2006	CTF	River	
G9085050	Skull Creek pool 300m SW of Mamina Outstation.	695396	8141394	7/11/2006	N/A	River	
G9085051	Quaker Creek Tributary @ Djangalla Ceremony site	702062	8136877	7/11/2006	N/A	River	
G9085052	Hobblestrap Creek @ pool 3km SW of Top Hobblestrap Yard	684091	8137370	8/11/2006	CTF	River	
G9085053	Hobblestrap Creek Tributary @ 1km NW Top H/strap Yard	685118	8140625	7/11/2006	trickle	River	
G9085054	Hobblestrap Creek 2.3km North of Top H/Strap Yard	686131	8142167	8/11/2006	CTF	River	
G9085055	Hobblestrap Creek @ 6.3km NE of Top H/strap Yard	688378	8145642	8/11/2006	CTF	River	
G9085056	Hobblestrap Creek 9km U/S Robinson Community Rd xing	694274	8152098	8/11/2006	< 1 est	River	
G9085057	Hobblestrap Creek @ 4km U/S Robinson Community Rd xing	698785	8154158	8/11/2006	CTF	River	
G9085058	Hobblestrap Creek 10m U/S Robinson Community Rd xing	702306	8155778	4/11/2006	10 est	River	
				14/12/2006	CTF		
G9085059	Robinson River D/S Nipper Road crossing	708541	8138231	13/12/2006	124	River	
				21/06/2007	111		
G9085060	Robinson River 50m U/S Wollogorang Road crossing	718786	8177748	6/11/2006	1280	River	
				14/12/2006	1299		
				18/06/2007	1098		
				24/10/2007	526		
G9085061	Nippers Creek 3.4km U/S Robinson River confluence	709356	8134971	13/12/2006	86	River	
G9085062	Robinson River @ Seven Emu Station Crossing	722357	8197057	12/12/2006	1329	River	
				16/06/2007	1117		
				18/07/2007	1331		
				28/09/2007	748		
				25/10/2007	652		
				23/11/2007	586		
				11/08/2008	487		
				20/10/2008	430		
G9085063	seven emu waterhole at old station site	728500	8193800	16/08/2006		River	
G9085064	u/s of 7 emu waterhole	730798	8190842	16/08/2006	20 est	River	
G9085065	rainbow serpent rockhole	729600	8192900	16/08/2006	CTF	River	

STATION	STATION NAME	EASTING	NORTHING	DATE OF FLOW RECORD	FLOW L/s	SITE TYPE	COMMENT
G9085066	seep on cliff edge of robinson river	728175	8209145	16/08/2006	0.1 est	Spring	
G9085067	bullock paddock waterhole/spring	742728	8221195	17/08/2006		Waterhole	Spring, intermittent
G9085068	waterhole at dunes/shark ck spring	744667	8221195	17/08/2006		Waterhole	Spring, intermittent
G9085069	dave yard swamp	748385	8215751	17/08/2006		Waterhole	Intermittent
G9085070	daves yard waterhole	748525	8214106	17/08/2006	N/A	River	Intermittent
G9085071	onion waterhole	747158	8211379	17/08/2006	15 est	River	Permanent waterhole
G9085072	emu waterhole	745937	8210956	17/08/2006	N/A	River	Permanent waterhole
G9085073	robinson river @ confluence poney pocket ck	695864	8123644	21/06/2007	N/A	River	
G9085074	nan spring	714242	8149032	13/12/2006	15 est	Spring	
				11/10/2007	7 est		
G9085075	mc craggan creek @ hwy	730050	8137913	23/08/2006	20 est	River	
				13/07/2007	2 est		
G9085076	kangaroo creek @ hwy	723960	8142227	23/08/2006	20 est	River	
				13/12/2006	7 est		
				18/06/2007	10 est		
				20/10/2007	7 est		
G9085077	nippers creek	709356	8134971	13/12/2006	41	River	
				21/06/2007	77		
G9085079	spirng along the track to 10 mile	706158	8140411	14/12/2006	0.25 est	Spring	
G9085080	wetland discharge creek near wundigalla	716804	8175488	14/12/2006	60 est	River	
				27/10/2007	30 est		
G9085081	sandstone spring on seven emu station	731115	8189654	12/12/2006	2 est	Spring	
G9085082	poney pocket ck u/s from robinson	696012	8123594	21/06/2007	N/A	River	
G9085093	Baker Waterhole	733450	8209254	13/07/2008	CTF	Waterhole	Intermittent
G9085094	Foelsche R 6 km d/s from Kelly Gap	694681	8161455	15/06/2007	60	River	
				24/10/2007	15 est		
G9085095	Foelsche R near Kelly Gap	687676	8158645	15/06/2007	21	River	
G9085096	Foelsche R d/s from Wulaburri o/s	697233	8187472	16/06/2007	360	River	
G9085097	Tributary to Foelsche east of Barramundi yard	679091	8147710	21/06/2007	CTF	River	
G9085098	Foelsche R D/s Barramundi yard	679091	8147710	21/06/2007	CTF	River	
G9085100	Watermelon Bend spring	700770	8212216	21/08/2006	0.1 est	Spring	
G9085101	Horse Creek at road crossing	707649	8187902	23/08/2006	1 est	River	
These sites are in the '908' catchment but have incorrectly been listed under '909'							
G9095012	Kangaroo Creek At Point Q	723324.8	8161667	5/08/1984	seepage	River	
G9095015	Kangaroo Creek At Point T	727424.8	8162767	7/08/1984	16	River	

909 CALVERT RIVER

STATION	STATION NAME	EASTING	NORTHING	COMMENCE	CEASE	NUMBER OF FLOW RECORDS
Gauging stations with a continuous height record and flow measurements						
G9090248	Little Calvert At Calvert Hills Homestead	746467	8093317	24/10/1968	29/10/1986	6
G9090249	Calvert River At U/s Burketown Road Crossing	758550	8095354	27/10/1968	29/10/1986	23

STATION	STATION NAME	EASTING	NORTHING	DATE OF FLOW RECORD	FLOW l/s	SITE TYPE	COMMENT
Water quality sites, some have river flow measured							
G9095000	Bluey Creek At Tannners Yard	738805	8109558		N/A	River	
G9095001	Bluey Creek At Bluey Waterhole	746925	8119368		N/A	River	
G9095002	Bluey Creek At Lagoon	725225	8098368		N/A	River	
G9095003	Bluey Creek At Blackfella Spring	719225	8084068	5/08/1984	0.3	Spring	
G9095004	Calvert River At Spring, Spring at Calvert River discharging to Fig Tree Waterhole	757775	8151350	7/08/1984	38?	Spring	
				6/12/2006	150 est		
				20/11/2007	100 est		
G9095005	Calvert River At Billabong	761225	8168367		N/A	River	
G9095006	Calvert River At Spring [west Side Of Road]	751325	8126168	6/08/1984	0.2	Spring	
G9095007	Calvert River At Spring In Gorge	750125	8143768	7/08/1984	1	Spring	
G9095008	Calvert River At Geo Pt.f	776525	8175667	7/08/1984	500	River	
G9095009	Calvert River At Photo Yard Spring	752625	8118168	9/12/2006	400 est	River	
				22/11/2007	60 est		
G9095010	Karn's Creek At Spring	766825	8139468	7/08/1984	44	River	
G9095011	Little Calvert River At Spring	744425	8074868		N/A	River	
G9095013	Calvert River At Point R	750225	8146168	7/08/1984	18	River	
G9095014	Calvert River At Point S	751425	8123168	6/08/1984	25	River	
G9095016	Surprise Creek At Point U	740525	8144668	7/08/1984	6	River	
G9095017	Calvert River At Point V	750225	8146268	7/08/1984	39	River	
G9095018	Calvert River At Point W, Karns ck us from Calvert confuence	757025	8149568	7/08/1984	115	River	

STATION	STATION NAME	EASTING	NORTHING	DATE OF FLOW RECORD	FLOW l/s	SITE TYPE	COMMENT
				7/12/2006	1684		
G9095019	Calvert River At Point X	757225	8149568		N/A	River	
G9095020	Pungalina Creek At Point Y	760725	8170767	7/08/1984	2	River	
G9095021	Calvert River At Point Z	754425	8162967	7/08/1984	10	River	
G9095022	Seigal Creek At Point Aa	769725	8064468		N/A	River	
G9095023	Calvert River At Point Ab	783624	8185067		N/A	River, tidal	
G9095024	Calvert River At Point Ac	761925	8071968		N/A	River	
G9095025	Bluey Creek At Point Ad	722625	8197667		N/A	River	
G9095026	Calvert River At Point Ae	765425	8085468		N/A	River	
G9095027	Little Calvert River At Point Af	743325	8088068	6/08/1984	CTF	River	
G9095028	Little Calvert River At Point Ag	743325	8088168		N/A	River	
G9095029	Calvert River At Point Ah	754925	8106268		N/A	River	
G9095030	Bluey Creek At Point Ai	738625	8106768		N/A	River	
G9095031	Little Calvert @ Xing north of H/stead	751427	8095597	11/12/2006	44	River	
				18/06/2007	30 est		
				20/10/2007	20 est		
				22/11/2007	25 est		
G9095032	Seigal Creek At Point An	770425	8062368	6/08/1984	20	River	
G9095033	Seigal Point At Point Ao	773125	8053168	6/08/1984	48	River	
G9095034	Road Xing At Surprise Creek	735475	8130868		N/A	River	
G9095035	Karns creek u/s from springs	764803	8140680	7/12/2006	237	River	
				20/06/2007	488		
				21/10/2007	120 est		
				21/11/2007	113		
G9095036	Karns ck 2 km u/s Calvert confuence	757552	8147243	20/06/2007	1791	River	
				21/11/2007	991		
				21/10/2008	669		
G9095037	Coconut spring ck @ track near Pungalina h/s	757589	8149515	6/12/2006	383	River	
				19/06/2007	347		
				27/09/2007	263		
				21/11/2007	203		
				21/10/2008	165		
G9095038	Calvert R @ track Xing behind Pungalina h/s	757532	8149889	6/12/2006	1997	River	
				20/06/2007	3362		
				16/07/2007	2906		

STATION	STATION NAME	EASTING	NORTHING	DATE OF FLOW RECORD	FLOW l/s	SITE TYPE	COMMENT
				27/09/2007	1203		
				21/11/2007	1230		
				21/10/2008	978		
G9095039	Horse Ck, southern site	734327	8085034	16/07/2007	< 5 est	River	
G9095040	Horse creek tributary	736197	8085807	16/07/2007	< 1 est	River	
G9095041	Horse Creek near Valley yard	738818	8086204	16/07/2007	CTF	River	
G9095042	Pool at black rock, Little Calvert R	743403	8089591	18/10/2007	CTF	River	
G9095043	Spring on tributary to Little Calvert River, picnic spot	749020	8094698	11/12/2006	15 est	Spring	
				18/10/2007	15 est		
G9095044	6-mile spring	751126	8094061	11/12/2006	10 est	Spring	
G9095046	9 mile spring western tributary near confluence	751590	8107301	22/11/2007	30 est	River	
G9095047	start of 9 mile spring	750745	8105977	22/11/2007	30 est	Spring	In creek
G9095048	Photo spring creek	753186	8117853	9/12/2006	100 est	Creek	
				22/11/2007	40 est		
G9095049	creek east of Calvert River concrete causeway.	758628	8096710	11/12/2006	1 est	River	
G9095050	Calvert at concrete Xing to homestead	757600	8096000	9/12/2006	50 est	River	
				11/12/2006	20 est		
				18/06/2007	20 est		
				20/10/2007	< 0.1		
G9095051	Bluey ck d/s from Blackfella spring	719786	8084085	16/07/2007	20 est	River	
G9095052	Bluey ck u/s from Blackfella spring	719049	8083965	16/07/2007	10 est	River	
G9095053	Net Creek	739198	8096490	9/12/2006	seepage	River	
G9095054	Spring at side of bank of Bluey Creek.	738100	8101700	9/12/2006	1 est	Spring	
G9095055	Bluey Creek u/s from Net Creek	738100	8101700	9/12/2006	CTF	River	
G9095056	Bluey ck u/s intersection with Calvert River	750770	8125247	17/07/2007	55 est	River	
G9095057	Calvert R u/s intersection with Bluey Ck	751200	8125400	17/07/2007	N/A	River	
G9095058	Calvert River @ Hwy xing	751406	8126169	23/08/2006	1000 est	River	
				11/12/2006	403		
				18/06/2007	327		
				13/07/2007	332		
				26/09/2007	94		
				22/11/2007	50-60 est		
G9095059	Calvert R side spring along Hwy Xing	751233	8126290	18/06/2007	5 est	Spring	
G9095060	Left bank spring,Calvert u/s Tufa fall	751900	8127000	11/12/2006	10 est	Spring	
				18/06/2007	10 est		

STATION	STATION NAME	EASTING	NORTHING	DATE OF FLOW RECORD	FLOW l/s	SITE TYPE	COMMENT
				19/07/2007	10 est		
				26/09/2007	10 est		
G9095061	Calvert R at tufa falls	752225	8127072	18/06/2007	200 est	River	
G9095062	Tufa fall ck, trib to Calvert	752225	8127072	11/12/2006	20 est	River	
				18/06/2007	35 est		
G9095063	surprise ck at hwy Xing	736336	8135078	23/08/2006	30 est	River	
				18/06/2007	30 est		
				13/07/2007	2 est		
				20/10/2007	15 est		
				22/11/2007	20 est		
G9095064	Small creek on way to Pungalina H/stead	7807045?	8119797	19/06/2007	10 est	River	
G9095065	lake Jabiru	770800	8145500	21/10/2007	N/A	Waterhole	Intermittent
G9095066	Lake crocodylus	769723	8148719	8/12/2006	N/A	Waterhole	Intermittent
G9095067	Karns Creek at hwy crossing	770705	8105010	23/08/2006	1 est	River	
				26/09/2007	dry		
G9095068	Karns Creek	771580	8129872	12/10/2007	120 est	River	
G9095069	Bandicoot spring near Karns Ck	761523	8142609	7/12/2006	350 est	Spring	
				20/06/2007	347		
				21/11/2007	281		
G9095070	bubbling sands spring near Karns ck	761345	8142845	7/12/2006	1000 est	Spring	
				20/06/2007	945		
				27/09/2007	796		
				21/11/2007	744		
				21/10/2008	662		
G9095071	Spring behind Pungalina homestead	757555	8149883	6/12/2006	5 est	Spring	
				16/07/2007	< 10 est		
				27/09/2007	6 est		
G9095072	Spring with ferns at Calvert River bank	757698	8151472	6/12/2006	40 est	Spring	
G9095073	Calvert River in the spring area	757698	8151472	6/12/2006	N/A	River	
G9095074	Tributary to the Calvert River with spring discharge	758368	8157630	6/12/2006	15	River	
				20/11/2007	5 est		
G9095075	Brangunna spring near Calvert west of Bath tub springs	759908	8164748	20/11/2007	ctf	Spring	
G9095076	Bath tub springs	758600	8165600	15/07/2007	30 est	Spring	
G9095077	creek east of bath tub springs	759886	8164753	15/07/2007	20 est	River	
G9095078	Crocodile creek 1 km from Calvert R	766149	8171097	21/06/2007	133	River	

STATION	STATION NAME	EASTING	NORTHING	DATE OF FLOW RECORD	FLOW l/s	SITE TYPE	COMMENT
G9095079	Crocodile ck at track crossing	765519	8165412	15/07/2007	50 est	River	
				20/11/2007	40 est		
				21/10/2008	20est		
G9095080	Creek west of Johnson ck	772718	8170163	21/06/2007	25 est	River	
G9095081	Creek west of Johnson Ck	769030	8169716	20/11/2007	ctf	River	
G9095082	Johnson creek	774999	8170568	21/06/2007	202	River	
G9095083	Calvert R @ Old coast rd xing	770690	8172472	15/07/2007	3888	River	
				20/11/2007	3643		
				21/10/2008	1196		
G9095084	Pungalina creek	760496	8170499	21/06/2007	256	River	
G9095085	Kieran springs creek	744673	8172527	28/10/2007	CTF	River	
G9095086	Kieran springs creek	739339	8181034	28/10/2007	CTF	River	
This should be in '909' but has been wrongly listed under '908'							
G9085007	Surprise Creek at Spring	749725	8146568	7/08/1984	11	River	

910 SETTLEMENT CREEK

STATION	STATION NAME	EASTING	NORTHING	DATE OF FLOW RECORD	FLOW L/S	SITE TYPE	COMMENT
Water quality sites, some have river flow measured							
G9105001	Crocodile Hole At Wollogorang Stn	797825	8059768		N/A	River	
G9105002	Echo Ck d/s Gorge	789986	8095857		N/A	River	
G9105003	Sandy Creek at old coast rd xing	780483	8167547	14/07/2007	390	River	
G9105004	Sandy Creek u/s from old coast rd xing	782091	8163174	21/06/2007	300 est	River	
G9105005	Sandy ck downstream Bullrush	776200	8154500	12/10/2007	90	River	
G9105006	Sandy ck	774689	8151432	15/07/2007	< 5	River	
G9105007	Dingo ck	789662	8162182	14/07/2007	< 1	River	
G9105008	Mountain creek	791897	8155701	12/10/2007	20 est	River	
G9105009	Mountain Creek at track Xing	793959	8157436	14/07/2007	108	River	
G9105010	Running ck d/s spring area headwaters	787214	8140841	12/10/2007	134	River	
G9105011	Running ck @ track crossing	800261	8147186	14/10/2007	125	River	
				26/09/2007	182		
				13/07/2007	370		
G9105012	tributary to Running ck with spring u/s	791002	8141086	12/10/2007	CTF	River	
G9105013	hobblechain ck	804800	8142200	13/07/2007	CTF	River	
G9105014	Camel ck	806000	8135200	13/07/2007	< 1	River	
G9105015	Collar ck at track xing	809500	8128000	13/07/2007	CTF	River	
G9105016	Gold Ck at track xing	814121	8120989	13/07/2007	CTF	River	
G9105017	Redbank ck at track xing	817450	8117595	13/07/2007	CTF	River	
G9105018	spring at Masterton cave	794353	8099946	14/10/2007	seep	Spring	

APPENDIX J: CHEMISTRY OF SURFACE WATER SITES

All water contains various kinds of dissolved salts (minerals). Small quantities of many of these salts are essential to good health. Excessive concentrations however, can limit the uses of the water.
Following is some information to help you interpret the water quality represented on the following pages. The information has been summarised from NRETAS technical fact sheets @ www.nt.gov.au/nreta/publications/natres/waterfactsheets.html. More information is available from this site.

Source of dissolves salts:
Salts in the water originate from minute quantities dissolved in rain water and from the chemical breakdown of rocks. Nitrate is also produced in the soil by natural biological activity. Over long periods of time evaporation concentrates them to varying degrees.

Guideline Values:
The maximum recommended values listed beside each salt are guidelines rather than strict limits. The reason for this is because there are often many factors governing how a particular salt affects the user. These can include a person's age and the total volume of water consumed. The guidelines given below are conservatively chosen in order to cover most situations.

Fluoride 1.5 mg/L **(Stock 2 mg/L)**	This limit is based on health considerations. Excess fluoride can be removed by water treatment.
Hardness 200 mg/L (Aesthetic guideline only)	Hardness is a measure of the amount of calcium and magnesium in the water. Hard waters can cause the build up of scale in hot water pipes and fittings. They also require more soap to obtain a lather.
Iron 0.3 mg/L	Above this limit, taste may be unacceptable but it does not pose a health problem. High iron concentrations give water a rust brown appearance resulting in staining of laundry, pipe encrustation and odour problems. A common way to remove iron is to aerate the water by cascading it into a tank and allowing the iron to floc or settle.
Nitrate 50 mg/L **(Stock 400 mg/L)**	Based on health considerations a limit of 50mg/L is recommended for babies less than three months old and 100mg/L for older children and adults. Nitrate levels can be reduced if necessary by water treatment.
pH 6.5 - 8.5 **(Stock 5.5 – 9.0)**	This is a measure of the acidity or alkalinity. Values less than 6.5 indicate acidic water and can results in corrosion of pipes and fittings. When pH is more than 7.5, the water is alkaline and encrustation of pipes with calcium carbonate can occur. pH can be treated.
Total Dissolved Solids (TDS) 500 mg/L **(Stock 10 000 mg/L)** **Chloride 250 mg/L** **Sulphate 250 mg/L** **(Stock 2000 mg/L)** **Sodium 180 mg/L**	Above these limits for TDS, chloride, sulphate and sodium, taste may be unacceptable but it does not pose a health problem. (Aesthetic guideline only) TDS is approximately equal to 0.6 x EC

The sites are listed in numerical order according to 'G' number.

Surface Water Site	Sample Date	Sample No:	Specific Conduct (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nitrate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulp-hate (mg/L)	Flou-ride (mg/L)	Iron (mg/L)	Silica (mg/L)	Other Analysis
G9080122	16/07/1965	116676	253	7.9	130	69	119	136	19	12		17	1	3	4.7	8		0.1	18	
G9080122	20/05/1975	116677	352	7.6	248	302	256	270	40	16		38		3	9		0.2			
G9080122	3/07/1975	116678	740	8						7			2			2		0.7	25	
G9080122	10/02/1976	116679	220	7.3	94	115	92	120	17	8		12	1	3	4	5	0.1		14	
G9080122	21/03/1976	116680	240	7.3	106	129	100	120	17	8	13	14	1	2	5	5	0.1	1	14	Phosphate, Boron
G9080122	30/04/1976	116681	570	7.7																
G9080122	26/06/1976	116682	640	7.8																
G9080122	2/11/1976	116683	640	7.6																
G9080122	26/01/1977	116684	170	7																
G9080122	15/03/1977	116685	330	7.7	162	198	159	170	26	9		23	1	3	6	11	0.2	0.5	17	Boron
G9080122	4/05/1977	116686	160	7.7																
G9080122	25/09/1977	116687	600	7.8	322															
G9080122	13/01/1978	116688	200	7.4																
G9080122	16/02/1978	116689	240	7.5																
G9080122	25/04/1978	116690	340	8.4																
G9080122	2/08/1984	116691	300	7.5	147	180	142	180	24	8	12	20	2	3	6	6	0.1	0.1	16	
G9080122	3/08/1995	152955	362	7.4	67	82							0.018							Heavy Metals
G9080122	22/11/1995	153746	428	8.2	220	268							0.008							Heavy Metals
G9080122	22/08/2006		620	8.31																Temp= 22.7

Surface Water Site	Sample Date	Sample No:	Specific Conduct (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nitrate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulp-hate (mg/L)	Flou-ride (mg/L)	Iron (mg/L)	Silica (mg/L)	Other Analysis
G9080122	13/12/2006		700																	Temp= 30.9
G9080122	15/06/2007		440	8.4																
G9080122	13/07/2007		505																	
G9080122	28/09/2007		580																	
G9080140	30/09/1968	116698	210	7.1	104	63	136	140	17	14		13	1	5	7	5	0.6	0.1	10	
G9085000	4/08/1984	116699	60	6.5	8	9	11	60	1	10	16	2	1	1	6	2	0.1	0.4	23	
G9085000	4/08/1984	116700	45	5.9	3	4	4	55	1	8	13	1	1	1	6	2	0.1	0.1	23	
G9085001	3/08/1984	116701	680	8	365	445	363	400	50	20	31	58	1	2	9	8	0.2	0.1	22	
G9085003	2/08/1984	116703	510	8.2	288	351	280	300	48	10	15	39	1	1	5	6	0.2	0.3	23	
G9085004	6/08/1984	116704	590	8	328	400	325	330	56	10	16	45	1	2	8	3	0.1	0.1	11	
G9085005	4/08/1984	116705	1900	7.4	220	269	737		216	300	489	48		17	130		0.2			
G9085006	3/08/1984	116706	740	8.1	404	493	409	420	44	18	30	73	1	2	10	11	0.1	0.1	23	
G9085007	7/08/1984	116707	35	6.2	9	11	7		1	8	12	1	1	1	3	1	0.1	0.1	13	
G9085008	7/08/1984	116708	30	5.2	1	1	4	25	1	8	14	1	1	1	4	1	0.1	0.4	18	
G9085009	3/08/1984	116709	730	7.9	409	499	419	400	77	8	13	55	1	2	5	11	0.1	1	27	
G9085011	16/07/1965	116712	69	7.7	8	5	30	70	1	18		6		1.2	20					
G9085012	14/07/1965	116713	83	7.4	23		27			21										
G9085012	15/07/1965	116714	78	6.9	30		46		4	12		8	18	21	3					
G9085013	14/07/1965	116715	80	6.7	29	18	18	100	4	18		2		9	10					
G9085015	14/07/1965	116717	208	7.9	107	60	106	127	18	11		14		4	5					
G9085015	21/08/2006		590	8.25																Temp= 25

Surface Water Site	Sample Date	Sample No:	Specific Conduct (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nitrate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulp-hate (mg/L)	Flou-ride (mg/L)	Iron (mg/L)	Silica (mg/L)	Other Analysis
G9085015	14/12/2006		620																	Temp= 30
G9085015	16/06/2007		533	>7.6																
G9085015	12/07/2007		533																	
G9085015	27/10/2007		548																	
G9085015	26/11/2007		539																	
G9085016	15/07/1965	116718	69	7.3	36	22	32	58	3	6		6		3	3					
G9085016	12/12/2006		120																	Temp= 31
G9085017	15/07/1965	116719	66	7.3	28	17	23	56	3	6		4		3	5					
G9085017	20/08/2006		260	7.69																Temp= 23.7
G9085018	16/07/1965	116720	89	7.3	39		18			9										
G9085019	2/08/1984	116721	160	7.1	69	84	62	95	10	8	12	9	2	3	7	5	0.1	0.2	9	
G9085019	3/08/1995	152956	149	7.8	60	73							0.008							Heavy Metals
G9085019	22/11/1995	153747	224	7	109	89							0.008							Heavy Metals
G9085020	2/08/1984	116722	370	8.1	203	248	185	210	28	10	16	28	1	3	7	6	0.1	0.1	8	
G9085021	3/08/1984	116723	870	7.8	489	596	487	510	90	16	25	64	1	3	8	13	0.2	0.5	34	
G9085022	3/08/1984	116724	750	7.9	421	514	424	410	76	8	13	57	1	2	5	11	0.1	0.5	23	
G9085023	3/08/1984	116725	680	8	375	458	377	390	57	14	23	57	1	2	8	19	0.1	0.2	38	
G9085024	3/08/1984	116726	540	8.2	294	359	300	320	38	10	16	50	1	1	10	9	0.1	0.1	31	
G9085024	15/10/2007		578																	

Surface Water Site	Sample Date	Sample No:	Specific Conduct (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nitrate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulp-hate (mg/L)	Flou-ride (mg/L)	Iron (mg/L)	Silica (mg/L)	Other Analysis
G9085024	27/10/2007		559																	
G9085025	4/08/1984	116727	550	8	296	360	299	310	48	10	16	43	1	2	7	9	0.1	0.1	28	
G9085026	4/08/1984	116728	240	7.7	103	125	105	130	17	14	23	15	1	1	10	2	0.1	0.3	21	
G9085026	14/12/2006		480																	Temp= 32
G9085026	27/10/2007		388																	
G9085027	4/08/1984	116729	490	8.3	259	316	265	270	42	10	16	39	1	2	7	8	0.1	0.1	24	
G9085029	4/08/1984	116730	180	7.4	79	97	76	120	14	8	12	10	1	1	6	4	0.1	0.3	27	
G9085029	16/08/2006		100	7.05																Temp= 22.7
G9085029	12/12/2006		410																	Temp= 31
G9085030	4/08/1984	116731	420	7.8	225	274	226	250	41	8	13	30	1	2	7	7	0.1	0.1	26	
G9085031	4/08/1984	116732	23400	7.7	159	194	2950			8510	14031									
G9085032	4/08/1984	116733	36300	7.6	130	159	4825			14750	24310									
G9085033	4/08/1984	116734	43800	7.7	122	149	6050			16830	27736									
G9085034	12/08/1984	116735	50000	8	113	138	6350			20000	32600									
G9085035	2/08/1984	116736	210	7.1	87	107	82	120	13	8	13	12	2	3	8	7	0.1	0.2	11	
G9085037	2/08/1984	116738	120	7.1	56	68	49	100	8	4	7	7	3	3	5	4	0.1	0.1	8	
G9085038	3/08/1995	152957	48	6.5	12.3	15							0.026							Heavy Metals
G9085038	22/11/1995	153748	76	6.4	17	21							0.008							Heavy Metals
G9085042	22/11/2007		715																	
G9085043	22/11/2007		615																	

Surface Water Site	Sample Date	Sample No:	Specific Conduct (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nitrate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulp-hate (mg/L)	Flou-ride (mg/L)	Iron (mg/L)	Silica (mg/L)	Other Analysis
G9085044	21/06/2007		680																	
G9085047	8/11/2006		560																	
G9085048	7/11/2006		194																	
G9085049	8/11/2006		802																	
G9085050	7/11/2006		621																	
G9085051	7/11/2006		794																	
G9085058	14/12/2006		630																	Temp= 31
G9085059	13/12/2006		740																	Temp= 32
G9085059	21/06/2007		674																	
G9085060	23/08/2006		640	8.1																Temp= 24
G9085060	14/12/2006		700																	Temp= 30
G9085060	18/06/2007		600	8																
G9085060	24/10/2007		609																	
G9085062	17/08/2006		530	8.19																Temp= 22
G9085062	12/12/2006		600																	Temp= 31
G9085062	16/06/2007		496	>7. 6																
G9085062	18/07/2007		510																	
G9085062	28/09/2007		519																	
G9085062	25/10/2007		538																	

Surface Water Site	Sample Date	Sample No:	Specific Conduct (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nitrate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulp-hate (mg/L)	Flou-ride (mg/L)	Iron (mg/L)	Silica (mg/L)	Other Analysis
G9085062	23/11/2007		510																	
G9085063	16/08/2006		30	6.8																Temp= 26
G9085064	16/08/2006			7.5																Temp= 25
G9085065	16/08/2006		20	7.02																Temp= 26
G9085065	28/10/2007		112																	
G9085066	16/08/2006		45	6.8																Temp= 21
G9085067	17/08/2006		3650	7.84																Temp= 22
G9085068	17/08/2006		600	7.83																Temp= 18
G9085069	17/08/2006		1790	7.96																Temp= 26
G9085070	17/08/2006		2460	7.82																Temp= 23
G9085071	17/08/2006		350	7.74																Temp= 21
G9085072	17/08/2006		320	7.76																Temp= 23
G9085073	21/06/2007		175	7.2																
G9085074	23/08/2006		750	7.75																Temp= 20
G9085074	13/12/2006		820																	Temp= 28
G9085074	28/09/2007		640																	

Surface Water Site	Sample Date	Sample No:	Specific Conduct (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nitrate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulp-hate (mg/L)	Flou-ride (mg/L)	Iron (mg/L)	Silica (mg/L)	Other Analysis
G9085075	23/08/2006		30																	Temp= 25
G9085075	13/07/2007		51	6.4																
G9085076	23/08/2006		790	8.13																Temp= 23
G9085076	13/12/2006		880																	Temp= 33
G9085076	18/06/2007		780	8																
G9085076	20/10/2007		844																	
G9085077	13/12/2006		810																	Temp= 31
G9085077	21/06/2007		743																	
G9085079	14/12/2006		600																	Temp= 28
G9085080	14/12/2006		700																	Temp= 29
G9085080	27/10/2007		627																	
G9085081	12/12/2006		30																	Temp= 30
G9085082	21/06/2007		358	7.6																
G9085093	13/07/2008		34	6.4																
G9085094	15/06/2007		570	8																
G9085094	24/10/2007		628																	
G9085095	15/06/2007		693	8																
G9085096	16/06/2007		620	>7.6																

Surface Water Site	Sample Date	Sample No:	Specific Conduct (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nitrate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulp-hate (mg/L)	Flou-ride (mg/L)	Iron (mg/L)	Silica (mg/L)	Other Analysis
G9085097	21/06/2007		503																	
G9085098	21/06/2007		405																	
G9085099	21/06/2007		384																	
G9085100	21/08/2006		560	7.46																Temp= 29
G9085101	23/08/2006		110																	
G9090248	16/07/1965	116739	158	7.68	40		41			12										
G9090248	13/01/1978	116740	120	7.1	55	67	50			5	8									
G9090248	20/01/1982	116741																		TSS
G9090248	23/02/1982	116742	125	7.3	50	62	45			3	5									
G9090249	30/04/1976	116743	460	7.6	217	264	215			18	30									
G9090249	13/01/1978	116744	180	7.1	70	85	66			16	26									
G9090249	5/08/1984	116745	650	8	323	394	324	380	39	30	49	55	1	2	19	10	0.1	0.1	9	
G9095000	16/07/1965	116746	152	7.5	67	41	61	88	8	15		10		1.8	14					
G9095001	5/08/1984	116747	160	6.7	68	83	63	85	12	8	15	8	1	2	7	4	0.1	0.1	8	
G9095002	5/08/1984	116748	140	6.7	57	70	52	90	9	12	20	7	2	2	9	4	0.1	0.4	8	
G9095003	5/08/1984	116749	320	6.8	89	108	75	190	13	42	70	11	1	6	34	14	0.4	1.8	27	
G9095004	7/08/1984	116750	580	7.9	315	385	334		63	10	15	43	1	4	6	6	0.1	0.1	26	
G9095004	6/12/2006		630																	
G9095004	20/11/2007		550																	
G9095005	7/08/1984	116751	400	8.2	212	259	212		34	8	12	30	1	2	5	3	0.1	0.1	20	
G9095006	6/08/1984	116752	500	8.5	257	289	247		41	20	34	35	3	11	10	6	0.2	0.3	49	

Surface Water Site	Sample Date	Sample No:	Specific Conduct (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nitrate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulp-hate (mg/L)	Flou-ride (mg/L)	Iron (mg/L)	Silica (mg/L)	Other Analysis
G9095007	7/08/1984	116753	20	5.9	1	1	1	20	1	6	10	1	1	1	2	1	0.1	0.1	14	
G9095008	7/08/1984	116754	220	7.7	95	115	95		18	14	22	11	1	1	8	1	0.1	0.1	16	
G9095009	6/08/1984	116755	530	8.2	278	339	273		42	18	30	41	1	2	9	7	0.1	0.1	21	
G9095009	9/12/2006		740																	
G9095009	22/11/2007		690																	
G9095010	7/08/1984	116756	240	7.7	114	140	109	150	17	10	16	16	1	3	6	2	0.1	0.1	27	
G9095011	6/08/1984	116757	90	6.3	14	17	11		1	18	28	2	3	1	14	6	0.1	0.2	67	
G9095012	5/08/1984	116758	230	7.6	110	134	97	130	18	16	26	14	1	1	9	3	0.1	0.1	22	
G9095013	7/08/1984	116759	210	7.4	95	116	92		16	10	16	12	1	3	7	3	0.1	0.1	15	
G9095014	6/08/1984	116760	580	8.4	317	386	316		36	18	28	55	1	2	10	6	0.1	0.2	20	
G9095015	7/08/1984	116761	45	6	2	2	7	45	1	12	18	1	1	1	6	1	0.1	0.1	14	
G9095016	7/08/1984	116762	40	6	8	9	7	40	1	8	14	1	1	1	4	1	0.1	0.4	14	
G9095017	7/08/1984	116763	120	7.3	51	63	45	75	8	8	13	6	1	1	8	1	0.1	0.1	12	
G9095018	4/07/1981	116764	440	7.9	240	293	224			10	16									
G9095018	7/08/1984	116765	370	7.8	191	232	186	220	33	8	14	25	1	3	5	4	0.1	0.1	25	
G9095018	7/12/2006		580																	
G9095019	7/08/1984	116766	100	6.6	40	49	38	65	7	6	10	5	1	1	5	1	0.1	0.5	12	
G9095020	7/08/1984	116767	45	6.2	8	10	7		1	8	12	1	1	1	5	1	0.1	0.1	17	
G9095021	7/08/1984	116768	30	6.3	5	7	4	30	1	6	10	1	1	1	4	1	0.1	0.1	18	
G9095022	6/08/1984	116769	250	8.5	94	115	83	140	12	24	40	13	2	2	17	6	0.1	0.1	8	
G9095023	7/08/1984	116770	32800	7.7	96	117	3900			11500	19000									
G9095024	6/08/1984	116771	85	6.6	16	19	17	40	2	14	21	3	2	2	9	3	0.1	0.2	15	

Surface Water Site	Sample Date	Sample No:	Specific Conduct (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nitrate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulp-hate (mg/L)	Flou-ride (mg/L)	Iron (mg/L)	Silica (mg/L)	Other Analysis
G9095025	5/08/1984	116772	80	6.4	19	23	16	55	3	10	16	2	2	2	8	1	0.1	0.2	8	
G9095026	6/08/1984	116773	110	6.6	35	43	29		3	12	20	5	2	2	9	3	0.1	0.3	10	
G9095027	6/08/1984	116774	190	7	87	106	84	120	22	8	14	7	1	2	5	3	0.1	0.1	10	
G9095028	6/08/1984	116775	160	7.4	77	94	73	100	19	8	12	6	1	2	5	2	0.1	0.3	6	
G9095029	6/08/1984	116776	190	7.6	85	103	81	110	16	4	7	10	1	2	8	2	0.1	0.7	12	
G9095030	6/08/1984	116777	130	7	51	61	45	80	8	10	16	6	1	2	8	2	0.1	0.5	9	
G9095031	11/12/2006		850																	
G9095031	18/06/2007		750																	
G9095031	20/10/2007		820																	
G9095031	22/11/2007		787																	
G9095032	6/08/1984	116778	250	7.6	94	115	86		13	20	32	13	2	3	17	5	0.1	0.4	15	
G9095033	6/08/1984	116779	280	7.9	120	147	109		17	18	28	16	1	4	15	6	0.1	0.4	19	
G9095034	16/07/1965	116780	78		20	12	22	63	4	18		3		1.2	22					
G9095034	30/09/1968	116781	68	6.5	20	12	40	50	2	12		4	1	3	8	2	0.5	0.1	7	
G9095035	7/12/2006		420																	
G9095035	20/06/2007		323																	
G9095035	21/10/2007		346																	
G9095035	21/11/2007		343																	
G9095036	20/06/2007		476	7.6																
G9095036	21/11/2007		498																	
G9095037	6/12/2006		460																	
G9095037	19/06/2007		476																	

Surface Water Site	Sample Date	Sample No:	Specific Conduct (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nitrate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulp-hate (mg/L)	Flou-ride (mg/L)	Iron (mg/L)	Silica (mg/L)	Other Analysis
G9095037	27/09/2007		465																	
G9095037	21/11/2007		451																	
G9095038	6/12/2006		510																	
G9095038	20/06/2007		455	7.6																
G9095038	16/07/2007		450	8.1																
G9095038	27/09/2007		477																	
G9095038	21/11/2007		484																	
G9095039	16/07/2007		1020																	
G9095040	16/07/2007		565																	
G9095041	16/07/2007		550																	
G9095042	18/10/2007		1123																	
G9095043	11/12/2006		0.87																	
G9095043	18/10/2007		758																	
G9095044	11/12/2006		960																	
G9095046	22/11/2007		711																	
G9095047	22/11/2007		854																	
G9095048	9/12/2006		810																	
G9095048	22/11/2007		706																	
G9095049	11/12/2006		820																	
G9095050	9/12/2006		830																	
G9095050	11/12/2006		860																	
G9095050	18/06/2007		619																	

Surface Water Site	Sample Date	Sample No:	Specific Conduct (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nitrate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulp-hate (mg/L)	Flou-ride (mg/L)	Iron (mg/L)	Silica (mg/L)	Other Analysis
G9095050	20/10/2007		827																	
G9095051	16/07/2007		333																	
G9095052	16/07/2007		264																	
G9095053	9/12/2006		1300																	
G9095054	9/12/2006		870																	
G9095055	9/12/2006		480																	
G9095056	17/07/2007		412	7.6																
G9095057	17/07/2007		621																	
G9095058	23/08/2006		630	8.36																
G9095058	11/12/2006		700																	
G9095058	18/06/2007		548																	
G9095058	13/07/2007		572																	
G9095058	20/10/2007		634																	
G9095058	22/11/2007		633																	
G9095059	18/06/2007		494	7.6 +																
G9095060	11/12/2006		690																	
G9095060	19/07/2007		560																	
G9095060	26/09/2007		595																	
G9095062	19/07/2007		627																	
G9095062	26/09/2007		669																	
G9095063	23/08/2006		640	8.32																

Surface Water Site	Sample Date	Sample No:	Specific Conduct (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nitrate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulp-hate (mg/L)	Flou-ride (mg/L)	Iron (mg/L)	Silica (mg/L)	Other Analysis
G9095063	18/06/2007		592	7.6 - 8.4																
G9095063	13/07/2007		596	7.2																
G9095063	20/10/2007		602																	
G9095063	22/11/2007		578																	
G9095064	19/06/2007		25	<=6.4																
G9095065	21/10/2007		102																	
G9095066	8/12/2006		20																	
G9095066	15/07/2007		17	6.4																
G9095066	21/10/2007		35																	
G9095067	23/08/2006		1030	7.92																
G9095068	12/10/2007		308																	
G9095069	7/12/2006		660																	
G9095069	20/06/2007		628																	
G9095069	21/10/2007		590																	
G9095069	21/11/2007		590																	
G9095070	7/12/2006		620																	
G9095070	20/06/2007		588																	
G9095070	19/07/2007		570																	
G9095070	27/09/2007		572																	
G9095070	21/10/2007		550																	

Surface Water Site	Sample Date	Sample No:	Specific Conduct (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nitrate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulp-hate (mg/L)	Flou-ride (mg/L)	Iron (mg/L)	Silica (mg/L)	Other Analysis
G9095070	21/10/2007	EL1259 4	414	8.2	227	227	220	220	31.5	8.2		34.2	0.005	2.6	5.1	<.1	0.1	<.02	23.4	Trace metals
G9095070	21/11/2007		542																	
G9095071	6/12/2006		600																	
G9095071	16/07/2007		555																	
G9095071	27/09/2007		525																	
G9095072	6/12/2006		680																	
G9095073	6/12/2006		570																	
G9095074	20/11/2007		632																	
G9095075	20/11/2007		781																	
G9095076	15/07/2007		674																	
G9095077	15/07/2007		588																	
G9095078	21/06/2007		126	6.8																
G9095079	15/07/2007			7.2 - 7.6																
G9095079	20/11/2007		289																	
G9095080	21/06/2007		22	6.4																
G9095081	20/11/2007		119																	
G9095082	21/06/2007		32	6.4																
G9095083	15/07/2007		367	8.3																
G9095083	20/11/2007		430																	
G9095084	21/06/2007		29	6.4																

Surface Water Site	Sample Date	Sample No:	Specific Conduct (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nitrate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulp-hate (mg/L)	Flou-ride (mg/L)	Iron (mg/L)	Silica (mg/L)	Other Analysis
G9095085	28/10/2007		116																	
G9095086	28/10/2007		192																	
G9105001	12/10/1982	116782	750	7.9	399	486	382	480	38	22	36	70	1	5	28	15	0.3	0.3	22	Lead, Copper, Zinc, Manganese
G9105002	1/09/1999	163868						120		22	36									
G9105002	1/09/1999	164091	33	7.1	7	8	7	17	1	6	10	1	1	1	4	1	0.1	0.3	15	
G9105003	14/07/2007		46	6.5																
G9105004	21/06/2007		63																	
G9105005	12/10/2007		57																	
G9105006	15/07/2007		130	6.8 - 7.2																
G9105007	14/07/2007		38	<6.4																
G9105008	12/10/2007																			
G9105009	14/07/2007		23	6.4																
G9105010	12/10/2007		33																	
G9105011	14/10/2007		39																	
G9105011	26/09/2007																			
G9105011	13/07/2007		40	6.6																
G9105012	12/10/2007																			
G9105013	13/07/2007		129																	
G9105014	13/07/2007		420																	

Surface Water Site	Sample Date	Sample No:	Specific Conduct (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nitrate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulp-hate (mg/L)	Flou-ride (mg/L)	Iron (mg/L)	Silica (mg/L)	Other Analysis
G9105015	13/07/2007		98																	
G9105016	13/07/2007		206																	
G9105017	13/07/2007		167	7.96																
G9105018	14/10/2007		83																	

APPENDIX K: RAINFALL RECORDER SITES

Station Number	Site	Easting	Northing	Commence	Cease	Recommence	Status
DE014707	WOLLOGORANG	813886	8094245	1/07/1993	30/04/1994		closed
DR014705	CALVERT HILLS STATION	748241	8093296	29/02/1968	31/03/2003		open
DR014706	ROBINSON RIVER	711533	8145362	30/09/1967	30/11/1986	30/04/1991	closed
DR014707	WOLLOGORANG	813886	8094245	31/12/1966	31/03/2003		open
DR014709	GREENBANK STATION	722750	8198749	31/10/1968	31/01/1974		closed
DR014718	REDBANK MINE	792678	8100095	30/06/1973	31/03/2003		open
DR014721	PUNGALINA	757811	8150386	31/03/1981	31/07/1982		closed
DR014727	DOOLGARINA	688773	8204879	31/05/1991	30/04/1994		closed
DR014728	BUJANA	700572	8200345	31/12/1994	31/03/1998		closed

Sites are all located in zone 53, Datum MGA94. These sites are operated by the Bureau of Meteorology.

Back Cover: Indigenous wooden food and water carrier – Coolamon or *Lujuluju* -purchased from Waralungku Arts, Borroloola

Daphne Mawson

Daphne Mawson, a Garrwa woman, related the following story about a coolamon of water. She lives in Borroloola and works at the Borroloola primary school teaching indigenous culture in Garrwa.

Story about the frog and the Pee Wee

Every night when I was little, my grandmother told me a story about the frog and the Pee Wee. It is a story of how the rivers came to be and not to be greedy. She said that a long, long time ago in the dreamtime there was a Pee Wee and a frog. The Pee Wee was the owner of a coolamon of water. He used to carry it around.

One day the Pee Wee camped under a tree and hid the Coolamon of water. The frog came to the Pee Wee to ask where he got water from. The Pee Wee said go north and the frog went north. In the evening he came back tired and weary and said there was no water there. 'Where did you get the water from' he asked? The Pee Wee replied 'ah I forgot, I got the water from the east'. So the frog went to the east and as he traveled he was getting very tired but he made it back to the Pee Wee. Once again he asked 'where did you get the water from'? The Pee Wee said 'Oh silly me, that's right I got it from the south'. Off he slowly went, he was getting very tired and very thirsty. But the frog still didn't find the water and went back to the Pee Wee. He asked the Pee Wee again, his lips were dry and parched, his voice was croaky 'Where did you get the water from'? The Pee Wee said 'I'm getting old, I keep forgetting, that's right, I got it from the west'. So off went the frog, he was very tired and dehydrated. By this time the Pee Wee was getting tired because he hadn't slept for days as he was guarding his coolamon from the frog. He fell asleep. Poor old frog slowly dragged himself back after not finding any water. He saw the Pee Wee had fallen asleep and grabbed a rock and smashed the coolamon. Water gushed everywhere and that's how the rivers were created. The Pee Wee woke up with a start and found his water gushing everywhere, he ran and grabbed the stick and bashed himself over the head crying for his water. Blood streamed all over his body and that's why today the black marks you see on the Pee Wee are the blood stains for when he cried for his water. Today when you hear the first storms you hear the frogs in the lagoons, that's the frogs teasing the greedy Pee Wee who wouldn't share his water.

This was the story my grandmother told to teach us to share everything, especially water which is needed for everyone's survival.