Excursion notes for the IAH International Groundwater Conference, Darwin 2002

REPORT 18/2002
S.J. TICKELL
DARWIN
July 2002
Cover Photo: Stalactites on a palaeo-tufa dam, Elsey Station near Mataranka, visited during the Daly Basin field trip.
INTRODUCTION
In May 2002 a groundwater conference was held in Darwin. It was organised by the Northern Territory Branch of the International Association of Hydrogeologists. Several field trips were held, both during and immediately after the conference. These included visits to sites of hydrogeological interest in the vicinity of Darwin and further afield. Notes for five of the excursions are compiled here and were prepared by the author with the assistance of Alan Puhalovich (ERA, Environmental Services Pty. Ltd.), Peter Jolly (Dept. Infrastructure, Planning and Environment), Danuta Karp (Dept. Infrastructure, Planning and Environment) and Dirk Megirian (NT Museum).

Excursion notes cover the following trips:

  Kakadu National Park
  Katherine-Daly Basin
  Litchfield park
  Coastal Plains of the Top End
  Darwin Rural Area
KAKADU NATIONAL PARK

Post Conference Tour

18 - 20 May 2002

Guide: Alan Puhalovich
SATURDAY 18 MAY 2002
08.00 This morning delegates will be collected from their accommodation for a 3 day Mary River and Kakadu National Park tour. Departing Darwin travelling via the Stuart and Arnhem highways to Mary River Park. En route there will be a stop at the Windows on the Wetlands Centre where you will be able to view the Marrakai Plains. The Centre also gives an overview of the importance of the wetlands and floodplains in this region. Travel on to the Mary River Park. Mary River Park is one of the Northern Territory’s newest National Parks, which consists of a series of billabongs and is able to support many species of wildlife all year round.
11.00am Cruise along the Mary River. Cruising up and down stream in the hunt for crocodiles, birds and viewing the unique river system.
1.00pm Lunch will provided after your cruise. Time to relax and cool down after lunch in the pool.
3.30pm There will be a wetland and wildlife safari of the area. After your wetland safari depart the Mary River Region for Jabiru.
7.30pm Dinner tonight will be provided in the Escarpment Restaurant. Accommodation: Gagudju Crocodile Hotel, Kakadu. Telephone 08 89792 800.

SUNDAY 19 MAY
After breakfast depart Jabiru for the northern region of Kakadu National Park. NB: Time allowed for scenic flight. This must be booked prior. Stopping at Mamukala wetlands for a 1km walk to view the birdlife and the fascinating wetlands. Stop at the Bowali Centre which contains a wealth of information on the Kakadu National Park and the local Aboriginal art and craft. 1.00pm A picnic lunch will be provided today. It is then time to head towards the Northern Region of the park to Ubirr Rock near the East Alligator River. View Aboriginal rock drawings, some up to 20,000 years old. Join the 3.00pm Guluyambi Cruise. Cruise along the East Alligator River, bordering the rocky escarpment of Arnhem Land. Generally there will be an aboriginal guide with the cruise and with the special permission of the local people, you will be able to go ashore in Arnhem Land (seasonal). Return to your accommodation approximately 5.00pm. Time at leisure. 7.00pm Dinner will be provided in the Escarpment Restaurant tonight. Accommodation: Gagudju Crocodile Hotel, Kakadu. Telephone 08 89792 800.

MONDAY 20 MAY
After breakfast depart at 08.00 to the Uranium Mine near Jabiru. 10.00 After your mine visit depart to Nourlangie Rock an ancient Aboriginal living shelter. The area surrounding Nourlangie has great diversity - creeks, billabongs, sandy alluvial plains, forest and sandstone escarpment. Rich in food sources; fish, waterfowl, wallabies, flying foxes and yams, groups of Aboriginals made this area one where they would make camp and utilise the natural resources. Whilst living in the area paintings of animals, insects and people that were done years ago, now help us to record human occupation in
the region. Signs and displays will give detailed explanations of the art and area.
12.00 Continue on to Cooinda for lunch at the Gagudju Cooinda Lodge.

1.00pm It is then time to join the Yellow Waters Billabong Cruise. Yellow Water is part of the South Alligator River floodplain. You will have the opportunity to see the varied birdlife Kakadu’s World Heritage wetlands, and perhaps a Croc or two.

2.30pm It is time to depart Kakadu for the return journey to Darwin. A refreshment stop will be made at Bark Hut, arriving Darwin approximately 6.00pm.

**Climate and drainage**

The coastal plains of the Northern Territory lie between $11^0$ and $17^0$ latitude. The climate is of the wet / dry tropical type with high temperatures throughout the year and only two distinct seasons. Thunderstorms herald the start of the wet season in November and may bring rain throughout the summer months. Occasional very intense but localised rain occurs when cyclones pass close to or cross the coast. Darwin’s annual rainfall falls mainly between November and March and totals some 1600mm. The “Top End” is influenced by the monsoon, which can usually be relied upon to bring summer rains. Permanent stream flow only occurs in a few of the region’s rivers, mainly due to the long dry season and the fact that most aquifers are of the fractured rock type, with small storage that limits the potential to provide base flow. On the rivers that cross the coastal plain, tidal influence can extend many tens of kilometres inland. The East Alligator and the South Alligator Rivers are the two major rivers that drain Kakadu Park.

**The Coastal Plains**

The coastal plains form a large proportion of Kakadu’s area. A brief geological history of their formation is given below:

18,000 years BP: At the height of the last ice age sea levels were some 120 metres lower than at present. The northern coastline was situated several hundred kilometres seaward of the present one. The areas of the present day coast were located mid way up the catchments where the environment was largely erosional.
By 7000 years BP the sea had risen close to the present level drowning the former river valleys that are now on the continental shelf. In low-lying areas (the river valleys) the coastline reached several tens of kilometres inland of the present day coast. These shorelines are marked in places by stranded chenier ridges.

Between 7000 and 4000 BP estuarine sediments accumulated and the shoreline prograded, gradually building up the coastal plain. Sedimentary environments present were mainly low energy include mangrove fringe, tidal flats and shallow estuarine. Higher energy environments include chenier ridges and tidal and alluvial channels. The sediments are dominantly muds and silts.

By 3000 years BP the current shoreline was established in areas such as the Adelaide, Mary, South Alligator and East Alligator Rivers and has been stable since then. Freshwater wetlands then became widespread after 2000 years BP.

Four morphological provinces can commonly be recognised on and adjacent to the coastal plains (the diagram below shows the Mary River which boarders the park). The plains pass from “Alluvial” in the narrow landward end to “Palaeo_Estuarine” and then into the wider “Coastal” plain on the seaward side. They are bordered by “Uplands”, low undulating areas with bedrock at or near surface.
ALLUVIAL PLAIN

Land surface
Fluvial sands & clays
Fluvial and "near shore" marine sands & clays
Mangrove mud
Basement
Dry Season Groundwater Movement

Dry SWL
Wet SWL
The groundwater flow characteristics in each of the provinces are summarised on the diagrams shown on the previous page. In the “Alluvial” and “Palaeo-Estuarine” zones areas of rainforest are maintained by groundwater discharge. The watertable in these low-lying areas is close to ground level throughout the year. Discharge is generally restricted to the margins of the plains where heavy confining clays are not present. The source of the groundwater is from fractured bedrock aquifers and in places from shallow aquifers in lateritic soil profiles. Discharge directly to the rivers only takes place in the more landward areas of the “Alluvial” zone where sediments are more permeable. Large amounts of salt are stored in the mangrove muds beneath the plains but are largely immobile.
RANGER URANIUM MINE
The site lies within the eastern part of the Pine Creek Geosyncline, which is a remnant of a deformed and metamorphosed Early Proterozoic sedimentary basin. The Early Proterozoic rocks are underlain by Archaean granitoid basement (Nanambu Complex) and unconformably overlain by flat lying Middle Proterozoic quartzites of the Kombolgie Formation and younger rocks and unconsolidated sediments. Hydrogeological conditions around Pit #1 comprise relatively tight schists (Early Proterozoic) and basement gneisses, and a permeable zone of fractured schists located in the south-east corner of the pit. The latter is the principal area of hydraulic connection between the pit and downstream groundwater and surface water systems.

Plate 1: Retention Pond 1 - main pond
- Retention Pond 1 (RP1) was constructed in 1980 at the Ranger mine for use as a reservoir of clean water in the water management system. For the first 10 years of mining RP1 received runoff from a catchment comprised largely of native vegetation and the pond remained essentially pristine.
- In recent years, the water quality in RP1 has degraded, particularly with respect to increased uranium concentrations, primarily due to the presence of waste rock stockpiles in the catchment. Groundwater seepage into the pond is a key determinant of water quality evolution.
- The ability to release water from RP1 during the wet season is a key element of the management of water on the Ranger site.
- A number of studies have been undertaken to identify and quantify the potential influences on the behaviour of RP1 and to temporally assess and quantify the effects of catchment management practices on the pond’s water quality.
Plate 2: Corridor Creek Wetlands

- These wetlands were constructed on the mine-site upstream of the Georgetown Billabong to "polish" runoff from the mine’s rock stockpiles and act as a buffer between the mine and the adjacent Kakadu National Park.
- Water is pumped to the upper catchment above the Brockman Bund in the dry season to maintain the wetlands.
- The wetlands have been shown to successfully remove metals (including Uranium) from waters.
- Interesting surface water-groundwater interactions occur in the catchment.
Plate 3: Ranger Mine’s Pit #1

- Since August 1996, neutralised tailings have been deposited into Pit #1 which is the void from which orebody 1 has been mined. Prior to mine closure, ERA is required to return all tailings to the mined out pits.
- A large volume of process water lies above the tailings and will be treated using Reverse Osmosis (RO) techniques in the near future.
- Hydrogeological investigations, primarily groundwater modelling and geophysical investigations have been used to assess options for post-closure capping of tailings and pit backfilling, and to assess long-term impacts on downstream groundwater quality.
Geology
The geology of the park is dominated by the Kombolgie Formation, the sandstone which forms the escarpments to the south and east. It is Proterozoic in age (1750my) and is relatively undeformed. It unconformably overlies folded and metamorphosed sedimentary rocks, granite and dolerite (1835 – 1900my) and Archean granite and metamorphics (2500my).

The following pages are taken from a booklet produced by AGSO (Australian Geological Survey Organisation), titled “Kakadu and Nitmiluk, a guide to the rocks, landform, plants, animals, Aboriginal culture and human impact.” This is highly recommended for “geological” visitors to the park and is available in the parks retail outlets. It also describes the various phases of aboriginal rock art in relation to Cainozoic sea level changes.
Katherine – Daly Basin Tour

Post Conference Tour

18 - 20 May 2002

Guides: Danuta Karp, Stein-Erik Lauritzen, Steven Tickell
Katherine-Daly Basin field tour

18-20 May 2002

Excursion Leaders:
  Danuta Karp, Department of Infrastructure, Planning and Environment
  Stein-Erik Lauritzen
  Steven Tickell, Department of Infrastructure, Planning and Environment

ITINERARY

18 May 2002 Saturday

08:00 Depart Darwin
11:00 Pine Creek Museum, historic Gold Mining town
11:30 Lunch in Pine Creek
13:00 Locality 1: Limestone towers along the Stuart Highway
13:30 Katherine directly to unload bags.
14:00 Karstic features around Katherine: Locality 2 unroofed caves, Locality 3: an ephemeral groundwater fed lake (polje), Locality 4: Katherine “Hot” Spring.
17:00 Hotel
18:00 Depart from the hotel for Crocodile Night Adventure at Springvale Homestead, Cruise / Dinner.
22:00 Arrive back at the hotel

19 May 2002 Sunday

07:30 Breakfast
08:30 Depart hotel, Locality 5 Sinkhole next to highway
10:00 Locality 6: Sinkholes & Cutta-Cutta Nature Park caves
12:30 Lunch at Mataranka
13:00 Locality 7: Mataranka Hot Spring, short walk and swimming
15:00 Locality 8: Tufa site on Elsey Station
18:00 Arrive back at hotel
19:00 Dinner at hotel

20 May 2002 Monday

06:30 Breakfast
07:30 Departure for Katherine Gorge, visit to Park HQ and 3 hour tour
12:00 Lunch at Katherine
13:30 Departure for Darwin
18:00 Darwin

Darwin to Katherine
PINE CREEK GEOSYNCLINE
The rocks exposed in road cuttings along the highway are mainly sedimentary rocks belonging to the Palaeoproterozoic Pine Creek Geosyncline. Sedimentation spanned the interval 2000 – 1870 Ma and the rocks were intruded by granites between 1870 and 1780 Ma. The shale, greywacke and sandstone has been closely to tightly folded along dominantly north to northeast trending axes and have undergone regional metamorphism to the lower greenschist facies. The Pine Creek area has been a major goldfield since the mid-nineteenth century.

The aquifers developed in these rocks are of the local fractured rock type. Bore yields are typically small (less than 1 litre/sec.) but can be locally high (10 litres/sec.) in the vicinity of faults. Dewatering borefields have been necessary for some of the open cut gold mines.

DALY BASIN
The highway crosses onto the Cambro-Ordovician Daly Basin some 10km south of the turn-off to Edith falls. The basin rests unconformably on the older rocks and consists of up to 700 metres of limestone, mudstone, dolostone and minor sandstone. Depositional environments range from peritidal to open shelf marine. The basin’s axis trends northwest-southeast and the rocks are only gently warped. The section comprises three formations; the Tindall Limestone (oldest), the Jinduckin Formation and the Ooloo Dolostone (youngest). We will only be visiting sites on the Tindall Limestone on this excursion.

Karstic features are well developed on the Tindall Limestone and we will inspect some of these, including sinkholes, ancient and modern caves, springs, tufa deposits and a polje (a groundwater fed lake). The formation hosts a regional scale, fractured and karstic aquifer. Groundwater flow at Katherine is along strike towards the Katherine River. At the end of the Dry season (April to November) groundwater maintains river flows typically of about 3 cumecs (250 ML/Day) via a series of karstic springs. Presently groundwater supplies part of Katherine’s water supply (1600 ML/Year) and a small irrigation industry (13000 ML/Year). The current management policy is to reserve 80% of recharge for environmental purposes.
Average monthly rainfall, Katherine

Annual rainfall for Katherine (water year October – September)
Locality 1
Limestone Towers
This site illustrates typical karst forms that have developed in this Wet/Dry tropical climate. Annual rainfall at Katherine is about 1000 mm, falling mainly between December and March. The rainwater tends to be acidic (pH 4 - 5) and temperatures are high throughout the year. These conditions have resulted in the moderate development of karstic landforms such as the towers at this site.

Locality 2
Unroofed Caves
The Daly Basin rocks have been exposed for considerable periods including the Mid Palaeozoic through to the Cretaceous and then throughout the Cainozoic. A brief marine incursion took place during the Early Cretaceous (118 My) and minor uplift followed soon after. The present day landscape has been forming since the Early Tertiary.

The cave deposits at this site lie ontop of a low hill and include stalactites and earthy cave floor sediment containing bones. The cave formations have been radiometrically dated at 50000 – 70000 years BP. To date no pre Cretaceous caves have been located although it is quite possible that they exist. Details of investigations at this site can be found in Appendix 1.

Locality 3
“Lake Hickey” An ephemeral groundwater fed lake (polje).
In 1998 the Katherine River experienced the largest flood on record. The town was inundated and groundwater levels also rose rapidly. “Lake Hickey” a flat low lying area, normally dry even at the height of the Wet season suddenly became a lake. It was filled by a combination of groundwater rising out of caves on the lake floor and from surface runoff. In normal drier years watertables were sufficiently low to allow runoff to drain underground.

This was the site of a dye test to determine the connection between the caves and the Katherine River. Tinopal was released into the watertable and was detected at two riverside springs, Springvale and Northbank after 11 and 3 days respectively. Secondary plumes were also recorded at each spring after 13 and 14 days respectively, indicating a complex flow path. The test proved the connection between the input point and the springs.
Possible interpretation of groundwater path flow from polje to springs located on the bank of the Katherine river. This may explain the existence of the second Tinopal peak in both springs after 13-14 days.
Diagram of base-level polje at Lake Hickey. The low water table represents the dry season water table level while the high water table represents the wet season water table in Katherine. Water table fluctuations between the wet and dry seasons in the Lake Hickey polje region have been measured as high as 9.5m.
Locality 4
Katherine “Hot” Spring
This spring is one of several that drain the Tindall aquifer. The river gains about 3
cumecs from springs and from less well-defined seepage into the riverbed.

The term “Hot Spring” is a misnomer because at 32\(^0\) it represents the ambient
temperature of groundwater in the region. Although inundated at the height of the Wet
season, the water chemistry remains constant. This suggests that only minor reverse
flow into the aquifer occurs during such times.
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<th>pH</th>
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Locality 5
Sinkhole next to highway
This feature is typical of catastrophic sinkhole collapse that can result from man’s interruption of the natural drainage. In this example the railway embankment blocked drainage, ponding water resulting in the sudden opening of the sinkhole. Other examples are known from the area mostly related to road construction or clearing for agriculture. In some cases attempts have been made to fill the holes and cap them with cement. Prevention is the best way to avoid the problem however.

Locality 6
Cutta-Cutta Nature Park caves
At this locality we will take a guided tour through a tourist cave.
The main corridors of the caves are linear and guided by fractures or palaeokarst dykes. Side chambers that are situated at a lower level than the main passage display irregular spongework (boneyard) morphology.

The main passage is a smooth, phreatic tube that was developed above a former fill of red, laminated clays and breccia. Scallop formed by water flow can be seen on the walls. These suggest a palaeo-flow of at least 60 litres/second. Small cupolas are present in places on the roof and these may suggest thermal waters but this is not conclusive here. The cave did however function as a spring in the past, leading water in the direction of the King River. Remnants of tufa enclosing breccia, plant material and snail shells occurs south of the present entrance.

The speleogenesis of the cave can be summarised as follows:

- Palaeokast development with fills along NW-SE fissures.
- Spongework and fissure development
- Drainage and deposition of massive speleothem, several events of laminated red clay and breccia fills.
- Re-flooding of cave, development of paragenetic tubes and cupola forms. Possibly hot water. Flow was to the south east. The cave acted as a spring.
- Draining of the cave, speleothem deposition. Present day watertable at about 30m below ground level. Present drainage direction is unknown
Localities 7

Mataranka Thermal Springs

The Mataranka Thermal Springs comprises a series of springs situated along a 30 km. stretch of the Roper River and its tributary the Waterhouse River. The river is incised into the surrounding plain and intercepts the watertable. From January to March the river level is above the springs, making them inaccessible. On a Dry season morning when the air temperature can drop to 15 degrees, the spring water at 32 degrees feels hot and steam can rise from the water. None are true hot springs however, as the ambient temperature of shallow groundwaters throughout the region is also about 32 degrees.

The water chemistry here shows higher values for most of the major ions compared to the Katherine springs. The reason for this may be that the aquifer in this area contains evaporite deposits, gypsum and halite. There is also a stark difference in chemistry between Rainbow and Bitter Springs on the one hand and Walkway and Fig Tree Springs on the other hand. The latter two springs are further east and have considerably higher values than the former two.
Locality 8
Tufa site on Elsey Station
At this site there are a series of sinkholes aligned along a drainage line. The walls of the sinkholes are steep and are covered with unusual tufa stalagmites. They have a bulbous form and are porous and spikey (like coral). The stalagmites and tufa terraces found elsewhere in the district originate from groundwater discharge. The area has not been studied at all so perhaps we can shed some light on the formation of these unusual features.
Appendix 1

Quaternary fossiliferous fissure-fills in the Tindall Limestone:
‘Zion’ and ‘Cutta Cutta’ sites
Dirk Megirian,
May 2002
Quaternary fossiliferous fissure-fills in the Tindall Limestone: ‘Zion’ and ‘Cutta Cutta’ sites
Dirk Megirian, May 2002

Vertebrate remains from sediments in-filling karstic structures in the Tindall Limestone were reported to staff at the Northern Territory Museum (MAGNT - Museums and Art Galleries of the Northern Territory) by hydrogeologists Danuta Karp and Stein-Erik Lauritzen in the early 1990s. These represent some of the first Quaternary fossil assemblages reported from the NT, and one of only a handful from the Australian tropics. An investigation of four sites, including the ‘Zion’ and ‘Cutta Cutta’ sites, was undertaken by Pyramo Marianelli as part of an BSc Honours degree through the Flinders University of South Australia, and the following brief account, necessarily simplified and generalised, is taken from Marianelli (1995). Any misrepresentations and errors are entirely the responsibility of this author.

‘Zion Site’ took its name from graffiti on a boulder near the highway proclaiming “This way to Zion”, with an arrow pointing towards the top of the hill, where the fossils were found. The ‘Cutta Cutta Site’ is within the Cutta Cutta Cave reserve. (Photo D. Karp)

Composition and taphonomy of the fossil assemblages
The fauna from each site (Table 1) is composed of extant taxa today found in association in monsoon vine forest (MVF) patches on sandstone outcrops across northern and northwestern Australia (Top End and Victoria River regions of the NT, and Kimberley of WA). Four of the 15 mammal species present (Parantechinus bilarni and P. dahli, Zyzomys maini and Leggadina forresti) have undergone significant range reductions and are now locally extinct due to loss of suitable habitat.

Zion. Fossil material from Zion site is fragmented but consistently well preserved throughout. A high proportion of skeletal elements are intact, and the assemblage is dominated by taxa with body-weights below 200 g. There is no evidence of hydrodynamic sorting, abrasion or rounding of skeletal elements, nor is there evidence of digestive corrosion. The age-structure within species is biased to the most active age-classes in a population, namely juveniles and young adults (i.e. the vagrants). The overall low species diversity, and size- and age-structure is inconsistent with an attritional assemblage and points to an active predator as the accumulating agent. The lack of digestive corrosion is inconsistent with a mammalian predator, but consistent with an avian predator that regurgitates undigestible material as pellets. An owl accumulator is indicated for the Zion assemblage. On the basis of the size-range of prey items, Tyto novahollandiae is indicated.
Cutta Cutta. The Cutta Cutta assemblage is dominated by microchiropteran bats and rodents (all below 200 g body-weight) represented almost entirely by isolated tooth-crowns. The very few pieces of bone recovered are severely corroded, rather than damaged by physical processes. The preservation implies a mammalian predator, and the prey species and their size ranges conform to accumulations produced by the Ghost Bat, *Macrodectes gigas*. The associated invertebrate remains (Table 1) are attributable to a separate source (see below).

Readymix and Site 1. These sites are not on the itinerary, but Site 1 is interesting faunistically. Readymix contains few vertebrate remains. The very poor preservation of bone is attributed to long exposure at the land surface before burial. The indications are that the assemblage is the result of natural attrition, with skeletal remains swept into a local sediment traps (i.e. fissures) by sheetwash. The Site 1 fossils on the other hand show evidence of both surface exposure and predator damage, including to *Petrogale* sp. of up to 3 kg body-weight. The presence of larger prey species excludes avian and bat accumulators, and even *Dasyurus hallucatus*. The assemblage most closely resembles accumulations attributed to *Sarcophilus harrisi* (the Tasmanian Devil), which is more of a scavenger than an active predator, but does take food items back to its lair. *Sarcophilus* is known from Aboriginal rock-art and skeletal remains to formerly have been present in the Northern Territory.

Sedimentology and petrography

**Zion**. Fossiliferous sediments are associated with coarse Tindall Limestone breccia, laminar calcite crystals, speleothems, travertines and pisolite, confined to a linear structure extending over ca. 40 m. The deposit strikes about 310°, which corresponds to one of the major joint planes in the Tindall Limestone.

The ‘matrix’ of the fossiliferous sediments consist of sparite, clay, detrital quartz and micritic peloids. Sedimentary features such grading, sorting and bedforms are absent. The peloids appear to ‘float’ (i.e. lack grain-to-grain contacts) in 5-20 µm neomorphic spar, and high primary porosity has been occluded by equant (blocky) calcite cement. Neomorphism, floating texture, and cementation (calcrete formation) represent pedogenic overprints of a sediment of probably colluvial origin. The associated pisolite, composed of polygonally-fitted pisoliths, represents a form of caliche rather than cemented (calcreted) primary pisoliths of flowing freshwater streams (e.g. ‘cave pearls’ or ‘spring peas’). Thus, a variety of caliche is associated with diagenetically-altered primary deposits either indicative of free-flowing water in a cave or cave-entrance settings (laminated calcite crusts, speleothems and travertine) and colluvial lithotypes (i.e. coarse breccias and the fossiliferous colluvium). The facies association
represents calichified (calcreted) cave or cave-entrance deposits exposed by karst collapse.

**Cutta Cutta.** Fossiliferous sediments occur on a scree slope, but near the top of scree are two large boulders more or less *in situ* preserving part of a stratigraphic sequence. The base of the fossiliferous sediments though is not exposed. The fossil-bearing bed also appears to be of colluvial origin, and contains sand-size detrital quartz, angular pieces of Tindall Limestone up to 20 mm, pisoliths, brecciated micritic crusts, and bioclasts principally in the form of abundant gastropod shells and shell fragments. Most clasts, including the gastropods, have micrite envelopes, i.e. they represent ‘coated’ grains. Original porosity is occluded by two types of calcite cement. The first generation is isopachous, bladed calcite formed under phreatic conditions. The remaining void space often contains geopetal silt (indicative of vadose environments), succeeded by a second generation of cement with blocky texture (phreatic conditions). The micritic crusts and pisoliths have pedogenic characteristics. The fossiliferous sediment is succeeded by a thin bed of pisoliths and larger coated grains thought to be a lag produced by hydrodynamic winnowing. A 20 cm thick travertine, dated by S. Lauritzen using U-series at ca. 50,000 years, caps the fossiliferous sediment, thereby providing a minimum age for the fossils. Thus, the indications are that the fossiliferous sediment was derived largely from pedogenic particles (coated grains, micritic crusts and pisoliths), accumulated sub-aerially, i.e. not under hydraulic traction. The sediment surface however was winnowed hydrodynamically before being capped by travertine. A complex diagenetic history under both vadose and phreatic conditions calcreted the deposit.

**Readymix and Site 1.** The fossiliferous sediments at Readymix are also calcreted colluvium, and are not associated with any other lithotypes. Site 1 has a broadly similar facies association to that recorded at Zion, but a different accumulator was responsible for the fauna, as already outlined above. S. Lauritzen dated the fossiliferous matrix (also calcreted colluvium) at 70,000 ybp using U-series.

**Palaeoclimatic inferences**

Calcrete and caliche are characteristic of semi-arid regions, though not restricted to that climatic zone. Optimum development occurs from 400-600 mm per annum, but their formation depends more on the balance between precipitation, evaporation and seasonality. Calcrete and caliche rarely forms in the seasonally-dry tropics (excluding case-hardening forms), which is attributed to high summer rainfall intensities that tend to remove carbonate from the system entirely (cf. Katherine region today: mean annual rainfall ~800 mm, ~90% falling between November to March, with high runoff).

The data indicate that around 50 –70,000 years ago, conditions around Katherine were conducive to calcrete formation. The associated fossil assemblages are modern in composition, closely resembling those found today in monsoon vine forest (MVF) patches in sandstone country to the north. These MVFs today occur where local edaphic conditions ensure adequate year–round moisture availability for this plant association. The association of the fossil fauna with calcrete implies that annual rainfall around Katherine was probably somewhat lower than today, but also less seasonal in its distribution and therefore effective enough to support MVFs. There is some supporting evidence for these general palaeoclimatic inferences from comparable palynological, lake water-level and atmospheric circulation data from elsewhere in northern Australia. Some of the more hardy plant species from these MVFs still grow in limestone country around Katherine in sheltered pockets with slightly deeper soils, and some examples can be seen at Cutta Cutta.
Table 1. Faunal composition and minimum number of (mammalian) individuals (MNI) recorded at each site. These figures are based only on diagnosable material, i.e. jaws and teeth, and therefore are not an indication of the total amount of fossil material recovered and analysed. The presence of non-mammalian taxa is simply indicated by ‘x’.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>common name</th>
<th>Zion</th>
<th>Site 1</th>
<th>Cutta Cutta</th>
<th>Readymix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dasyuridae</td>
<td>Quoll family</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>gen. et sp. indet.</td>
<td>(undetermined quoll)</td>
<td>2</td>
<td>4</td>
<td>2</td>
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<td>Dasyurus hallucatus</td>
<td>Northern Quoll</td>
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<td>2</td>
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<td>Sandstone antechinus</td>
<td>1</td>
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<td>Common Planigale</td>
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<td></td>
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<tr>
<td>Peramelidae</td>
<td>Bandicoot family</td>
<td></td>
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<tr>
<td>Isoodon macrourus</td>
<td>Northern Brown Bandicoot</td>
<td>2</td>
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<tr>
<td>Macropodidae</td>
<td>Kangaroo family</td>
<td></td>
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<tr>
<td>Macropus sp.</td>
<td>large kangaroo</td>
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<tr>
<td>Petrogale sp.</td>
<td>rock wallaby</td>
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<tr>
<td>Pseudocheiridae</td>
<td>Ringtail possum family</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Pseudocheirus (Petropseudes) dahl</td>
<td>Rock Ringtail Possum</td>
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<td>Muridae</td>
<td>Rat and mouse family</td>
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<tr>
<td>Zyzomys maini</td>
<td>Main’s Rock Rat</td>
<td>32</td>
<td>30</td>
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<td>Delicate Mouse</td>
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<td>1</td>
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<td>Western Chestnut Mouse</td>
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<tr>
<td>Laggadina forresti</td>
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<td>Rattus tunneyi</td>
<td>Pale Field-rat</td>
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<td>False vampire-bat family</td>
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<td>Macderma gigas</td>
<td>Ghost Bat</td>
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<tr>
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<td>Horseshoe-bat family</td>
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<tr>
<td>Rhinonicteris aurantius</td>
<td>Orange Horse-shoe Bat</td>
<td>6</td>
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</tr>
<tr>
<td>non-mammalian taxa</td>
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<tr>
<td>Hylidae – Litoria cf. rubella</td>
<td>Desert Tree Frog</td>
<td></td>
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<tr>
<td>Agamidae</td>
<td>dragons</td>
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<td>x</td>
<td></td>
<td></td>
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<tr>
<td>Gekkonidae</td>
<td>geckoes</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Scincidae</td>
<td>skinks</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Boidae or Elapidae</td>
<td>pythons and/or elapid snakes</td>
<td>x</td>
<td>x</td>
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<td>x</td>
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<tr>
<td>Gastropoda</td>
<td>cf. land snails</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Crustacea</td>
<td>cf. freshwater crayfish</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Reference
LITCHFIELD PARK
AND
RUM JUNGLE URANIUM MINE

Mid Conference Tour
15 May 2002

Guides: Trevor Haig, Sandy Pidsley, Mick Verma
08.00 Depart from hotels for Litchfield National Park. Travel via the Stuart Highway and the picturesque township of Batchelor.

Visit the abandoned Rum Jungle mine site – the site of Australia’s first Uranium mine. The site was extensively rehabilitated in the 1980’s to reduce the downstream impacts of acid mine drainage. A tour of the mine site will be provided.

On to the Batchelor Butterfly farm for morning tea.

Continue into Litchfield, which is situated approximately 140 km south – west of Darwin. Litchfield and its immediate surrounds cover 143,000 hectares.

Visit the Termite Mounds and learn about how the termites live and construct these amazing mounds.

Litchfield National Park is on top of a table top plateau and is well known for its waterfalls. View Florence and Tolmer Falls then onto Wangi Falls for a picnic lunch and a swim in the clear pools. A walk around the top of the falls gives great views across the park.

Depart Litchfield returning to Darwin approximately 17.00. Drop off Stokes Hill Wharf and hotels.
Litchfield Park

Geology
The parks geology is dominated by the Depot Creek Sandstone, a Middle Proterozoic (1750my) formation that forms the Table Top Range with its cliffs and gorges. It is the lateral equivalent of the more well known Kombolgie Formation of the Arnhemland plateau in Kakadu National Park. The sandstone is massive to well bedded and commonly indurated at the surface to give the rock a quartzitic appearance. The sandstone is usually flat lying and is relatively undeformed. It unconformably overlies strongly folded Early Proterozoic shales.
Groundwater
The main streams, which drain the Table Top Range, flow throughout the Dry season. They are spring fed from a shallow aquifer developed in weathered rock, sandy soil and laterite on top of the plateau. Monsoon rainforest flanks these groundwater fed streams.

The sandstone itself only constitutes a minor fractured rock aquifer, with limited prospects for bore water supplies. A further set of springs is found at the base of the Range associated with the unconformity between the sandstone and underlying shale. Many of these springs are also permanent and support patches of monsoon rainforest. The composition of spring water in Litchfield Park is typical of non-carbonate groundwaters in the Top End, with low TDS and low pH. In the table below a chemical analysis of a spring water is compared to Darwin rainwater.

<table>
<thead>
<tr>
<th></th>
<th>Woolaning Spring</th>
<th>Rainwater (Darwin)</th>
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</thead>
<tbody>
<tr>
<td>TDS(mg/l)</td>
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<td>6</td>
</tr>
<tr>
<td>Conductivity(uS/cm)</td>
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<td>13</td>
</tr>
<tr>
<td>pH</td>
<td>4.7</td>
<td>4.9</td>
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<td>Temperature(deg.C)</td>
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<td></td>
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<tr>
<td>Sodium(mg/l)</td>
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<td>Potassium(mg/l)</td>
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<td>Hardness(mg/l)</td>
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<td>Chloride(mg/l)</td>
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</tr>
<tr>
<td>Sulphate(mg/l)</td>
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<td>.001</td>
</tr>
<tr>
<td>Bicarbonate(mg/l)</td>
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<td>.016</td>
</tr>
<tr>
<td>Fluoride(mg/l)</td>
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<tr>
<td>Silica(mg/l)</td>
<td>11</td>
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</tbody>
</table>
COASTAL PLAINS OF THE TOP END

Mid Conference Tour

15 May 2002

Guide: Steven Tickell & Daryl Chin
COASTAL PLAINS OF THE TOP END

8:00       Depart city hotels

9:30 – 10:30  Fogg Dam Conservation Reserve, “Woodlands-Water Lilly” walk
              • Vegetation & wildlife
              • Groundwater and ecosystem

10:50 – 12:30  Adelaide River “Jumping Croc” Cruise (at the Arnhem Hwy.). The 11am cruise would be best but other departures are at 9am and 2:30pm.
              • Wildlife

12:30 – 1:30  Lunch at “Jumping Croc”

1:40 – 2:25  Windows on the Wetlands interpretative center.
              • Geological history of coastal plain formation
              • Groundwater and the Coastal Plains

3:20 – 4:40  Howard Springs via back roads in Humpty Doo, swimming or rainforest walk
              • Land and groundwater use
              • Karstic spring
              • Groundwater dependant ecosystem
              • Vegetation & wildlife

5:20       City
Introduction
The coastal plains of the Northern Territory lie between 11° and 17° latitude. The climate is of the wet / dry tropical type with high temperatures throughout the year and only two distinct seasons. Thunderstorms herald the start of the wet season in November and may bring rain throughout the summer months. Occasional very intense but localised rain occurs when cyclones pass close to or cross the coast. Darwin’s annual rainfall falls mainly between November and March and totals some 1600mm. The “Top End” is influenced by the monsoon, which can usually be relied upon to bring summer rains.

Permanent stream flow only occurs in a few of the region’s rivers, mainly due to the long dry season and the fact that most aquifers are of the fractured rock type, with small storage that limits the potential to provide base flow. On the rivers that cross the coastal plain, tidal influence can extend many tens of kilometres inland.

The Coastal Plains.
18,000 years BP: At the height of the last ice age sea levels were some 120 metres lower than at present. The northern coastline was situated several hundred kilometres seaward of the present one. The areas of the present day coast were located mid way up the catchments where the environment was largely erosional.

By 7000 years BP the sea had risen close to the present level drowning the former river valleys that are now on the continental shelf. In low-lying areas (the river valleys) the coastline reached several tens of kilometres inland of the present day coast. These shorelines are marked in places by stranded chenier ridges.

Between 7000 and 4000 BP estuarine sediments accumulated and the shoreline prograded, gradually building up the coastal plain. Sedimentary environments present were mainly low energy include mangrove fringe, tidal flats and shallow estuarine. Higher energy environments include chenier ridges and tidal and alluvial channels. The sediments are dominantly muds and silts.
By 3000 years BP the current shoreline was established in areas such as the Adelaide, Mary, South Alligator and East Alligator Rivers and has been stable since then. Freshwater wetlands then became widespread after 2000 years BP.

Four morphological provinces can commonly be recognised on and adjacent to the coastal plains. The plains pass from “Alluvial” in the narrow landward end to “Palaeo_Estuarine” and then into the wider “Coastal” plain on the seaward side. They are bordered by “Uplands”, low undulating areas with bedrock at or near surface. The groundwater flow characteristics in each of the provinces are summarised on the diagrams shown on the next page.
Stop 1 Fogg Dam Conservation Reserve
This site is on a minor arm of the Adelaide River floodplain and is within the “Palaeo_Estuarine” zone. The soil is organic rich black cracking clay and is likely underlain by saline mangrove mud. The black clay accumulates during the seasonal inundation by fresh water.

The rainforest that the “Woodlands to Waterlily” walk passes through are maintained by groundwater discharge. The watertable in these low-lying areas is close to ground level throughout the year. Discharge is generally restricted to the margins of the plains where heavy confining clays are not present. The source of the groundwater is from fractured bedrock aquifers and in places from shallow aquifers in lateritic soil profiles. Discharge directly to the rivers only takes place in the more landward areas of the “Alluvial” zone where sediments are more permeable. Large amounts of salt are stored in the mangrove muds beneath the plains but are largely immobile.
**Darwin Rural Area**

Town supply: McMinns Borefield, supplements Darwins dam supply, also used to raise the pH. Typical analyses of groundwater and water from Darwin River Dam (the main supply) are shown in the table above.

Rural water usage: Most blocks are dependant on groundwater and each has their own bore. In the 1960’s there were about 100 bores, now there are more than 4000. This increased usage is reflected on the bore hydrograph below. Dry season water levels have been falling in recent years despite the above average rainfalls over the past decade. Most blocks are hobby farms (2ha) but there are an increasing number of larger blocks devoted to commercial horticulture. Mangoes are the main crop but bananas, rambutans, vegetables and flowers are also grown.

**Groundwater Issues:**

Over use of the resource, competing uses (town Vs local domestic Vs horticultural) and the effect of extraction on the native vegetation.

Joint studies have been done by NTU, CSIRO and the NT government to determine water use of the native vegetation, and its dependance on groundwater. The main vegetation type is Eucalyptus miniata (Woollybutt) and E.tetrodonta (Stringybark) open forest/woodland. Mature trees use up to 30 litres of water per day. The conclusion of the study is that it is not a groundwater dependant ecosystem. Wet season rainfall and water storage in the unsaturated zone is sufficient to tide the plants through the long dry season. Groundwater extraction will have little impact on the savanna vegetation but it may reduce the dry season stream discharge.

( the two figures below are from L.Hutley, Northern Territory University)
EUCALYPT SAVANNA WATER BALANCE

**Rainfall (1720 mm)**
- Evapotranspiration (1110 mm)

**Water Balance**

- **Runoff and Shallow Throughflow (410 mm)**
- **Groundwater Flow to Howard River (180 mm)**
- **Groundwater Surplus (20 mm)**

**Groundwater ages with depth**

- CFC-12 AGE (Yrs)

- **Groundwater recharge**
  - 200 mm yr⁻¹
  - (Velocity x porosity)
**Howard Springs**
The spring discharges from the Lower Proterozoic Koolpinyah Dolomite (2000 million years old). The dolomite is overlain 65 metres of Cretaceous aged claystone and clayey sandstone. It is located near the margin of the dolomite aquifer and is in an eroded sinkhole. The collapsed rock beneath the sinkhole provides pathway for the deep groundwater to find its way through the overlying claystone. Faulting may also have influenced the springs location. The springs end of Dry season flow averages about 30 litres/second.

The rainforest that flanks the spring represents a remnant of vegetation types that were much more widespread in the Tertiary. Similar patches of rainforest across the Top End are always associated with groundwater discharge.

An analysis of the spring water is tabled below, it is typical of groundwater from dolomite aquifers in the Top End.

<table>
<thead>
<tr>
<th></th>
<th>Howard Spring</th>
<th>Bore Rn6231</th>
<th>Darwin River Dam</th>
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<tr>
<td>Silica (mg/l)</td>
<td>14</td>
<td>7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Howard Springs - How It Formed.

1. Solution cavities develop along a fault.

2. Overlying rock collapses, forming a sinkhole and a groundwater-fed basin.

3. Stream erosion cut back into the sinkhole, removing all but the southern wall. The spring formed as groundwater was able to drain to the Howard River.
DARWIN RURAL AREA

Mid Conference Tour

15 May 2002

Guide: Peter Jolly
ITINERARY

Time: 8:00am to 5:30pm

Depart Carlton Hotel at 8:00am to:

- Doctors' Gully in central Darwin where you can participate in the "Boardwalk" through the rainforest and inspect some aspects of Darwin's urban hydrogeology.
- Visit Aquascene and feed the fish.
- Departing Darwin via the Stuart Highway to Howard Springs, a popular recreational feature based on a spring discharging from a Lower Proterozoic dolomite aquifer.
- Jenny's Orchid Farm for morning tea and an inspection of her unique collection of orchids and other tropical plants. During this trip an overview of some of the unique characteristics of the hydrogeology of the Top End will be provided.
- Territory Wildlife Park. This park is based around another large spring discharging from a Lower Proterozoic dolomite aquifer. Lunch is provided and you will get the chance to meet some of the Top End's unique animals.
- Berry Springs. The opportunity to go for a short swim while enjoying afternoon tea.
- Return to Darwin. Drop off at Stokes Hill Wharf at 5:30pm for meal and drinks (at participant’s own cost). Free shuttle bus will run from Wharf to Hotels.
**HISTORY OF DARWIN’S WATER SUPPLY**

Darwin’s early water supplies were acquired from bores, wells and overhead tanks, which in many cases were depleted by the end of the Dry. Another disadvantage and a huge health hazard was that the absence of a sewerage system until after the Second World War always threatened Darwin’s drinking water supplies. In the early years of settlement, the majority of wells constructed were never deeper than 23 metres and bores were not much deeper than this. In most cases, water was pumped by windmills or by crude oil or kerosene fuelled pump engines into overhead tanks and then gravitated to house tanks. One windmill or engine would usually be shared amongst neighbours and could pump water to four or more households. Those who could not afford the expense of a pump used manual pulleys and buckets to transport water into their homes. Water tanks were the preferred choice of domestic water supply, with government owned residences having a 13,600 litre tank capacity and government offices and buildings slightly larger at 23,000 litres. In 1928, it was estimated that Darwin had 200 wells and 22 bores. Most of these groundwater supplies had usually dried up by the end of the Dry and deeper wells or bores were, in most cases the only sources of water available. In times of hardship, many people were forced to obtain water from others or had to have it transported in, which was an expensive process. During the Darwin water shortages of 1913 for instance, water was sold for 3 pence per bucket.

Darwin’s first reservoirs were One Mile Dam and Three Mile Dam which were owned by shipping services and the Commonwealth Railways. One Mile Dam held 22.7 megalitres and was replenished by a spring at the bottom of the dam. The water from the dam was pumped into overhead tanks which was then piped to railway staff housing, the railway workshops and the jetty. Three Mile Dam had a capacity of 10.6 megalitres and obtained its supplies from surface drainage. The water from this dam was also pumped into overhead tanks and travelled the same route as that from the One Mile Dam. Although the two dams obtained water from completely different sources, none the less they were subjected to the same fate as the town’s bores and wells at the end of the Dry. On many occasions, Vestey’s Meat Works, the largest employer at the time, would supply these dams in times of shortage. Not surprisingly, there was a problem acquiring quality drinking water. Throughout the early 1900’s, this concern was raised repeatedly by the Government Medical Officer. The main issue was the sanitary conditions and the fear that unless an adequate drainage and sewerage system was installed in the town the water supply would become dangerously contaminated. So legislation for the first time, was introduced to protect individually owned water supplies. The legislation forced a well owner to erect a concrete collar around their well and to cover the opening.

Until Darwin acquired water reticulation in 1941, the town was continually plagued with water shortages and the threat of water contamination. In 1930, water was a scarce commodity and residents began to steal water from the One Mile Dam. In 1934, water supplies for consumption and shipping purposes had dried up. Trains were used to transport water from the Darwin River which was located some 70kms away. It was reported that “people were compelled to cart water three miles; that the town wells were dry...the hotels are short of water for baths and domestic purposes”. However, it was not until the advent of World War II and the need for a military presence in the north that a secure, safe and reliable water supply was established for Darwin.

Manton Dam, located 65km south from Darwin was a joint project undertaken by the Defence Department and the Commonwealth Department of Works at a cost of 87,000 pounds. Construction of the dam commenced in 1939 and Darwin received its first reticulated water supply on 10 March 1941. An additional bonus was that a water scheme now allowed residents to have a sewerage system in their homes. In 1964 bores were drilled into an aquifer developed in Lower Proterozoic dolomite near McMinns Lagoon to supplement the existing supply and to soften the surface supply. The borefield presently provides approximately 20 megalitres per day of Darwin’s water. In 1966 two water storage reservoirs and a booster station at McMinns Borefield were constructed 25 km from Darwin. Water from both Manton Dam and the McMinns Borefield was pumped into the two reservoirs. From the reservoirs, the water then travelled to storage facilities in and around Darwin.

An increasing population necessitated the need to develop a new water supply for Darwin, and on 29 June 1972, the $9 million Darwin River Dam was officially opened by William McMahon, the then Prime Minister. The dam’s capacity of 259,000 megalitres is 11 times larger than that of Manton Dam. Darwin’s current annual water consumption is 38300 megalitres.
Doctors Gully is located in the heart of Darwin. The groundwater that discharges in this gully flows directly into Darwin Harbour (See Figure 1).

**History**

In February 1869 Dr Robert Peel (See Figure 2) and a team of well diggers went ashore at Doctors Gully in search of a good supply of potable water. Runoff water would have been reasonably abundant at this time of year however there was a need to find a suitable supply of water that would not run dry during the dry season months. Peel’s successful well digging coupled with a good wet season runoff suggested that the gully be made the major watering point for the camp and stock. Peel’s Well was an important source of water for visiting shops for many years. Initially water was carried by the ships’ boat to the camp below Fort Hill but eventually was hauled by wagon.

**Market Garden**

Apart from finding a good supply of freshwater the next necessity was a garden to supply fresh vegetables and fruit for the camp. Seeds and plants were quickly planted in the rich floodplain of Doctors Gully and watered from its abundant well and adjacent creek. Many vegetables flourished including cress, radishes, melons potatoes and also sugarcane and bananas. A vegetable Garden reserve and adjacent water reserve was then established in 1872 (See figure 3). For many years the Gully provided ample fresh water for a very successful Market Garden.

In 1873, the water was highly regarded for its quality and became the base ingredient used by a softdrink factory and brewery. However in 1874 due to illness upon the proprietor the operations ceased.
Figures 3 and 4 feature a hospital reserve just above the gully. In 1874 the hospital was opened due to the increasing number of outbreaks of malaria within the settlement. The hospital was built on top of the north western cliff enclosing the gully. In 1913 A. Holmes describes the hospital in 1911 “… The drains were incomplete and ineffective, often offensive… urinal and earth closets situated on verandahs… a Chinese gardener used the night soil as fertiliser in the adjacent gully and sold the vegetables back to the hospital…(Dermoudy, 1995).
Chinese

During the early 1900’s there was a strong Chinese presence in Darwin and there was construction of a number of Chinese temples. Figure 5 is a photograph of a Haka Temple built on the foreshore of Doctors Gully. The gully was handed over to the control of the Town Council for public purposes on 31/1/1921, as was the whole of the Esplanade. This marks the end of the Market Garden era.

RAAF

In the 1930’s Doctors Gully was used by fishermen and small trading vessels, which were able to enter the small creek that led to the well. The next phase in history came about with the threat of war with Japan. In 1939 the RAAF formed a flying Boat Squadron and based it out of Doctors Gully. There was a construction of a ramp and some buildings in 1941 as well as jetties and slipways for workboats and a refuelling tripod. Aircraft and personnel did not however become permanent residents of Doctors gully until 1944. The bombing of Darwin illustrated the vulnerability to aerial attacks of the fuel tanks at Stokes Hill. The government then decided to build underground oil tanks in the escarpment surrounding the city. They also constructed 5 aboveground oil tanks at the edges of town, two of which were located in Doctors Gully.

Fish

After the war the government decided to hire a caretaker of Gully in order to prevent vandalism within the area. Carl Atkinson took over the caretaker’s position in 1946. In 1962 Atkinson started to attract mullet to the surface on high tides by feeding them bread. He also experimented with meet and found that Carnivores could be attracted as well. He soon had Batfish, Bream, Milkfish and catfish feeding every high tide. In 1964 he convinced the government to declare a suitable area as a Fish Reserve. In 1979 he decided to retire to New South Wales and left the venture to Marshall and Cherry perron to take over. The Perrons have developed the area and employ 10 staff and have over 500 visitors a day (statistics from 1995).
Figure 8 is a photo of the relic of Peels Well. Just a small cement structure today it provided many people with vital freshwater. In October 1969 the groundwater level was recorded at 2.1m. And even after the removal of 2000-2500 Litres the level only fell to 1.5m.

Doctors Gully is part of a perched aquifer. There is an impermeable layer of siltstone that acts as a confining layer for the groundwater. This formation has been geologically “squashed” and the layers are now vertical, which makes water penetration near impossible. The escarpment is made up of a claystone which has reasonably high porosity and permeability. Precipitation therefore infiltrates the claystone until it hits the siltstone. On top of this layer of siltstone there is a small band of gravel that allows free movement, under gravity, of water to flow towards the gully’s creek. Figure 9 depicts the geology of Doctors Gully.

Today pollution is a serious threat to water resources, and Doctors Gully is no exception. Pollution in Doctors Gully is most likely to occur via drainage pipes. Figure 10 displays the layout of pipes draining to Doctors Gully. The catchment area is quite large with the drains discharging into the creek at Doctors Gully. Disposal of household pollutants (washing detergent etc) all can enter the drainage pipes and effect the Doctors Gully ecosystem.

The stream discharges into Darwin Harbour very close to the Aquascene fish feeding venture. Pollutants could have an adverse impact on this tourism venture. Fig 10
Knuckeys Lagoon (drive past, not stopping)
There is similar geology here as at Doctors Gully but the Proterozoic formation is dolomite instead of siltstone. Karstic solution features like Knuckeys Lagoon are common over dolomite. Such depressions represent collapses propagated to the surface through up to 60 metres of overlying Cretaceous clay. Most lagoons are recharge points to some extent while others in low lying areas are windows on the watertable. The dolomite is widespread but virtually never outcrops because it is deeply weathered.

Howard Springs
The spring discharges from the Lower Proterozoic Koolpinyah Dolomite. The dolomite is overlain by Cretaceous aged claystone and sandstone. It is located near the margin of the dolomite aquifer and is in an eroded sinkhole. The collapsed rock beneath the sinkhole provides pathway for the deep groundwater to find its way through the overlying Cretaceous claystone and sandstone. Faulting may also have influenced the location of the springs.

The Dam and pool were constructed by the Army in the early 1940’s to provide a water supply source. After the construction of Manton Dam the pool has been used for recreation.

An analysis of the spring water is provided in the following table. It is typical of groundwater from dolomite aquifers in the Top End.

<table>
<thead>
<tr>
<th>WATER CHEMISTRY</th>
<th>Howard Springs</th>
<th>Berry Springs</th>
<th>Bore RN6231</th>
<th>Darwin River Dam</th>
<th>Rainwater (Darwin)</th>
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<tr>
<td>TDS(mg/l)</td>
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<td>180</td>
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<td>Silica(mg/l)</td>
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<td>7</td>
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Darwin Rural Area

Town supply: McMinns Borefields supplements Darwins dam supply. Typical analyses of groundwater and water from Darwin River Dam (the main supply) are shown in the previous table.

Rural usage: Most blocks are dependant on groundwater and each has their own bore. In the 1960’s there were about 100 bores, now there are more than 4000. This increased usage is reflected on the bore hydrograph below. Dry season water levels have been falling in recent years despite the above average rainfalls over the past decade. Most blocks are hobby farms (2ha) but there are an increasing number of larger blocks devoted to commercial horticulture. Mangoes are the main crop but bananas, rambutans, vegetables and flowers are also grown.
Joint studies have been done by NTU, CSIRO and the NT government to determine water use of the native vegetation and its dependance on groundwater. The main vegetation type is Eucalyptus miniata (Woollybutt) and E. tetrodonta (Stringybark) open forest/woodland. Mature trees use up to 30 litres of water per day. The conclusion of the study is that it is not a groundwater dependant ecosystem. Wet season rainfall and water storage in the unsaturated zone is sufficient to tide the plants through the long dry season. Groundwater extraction will have little impact on the savanna vegetation but it may reduce the dry season stream discharge.

Berry Springs / Wildlife Park
Berry Springs is the main outlet for a Lower Proterozoic dolomite aquifer similar to that which occurs at Howard Springs. The dolomite forms a small basin structure that is truncated at its northern end by a fault. The spring occurs at a low point in the landscape along the fault where the aquifer is in contact with impermeable shale. Berry Springs actually consists of numerous individual springs that spread along both the main fault and smaller ones, all of which are interconnected.

In the Berry Springs Nature Reserve, the main springs can be viewed from the boardwalk on the Territory Wildlife Park rainforest walk. The springs combine to form a tributary of Berry Creek. The tributary flows over a small waterfall where it joins the creek. Recent work has indicated that for most of the period since rainfall records commenced for Darwin in 1887, the flow from the springs has been in excess of 100 litres per second. Springflows of approximately 10 litres per second are likely to have occurred at the end of the dry season in only 2 years (1906 and 1970).

A chemical analysis of the spring water is shown in the table above. Groundwater in the basin is also used to irrigate a variety of tropical fruit crops such as mangoes, rambutans, paw paws and mangosteens. It is also bottled and sold as “spring water”. A locality map and a geological cross-section are shown on the attached diagram.