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HYDROGEOLOGY REPORT NO. 189

ASSESSMENT OF POTENTIAL GROUNDWATER CONTAMINATION FROM THE MOORE RIVER

by

Louise Stelfox

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…MISSION

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NOTE

Water & Rivers Commission

Perth, March 2001

Foreward

'You can compare a river with a human being. Alter one little bit and it is like taking out the heart - you can expect to see some fundamental changes. No surgeon would contemplate doing this unless it was replaced with a structure that performed exactly the same hydraulic or filtering functions.' Jim Masters, author of Principles of River Management.

Jim Masters was awarded the Order of Australia in 1994.

Acknowledgements

The interest and assistance of many people are acknowledged in the preparation of this report: those living and working along the Moore River, Agriculture WA officers at Moora and staff of the Water & Rivers Commission.

Further details relating to this report are available from Louise Stelfox, Hydrogeologist, or the Information Officer, Water & Rivers Commission, Tel: (08) 9278 0300. File 25042txt.doc contains information lists.

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Summary

The Water & Rivers Commission has carried out a four month NHT funded study to establish groundwater-river interaction along the Moore and Coonderoo Rivers. The aim of the study was to establish whether the fresh groundwater resource underlying the coastal sand plain is threatened by the salinity of the Moore and Coonderoo Rivers. The study has addressed surface flows, groundwater levels, salinity and nutrients in the surface and groundwater systems.

There is a variable annual salt load coursing down the Moore and Coonderoo Rivers. Reaches of river which are gaining or losing flow have been identified. Saline water is leaching into the Swan Coastal Plain aquifer south west of Cowalla Bridge. The rising groundwater salinity will have an impact on coastal groundwater public water supplies and further groundwater abstraction from the superficial aquifers. The deeper aquifers are not considered to be at risk from any surface water contamination.

The increasing demand for groundwater abstraction in the lower Moore catchment means that implementation of best management practice is essential to ensure that salinity increases are minimised within the superficial aquifer and the rivers. The Water and Rivers Commission must continue routine monitoring of surface water and groundwater in the Moore River catchment to assess the effectiveness of current water resource management practice. The continuation of sustainable water allocation by the Commission in the Moore catchment is essential to ensure that surface and groundwater resources are not compromised in terms of quantity and quality.

Groundwaters to the south of the Gingin Brook contain elevated nutrient concentrations. These are considered to have the potential to adversely impact upon the Gingin Brook and lower Moore River and estuary.

The Commission recommends that the Moore River Council continues to work with government agencies to guide investigations and policy development such that the livelihoods of people, and the environment, are protected.

1. Introduction

1.1 Location

The Moore River is located approximately 100km north of Perth, Western Australia, and discharges into the Indian Ocean at Guilderton (Figure 1).

The river has two branches: the Moore River North and the Moore River East. The Moore River North drains the Miling area to the north east of Moora. The river then drains in a southerly direction across the Victoria Plains. It joins the Moore River East west of Mogumber. The Moore River then flows west to Regans Ford, before flowing in a southerly direction to its confluence with the Gingin Brook. The Moore River then diverts west to drain into the sea at Guilderton.

The course of the Coonderoo River is from the Yarra Yarra Lakes to Moora. At Moora, during times of flood, the Coonderoo River flows into the Moore River North.

1.1.1 Study Area

The study area covers the catchment within the Perth Basin extending from the Yarra Yarra Lakes to the Moore River estuary at Guilderton (Figure 1).

1.2 Background

Groundwaters in the study area fall into two broad categories:

(i) those in deep sandy aquifers of the Perth Basin and Swan Coastal Plain west of the Darling Scarp which are predominantly fresh; and
(ii) those underlying cereal growing farmland on sandy loam and clay soils east of the Darling Scarp, which are predominantly saline.

The fresh water underlying the coastal sand plain has significant value for human consumption, irrigation of horticultural areas and gardens, and for stock watering.

There are community concerns that the fresh groundwater resource is threatened by saline water carried down through the catchment by the Moore and Coonderoo Rivers. Saline contamination can occur in two ways: by floodwaters trapped on the floodplain; and by recharge of groundwater through leakage from the river bed. The river water may also contain nutrients and agricultural chemicals.

The extent or significance of this concern has never been studied. For example it was not known whether the Moore River is a recharging (gaining flow) or a discharging (losing flow) stream where it crosses the Swan Coastal Plain. This can be determined by relating the elevation of the river to the elevation of groundwater within bores close to the river, and from studying groundwater and surface chemistry along the Moore and Coonderoo Rivers.

The National Heritage Trust financed this project.

1.3 Project Description and Objectives

In order for appropriate land management strategies to be carried out, an understanding of the interaction of groundwater and surface water is necessary. The aim of this study is to provide relevant information on the surface water flow and groundwater flow mechanisms along the Coonderoo and Moore Rivers. Critical to this process is gaining an understanding of which sections of the rivers are recharging (gaining flow) or discharging (losing flow).

1.3.1 Target Audience

This report has been written with the following target audience in mind:

- land care groups
- farmers
- water managers
- local government
- environment groups
- the local community.

The Water & Rivers Commission recognises that community involvement and co-operation is a crucial part of this study. Whilst in the course of this study there has not been time to consult all groups it is hoped that this report will act as a foundation stone upon which further data, interpretation and understanding can be gained.

1.3.2 Activities undertaken

The study period was four months between November 2000 and March 2001. The following activities have been undertaken:

a) Study area reconnaissance
b) Literature collation
c) Data collation – in the office and in the field
d) Drafting of maps and long section
e) Site survey and chemical sampling
f) Consultation with members of the target audience
g) Report and poster preparation
h) Presentations

1.3.3 Project Limitations

Whilst every effort has been made to present real data it is recognised that hydrology is a dynamic subject. Some data is old and values may have increased or decreased since the time the data was collected. For example, groundwater levels may have risen, salinity or nutrient data may have changed.

The project time constraint has meant that all historic data cannot be validated for this report. Where the actions of any party are reliant upon any data reported, it is recommended that the validity of this data is checked by the collection of further data in the field.

2. Physical Features

The drainage channels of the Coonderoo and Moore Rivers have developed over many thousands of years. An appreciation of the physical features of the earth and their causes (the physiography), and their relation to each other, can assist in the understanding of the interaction of groundwater and surface water along the river channels.

2.1 Geological History

The Australian continent was once part of Gondwana, the great southern supercontinent. While attached to Africa, India and Antarctica, drainage patterns were established into the Australian continent. The west coast of Western Australia originated when India moved away from Australia 132 million years ago, creating the Indian Ocean. Antarctica finally separated from Australia 45 million years ago. With the freeing of the supercontinent connections new drainage patterns resulted, some rivers now draining to the sea (White, 1997).

Western Australia was uplifted and the old plateau, the Yilgarn Craton was eroded flat. The great antiquity of the landscape, and the length of time available for weathering have resulted in low nutrient soils.

The Australian climate has become drier over the last 15 million years, resulting in many rivers becoming ephemeral (short periods of flow) and with chains of salt lakes in their beds.

Over the last million years the sea level has risen and fallen in response to the tying up and freeing of water in the ice caps. Sea level change has sculptured the coast of Western Australia and resulted in the deposition of marine sediments. The Gingin Scarp marks a former coastline.

The erosion of the Yilgarn Craton and the deposition of both continental and marine sediments have formed the Perth Basin to the west of the Darling Ranges. The Perth Basin comprises a series of permeable and non-permeable rocks. The permeable or water bearing aquifers have been exploited for water supply.

Where a river cuts its way through permeable rocks there is likely to be groundwater-surface water interaction. Where the river flows over or through impermeable rocks there is unlikely to be groundwater-surface water interaction.

2.2 Landforms

The sediments within the Perth Basin have been subject to gentle tilting and faulting, resulting in some of the physical features seen today. The physical features, or landforms, seen today are related to the underlying geology and erosion processes.

From the coast travelling inland within the Moore River catchment the physical features fall into distinct regions as shown in Figure 1. These are generally north to south orientated and parallel with the coastline.

From the coast to the inland region, the landform features are described as the Swan Coastal Plain (Coastal Belt and the Bassendean Dunes), the Dandaragan Plateau, the Yarra Yarra Region and the Darling Plateau.

The Coastal Belt consists of shoreline deposits, dunes and hills of dune limestone (Tamala Limestone), and is approximately 8km wide. The Bassendean Dunes form low hills on a plain up to 100m above sea level and as much as 20km wide. The Dandaragan Plateau is sand and laterite (ironstone) covered and is relatively flat at 200-300m above sea level. The Yarra Yarra Region has an average elevation of 200m. It is bounded on the east by the Darling Fault scarp and forms a north-south strip between the Darling and Dandaragan Plateaus (Playford, 1976). This area is very flat and dominated by salt lakes. The Darling Plateau has an average elevation of 400m above sea level.

2.3 River History

The twists and turns of the Moore River channel and its tributaries are the result of a complex history. What we see now as the Moore River is really parts of the courses of several rivers joined together.

Orginally, westward drainage from the Darling Plateau was prevented from flowing west by uplift of the Perth Basin, and the Coonderoo and Moore River valleys ran south from what is now the Yarra Yarra Lakes along the Darling Scarp. With time the drainage channel filled with (alluvial) sediments to form a *palaeochannel.*

The original river turned south-east at Mogumber to cut the valley now occupied by the Brockman River. This valley was infilled with up to 30 metres of sediments between 2 – 5 million years ago.

At some stage, a stream may have cut back from Regans Ford, from where there was a coast line about 2 million years ago, and captured the Moore River at Mogumber, making it do a right turn. Alternatively, the river may have found its course blocked to the south, and overflowed to the west, cutting the gorge from Mogumber to Regans Ford.

The Moore River may once have drained west to the Indian Ocean in the vicinity of Ledge Point, although the current topography gives no clue as to the outlet. With the onset of drier conditions, and recession of the coast during the ice ages, maybe 100,000 years ago, the build up of dunes along the coast may have prevented the river reaching the sea.

The north and western banks of the Karakin Lakes have been cut into by water. The Karakin Lakes may be a former interdune valley within the Bassendean Sands; a remnant ox-bow lake feature; or a sharp bend in the river, where the river was forced to turn sharply south by the development of the dunes.

The north to south drainage of the Moore River from the Karakin Lakes to the confluence with the Gingin Brook is constrained to the west and east by limestone ridges. Fossil evidence (pers. Comm., Grant, 2000) suggests that this is a young channel, supporting the hypothesis that the Moore River has changed its direction from a former drainage route. The Moore River has migrated west in the stretch between the Karakin Lakes and the confluence with the Gingin Brook, and is cutting into the eastern edge of the western limestone ridge.

Where the Moore River joins the Gingin Brook it turns sharply west and, sand bar permitting, flows into the sea at Guilderton. Fossil evidence suggests that the Gingin Brook is an old flow channel. The Gingin Brook and/or the Moore River have eroded the limestone to break through into the Indian Ocean.

3. Hydrology

3.1 River Flow

The Coonderoo River is ephemeral (i.e., it doesn't flow every year) whereas the Moore River is seasonal (i.e., it flows every year). The Moore River gained its name from the Aboriginal name for the deep pools, or 'Mur', in the river west of Mogumber, and after the European explorer George Fletcher Moore (Laurie, 1995) .

During the summer the Coonderoo and the Moore River North are generally dry. The Moore River catchment has experienced periods of extreme drought and extreme flooding. A severe drought was experienced in 1914. Severe floods were experienced in the winters of 1907, 1912, 1917, 1932, 1955, 1964 and 1999 (Laurie, 1995.)

During the flood of 1999 the Coonderoo River flowed into the Moore River North at Moora [in July 1999, at a rate of 27 m^3/s (Yesertener et al 2000)]. The Coonderoo and Moore essentially are one river system with a catchment area of 13,600 km^2. In years of 'normal' rainfall the perennial (all year round) head of the Coonderoo River is Salt Creek (see Figure 2), giving a catchment area of 9,100 km^2 (Muirden, 2001).

In years of exceptionally high rainfall, the water courses of the Yarra Yarra Basin and the Moore River catchment could potentially link-up to form one river with a catchment area of 55, 700 km^2. In ancient times the Ninghan Basin (to the north east of the Moore River North) also linked up to the 'Greater Moore' (Yesertener et al, 2000).

3.1.1 Flow records

Flow readings in the study area commenced at Quinns Ford, 10km upstream of Regans Ford, in May 1969 (Water & Rivers Commission data). The catchment area is defined as 12,400 km^2, the average rainfall as 400mm per annum, and the average evaporation as 2,350mm per annum.

The mean and median monthly flows for 1969 to 1999 are given in Table 1.

Table 1 **Monthly flows recorded at Quinns Ford, 1969 to 1999.**

(Units are megalitres or thousands of cubic metres.)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	239	745	3,128	1,013	3,730	8,944	24,032	20,737	6,461	1,497	375	275
Median	62	115	182	213	798	4,367	11,339	15,432	2,421	757	235	173

The median flow is the middle flow within the range of flows recorded, while the mean flow is the average flow recorded in each month. The mean flow is biased towards high flows. As would be expected with respect to rainfall, peak flows coincide with winter rainfall, during June, July, August and September.

The Water & Rivers Commission currently has ten flow gauging stations in the Moore River catchment with the primary purpose of measuring flood levels and flows. These can be located in Figure 2.

Table 2. **Water & Rivers Commission flow gauging locations in the Moore River catchment**

Station	Name	Easting	Northing	Date monitoring commenced
617001	Quinns Ford, Moore River	387900	6571700	May 1969
617003	Bookine Bookine, Gingin Brook	369230	6534020	April 1972
617006	Bennies Road, Moore River	359550	6545520	May 1996
617009	Wourie Pool, Moore River East	415900	6568150	May 1999
617010	Moora Caravan Park, Moore River	404425	6609970	June 1999
617011	Long Pool Bridge, Moore River North	420580	6616910	June 1999
617012	Roundhill, Moore River North	426800	6618015	June 1999
617013	Nardy Road, Moore River North	429000	6623650	June 1999
617015	Waterville Road, Moore River	366000	6540060	May 2000
617058	Gingin town, Gingin Brook	397000	6532000	Jan 1957

At the time of writing high quality flow discharge data is available for Quinns Ford on the Moore River and Bookine Bookine and Gingin town on the Gingin Brook, while estimated discharge data is available for the others. Continuous conductivity data is available for Quinns Ford and Moora Caravan Park.

Figure 3 shows recorded river flows and salinities for 1999 for four sampling site stations along the Coonderoo and Moore Rivers; Dandaragan Road Bridge at Moora, Gillingarra Bridge, Quinns Ford and Waterville Road. The peak flows observed in March were a result of Cyclone Elaine. The peak flows from May-July coincide with frontal systems. Upstream of Quinns Ford the Coonderoo and Moore Rivers were dry (apart from Eagle Hill Tributary and Salt Creek) prior to the March 1999 flood. Figure 3 shows the river flows peaked at the following approximate flow rates:

Coonderoo River, Dandaragan Road Bridge	100,000 l/s (estimate)
Moore River North, Gillingarra Road Bridge	290,000 l/s (estimate)
Moore River, Quinns Ford	450,000 l/s (actual)
Moore River, Waterville Road	150,000 l/s (estimate)

The peak flows increased down the river system except downstream of Quinns Ford where the peak flow at Waterville Road was less than the peak flow at Quinns Ford. This is due to the storage effect of the flood plain, loss of water from the river into groundwater and by evaporation. To calculate actual flow loss from the river to the groundwater it is important to have the Waterville Road gauging station rated for flood flows.

3.1.2 Field Observations

This four month study was undertaken during the summer months of November 2000 to February 2001 inclusive during which time there was negligible rainfall. The Coonderoo River was dry. The Moore River started flowing as a consequence of groundwater discharge from Palms Park Spring on the Moore River North (Figure 2), and from east of Wourie Pool on the Moore River East. Photographs are in Appendix I.

The hydrological observations made during November 2000 to February 2001 inclusive are reported in Appendix II. Locations of observation sites are shown in Figure 2.

River flows decreased during the study period. The river flows observed during February 2001 were mainly derived from groundwater discharge. Measurement of river flows on 24 February 2001 (Figure 11) confirmed those reaches, or sections, of the Moore River which were gaining flow from groundwater discharge, and those reaches which were losing flow to the aquifer.

Table 3. River Flow Measurement in February 2001

	Reach	Change in flow (m^3/d) (+/-16%)	Losing/Gaining
a)	Mogumber to Quinns Ford	+6,000	Gaining
b)	Quinns Ford to Mogumber Road West river access	+7,000	Gaining
c)	Mogumber Road West river access to Regans Ford	+14,000	Gaining
d)	Regans Ford to Cowalla Bridge	+11,000	Gaining
e)	Cowalla Bridge to Bennies Road	-18,000	Losing
f)	Bennies Road to Waterville Road	-14,000	Losing
g)	Waterville Road to confluence with Gingin Brook (Gingin Brook contribution only)	+7,000 minimum	Gaining
h)	Gingin Brook confluence with Moore River & Lancelin Road Bridge	+12,000	Gaining
i)	Lancelin Road Bridge to Moore River estuary	Not recorded	Considered to be gaining

The river was gaining significant flow between Mogumber and Regans Ford. The river was losing flow between Cowalla Bridge and downstream of Bennies Road. The net gain in river flow between Mogumber and Lancelin Road Bridge was approximately 18,000m^3/d.

4. GEOLOGY

4.1 Regional Setting

The Moore and Coonderoo Rivers flow across the Yilgarn Craton and the Perth Basin. These geological provinces are separated by the Darling Fault as shown in Figure 4.

The **Yilgarn Craton** to the east of the Darling Fault comprises very old crystalline rocks; granite, metasediments and gneisses. The Darling Ranges are generally synonymous with the Yilgarn Craton.

The **Perth Basin** comprises sedimentary rocks in a north-south orientated trough, to the west of the Darling Fault. The majority of these rocks were laid down in a rift valley 280 to 65 million of years ago (between the Permian and Cretaceous). The earlier sediments were mostly deposited in a continental, alluvial environment, whereas the sediments younger than 110 million years old (Late Cretaceous) are of marine origin, formed after the separation of India, and the break up of the supercontinent, Gondwana. The land surface was uplifted in the Eocene, around 40 million years ago, with the development of the modern drainage pattern, some of which has been preserved by lateritisation. Later modification of the drainage has left palaeochannels (old river valleys) infilled with sands and clays of Late Miocene to Pliocene age (around 5 million years old). Fluctuating sea levels in the last million years have led to the deposition of superficial sediments on the Swan Coastal Plain west of the Gingin Scarp.

Figure 5 shows the stratigraphy of rock deposition (the order in which rocks were laid down).

4.1.1 Geological Investigations

The sedimentary rocks of the Perth Basin are poorly exposed at the surface. The rocks exposed in the gorge between Regans Ford and Mogumber are very difficult to identify due weathering and the similarity of shale and sandstone throughout the sedimentary sequence. The stratigraphy has been determined by borehole descriptions, downhole geophysics, and fossil dating (palynology) of drilled rock cores.

The exploratory drilling projects in the area, carried out by the Geological Survey of Western Australia are the:

- Agaton project (Balleau & Passmore, 1972)
- Watheroo – Jurien Line (Harley, 1974)
- Moora Line (Briese, 1979)
- Salvado Project (Moncrief & Tuckson, 1987)
- Cataby Project (Kern, 1988)
- Gillingara Line (Moncrieff, 1989).

The Water & Rivers Commission recently investigated the hydrogeology south of the Yarra Yarra Lakes (Yesertener, 1999) in a related NHT funded project. The resulting reports, along with others, have been used in interpreting the geology beneath the Moore and Coonderoo Rivers. This report is mainly concerned with the shallow and, usually, younger rocks of Cretaceous age upwards.

4.2 Rock Types by Area

Downstream of Mogumber the Moore River flows across the Perth Basin. To the north, the Moore River North, Moore River East and the Coonderoo River mainly flow over the Yilgarn Craton. However small stretches of these rivers also flow across the Perth Basin. Figure 6 is a cross section drawn along the beds of the Moore and Coonderoo Rivers. The cross section shows the geology beneath the river beds.

As discussed in Section 2, differing geology often erodes to give different landforms. The geology beneath the rivers is described below.

Coastal Belt

The Coastal Belt is up to 8km wide and comprises Holocene (Figure 5) shoreline deposits and dunes backed by hills of the middle-late Pleistocene Tamala Limestone (Playford et al, 1976). The Tamala Limestone is leached at the surface, leaving a residue of yellow to white quartz sand. Caves systems occur in the Tamala Limestone. These have been identified along the edges of the limestone ridges to the west of Cowalla Road and along Baramba Road. The shoreline deposits and Tamala Limestone are Quaternary in age and are grouped as *superficial formations*. The Coastal

Belt is underlain by the Lancelin Formation (see below).

Bassendean Dunes

The Bassendean Dunes, formed by the Bassendean Sand, are up to 20km wide and form low hills of quartz sand. Also Quaternary in age, the Bassendean Sand is also grouped with the superficial formations. The Bassendean Dunes are underlain by the Osborne and Leederville Formations (described below).

Dandaragan Plateau

The Gingin Scarp is a former shoreline along which the Brand Highway has been constructed. It forms the western edge of the Dandaragan Plateau. The eastern edge is defined by the Darling Scarp. The Dandaragan Plateau is a **sand and laterite** (weathered iron rich rock) capped plateau overlying Cretaceous rocks. The sand and laterite can be up to 5m thick and are termed as *surficial deposits*. They cover most of the Cretaceous rocks on the Dandaragan Plateau (Moncrieff, 1989).

The Moore River has dissected the Dandaragan Plateau to expose older Cretaceous rocks of the Leederville Formation to the east of Regans Ford (Moncrieff, 1989). The Leederville Formation comprises Cretaceous sandstone, shale, siltstone and conglomerate (Playford et al, 1976). To the east of Quinns Ford the Leederville Formation is overlain by the Dandaragan Sandstone (also known as the Henley Sandstone Member elsewhere in the Perth Basin) and the Osborne Formation. These are overlain by the Lancelin Formation. (Figure 5). The Dandaragan Sandstone contains feldspathic sandstone, with minor claystone and shale. The Osborne Formation comprises glauconitic siltstone, claystone, shale and sandstone. The Lancelin Formation consists of light to greenish grey, sandy mudstone, sandy siltstone and silty sandstone. It has three members: the Molecap Greensand at the base, the Gingin Chalk in the middle, and the Poison Hill Greensand at the top.

East Dandaragan Plateau, Moore Valley

To the west of Mogumber the Osborne Formation outcrops between the Lancelin Formation and the Darling Fault (Figure 6), and continues northwards, underlying alluvial deposits and probably palaeochannel sediments. The Moore River North traverses Archaean granites and gneisses and then alternately the Osborne Formation (or other Cretaceous rocks) and the Moora Group. The Moora Group rocks are very old, Proterozoic (about 1,000 million years old) and consist of orthoquartzite, chert and siltstone.

The presence of the Osborne Formation continuing to the east of the Darling Fault is questionable. Between the salt lakes to the west of Moora, and Moora town, the Moora Artesian bore was drilled in 1913. This bore indicates that here the Leederville Formation is present beneath the surficial deposits. Recent drilling in Moora also indicates the presence of the Leederville Formation at shallow depth (pers. comm., Russell Speed, AgWA, 2001).

Yarra Yarra Terrace

Between the Yarra Yarra Lakes and the Marchagee Track the Coonderoo River is underlain by a palaeochannel. The palaeochannel is an old drainage route of approximately 30m thickness. It comprises sands, gravels and plastic clay deposited in the late Tertiary (Pliocene), less than 5 million years old. It is considered that the palaeochannel extends south to Mogumber, although its width and depth are questionable. The palaeochannel sediments are also termed *surficial deposits*.

Between the salt lakes at Watheroo and the Marchagee Track the Coonderoo River has crossed the Darling Fault. Beneath the palaeochannel the Parmelia Formation (Cretaceous) has been faulted against older Jurassic and Triassic rocks (Figure 6). The Jurassic units are the Yarragadee Formation, Cadda Formation, Cattamarra Coal Measures and the Eneabba Formation. The Triassic units are the Lesueur Sandstone and Kockatea Shale (Yesertener, 1999).

5. HYDROGEOLOGY

5.1 Regional Setting

This study is mainly concerned with groundwater flow close to the Moore and Coonderoo Rivers. Groundwater flows through, and is stored by, some rocks (e.g. sands and sandstones). These are termed *aquifers*. Other rocks impede the flow of groundwater and cannot hold water in storage (e.g. clays, shales, mudstones and siltstones). These are termed *non aquifers*, *aquitards*, *aquicludes* or *confining beds*.

5.2 Areal Setting

The late Jurassic and Cretaceous sandstones of the Perth Basin form important aquifer systems from which groundwater can be abstracted. The right hand column of Figure 5 shows those rock types termed aquifers.

The major aquifers in the area are the Quaternary *superficial aquifer* west of Regans Ford, the Tertiary palaeochannel *surficial aquifer* and the late Jurassic and Cretaceous *Leederville-Parmelia aquifer*. The Poison Hill and Mirrabooka aquifers are minor aquifers.

The term 'aquifer' does not imply rapid groundwater flow. The rocks forming the Perth Basin aquifers are rarely continuous in a horizontal plane. At the same depth sands and siltstone/mudstone/shale may be found next to each other. Equally different rock types have been laid down vertically. This constrains how quickly groundwater can flow in a vertical or a horizontal direction. The rate of groundwater flow is governed by the *lowest* permeability, and the groundwater head which drives the movement of groundwater. As a consequence groundwater can move very slowly in rocks. A distance of 3m in a year could be typical in the Leederville-Parmelia Aquifer. In less cemented strata, like the younger sands of the superficial formations, groundwater flow rates can be of the order of 50-150m in a year. Groundwater flow rates may be greater in the Tamala Limestone, depending upon the degree of interconnectivity of solution features (Davidson, 1995) .

5.2.1 Groundwater Level Records

Groundwater level records have been collated from the hydrogeological investigation reports listed in section 4.1.1 and from the Water & Rivers Commission AQWABase groundwater database. Up-to-date groundwater level data was collected in the field during the study period. All groundwater level data, with the date of collection, are recorded in Appendix III. The groundwater level data has been used to draw groundwater contours along the rivers (Figure 7). A groundwater contour is a line upon which all groundwater heads are equal. The figures on the groundwater contours in Figure 7 are groundwater head in metres above Australian Height Datum (m AHD).

Groundwater hydrographs (water level data plotted against time) for the study area show typical seasonal fluctuations and long term trends. At some bores groundwater levels have been rising. Appendix IV contains those groundwater hydrographs which have been exhibiting an upward trend in water levels. In the lower section of the Moore River, the Salvado bores, 3A, 7A, 8A, 12A and 18A, have experienced rising groundwater levels since monitoring began in 1980. The sharp rise in groundwater levels in 1999 follow the high rainfall and the flood of that year. The overall rising trends are not seen elsewhere within the superficial aquifer. The rising water levels could be related to flow leakage from the Moore River into the aquifer between Cowalla Bridge and downstream of Bennies Road.

The hydrographs for the Gillingarra bores GL6W and GL8W show that water levels within the Leederville-Parmelia Formation and the Dandaragan Sandstone within the Osborne Formation are locally rising (Appendix IV). [The Dandaragan Sandstone within the Osborne Formation is locally in hydraulic continuity with the Leederville-Parmelia aquifer.]

5.2.2 Cross Section

The cross section along the Moore and Coonderoo riverbeds (Figure 6) shows the geology and hydrogeology beneath the Moore, Moore River North and Coonderoo Rivers, between Guilderton and the Yarra Yarra Lakes. Water levels from the bores shown in Figure 4 and the water contours shown in Figure 7 are plotted on the cross section. Water heads consistently above the river bed demonstrate those river reaches which are gaining flow from groundwater discharge. Those water heads which were consistently below the river bed show those reaches which are losing flow to groundwater. Where groundwater heads are consistently at the same elevation as the river bed it is considered that these reaches are not losing or gaining significant flow. These river reaches are flowing across non-aquifers.

The flow data shown in Figure 9 and discussed in section 3.1.2, and the groundwater level contours, show that the Moore River is gaining from groundwater discharge downstream of Mogumber, except between Cowalla Bridge and downstream of Bennies Road, where the Moore River is losing, by leakage into the superficial aquifer.

6. SALINITY

6.1 Background

Salt arrives in Western Australia from the sea, carried by wind and rain. Over a very long time a vast tonnage of salt has been acquired. Salt has built up at the water table in areas of poor drainage. This phenomenon is natural, and is known as **primary salinity**.

The hydrology of Australia has changed as a consequence of land clearing. The natural landscape was in balance with the trees using the available rainfall, resulting in stable and low groundwater levels. The water balance has changed as less water is now taken by the vegetation, leaving more to percolate to groundwater which has resulted in rising water tables. The salt naturally deposited and leached down to the soils and low water tables in the past is brought up by the rising groundwater. Salinisation of soil, of near surface groundwater and of rivers results. This is a human-induced phenomenon commonly referred to as 'dryland salinity', and in text books as 'secondary salinity'. **Secondary salinity** is defined as salinisation resulting from a change in landuse which causes a change in the hydrology. Land clearing and low water use pasture and cereals contribute to secondary salinisation as more water infiltrates the land. Irrigation can also contribute to the increased concentration of salt through evaporation.

The flat terrain of Western Australia means that many rivers cannot easily transport salt run-off from the land to the sea. Salt pans are a feature of poor drainage and are naturally saline.

Soil salinity carries the additional problem of **alkalisation.** Sodium ions (from the salt) disperse the fine clay particles in the soil, resulting in the collapse of the soil's structure. The soil then swells, pores are clogged and it becomes less permeable. Thus soils with a high clay content are sensitive to **water logging** (White, 1997).

6.1.1 Salinity Classification

Salinity is the measure of the dissolved (soluble) salt content in water. Total Soluble Salts (TSS) and Total Dissolved Solids (TDS) are measured by different processes, (chemical analysis and evaporation respectively) but for most purposes they can be read as the same thing. Measurements are usually in milligrams per litre (mg/L) or parts per thousand (ppt). Measurements in ppt can be converted to mg/L by multiplying by 1000.

The classification of salinity can vary depending upon the use of the water as shown in Table 4 (Water & Rivers Commission, 1998).

Table 4. Classification of Salinity dependent on Use of Water

	Water Supply Classification (mg/L TDS)	Environmental Classification (mg/L TDS)	Wetland Plants Classification (mg/L TDS)
Fresh	<500	<500	<3000
Marginal	500-1500 500-1000 acceptable based on taste >1000 can result in scaling and corrosion of pipework	500-1500	
Brackish	1500-5000	1500-5000	<10,000 all year <3,000 after inflow
Saline	>5000	>5000	<50,000 all year <10,000 after inflow
Hypersaline	>35,000 Having a salinity greater than seawater.	>35,000	

Salinity is also often expressed as electrical conductivity (EC), measured using an electronic probe attached to a conductivity meter as shown in Photograph 13.

6.2 Within the Study Area

The Coonderoo and Moore River catchments are affected by both primary and secondary salinity. Low rainfall, poor drainage and high evaporation have resulted in the concentration of salt in the soil. Whilst some of the salt runs off into streams, much of it leaches into groundwater.

Groundwater discharge on the eastern edge of the Perth Basin, together with saline groundwater flow from the Yarra Yarra Lakes has given rise to the concentration of salts in groundwater and in discharge features such as salt lakes along the Coonderoo River. This is an area of natural groundwater discharge and consequent high groundwater salinity, which can be expected to have changed in accordance with climatic fluctuations.

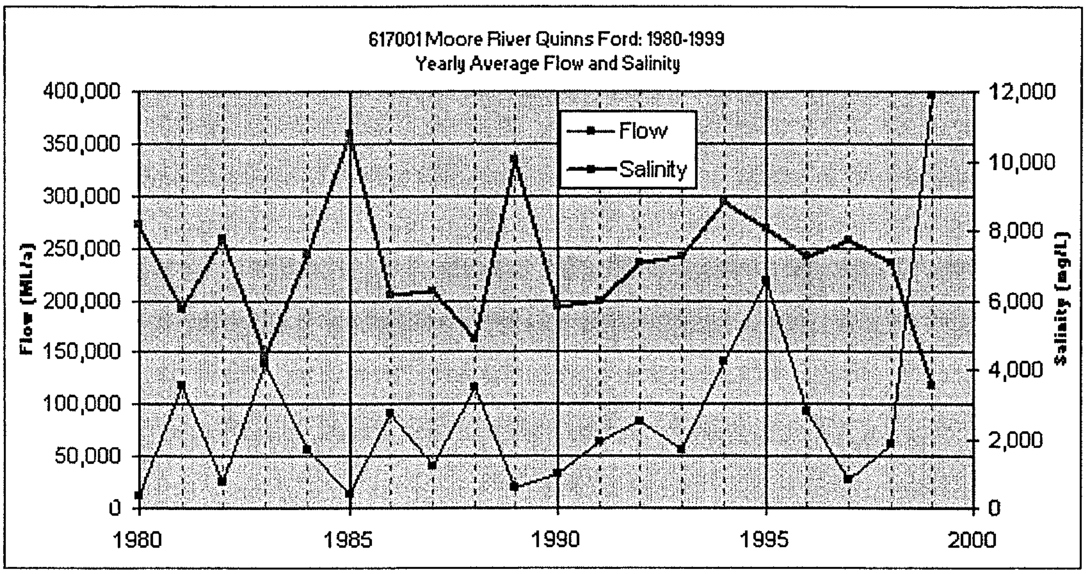
Clearing of native vegetation on the clay rich soils of the Darling Plateau (see Figure 1) has resulted in a rise in water table, and the mobilisation of stored salts within the soil. This has led to salinisation of water courses, and increased salinity of run off in tributaries to the Moore and Coonderoo Rivers.

6.2.1 At Quinns Ford

The long term flow weighted average total dissolved solids (TDS) [total flow divided by total mass of salt] reported at the Quinns Ford flow gauging station on the Moore River for the years 1969 to 1999 is 7,000mg/L (Muirden, 2001). High river flows correspond to low river salinities due to dilution as a consequence of the large proportion of direct run off of rainfall.

Figure 8 shows that between 1980 and 1999 the yearly flow weighted average salinity of the Moore River at Quinns Ford has fluctuated between 3,500 mg/L and 10,800 mg/L. Between 1980 and 1999 the long term average flow was 90,100 Ml/a; the long term flow weighted average salinity 7,000 mg/L and the average load of salt which had passed down the river at Quinns Ford in this time 550,000 tonnes/annum (550kt/a). In comparison, between 1990 and 1999 the long term average flow was 117,400 Ml/a; the long term average salinity 6,800 mg/L and the average load of salt in this time was 730,000 tonnes/annum (730kt/a).

Figure 8 Yearly average river flow and salinity at Quinns Ford, 1980 to 1999



1995 and 1999 were high flow years at Quinns Ford on the Moore River. If these years are excluded (as exceptional) then the average salt load for 1980 at Quinns Ford was 300kt/a*, whereas the average salt load for 2000 was 700kt/a* (Muirden, 2001). [*Calculated using 7 year averages centred on the years 1980 and 2000.] So, even when 1995 and the 1999 flood are ignored, the volume of water and the tonnage of salt passing Quinns Ford were greater in the year 2000 than in 1980.

Measuring salinity concentration alone is not sufficient an indicator of salt flowing down a river if the long term average flow rate has increased. Salt load can be calculated by multiplying the instantaneous flow rate with the instantaneous salinity. The more frequently the flow and chemistry are measured (particularly during fluctuating flow rates like during a flood), the more accurate the salt load estimate.

The average salt load passing down the Moore River in any year is largely dependent upon the flow, and hence rainfall in that year. During the late 1970's, low rainfall resulted in low flows at Quinns Ford and corresponding low salt loads. In the 1980's flows and salt loads were typically greater than during the 1970's. The 1990's are punctuated by high flows and salt loads in the mid and late years. It is necessary to do further monitoring of flows and salinities to determine any trend for flow and salt load increases.

Early explorers found the Moore River to be fresh and suitable for drinking. Salinisation of the river is considered to have started as a consequence of clearing, since the 1850s. The increase in average flows and tonnage of salt measured at Quinns Ford have resulted from upstream rainfall in conjunction with:

- rising groundwater tables
- mobilisation of salt on cleared land
- increased runoff on cleared land
- increased drainage in the catchment since 1990.

During this study, downstream of the confluence of the Moore River North and the Moore River East, the salinity of the river water was observed to decrease. This is attributed to fresher groundwater (approximately 500-1,000 mg/L) than that in the river discharging into the Moore River west of Mogumber. The presence of groundwater springs at Palms Park and Mogumber Mission (see Figure 2) and the gaining flow rates are evidence of groundwater discharge.

6.2.2 Along the Coonderoo & Moore Rivers

During the study, surface water and groundwater salinity data were collected and collated (Appendices V and VI).

The bicarbonate/chloride ion ratio, and the sulphate/chloride ion ratios (Appendices V and VI) have been calculated to assist in fingerprinting the source of the water in the rivers. River water tends to have a greater bicarbonate/chloride ratio whereas groundwater generally has a greater sulphate/chloride ratio (USGS, 1992). This method has been helpful in establishing that much of the surface flow in the rivers sampled during the study period was derived from groundwater discharge.

7.2.2.1 Surface Water

a) During Floods

Figure 3, the 1999 river flow and salinity plots, demonstrate that the salinity of the river water decreases down the catchment. In December 1999, after the 1999 floods, the salinities of the interconnected Coonderoo and Moore Rivers were:

Coonderoo River,Dandaragan Road Bridge	32,000mg/L
Moore River North, Gillingarra Road Bridge	25,000 mg/L
Moore River, Quinns Ford	8,000 mg/L
Moore River, Waterville Road	5,000mg/L

The Coonderoo and Moore Rivers decreased in salinity as they flowed to sea.

In all cases there was an increase in the salinity of the rivers in the months following the wet winter of 1999. Figure 3 shows that the high winter river flows were followed by increases in river salinity. Successive pulses of rainfall resulted in further increases in river salinity. This is explained by rainwater mobilising salt on the land, within salt lakes and shallow high salinity water logged ground. The mobile salt is released into the river. Figure 9 shows the relationship between a flood pulse flowing down the Coonderoo River (generally dry) and the salinity of the river water.

The delay between the flow and salinity peak is attributed to dilution of the salt load (or mass) by the flood waters. The load of salt in the river at any time is the product of the salinity (concentration or mass per unit volume) and the flow rate (volume per unit time):

$$\text{Mass} = \text{concentration} \times \text{volume.}$$

The salt load in the river with time due to the passage of the flood flow peak may plot as a bimodal peak as shown in Figure 9.

b) During summer months (dry periods)

Field samples taken during the study period also show that in general the salinity of the Moore River decreases as the river flows to the sea. This is attributed to fresher, or lower salinity, groundwater discharging downstream and diluting the salinity of the water present within the river.

The salinities in the lower Moore River were measured on 7 and 24 February 2001 (Appendix V). On both dates a decrease in the salinity of the river water was measured between Cowalla Bridge and Bennies Road. Figure 10 shows the river salinities as measured on 24 February 2001. The increase in river salinity between Cowalla Bridge and Bennies Road is due to the leaking of the river into the groundwater, and evaporation. Between Bennies Road and Waterville Road there is a reduction in salinity indicating that relatively fresh groundwater discharges into the Moore River between Bennies Road and Waterville Road.

6.2.2.2 Groundwater

Groundwater salinity data is given in Appendix VI. The distribution of groundwater salinities for the lower Moore catchment are shown in Figure 10, with the salinity of the Moore River as measured on 24 February 2001.

Using the flows (Figure 11) and salinities (Figure 10) measured on the 24 February 2001 it is possible to estimate the average groundwater salinity discharging into the Moore River between measuring sites. This assumes that all discharge is from groundwater.

As, mass = concentration x volume,

The average groundwater salinity discharging between Quinns Ford and Regans Ford can be calculated:

$$c_1v_1 + c_2v_2 = c_3v_3$$

i.e., $3330 \times 102 + c_2 \times (346 - 102) = 1450 \times 346$

$c_2 = 501700 - 339660/ 244 = 660$ mg/L

A groundwater salinity of 660 mg/L is comparable with the Leederville-Parmelia groundwater salinity (550 mg/L in GL6W), confirming that the groundwater discharge into the river is likely to be from this aquifer.

Downstream of Cowalla Bridge, where the Moore River starts to lose flow, saline water has migrated into the superficial aquifer. This has resulted in a saline plume between the Moore River and the coastline, south of the Karakin Lakes.

The groundwater chemistry data (Appendix VI) for bores downstream of Cowalla Bridge, along and to the west of the Moore River, show that the salinity of the groundwater in the bores has not deteriorated since 1980. It would be prudent to continue to monitor groundwater salinity south of Karakin Lakes, and to install more bores to track the progress of the saline plume. A typical flow rate in the superficial aquifer is 50-150m per year (Davidson, 1995).

7. NUTRIENTS

7.1 Sources of Nutrients

Plant growth (via photosynthesis) needs warmth, light and inorganic nutrients, biologically available nitrogen and/or phosphorus (ANZECC, 1992). The most biologically available nutrients available to algae naturally present in the rivers are:

- nitrogen as ammonia (NH_3) and nitrate (NO_3^-)
- phosphorus as (ortho)phosphate ($P0_4^{3-}$).

Elevated nutrients in shallow slow flowing rivers typical of the Moore River catchment can lead to the growth of microscopic free-floating or weakly mobile aquatic plants (phytoplankton). Algal mats (macroalgae) and blue-green algae (cyanobacteria) are forms of phytoplankton. To be identified the phytoplankton must be sampled and analysed. [Further information on algal blooms can be obtained from free Fact Sheets available from the Water and Rivers Commission's library and Regional Offices, Tel: (08) 9278 0464.]

Native Australian flora has adapted to low-nutrient soils. Many native plants are tolerant of some salt, and most are drought tolerant. Introduced crops require added fertilisers and are salt and drought sensitive (White, 1974). Clearing vegetation releases nitrogen and phosphorus (Dr Graham Harris, CSIRO), as do bush fires. As the nitrogen export from the catchment is increased proportionately more ammonia (NH_3) and nitrate (NO_3^-) is released. Nutrients such as nitrates and phosphates have been added to soils by fertilisers. In addition, the introduction of sheep and cattle has introduced ammonia, nitrates, phosphates and organic carbon. (Organic carbon contributes to an increased biological oxygen demand in a river, depleting it of oxygen which is essential for life).

The introduced nutrients may be washed out of water-logged soils or leached out of sandy soils (by rain or irrigation) or may be deposited directly in a river by livestock. Within the Moore catchment sheep and cattle are mainly located close to the Moore River downstream of Waterville Road and along the Gingin Brook. In these stretches the livestock are guaranteed drinking water all year round, as the rivers are both accessible and fed by groundwater discharge.

Land clearing is considered to have increased the magnitude of flooding, but not the frequency. Floods contribute the majority of nutrient load to a river by:

i) washing nutrients from the land

ii) eroding the river bed and banks at high flow rates, releasing particulate material and associated nutrients.

Whilst nutrient concentrations in a river system are good indicators for the risk of algal growth, it is important to measure the *amount* (or mass) of nutrient flowing down a river. Most of the annual nutrient load is transported down a river during high flow conditions. High frequency sampling over a flood event is essential if the annual total load of nutrients transported by a river is to be reliably estimated (ANZECC, 1992). Annual flow monitoring and nutrient sampling is essential to establish any variation in the load of nutrient being transported down a river.

7.2 Within the Study Area

Man's clearing and introduction of nutrients into the Coonderoo and Moore River catchments has inevitably altered the biology and ecology of the study area. Anecdotal information from the community is that the occurrence of algal mats has increased along the lower reach of the Moore River (Mischa Cousins, Water & Rivers Commission, 2001).

7.2.1 In Surface Waters

The Australian and New Zealand Environment and Conservation Council gives indicative concentration guidelines for nutrients in rivers and estuaries (ANZECC, 1992). These guidelines are summarised in Table 5.

Table 5. ANZECC Water Quality Guidelines for Rivers and Estuaries

	Rivers (mg/L)	Estuaries (mg/L)
NH3-N		<0.005
NO3-N		0.010-0.100
Total-N	0.10-0.75	
PO4-P		0.005-0.015
Total-P	0.01-0.10	

Upon completion of the lower Moore River and Gingin Brook nutrient study currently being conducted by Mischa Cousins, Water & Rivers Commission (1999 - 2002), tighter guidelines may become available for the tabulated concentration ranges.

During the study nutrients have been sampled in flowing tributaries of the Coonderoo River, the Moore River and Gingin Brook (Appendix V). The sampling locations are shown in Figure 2.

From this study and other work (Cousins, 2000) background concentrations of nutrients in the Moore River are considered to be:

Total nitrogen:	0.13 mg/L
Ammonia:	<0.005 mg/L
Oxidised nitrogen:	<0.005 mg/L (nitrite plus nitrate)
Total phosphorus:	0.01 mg/L
(ortho)phosphate:	<0.003 mg/L

Comparison of the ANZECC guideline concentration ranges with the nutrient concentrations sampled in late summer in the rivers of the Moore catchment indicates those stretches of rivers with elevated nutrients. These are downstream of Waterville Road on the Moore River and from at least Bookine Bookine Road on the Gingin Brook. Lush green vegetation is observed along these lower sections of the Moore River and the Gingin Brook. The presence of such vegetation could be related to the high nutrient content of the waters in these areas.

Nutrient concentrations sampled in the rivers during February 1999 and February 2000 were higher than the concentrations detected in February 2001. Such variations are related to rainfall. A rain event in the catchment preceding sampling can result in higher nutrient concentrations in the rivers. It is important to stress the extreme variability of surface water chemistry data. Only long term monitoring can assist in determining trends.

In order to assess whether the annual nutrient loading is increasing along the lower Moore River and Gingin Brook it is necessary to establish accurate flow measuring stations and year round sampling of the surface waters at the same locations.

As summer river flows are derived from groundwater discharge it is important to address the concentration of nutrients in groundwaters feeding the lower Moore River and Gingin Brook.

7.2.2 In Groundwater

From the data collected and collated the background concentrations of nutrients in the groundwaters of Moore River catchment are considered to be:

Total nitrogen:	0.1-1.0 mg/L
Ammonia:	<0.05 mg/L
Oxidised nitrogen:	<0.01 mg/L* (nitrite plus nitrate as N)
Total phosphorus:	0.01 – 0.1 mg/L
(ortho)phosphate:	<0.025 mg/L

*Along the coast, in the limestone belt where *Acacia* vegetation is abundant, nitrate concentrations tend to be slightly higher (0.22 – 1.5 mg/L as NO_3-N). The *Acacia* is a nitrogen fixing plant (Davidson, 1995).

Nitrogen, ammonia & oxidised nitrogen

Denitrification is important as it provides a pathway by which excess nitrogen in soils may be released into the atmosphere. The Bassendean Sands are generally observed to have low concentrations of nitrogen (ammonia and nitrate) as these soils promote denitrification (high levels of dissolved organic carbon, pH of 5 to 7 and low redox potential). Nitrate is highly soluble and hence is readily leached from the soil by water (Kesley, P., 2001).

Total Nitrogen

There has been limited sampling of total nitrogen in the groundwaters of the lower Moore catchment. Sampled total nitrogen concentrations in groundwater have generally been less than 1.0mg/L. However elevated total nitrogen concentrations have been identified in 1998 south west of Regans Ford (S21A), in 1998 south of the Karakin Lakes (S7A) and in 1981 south of the Gingin Brook (GB11) (Appendix VI). These are considered to be associated with agricultural land use.

Ammonia

The spatial distribution and concentration ranges of ammonia in groundwaters sampled in the lower Moore catchment are shown in Figure 12(a). The majority of samples, taken on different dates, and using differing methods, have been above 0.1mg/L. This exceeds the ANZECC guideline concentration for estuaries (0.005 mg/L).

Total oxidised nitrogen

Groundwater sample locations and dates are shown in Figure 12(b). Local groundwater concentrations greater than 0.1mg/L appear to be associated with farming land use: horticulture, intensive poultry and pigs.. Groundwater to the south of the Gingin Brook flows to the north west, into the Gingin Brook and lower Moore River. The Water & Rivers Commission recommends that groundwaters discharging to estuaries do not exceed 0.1mg/L.

The World Health Organisation standard for nitrate in drinking water is 10mg/L NO_3-N. Elevated nitrates have been linked to Blue Baby Syndrome. It is recommended that groundwaters with nitrate concentrations exceeding this concentration are not used for drinking water.

Phosphorus and orthophosphate

Phosphorus occurs as (ortho-)phosphate in soils and is generally, except in sands soils, strongly bound to soil particles. Phosphorus is lost from the soils in particulate form in surface erosion, and is leached in soluble form. The sandy soils of the Swan Coastal Plain export large quantities of phosphorus to Western Australia's rivers in soluble form (SRP or soluble reactive phosphorus). The clay and lateritic soils of the Dandaragan and Darling Plateaus are able to retain phosphorus by adsorption. Where the soils are able to retain phosphorus and where the depth to the water table is great, the time for phosphorus to leach to the groundwater is in the order of thousands of years (Kelsey, 2001). Once a soil's capacity to adsorb phosphate has been saturated, any further phosphate applied to the soil in excess of that required for plant growth, will quickly leach to groundwater.

Total phosphorus

There is limited data for the concentration of total phosphorus in groundwater in the lower Moore catchment. Sampling methods and dates vary. Concentrations in excess of 0.1mg/L were from the same bores as those samples with elevated total nitrogen (Appendix VI).

(Ortho)phosphate

The spatial distribution for the sampling of (ortho)phosphate, along with the dates of sampling, are shown in Figure 12(c). Sampling methods and dates vary. Approximately half of the bores sampled contain groundwaters with (ortho)phosphate concentrations which exceed the ANZECC guidance concentrations for rivers shown in Table 5 (0.005 – 0.015 mg/L).

On the sandy soils of the Swan Coastal Plain nutrient-enriched groundwater discharges to the Gingin Brook, the Moore River, and ultimately the estuary. Over-application of nutrients for horticultural use, and the discharge of animal faeces in the Swan Coastal Plain is therefore a serious concern for ecology within the lower Moore River catchment. Education and guidance is needed for agriculturalists and horticulturalists to ensure fertilisers are applied at the optimum timing and rates, enough for plants, but not too much such that the nutrients leach to the water table. Increased efficiency in fertiliser application will reduce farming costs.

Suphate/chloride ratio

A natural groundwater could be expected to have a sulphate to chloride ratio of 0.03 to 0.05. The oxidation of sulphides in the soil and the application of fertilisers can lead to an increase in the sulphate/chloride ratio (Davidson, 1995). The groundwater quality data in Appendix VI indicate that fertilisers may be impacting on groundwater quality in the lower Moore River catchment.

Groundwater springs discharging into the Moore River at Caraban Rocks, downstream of Lancelin Bridge, in December 1999 were sampled for nutrients in December 1999. (Access to these springs is only possible when the river level has dropped as a consequence of the sand bar at Guilderton having been broken.) Concentrations of total nitrogen (3.3 mg/L) and total oxidised nitrogen (2.5 mg/L) were extremely high.

As the lower reaches of the Moore River and Gingin Brook are gaining flow from groundwater discharges, elevated nutrient concentrations in the groundwaters are considered to result in elevated nutrient concentrations in the lower Moore River and estuary.

8. Groundwater-River Interaction

8.1 Along the Moore and Coonderoo Rivers

This section is to be read in conjunction with the cross section in Figure 6. All site locations referred to are shown on Figure 2.

Yarra Yarra Lakes to Marchagee Track

Below the Yarra Yarra Lakes the Coonderoo River is underlain by a palaeochannel of approximately 30m depth. The river is gaining flow from the palaeochannel and the Perth Basin (Lesueur Sandstone and Eneabba Formation) until Launer Road. Downstream of Launer Road the Coonderoo seasonally recharges groundwater (Yesertener, 1999). Between Greenhead Road and south of the Marchagee Track any flow within the Coonderoo River recharges the groundwater. Lakes Eganu and Pinjarrega are considered to be in hydraulic continuity with the water table. Information from CALM indicates that the bed of Lake Pinjarrega is at 221m AHD and that the bed of Lake Eganu is at 227m AHD.

Watheroo to Moora

Groundwater discharges at the Coonderoo River bed to produce the salt lakes at Watheroo, Namban, Coomberdale Road and Moora. One source of groundwater discharge is considered to be a shallow and elevated water table draining from the Yilgarn Craton on the east side of the Darling Fault. Due to low relief and poor drainage the groundwater discharge ponds and is subject to evaporation.

Groundwater levels measured in the Watheroo Line bore, WL1, and the Moora Line bore, ML1, suggest that groundwater may also be discharging from the Leederville-Parmelia Aquifer to the west of the Darling Fault. (The Leederville Formation has been identified at depth to the west of the Coonderoo River and within Moora.)

Moore River Valley North

The Moore Valley (between Moora and Mogumer) has groundwater levels close to the river bed elevation. It does not appear to be significantly losing or gaining flow. However the river does go dry in this stretch during summer months. During the dry season the Moore River North starts to flow at Palms Park Spring north of Mogumber. This spring is considered to be discharging from the Poison Hill or Mirrabooka Aquifers of the Lancelin Formation.

Mogumber to Regans Ford

West of Mogumber the Moore River flows west, crosses the Darling Fault and flows across the gently tilted Cretaceous rocks. The river gains as it flows across the Lancelin Formation, and strongly gains between Quinns Ford and Regans Ford as it crosses the Leederville-Parmelia Aquifer.

Cowalla Bridge to Waterville Road

Downstream of Regans Ford the groundwater pressure head in the Leederville aquifer is at a slightly higher elevation than the groundwater table in the superficial aquifer.

The Moore River continues to gain flow until it crosses the Tamala Limestone downstream of Cowalla Bridge. Between Cowalla Bridge and Waterville Road the Moore River loses flow. It is strongly losing between Cowalla Bridge and Bennies Road. Loss of river flow into the superficial aquifer starts where the river crosses the Tamala Limestone, and the groundwater starts to become salty. This strongly losing section starts immediately ESE from bore S3A (E = 358950, N = 6561270), and may finish SE of Karakin Lakes (E = 357450, N = 6558430) as shown on Figure 10.

Groundwater starts to discharge again into the Moore River upstream of Waterville Road. This is demonstrated by the lower salinity of the river at Waterville Road compared to that at Bennies Road, and the increased nutrient concentrations in the river water compared to those upstream.

Confluence with the Gingin Brook

Downstream of its confluence with the Gingin Brook, the Moore River gains flow from groundwater discharge. The low salinity and elevated nutrient concentrations in groundwater to the south of the Gingin Brook are discharging into the lower section of the Moore River.

8.2 Potential for Groundwater Contamination

The main risk to groundwater quality from salt contamination from the Moore and Coonderoo Rivers is the losing reach between Cowalla Bridge and downstream of Bennies Road. Saline groundwater occurs downstream of Cowalla Bridge and around Karakin Lakes.

Downstream of Regans Ford flooding results in the ingress of brackish water a short distance (approximately fifty metres) into the superficial aquifer adjacent to the river. Elsewhere contamination in the river will leak into underlying sediments where a preferential hydraulic head results in surface water leaking out of the river and into the aquifer. The reaches of river where surface water is considered to leak into groundwater along the Coonderoo and the Moore Rivers are shown diagrammatically in Figure 6 as 'losing sections'.

There is the potential for the Coonderoo River to contaminate the Leederville-Parmelia aquifer downstream of Marchagee Track, *if* the groundwater head in the palaeochannel is greater than the groundwater head in the underlying aquifer. Upstream of Regans Ford the Leederville aquifer is only at risk of contamination from the river, *if* groundwater abstractions from the Leederville aquifer lower the groundwater heads below the river flood levels. (This would result in the vertically downwards flow of river flood water into the Leederville aquifer.)

Upstream of Mogumber the impact of clearing is that rising water tables are resulting in water logged ground (ie, secondary salinisation or dry land salinity). Engineered drainage may reduce water logging, but it also releases salt into the rivers more quickly than would occur without drainage. On the sandy soils downstream of Mogumber intensification of land use coupled with any over application of fertiliser results in nutrients being leached to the water table. Heavy rainfall together with dryland salinity and the over application of nutrients means that the incidence of flooding and contaminated (salinity and nutrients) pulses of surface water coursing down the Coonderoo and Moore Rivers could increase. Greater contaminant loading on the superficial aquifer within the Perth Basin to the south west of Cowalla Bridge is likely to result. As the resulting salinity of the aquifer exceeds the guidelines for potable use there will be a socio-economic impact on future usage from this aquifer.

The long term impact of any climate change on weather patterns in Western Australia is uncertain.

If there was a change to more cyclonic activity this too could enhance the salt and nutrient loads in the Moore River.

The data collected from the gauging and sampling station at Quinns Ford has been important in demonstrating the variation in annual salt load being transporated down the Moore River. One of the recommendations of this report is for further continuous gauging and sampling stations to be established downstream of Quinns Ford by the Water & Rivers Commission. The resulting data can be used to determine which sections of the river are leaking saline water to groundwater within the Perth Basin aquifers. The findings of any investigation would ensure that water management strategies are actioned to ameliorate aquifer contamination.

In the meantime continued careful consideration of groundwater resources available for licensing along the Moore River by the Water & Rivers Commission is very important to ensure that the river quality is not compromised and that contaminated groundwater is not pulled through the aquifers to contaminate hitherto uncontaminated areas. Sustainable groundwater abstraction and groundwater quality monitoring is critical to ensure best management practice and protection of our water resources.

9. Conclusions

& Recommendations

The recommendations have been prioritised according to what is considered actionable within current resourcing.

High Priority

1. Saline water from the Moore River is leaching into the Swan Coastal Plain aquifer downstream of Cowalla Bridge. This will lead to rising groundwater salinity in the coastal aquifer and will have an impact on coastal groundwater public water supplies and further groundwater abstraction.
   Instigate *annual* groundwater level and quality monitoring in the Commission's Salvado monitoring bores in the Swan Coastal Plain west of the lower north to south stretch of the Moore River (approximately 8 bores), and a set of bores to the south of the Gingin Brook. Water & Rivers Commission to analyse the data, quantify the risk and report as part of the Gingin Groundwater Area Management Plan.

2. The contaminated groundwater plume in the coastal superficial aquifer will have a limitation on groundwater usage in this locality.
   Address the importance of the groundwater resources in the superficial aquifer of the Coastal Plain. Establish a strategy to manage salinity contamination of groundwater resources downstream of the salinity source.

3. There is an increasing demand for groundwater abstraction in the lower Moore catchment, eg for olives, pawlonia and carrots. There is concern that saline groundwater may migrate from the river as a consequence of large bore abstractions.
   Advise all applicants to position abstraction bores at sufficient distance from the river (based on abstraction rate and aquifer characteristics) to prevent river flow from being

drawn into the bores. Being too close would result in the bore water quality, aquifer quality and river flow being compromised.

Require:

i) **new production bores in at risk areas to supply a detailed driller's log, geophysical log and chemical analyses as part of the licence application**

iii) **applicants to monitor**

a) monthly abstraction rates

b) monthly groundwater levels and

c) groundwater quality biannually/annually

at the boundaries of the properties and to interpret and report annually to the Water & Rivers Commission.

Water & Rivers Commission to use the data to model the impacts of groundwater abstraction on groundwater levels, groundwater quality, wetlands and river flow.

4. There are elevated nutrient concentrations in the aquifers and rivers of the lower Moore River and Gingin Brook.

   i) **Educate and give guidance to horticulturalists on the timing and rates of nutrient application. Information could be provided as part of the licensing process.**

   ii) **Instigate regular groundwater level monitoring and chemical sampling in monitoring bores in the areas at risk. Evaluate and report in the Gingin Groundwater Area Management Plan.**

   iii) **Produce an action plan to advise developers and planners on nutrient application rates [and point sources of pollution (e.g., septic tanks)] to ensure sustainable development without compromising the environment.**

Medium Priority

5. There is a variable mass of salt, or salt load, being carried down the Moore River with time. Increased flows during wet periods could result in more saline water flowing into the superficial aquifer downstream of Cowalla Bridge with time.

   The Water & Rivers Commission to continue to maintain accurate flow monitoring and sampling stations along the Moore River to determine the variation in annual salt load down the river.

6. There is groundwater discharge into the Moore River between Mogumber and Cowalla Bridge. Increasing river flow rates and groundwater springs were observed in this section during the summer of November 2000 to February 2001 inclusive.
The Water & Rivers Commission to establish high quality flow monitoring and sampling stations to establish the quantity and chemistry of the fresher groundwater being discharged and therefore maintaining the quality of the Moore River downstream from Mogumber. The Water & Rivers Commission to continue to evaluate the environment's needs when revising licensing allocations for groundwater abstraction.

7. Clearing has resulted in rising shallow groundwater to the west of the Coonderoo River. The salt lakes in this area which are supported by groundwater discharge are at risk of increasing salinisation.
Monitor the salinity within shallow groundwater to the west of the lakes. Advise CALM on the risk to ecology.

8. The Moore River system can extend up to and include the Yarra Yarra Basin in extremely wet years when the Yarra Yarra Lakes overflow into the Coonderoo River. The potential for surface water extension may increase with increased land drainage.
Cater for the wider 'Greater Moore' catchment in any plans. Ensure that the information in this study and subsequent reports is made available to the appropriate catchment groups.

Low Priority

9. There could be hydraulic continuity between the Coonderoo River and the Leederville-Parmelia aquifer downstream of the Marchagee Track, and therefore the potential for saline river water to drain into the aquifer via the palaeochannel. In view of increasing groundwater abstractions for paulownia, olives, grapes, corn, sorghum, lucerne, almonds, fruit and citrus trees irrigation to the west of the Coonderoo River there is a need for greater understanding of the hydrogeology.
Install piezometers to the west of the Coonderoo River to establish the deep and shallow groundwater heads and quality to ascertain the direction of groundwater flow and hence to quantify the risk to the aquifer.

10. A palaeochannel (an old drainage route) comprising permeable sediments has been identified between the Yarra Yarra Lakes and Lake Pinjarrega. This probably extends along the Darling Fault to the south, to Mogumber and into the Brockman River. When the Coonderoo and Moore Rivers are dry there may be groundwater flowing at depth in the paleaochannel.

Determine any hydraulic linkage between the Moore and Brockman River to qualify any risk of saline flow between the two rivers and the potential to contaminate aquifer systems and wetlands.

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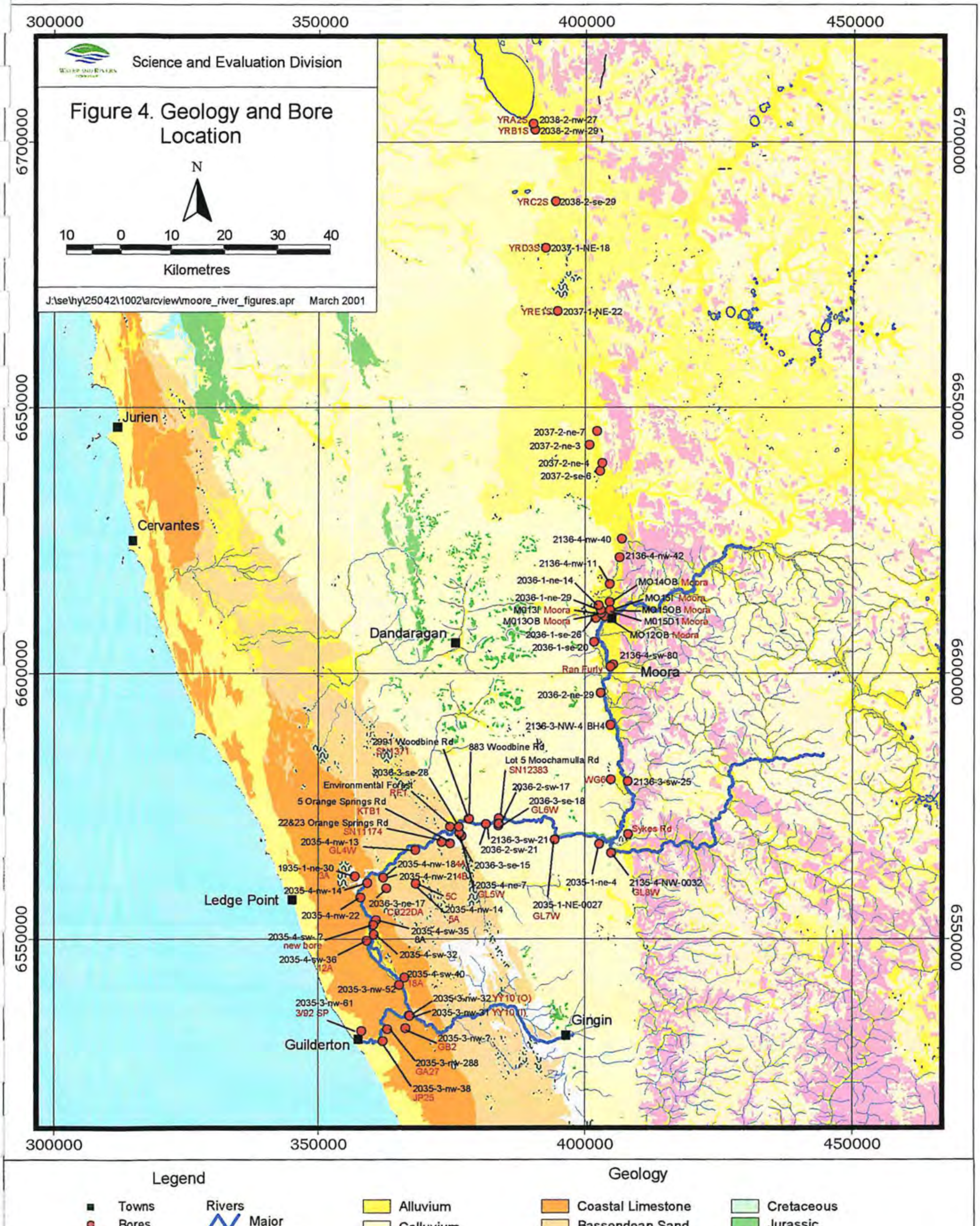

Science and Evaluation Division
Figure 4. Geology and Bore Location
N
Kilometres
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Jurien
Cervantes
Dandaragan
Moora
Ledge Point
Guilderton
Gingin
Legend
Towns
Bores
Lake
dykes
Rivers
Major
Minor
Geology
Alluvium
Colluvium
Sand
Swamp Deposits
Coastal Limestone
Bassendean Sand
Pleistocene
Tertiary
Cretaceous
Jurassic
Triassic
Archaean & Proterozoic

Figure 5. STRATIGRAPHIC SEQUENCE

Age in Millions of Years	TIME-ROCK UNIT				STRATIGRAPHY	SYMBOL	GROUND-WATER
	PHANEROZOIC	CAINOZOIC	QUATERNARY	HOLOCENE	SURFICIAL DEPOSITS	Q-T	Surficial Aquifer
2	PHANEROZOIC	CAINOZOIC	QUATERNARY	PLEISTOCENE	SUPERFICIAL FORMATIONS	Q-T	Superficial Aquifer
5	PHANEROZOIC	CAINOZOIC	TERTIARY	PLIOCENE	PALAEOCHANNEL DEPOSITS	Q-T	Surficial Aquifer
26	PHANEROZOIC	CAINOZOIC	TERTIARY	MIOCENE	Laterite		
38	PHANEROZOIC	CAINOZOIC	TERTIARY	OLIGOCENE	Laterite		
54	PHANEROZOIC	CAINOZOIC	TERTIARY	EOCENE	Laterite		
	PHANEROZOIC	MESOZOIC	CRETACEOUS		Poison Hill Greensand Gingin Chalk MoleCap Greensand	Kul	P.Hill Aq. / Mirrabooka Aquifer
100	PHANEROZOIC	MESOZOIC	CRETACEOUS		Osborne Formation Henley Sandstone Member or Dandaragan Sandstone	Kuo Kud	Mirrabooka Aquifer Confining beds
	PHANEROZOIC	MESOZOIC	CRETACEOUS		LEEDERVILLE FARM	Kll	Leederville-Parmelia Aquifer
144	PHANEROZOIC	MESOZOIC	CRETACEOUS		PARMELIA FORMATION	Kp	Leederville-Parmelia Aquifer
	PHANEROZOIC	MESOZOIC	JURASSIC		YARRAGADEE FORMATION	Jy	Confining beds Yaragadee Aquifer
	PHANEROZOIC	MESOZOIC	JURASSIC		CADDA FORMATION	Jd	Confining beds
	PHANEROZOIC	MESOZOIC	JURASSIC		CATTAMARRA COAL MEASURES	Jc	Minor Aquifer
213	PHANEROZOIC	MESOZOIC	JURASSIC		ENEABBA FORMATION	Je	Major Aquifer
240	PHANEROZOIC	MESOZOIC	TRIASSIC		LESUEUR SANDSTONE	TRl	Major Aquifer
253	PHANEROZOIC	MESOZOIC	TRIASSIC		KOCKATEA SHALE	TRk	Minor Aquifer
600	PHANEROZOIC	PALAEOZOIC				TRk	Minor Aquifer
2500	PC	PROTEROZOIC			MOORA GROUP	PC	Minor Aquifer
3700	PC	ARCHEAN			GRANITES AND GNEISS OF THE YILGARN CRATON	PC	Minor Aquifer

PC PreCambrian

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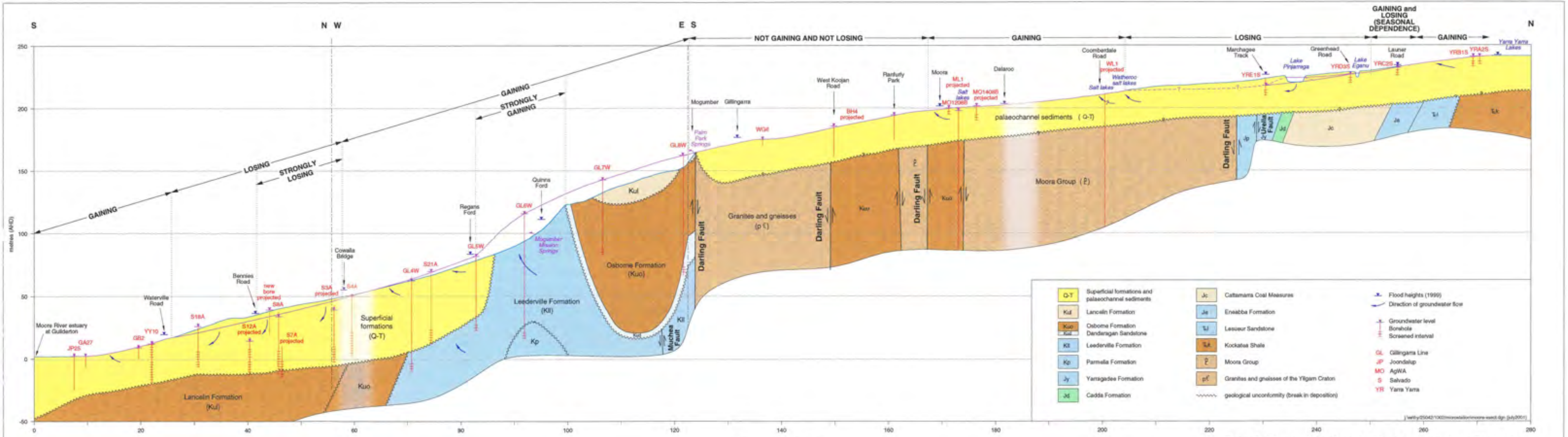

Figure 6: Cross-section along the Moore and Coonderoo Riverbeds (Guilderton to Yarra Yarra Lakes)

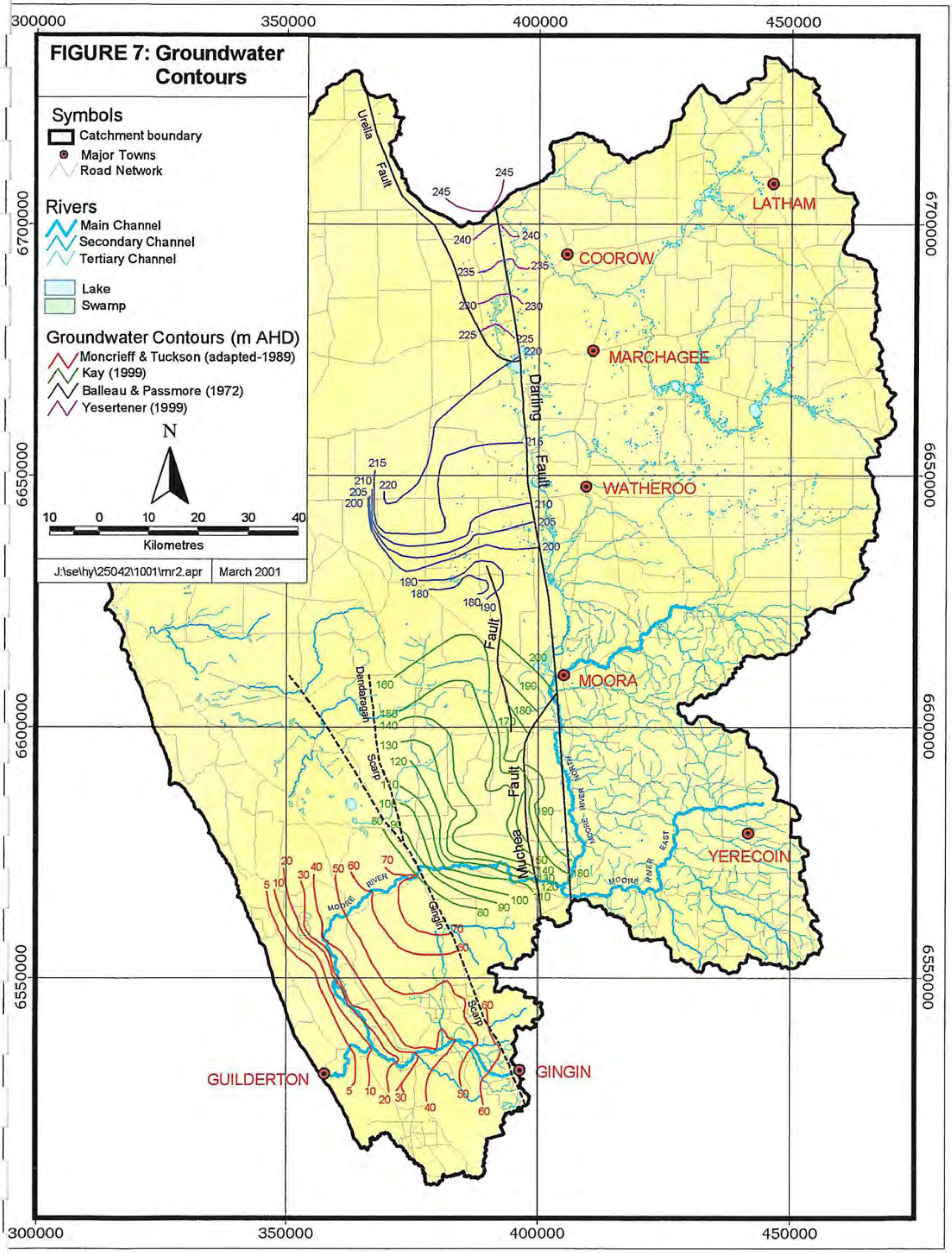
FIGURE 7: Groundwater Contours
Symbols
Catchment boundary
Major Towns
Road Network
Rivers
Main Channel
Secondary Channel
Tertiary Channel
Lake
Swamp
Groundwater Contours (m AHD)
Moncrieff & Tuckson (adapted-1989)
Kay (1999)
Balleau & Passmore (1972)
Yesertener (1999)
N
10 0 10 20 30 40
Kilometres
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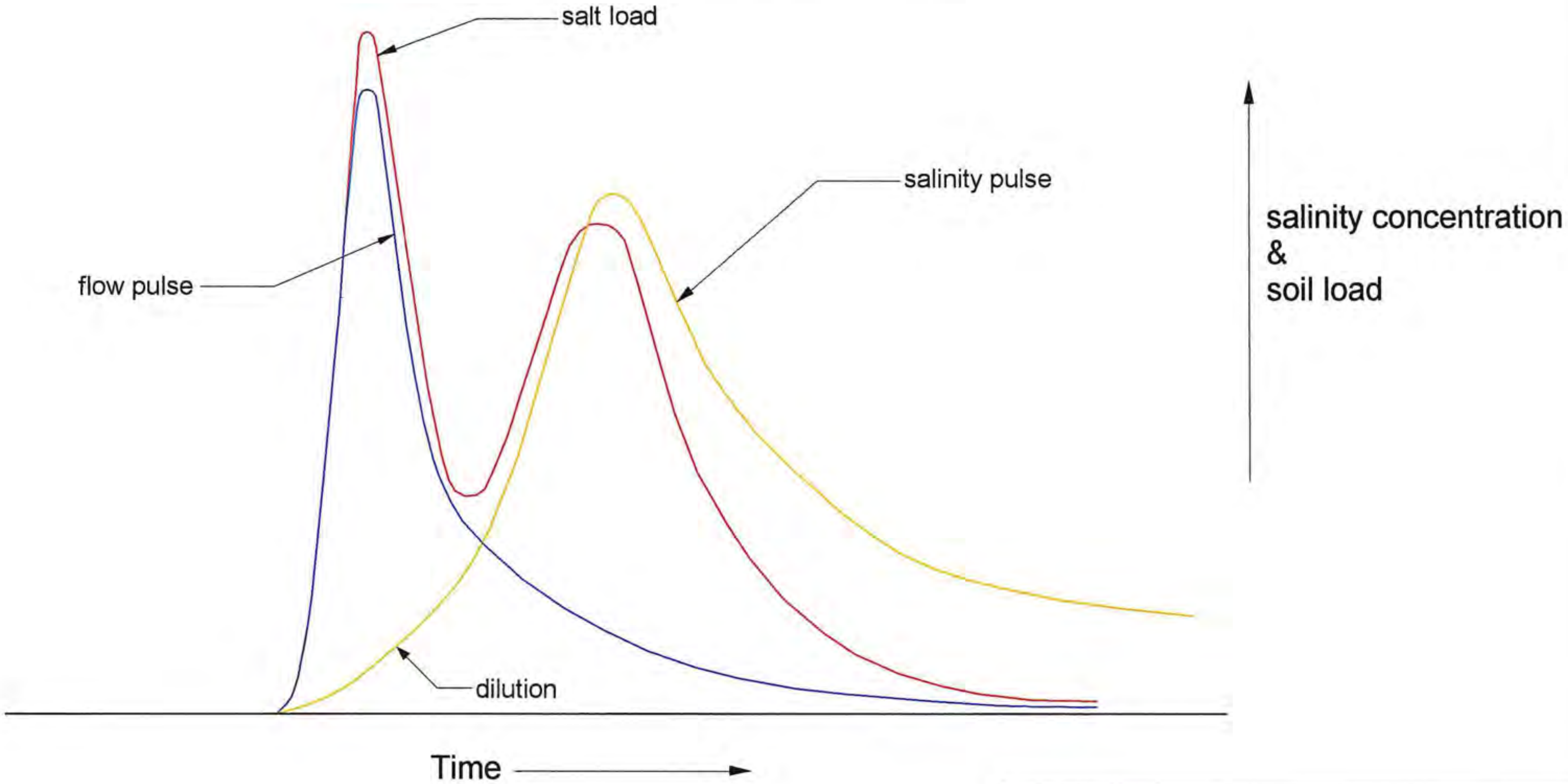
March 2001
300000
350000
400000
450000
6700000
6650000
6600000
6550000
LATHAM
COOROW
MARCHAGEE
WATHEROO
MOORA
YERECOIN
GUILDERTON
GINGIN
Urella Fault
Darling Fault
Muchea Fault
Dandaragan Scarp
Gingin Scarp
MOORE RIVER
NORTH
EAST

Figure 9: Relationship between River Flow, Salinity and Salt Load



Flow pulse preceding salinity pulse down the river
salt load is the product of the flow rate and salinity

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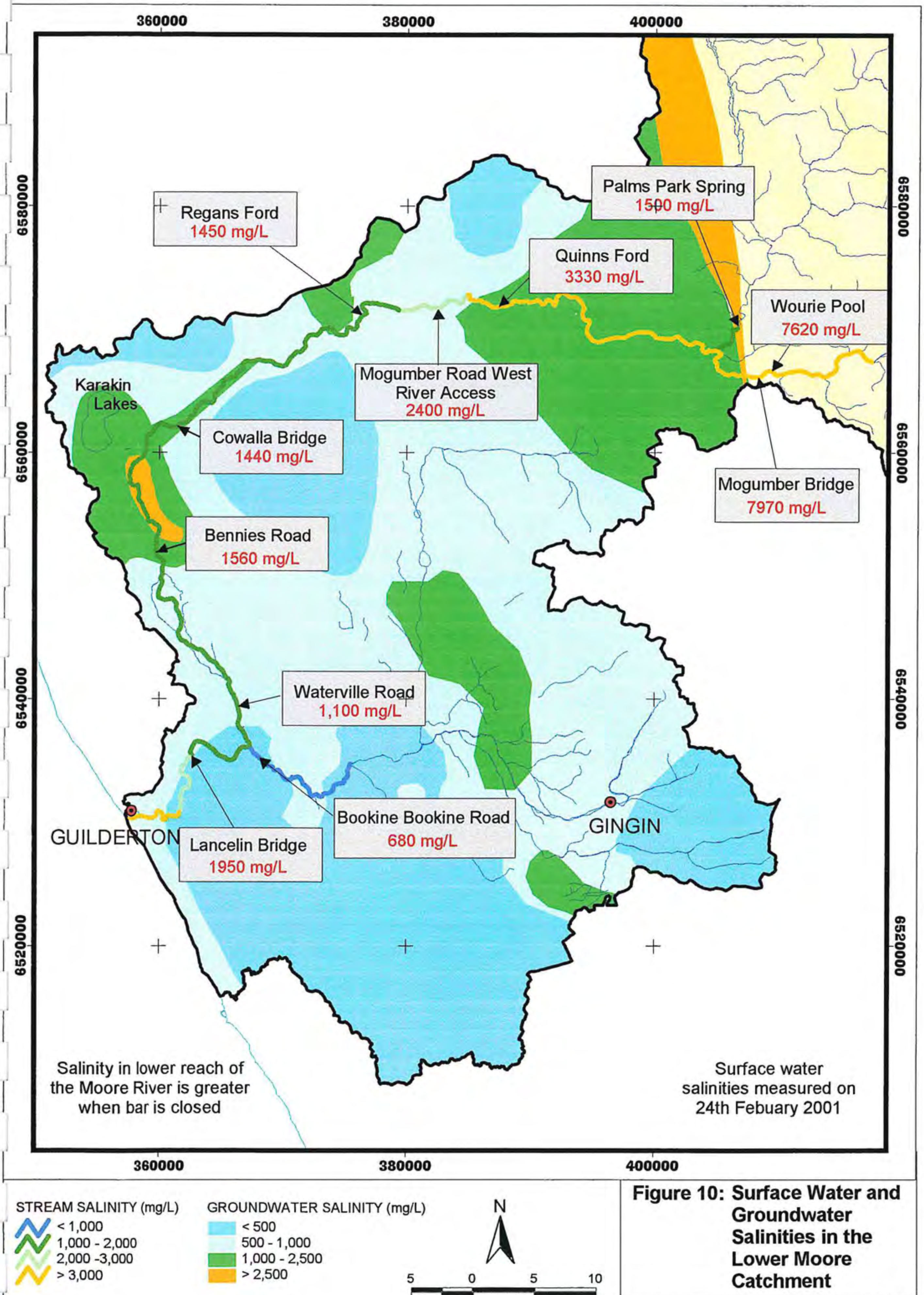

Figure 10: Surface Water and Groundwater Salinities in the Lower Moore Catchment

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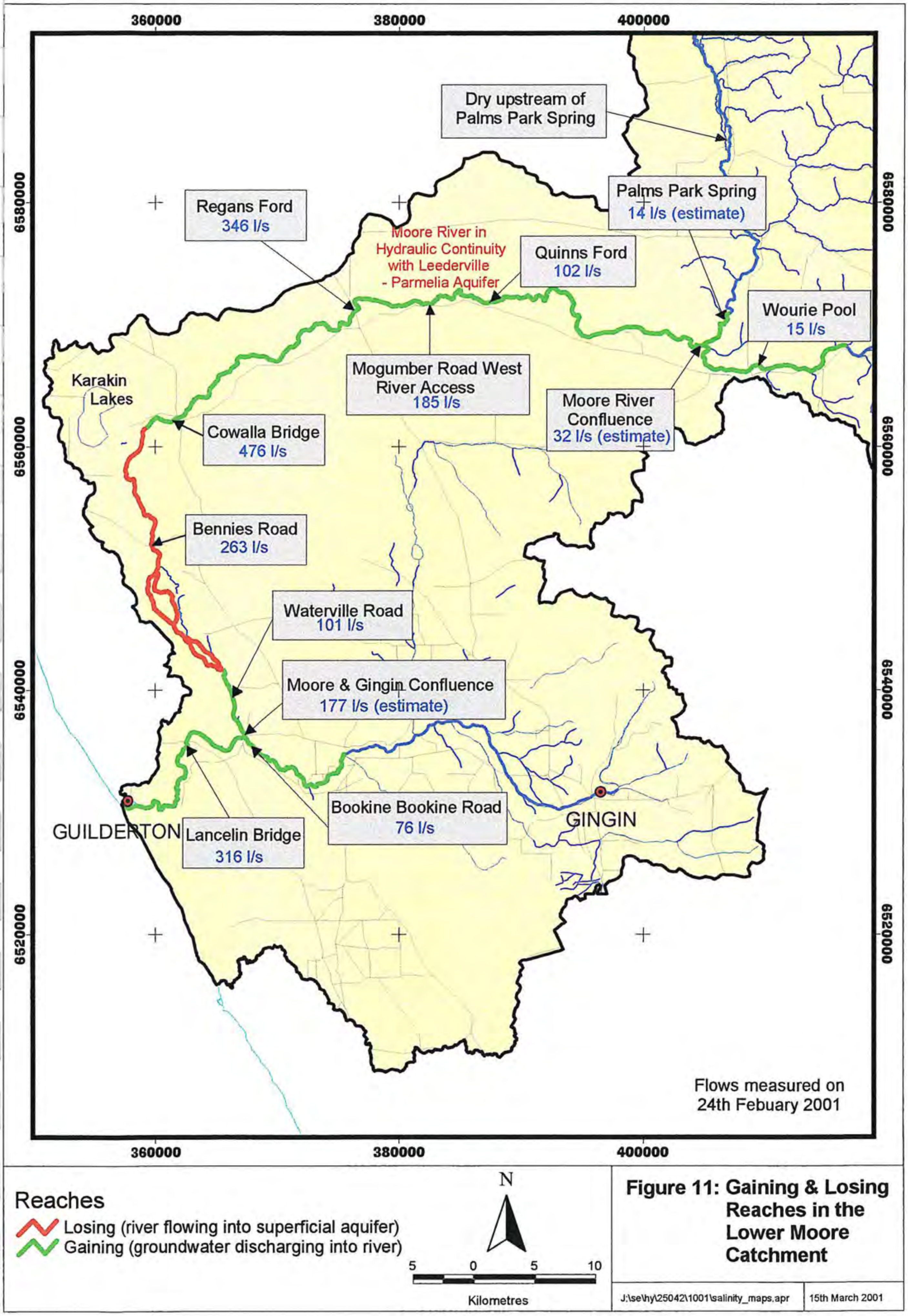

Figure 11: Gaining & Losing Reaches in the Lower Moore Catchment

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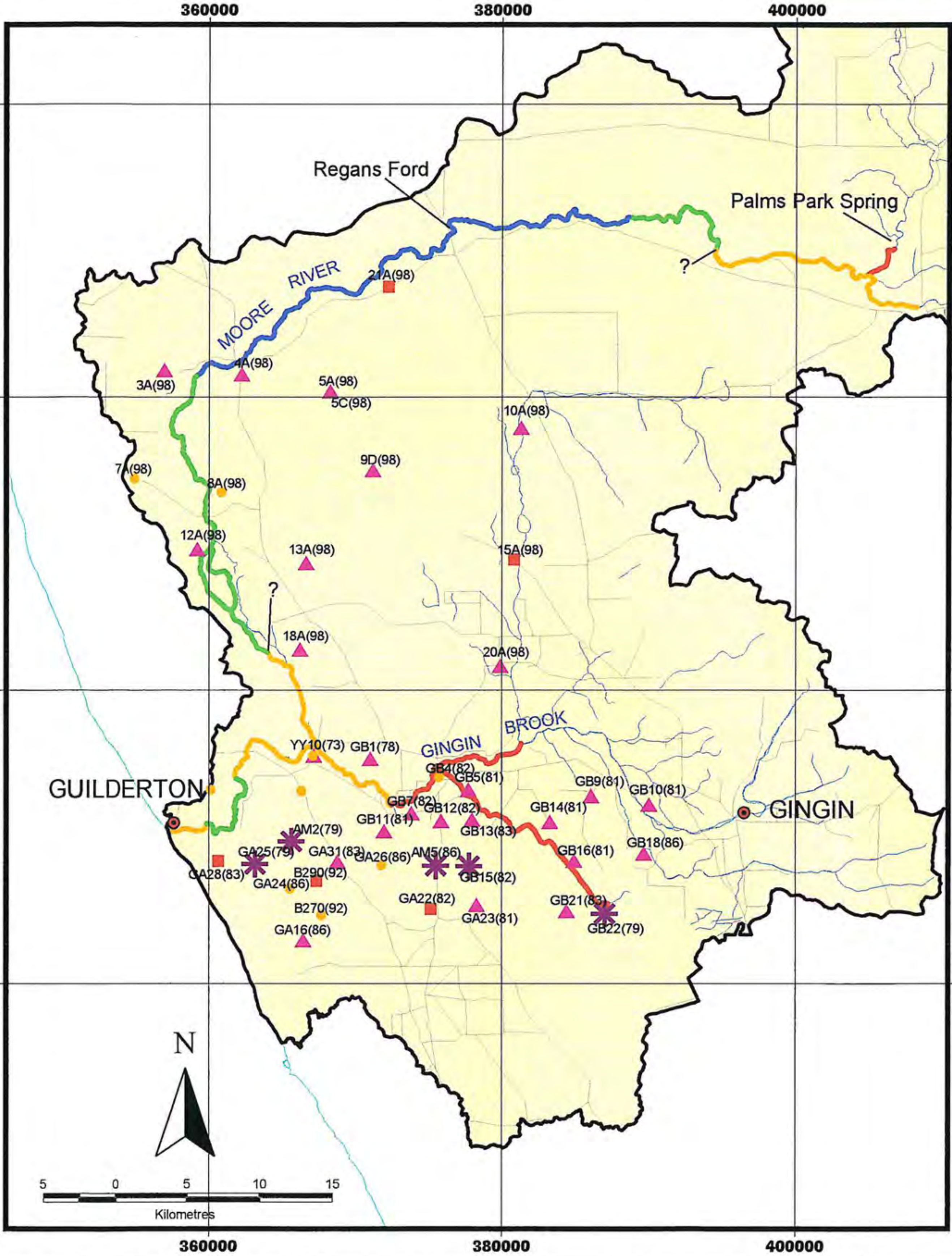

Surface Water Concentrations for Febuary 2001

- < 0.005
- 0.005 - 0.01
- 0.01 - 0.05
- > 0.05

Groundwater Concentrations for various dates
NH_3-N (ammonia)

- < 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- > 0.5

(83) Sampling Date 1983

Figure 12(a): Water Chemistry NH_3-N (ammonia)

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19th March 2001

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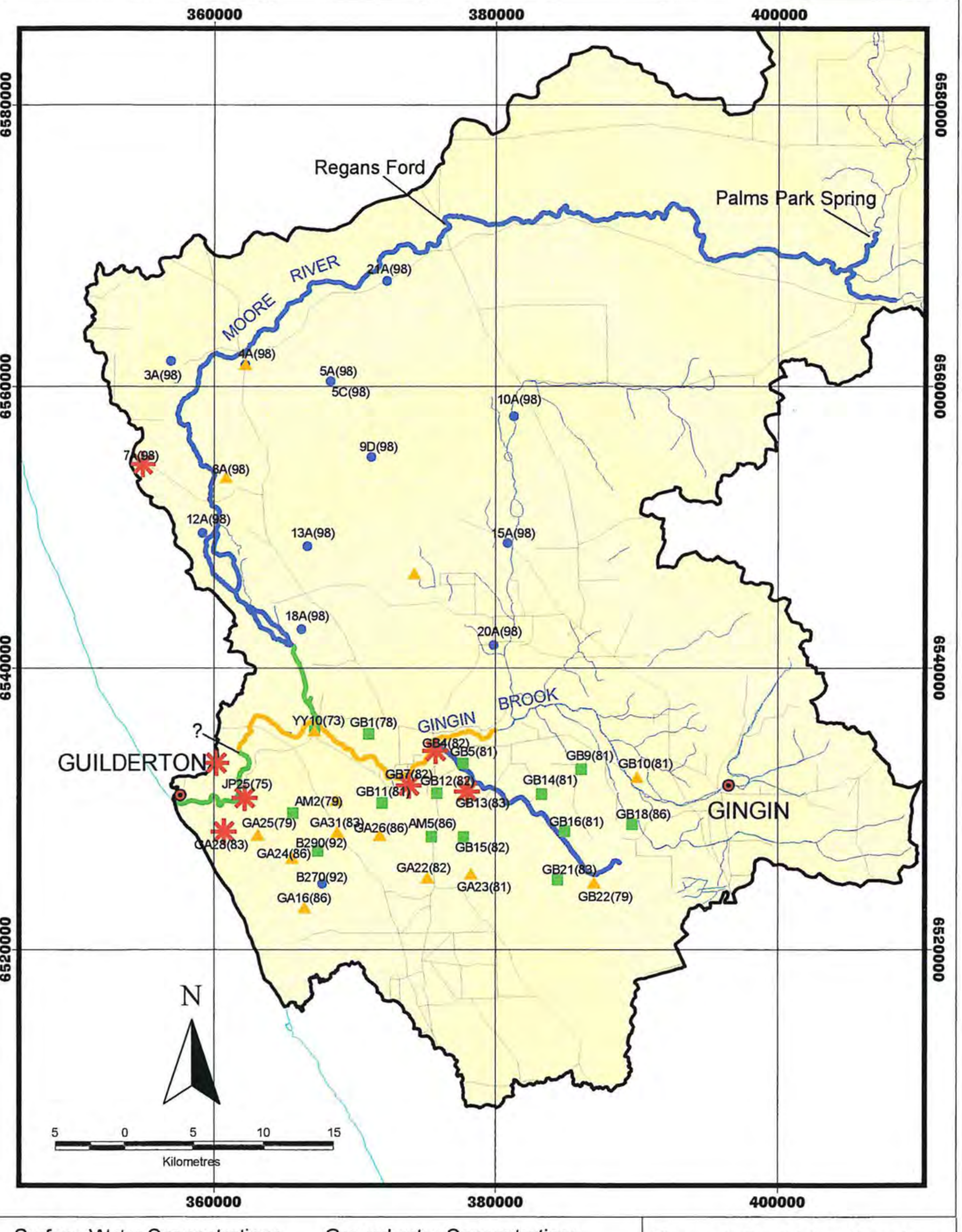

Surface Water Concentrations for Febuary 2001

- < 0.01
- 0.01 - 0.1
- 0.1 - 1.0
- > 1.0

Groundwater Concentrations for various dates NOx-N (oxidised nitrogen)

- < 0.01
- 0.01 - 0.1
- 0.1 - 1.0
- > 1.0

(83) Sampling Date 1983

Figure 12(b): Water Chemistry NOx-N (oxidised nitrogen)

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19th March 2001

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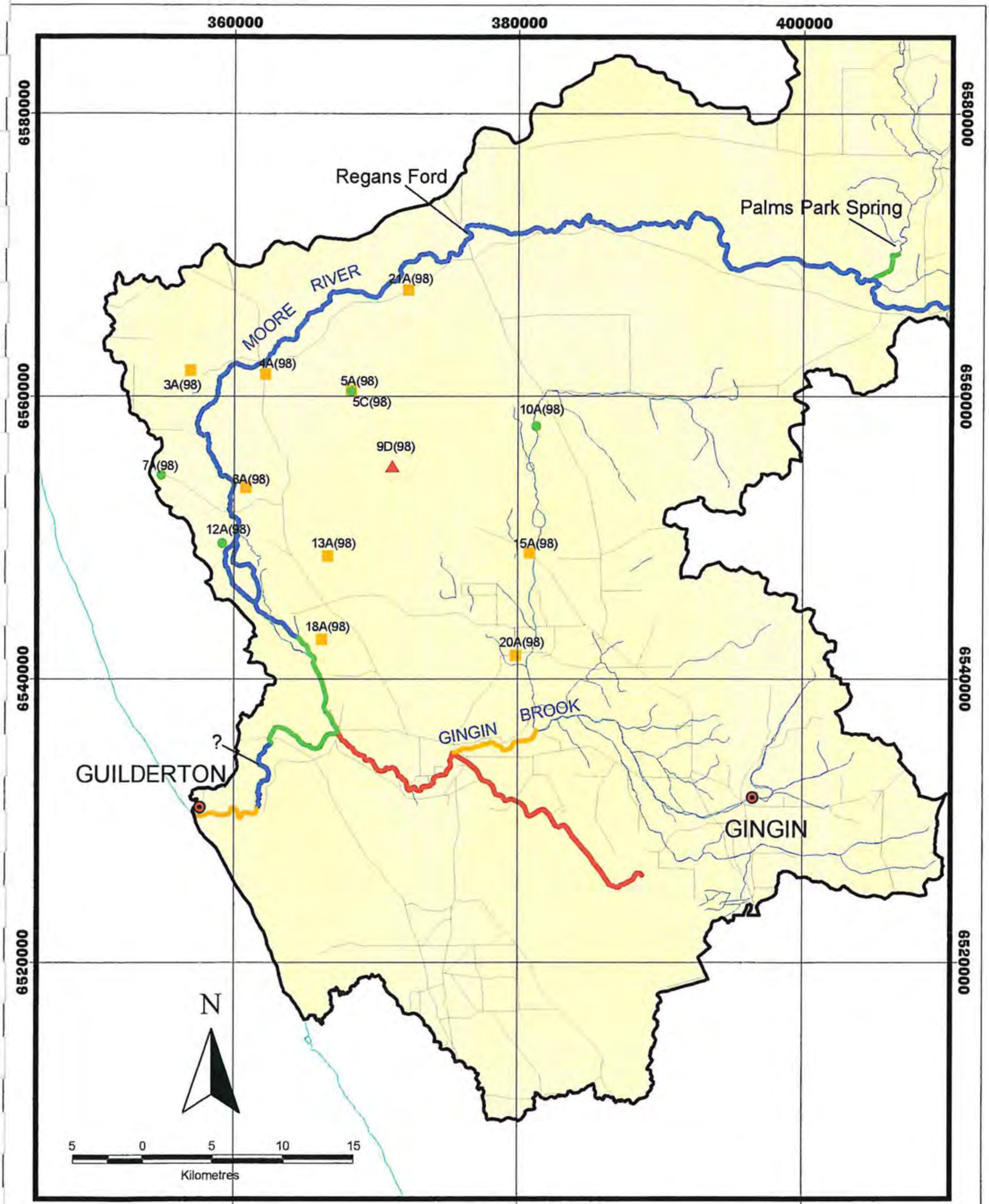

Surface Water Concentrations for Febuary 2001

- < 0.01
- 0.01 - 0.1
- 0.1 - 1.0
- > 1.0

Groundwater Concentrations for various dates

PO_4-P (ortho phosphate)

- 0.015 - 0.03
- 0.03 - 0.1
- 0.1 - 1.0
- > 1.0

(83) Sampling Date 1983

Figure 12(c): Water Chemistry PO_4-P (ortho phosphate)

WATER AND RIVERS COMMISSION

19th March 2001

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APPENDIX I

PHOTOGRAPHS

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Photo 1 Guilderton. Sand bar at the mouth of the Moore River, 15/11/00.

Photo 2 Guilderton. The moore Estuary from the ocean and sand bar, 15/11/00.

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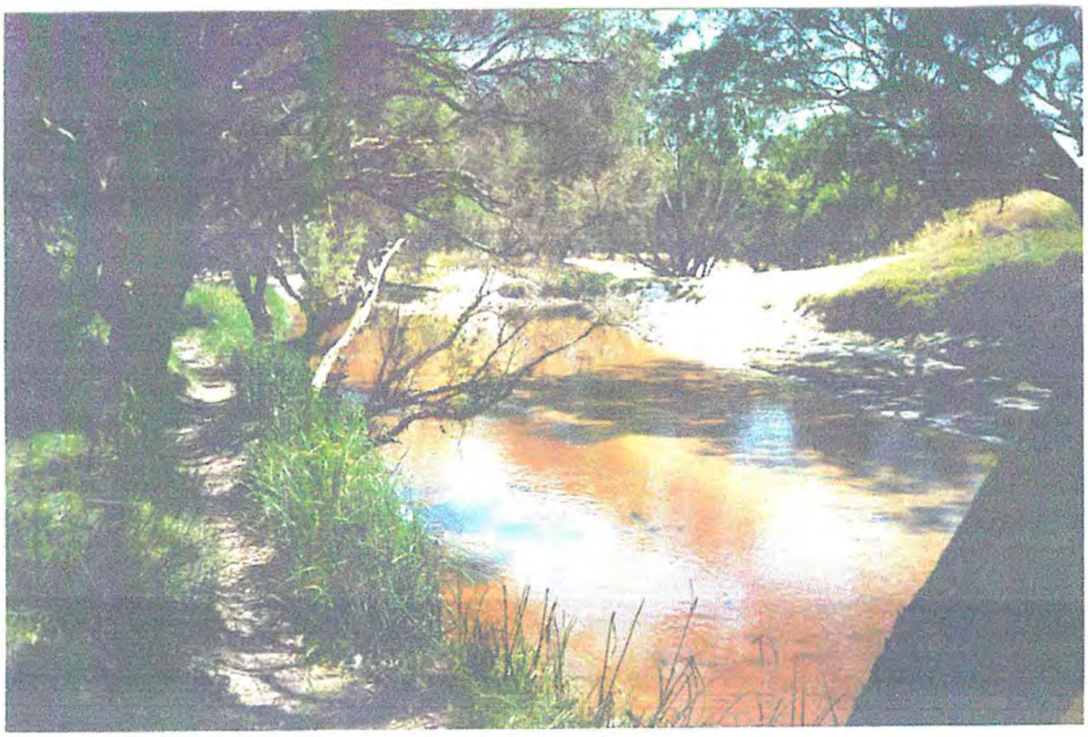


Photo 3. Moore River at Lancelin Road Bridge, 15/11/00.

Photo 4. Waterville Road. Limestone boulders as flood defence. Groundwater springs seep into the Moore River to the right of the picture, 15/11/00.

Photo 5 Waterville Road. Groundwater springs on east bank, 15/11/00.

Photo 6 Waterville Road. View upstream, looking north, 15/11/00.

Photo 7. East of Waterville Road Bridge. Groundwater in the flood plain [E = 366000, N = 6540625], 15/11/00.

Photo 8. Bennies Road. Flood gauging station on east bank. High salinity area. Paper barks (Melaleucas), which favour a high groundwater table, growing on the east side of the river, 15/11/00.

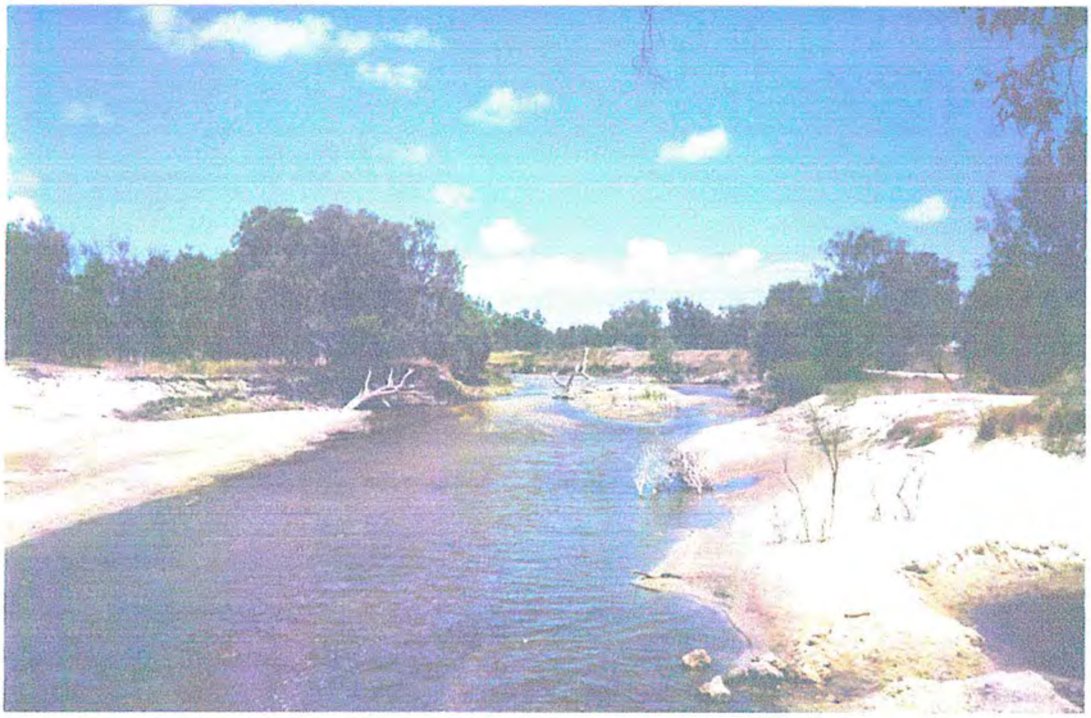


Photo 9 Bennies Road. View south, 21/12/00.

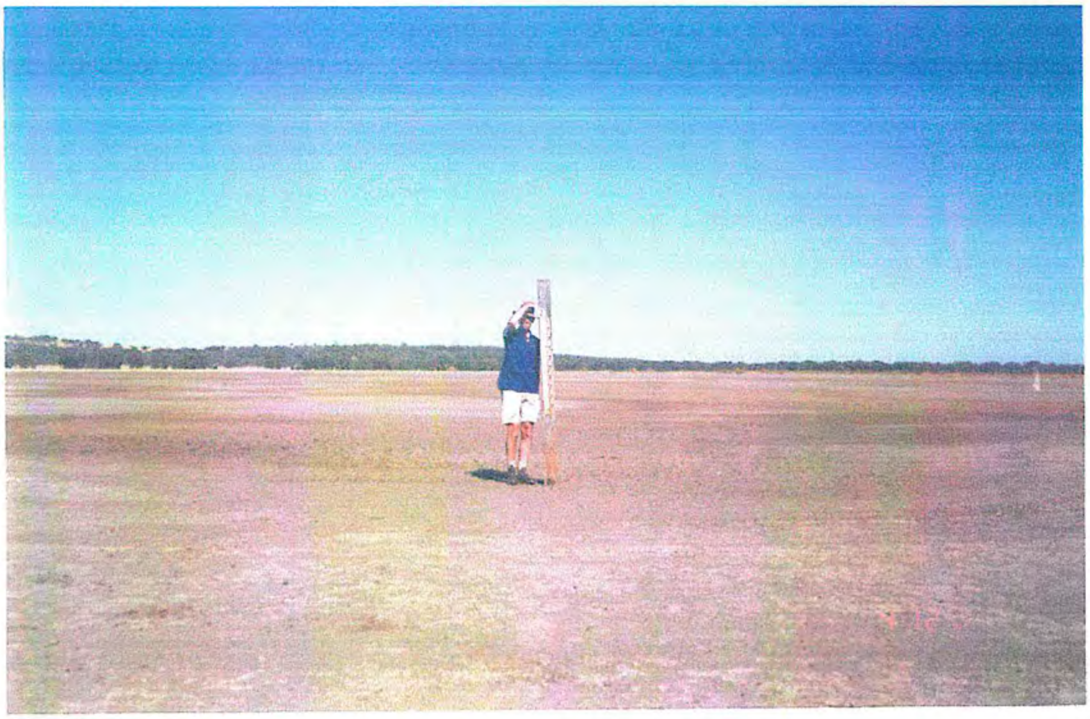


Photo 10 Karakin Lakes viewed from the north west, 07/02/01.

Photo 11 Northern end of the Karakin Lakes, looking east, 21/12/2000.

Photo 12 Moore River flowing beneath Cowalla Bridge, 07/02/01

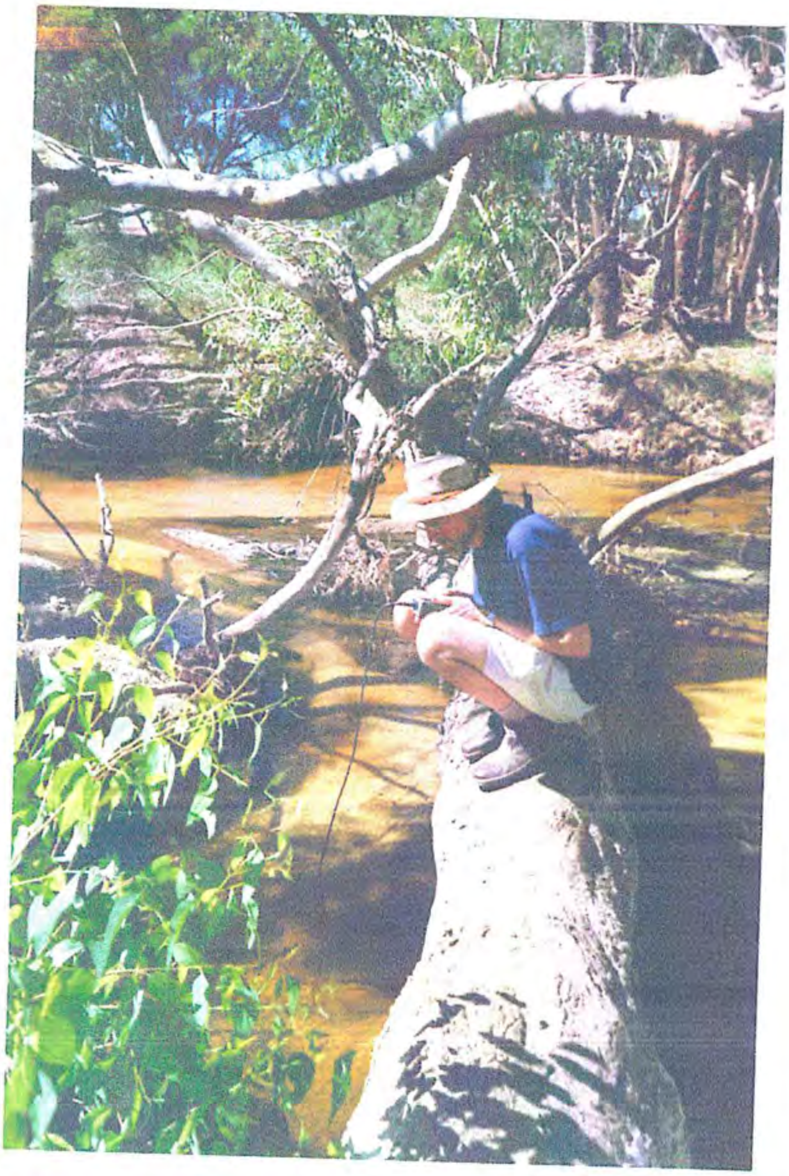


Photo 13 Sampling electrical conductivity, EC, (salinity) of the Moore River at Cowalla Bridge, 07/02/01.

The salinity of the river water decreased between December 2000 and February 2001, from 1880 to 1440 mg/l. During summer months the flow is supported by groundwater discharge.

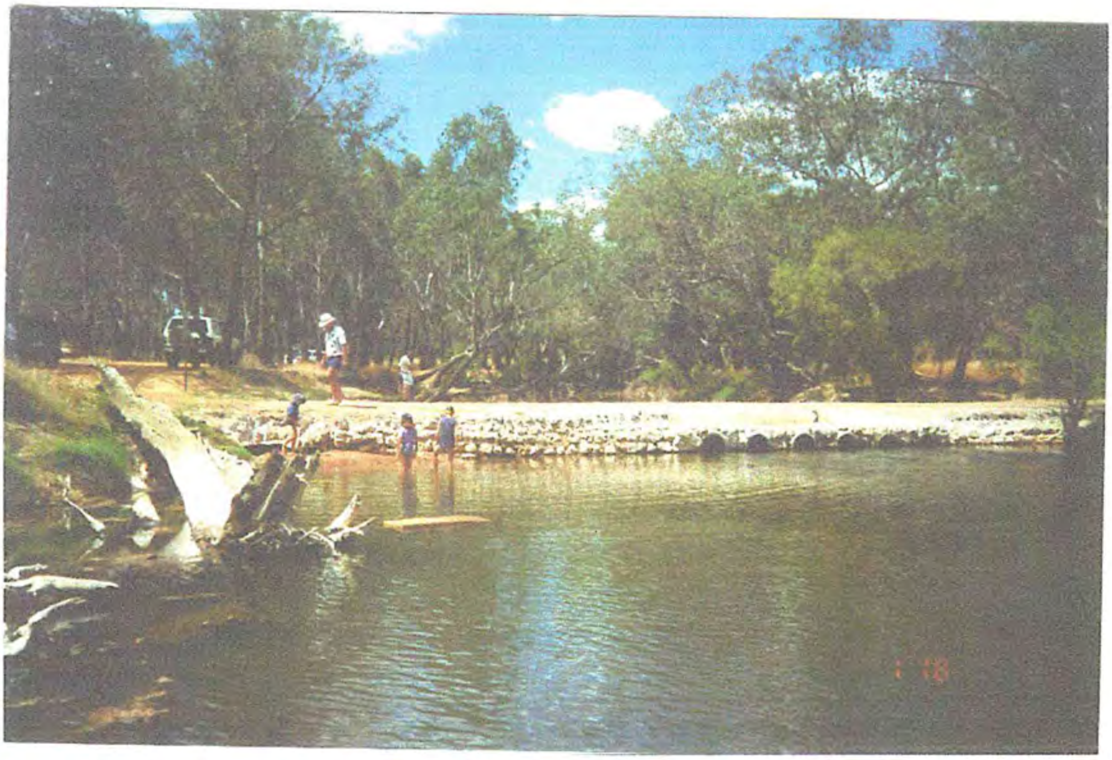


Photo 14 Regans Ford, looking upstream/east, 15/11/00.

Photo 15 Moore River north of Mogumber Road West. Moochamulla cliff area. Narrow section. Cretaceous outcrop exposed on southern bank (Osborne Formation underlain by the Leederville Formation). Flow in river, 15/11/00.

Photo 16 Mogumer Mission Spring. Groundwater seeping out of exposed Cretaceous rock north of the river, 07/02/01. Spring flow forms a stream flowing into the Moore River (flow rate approx. 150 l/s).

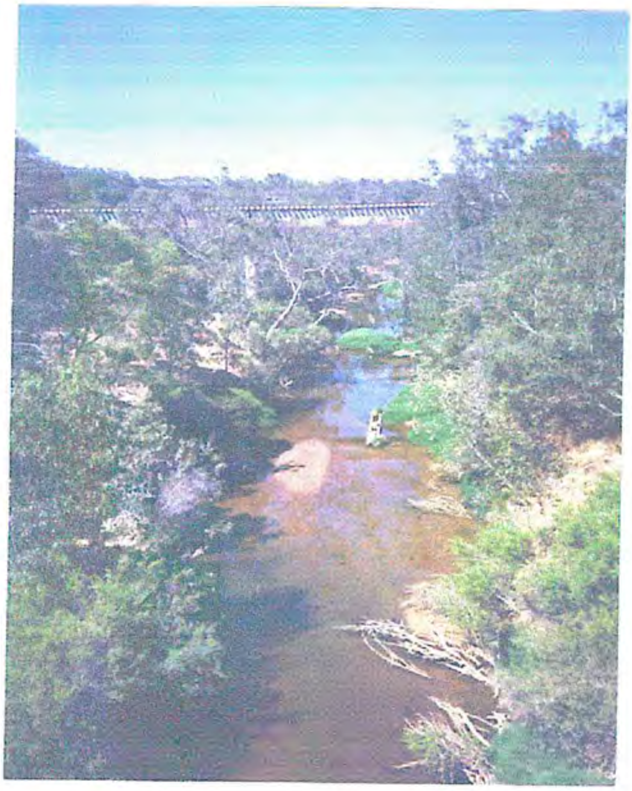


Photo 17 The Moore River East viewed from Mogumber Bridge. Looking downstream/west, with the railway line in the background 06/12/2000. Flow here is considered to be groundwater discharge.

Photo 18 Palms Park Spring. Groundwater bubbling up at the toe of a gum tree in the bed of the Moore River North, 07/02/01.

There was no flow in the river upstream of the spring. The salinity of the spring water was 1,500mg/l in February 2001.

Photo 19 Wourie Pool, Moore River East, 07/02/01.

Photo 20 Moore River North at Gillingarra Road West. Standing water in the riverbed, 15/11/00.

Photo 21 Boxhall Road, view south. Moore River North is almost dry, 15/11/00.

Photo 22 Koojan Road West. Moore River North, looking north, 06/12/00.

Photo 23 Flood gauge board in the Coonderoo River. Viewed upstream/north from Dandaragan Road Bridge, west of Moora, 06/12/00.

Photo 24 Moore River North from Dandaragan Road Bridge, viewed south, 06/12/00.

Photo 25 Coomberdale West Road. View north. Salt pans. When flowing, the Coonderoo River flows through these salt pans, 15/11/00.

Photo 26 Eagle Hill Trib, viewed upstream/east. A tributary of the Coonderoo River. The presence of bull rushes indicates groundwater fed, all year round flow, 14/02/01. Salinity was 2,600mg/l in February 2001.

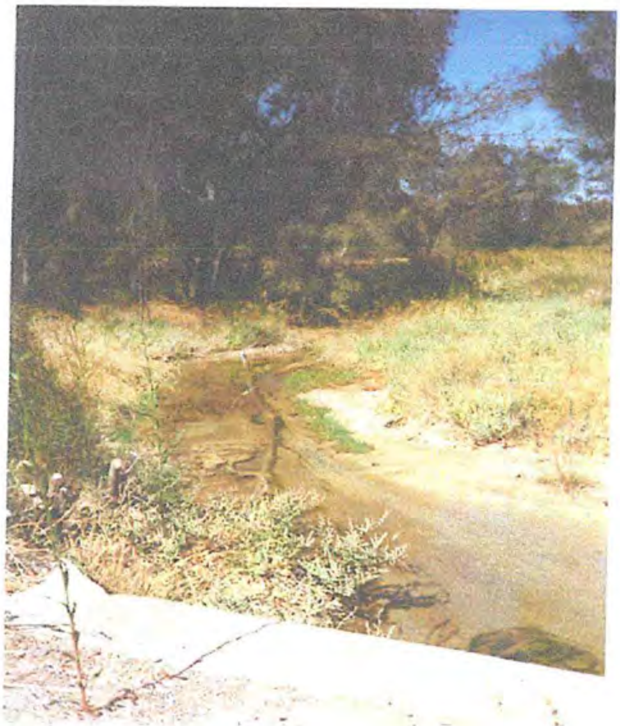


Photo 27 Salt Creek, looking upstream/east at the Midlands Road crossing. Another tributary of the Coonderoo River, 14/02/01.
Salinity measured as 7000mg/l (14/02/01).

Photo 28 Southern edge of Lake Pinjarrega. Demonstrating the height of the 1999 flood. See bleached line on tree. Peter Muirden standing on old DOLA spot height marker, 14/02/01.

Photo 29 Lake Pinjarrega. View from the southern end, 14/02/01. Samphires are tolerating the hypersaline water. 97,000mg/l in February 2001.

Photo 30 Dead trees in Lake Pinjarrega, 14/02/01.
The lake has become more saline with time.

Photo 31 Marchagee River, a tributary of the Coonderoo Eriver, at Greenhead Road. Viewed upstream/south, 14/02/01.

Photo 32 Dry and salty Coonderoo riverbed at Launer Road. Rusted Water & Rivers Commission investigation bores from 1999 in the foreground, 14/02/01.

Photo 33 Dry Coonderoo riverbed at Eneabba Road. Viewed north, 14/02/01.

Photo 34 Information sign at southern end of Yarra Yarra Lakes, 14/02/01.

Photo 35 Gauge board in the Yarra Yarra Lakes, 14/02/01. Demonstrating:
top - overflow level
bottom - maximum 1999 flood level.

Photo 36 Sand bar at the overflow point from the Yarra Yarra Lakes, 14/02/01.

Photo 37 Yarra Yarra Lakes, viewed from the south, 14/02/01. Information sign and gauge board in the foreground.

APPENDIX II

HYDROLOGICAL OBSERVATIONS

APPENDIX II: HYDROLOGICAL OBSERVATIONS

The following hydrological observations were made during November 2000 to February 2001 inclusive (unless stated). Locations are shown in Figure 3, photographs in Appendix II and surface water chemistry data in Appendix III.

Location	Observation
Yarra Yarra Lakes (E = 395000, N= 6668000)	0.4m water in the bottom, 1.7m below the overspill level (Sep-00). Salt encrusted base. February 2001, 0.2m projected depth of water in the lake (pers. comm., Peter Muirden, WRC). A very large lake system. Water present in northern end of large southern lake. Gauge board in SSW end. Wind fetch can raise the water level at the southern end of the lakes. Sand bar across the outlet to the Coonderoo River. Considered man-made.
Coonderoo River, Yarra Yarra Lakes to Lake Pinjarrega	Dry, salty, defined river bed. Yellow WRC investigation bores present along and across the river channel from south of Yarra Yarra Lakes to Marchagee Road south of Lake Pinjarrega. Bush has been mostly cleared, except around Lake Pinjarrega (Nature Reserve). Some pools of standing water in Marchagee River and Coonderoo River at Greenhead Road. Surface water flow considered to reach Lake Eganu (E = 390000, N = 6680900) but not Lake Pinjarrega (Peter Muirden, WRC, pers. comm., 2001). Lake Eganu receives annual low flows from the Coonderoo and Marchagee Rivers and is considered to protect Lake Pinjarrega from the very high salinities. Lake Eganu overflows approx every 5 years (Peter Muirden, WRC, pers. comm., 2001). Prior to 1993 dead *Melaleuca sp.* & *Casuarina obesa* trees were identified around the lake edge with samphire growing under the dead trees (Halse et al, 1993). This indicates that the lake has become progressively more saline. Feb 2001, dry surface water drainage channels to the east of the Coonderoo River. None to the west. Considered to be related to underlying geology. Clays to the east and sands to the west.
Lake Pinjarrega (E =395600 , N = 6672000)	Contained water in February 2001. Estimated depth of 0.5m. Could be residual 1999 flood waters and/or groundwater fed from the west. DOLA land survey marker at southern end of lake [HX 615 – no spot height available from DOLA]. Trees bleached up to approx. 1.5m indicating level of 1999 flood (approx. 2.2m above DOLA survey point). See photographs. Dead trees in lake. Prior to 1993, 28% of the surface area of the lake was open water. Lake Pinjerrega had extensive *Melaleuca lanceolata* in the outer part of the lake and an open *Melaleuca sp.* woodland in the centre. Except at the periphery all the *Melaleuca sp.* were dead (Halse et al, 1993). The *Melaleuca* trees require freshish groundwater. The fact that these are now dead shows that the lake was once fresh, and has become more saline. Lake Pinjarrega was observed to fill in 1999. (pers. comm., Bob Taylor, SKM). Thereafter drained south into the Coonderoo River for 4-6 months. Considered a flood retention basin. Casereena trees still alive on edges of lake. Dead trees in water. Receives inflow from Gunyidi North Trib in most years (perennial), but not from the Coonderoo (Peter Muirden, WRC, pers. comm.,

	2001).
Coonderoo River, Lake Pinjarrega to Moora	Coonderoo River flows out of Lake Pinjarrega approximately once every 5 years. Land in this area is mostly cleared for farming. Dry defined river channel. February 2001, Salt Creek and Eagle Hill Trib were flowing. Bull rushes and Melaleuca trees. Both considered to be groundwater fed. South of Salt Creek the Coonderoo River flows every year. Standing water observed in shallow pools at Watheroo West Road, Namban Road West and Coomberdale Road West. Moore River North flows through salt lakes at Coomberdale Road West. These salt lakes could be fed by shallow groundwater from the west.
Moora salt lakes, Coomberdale Road West (E = 400000, N = 6610200)	Salt lakes considered shallow groundwater fed features (on top of Osborne Formation) (Philip Commander, WRC, pers. comm., 2000). Nov 2000, small pool of water visible in large salt encrusted lake. Dead trees in the lakes indicate that groundwater discharge has increased in salinity.
Moore River North, Dandaragan Road Bridge, Moora (E = 403000, N = 6610000)	Shallow pools in the river bed (Dec-00).
Moore River North, Barberton Road West (E = 404500, N = 6601500)	Dry river bed (Dec-00)
Moore River North, West Koojan Road (E = 405400, N = 6590500)	Dry river bed (Dec-00)
Moore River North, Boxhall Road (E = 407500, N = 6584500)	Poor floodway constructed. Shallow pools of water in an otherwise dry river bed (Nov-00).
Moore River North, Gillingara Road West (E = 409000, N = 6578000)	Shallow pools of water in an otherwise dry river bed (Nov-00)
Moore River North, Palm Park spring (E = 406000 , N = 6569500)	Stagnant pools with no flow in the river upstream of the spring. Groundwater spring bubbling up at toe of river gum tree in river bed at approx. 159m AHD. Fine black silt/organic matter rippled on bed of river downstream of spring. 10m high banks. Flood debris in trees approx. 4m above river bed. 24 Feb 2001, spring flow into river 14l/s (+/-8%).
Moore River East, Wourie Pool (E =415907 , N= 6568145)	WRC flow gauging station. Feb 2001. Flow rate approx. 30l/s or 2,500m^3/d. Shallow depth. Flow through 3 channels under bridge. Large shallow groundwater catchment area on the Yilgarn Craton. 24 Feb 2001, spring flow into river 15l/s (+/-8%).
Moore River East, Mogumber Bridge	Steep banks to the river bed. Shallow depth. Could be gauged to the east of the road bridge.

(E = 408500, N = 6562000)	24 Feb 2001, river flow 14l/s (+/-8%).
Moore River, Quinns Ford (E = 387900, N = 6571700)	Steep descent from Mogumber Road. Narrow channel. Flow in river. WRC telemetered flow gauging station 1km upstream of river crossing. Feb 2001, flow 171 l/s or 14, 770 m^3/d. 24 Feb 2001, river flow 18l/s (+/-8%).
Moore River North, Mogumber Mission Spring (E = 384900, N =65718500)	The tight meander in the river has cut into the northern bank, exposing Cretaceous sandstone and conglomerate overlying a shale layer (Leederville Formation). In Feb 2001 water seepage from the top of the shale horizon (TDS = 640 mg/l) was observed to flow into a stream (TDS = 1050 mg/l) which entered the Moore River at 15 l/s. Lush vegetation in this northern bank rock bound amphitheatre suggests the Moore River receives groundwater discharge from this area.
Moore River, Mogumber Road West river access (E = 382600, N = 6571600)	Wide channel. Flow in river. Shallow depth (Jan-00). Lush vegetation along southern bank. Flood debris high in trees. Moore River has cut down through the rock sequence. Very steep southern bank. Less steep northern bank. 24 Feb 2001, river flow 185l/s (+/-8%).
Moore River, Mogumber Road West Springs (E = 382600, N = 6571580)	Located along access road, on the south bank of the river. Red iron coloured springs (Jan-01). Diminished flow in Feb 2001. Bullrushes and lush green vegetation below the spring line. Suggests perennial groundwater spring discharge at approx. 75m AHD. Considered to be fed by a surficial (laterite and sands) aquifer.
Moore River, Regans Ford (E = 376400, N = 6571000)	Wide river section. Significant flow (Nov-00). Lower level & less flow (Feb-01). Flood debris approx 4-5m high in trees. Feb 2001, flow rate estimate: 220 l/s or 19,000 m^3/d. 24 Feb 2001, river flow 346l/s (+/-8%).
Moore River, Cowalla Bridge (E = 362000, N = 6562300)	Medium width of river section. Sandy river bed. Feb 2001, river meandering between sand banks in river. Flow rate estimate: 275 l/s or 23,800m^3/d. 24 Feb 2001, river flow 476l/s (+/-8%).
Moore River, Karakin Lakes (E = 355000, N = 6562000)	The Karakin Lakes are a natural swamp feature which fill with rainwater every year, and then soak away (Allan Knight, 28 Baramba Road, pers. comm., 2001). Large flat sandy area. Lakes dry with cracked mud base. Flood gauge board in centre of last wetted area at the north end of the lakes. Rushes growing towards southern end (Jan 2001). Along the north and western banks of the lakes water has historically cut into the sand dunes, suggesting a 2m plus depth of water in the lakes. Surface water drainage out of the lakes was probably via their south east end, the Karakin Brook, into the Moore River. In 1923 the Karakin Brook was dammed by a levee bank to encourage dairy farming in the area (Bill de Burgh, Baramba Farm, pers. comm., 1997). In 1999 the levee bank was breached by flood water in the Moore River and the lakes flooded. 'The worst flood since 1951.' The presence of clay and alluvial soils underlain by a 1m thick clay layer on properties 27 & 28 Baramba Road, to the east of the Karakin Lakes, could indicate a former course of the Moore River into the lakes.
Moore River, Bennies Road	Flood gauge board to north of bridge. Wide river section. White sand banks. Melaleuca trees growing east of the river suggest a perennially high water table. Declining flow rate (Nov-Feb-01). Feb 2001, flow rate estimate approx. 337 l/s or 29,100 m^3/d.

(E = 359550, N = 6545520)	24 Feb 2001, river flow 263l/s (+/-8%).
Moore River, Waterville Road (E = 366000, N = 6540000)	Nov 2001, groundwater fed pool within the flood plain to the east of the river [E = 366000, N = 6540625]. Wide shallow river. Limestone boulders used for flood roadway protection. 24 Feb 2001, river flow 101l/s (+/-8%). Groundwater spring discharges south of the road on the eastern bank. Algal growth suggests high nutrient content in groundwater (Nov-00). Spring flow had declined to seepage by Feb 2001.
Gingin Brook, Bookine Bookine Road (E =369230 , N = 6534020)	WRC flow gauging station and fish pass. Flow is backed up approx. 1.5m upstream of the gauging station weir. 24 Feb 2001, brook flow 76l/s (+/-8%).
Gingin Brook, Guilderton Road (E = 366600, N = 6536000)	Narrow section, deep water. Brown with tannin. Little change in water level between Dec 2000 & Feb 2001. Lush green vegetation suggests high nutrient content of the water.
Moore River, Lancelin Road (E = 362400, N = 6536000)	Narrow river. Brown water. Decreasing depth of flowing water between Nov 2000 to Feb 2001. 24 Feb 2001, spring flow into river 316l/s (+/-8%).
Moore River, Caraban Rocks (E = , N =)	Wide meandering river. Groundwater springs visible entering river from south bank at times of low river level, eg. when the estuary sand bar is broken in summer (pers. comm., Mischa Cousins, WRC, 2000).
Moore River Estuary, Guilderton (E = 357000, N = 6530400)	Wide picturesque estuary dammed by the sand bar on 4 out of 5 visits (Nov 2000 to Feb 2001). The Guilderton sand bar opens and closes year round every few weeks under natural conditions as the head of water in the river builds up sufficiently to break the bar. With a couple of days the wind has built up the beach sand sufficiently to close the bar again (Mischa Cousins, WRC, pers. comm., 2001).

APPENDIX III

BORE DATA

APPENDIX III BORE DATA ALONG THE MOORE & COONDEROO RIVERS

Name	Bore ID	E	N	Depth of bore	Depth to water	Date of measurement	Lithology	Elevation GL* (m AHD)	Bottom elevation (m AHD)	Elevation TOC (m AHD)	Slotted/ screened interval (m)	Potential Head (m AHD)	Data Source
3/92 SP	2035-3-nw-61	358000	6532485	93	59(p)	Sep-00	Limestone	46	-13			60	Pers comms, Jo Miotti
JP25	2035-3-nw-38	362020	6530585	39	11.8	Mar-00	Sup		-25.7	13.27		1.5	WRC
GA27	2035-3-nw-288	362850	6532853	35.7	24	Mar-00	Sup		-9.5	26.21		2.2	WRC
GB2	2035-3-nw-?	366240	6532975	64.6	52.8	Jan-99	Sup		-2.2	62.36		9.6	WRC
YY10 (I)	2035-3-nw-31	367050	6535380	42	15.2	May-00	Sup	27.3	-15.6	26.39	17-47	11.2	WRC
YY10 (O)	2035-3-nw-32	367027	6535357	73	16.6	May-00	Sup	27.3	-45.2	27.82		11.2	WRC
	2035-3-nw-52	365132	6541132	22.5	3.7	1984	Sup	24	1.5			20	AQWAB
S3A	1935-1-ne-30	356800	6561660	75	6.1	Mar-00	Ascot Fm	45.23	-29.77	46.43	38-50	40.3	WRC
S4A	2035-4-nw-18	362080	6561380	75	4.6	Mar-00	Ascot Fm	53.90	-21.1	54.64	37-55	50	WRC
S5A	2035-4-nw-14	368160	6560210	69	12.2	Mar-00	Guildford	65.79	-3.21	67	32.2-44.2	54.8	WRC
S5C	2035-4-nw-20	368160	6560210	45	11.3	Jun-00	Guildford	65.78	20.78	66.05	31.8-44.0	54.8	WRC
	2035-4-sw-32	360331	6550635	52	2.1	?		39	-13			37	AQWAB
S8A	2035-4-sw-35	360750	6553380	66.6	3.9	Mar-00	Ascot Fm	38.16	-28.44	38.87	34-52	34	WRC
	2035-4-sw-35	360750	6553380	66.6	3.2	Jan-01	Ascot Fm	38.11	-28.49	38.87	34-52	35	WRC
new bore	2035-4-sw- ?	360250	6552500	30	10	1998		50	20			40	G Grant
S7A	1935-1-se-21	354750	6554280	114	53.5	Mar-00	Ascot Fm	59.95	-54.05	60.73	64.7-76.1	7.2	WRC
	2035-4-nw-22	357838	6557660	44	8.5	Mar-86		47	3			39	AQWAB
Alan Knight's shed bore	2035-4-nw-?	359000	6562000	30	4	Feb-01	Sup	55	25			51	Pers comm
Alan Knight's garden bore	2035-4-nw-?	359000	6562000	30	4	Feb-01	Sup	55	25			51	Pers comm
	2035-4-nw-14	359133	6560378	42	4	Nov-84		49	7			45	AQWAB
S12A	2035-4-sw-36	359050	6549480	59.5	8.6	Mar-00	Ascot Fm	33.52	-25.98	34.3	40.1-46.1	25.7	WRC
S18A	2035-4-sw-40	366100	6542610	60	14.4	Mar-00	Ascot Fm	38.14	-21.86	39.47	35-47	25.1	WRC
private bore	29 Millbank Ave 2035-4-sw-?	362000	6556700	52	10	Apr-91	Sup	57	5			47	Pers comms - David Lombardo
S4B	2035-4-nw-21	362080	6561380	57	4.4	Aug-00	Ascot Fm	53.89	-3.11	54.41	38.5-57.0	50	WRC
CS22DA	2036-3-ne-17	362700	6559400	53.8	36.1	Dec-97	Yaragadee	136.95	83.15	137.83	29-35	101.7	WRC
GL4W	2035-4-nw-13	368150	6566600	95	13.84	Jun-00	Kll	77.07	-17.93	77.47	84-90	67.2	WRC
S21	2035-4-ne-8	372170	6567350	81	5.58	Mar-00	Guildford - Yoganup	74.39	-6.61	75.58	51-63	70	WRC

Name	Bore ID	E	N	Depth of bore	Depth to water	Date of measure ment	Lithology	Elevation GL* (m AHD)	Bottom elevation (m AHD)	Elevation TOC (m AHD)	Slotted/ screened interval (m)	Potential Head (m AHD)	Data Source
KTB1	new bore: Kallamar Estate, 5, Orange Springs Road	374650	6567860	<60	7.36	Jan-00	Sup	77	>17			70	SN13755
KTB2	Kallamar Estate	374650	6567850	>60	7.3	Jan-00	Kll	77	<17			70	SN13755
RF1	new bore Environmental Forest Farms	374650	6571000	59	8	Oct-00	Sup	78	19			70	SN11714 & ERM
SN11174	22& 23 Orange Springs Rd (Mrs Lee)	373060	6568040	64			Sup	80	16			?	Pers comms
	22& 23 Orange Springs Rd (Mrs Lee)	373060	6568040	25			Sup	80	55			?	Pers comms
	883, Woodbine Road	378100	6572500	3.0 (soak)	?	?	Sup	80	77			?	Pers comms
SN1371	2991, Woodbine Road	378200	6572500	48	21.5	Nov-95	Sup	85	37			58.5-68.5	SN1371 & comms
GL5W	2035-4-ne-7	376750	6569250	60	2.9	Jan-00	Kll	85.29	25.29	85.55	52-58.4	rising 82.6	WRC
SN12383	Lot 5, Moochamulla Rd	383770	6572620	40.5	20	Aug-99	Sup	100	59.5			80	Pers comms
	2036-3-se-15	376335	6569738	15	11	Oct-80		80	65			69	AQWAB
	2036-3-se-28	376250	6571000	30	6	Sep-96		77	47			71	AQWAB
GL6W	2036-3-se-18	383700	6571200	114	12.6	Aug-00	Jkp	127.56	13.56	127.87	100-106	rising 115.2	WRC
groundwater spring	Mogumber Mission	384200	6571600	n/a	n/a	Feb-01	Kll	90	n/a	n/a	n/a	90	Field
groundwater springs	Mogumber Road West	382600	6571580	n/a	n/a	Jan-01	Surficial	85	n/a	n/a	n/a	85	Field
Peter Detchon's bore	2 Orange Springs Road	366000	656530	19	11	Jan-01	Surficial	70	51			59	Pers comm
	2036-2-sw-21	381375	6571530	42	19	?		80	38			61	AQWAB
	2036-2-sw-17	383749	6571557	37	22	Oct-79		110	73			88	AQWAB
GL7W	2035-1-ne-27	394269	6568481	61	32.1	Dec-99	Kup+	145.19	84.19	145.4	54-60	144	WRC

Name	Bore ID	E	N	Depth of bore	Depth to water	Date of measurement	Lithology	Elevation GL* (m AHD)	Bottom elevation (m AHD)	Elevation TOC (m AHD)	Slotted/ screened interval (m)	Potential Head (m AHD)	Data Source
	2035-1-ne-4	402608	6567659	32	?							?	AQWAB
GL8W	2135-4-nw-0032	404881	6565964	103	32	Dec-85	Kud	171.50	68.5	171.97	97-103	162	WRC
groundwater spring	Palms Park Spring	406000	6569500	n/a	n/a	Feb-01	Kul?	159	n/a	n/a	n/a	159	Field
Sykes Rd		408000	6569500	13.1	1.00	Dec-00	Surf	180	166.9			179	AgWA
	2136-3-sw-21	381375	6571530	18	5.00	?	?	188	170				AQWAB
	2136-3-sw-25	407960	6579530	18	?	?	?	183	165				AQWAB
WG6		404800	6579800	5	1.5	Jul-95	Surf	178	173			177	AgWA
BH4	2136-3-nw-4	404720	6590075	25	9.1	Dec-00	Kll?	197	172			188	Field
	2036-2-ne-29	402845	6596067	28.3	25.9	?	?	195	166.7			169	AQWAB
	2136-4-sw-80	405230	6601448	21	10.7	?	?	197	176			186	AQWAB
Ranfurly Park	new bore	404700	6601000	19.1	1.02	Dec-00	Surf	195	175.9			194	AgWA
Ranfurly Park	new bore	404700	6601000	4.8	1.04	Dec-00	Surf	195	190.2			194	AgWA
	2036-1-se-20	401623	6605634	4.6	0.3	?	?	200	195.4			200	AQWAB
	2036-1-se-26	401934	6610175	4	3.4	?	?	204	200			201	AQWAB
Moora Line	ML1A	397082	6612597	756	16	1974	Kll	213.25	-542.75	213.81	622-629	198	WRC
Moora	new bores: MO12OB	403626	6610506	5.3	2.95	Oct-00	Surf		197.63	202.93	1.5-5.0	200	AgWA
Moora	M013I	402943	6611058	30.1	3.47	Oct-00	Surf		172.16	202.26	27.3-29.3	199	AgWA
Moora	M013OB	402944	6611056	8.7	3.46	Oct-00	Surf		193.61	202.31	6.0-8.0	199	AgWA
Moora	MO14OB	404536	6613175	11.7	2.64	Oct-00	Surf		192.32	204.02	7.4-11.4	201	AgWA
Moora	M015D1	404595	6611692	30	3.32	Oct-00	Surf		174.33	204.33	27.5-29.5	201	AgWA
Moora	MO15I	404596	6611695	22.1	3.45	Oct-00	Surf		182.31	204.41	19.8-21.8	201	AgWA
Moora	MO15OB	404594	6611689	12.9	3.34	Oct-00	Surf		191.51	204.41	8.4-12.4	201	AgWA
	2036-1-ne-29	402835	6611633	6.4	4.4	?	Surf	199	192.6			195	AQWAB
	2036-1-ne-14	402429	6612586	9.1	7.5	?	Surf	198	188.9			191	AQWAB
	2136-4-nw-11	404529	6616576	10.7	2.1	?	Surf	200	189.3			198	AQWAB
	2136-4-nw-42	406388	6621606	2	1.4	?	Surf	215	213			214	AQWAB
	2136-4-nw-40	406781	6625053	7	5	?	Surf	218	211			213	AQWAB
	2037-2-se-6	402696	6637863	2	1.7	?	Surf	220	218			218	AQWAB

Name	Bore ID	E	N	Depth of bore	Depth to water	Date of measure ment	Lithology	Elevation GL* (m AHD)	Bottom elevation (m AHD)	Elevation TOC (m AHD)	Slotted/ screened interval (m)	Potential Head (m AHD)	Data Source
	2037-2-ne-4	403102	6639337	4	3.6	?	Surf	221	217			217	AQWAB
	2037-2-ne-3	400720	6642730	3	2.4	?	Surf	222	219			220	AQWAB
	2037-2-ne-7	402076	6645345	2.4	0.9	?	Surf	223	220.6			222	AQWAB
WL1	2037-2-ne-18	396000	6645000	551.7	24	1972	Kll	234	-317.7		208-218	210	WRC
WL1	2037-2-ne-18	396000	6645000	551.7	23	1972	Jy	234	-317.7		506-515	211	WRC
YRE1S	2037-1-nw-22	394722	6667940	15	7.17	Apr-99	Palaeo-channel sand & gravel	225.3	210.26	226.35	11.5-14.5	218.6	WRC
YRD3S	2037-1-ne-18	392480	6679814	9	2.85	Apr-99	Palaeo-channel sand & gravel	228.8	219.78	229.45	5.5-8.5	225.9	WRC
YRC2S	2038-2-se-29	394316	6688555	6	0.57	Apr-99	Palaeo-channel sand & gravel	232.5	226.48	233.07	3.0-6.0	231.9	WRC
YRB1S	2038-2-nw-29	390384	6702050	8	0.83	Apr-99	sandy clay	241.4	233.44	242.05	5.0-8.0	240.6	WRC
YRA2S	2038-2-nw-27	390033	6703244	8	1.64	Apr-99	sandy clay	242.9	234.87	243.44	5.0-8.0	241.2	WRC

Notes

Geology

Sup	Superficial aquifers	Kll	Leederville Formation	Jy	Yaragadee Formation
Surf	Surficial strata	Kup	Parmelia Formation		
Kul	Lancelin Formation				
Kuo	Osborne Formation				
Kud	Dandaragan Sandstone				

Elevations

TOC Top of casing

GL* Ground level, estimated from topographic maps

APPENDIX IV

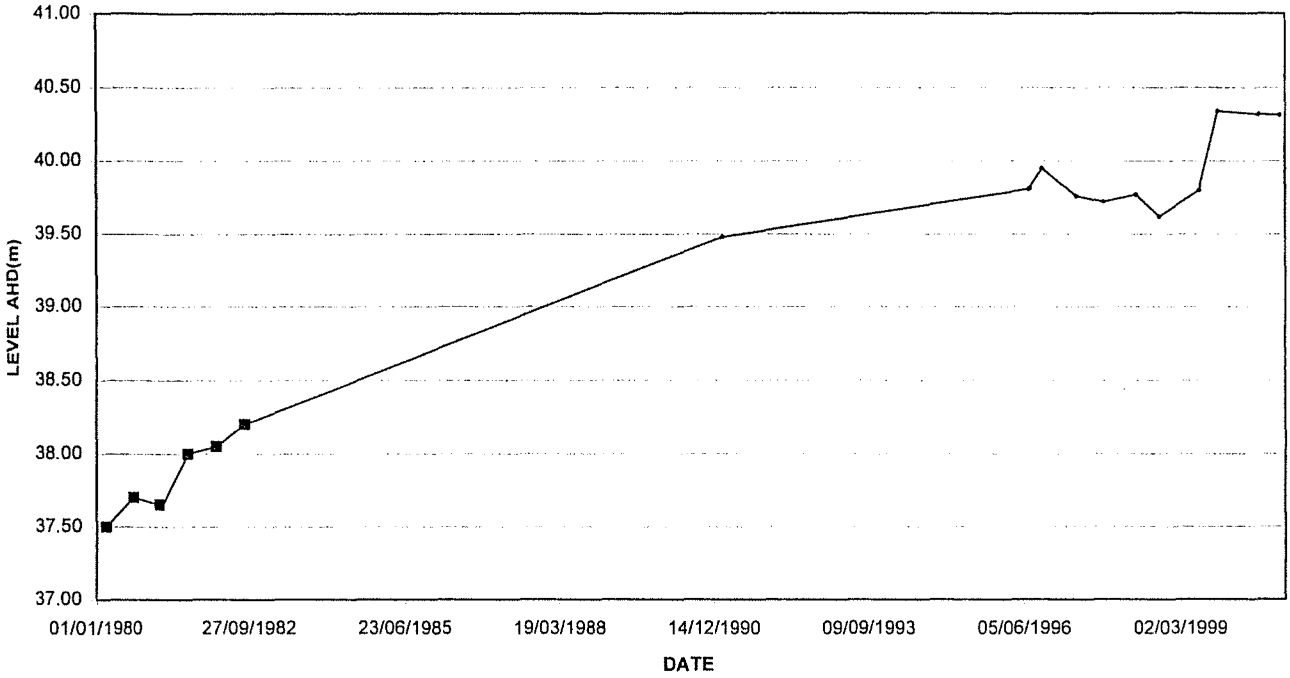
GROUNDWATER HYDROGRPAHS

WATER AND RIVERS COMMISSION

61730004 SALVADO LINE 3A

Easting = 356939.00 Northing = 6561810.00 Zone = 50 AHD = 46.428(TOC) WIN SITE ID = 6588

• = Good Record ● = Satisfactory Record. ▲ = Water Level is Above the Datum. ■ = Water Level is Below the Reading

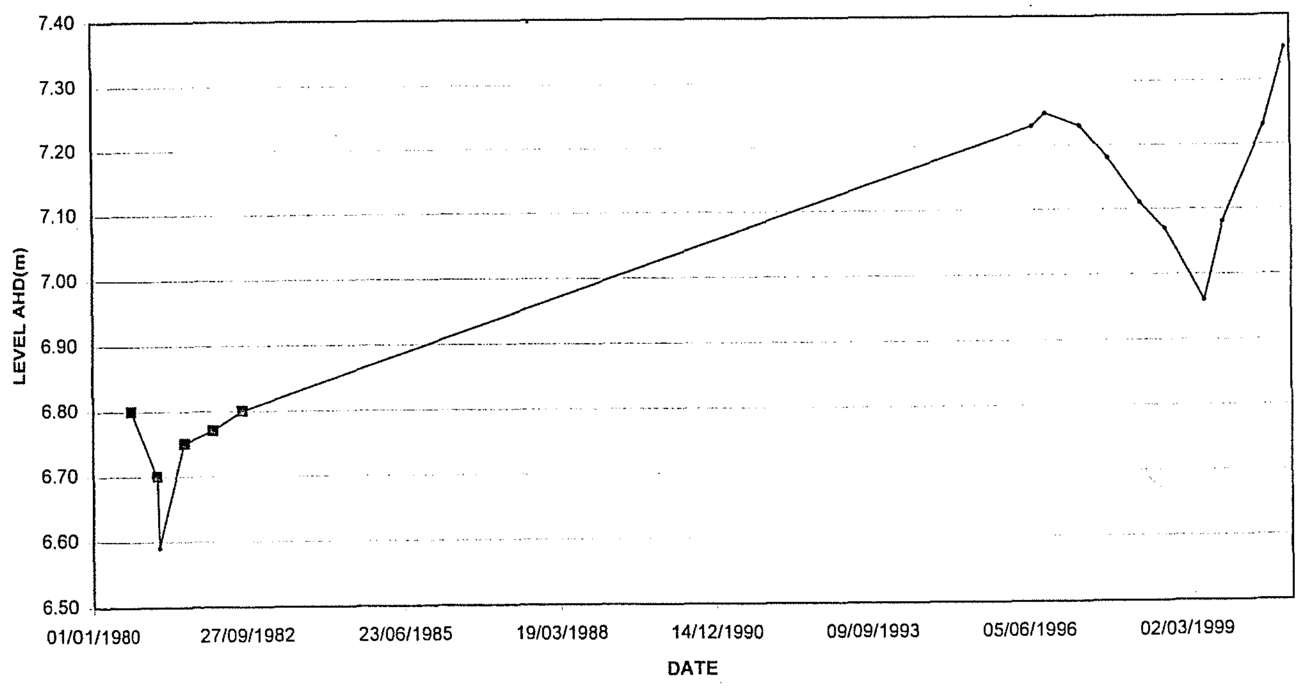


WATER AND RIVERS COMMISSION

61730010 SALVADO LINE 7A

Easting = 354889.00 Northing = 6554430.00 Zone = 50 AHD = 60.730(TOC) WIN SITE ID = 6594

• = Good Record. ● = Satisfactory Record. ▲ = Water Level is Above the Datum. ■ = Water Level is Below the Reading.



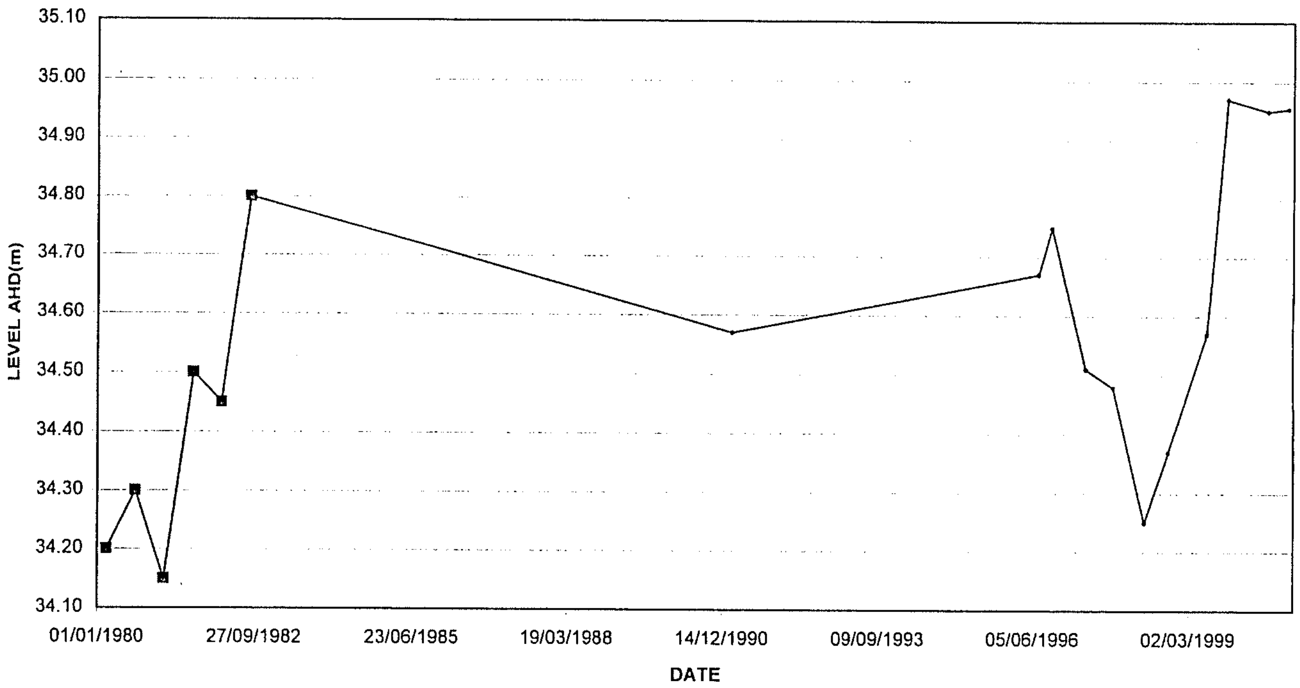
Printed 13:47 29/03/2001

WATER AND RIVERS COMMISSION

61730011 SALVADO LINE 8A

Easting = 360889.00 Northing = 6553530.00 Zone = 50 AHD = 38.870(TOC) WIN SITE ID = 6595

• = Good Record ● = Satisfactory Record ▲ = Water Level is Above the Datum. ■ = Water Level is Below the Reading.

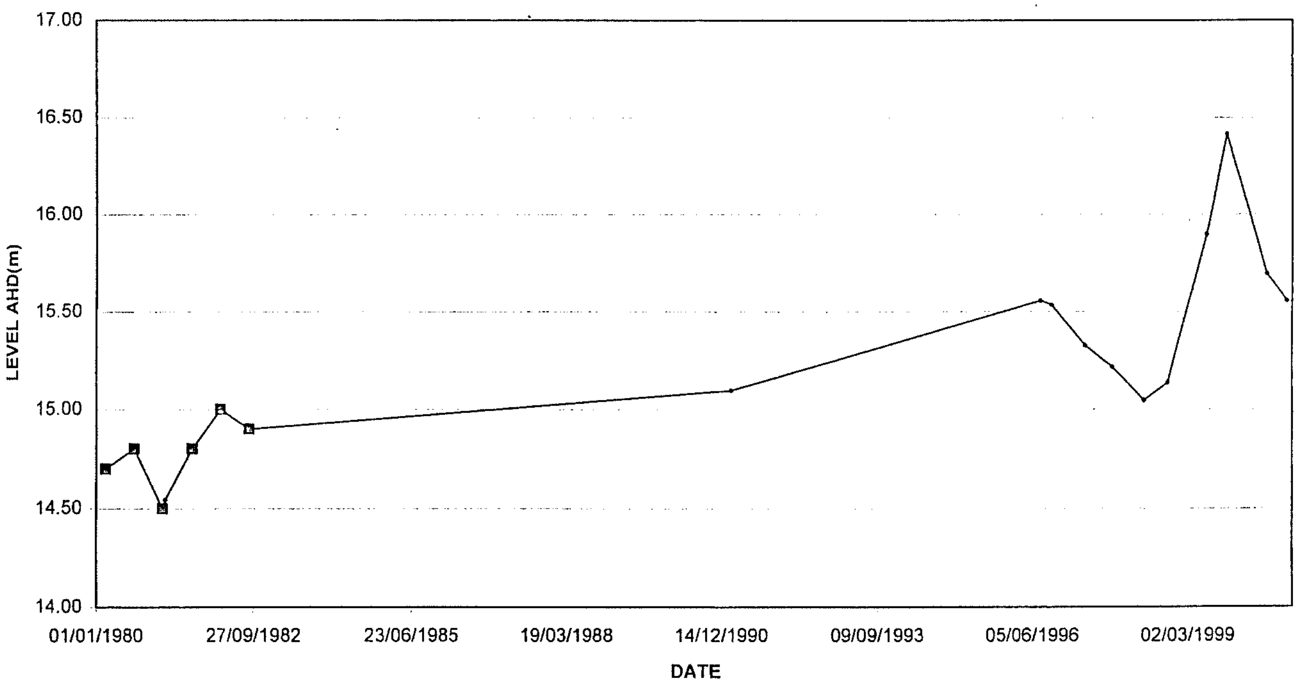


WATER AND RIVERS COMMISSION

61730016 SALVADO LINE 12A

Easting = 359189.00 Northing = 6549629.00 Zone = 50 AHD = 34.295(TOC) WIN SITE ID = 6600

• = Good Record ● = Satisfactory Record ▲ = Water Level is Above the Datum. ■ = Water Level is Below the Reading.



61730022 SALVADO LINE 18A

Easting = 366239.00 Northing = 6542759.00 Zone = 50 AHD = 39.466(TOC) WIN SITE ID = 6606

♦ = Good Record, ● = Satisfactory Record, ▲ = Water Level is Above the Datum, ■ = Water Level is Below the Reading.

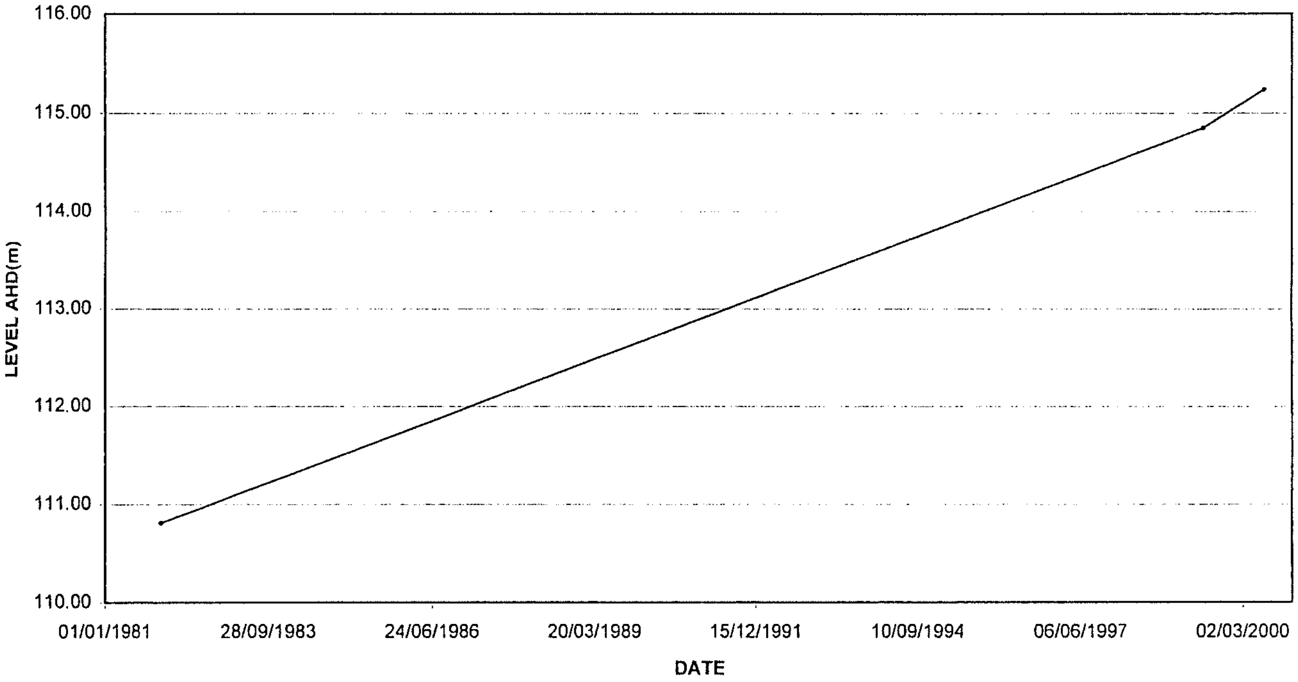
Printed 13:47 29/03/2001

WATER AND RIVERS COMMISSION

61730057 GILLINGARRA LINE GL6W

Easting = 383839.00 Northing = 6571350.00 Zone = 50 AHD = 127.870(GL) WIN SITE ID = 6641

• = Good Record. ● = Satisfactory Record. ▲ = Water Level is Above the Datum. ■ = Water Level is Below the Reading.



WATER AND RIVERS COMMISSION

61730065 GILLINGARRA LINE GL8W

Easting = 405139.00 Northing = 6566150.00 Zone = 50 AHD = 171.970(GL) WIN SITE ID = 6649

• = Good Record. ● = Satisfactory Record. ▲ = Water Level is Above the Datum. ■ = Water Level is Below the Reading.

APPENDIX V

SURFACE WATER CHEMISTRY DATA

APPENDIX V SURFACE WATER CHEMISTRY DATA

River	Site Name	Sample Date	Econd (Ms/m)	TDS (mg/l)	*TDS calculatn method	HCO3 (mg/l)	Cl (mg/l)	NH3-N	NOx-N or NO3-N (mg/l)	Total N	SO4-S (mg/l)	FRP or PO4-P (SOL) (mg/l)	Total P	Fe sol (mg/l)	pH	HCO3/Cl	SO4/Cl
Coonderoo River	Lake Pinjarrega	14-Feb-01	17000	97000	lab	320	55000	0.021	0.071	4.7	5100	0.015	0.07	<0.5	7.7	0.01	0.09
Coonderoo River	Salt Creek	14-Feb-01	1200	7000	lab	570	3500	<0.005	0.071	0.48	420	<0.003	0.02	<0.05	8.5	0.16	0.12
Coonderoo River	Eagle Hill Tributary -u/s	14-Feb-01	440	2600	lab	110	1300	<0.005	4.2	4.8	150	<0.003	0.03	0.05	7.8	0.08	0.12
Coonderoo River	Eagle Hill Tributary - d/s	14-Feb-01	500	2900	lab	140	1500	0.016	0.21	1.1	180	0.041	0.07	<0.05	7.5	0.09	0.12
Moore River North	Palms Park spring	14-Feb-01	275	1500	lab	65	720	0.061	<0.005	0.07	85	0.03	0.071	0.35	6.6	0.09	0.12
Moore River East	Wourie Pool	07-Feb-01	1260	8100	lab	360	3900	0.036	0.005	0.54	310	0.006	0.05	<0.05	8.1	0.09	0.08
Moore River East	Wourie Pool	24-Feb-01	1330	7620	conv.sheet										8.2		
Moore River East	Mogumber Bridge	07-Feb-01	1350	8700	lab	370	4200	0.022	<0.005	0.6	310	<0.003	0.04	<0.05	8.1	0.09	0.07
Moore River East	Mogumber Bridge	24-Feb-01	1390	7970	conv.sheet										8.1		
Moore River	Quinns Ford	07-Feb-01	650	3900	lab	140	1900	<0.005	0.27	0.29	140	<0.003	0.02	<0.05	7.3	0.07	0.07
Moore River	Quinns Ford	24-Feb-01	600	3330	conv.sheet										7.5		
Mogumber Mission	Stream beneath groundwater spring	07-Feb-01	187	1100	lab	25	500	0.008	0.29	0.32	30	0.004	0.03	<0.05	6.5	0.05	0.06
Moore River	Regans Ford	06-Dec-00	373	2,200	conv.sheet			<0.005	<0.005	0.24		<0.003	0.01	0.25	7.2		
Moore River	Regans Ford	07-Feb-01	340	2,000	lab	80	950	<0.005	<0.005	0.13	60	<0.003	0.01	<0.05	7.2	0.08	0.06
Moore River	Regans Ford	24-Feb-01	280	1,450	conv.sheet										6.5		
Moore River	Cowalla Bridge	21-Dec-00	354	1,880	conv.sheet	100	1000	0.005	<0.005	0.29	70	0.012	0.02	0.05	7.4	0.10	0.07
Moore River	Cowalla Bridge	07-Feb-01	325	1,710	conv.sheet	340	860	<0.005	<0.005	0.26	80	0.003	0.02	<0.05	7.8	0.40	0.09
Moore River	Cowalla Bridge	24-Feb-01	280	1,440	conv.sheet										7.7		
Moore River	Bennies Road	21-Dec-00	380	2,020	conv.sheet	110	1100	0.008	<0.005	0.31	75	0.01	0.01	0.05	8.1	0.10	0.07
Moore River	Bennies Road	07-Feb-01	340	1,700	lab	110	860	0.008	<0.005	0.31	65	<0.003	0.02	<0.05	8.3	0.13	0.08
Moore River	Bennies Road	24-Feb-01	300	1,560	conv.sheet										8.2		
Moore River	Waterville Road	04-Feb-99	218	1,200	field			0.0025	0.007	0.54		0.005	0.15		8.4		
Moore River	Waterville Road	03-Feb-00	623	3,420	field			0.007	0.53	1.2		0.0015	0.04		7.5		
Moore River	Waterville Road	21-Dec-00	291	1,570	field			0.0025	0.011	0.44		0.0015	0.01		8.8		
Moore River	Waterville Road	07-Feb-01	280	1,400	lab	160	630	0.06	0.024	0.9	50	<0.003	0.03	<0.05	7.5	0.25	0.08
Moore River	Waterville Road	24-Feb-01	214	1,100	conv.sheet										7.1		
Gingin Brook	Bookine Bookine Road	04-Feb-99	218	1,200	field			0.0025	0.022	0.64		0.1	0.27		7.8		
Gingin Brook	Bookine Bookine Road	03-Feb-00	174	880	field			0.013	0.055	0.51		0.15	0.18		7.3		
Gingin Brook	Bookine Bookine Road	21-Dec-00	131	690	field			0.008	0.023	0.37		0.13	0.13		8.3		
Gingin Brook	Bookine Bookine Road	24-Feb-01	130	680	field										7.8		
Gingin Brook	Gingin Road Bridge	07-Feb-01	n/a	810	lab	230	300	0.005	<0.005	0.4	<10	0.1	0.15	<0.05	8.1	0.77	

River	Site Name	Sample Date	Econd (Ms/m)	TDS (mg/l)	*TDS calculatn method	HCO3 (mg/l)	Cl (mg/l)	NH3-N	NOx-N or NO3-N (mg/l)	Total N	SO4-S (mg/l)	FRP or PO4-P (SOL) (mg/l)	Total P	Fe sol (mg/l)	pH	HCO3/Cl	SO4/Cl
Moore River	Lancelin Road	04-Feb-99	197	1,100	field			0.0025	0.13	0.62		0.02	0.19		8.1		
Moore River	Lancelin Road	03-Feb-00	554	3,000	field			0.018	0.5	1.1		0.008	0.05		7.5		
Moore River	Lancelin Road	21-Dec-00	173	920	field			0.016	0.14	0.47		0.037	0.05		8.4		
Moore River	Lancelin Road	07-Feb-01	170	940	lab	190	410	<0.005	0.089	0.38	20	0.013	0.06	<0.05	6.7	0.46	0.05
Moore River	Lancelin Road	24-Feb-01	100	510	conv.sheet										7.7		
Moore River	Caraban Rocks	04-Feb-99	172	900	field			0.0025	0.94	1.4		0.008	0.16		8.3		
Moore River	Caraban Rocks	03-Feb-00	537	2,890	field			0.031	0.73	1.4		0.012	0.05		7.6		
Moore River	Caraban Rocks	21-Dec-00	215	1,150	field			0.04	0.45	0.73		0.004	0.02		8.6		

*** TDS determination method:**
lab -laboratory method (by evaporation at 180 degrees C))
conv.sheet - WRC's conductivity to salinity conversion sheet (2001), using field EC and field temperature
field - field instrument, using EC & field temperature

APPENDIX VI

GROUNDWATER CHEMISTRY DATA

APPENDIX VI GROUNDWATER CHEMISTRY DATA
FROM BORES & SPRINGS ALONG THE MOORE & COONDEROO RIVERS

Name	Bore ID	Sample Date	Econd (mS/m)	TDS (mg/l)	HCO3 (mg/l)	Cl (mg/l)	NH3-N (mg/l)	NOx-N or NO3-N (mg/l)	Total N (mg/l)	SO4-S (mg/l)	FRP or PO4-P (sol) (mg/l)	Total P (mg/l)	Fe (sol)+ (mg/l)	ph	HCO3/Cl	SO4/Cl
AM2	61715001	Mar-76		1340	299	473	0.970	0.020		98		0.02	0.1	8.4	0.63	0.21
AM3	61715002	May-91	116	669	75			0.200		36			0.05	6.4		
AM5	61715008	Sep-86		1220	137	577	0.510	0.020		61		0.01	0.7	8.4	0.24	0.11
3/92 SP	2035-3-nw-61	Sep-00	88	469												
B270	2035-3-sw-0040	Nov-92					0.020	0.010						8.3		
B290	2035-3-sw-0042	Nov-92					0.080	0.030						8		
JP25	2035-3-nw-38	Feb-75	73	520	241	730		1.580		6			0.05	7.7	0.33	0.01
GA16	61710011	May-86		617	263	142	0.110	0.220		11			2.8	7.3	1.85	0.08
GA17	61710062	Feb-86		380		114	0.020	0.100		9		0.02		7.4		0.08
GA18	61710075	Apr-86		200	15	91	0.140	0.080		19		0.05	0.25	5.4	0.16	0.21
GA22	61710065	Jul-82		170	21	53	0.060	0.360		32		0.01	0.28	6.1	0.40	0.60
GA23	61710076	Mar-81		215	12	91	0.440	0.220		30		0.05	0.4	5.3	0.13	0.33
GA24	61710008	May-86		446	162	127	0.020	0.350		7			0.06	6.9	1.28	0.06
GA25	61710006	Jan-79		538	241	117	0.700	0.600		13		0.01	0.13	7.2	2.06	0.11
GA26	61710022	May-86		316	28	156	0.030	0.220		10			0.01	6.1	0.18	0.06
GA27	2035-3-nw-288	Jan-79		517	215	105	0.100	3.600		15		0.02	0.18	7.2	2.05	0.14
GA28	61710001	Jan-83		516	226	112	0.060	1.300		11		0.03	0.07	7.8	2.02	0.10
GA31	61710017	Jan-83		320	82	115	0.130	0.220		8		0.01	2.6	6.7	0.71	0.07
GB1	61710024	Jan-78		645	154	239	0.280	0.020		24		0.01	0.44	7	0.64	0.10
GB2	61710013	Apr-81		505	238	69	3.380			20		0.02	0.05	7.2	3.45	0.29
GB2	61710013	Apr-91	69	505	238	79	0.030	3.380		20		0.02	0.05	7.2	3.01	0.25
GB3	61710064	Apr-77		580		91								4.1		
GB4	61710074	Jun-82		425	70	152	0.020	8.100		23		0.01	0.05	6.5	0.46	0.15
GB5	61710079	Apr-81		566	67	267	0.160	0.020		24		0.02	3.2	6.2	0.25	0.09
GB7	61710066	Jun-82		305	76	76	0.310	1.500		40		0.03	0.16	6.5	1.00	0.53
GB8	61710086	Apr-77		170		53								4.3		

Name	Bore ID	Sample Date	Econd (mS/m)	TDS (mg/l)	HCO3 (mg/l)	Cl (mg/l)	NH3-N (mg/l)	NOx-N or NO3-N (mg/l)	Total N (mg/l)	SO4-S (mg/l)	FRP or PO4-P (sol) (mg/l)	Total P (mg/l)	Fe + sol (mg/l)	ph	HCO3/Cl	SO4/Cl
GB9	61710087	Nov-78		200	2	78	0.390	0.050		44		0.22	1.2	4	0.03	0.56
GB10	61710087	Dec-78		830	2	411	0.240	0.150		84		0.22	1.2	4.5	0.00	0.20
GB11	31710023	Apr-81		741	52	300	0.320	0.020		130		0.01	11	5.9	0.17	0.43
GB12	61710073	Jun-82		609	27	197	0.410	0.020		183		0.03	19	5.7	0.14	0.93
GB13	61710078	Jan-83		199	9	77	0.200	1.500		29		0.01	0.22	5.6	0.12	0.38
GB14	61710087	Nov-78		200	2	78	0.390	0.050		44		0.22	3.7	4.8	0.03	0.56
GB15	61710077	Apr-81		773	43	243	0.640	0.020		227		0.02	2.4	5.8	0.18	0.93
GB16	61710092	Apr-81		1260	24	632	0.480	0.070		165		0.08	70	4.9	0.04	0.26
GB17	61710062	Feb-86		380		114	0.020	0.100		9		0.02		7.4	0.00	0.08
GB18	61710075	Apr-86		200	15	91	0.140	0.080		19		0.05	0.25	5.4	0.16	0.21
GB21	61710089	Jan-83		190	2	81	0.370	0.030		33		0.01	0.38	4	0.02	0.41
GB22	6171006	Jan-79		530	241	117	0.700	0.600		13		0.01	0.13	7.2	2.06	0.11
GG8(1)	61710084	Dec-80		118	6	58	0.170	0.020		11		0.12	19	6.2	0.10	0.19
GG8(0)	61710085	Dec-80		250	24	116	0.480	0.020		9		0.04	2.4	5.2	0.21	0.08
King Brothers	2035-3-sw-0001	Jul-73						0.450						7.6		
YY8	61618122	Oct-79	56	390	128	103		0.220		3				8.3	1.24	0.03
YY10 (I)	2035-3-nw-31	Aug-73		610	217	82	0.140	0.220	0.360	19		0.01	0.05	7.5	2.65	0.23
YY10 (I)	2035-3-nw-31	Oct-80	109	709	210	336	0.170	0.220		22		0.02	1.5	7.6	0.63	0.07
YY10 (O)	2035-3-nw-32	Oct-80	57	300	24	146	0.050	0.440		17		0.01	0.08	5.9	0.16	0.12
S3A	1935-1-ne-30	Feb-80	290	1450	134	761		<1		67				7.4	0.18	0.09
3A	61730004	May-98	222	1140		579	0.197	0.004	0.291		0.095	0.10	0.42	7.3		
S4A	2035-4-nw-18	Feb-80	109	580	195	247		<1		2				7.7	0.79	0.01
4A	61730005	May-98	113	580		227	0.440	0.005	0.620		0.083	0.09	5.29	7.1		
4B	2035-4-nw-21	Oct-80	117	590	201	250		1.000		2				8.2	0.80	0.01
5A	2035-4-nw-14	May-98	34	180		76.3	0.270	0.004	0.420		0.047	0.06	1.92	6.6		
S5C	2035-4-nw-20	Nov-80	46.2	220									2.6	7		
5C	61730007	May-98	307	1610		75.3	0.253	0.005	0.404		0.007	0.01	10.1	6.7		
	2035-4-sw-32	Jun-85		740		825		1.000		18				7.7		0.02

Name	Bore ID	Sample Date	Econd (mS/m)	TDS (mg/l)	HCO3 (mg/l)	Cl (mg/l)	NH3-N (mg/l)	NOx-N or NO3-N (mg/l)	Total N (mg/l)	SO4-S (mg/l)	FRP or PO4-P (sol) (mg/l)	Total P (mg/l)	Fe + sol (mg/l)	ph	HCO3/Cl	SO4/Cl
S7A	1935-1-se-21	Aug-80	228	1140	238	516		1.000		59				7.5	0.46	0.11
7A	61730010	May-98	157	810		604	0.005	1.182	1.220		0.022	0.02	0.12	6.9		
S8A	2035-4-sw-35	Mar-80	325	1630	329											
8A	61730011	May-98	295	1530		816.6	0.005	0.840		0.076	0.078	2.97	7.1			
S8A	2035-4-sw-35	Jan-01	276	1300	260	590	0.007	0.310	0.680		0.017	0.06	<0.05	7.9	0.44	
9D	61730013	May-98	72.6	380		111	0.387	0.004	0.648		0.122	0.20	10.6 tot	7.3		
new bore	2035-4-sw-?	~1998		2000												
	2035-4-nw-22	Mar-86		500												
Alan Knight's shed bore	2035-4-nw-?	Feb-01		1200	250	470	0.550	<0.005	0.590	40	<0.003	0.08	<0.05	6.6	0.53	0.09
Alan Knight's garden bore	2035-4-nw-?	Feb-01		980	260	350	0.290	<0.005	0.320	70	0.003	0.08	<0.05	7.3	0.74	0.20
10A	61730014	May-98	165	850		444	0.168	0.006	0.304		0.012	0.02	0.51	5.7		
11A	61730028	May-98	274	1410		728	0.152	1.464	1.570		0.020	0.02	0.34	6.9		
S12A	2035-4-sw-36	Aug-80	136	730	205	295		<1		40				7.5	0.69	0.14
12A	61730016	May-98	157	800		335	0.260	0.009	0.350		0.026	0.04	5.96	7.2		
13A	61730017	May-98	101	520		201	0.353	0.006	0.450		0.091	0.10	5.78	7.2		
14A	2035-4-se-0042	Apr-80						0.450						7.9		
14A	61730019	May-98	103	530		195	0.445	0.004	0.610		0.106	0.11	1.92	7.2		
15A	61730020	May-98	150	770		351	0.064	0.008	0.081		0.047	0.05	2.3	6.3		
17A	61730021	Aug-80		860												
S18A	2035-4-sw-40	Mar-80	97	530	249	187		3.000		3				7.8	1.33	0.02
18A	61730022	May-98	109	560		211	0.250	0.005	0.340		0.069	0.07	3.61	7.1		
20A	61730025	May-98	188	960		485	0.386	0.007	0.440		0.076	0.08	3.74	6.3		
S21A	2035-4-ne-8	Mar-80	64	350	15	162		<1		41				7.1	0.09	0.25
21A	61730027	May-98	75	390		181	0.070	0.011	2.350		0.042	0.21	6.91	5.9		

Name	Bore ID	Sample Date	Econd (mS/m)	TDS (mg/l)	HCO3 (mg/l)	Cl (mg/l)	NH3-N (mg/l)	NOx-N or NO3-N (mg/l)	Total N (mg/l)	SO4-S (mg/l)	FRP or PO4-P (sol) (mg/l)	Total P (mg/l)	Fe + sol (mg/l)	ph	HCO3/Cl	SO4/Cl
S22	2035-3-nw-0039	May-76						1.800						7.4		
22A	61730029	May-98	65	340		67	0.005	7.720			0.015	0.01	0.08	7.2		
29 Millbank Ave		Apr-91		760	190	39		7.300					0.15	7.3	4.87	
CS22DA	2036-3-ne-17															
GL4W	2035-4-nw-13	Nov-81	190	1050	224	484		<1		35				7.8	0.46	0.07
KTB1	new bore Kallamar Estate: 5, Orange Springs Road	Jan-00	600	380	20	150		0.880		21			0.25	6.2	0.13	0.14
KTB2	Kallamar Estate	Jan-00	1400	900	25	410		<0.2		40			0.85	6.1	0.06	0.10
RF1	new bore Environmental Forest Farms	Aug-00	176	1056		509	0.020	2.000		31	<0.01		<0.1	5.1		0.06
RF1	EFF	Oct-00	157	524		164	0.020	2.100		14	0.320		0.06	5.46		0.09
SN11174	22& 23 Orange Springs Rd	Nov-00	90	500	24								0.7	5.6		
	22& 23 Orange Springs Rd	Apr-99	44	240	18								1	6		
	883, Woodbine Road	Apr-00	276	1610		790		0.440					0.2	6.3		
SN1371	2991, Woodbine Road	Apr-00	380	2350		1100		1.580					0.3	5.5		
GL5W	2035-4-ne-7	Aug-81	163	849	18	461		<1		44				7	0.04	0.10
SN12383	Lot 5, Moochamulla Rd	Aug-99		600												

Name	Bore ID	Sample Date	Econd (mS/m)	TDS (mg/l)	HCO3 (mg/l)	Cl (mg/l)	NH3-N (mg/l)	NOx-N or NO3-N (mg/l)	Total N (mg/l)	SO4-S (mg/l)	FRP or PO4-P (sol) (mg/l)	Total P (mg/l)	Fe + sol (mg/l)	ph	HCO3/Cl	SO4/Cl
	2036-3-se-15	?		5000												
	2036-3-se-28	?		1144												
GL6W	2036-3-se-18	Aug-81	98.2	551	70	250		<1		28				7.4	0.28	0.11
groundwater spring	Mogumber Mission	Feb-01	114	590												#DIV/0!
groundwater springs	Mogumber Road West	Jan-01	292	1500	5	740	0.110	0.021	1.900	25	0.006	0.13	13	5.5	0.01	0.03
Peter Detchon's bore	2 Orange Springs Road	Jan-01	42.5	250	15	110	0.520	0.020	1.300	<10	0.012	0.03	0.3	5.9	0.14	
	2036-2-sw-21															
	2036-2-sw-17			920												
GL7W	2035-1-NE-0027	Feb-86	145	760	58	378				40			0.1	7.6	0.15	0.11
	2035-1-ne-4			2145												
GL8W	2135-4-NW-0032	Dec-85	316	1720	37	905				128			0.2	7.3	0.04	0.14
Palms Park Spring	Palms Park Spring	Feb-01	275	1,500	65	720	0.061	<0.005	0.070	85	0.030	0.71	0.35	6.6	0.09	0.12
Sykes Rd		Dec-00	16.5	12,000			0.034	0.270	0.790		0.007	0.04	<0.05	7.2		
	2136-3-sw-21	?		4,300												
	2136-3-sw-25	?		2,100												
WG6																
BH4	2136-3-nw-4	Dec-00		530			0.590	0.220	2.500		0.010	0.14	0.32	7.6		
	2036-2-ne-29	?		1,484												
	2136-4-sw-80	?		3,815												

Name	Bore ID	Sample Date	Econd (mS/m)	TDS (mg/l)	HCO3 (mg/l)	Cl (mg/l)	NH3-N (mg/l)	NOx-N or NO3-N (mg/l)	Total N (mg/l)	SO4-S (mg/l)	FRP or PO4-P (sol) (mg/l)	Total P (mg/l)	Fe + sol (mg/l)	ph	HCO3/Cl	SO4/Cl
Ran Furly	new bore - deep	Dec-00	1900	19,000			<0.005	0.340	1.500		0.017	0.08	<0.05	6.9		
Ran Furly	new bore - shallow	Dec-00	>2000	27,000			0.710	0.017	4.200		0.013	0.44	0.45	6		
	2036-l-se-20	?		2,943												
	2036-1-se-26	?		5,550												
AgWA Moora	new bores: MO12OB	Oct-00	3680													
AgWA Moora	M013I	Oct-00	4340													
AgWA Moora	M013OB	Oct-00	3320													
AgWA Moora	MO14OB	Oct-00	4770													
AgWA Moora	M015D1	Oct-00	2850													
AgWA Moora	MO15I	Oct-00	3820													
AgWA Moora	MO15OB	Oct-00	2980													
	2036-1-ne-29	?	3,321													
	2036-1-ne-14	?		735												
	2136-4-nw-11	?		8,604												
	2136-4-nw-42	?		2,028												
	2136-4-nw-40	?		3,430												
	2037-2-se-6	?		378												
	2037-2-ne-4	?		279												
	2037-2-ne-3	?		331												

Name	Bore ID	Sample Date	Econd (mS/m)	TDS (mg/l)	HCO3 (mg/l)	Cl (mg/l)	NH3-N (mg/l)	NOx-N or NO3-N (mg/l)	Total N (mg/l)	SO4-S (mg/l)	FRP or PO4-P (sol) (mg/l)	Total P (mg/l)	Fe + sol (mg/l)	ph	HCO3/Cl	SO4/Cl
	2037-2-ne-7	?		900												
YRE1S	2037-1-NE-22	Mar-99	200	12,000	100	7,200		<0.2		1,400			0.1	7.6	0.01	0.19
YRD3S	2037-1-NE-18	Mar-99	640	38,000	240	18,000		0.400		2,600			<0.5	10.4	0.01	0.14
YRC2S	2038-2-se-29	Mar-99	880	53,000	210	26,000		<0.2		3,500			<0.5	7.6	0.01	0.13
YRB1S	2038-2-nw-29	Apr-99	1100	66,000	240	33,000		4.000		2,600			4.3	7.8	0.01	0.08
YRA2S	2038-2-nw-27	Mar-99	740	44,000	230	24,000		0.400		1700			2.4	7.5	0.01	0.07

Notes

Fe (sol)+ - Iron concentrations for the Salvado bores are totals, not soluble iron.

APPENDIX VII

GROUNDWATER NUTRIENT DATA FROM SOUTH OF GINGIN BROOK

APPENDIX VII

GROUNDWATER NUTRIENT DATA FROM SOUTH OF THE GINGIN BROOK

	SiteID	Easting	Northing	Owner	SiteID	Sample Date	Laboratory	Sample Method	NH3-N / NH4-N (Sol) mg/L	NO3 (Sol) mg/L	NO3-N (Sol) mg/L	P (persulphate Tot) mg/L	P (Reactive Tot) mg/L	pH	SiO2 (Reactive Sol) mg/L
1	1935-2-NE-0005	357191	6530616	MR MURRAY	1935-2-NE-0005		Unknown	Unknown						7.1	
2	1935-2-NE-0006	357160	6531727	GUILDETON WATER SUPPLY	1935-2-NE-0006		Unknown	Unknown						7.4	
3	2035-3-NE-0014	372973	6533836	D R JONES	2035-3-NE-0014	27/06/1973	Chemistry Centre WA (pre1993)	Unknown		1				8	22
4	2035-3-NE-0046	371920	6540769	GSWA	2035-3-NE-0046	29/04/1980	Chemistry Centre WA (pre1993)	Air Lift		1				7.7	22
5	2035-3-NE-0047	371920	6540767	GSWA	2035-3-NE-0047	24/10/1980	Chemistry Centre WA (pre1993)	Pump Test						7.3	
6	2035-3-NE-0047	371920	6540767	GSWA	2035-3-NE-0047	24/10/1980	Chemistry Centre WA (pre1993)	Pump Test		1				7.9	22
7	2035-3-NE-0052	378029	6534947	D I & R SMITH	2035-3-NE-0052		Unknown	Unknown						7.1	
8	2035-3-NW-0012	361902	6533926		2035-3-NW-0012	17/12/1965	Chemistry Centre WA (pre1993)	Unknown						6.9	18
9	2035-3-NW-0012	361902	6533926		2035-3-NW-0012	11/02/1966	Chemistry Centre WA (pre1993)	Unknown		1				7.8	14
10	2035-3-NW-0012	361902	6533926		2035-3-NW-0012	29/10/1965	Chemistry Centre WA (pre1993)	Unknown						8.4	
11	2035-3-NW-0013	367251	6535615	GSWA	2035-3-NW-0013	15/06/1966	Chemistry Centre WA (pre1993)	Unknown		1				6.9	9
12	2035-3-NW-0013	367251	6535615		2035-3-NW-0013	13/07/1966	Chemistry Centre WA (pre1993)	Unknown		1				7.4	2
13	2035-3-NW-0013	367251	6535615		2035-3-NW-0013	05/08/1966	Chemistry Centre WA (pre1993)	Unknown		1				8	4
14	2035-3-NW-0013	367251	6535615		2035-3-NW-0013	01/06/1966	Chemistry Centre WA (pre1993)	Unknown						8.4	
15	2035-3-NW-0013	367251	6535615		2035-3-NW-0013	03/06/1966	Chemistry Centre WA (pre1993)	Unknown						8.6	
16	2035-3-NW-0016	358234	6530636		2035-3-NW-0016		Unknown	Unknown						7.1	
17	2035-3-NW-0017	357766	6530574	GINGIN COUNCIL	2035-3-NW-0017		Unknown	Unknown						7.6	
18	2035-3-NW-0027	367582	6532877	CROOT "WARRADALE PTY LTD"	2035-3-NW-0027		Unknown	Unknown						7.5	
19	2035-3-NW-0031	366990	6535346		2035-3-NW-0031		Unknown	Unknown						7.5	
20	2035-3-NW-0038	362217	6530538	GSWA	2035-3-NW-0038	06/02/1975	Chemistry Centre WA (pre1993)	Unknown		7				7.7	13
21	2035-3-NW-0039	359916	6533420	GOVT	2035-3-NW-0039	01/05/1976	Chemistry Centre WA (pre1993)	Air Lift		8				7.4	
22	2035-3-NW-0044	366752	6529994	MET WATER BOARD	2035-3-NW-0044	09/03/1976	Chemistry Centre WA (pre1993)	Pump Test						7.8	
23	2035-3-NW-0044	366752	6529994	MET WATER BOARD	2035-3-NW-0044	05/03/1976	Chemistry Centre WA (pre1993)	Pump Test						8	
24	2035-3-NW-0044	366752	6529994	MET WATER BOARD	2035-3-NW-0044	09/01/1976	Chemistry Centre WA (pre1993)	Air Lift		1				8.2	26
25	2035-3-NW-0044	366752	6529994	MET WATER BOARD	2035-3-NW-0044	04/03/1976	Chemistry Centre WA (pre1993)	Air Free	0.97	1	0.02		0.02	8.4	5
26	2035-3-NW-0062	367548	6532063	SUN CITY FARMS	2035-3-NW-0062		Unknown	Unknown						6.9	
27	2035-3-SE-0019	375643	6527891	MET WATER BOARD	2035-3-SE-0019	15/09/1989	Chemistry Centre WA (pre1993)	Unknown		1				7.8	12
28	2035-3-SE-0019	375643	6527891	MET WATER BOARD	2035-3-SE-0019	15/09/1989	Chemistry Centre WA (pre1993)	Unknown		1				7.9	16
29	2035-3-SE-0019	375643	6527891	MET WATER BOARD	2035-3-SE-0019	28/03/1977	Chemistry Centre WA (pre1993)	Unknown						9.1	
30	2035-3-SE-0019	375643	6527891	MET WATER BOARD	2035-3-SE-0019	22/06/1978	Chemistry Centre WA (pre1993)	Bailer						10.5	
31	2035-3-SW-0001	363731	6525323	KING BROTHERS	2035-3-SW-0001	04/07/1973	Chemistry Centre WA (pre1993)	Unknown		2				7.6	10
32	2035-3-SW-0040	367587	6524518	WAWA	2035-3-SW-0040	18/11/1992	Chemistry Centre WA (pre1993)	Submersible	0.02	1	0.03	0.01		7.4	13
33	2035-3-SW-0040	367587	6524518	WAWA	2035-3-SW-0040	18/11/1992	Chemistry Centre WA (pre1993)	Submersible	0.02	1	0.12	0.01		7.4	11
34	2035-3-SW-0040	367587	6524518	WAWA	2035-3-SW-0040	18/11/1992	Chemistry Centre WA (pre1993)	Submersible	0.02	1	0.11	0.01		8.3	13
35	2035-3-SW-0042	367252	6526825	WAWA	2035-3-SW-0042	17/11/1992	Chemistry Centre WA (pre1993)	Submersible	0.02	1	0.08	0.01		7.7	15
36	2035-3-SW-0042	367252	6526825	WAWA	2035-3-SW-0042	17/11/1992	Chemistry Centre WA (pre1993)	Submersible	0.08	1	0.03	0.03		8	12
37	2035-4-SE-0020	372307	6546218	GSWA	2035-4-SE-0020	30/04/1980	Chemistry Centre WA (pre1993)	Air Lift		2				7.9	25
38	2035-4-SW-0040	366196	6542399	GSWA	2035-4-SW-0040	20/03/1980	Chemistry Centre WA (pre1993)	Air Lift		1				7.8	2

For further nutrient data see also SED/groundwater/HY25042/25042034.xls

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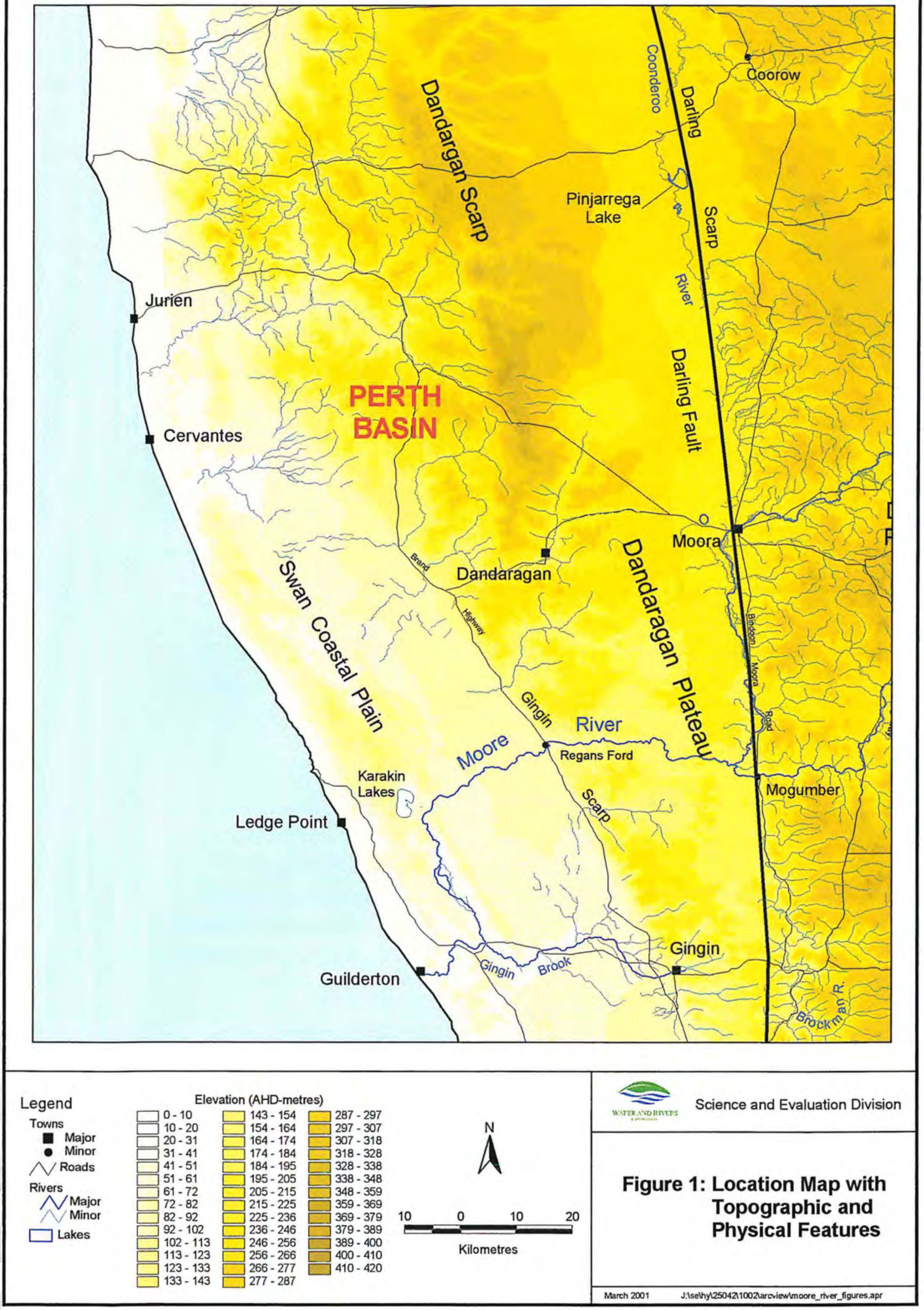

Science and Evaluation Division

Figure 1: Location Map with Topographic and Physical Features

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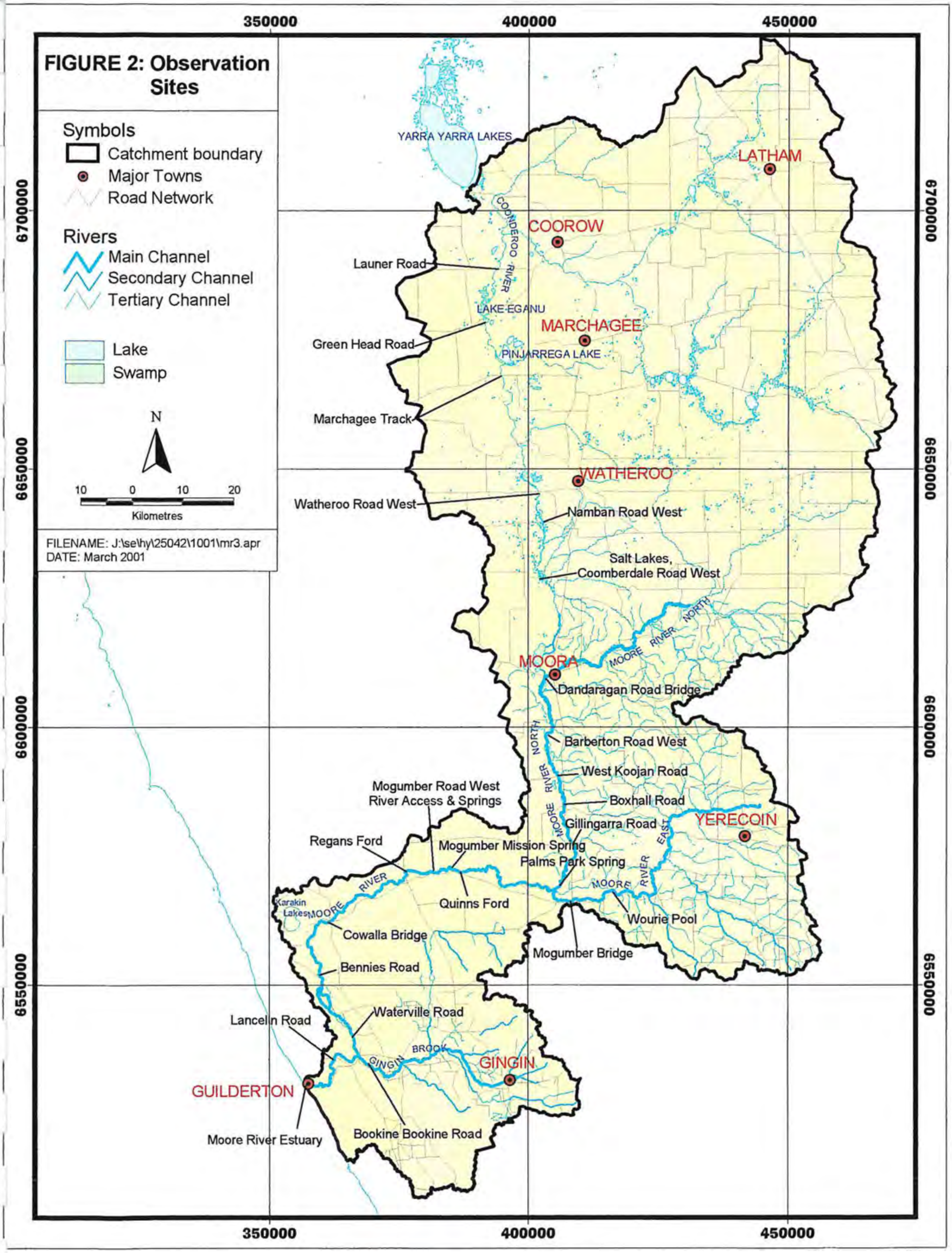
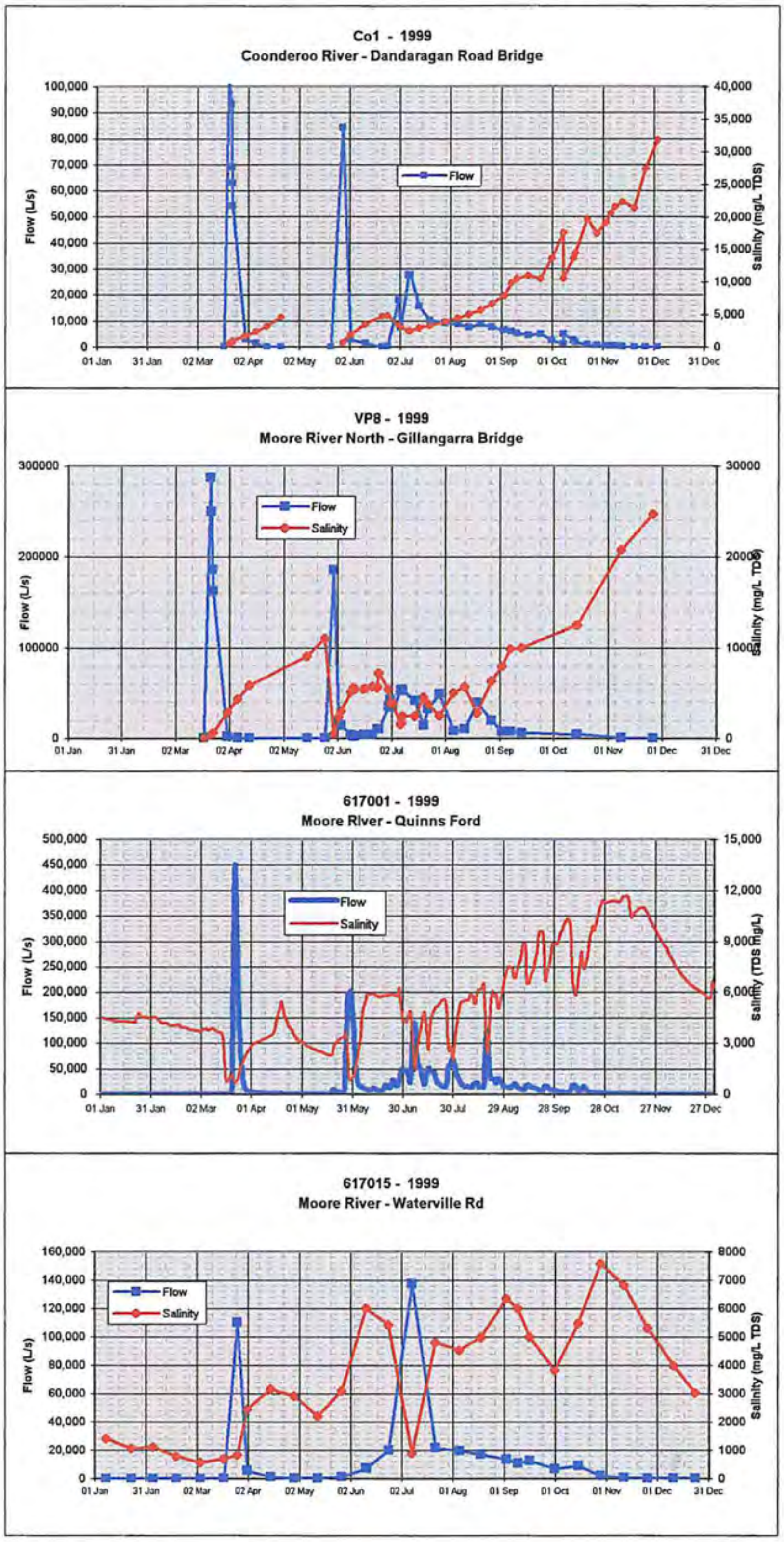


FIGURE 2: Observation Sites
Symbols
Catchment boundary
Major Towns
Road Network
Rivers
Main Channel
Secondary Channel
Tertiary Channel
Lake
Swamp
N
10 0 10 20
Kilometres
FILENAME: J:\se\hy\25042\1001\mr3.apr
DATE: March 2001
350000
400000
450000
6700000
6650000
6600000
6550000
YARRA YARRA LAKES
LATHAM
COOROW
CONDEROO RIVER
Launer Road
LAKE EGANU
MARCHAGEE
Green Head Road
PINJARREGA LAKE
Marchagee Track
WATHEROO
Watheroo Road West
Namban Road West
Salt Lakes, Coomberdale Road West
MOORE RIVER NORTH
MOORA
Dandaragan Road Bridge
Barberton Road West
West Koojan Road
Boxhall Road
Gillingarra Road
YERECOIN
MOORE RIVER EAST
Mogumber Road West River Access & Springs
Regans Ford
Mogumber Mission Spring
Palms Park Spring
MOORE RIVER
Quinns Ford
Karakin Lakes
Cowalla Bridge
Wourie Pool
Mogumber Bridge
Bennies Road
Waterville Road
Lancelin Road
GINGIN BROOK
GINGIN
GUILDERTON
Moore River Estuary
Bookine Bookine Road

Figure 3: Flows & Salinities in the Moore River during 1999

(From Peter Muirden, WRC, 2000)



For site locations see Figure 2. FILE: J:\se\hy\25042\1002\etc\25042025.xls DATE: March 2001