BREMER RIVER AND DEVILS CREEK
RIVER ACTION PLAN

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Bremer River and Devils Creek River Action Plan

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This report is dedicated to Athol Jury

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How to use this report

This report was prepared for the Water and Rivers Commission, community groups and the landholders from the Bremer River Catchment.

Section 1 provides introductory information on the river and the foreshore condition survey. Section 2 describes the natural resources, heritage and land tenure within the catchment. Section 3 is divided into river and estuarine information. Section 4 details the foreshore condition survey results and identifies the management issues faced by the landholders. Management recommendations are provided. Detailed information on foreshore condition and fencing status and corresponding maps are included. Section 5 includes case studies and historical stories from oral transcipts.

Map 1 uses colour codes to show the foreshore condition of the main channel of the Bremer River and Devils Creek (inside front cover pocket). Map 2 shows the area in 12 locations that are individually detailed in 12 map sheets. Each sheet details the foreshore condition and illustrates the existing and proposed works of the landholders in response to waterways management (Section 4).

Abbreviations

AgWA	Agriculture Western Australia
CALM	Department of Conservation and Land Management
FBR	Fitzgerald Biosphere Reserve
FRNP	Fitzgerald River National Park
JLCDC	Jerramungup Land Conservation District Committee
MYBP	million years before present
NHT	Natural Heritage Trust
RAP	The South Coast Regional Assessment Panel
SCRIPT	The South Coast Regional Initiative Planning Team
UNESCO	United Nations Education, Scientific and Cultural Organisation
WRC	Water and Rivers Commission
RVPS	Remnant Vegetation Protection Scheme

Summary

The Bremer River is situated in the South Coast Region of Western Australia, approximately 165 kilometres east of the City of Albany (see Figure 1). It is in the Fitzgerald Biosphere sub-region, an internationally recognised area of significant heritage and environmental value.

The Bremer River is the major tributary draining into the Wellstead Estuary, and is approximately 70 kilometres in length. The river flows through cleared agricultural land before meandering through the Fitzgerald River National Park and draining into the Wellstead Estuary. A sandbar divides the estuary from the Southern Ocean.

The Wellstead Estuary lies on the southern side of the town of Bremer Bay, a popular holiday destination. The estuary is used by the Bremer Bay community and tourists for recreation and provides a unique estuarine habitat. The estuary retains extensive fringing vegetation, relatively undisturbed by humans, and lies within a nature reserve and the Fitzgerald River National Park.

The Bremer River Catchment covers an area of 716 km², and is made up of the Carlawillup, Devils Creek and Bremer River sub-catchments. The area was opened up for clearing in the 1950s as part of the War Service Land Settlement Scheme. About 50% of the catchment was cleared by 1968 and 80% by 1984 (Hodgkin and Clark, 1987).

The aim of the Foreshore Condition Survey was to provide the Water and Rivers Commission, community groups, Landcare groups and the landholders' with information on the condition of the Bremer River and Devils Creek so that these waterways can be better managed. The survey was conducted in October 1999 using the 'Foreshore Condition Assessment and Survey Technique' developed by Dr Luke Pen and Margaret Scott, 1995 (Pen and Scott).

The survey showed that some sections of the river were in A grade condition and almost 80% had been fenced. Seventy-six percent of Devils Creek has also been fenced, however landholders planned to complete a further 12% in 2000/2001. Overall the survey showed that landholders have long-term plans to fence nearly the entire Bremer River and Devils Creek.

The landowners and the survey identified sedimentation, erosion, salinity and loss of riparian vegetation as significant management issues. Weed invasion is also a threat to the biodiversity and environmental value of the riparian vegetation.

Landholders have protected and restored some areas of the river foreshores by fencing and revegetating. They also plan to undertake considerable works to protect waterways in the catchment.

The report and the associated maps provide detailed information on the Foreshore Condition of the Bremer River and Devils Creek. The recommendations mostly reflect the future plans of the landowners. Time and funding are the key to restoration work. The Water and Rivers Commission is providing some financial assistance to fence the priority areas.

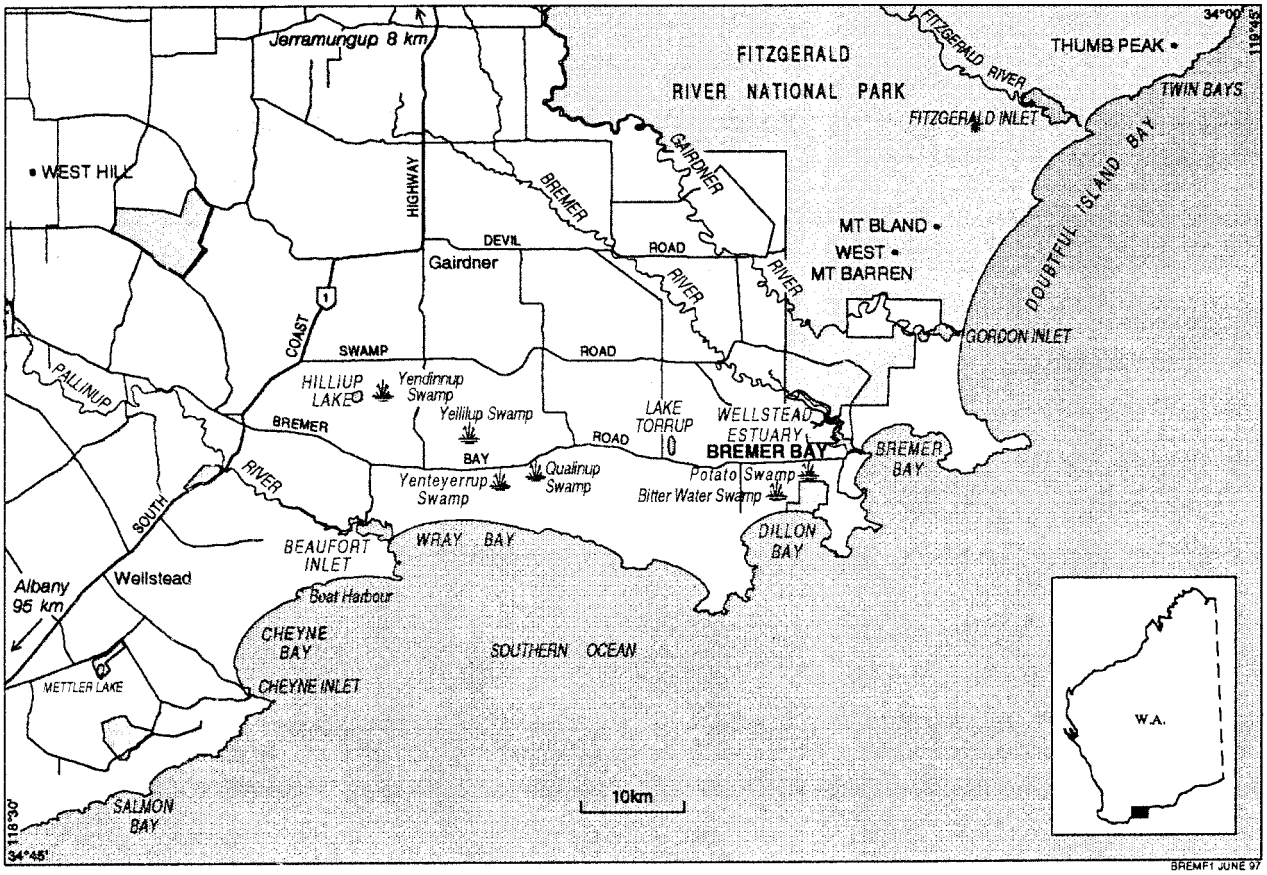


Figure 1. The Bremer River catchment

1. Introduction

The issue

Many Western Australian rivers are becoming degraded as a result of human activity within and along waterways and through the off-site effects of catchment and land uses. The erosion of foreshores and invasion of weeds and feral animals are some of the more pressing problems. Water quality in our rivers is declining with many carrying excessive loads of nutrients and sediment and in some cases contaminated with synthetic chemicals and other pollutants (WRC, 1999).

The Water and Rivers Commission (WRC) is responsible for coordinating the management of the state's waterways. The WRC, in partnership with local community groups, developed the project titled "Development and Implementation of Local River Action Plans" funded by the National Heritage Trust. A component of this project is to conduct foreshore surveys on priority waterways in the South Coast Region.

Aim

The aim of the Foreshore Condition Survey was to provide the Water and Rivers Commission, community groups, Landcare groups and the landholders' with information on the condition of the Bremer River and Devils Creek so that these waterways can be better managed.

Objectives

The objectives of the project were to:

(i) provide a benchmark for future work to protect and rehabilitate the Bremer River and Devils Creek;

(ii) provide a management tool to improve the use of limited resources; and

(iii) provide a sound technical basis for future funding and/or project submissions.

The study area

The study area includes the main channel of the Bremer River and its tributary - Devils Creek. Map 1 shows the Bremer River and Devils Creek, and the associated catchments, Carlawillup, Devils Creek and Bremer River. The river begins approximately 5 kilometres south of Jerramungup on Kent Location 1288 and flows in a southeasterly direction towards the coast. Eighty per cent of the 716 square kilometres-catchment is cleared (RAP and SCRIPT[1], 1997). The upper and middle reaches are in agricultural areas while the lower river meanders through the Fitzgerald River National Park (FRNP) and eventually enters the Wellstead Estuary. A sandbar divides the estuary and the Southern Ocean. The survey was conducted on the River, in the cleared portion of the catchment, with the assumption that the condition of the vegetation in the Fitzgerald River National Park would be pristine (A grade).

The focus area of the study was the main channel of the Bremer River and the main tributary, Devils Creek. The survey covered the channel embankments, floodplain, riparian zone and adjacent landuse to the main channel of the waterways. The study area encompassed 23 landowners who are engaged in agricultural production. A small granite mine operates adjacent to the Bremer River.

Background

The Bremer River is important in context of the Wellstead Estuary and its importance to Bremer Bay. The town of Bremer Bay is a popular holiday and tourist destination, particularly in summer. The Wellstead Estuary provides holidaymakers with recreational opportunities including fishing, canoeing or boating and an aesthetically pleasing backdrop to the Bremer Bay townsite.

[1] *RAP (The South Coast Regional Assessment Panel) SCRIPT (The South Coast Regional Initiative Planning Team)*

There is concern that the estuary is showing signs of nutrient enrichment as algae species such as chaetomorpha and enteromorpha are found more extensively throughout the estuary, and also the mamacrophyte Pappia.

Other estuary management issues were identified by Hodgkin and Clark (Hodgkin and Clark, 1987). These included the gradual shallowing of the estuary and a possible accelerated rate of sedimentation. In summer when the bar is closed and there is no river flow to replace evaporative loss, the water level drops, areas of decaying weed become exposed and it can become difficult to launch boats near the town. When this happens the Shire of Jerramungup opens the sandbar to encourage the system to flush. This maintains a relatively constant water level and prevents the estuary from becoming hypersaline (Hodgkin and Clark, 1987).

It is not known whether runoff from agricultural land is negatively impacting on the river and its estuary from an increased rate of sedimentation and/or an increase in nutrient loads. However, the environmental value of the river and the estuary need to be protected. Anecdotal observations from landowners in the Bremer River catchment indicate that the naturally saline river has become more saline since clearing in the 1950s and that algae in the estuary has increased.

The Bremer River Foreshore Condition Survey forms part of the 'Development and Implementation of Local River Action Plans' project. This project was developed by the Water and Rivers Commission in partnership with local community groups and was funded by the Natural Heritage Trust. The work aims to improve the condition of foreshore areas by reducing the likelihood of erosion and subsequent transportation of sediments and nutrients downstream into the Wellstead Estuary. Considerable on-ground work has been done in the Bremer River catchment and the survey identifies where this work has been undertaken and future priority areas.

Previous work within the Bremer River catchment has included a part survey of the Carlawillup sub-catchment and a catchment plan for the South West Bay catchment. In addition, funds have been allocated to fence and protect waterways in both these sub-catchments in accordance with the foreshore surveys. Demonstration sites have also been established in the South West Bay catchment. Other studies titled 'A Physical and Floristic Survey of Native Vegetation Remnants in the Bremer River Catchment' by Martin Heller and Nadine Brown have been published (Heller and Brown, 1996). Martin Heller also compiled information in a publication titled 'Fauna of the Bremer River Catchment' (Heller, 1996). In June 1987, Ernest P. Hodgkin and Ruth Clark studied the Wellstead Estuary, the estuary of the Bremer River (Hodgkin and Clark, 1987). This inventory was produced as part of the Environmental Protection Authority's Estuarine studies series.

The Water and Rivers Commission identified the Bremer River as a priority waterway in 1998. It was selected on several criteria including environmental condition of the waterway, environmental significance of the waterway, the ability to make changes, community benefits of protecting the waterway and the activity levels of groups within the catchment.

The Bremer River has a broad vegetated corridor along its main channel, which contributes to the environmental values of the river. Upper parts of the river flow predominantly through farming country before passing through the Fitzgerald River National Park (FRNP) and draining into the Wellstead Estuary, near Bremer Bay. The Wellstead Estuary has considerable recreational value due to its proximity to the Bremer Bay townsite and has significant habitat values due to its extensive fringing vegetation. The Estuary also does not appear to be seriously eutrophic. Upstream tributaries are showing signs of degradation, with evidence of erosion, salinity, sedimentation of river pools and loss of fringing vegetation. The survey identifies these areas and the WRC offered grant assistance for protection and restoration work.

[2] *United Nations Education, Scientific and Cultural Organisation*

Description of the area

The Bremer River and Devils Creek are on the South Coast of Western Australia and in the Fitzgerald Biosphere sub-region. The Fitzgerald Biosphere is the largest of six sub-regions on the South Coast of Western Australia and is an internationally recognised area of significant heritage and environmental value. The Fitzgerald Biosphere Reserve (FBR) is named after the Fitzgerald River National Park and is recognised as an international biosphere reserve under UNESCOs[2] Man and the Biosphere Program.

A Biosphere Reserve is an area dedicated to helping discover how people and nature can flourish together. Each Biosphere Reserve must contain a Core Zone—a biologically rich area where plants and animals can exist and evolve largely undisturbed by people. The Fitzgerald River National Park forms the biologically rich Core Zone for this Biosphere. Adjoining or surrounding the Core Zone is a Buffer Zone where land uses and activities are managed to help protect the core. Nature reserves, public lands and wildlife corridors form a patchwork Buffer Zone around the Fitzgerald River National Park. The outermost area, the Zone of Cooperation, is the surrounding communities and farmland, an area where landowners, communities, researchers, and government agencies work together to find ways to use the environment without degrading it (Fitzgerald Biosphere Reserve Brochure). The Bremer River Foreshore Survey was carried out in this Zone of Cooperation.

The Fitzgerald River National Park is the focal point of the area and was gazetted in 1972. In 1978 the FRNP was accepted as an International Biosphere Reserve by UNESCO. The FRNP has approximately 1 883 plant taxa and new species are being discovered each year adding to the considerable biodiversity of the area. The south-west of Western Australia has approximately 8 000 plant taxa with the FRNP having almost a quarter (23%) of the South West's flora (Newbey updated by McQuoid, 1997). The area is also a significant plant endemism and about 72 taxa do not grow anywhere else in the world. Most of these plants grow on the quartzite range system, although other important landforms for endemism are the incised river valleys, associated breakaways and marine plain (Newbey updated by McQuoid, 1997).

Two towns and one locality are in close proximity to the Bremer River and Devils Creek. The coastal town of Bremer Bay overlooks the Wellstead Estuary, the estuarine section of the Bremer River. Jerramungup, the largest town in the Shire of Jerramungup, is approximately 5 kilometres north of the starting point of the river, and the locality of Gairdner is in the fork of Devils Creek where tributaries start.

The values of fringing vegetation

Fringing vegetation is important for streambank stabilisation, soil conservation, sediment and nutrient retention and the ecology of the environment. These values have been identified (Pen 1994) and are described below.

Streambank stabilisation and soil conservation

The soils of the natural stream valley support a varied flora of trees, shrubs, sedges and herbs. In turn, the vegetation supports the stream bank and protects it from erosion and subsidence. It does this in a number of ways. Firstly, fringing vegetation increases stream bank roughness which acts to dissipate the energy of running water reducing the erosive capacity of the stream flow (Troeh *et al.*, 1980).

Secondly, roots and rhizomes bind and reinforce the embankment soil. The large roots of trees anchor the embankment and the smaller roots and rhizomes of shrubs, sedges and grasses hold the soil firmly at the surface between the large tree roots. In fact, the soil root matrix can add extra cohesion of the order of ten times that of an unvegetated embankment (Thorne, 1990).

The roots and rhizomes also act to loosen and break up the soil which enables the rapid infiltration of rainwater (Riding and Carter, 1992). This infiltration and the extraction of water by the plants causes the bank to be drier than a similar unvegetated bank. In wet weather, this means that the embankment is less likely to become saturated with water, and thus is less prone to mass failure, such as subsidence and toppling caused by the added bulk weight of the water (Thorne, 1990).

Lastly, riparian vegetation is highly resilient, exhibiting quick regeneration and recolonisation following severe floods. In this way the vegetation helps stabilise the river system against the effects of severe erosion and sedimentation (DeBano and Schmidt, 1990).

Ecological values

Streamline vegetation has natural resource value and provides a range of habitats for a large variety of plants and animals, particularly species, which are restricted to moist or aquatic environments, or species that are restricted to particular rivers or streams. For example, the freshwater streams along the south coast provide one of the few breeding environments for the Pouched lamprey, (Geotria australis) and some of the freshwater streams along the Leeuwin Naturaliste Ridge are the only known habitat for the rare snail, *Austroassiminea letha*.

Furthermore, as stream systems are linear in form and cover long distances, their vegetation helps to create ecological corridors. These natural corridors, along with unnatural ones such as vegetated strips planted along road and rail reserves, enable plant and animal species to move between larger patches of remnant habitat (Hussey *et al*., 1989).

Sediment and nutrient retention

Ongoing international research increasingly highlights the important function that riparian zone vegetation has in filtering sediment and nutrients carried in flowing waters. Work on vegetated buffer strips along waterways or between waterways and agricultural land has shown that vegetation of many forms, including grasslands, sedgelands, woodlands and forests, can filter and retain substantial amounts of sediment and nutrients (Knauer and Mander, 1989). Dissolved nutrient, especially nitrate, are readily taken up and assimilated by plants (Pinay *et al.*, 1990).

By reducing stream flow, riparian vegetation promotes sediment deposition (Thorne, 1990). Sand can be deposited even where water is fast moving and silt will settle out where vegetation causes a marked reduction in flow. However, near-still water, such as that caught in densely vegetated floodplains, is required for the deposition of the very fine clay fractions (Troeh *et al.,* 1980). Over time, substantial stream bank and floodplain accretion can occur in certain areas as a result of sediment deposition, and this can alter hydrological processes (Thorne, 1990). The removal of suspended sediment by vegetation is especially important. Water carrying sediment has a greater momentum and is more abrasive than clean water, and therefore has an increased ability to cause erosion (Troeh *et al.*, 1980).

Much of the nutrient trapped in the vegetation of waterways or in buffer strips is assimilated by the vegetation. Generally, the longer the water is held by the vegetation, the greater the uptake of nutrients (Howard-Williams and Downes, 1986). The nutrients are eventually released back into the water column when plant material decays but much of this will once again be assimilated. In this way, the riparian system retards the rate of transfer of nutrient particles downstream, in a process known as nutrient spiralling (Pinay *et al.,* 1990).

Nitrogen can be removed from riparian systems completely. This occurs via the biochemical process of denitrification, which causes nitrate to be converted to gaseous nitrogen. This process can be the major form of removal in certain riparian zones and during particular environmental conditions such as those which occur during and after flooding (Pinay *et al.*, 1990).

Recreational and landscape value

The Bremer River and the Wellstead Estuary have important recreational and landscape values. The estuary is used throughout the year for canoeing, boating and fishing by the local residents and tourists and it provides an aesthetically pleasing background to the townsite of Bremer Bay. The picturesque river meanders through farmland and has numerous pools that are present all year round. These pools provide a valuable environment for wildlife including waterbirds, reptiles and aquatic organisms.

2. Catchment information

Catchment

A catchment is recognised as the most appropriate level on which to base management of the environment because it is a natural landscape feature that influences much of the activity within its boundaries. A catchment is a drainage area bounded by the highest points in a landscape from which all runoff water flows to a common low point.

The Bremer River catchment covers an area of 716 square kilometres and includes three sub-catchments: Carlawillup, Devils Creek and Bremer River. The catchment supports a wide range of landuses including agriculture, granite mining, nature conservation, tourism and recreation. The cleared land is used primarily for agriculture which incorporates sheep, cattle and cropping, and is the main industry in the Shire of Jerramungup (RAP and SCRIPT, 1997). A granite mine, located on 100 ha of land adjacent to the Bremer River in the Carlawillup sub-catchment, is the only industry of its kind in the Shire.

The unique flora and fauna of the region is conserved in the Fitzgerald River National Park which provides tourism, nature conservation and recreation opportunities. The Bremer River and Wellstead Estuary also provide recreational value for bushwalking, hiking, bird watching, canoeing, boating, and fishing.

Community

There are three distinct communities in the catchment: Jerramungup, Gairdner and Bremer Bay.

Jerramungup

The Jerramungup townsite is not located within the Bremer River catchment boundaries but is only 5 km north-northwest. Jerramungup is the largest town within the Shire of Jerramungup and has Shire Offices, a District High School and Medical Centre.

Gairdner

The locality of Gairdner has a primary school, community hall, dam and refuse disposal site and a sporting ground. Corporate Bulk Handling has a 'grain receival point' in the upper area of the Devils Creek sub-catchment.

Bremer Bay

Bremer Bay is the townsite located at the southern end of the catchment. The townsite overlooks the Wellstead Estuary, situated on the south western bank of the estuary. Bremer Bay is a popular holiday destination, particularly in summer. Its drawcard is the clear, blue ocean waters and white, sandy beaches that attracts holiday pursuits including whale watching, wild flowers, fishing, boating, adventure sports and general relaxation.

Context

The land within the Bremer River catchment is managed by landowners, who are mainly involved in agriculture, and CALM, who oversee the maintenance of the Fitzgerald River National Park. Carlawillup Reserve, a small portion of public land, is located at the Carlawillup Rockhole on Carlawillup Road. This significant heritage site is important because it was once an Aboriginal dancing ground and ceremonial meeting place and was also used as a watering hole for sheep by the Hassells who were the first pastoralists in Jerramungup.

The landowners are concerned with the protection and restoration of the Bremer River and its tributary, Devils Creek, primarily because mismanagement can negatively impact on the agricultural productivity of the land. This is apparent on some properties where salinity and erosion are encroaching on the farmland as a direct result of the past practice of removing riparian vegetation. Most landowners, who haven't already, would like to fence out the Bremer River and Devils Creek but concerns over conditions, covenants and ownership, as well as farm priorities, expense, time and the disruption to paddocks and existing fences hinder restoration work.

It is important for landholders to work as a group when addressing natural resource management issues. Proactively working together is essential as land degradation issues do not stop at the neighbour's boundary. A Catchment group is therefore more likely to attract assistance and funding than individual landowners.

Physiography

The upper reaches of the Bremer River (north of Devils Creek Road) flow through a dissected plateau of hard Archaean granitic rock, capped by sandplain that rises from 20 to 100 metres above sea level. The sandplain soils are generally sands with some lateritic gravels overlying dense mottled clays, waterlogged in the wetter winters and with little or only sluggish runoff. In its lower reaches the river meanders in a narrow, deeply dissected valley with steep escarpments exposing the weathered country rocks, mostly the softer, flat-bedded Pallinup Siltstone (tertiary marine sediments of the Plantagenet Group). These sandplains and the clayey slopes below them, would provide the main source of fine-textured sediments within the catchment (Hodgkin and Clark, 1987).

Geology

The basement rocks consist of Archaean granite and gneiss of the Yilgarn Craton (3800 MYBP[3]), and Proterozoic gneiss and metasedimentary rocks of the Albany-Fraser Orogen that developed between 1.8 and 1.1 billion years ago. These rocks are partly covered by Cainozoic era (65 MYBP) sedimentary rocks and a well-developed regolith. Isolated basement highs form monadnocks that protrude through the sediments or lie just below the surface (Dodson, 1997).

The Archaean rocks of the Yilgarn Craton are intruded by numerous sub-vertical sheet-like intrusions called dykes. This east-west series of dolerite dykes, known as the Gnowangerup Dyke Suite, has intruded the Archaean rocks to the north of the contact with the Albany-Fraser Orogen (RAP and SCRIPT, 1997). Dyke intrusion is evident on the Bremer River and Devils Creek.

The Cainozoic sedimentary rocks consist of Tertiary period (1.6 to 65 MYBP) sedimentary rocks of the Plantagenet Group of the Bremer Basin, and surficial sediments. The Plantagenet Group, in turn, comprises two distinct lithofacies: the Werillup Formation and the Pallinup Siltstone. The Werillup Formation infills Cretaceous (65 to 144 MYBP) to early Tertiary (1.6 to 65 MYBP) palaeodrainages formed during the continental break-up of Australia and Antarctica, and is overlain by horizontally bedded Pallinup Siltstone (Dodson, 1997).

Uplift along the Jarrahwood axis to the north of Jerramungup, probably during the Oligocene, tilted the Tertiary sediments slightly to the south and rejuvenated south-trending drainage (Cope, 1975). This is a unique feature of the south coast region as all the rivers drain in a south south-easterly direction.

Cainozoic surficial deposits, which form a thin cover over most of the remainder of the sheet, are derived through erosion of the duricrust, Tertiary sediments and basement rock. The surficial deposits consist of eolian sand, colluvium, lacustrine deposits of thin clay and silt and, near the coast, shelly sandstone and coastal dune sand. To a lesser extent, a thin pisolitic laterite has also developed near the top of the Tertiary Plantagenet sediments (Dodson, 1997).

Hydrogeology

The Bremer River catchment is underlain almost entirely by fractured and weathered Archaean and Proterozoic gneiss and granite. These basement rocks form relatively impermeable barriers to the movement of groundwater. The dolerite dykes tend to be igneous textured, typically appear to lack fractures, and generally impede groundwater flow (Dodson, 1997).

The basement rocks are overlain, in part, by sedimentary rocks of the Tertiary Plantagenet Group. They are characterised by low permeability due to their silty or clayey nature. However, they are generally the most porous of the area and are thus considered the best aquifers. The aquifers occupy broad, flat depressions, and locally lie within paleochannels on the uneven basement paleosurface (paleo meaning ancient). Quaternary sediments which overlie the area, are generally unsaturated, except at the coast and within alluvium and lacustrine deposits (land formed by washed-up earth and sand) (Dodson, 1997).

[3] *MYBP is million years before present*

The watertable generally forms a continuous surface throughout the area, broken only by basement outcrop in the northwest. Depth to groundwater is generally less than 5 m in valleys below ground surface, but may reach 20 m (Dodson, 1997).

Groundwater flows in the direction of decreasing potential, from a maximum of about 300m AHD[4] in the northwest to near sea level at the coast. Groundwater discharges at the coast and along drainage courses, like the Bremer River and Devils Creek. Groundwater is also discharged by evapotranspiration, or evaporation where the watertable intersects the surface or is cut by incised drainage (Dodson, 1997).

The groundwater is predominately saline, ranging from less than 1000mg/L TDS[5] in the Quaternary coastal sediments, to more than 35 000mg/L in weathered and fractured basement aquifers. Groundwater salinity increases to the north and east as rainfall decreases (Dodson, 1997).

Climate and Rainfall

The catchment experiences a Mediterranean type climate with cool, wet winters and warm to hot, dry summers. The average monthly minimum and maximum temperatures for Bremer Bay range from 14 to 26° C during summer months, and from 7° C to 16° C during the winter months. Areas near the coast often receive a cooling southeasterly sea breeze by early afternoon throughout the summer months (Dodson, 1997).

Average annual rainfall is 630 mm for Bremer Bay, and decreases inland to approximately 400 mm at Jerramungup. This illustrates the sharp decrease in rainfall from the south of the catchment to the north. Most of the rain falls during the winter months and is associated with moist air in low-pressure systems passing over, or to the south, of the area. The wettest month is June and the driest being January. Pan evaporation for Jerramungup is about 1600 mm per annum (Dodson, 1997).

[4] *Australian Height Datum*
[5] *Total Dissolved Salts*

Vegetation

The vegetation communities for the Bremer River catchment are shown below and published in 'A Physical and Floristic Survey of Native Vegetation Remnants in the Bremer River Catchment' (Heller and Brown, 1996). During this survey, Heller and Brown also identified the following priority flora in the Bremer catchment; *Hakea brachyptera – CALM Priority 3 and Astroloma microphyllum – CALM Priority 2.*

Boronia clavata is a Priority 2 species restricted to the vicinity of the lower reaches of the Bremer and Gairdner Rivers. It generally occurs in narrow alluvial floodplains in assoication with thickets of other shrubs. It is an upright shrub, usually 1.5-2 m tall. The plant has pale yellowing green flowers. Any sightings of this species, which is currently threatened with extinction, should be reported to CALM.

CALM Priority 2 is taxa with few poorly known populations on conservation lands. Species that are known from one or a few localities on lands not under immediate threat, including nature reserves, national parks, vacant crown land and water reserves. These species are under consideration for declaration as Endangered Flora but are in need of urgent high priority, further survey (Hopper *et al*., 1990).

CALM Priority 3 is taxa with several poorly known populations, some on conservation lands. Species which are found at several localities, some of which are on lands not under immediate threat. These species are under consideration for declaration as Endangered Flora but are in need of further survey (Hopper *et al*., 1990).

1. Yate Woodland
Structure: Tall trees, open, predominately sedge understorey.
Location in Catchment: Adjacent to water courses and seasonally damp areas.
Dominant Species: *Eucalyptus occidentalis* var. occidentalis, *Sedges sp.*

2. Casuarina Woodland
Structure: Closed, usually in thickets, basically lacking shrub and ground layers.
Location in Catchment: Adjacent to rivers, orming pure stands in granite areas.
Dominant Species: *Allocasuarina huegliana*.

3. Moort Woodland
Structure: Tall trees, open, predominately sedge understorey.
Location in Catchment: Adjacent to water courses and seasonally damp areas.
Dominant Species: Eucalyptus occidentalis var. occidentalis, *Sedges sp.*

4. Banksia Shrubland
Structure: Closed, 1.5 m+
Location in Catchment: Sand plains.
Dominant Species: Banksia spp., *Lambertia inermis*, *Adenanthos cuneatus.*

5. Casuarina Shrubland
Structure: Predominantly sheoak, 1.5 m+
Location in Catchment: Sand on granite.
Dominant Species: *Allocasuarina campestrus, Grevillea hookeriana, Thryptomene australis*.

6. Melaleuca Shrubland
Structure: Thickets, 1.5 m+
Location in Catchment: Watercourses.
Dominant Species: *Melaleuca hamulosa,Melaleuca acuminata, Melaleuca cuticularis, Melaleuca pauperiflora.*

7. Acacia Shrubland
Structure: Tall thickets.
Location in Catchment: Granite.
Dominant Species: *Acacia lasiocalyx.*

8. Mallee Heath
Structure: Dense, high diversity of Proteaceous and Myrtaceous shrubs under mallee, low.
Location in Catchment: Sand over a variety of substrates.
Dominant Species: Eucalyptus spp.

9. Mallee Shrubland I
Structure: Proteaceae understorey, dense, high plant diversity, shrubs 1.5 m+
Location in Catchment: Sand over substrate.
Dominant Species: Eucalyptus spp., Banksia spp., Chittick *etc.*

10. Mallee Shrubland II
Structure: Broombush understorey, less dense, shrubs 1.5 m+
Location in Catchment: Stony.
Dominant Species: Eucalyptus spp.,*Melaleuca uncinata (Broombush).*

11. Riverine – River or creek line vegetation. This community includes several previously described communities, mainly Yate woodland, Casuarina woodland and Melaleuca shrubland. There is often a predominance of taller trees, usually with a dense understorey of Melaleucas and large sedges. Lower in the catchment, (observed mainly on Devils Creek) a Flood plain community comprising mainly of Woodland, *Eucalyptus decipiens* over *Calothamnus gracilis, Leptospermum oligandrum* and *Banksia repens* developed.

Fauna

The fauna of the Bremer River catchment that is listed below was compiled by Heller (Heller, 1996) using information from landowners and on-site observations. It is based on vegetation community associations from Sanders (Sanders, 1996).

MAMMALS

Short-beaked Echidna
Chuditch
Yellow-footed Antechinus
Red-tailed Phascogale
Fat-tailed Dunnart
Grey-bellied Dunnart
Southern Brown Bandicoot
Common Brushtail Possum
Tammar Wallaby
Western Grey Kangaroo
Western Brush Wallaby
White-striped Freetail-bat
Lesser Long-eared Bat
Gould's Wattled Bat
Chocolate Wattled Bat
Southern Forest Bat
Ash-grey Mouse
Western Mouse
House Mouse
Bush Rat
Black Rat
Fox
Cat
Rabbit
Western Pygmy-possum
Honey-possum

FROGS

Slender Tree Frog
Spotted-thighed Frog
Quacking Frog
Western Spotted Frog
Moaning Frog
Sand Frog
Banjo Frog
Turtle Frog
White-footed Trilling Frog
Guenther's Toadlet
Glauert's Froglet
Bleating Froglet
South Coast Froglet

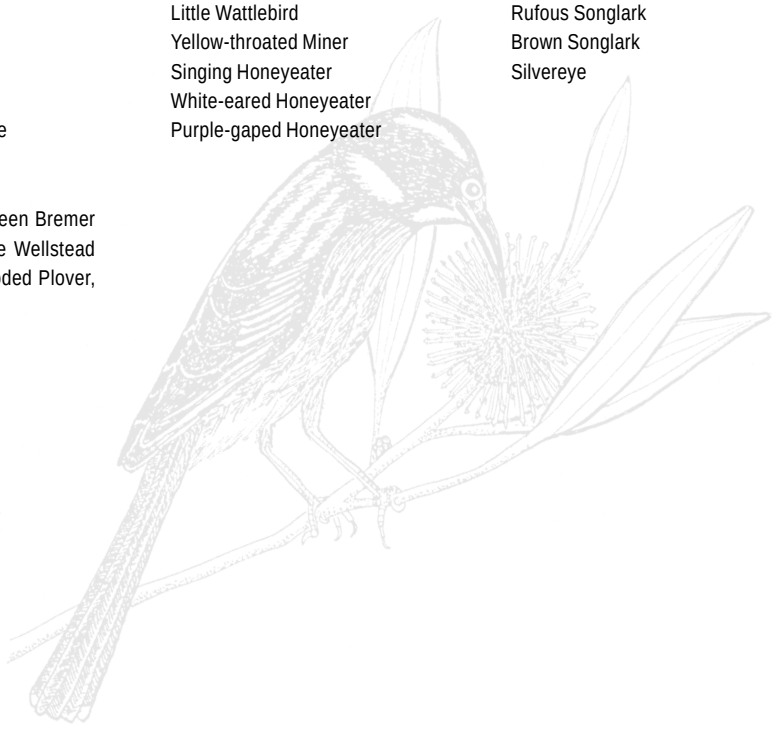
REPTILES

Western Long-necked Tortoise
Clawless Gecko
Wheatbelt Gecko
Spiny-tailed Gecko
Marbled Gecko
Yellow-chinned Worm Lizard
Southern Delma
Fraser's Delma
Southern Scaly-foot
Spotted Sand Dragon
Ornate Rock Dragon
Western Bearded Dragon
Chapman's Dragon
South-western Cool Skink
Southern Shinning Skink
Chain-striped Ctenotus
Gern Ctenotus
Elven-striped Ctenotus
Red-legged Ctenotus
King's Skink
Southern Sand Skink
Napoleon's Skink
Orange-bellied Earless Skink
Peron's Earless Skink
Orange-tailed Lerista
Small-eared Lerista
Grey's Menetia
Brown Morethia
Bluetongue
Bobtail
Rosenberg's Monitor
Common Blind Snake
Carpet Python
Crowned Snake
Bardick
Western Tiger Snake
Dugite
Square-nosed Snake
Gould's Snake
Black-backed Snake

BIRDS

Emu
Malleefowl
Stubble Quail
Brown Quail
Blue-billed Duck
Musk Duck
Freckled Duck
Black Swan
Cape Barren Goose
Australian Shelduck
Australian Wood Duck
Pacific Black Duck
Australasian Shoveler
Grey Teal
Chestnut Teal
Pink-eared Duck
Hardhead
Australasian Grebe
Hoary-headed Grebe
Great Crested Grebe
Darter
Little Pied Cormorant
Pied Cormorant
Little Black Cormorant
Great Cormorant
Australian Pelican
White-faced Heron
White-necked Heron
Great Egret
Nankeen Night Heron
Australasian Bittern
Australian White Ibis
Straw-necked Ibis
Royal Spoonbill
Yellow-billed Spoonbill
Osprey
Black-shouldered Kite
Square-tailed
Whistling Kite
White-bellied Sea Eagle
Spotted Harrier
Swamp Harrier
Brown Goshawk
Collared Sparrowhawk
Wedge-tailed Eagle
Little Eagle
Brown Falcon
Australian Hobby
Peregrine Falcon
Nankeen Kestrel
Bailoon's Crake
Australian Spotted Crake
Spotless Crake
Black-tailed Native-hen
Eurasian Coot
Australian Bustard
Black-tailed Godwit
Bar-tailed Godwit
Whimbrel
Common Greenshank
Common Sandpiper
Red-Necked Stint
Painted Button-quail
Pied Oystercatcher
Sooty Oystercatcher
Black-winged Stilt
Red-necked Avocet
Banded Plover
Eastern Golden Plover
Grey Plover
Red-capped Plover
Black-fronted Dotterel
Hooded Plover*
Red-kneed Dotterel
Banded Lapwing
Pacific Gull
Silver Gull
Gull-billed Tern
Caspian Tern
Crested Tern
Rock Dove
Laughing Turtle-Dove
Common Bronzewing
Brush Bronzewing
Crested Pigeon
Purple-crowned Lorikeet
Regent Parrot
Western Rosella
Australian Ringneck
Elegant Parrot
Rock Parrot
Short-billed Black Cockatoo
Galah
Pallid Cuckoo
Fan-tailed Cuckoo
Horsfield's Bronze-Cuckoo
Shining Bronze-Cuckoo
Southern Boobook
Barn Owl
Tawny Frogmouth
Spotted Nightjar
Australian Owlet-nightjar
Laughing Kookaburra
Sacred Kingfisher
Rainbow Bee-eater
Splendid Fairy-wren
Blue-breasted Fairy-wren
Southern Emu-wren
Spotted Pardalote
Striated Pardalote
White-browed Scrubwren
Shy Heathwren
Striated Fieldwren
Weebill
Western Gerygone
Inland Thornbill
Yellow-rumped Thornbill
Red Wattlebird
Little Wattlebird
Yellow-throated Miner
Singing Honeyeater
White-eared Honeyeater
Purple-gaped Honeyeater
Yellow-plumed Honeyeater
Brown-headed Honeyeater
White-naped Honeyeater
Brown Honeyeater
New Holland Honeyeater
White-cheeked Honeyeater
Tawny-crowned Honeyeater
Western Spinebill
White-fronted Chat
Scarlet Robin
Red-capped Robin
Western Yellow Robin
Southern Scrub-Robin
White-browed Babbler
Crested Bellbird
Golden WhistlerRufous Whistler
Grey Shrike-thrush
Restless Flycatcher
Grey Fantail
Willie Wagtail
Western Whipbird
Varied Sittella
Magpie-lark
Black-faced Cuckoo Shrike
White-winged Triller
Black-faced Woodswallow
Dusky Woodswallow
Grey Butcherbird
Australian Magpie
Grey Currawong
Australian Raven
Richard's Pipit
Red-eared Firetail
Welcome Swallow
Tree Martin
Fairy Martin
Rufous Songlark
Brown Songlark
Silvereye

***** Hooded Plover slightings have occurred at 16 sites between Bremer Bay and Hopetoun, including the Wellstead Estuary. The Wellstead estuary has recorded one of the highest numbers of Hooded Plover, and highest density of breeding records.



Aboriginal heritage

The Aboriginal history of the Bremer River and the adjacent area is relatively unknown. At the time of European settlement, the Aboriginal group, Goreng (Koreng), occupied the Gnowangerup - Bremer Bay area and spoke the Noongar (Nyungar) language (Shire of Jerramungup, 1994).

Roni Forrest and Stuart Crowe produced a report on the Noongar social history of the Jerramungup region titled 'Yarra-mo-up: Place of the Tall Yate Trees' (Forrest and Crowe, 1996). This report includes some reference to the significant site, Carlawillup Rockhole that is on the Bremer River.

Carlawillup Rockhole, 11 km south of Jerramungup, is highly recognised as having important cultural and heritage value to the Noongar people. It was a significant dance and meeting place for Noongars of the area who met there for religious ceremonies, gathering and trade. Some of the items traded with other groups were ochre and baby girls. This was to keep the bloodline fresh and to prevent in-breeding within the tribe (Forrest and Crowe, 1996).

Many adaptations of Noongar names for place names are evident. Carlawillup Rockhole was called Carlawilgieup, meaning fire (carl) and ochre (wilgie), the place where people met and held ceremonies. Other locals refer to this place as Carlawirrup (Forrest and Crowe, 1996). Banjelungup is the Noongar name for Bremer Bay, meaning 'silver bream jumping'. Jerramungup was adapted from the Noongar name for the area which was Yarra-Mo-Up.

European heritage

There are no cultural sites recognised by the Shire under the *Heritage of Western Australia Act (1990)* near the Bremer River, but remains of a 100-year-old house can be found at Carlawillup Rockhole where a settler kept horses. On Kent Location 1916, a track into the Fitzgerald River National Park passes by old sheepyards that were apparently used by the Hassells, who were the first settlers of Jerramungup, when droving their sheep from 'Jarramungup' estate to Bremer Bay.

A history story has been developed for the Bremer River Catchment and is included in this publication.

Land tenure

The upper part of the catchment is privately-owned, except for a public reserve at Carlawillup Rockhole, on Carlawillup Road. The lower catchment is held in public ownership in the form of the Fitzgerald River National Park. The Wellstead Estuary is partly situated in the Fitzgerald River National Park and the lower part in a Nature Reserve. A narrow strip of reserve vested in the Jerramungup Shire, borders the lower reaches of the river and the upper part of the estuary (Hodgkin and Clark, 1987).

3. Waterways information

Rivers – Bremer River

The Bremer River is approximately 70 km in length. Devils Creek is its only major tributary, and enters the river on the south side about 20 km upstream from the mouth of the Wellstead Estuary. A number of pools in the river bed, some up to a kilometre long, retain water throughout the year but apart from these the channel is dry much of the time (Hodgkin and Clark, 1987).

The river starts approximately 5 km south of Jerramungup and flows in a south-east direction in a relatively narrow catchment to the Wellstead Estuary.

The catchment area is 716 km^2, with 80% of it cleared (RAP and SCRIPT, 1997). The upper and middle reaches flow through agricultural land with the lower river meandering through the Fitzgerald River National Park (FRNP) and eventually entering the Wellstead Estuary. A sandbar divides the estuary from the Southern Ocean.

Hydrology

The Bremer River is a ephemeral river system that flows mainly after winter rainfall events. Although no flow measurements have been taken, anecdotal observations from landowners in the Bremer River Catchment indicate that the river now flows more frequently, particularly during summer. Landholders have also noted that the naturally saline river has become more saline since clearing in the 1950s. The estimated mean annual runoff is 3.8 mm, with a mean flow to the estuary of 2.64 x 10^6 m^3 (Hodgin and Clarke, 1987).

It is estimated that the clearing of native vegetation in the catchment and replacing it with lower water-using annual crops and pastures may have increased the river's annual flow by 2-3 times. The changes in the surface water and sub-surface processes in the Bremer River landscape are likely to include:

- larger volumes of runoff due to saturation-excess;
- faster surface flows;
- higher peak flows during floods (high water levels during floods);
- shorter periods of peak flows (high velocity of water flow);
- siltation, where flood water slows down and drops suspended soil particles;
- more water entering the groundwater system;
- a higher proportion of waterlogged areas;
- increases in frequency of waterlogging and inundation; and
- increases in areas affected by groundwater discharge and salinity.

Water quality

Water quality of the Bremer River and Devils Creek was not researched in this study but anecdotal observations from landowners conclude that the systems have become more saline. At some sites, the water was once used for stock and there were yabbies present but now the water is too salty for either. Some pools in the Bremer River are fresher than others. The freshness of the water at Carlawillup Rockhole is such that some farmers mix it with chemicals for spraying.

There has been no comprehensive monitoring of the Bremer River, however there has been one-off samples taken where the Bremer River crosses Devils Creek Road by the Public Works Department between 1966 – 1971 (data recorded on the Water and Rivers Commission's data base). These recordings only provide an indication of salinity levels in the river, as these would differ due to seasonal variability, particularly the amount of rainfall received. Seawater is approximately 35 600 mg/lt hence the water quality would be deemed relatively fresh (human consumption is 500 – 1600 mg/lt).

Salinity measurements of the Bremer River 1966 – 1971

Site	Sample Time	Chloride mg/l
6021034	18 July 1966	900
6021034	19 September 1966	2650
6021034	11 October 1967	750
6021034	15 July 1968	1600
6021034	26 July 1971	425
6021034	15 November 1971	607

Source: Public Works Department

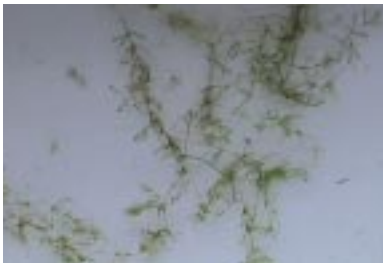
Aquatic flora

In January 1999, the WRC, Community Landcare Officers and local farmers sampled four river systems, including the Bremer River. Seven sites were sampled along the Bremer River for aquatic plants and native fish. Both macrophytes and algae can indicate the health of a waterway, however the type of aquatic plants and the density of species found in river systems is influenced by a number of factors such as temperature, light availability, salinity, waterflow and nutrient concentration. For this reason, there is often variation in aquatic plant growth within and between seasons. Prolific growth is often experienced in late spring and during summer.

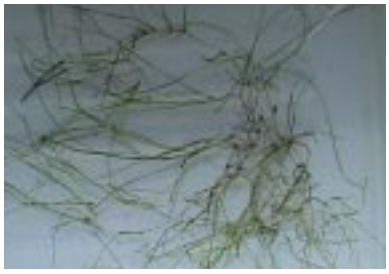
The snapshot recorded the aquatic plant *Chara* at a pool on Devils Creek Road and *Ruppia megacarpa* at Carlawillup Reserve. *Ruppia* is an annual or short-lived perennial that holds its fruits on prominent stalks. This is found in a wide range of environments including estaurine environments and freshwater pools that are flowing or still. Chara is a branched algae commonly known as stoneworts or musk grass. These are important habitat for many invertebrates and are used as a spawning site by some fishes.

The blue-green algae *Nodularia*, a potentially toxic species, was noticed in a pool on the river where the flow had been modified Blue green algae cells are microscopic and group in colonies or chains. These form scums when large numbers form at the water surface. Blue-green alage blooms are a natural pheonomena and while it is not exactly clear what factors trigger a bloom, excess nutrients can certainly increase the intensity of the blooms. These algae blooms can be toxic and alternative supplies must be found for stock watering and domstic supplies. Maintaining a sufficient flow of water to prevent stratification is a way to keep water mixed to prevent algae blooms.

Green algae species – cladophora and enteromorpha (locally known as 'Snot Weed') were also recorded. These are filametrous algae that can grow in clumps and form large mats. The filaments are about the diameter of human hair and may be branched. Cladophora filaments feel like course hair, whereas enteromorpha feels like wet, soapy hair.



Chara species, *collected in the Bremer River*



Ruppia sp, *collected in the Bremer River*

Aquatic fauna

Fish

Based on samples taken, it is likely that three fish including the Spotted Minnow, Blue Spotted Goby and Wallace's Hardyhead Fish would exist in the Bremer River (David Morgan, pers. comm., 2000). Black Brim are likely to live in the lower areas of the Bremer River. Hodgin and Clarke (1987) recorded the following species in the estuary, which are also likely to be found in the Bremer River.

Black bream	*Acanthopagrus butcheri*
Hardyhead	*Atherinosoma elongata*
Hardyhead	*Atherinsoma wallacei*
Goby	*Pseudogobius olorum*
Spotted minnow	*Galaxias maculatus*

Macroinvertebrates (aquatic bugs)

Macroinvertebrates consist of worms, snails, crustaceans (prawns and marron) and insects (eg. mayflies, stoneflies, beetles, and bugs). For many of the insects, only the larval stages are truly aquatic. Many macroinvertebrate species are found in the waterways throughout the Bremer River Catchment, however a comprehensive monitoring program has not yet been done. A comprehensive program that includes

monitoring macroinvertebrates and water quality to detect long-term changes to the health of the river system is recommended.

Macroinvertebrates play an important role in the ecology of the river system. In the upper catchment, macroinvertebrates are responsible for shredding larger particles including bark, leaves and other detritus that falls into the waterway. Further downstream, macroinvertebrates such as worms, gilgies and marrow take small particles of organic matter from the sediment and digest them further. The algae that grows on the rocks is 'scraped off' by snails and limpets. There are also predator species of macroinvertebrates such as the dragon fly, adult beetles and stonefly larvae that prey on smaller animals.

The survival of macroinvertebrates, and in turn the survival of larger animals like fish that are dependent upon macroinvertebrates, links closely to the quality of the water. Macroinvertebrates are sensitive to changes in the physical and chemical conditions of the water, including salinity changes, flow changes and temperature changes.

The most important feature in a stream is vegetation – including logs, branches, bark and leaves. It forms the basis of a food web for macroinvertebrates in our waterways. Vegetation removal can impact on; food availability (removal of riparian vegetation upstream can have serious consequences on downstream macroinvertebrates that rely on the input of organic matter to the system), light penetration, water flow, sediment levels and temperature of the water. Protection of foreshore vegetation is vital to ensure the protection of the ecological attributes of our river system.

Estuarine – Wellstead Estuary

Wellstead Estuary is the mouth of the Bremer River and opens onto the western end of Bremer Beach, in Bremer Bay, about 180km north-east of Albany. The town of Bremer Bay is situated on the western shore of the Inlet. The narrow winding channel of the Bremer River flows in a south-easterly direction toward the coast. Before draining to the ocean the Bremer River broadens into a very shallow meandering lagoon that is approximately 4 km long and up to 600 m wide.

Wellstead Inlet, the estuarine portion of the Bremer River, extends inland 13km from the coast and includes the lagoon and 9 km of the narrow river channel. The Estuary has about 300 ha of surface area and the volume at bar breaking is estimated to be about 5000 ML.

The mouth of the Estuary is sheltered in Bremer Bay which is protected from the prevailing south-westerly swell by granitic headlands to the south and east. Consequently, the coastal sediment transport caused by wave action and near shore currents is much smaller at the mouth of Wellstead Estuary compared to other Inlets on the south coast. As a result the sand bar at the mouth of Wellstead Estuary builds slower and lower and can stay open for longer periods than other Inlets. The sandbar usually builds to a height of about 1 m to a maximum of 2 m above mean sea level. The bar may break naturally or may be artificially breached. Depending on when the bar is opened and the water level at opening, it may stay open for a few months to several years. The vegetation fringing the Estuary is dominated by the salt tolerant paperbark *Melaleuca cuticularis*, the samphire *Sarcocornia blackiana* and the sea rush *Juncus krausii*. The catchment of Wellstead Estuary is poorly defined but is estimated to be approximately 700 km^2. The 70-km long Bremer River is the largest watercourse in the catchment. Its channel is usually dry except for isolated river pools that retain water throughout the year. Devil Creek is a major tributary of the Bremer River. At least half of the Wellstead catchment (350 km^2) has been cleared of native vegetation.

Water quality

Hodgkin and Clarke (1987) describes some water quality data for the Wellstead Estuary as part of the Environmental Protection Authority series 'Estuaries and Coastal Lagoons of South Western Australia'.
Salinity varies greatly as a result of rainfall, evaporation, estuary depth and whether the sandbar is open or closed. Stratification may occur in the deeper water, with wind stress the main cause of mixing. The surface water is generally well oxygenated, but when the water is stagnant or stratification is prolonged, there will be some degree of deoxygenation in water below the halocline. Other than this, there is very limited historical water quality data for Wellstead Inlet.
More recent water quality data has been collected for the estuary as part of the 'South Coast Inlets Environmental Monitoring Project'. This project involves estuarine water quality monitoring and data collection in several inlets on the south coast of Western Australia. The project is managed by the South Coast Office of the Water and Rivers Commission and began in September 1997. Sampling occurs quarterly, so that data is collected during each season.

The sampling program provides information on the important processes controlling water quality and routine data for monitoring health effects and trends in the inlet. Between October 1997 and March 2000 the estuary has been sampled nine times.

Sampling sites

Five monitoring sites have been established in Wellstead Estuary (see Figure 3:1). Depending on water level, all five may not necessarily have been sampled (a sixth has been sampled on one occasion). The first site is about 1 km upstream from the bar and the other sites are located at about 1 km intervals to a distance of about 5 km upstream from the bar. Sites closest to the bar are shallower than those further upstream.

Parametres monitored

At each site:

- profiles of dissolved oxygen, temperature and salinity are recorded at 0.5 m intervals from the surface to the bottom using a Hydrolab H2O instrument;

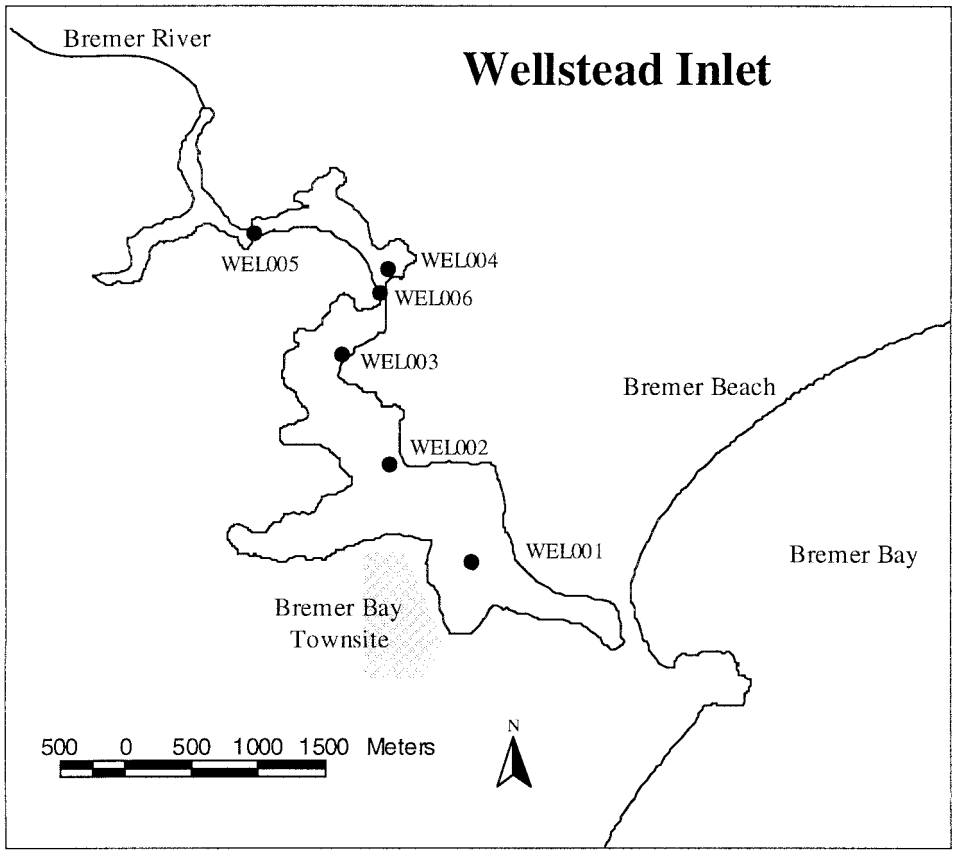


Figure 3:1. Sampling locations of the Wellstead Estuary water quality monitoring program

- surface and bottom water samples are collected at each site and analysed for total nitrogen (TN) and phosphorous (TP), chlorophyll pigments (*Chl a,b,c*, phaeophytin), water colour and dissolved fractions of nitrogen and phosphorous (after 0.45 um filtration): ammonium (NH4-N), nitrate/nitrite (NOx-N), filterable reactive phosphorus (FRP); and
- Samples are collected to identify the species of phytoplankton present.

Salinity profiles

On the eight occasions sampled, the salinity ranged from 22 ppt to in excess of 70 ppt. For the most part the salinity was close to that of seawater between 30 ppt and 40 ppt (seawater is 34-36 ppt, depending on the season). The peak salinities were recorded in the late summer sampling runs of March 1998 (in excess of 70 ppt) and March 1999 (44 ppt) and the lowest salinities in October 1997, November 1998, July 1998, and March 2000.

The high salinities in March 1998 and March 1999 would have resulted from the evapo-concentration of salt in the Estuary over the summer period. Salt concentrations increased by at least 2.2 times over the 1997/1998 summer and by up to 1.4 times over the 1998/1999 summer. The evapo-concentration of salt over the 1997/1998 summer was greater than the 1998/1999 summer because the sandbar was closed to the ocean during the former and open during the later. (Although rainfall over the two periods was similar, due to the sheltered position of the Estuary mouth, the open/closed status of the bar can reflect flood events that happened more than a year earlier.)

The lower salinities (more than 20 ppt and therefore still very salty) in October 1997, November 1998, July 1998 and March 2000 would have resulted from inflows from the Bremer River. On these occasions there was a fairly strong horizontal gradient, up to 8 ppt, over the 5 km distance of our surveys (with upstream sites fresher than downstream sites due to the river flow).

There was very little vertical salinity stratification in the section of the Estuary that the surveys covered (at most 3 ppt) and it was generally in the river channel not the lagoon. The limited vertical stratification in the lagoon is probably a reflection of the shallow depth of the Inlet were the wind is easily able to mix vertically.

The only consistent seasonal trend in salinity in Wellstead Estuary was an increase over summer as a result of evapo-concentration of salts. This pattern was broken with rainfall in February 2000. The three major factors that determine the salinity of the estuary are; rainfall, evaporation and bar status, however only evaporation has a strongly seasonal period. The rainfall was sporadic and aseasonal with no clear annual pattern over the period of our sampling. While the bar opened in response to the largest of these aseasonal-rainfall events it takes long periods to close and as a consequence its status is also irregular.

Dissolved oxygen profiles

Dissolved oxygen concentrations ranged from 4 mg/L to about 13 mg/L throughout the sampling period. Considering the effects of salinity and temperature it represents a range of about 50% – 160% saturation. None of the sampling occasions recorded low or extremely low dissolved oxygen concentrations.

The absence of vertical salinity stratification in the section of the Estuary explains the absence of low or extremely low dissolved oxygen concentrations. It is possible that in the river channel there may be deep holes (3 – 5 m deep) that could be anoxic. Such regularly anoxic deep holes are found in the river channels of the adjacent Beaufort and Gordon Inlets. In the upper Wellstead, where the sampling program did not extend, Hodgkin and Clark (1987) reported deep holes.

The high dissolved oxygen concentrations recorded in Wellstead Estuary (at times in excess of 150% saturation), particularly in the lagoon, would have been a result of the photosynthesis of aquatic plants, such as the seagrass *Ruppia* and the stonewort *Lamprothamnium*. The slightly increasing gradient in dissolved oxygen concentrations from the river channel to the lagoon probably results from the shallower water and greater abundance of aquatic plants in the lagoon over the river channel.

Dissolved oxygen concentrations in the later summer sampling periods of March 1998 and March 1999 tended to have lower concentrations than the winter, as a result of the higher temperatures. The March 2000 concentrations were the lowest recorded, probably as a result of the January rains that deposited a large amount of organic matter from the catchment.

Temperature profiles

Temperature ranged from 10°C – 23°C throughout the sampling period. Seasonally the Estuary temperature behaved as expected with the lowest temperatures in winter and the highest temperatures in late summer. The upper sites in the Estuary tended to be slightly warmer than those closer to the bar and some slight temperature stratification was observed with surface waters being up to 2°C warmer than bottom waters.

Nutrients and photosynthetic pigments (Grab Samples)

On the eight occasions sampled the TP ranged from the detection limit of 0.01 mg/L up to 0.22 mg/L with a median of 0.05 mg/L. The TN ranged from 0.25 mg/L up to 2.5 mg/L with a median of 0.75 mg/L. The highest concentrations were recorded in March 1998, March 1999 and March 2000.

The dissolved nutrient fractions were only measured on five of the eight sampling occasions. The filterable reactive phosphorus concentrations ranged from the detection limit of 0.003mg/L up to a maximum of 0.027 mg/L with a median of just 0.004 mg/L. The ammonium concentration ranged from the detection limit of 0.005 mg/L up to a maximum of 0.18 mg/L with a median of 0.022mg/L. The nitrate/nitrite concentration ranged from the detection limit of 0.005mg/L up to a maximum of 0.35mg/L with a median of non-detect (ie below 0.005mg/L). The highest concentrations of dissolved nutrients were recorded in March 1998, March 1999 and March 2000. The 1992 ANZECC guidelines for estuaries suggest that; filterable reactive phosphorus concentrations less than 0.005 mg/L to 0.015 mg/L, ammonium concentrations less than 0.005 mg/L and nitrate concentrations less than 0.01 mg/L to 0.1 mg/L are desirable to avoid algal problems.

The shallow depth and lack of stratification in Wellstead Estuary meant that the difference between discrete surface and bottom water nutrient samples was often negligible.

The high TN and TP concentrations in March 1998 and March 1999 were most probably caused by the evapo-concentration of dissolved materials in the Inlet, especially given that the nutrient concentrations appeared to increase by roughly the same proportions as the salinity of the Inlet. The concentrations of dissolved nutrients also increased over these periods. The ratios of dissolved nutrients to total nutrients increased significantly during periods of evapo-concentration suggesting that there was a change in the nutrient partitioning as the evapo-concentration was occurring. The high concentrations of total and dissolved nutrients in March 2000 would have resulted from an increase in catchment-derived material following the rains of January 2000.
Despite the lack of a surface to bottom nutrient gradient, bottom samples often had significantly higher concentrations of chlorophyll than surface samples. Two explanations for this are that motile species (such as dinoflagellates or cryptophytes) were residing low in the water column or that there was a greater biomass of heavier microalgae (such as epiphytic diatoms), that had sloughed-off their host, residing low in the water column.

Total nutrients tend to be higher in the river channel than the lagoon although this pattern is not reflected in the dissolved nutrients. This may be caused from suspended material being carried down the river channels and settling out before it reaches the lagoon.

Molar ratios of dissolved inorganic nitrogen to dissolved inorganic phosphorus were uniformly below 16:1 and mostly below 10:1 for the first four of the five occasions when dissolved nutrients were measured. This suggests that nitrogen availability maybe slightly more limiting to phytoplankton than phosphorus–based on the Redfield ratio. The same analysis of the March 2000 data indicates that there was a massive excess of dissolved inorganic nitrogen introduced by the January rains.

The major reasons for the nutrient concentrations were the summer evapo-concentration levels in the Estuary and the inflow that introduced new nutrients. The lack of anoxia suggests that nutrients lost to the sediment are probably being trapped in the case of phosphorus or denitrified in the case of nitrogen. If anoxia were to occur, then there may be significant nutrient recycling from the sediment.

Aquatic plants

The bed of the Wellstead Estuary is covered in a thick crop of plants dominated by the halophytic seagrass *Ruppia megacarpa*, the charophyte (stonewort) macroalgae *Lamprothamnium papulosum* and the green macroalgae *Polyphysa peniculus*. Seagrass, in particular, often carries a heavy epiphytic load of filamentous green algae.

Hodgin and Clarke (1987) recorded a large number of phytoplankton species in Wellstead Estuary in 1974. They included a colonial green algae (probably Gloeocystis), the chlorophyte Scotiella, two species of dinoflagellage, a few diatoms and a filamentous blue-green algae.

This sampling program recorded a consistent flora of chlorophytes, cryptophytes, diatoms and dinoflagellates present at concentrations of about 10 cells/mL up to 120 cells/mL. On three occasions cyanobacteria were detected in the water column, and in November 1998 a significant amount (~30,000 cells/ml) of the cyanobacteria *Oscillatoria* was detected at one of the three sites sampled. The *Oscillatoria* was probably either suspended benthic material or had been washed in from a river pool. In March 1998 there was a significant bloom (about 85,000 cells/mL) of the dinoflagellates *Cachonina* and *Heterocapsa*. This dinoflagellate bloom may have been in some way related to the significant evapo-concentration that had occurred over the previous summer. In July 1998 low levels of haptophytes (about 3,000 cells/mL) were present and in November 1999 there was a significant of picoplankton bloom (~300,000 cells/mL).

Aquatic fauna

There are significant differences in aquatic fauna recorded in the estuary depending on whether the bar is open or closed. When the bar is closed for a long time, only the true estuarine species survive. When the bar is open, several species enter and survive in the estuary until the salinity becomes too extreme.

Fish

Fish populations also change with the condition of the estuary and can be categorised as either estuarine – species which spend their whole life cycle in the estuary, or as marine – species which spawn at sea and are recruited to the estuary at some stage of their life cycle. Hodgin and Clarke (1997) recorded the following fish species from Lenanton, 1974 and pers. comm.

Fish species recorded from Wellstead Estuary (Hodgin and Clarke, 1987)

Common Name	Scientific Name
Estuary	
Black bream	*Acanthopagrus butcheri*
Hardyhead	*Atherinosoma elongata*
Hardyhead	*Atherinsoma wallacei*
Goby	*Pseudogobius olorum*
Spotted minnow	*Galaxias maculatus*
Marine	
Yellow-eye mullet	*Aldrichetta forsteri*
Sea mullet	*Mugil cephalus*
Cobbler	*Cneidoglanis macrocephalus*
King george whiting	*Sillaginodes punctatus*
Australian herring	*Arripis georgianus*
Australian salmon	*Arripis trutta*
Tarwhine	*Rhabdosargus sarba*
Southern sand flathead	*Platycephalus bassensis*
Trevally	*Pseudocaranx sp.*
Long snouted flounder	*Ammotretis rostratus*
Small toothed flounder	*Pseudorhombus jenynsii*
Six spined leatherjacket	*Meuschenia freycineti*
Banded toadfish	*Torquigener pleurogramma*
Soldier fish	*Gymnapistes marmoratus*

Wellstead Estuary Information Evening – 2000

Notes by

Kaylene Parker,Rivercare Officer – Water and Rivers Commission

"I thought Id begin by putting your estuary in perspective of other estuaries. In the South Coast region stretching from Walpole to Esperance – there are over 25 estuaries and inlets. Estuaries differ in their size, water quality, size of the catchment, how often they open to the sea, the animals and birds that use them...

Estuaries are the interface between the land and the ocean. They capture all the surface water runoff and groundwater from the catchment, and the sea water as it flows in once the bar has opened to the sea. This creates an estuarine environment of brackish water that harbours plants and animals that have evolved to cope with this environment.

In the South Coast, we have some almost pristine estuarine systems entirely located within National Parks like the Broke Inlet near Walpole and St Mary's Inlet in the Fitzgerald River National Park. We have some inlets that open all-year- round including the Nornalup Inlet, to other inlets such as the Culham Inlet – which has only opened twice in recorded history (and opened with a velocity and force removed sand dunes, road culverts, telephone poles). In 1999, the Oldfield catchment flooded, and the salinity level in the estuary changed from twice the concentration of sea water, to one- tenth concentration - within a day. Everything living within that estuary had to cope with this change - the plants that live in the water, the fringing plants, the fish, the macroinvertebrates….

Estuaries not only have unique ecological values, but many varied historical, cultural and social values. The Oldfield Estuary is a unique estuary where aboriginal families relied on the fish and mussels they caught to survive, it fed those first settlers when times got hard. In fact, we still rely on our estuaries to feed us, and there are numerous commercial fishing industries reliant on our estuarine systems, and many recreational fishermen who enjoy putting in a line to catch a fish for tea.

Focussing on the Wellstead Estuary - this is the final point for all the water draining from its700km2 catchment. The estuary extends 13km from the coast and includes the lagoon and some 9km of the narrow river channel. The Bremer River and its main tributary are the main waterways draining to the estuary, Except for isolated river pools that retain water year round, the Bremer River channel is usually dry. At least half of the Wellstead catchment has been cleared (350 km^2) of native vegetation.

Wellstead estuary is a relatively youthful estuary and probably formed in the last four thousand years. As the sea levels rose 6500 years ago, the Wellstead Estuary would have been like a'a drowned river valley' or a sheltered marine embayment. As the sea levels retreated, the bar formed from sand carried along the bay shore forming the tidal delta, and the estuary we know today.

The estuary breaches its sandbar during periods of high rainfall, usually during winter however summer floods have resulted in the estuary opening. The sandbar usually builds to a height of 1-2 metres above sea level. The bar may break naturally or may be artificially breached. The bar may stay open for a few months to several years depending mainly on the amount and duration of rainfall.

Salinity in the estuary ranges from almost fresh following winter rain, to almost twice the concentration of seawater in summer. Temperature ranges from 12 degrees in winter to 25 degrees in summer. There are various aquatic plants that are found in the estuary including Ruppia megacarpa (grass-like seagrass), also green algae visible during the summer months. There have been reports by the community that the amount of these species has increased over the years.

Unfortunately our estuaries across the South Coast Region are facing many problems. Sediment runoff from the catchment is filling our river pools and shallowing our estuaries. Nutrient runoff is also causing increased algae growth and fish deaths in our estuaries. Foreshore vegetation in upper catchment is declining from salinity and uncontrolled stock access. Farmers are doing lots of work in the upper catchment, but there is still a lot to do. And as you know, the economic climate is not that favourable for landcare works. There is also urban pressure impact estuaries, increasing tourism pressure, increased pressure for subdivisions, housing developments, people clearing foreshore vegetation to get a better view, weeds, sewerage issues.

Working together is the first step in helping to protect our estuaries for future generations. If we can learn about them and know what condition they are in, then we can then work together to protect them. It may be little things, like not washing your car on the pavement so the detergents don't wash into the stormwater, it may be ensuring your sewerage system is working properly, or connecting to deep sewerage if it is available. It also may mean fencing the Bremer River and the tributaries in the upper catchment, it may mean planning proper walk trails around the inlet to stop the damage being done to the fragile foreshore vegetation. It may be producing pamphlets so tourists learn about how they can look after the natural environment of Bremer Bay. In all, it relies on the community, to drive what is needed to protect your local estuary."

Bar opening and closing dates
Wellstead Estuary/Bremer River

YEAR	MONTH	BAR STATUS	COMMENTS
1946		Bar broke	
1951	September	?	
1952		Bar closed	
1955	17 February	Bar broke	
1957	17 July	Bar closed	
1959	13 Sept	Bar broke	
1960	1 Nov	Bar closed	
1962		Bar opened	
1963		Bar closed	
1966	1 july	Bar opened	
1967	20 dec	Bar closed	
1968	4 feb	Bar opened	
1969	9 feb	Bar closed	
1971	9 nov	Bar opened	
1972	March	Bar closed	
1977	7 nov	Bar opened	
1977	21 dec	Bar closed	
1978	1 july	Bar opened	
1979	6 march	Bar closed	
1979	16 march	Bar opened	
1979	14 nov	Bar closed	
1982	23 jan	Bar opened	
1982	10 sept	Bar closed	
1984	15 Sept	Bar opened	Opened by Shire of Jerramungup
1985	29 May	Bar closed	
1986	26 July	Bar opened	Lot of water from inland
1986	26 sept	Bar closed	
1988	3 may	Bar opened	
1990	23 Sept	Bar closed	Closed as a result of work by Jerramungup Shire
1990	24 Sept	Bar opened	Naturally
1990	26 Sept	Bar closed	Closed naturally
1992	1 Sept	Bar opened	Opened by Shire – grader driver . Estuary still open 13th May – 1993.
1994	1 August	Bar closed	Opened one year and 11 months. Very rough and high seas caused closure
1995-96,		Bar closed	Dry conditions have seen no opening of Bremer River for two years.
1997	10 sept	Bar opened	With good rains in May, July , August – saw Bremer River and Estuary fill to breaking point, which it did in September.
1997.	10 October	Bar closed	Estuary has remained full.
1998	12 May	Bar opened	Opening on South side from sea to estuary because of very high tides and rough seas. Estuary still fully on tidal conditions.
1999	16 March	Bar closed	
1999	15 May		Above normal tides have been coming over full width of the bar, irrespective of tide conditions. Today being one of the highest in a 13 day period.

Source: Alice Thomas

Other recordings by Alice Thomas

Hunter River

- 10th August 1979, the land-locked Hunter River Bremer Bay broke for the first time since the late 1890s – as far as known.
- Land locked Hunter River – fresh water, broke 16th August 1986, second time since recordings have been taken.
- 29 January 1990, Hunter River broke after 4-5 inches in 24 hours.
- August 29 1992, Hunter River opened after receiving approximately 6 inches of rain.
- Hunter river broke appoximately 28-29th August, 1997.

Gairdner River

- 10.00am 5th January 1984, Gairdner River opened. Also opened on approximately 3 May 1988.
- 3 August 1984 – roughest seas for many years, causing beach damage and sinking of Ships in Bremer Bay area.
- Gairdner River broke to sea 26 August 1998.

Mary Anne River

- Opened 30th August 1992. This information was given to Alice by Dr Richard Holst while he was on a whale watch expedition.
- Fisheries Department and EPA Dr Hodgkin called in to check on the opening and closing of the River on 11th May 1983.

Research projects

Project Title

Benthic nitrogen cycling in shallow temperate coastal lagoons with intermittent oceanic connection: the role of meiofauna and hypersalinity. (The effect of sediment-dwelling fauna and high salinities on nitrogen cycling in coastal lagoons).

Jane Griffith, PhD candidate, Department of Environmental Management, Edith Cowan University, Joondalup WA 6027. Supervisor Dr Paul Lavery and Dr Pierre Horwitz. Year started – Feb 1999

Summary

Some coastal lagoons have entrances that are often blocked by sandbars. This lack of flushing makes them very susceptible to increases in the amount of nutrients and organic matter entering them. Excess nutrients can lead to algal blooms. In contrast to fully opened estuaries, coastal lagoons are poorly studied–despite Australia having a large number of them.

To understand more about these systems and how they might respond to the results of human activity, I am examining how nitrogen is processed within the sediments. The small animals that live within the sediment such as worms, nematodes and insect larvae, as well as the microscopic plants that live on top of the sediment, all affect how nitrogen is processed. I am focussing my study on the role that these organisms play in the nitrogen cycle. In addition, because these coastal lagoons are often barred from the sea and their rivers have low flow rates during summer, they may contain water that is 2-4 times saltier than seawater. Under these conditions the water is termed 'hypersaline'. How nitrogen is processed during periods of hypersalinity is poorly understood and so, I will be investigating this aspect as well.

The coastal lagoons being studied are Wellstead Estuary, Saint Mary Inlet, Hamersley Inlet and Oldfield Estuary. I will be visiting some or all of these coastal lagoons during 1999-2001.

Expected outcomes

This research will contribute to our understanding of how coastal lagoons' function. It will provide information on the rates and processes of nitrogen cycling, which are needed to manage the systems effectively. Information about the ecology of the fauna living within the sediment will also be attained. These small animals are a very important part of the food web, providing food for both fish and birds.

Results to date

Like most estuaries and coastal lagoons the coastal lagoons studied have very few animals which can thrive under their harsh conditions. Compared to adjacent marine areas, these coastal lagoons have low biodiversity (see table over). However, although there may not be many species, those that are present occur in large numbers. One site in Wellstead Estuary had over 63,000 worms, insect larvae and small crustaceans per square metre of sediment when sampled during June 1999. That is a lot of fish food! At the time of sampling Hamersley Inlet had salinity twice as high as normal seawater but still had over 25,000 invertebrate animals per square metre. This was much higher than the density of animals at Oldfield Estuary, which had brackish water (salinity lower than seawater), indicating that when coastal lagoons are hypersaline they can still support abundant life.

TABLE Distribution and abundances of benthic macrofauna at sites from Hamersley Inlet (H), Saint Mary Inlet (S), Wellstead Estuary (W) and Oldfield Estuary (OF) during June 1999. Densities are given as: □ = 0-100, □ = 101-1000, □ = 1001-10 000 and □ = 10 001-100 000 animals.m^{-2}. Family names are underlined.

Site	H2	H3	H4	S2	S3	S4	S5	W2v	W2b	W3	W4	W5	OF2	OF3	OF4	OF5
Species																
Polychaeta																
Capitellidae																
Capitella capitata	□	□		□	□	□	□	□	□	□	□	□	□	□	★	□
Orbinidae																
Scoloplos normalis								★	★	□	□	★	□	★	□	★
Nereidae																
Ceratonereis aequisetis								□	□		□	★		★	□	★
Spionidae																
Pseudopolydora gibbisi												□		★	□	★
Prionospio aucklandica								★			□					
Prionospio tatura								★				□				
Pectinariidae																
Pectinaria antipoda								□								
Lumbrinereidae																
Lumbrinereis cf. *latreilli*								□								
Cirratulidae																
Cirratulus sp.								□								
Hesionidae sp.											□					
Mollusca																
Psammobiidae																
Soletellina alba								★	□							
Veneridae																
Katelysia scalarina								□		□						
Tellinidae																
Tellina margaritina								□								
Bullidae																
Bulla quoyii								★								
Dialidae																
Diala suturalis								★								
Trochidae																
Thalotia conica								□								
Litiopidae																
Alaba monile								□								
Batillariidae																
Batillaria estuarina								□								
Hydrococcidae																
Hydrococcus brazieri											★					
Pomatiopsidae																
Coxiella sp														□	□	
Hydrobiidae																
Aschoris occidua															★	★
Crustacea																
Corophiidae																
Corophium insidiosum								★	□	□	□	□		★	□	
Melitidae																
Melita sp.								□		★	□	□		★	★	
Aoridae																
Grandideriella sp											★	★				
Palaemonidae																
Macrobrachium sp 1													□		□	
Macrobrachium sp 2															□	
Sphaeromatidae																
Exosphaeroma serventii															★	□
Insecta																
Chironomidae																
Cladopelma curtivalva	□	□	□	□	□	★										
cf. *Chironomus alternans*								★	□	□	□	□				
Chironomidae sp 1											□	★				
Chironomidae sp 2													★	★		
Dicrotendipes conjunctus															★	□
Kiefferulus sp 1															★	★
Ceratopogonidae sp		□														
Ephydridae sp												□				
Leptoceridae sp	□	★			★	□	□							□	★	
Philorheithridae sp													□		★	★
Nymphulinae sp 1															□	
Total species for each lagoon			**4**				**3**					**25**				**17**

Project Title

Macrophyte – invertebrate interactions in selected estuarine systems on the Southwest Coast of Western Australia

Vanessa Forbes, Phd Student, Botany Department, University of Western Australia, Crawley WA 6907. vforbes@cyllene.uwa.edu.au Supervisor: Associate Professor Di Walker.

Summary

Many studies have been done to gain knowledge and understanding of the individual components that make up our estuarine or coastal lagoon systems on the South Coast of WA. These studies have been localised to particular systems of interest, and the focus mainly concentrated on fish populations and biology, submerged aquatic macrophyte–particularly *Ruppia megacarpa*, and anthropogenic influences. Few invertebrate studies have been done and little is known of these organisms or their specific roles in these systems. While we can draw on knowledge gained through studies in similar systems, from the same or different regions or even other parts of the world, it is difficult to ignore the individual character of each system based on its own physical, geological and biological features.

In general we know that each component has its role to play in the system. Macrophytes stabilise sediments, oxygenate waters and sediments, act as a source and sink for nutrients, and provide habitat space for invertebrates–including shrimp, and vertebrates–particularly larval and juvenile fish. Invertebrates themselves return detritus (dead plant material) as nutrients to the sediments and are a valuable food source for larger organisms, namely fish, in the food chain. Apart from the pleasure we gain from 'dropping in a line' at the weekend, fish also have their role to play in the system, acting as detritivores recycling dead organic matter or predators controlling invertebrate or smaller fish populations. These are important considerations when considering a healthy system.

My study aims to look at the more specific interactions between invertebrates and macrophytes in two systems: Wilson Inlet and the Wellstead Estuary. These systems differ no only in size, or structure (Wilson being a basin system and Wellstead a channel system), but also in the amount of run-off they receive from rainfall. This in turn influences the chance of a natural-bar opening or the duration that it remains open for and the opportunity to flush itself and receive important marine inputs. The study will involve the collection of a seasonal database of invertebrates, both infauna (those living within the sediments) and epifauna (those living outside the sediment but associated with the sediment surface) in relation to the macrophytes. This will provide information not only of the diversity of the species within the estuaries and seasonal fluctuations in their abundance, but also gives insight into the relationship between macrophytes and invertebrates. Through various experimental techniques, emphasis will then be placed on determining specific links between these components and evaluating the importance of these links relating to the functioning of the system.

Results so far show that the Wellstead Estuary is diverse and abundant in macrophytes, supporting a suite of invertebrates from all representative groups. It is however too early in the study to draw specific conclusions as to how these components interact or their importance.

4. Foreshore survey, results and recommendations

Approach

The Bremer River Foreshore Survey was done using the Stream Foreshore Assessment and Survey Technique developed by Pen and Scott as a guide (Pen and Scott, 1995). Aerial photographs were used in the mapping process which involved recording the:

- fencing status (existing and proposed);
- stock crossings;
- revegetation (present and proposed);
- perennials (present and proposed); and
- piezometers.

Landholders provided information on the historical and Aboriginal significance of the river, anecdotal recordings- especially in regard to water quality, flora and fauna and the future management plans. This added another dimension to the overall picture of the Bremer River.

Stream foreshore assessment and survey technique

Pen and Scott's Foreshore Assessment Survey proved inexpensive and an efficient means of assessing the main channels of the Bremer River and Devils Creek. Pen developed this technique from observations on rivers of the South West of Western Australia. For this reason, the survey was adapted to suit the south coastal Bremer River.

The assessment technique classifies the condition of the foreshore as being in A, B, C or D grade (see photos over) which represents respectively a pristine foreshore to a completely degraded foreshore. Pen and Scott's technique breaks these grades down further, fore example A1, A2, A3, B1, B2 and so on, to provide a more detailed assessment, but for this survey a broader picture was required. The grading system is outlined below and illustrated in Figure 4:1.

A GRADE FORESHORE

Pristine – slightly disturbed.

A grade is where the foreshore has health native bush, similar to that which you se in most nature reserves and national park

B GRADE FORESHORE

Good condition.

B grade is where the bush along the strea is in relatively good condition, howeve some weeds have started to colonise th bush.

C GRADE FORESHORE

Erosion – prone.

C grade is where the foreshore supports onl trees over weeds or pasture. Bank erosio and sedimentation may be occurring.

D GRADE FORESHORE

Ditch.

D grade is where the stream is little mor than an eroding ditch or drain.

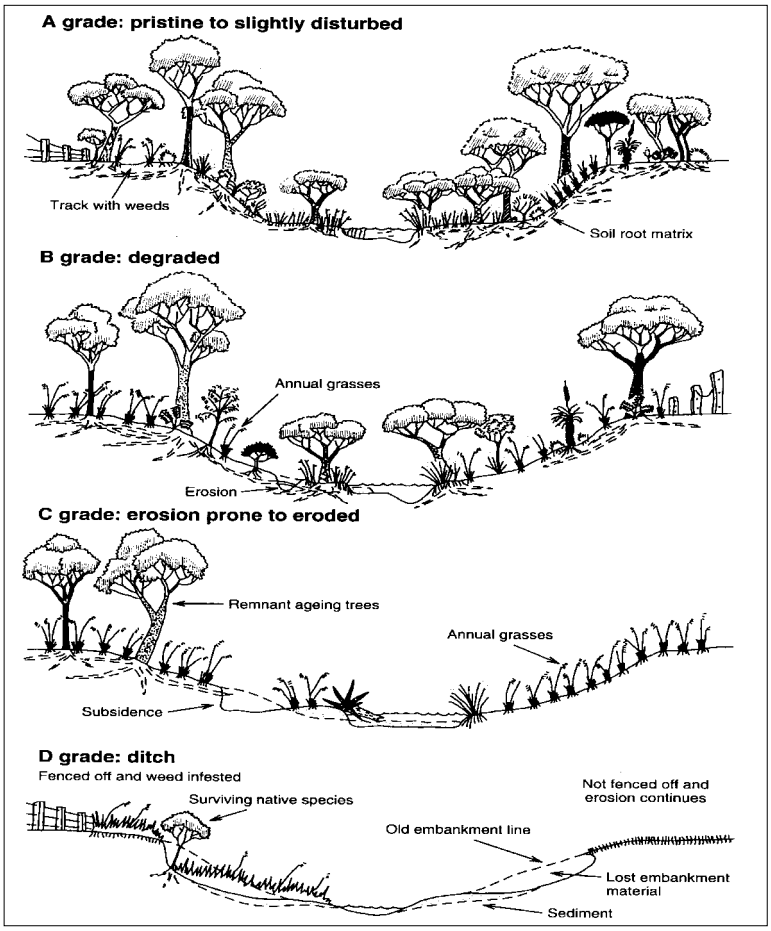


Figure 4:1. Stages of degradation on river foreshores (Penn and Scott, 1995)

A Grade vegetation of the Bremer River – near pristine

B Grade – note the weeds and slight disturbance in the understorey

C Grade – note the soil disturbance, lack of native understorey and presence of weeds

D Grade – note the erosion, lack of vegetation, visible salt and presence of salt tolerant plant species such as Samphires and saltbush

Management issues

The management issues faced by the landowners varies throughout the catchment due to; the location within the catchment, past and current management practices, fencing status and livestock access. These management issues are summarised below.

Loss of native riparian vegetation

In the cleared area of the upper Bremer catchment, only areas where fringing vegetation is backed by substantial remnant vegetation, or where it has been fenced off for a long time, is the integrity of the riparian vegetation secure. Areas that have been disturbed through clearing, grazing and erosion have altered vegetation communities and the understorey native species have been replaced with exotics such as wild oats and veldt grass.

Introduced grasses and other weeds do not support the river banks because they do not create a deep soil-root matrix like native vegetation. This can lead to erosion. The importance of riparian vegetation and the effects of its removal have been discussed early in this report.

Weed invasion

Weeds displace native species, altering the diversity and interactions of the flora and its value for fauna. Weeds are plants which provide no use to humans; they grow where they are not wanted. They establish and reproduce quickly and are 'disturbance opportunists' that rapidly invade disturbed areas before the native vegetation has a chance (Hussey *et al.*, 1997).

In cleared areas of the Bremer River, weed establishment has flourished and they dominate the understorey in many remnant areas. Animals, wind and water disperse seeds enabling even areas in pristine condition to become disturbed by weeds.

Effects of weeds on bush

Weeds can impact the bush by:

- competing directly with established native vegetation, inhibiting growth and displacement of native species;
- replacing diverse native plant communities with more uniform weed communities;
- inhibiting native plant regeneration through competition;
- altering the nutrient cycling of natural communities;
- changing the soil acidity;
- increasing the fire hazard; and
- altering the resources available for fauna by:
- changing the habitat and
- changing the food availability.

Useful references in weed management (Hussey *et al.*, 1997)

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Hussey, B.M.J., and Wallace, K.J., 1992, *Managing Your Bushland*. Department of Conservation and Land Management, Perth.

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Scheltema, M., and Harris, J., (eds), 1995, *Managing Perth's Bushlands*. Greening Western Australia, Perth.

Erosion and siltation

Banks sometimes naturally erode on bends, however when vegetation is cleared, they can become unstable causing extensive erosion along the floodway and the build up of sediment that is slowly washed downstream (Water and Rivers Commission, 1999).

Erosion occurs mainly in the upper reaches of the Bremer River and Devils Creek. The channel was not evident when first cleared but eventually, after winter rains on cleared and cultivated lands, the channel became more defined and eroded into the farmland. Where the land is cleared to the channel edge, undercutting of the banks and erosion is occurring. This erosion removes a large amount of sediment, washing it downstream where it deposits in neighbouring properties. Siltation is presenting a problem in Devils Creek, especially in the upper catchment, where the original creek line has filled with sediment and a new channel has formed. This is widening the area where water flows, threatening vegetation and farmland.

Erosion not only causes a valuable loss of soil, it also affects the system downstream where it contributes to a significant level of sediment deposition and silting-up of the channel. Management issues as a result of erosion and siltation on the Bremer River and Devils Creek include an increase in erosive power of stream flow, increased flood potential due to the silting up of the channel, widening of the channel and flood plains threatening vegetation and farmland.

Salinisation

Areas affected by salinity are evident on both Bremer River and Devils Creek. They can be separated into two distinct saline communities: areas that have been saline for a long period of time and areas that have only recently[3] succumbed to salinity. The areas that have been saline for a long time are void of tall trees and are vegetated with the Chenopod, samphire. Some of these areas have been revegetated using salt-bush with varying degrees of success.

The areas that have only recently succumbed to salt, are surrounded by tall Yate trees (*Eucalyptus occidentalis*), saltwater paperbarks (*Melaleuca cuticularis*) and samphire understorey. Salinisation of farmland is a major concern of the landowners in these areas because they are worried that the salt will encroach on productive farmland. The current realisation is that the rising water tables must be addressed and controlled to stop the mobilisation of stored salts. To address the rising water tables and prevent salinisation of farmland landholders need to use more water higher up in the landscape. This may include planting perennials such as lucerne, or planting trees higher up in the catchment, or implementing water management control devices.

Breaks in ecological corridor

The loss of native riparian vegetation and replacement with monocultures and exotics breaks up the ecological corridors used by mammals and birds. Some areas along the Bremer River and Devils Creek have little native vegetation, especially native tree species. Ecological simplification in rural environments has reduced species diversity and several species of flora and fauna. Fragmentation of native vegetation in the Western Australian wheatbelt has led to significant impacts in the form of either extinctions or loss of viable populations of flora and fauna (Hobbs, 1987).

Refuse disposal

The river has been used by individuals for the dumping of sheep carcasses, old wire and old machinery. The effects from this dumping are unknown but, being in such close proximity to the river, there is concern for the water quality.

A large amount of rubbish, from machinery to domestic refuse, has been dumped approximately 40 metres on the western side of the Bremer River on Devils Creek Road. This site is an old Shire gravel pit and the Jerramungup Shire intend to address this issue.

The Gairdner Community's refuse disposal site is located less than a kilometre from Devils Creek in the upper catchment. This is a landfill site with old pits covered and new pits excavated to an approximate depth of two metres. The implications for the environment are unknown.

Foreshore condition summary

The key issues identified by the landholders in regard to waterways management include salinity, erosion, loss of riparian vegetation, rising water table, sedimentation and rabbits.
From the anecdotal recordings, landholders have noticed that the waterways have become more saline.

[3] *Recently defined as in the last decade.*

From the anecdotal recordings, landholders have noticed that the waterways have become more saline. In the early years, (1960s), the waterway was nearly fresh in various locations and yabbies were present. Other observations of fauna, both recently and in the past, have included turtles, bream and native minnows. The landholders have also seen the decline of the Yate trees, whether it be attributed to fire, salinity or inundation.

Landholders have noted flood events on various occasions, especially in 1988. Degradation of the waterway can be attributed in part to the floods. Flood events have caused erosion, redirection of the main channel, uprooting of vegetation and sedimentation of the channel.

Since clearing in the 1950s the Bremer River and Devils Creek have been used for watering stock, swimming, grazing, sand/gravel extraction, rubbish dumping and water pumping. However, no one swims in the waterways anymore and very few landholders still engage in any of these activities.

The previous restoration work carried out in the Bremer River catchment includes fencing, revegetation and the construction of contour banks. Protection and restoration were undertaken for he following reasons:

- presence of poison pea bush;
- non-arable land;
- for conservation; and
- for the protection of farmland from erosion or salinity.

The landholders have learnt many lessons and seen many improvements. Many feel that the land was over-cleared and that those mistakes are now apparent on the landscape. Every year, landholders, engaged in revegetation activities, are learning what does and does not work.

Future management plans are illustrated in the Action Plan map. This involves various combinations of fencing, revegetation and perennials to combat the key issues specific for each location. Perennials are being used more effectively in recharge areas, to combat rising water tables because they use more water. Some landowners have already used perennials, such as lucerne, tall wheat grass or Rhodes grass.

Piezometers are a useful tool for monitoring groundwater movement. Many landholders within the catchment already monitor piezometers regularly and it is proposed to install more of this useful tool.

Reading the maps

The Bremer River catchment was separated into individual locations to make surveying easier (see Map 2 opposite). The following maps and information detail the foreshore condition and management recommendations.

The site information was provided by the landowners and from on-site observations. The information covers:

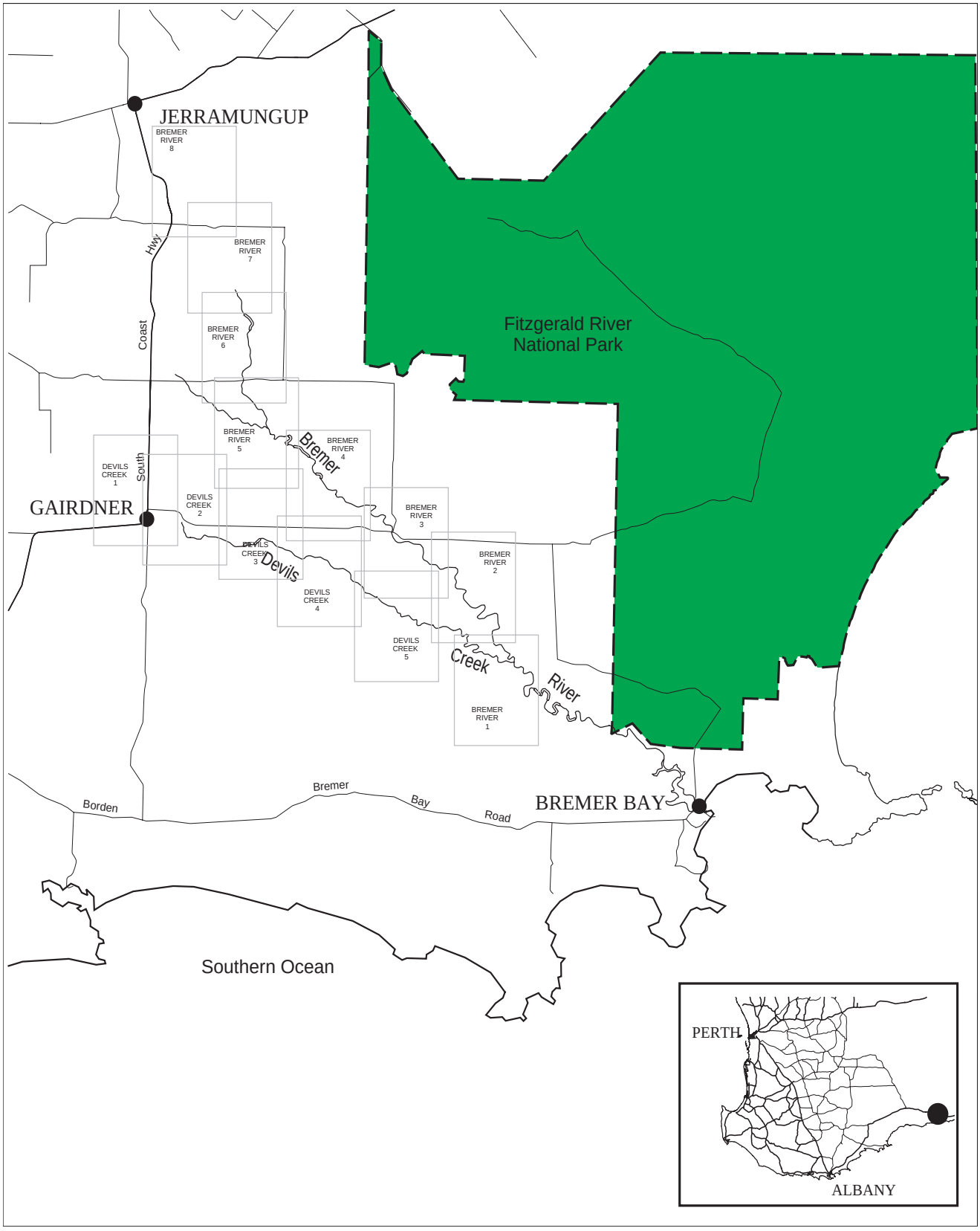
- key management issues;
- foreshore condition descriptions and grades;
- Heller and Brown's (1996) comments on vegetation condition;
- management recommendations;
- anecdotal recordings;
- flood effects;
- uses of river/creek;
- historical stories;
- previous restoration work and why it was done;
- lessons learnt/improvements seen;
- future management plans;
- perennials: present/planned; and
- piezometers: present/planned.

The maps illustrate existing works including:

- fencing status;
- stock crossings;
- revegetation;
- perennials; and
- piezometers.

The maps show the foreshore condition grades with corresponding colours. The grades are as described in Figure 4:1.

Note: *Map 1 shows the foreshore condition for the entire Bremer River Catchment, comprising of the three sub-catchments, Carlawillup, Bremer River and Devils Creek (located in the pocket inside the front cover). Map 2 is the key to the 13 individual maps that show more detail and are labelled Bremer River 1–8 and Devils Creek 1–5. Landholders can find their property by referring to Map 2. The site information is described for each individual location and is titled according to the Kent Location number.*



Map 2 (showing the individual locations Bremer 1-8 and Devils Creek 1-5)

Index – Map 2

Map No.	Location	Pages (between)
Bremer River		
8	1288, 1287	4:10 – 4:11
7	1392, 1391	4:12 – 4:13
6	1397	4:14 – 4:15
5	1463, 1464, 1465	4:16 – 4:17
4	1480, 1481, 1479	4:18 – 4:19
3	1482, 1486, 1485, (pt) 1874	4:21 – 4:22
2	(pt) 1874	4:22 – 4:23
1	1922 (in Devils Creek Section)	4:22 – 4:23
Devils Creek		
5	1514, 1515, 1922 pt 1487 (pt)	4:24 – 4:25
4	1487, 1488, 1489 (pt)	4:26 – 4:27
3	1489, 1490, 1479, 1491 (pt)	4:28 – 4:29
2	1491 (pt), 1492, 1476, 1475	4:30 – 4:31
1	1476 (pt), 1474, 1473, 1475 (pt)	4:32 – 4:33

LOCATION 1288 MAP SHEET: BREMER 8

Catchment: Carlawillup

Key issues: Encroaching salinity.

Condition: Classified as B grade vegetation by Kaylene Parker in 1998.

Heller and Brown (1996) Comments: Yate Woodland (70%) and Riverine Yate/Melaleuca (30%). Overall condition 'modified', some areas alright, better further from creek. Old and young seedlings where area is fenced. A lot of introduced grasses. Creekline is very salty. Banks quite well vegetated but there is a high incidence of exotic grasses and pasture plants.

Recommendation: Fence off proposed areas.

Flood levels: Flood in 1988 caused water erosion in depressions that had been cleared.

Anecdotal Recordings: Over the last 25 years it has got noticeably saltier, but not much has changed in the last seven years.

Previous restoration works: Fenced out most of river.

Why restoration done: To stop degradation by stock.

Future management plans: Fence out tributaries and revegetate one eastern tributary-consider using profitable trees e.g. sandalwood.

Perennials: Plans for lucerne in one paddock lying south of tributary, to assist with salinity problems. This could be done in 2000.

Piezometers: One located north of Bremer River on Scott Creek. Last reading 5.7 m but this is approximate. Previous readings have indicated 6 m.

LOCATION 1287 MAP SHEET: BREMER 8

Catchment: Carlawillup

Condition: Only fenced part of the way either side. The site was not visited but aerial photos were used.
Classified as B grade.

Heller and Brown (1996) Comments: Yate Woodland (80%) and Riverine Yate/Melaleuca (20%). Overall condition 'modified'. Understorey is grazed but not continually. Young yates-regeneration of trees but understorey is not regenerating. Area fenced but sheep graze. Entire remnant lacks species. Area, although fenced is grazed, but not continually as there is little water. Landowner plans to remove the fence on the Eastern side so that sheep can get to the dam.

Recommendations: Carry out proposed fencing and restrict stock access.

Anecdotal recordings: River has become saltier.

Use of river: Use freshwater at Carlawillup Rockhole, (for mixing with chemicals for spraying).

Historical stories: At Carlawillup Rockhole there are foundation stones from the 100-year-old house. It was also a stock watering hole for the Hassells, the first settlers of Jerramungup, when travelling their sheep. Aboriginal significance exists. '*Yarra-mo-up: place of the tall yate trees'* by Roni Forrest and Stuart Crowe, mentions Carlawillup Rockhole as a significant dance and meeting place for Noongars of the area in earlier times. This was where they used to meet for religious ceremonies and gathering and trade. Some items traded with other groups were ochre and baby girls. Informant A recalls being told they traded baby girls to keep the 'bloodlines fresh in order to prevent in-breeding with the tribes'. Carlawillup Rockhole was called Carlawilgieup, meaning fire (carl) and ochre (wilgie), the place where people met and held ceremonies. Other local knowledge holders refer to this place as 'Carlawirrup' (Forrest and Crowe, 1996).

Previous restoration works: Fenced out some of the river.

Future management plans: Fence out tributaries and parts of the river.

LOCATION 1391 MAP SHEET: BREMER 7

Catchment: Carlawillup

Key issues: Salinity.

Condition: Fenced off. Part of Carlawillup Rockhole is a reserve. Classified as A grade.

Heller and Brown (1996) Comments: Riverine Yate/ Melaleuca (20%), Yate Shrubland (30%), Mallee Heath (30%) and Casuarina Woodland (20%). Overall condition is 'very good'. All fenced due to poison. Remnant very dense. Shrubs are extremely large. Area fenced due only to rocks (granite) and poison. Much of remnant recently cleared.

Recommendations:

Anecdotal recordings: River has become saltier.

Previous restoration works: Fenced waterways on property.

LOCATION 1392 MAP SHEET: BREMER 7

Catchment: Carlawillup

Key issues: Salinity (on the tributary flowing parallel to Bremer River).

Condition: Northern section of the river is fenced off, covenant number on it as part of Remnant Vegetation Scheme. It is in very good condition, classified as A grade. Section below this is unfenced. Few dead Yates, but a lot of healthy Yates. Mixed vegetation, with Melaleucas, Yates, Casuarinas etc. Classified as B grade condition, weeds present, grazed periodically throughout the year, regeneration apparent. Good stand of saplings. Fenced section below this is in similar condition, classified as B grade. Creekline cuts very close to fence in one point. Bottom fenced section, below stock crossing is in good condition, classified as A grade.

Heller and Brown (1996) Comments: Riverine Yate/ Melaleuca (20%), Casuarina Shrubland (40%) and Mallee Heath (40%). Overall condition of remnant is 'very good'. Fenced section of remnant is excellent-very dense, high plant diversity. Large variety of orchids.

Recommendations: Carry out proposed fencing, especially on the eastern tributary that runs parallel to Bremer River. Restrict stock access. Revegetate saline tributary and use perennials higher in the landscape.

Anecdotal recordings: River has become saltier

Previous restoration works: Fenced out some of the river.

Future management plans: Fence out tributaries and parts of the river. Establishment of lucerne pasture near the tributary that is going saline to address rising water tables.

Perennials: In future, use lucerne pasture.

Piezometers: Four piezometers near the tributary, the piezometer in salt patch reads at 30 cm, the water table is very close to surface. Other piezometers read 4-5 m.

LOCATION 1397 MAP SHEET: BREMER 6

Catchment: Carlawillup

Key issues: Loss of riparian vegetation, erosion and salinity.

Condition: The condition varies along the river. The southern section is in good condition, with dense vegetation. The Yates are healthy, with some large dead yates which probably died due to fire – evidence of charcoal on trunks. The understorey is predominately native sedges, with exotic weeds. No fences, livestock currently grazes. This section is graded as B. Suitable for application to Remnant Vegetation Scheme.

The middle section is lacking riparian vegetation, especially on the eastern side where there are no trees, only a few native sedges and weeds. Some undercutting of the bank is occurring and there is a large amount of sediment in the channel. An old fence is present for approximately 2.5 km on the western bank but does not restrict access to stock at either end. On western bank, rabbits are abundant. Classified as C grade.

From aerial photos the northern section appears to be in good condition and it is quite a wide remnant. The eastern bank may partially be degraded. Presume unfenced. Classified as B grade.

Heller and Brown (1996) Comments: Not surveyed.

Recommendations: Fence out river.
Restrict stock access.
Revegetate both sides.
Rabbit control on western bank.

Flood levels: Sediment washed downstream and erosion.

LOCATION 1463 MAP SHEET: BREMER 5

Catchment: Carlawillup

Key issues: Erosion and salinity of farmland adjacent to Kombi Creek.
No issues in regard to Bremer River.

Condition: The Bremer River area has never been cleared or grazed as poison is present. Fenced entirely. It was subject to a fire which killed the Yates (year unknown but a long time ago). Saplings of Yates present. Weeds on perimeter in some sections. Classified as A grade - near pristine, only slightly disturbed. A granite mine is present but no classification will be allocated to this.
Kombi Creek is a minor tributary of Bremer River that flows from north-west to meet up with Bremer River in Location 1464. Only some sections fenced, but the current owner has fenced most of the creek out with only the southern fence to be finished, (the posts and top wire are done). A fire passed through a section approximately 15 years ago. Sheep can longer drink the water.

The western section is in good condition, with very few weeds on the perimeter, there are excellent stands of Moort in various stages, classified as A condition.

The eastern section, using the stock crossing as a divide, is not as wide as the western section and has obviously been impacted on by sheep. The creek has split into two channels, with the southern one eroding. The vegetation, however, is in good condition. Overall classification for this eastern section is B. It is going to be fenced and stock restricted.

Heller and Brown (1996) Comments: Mallee Shrubland (40%) and Riverine (60%). Overall condition 'good'. Eastern half is degraded, only the river area is left. Not many weeds but signs of grazing leading to reduction in species diversity. Along the river, rabbits appear a problem. Some dead sheep and refuse disposal. Not all the remnant is fenced but finance is approved for the southern section of remnant to be fenced. Good areas of remnant on western boundary, eastern boundary very narrow and degraded in parts.

Recommendations: Fence proposed areas, especially the southern tributary of Kombi Creek.

Anecdotal recordings: Kombi Creek has become saltier, was once used as a stock watering hole. Turtles found in Bremer River. Bream were once found in pools.

Use of river: Kombi Creek was used to water stock in the past.
Granite mined on western side of river approximately 1.5 km west of the main channel.

Previous restoration works: Fenced out Bremer River and in process of fencing Kombi Creek.

Why restoration done: Presence of poison, and stony country.

Future management plans: Carry out proposed fencing. Fence out salt-affected farmland and revegetate.

Perennials: Consider salt bush for revegetation of salt affected land.

LOCATION 1464 MAP SHEET: BREMER 5

Catchment: Carlawillup

Key issues: Erosion.

Condition: Classified as B grade along the whole river section, except near a western tributary, which is suffering from water erosion with undercutting of banks and removal of riparian vegetation. Little vegetation is present in some parts of this section and it is therefore classified as C grade. The rest of the river has been grazed and has therefore been infested with weeds. The understorey is largely dominated by weeds and dead yate trees are present in the channel. No erosion evident. It is fenced off and some areas would benefit from direct seeding or revegetation with seedlings but generally the vegetation is in good condition.The fencing has incorporated area previously pastured with wide buffer zones infested with weeds and little native vegetation.

Heller & Brown Comments: Riverine Shrubland, Casuarina Woodland and Breakaway. Overall condition 'very good'. Exotic grasses present but it is not too bad. Burnt, dead mature age Yates. Regenerating. Remnants fenced back from vegetation line. No regeneration of native species beyond orginal line, possibly due to soil compaction.

Recommendations: Revegetate wide buffer zones.
Revegetate eroded tributary.

Anecdotal recordings: Observed turtles and native minnows.

Use of river: Water was once pumped out of the freshwater pool but it is saline now. Evidence of past grazing.

Previous restoration works: Fenced 9 years ago (natural regeneration occurred after fencing).

Future management plans: Fence out all minor tributaries.

Perennials: None

LOCATION 1465 MAP SHEET: BREMER 5

Catchment: Carlawillup

Key issues: Erosion.

Condition: Classified as B grade along the entire river section except near a western tributary which is suffering from water erosion with undercutting of banks and removal of riparian vegetation. Little vegetation is present in some parts of this section and is therefore classified as C grade. The rest of the river has been grazed and has therefore been infested with weeds. The understorey is largely dominated by weeds and dead yate trees are present in the channel. No erosion evident. It is fenced off and some areas would benefit from direct seeding or revegetation with seedlings but generally the vegetation is in good condition. The fencing has incorporated previouly pastured areas with wide buffer zones infested with weeds and little native vegetation.

Heller and Brown (1996) Comments: Mallee Heath and riverine shrubland. Understorey dominated by exotic grasses. Weeds are mainly in the creekline. Soil movement. Remnant is all riverine vegetation. Mallee areas cleared to edge of melaleucas. Lot of dead Yates but these have been burnt (not saline). In general vegetation quite dense.

Recommendations: Revegetate the buffer zones.
Revegetate eroded tributary.

Anecdotal recordings: Observed turtles and native minnows.

Use of river: Used to pump out of the freshwater pool years ago but it is now saline. Evidence of past grazing.

Previous restoration works: Fenced 9 years ago (natural regeneration occurred after fencing).

Future management plans: Fence out all minor tributaries.

Perennials: None

LOCATION 1479 MAP SHEET: BREMER 4

Catchment: Bremer River

Key issues: Erosion from minor tributaries.

Condition: Tributary running through the centre of farms is classified as A in broad vegetation section, weeds are present but there is still a dominant native understorey. Some sedimentation has occurred in the creekline of this tributary. Small tributaries running into this range from B to C grade. All fenced off, or currently being fenced, with some revegetation by seed. Success of this revegetation by direct seeding is varied. One tributary fenced and revegetated but the understorey is minimal. Landowner noted this reduced the odour from stagnant water during summer. Presence of odour in summer, and algae indicate slight nutrient enrichment.

Heller & Brown Comments: Very good condition. Mallee Shrubland. All fenced, ungrazed.

Recommendations: Carry out proposed fencing and continue with revegetation work.

Anecdotal recordings: Change in water quality of the tributary that runs through the centre of farms, it was fresh in 1959 but turned salty late 1970s. Native (striped) minnow present in pools. A dead turtle was found a few years ago on the track (stock crossing) in the path of the tributary. Trout sighted in early 1960s.

Previous restoration works: Revegetation and fencing. Contour banks.

Why restoration done? Fenced off vegetation as poison plant present, sandy soils and some areas inhospitable ie. rocky, steep (rough country).

Any lessons learnt? Improvement seen?
Revegetation involves planting 4000 seedlings. Survival rate of 200-300 seedlings.

Future management plans: Fencing off tributaries.

Perennials: Rhodes grass planted adjacent to the tributary that runs through the centre of the farm. Lucerne planned for 2000 in a lower paddock to address salinity issues (not significant to Bremer River).

LOCATION 1480 MAP SHEET: BREMER 4

Catchment: Bremer River

Condition: The Bremer River is classified as A grade. It has never been cleared, fenced or had stock. Weeds are present on the perimeter but the native understorey is still present. Vegetation varies from Yate woodlands near river pools to dense Sheoak (Casuarina) Woodlands. The pool that was visited is not as salty as seawater (approx. 20mS/cm). No aquatic vegetation in the pool.

Heller and Brown (1996) Comments: Degraded to the east where it meets the Bremer River and remnant bush. Mallee Shrubland and Riverine (Yate/Melaleuca/Mallee Shrubland). Overall rating 'good condition'. Evidence of past grazing.

Use of river: Pool visited on the Bremer River had evidence that it was used by previous owner for stock watering.

Previous restoration works: Pines planted near river to stop sandy blowout.

Future management plans: Fencing off of tributaries west of Bremer River.

LOCATION 1481 MAP SHEET – BREMER 4

Catchment: Bremer River

Condition: Varies from A grade to B to C in different sections. C grade appears to have erosion, sedimentation and little vegetation present (from aerial photos). B grade probably weed-dominated understorey, as river is grazed. Not fenced immediately adjacent to river.

Heller and Brown (1996) Comments: Not surveyed.

Recommendations: Fence out river.
Restrict livestock access.

Use of river: Grazing by sheep, protection for sheep when lambing.

LOCATION 1482 MAP SHEET: BREMER 3

Catchment: Bremer River

Key issues: Vegetation decline.

Condition: The Bremer River is classified as B-C grade. It is only fenced in two sections, recently grazed, human disturbance with tracks, vegetation not very wide in one section. Large pools and granite outcrops.

Heller and Brown (1996) Comments: Banksia shrubland. Overall condition 'very good'. No fencing, edges grazed. Very good Banksia shrubland, although unfenced, good vertical strata. Very large banksias. Remnant unburnt.

Recommendations: Fence out river and allow to naturally regenerate. Middle section has a small buffer zone of vegetation, needs to be widened and revegetated.

Anecdotal recordings: Black bream present in river in 1960s. Native fish (minnows) present.

Use of river: A tributary dammed at one point, rubbish present (old metal etc) in one remnant.

Previous restoration works: Fenced off two sections. Contour banks.

Why restoration done? Fenced off some vegetation as poison pea plant present.

Future management plans: Landowner selling property, WRC offered $600/km fencing, unlimited amount for the river area, pass this information to purchaser.

Perennials: Some perennials trialed near vegetation adjacent to river, only Veldt Grass still present.

LOCATION 1485 MAP SHEET: BREMER 3

Catchment: Bremer River

Condition: Classified as A. Fenced off, no grazing. Has aquatic vegetation in some parts and overhanging riparian vegetation. Very healthy mallee scrub and Yate woodlands.

Heller and Brown (1996) Comments: Remnant not surveyed.

Anecdotal recordings: Turtles present in flood years. Native fish caught in dam adjacent to the river (size approx 15 cm, silver colour, width of finger).

Flood levels: Flood in 1988.

Use of river: Past owner pumped out some water for stock.

Previous restoration works: Fenced.

Piezometers: One near river, reading says water table approx. 22 m below surface.

LOCATION 1486 MAP SHEET: BREMER 3

Catchment: Bremer River and Devils Creek

Key issues: Salinity and erosion.

Condition: Bremer River: Always been fenced off, few weeds on perimeter but overall condition of Mallee Scrub is very good, classified as A. Area to the north-west, understorey dominated by weeds, but generally in good condition. Some old machinery dumped. Refuse disposal site to north of property on crown land.

Devils Creek corridor is heavily eroded and weeds present. South fence erected in 1998, under the Remnant Vegetation Scheme. Natural regeneration of understorey and tree species. Erosion to the south of the creekline, as continuation from Location 1487 on the western side where channel has changed direction, causing erosion in he paddock. This has been incorporated into the fence line with a large buffer zone. Vegetated area is classified as B grade and eroded area classified as C. Overall a C.

Heller and Brown (1996) Comments: Devils Creek Corridor has good remnant in the east, degraded remnant in the west. Open Woodland (50%) and Riverine (50%). Overall condition 'modified', stock have badly degraded this remnant. In most parts only there is only one tree layer and exotic weeds as understorey. High percentage of weeds. Nearly all the *Hakea nitida* are dead, eucalypts alright there is no regeneration. A lot of dead shrubs, fire will probably help to regenerate. Lots of exotic grasses. In 1996, current owner was going to fence creek line, as there were no fences. A lot of silt and sand deposits along creek line and outside of vegetation (creek has made new course into paddock).

Recommendations: Revegetate Devils Creek corridor.
Renew boundary fence near Bremer River.

Flood levels: Obvious that a flood year caused the erosion and redirection of the channel.

Use of river: Old gravel pit near the Bremer River, now used as refuse disposal site (crown land), some machinery dumped in an area to the north-west of the river.

Previous restoration works: Fenced out entire Devils Creek. Other remnants on the farm fenced under the Remnant Vegetation Protection Scheme.

Future management plans: Renewing fences, especially boundary fence near Devils Creek.

LOCATION 1874 MAP SHEET: BREMER 2

Catchment: Bremer River

Condition: Classified as A. Fenced off, no grazing, only a few weeds present. Has aquatic vegetation in some parts and overhanging riparian vegetation. Very healthy mallee scrub and Yate woodlands. Only slightly disturbed near stock crossings. South West Bay tributary fenced out.

Heller and Brown (1996) Comments: Mallee Shrubland and Riverine. Overall condition 'good'. Very old vegetation. Remnant vegetation is old and has not been burnt for several years but is in good condition.

Anecdotal recordings: Turtles present in flood years.

Flood levels: Flood in 1988, some sediment build up in flood years.

Use of river: Pumped out some water for stock in dry year.

Previous restoration works: Fenced.

Why restoration done? Fenced off when arrived, poison pea present.

Future management pans: Thicken up revegetation in other parts of farm

LOCATION 1514 MAP SHEET: DEVILS CREEK 5

Catchment: Devils Creek

Condition: Only a small part of the creek flows through this property on the very north-eastern corner of the boundary. It is and always have been fenced off and has not been grazed for 15-20 years. The understorey is dominated by weeds on the perimeter but is in near pristine/slightly disturbed condition in the centre. The vegetation is Mallee scrub, with Banksia dominant in the understorey. Yates also present. Classified as B on perimeter and A in middle.

Heller and Brown (1996) Comments: Riverine and Mallee Shrubland vegetation communities. Overall condition 'good'. Some weeds along the southern edge of river. Signs of past grazing by sheep. Fenced all around. Rabbits evident.

Anecdotal recordings: Some Yates (salt, inundation, lerp) that died 20-30 years ago.

Flood levels: Flood in 1988 destroyed fences.

Previous restoration works: Revegetation and fencing on other areas of the property.

Why restoration done? Fenced off originally, poison pea plant present.

Future management plans: Revegetation and fencing works throughout the rest of the farm.

Perennials: Saltbush planted for revegetation on the property but not adjacent to the creek.

LOCATION 1515 MAP SHEET: DEVILS CREEK 5

Catchment: Devils Creek

Condition: Deeply incised. Never been cleared, except for a portion south of the creek which was chained when first cleared. It has since been entirely fenced off and natural regeneration has occurred. Healthy system, Yates in good condition. Classified as A condition.

Heller and Brown (1996) Comments: Part of Devils Creek Corridor: river system, all fenced. Good remnants either side. Riverine (20%), Mallee Shrubland (10%), Mallee Heath (60%) and Floodplain, Eucalyptus shrubland (10%). Vegetation was originally bulldozed to the river. Has regenerated well, little senescence. Bush is in excellent condition for the entire remnant. Very dense along the river, little to no sign of damage in this area. Fenced for 15 years.

Flood levels: In 1988, a flood washed out the stock crossing which is now covered in regenerating vegetation. A new stock crossing was established.

Previous restoration works: Fenced out, revegetation on other parts of the farm. Revegetation on the minor tributary was carried out 12 years ago.

Why restoration done? Presence of poison pea plant but if cleared it would cause massive erosion problems.

Any lessons learnt? Improvement seen?
Revegetation very successful, especially useful for stock protection.

Future management plans: Further fencing and revegetation of areas on the rest of property.

LOCATION 1922 MAP SHEET: DEVILS CREEK 5

Catchment: Devils Creek

Condition: Never cleared (except a small area adjacent to the river which is now fenced and regenerating). Classified as A condition.

Heller and Brown (1996) Comments: Not surveyed.

Recommendations: Carry out proposed fencing.

Anecdotal recordings: Various pools retain water all year. Turtles and unhealthy yabbies present. Noticeably saltier.

Flood levels: In 1988, the creek in the western section flooded out into the paddock. As a consequence it is planned to fence out this area.

Use of river: Pumped water out of the Bremer River for use as stock.

Previous restoration works: Always been fenced. A new fence has been erected on the southern boundary of the creek to the west. Fenced remnants throughout the farm, noticed regeneration in areas where the stock have been excluded and fences erected.

Future management plans: Fence out a section in the west that the creek claims in flood years, and fence out vegetation to the east.

LOCATION 1487 MAP SHEET: DEVILS CREEK 4

Catchment: Devils Creek

Key issues: Erosion.

Condition: Near a stock crossing to the east, the vegetation is in acceptable condition, but throughout is classified as C grade. Dead yates. Understorey dominated by weeds. Obviously grazed.

Heller and Brown (1996) Comments: Creek degraded to the east, average to the west. Overall condition 'very modified'. Highly degraded from constant grazing. Plenty of losses; very few species (low species diversity). No understorey or healthy shrub layer.

Recommendations: Fence off unfenced area.
Restrict stock grazing.
Rehabilitate understorey.

Anecdotal recordings: People once swam in the Bremer River on Location 1481

Flood levels: Flood in 1970s caused the massive erosion, and redirection of the channel in the eastern section.

Use of river: Grazing, excavation sand.

Previous restoration works: Fencing.

Why restoration done? Landowner wants to fence out river but is having difficulty finding the time.

Future management plans: Fence out the entire creekline and restrict sheep.

Perennials: Plans on this location to use lucerne in future.

Piezometers: One located south of the creekline which was dry when installed but has not been recently monitored.

LOCATION 1488 MAP SHEET: DEVILS CREEK 4

Catchment: Devils Creek

Key issues: Concerned about encroaching salinity from the upper catchment.

Condition: Western section, virgin vegetation, never cleared or grazed, there are no weeds except near the stock crossing where the understorey also is dominated by native species. Classified as A.

Eastern sections both classified as B. Middle section was grazed 10 years ago and periodically this year. Weeds dominant the understorey. Little erosion near the stock crossing. The eastern section is similar, grazing stopped 6 years ago, weeds abundant but vegetation community is in good condition with seedlings and saplings of native species present. Little sediment present. Revegetation of the upper banks on both sides with native trees, using seedlings as direct seeding was not successful.

Heller and Brown (1996) Comments: Along the creek it is fenced on the boundaries and the laneway is fenced through middle. Good vegetation to the west, degraded to the east. Riverine woodland and Mallee Shrubland. Overall condition 'good'. Mallee sections on stony ground are very good, Dominance of exotic grasses through the river Modified condition. Small section rubbish present. Revegetate with blue gum and mallees. Half the length of the river has not been grazed for 15 years (middle section). Weeds prominent throughout; otherwise in quite good condition although fairly old. Western section on stony ground never grazed and is in very good condition. Eastern section, that is grazed (fenced) has basically no shrub layer and exotic grasses as understorey; the trees are old but fairly heavily wooded, only the understorey is suffering.

Recommendations: Restrict grazing.

Anecdotal recordings: Creek was once used for swimming and to pump out water but now the salinity levels are too high. Turtles and native minnows have been observed in the past.

Flood levels: Flood in 1988.

Use of river: Stock water and swimming in past. Grazing by sheep in past (and occasionally now or in dry years).

Previous restoration works: Fenced and revegetation. Revegetation is a continual project.

Any lessons learnt? Improvement seen? Did not clear to the river's edge which was crucial to maintain pristine river conditions. More success with seedlings in revegetation than in direct seeding.

Future management plans: Revegetation is an ngoing process.

Perennials: Lucerne planned.

Piezometers: Fourteen piezometers throughout the entire farm. Some indicate that the groundwater is close to the surface.

LOCATION 1489 MAP SHEET: DEVILS CREEK 3

Catchment: Devils Creek

Key issues: Salinity, rabbits and erosion of creek banks.

Condition: Eastern side is in very good condition, classified as A grade. Never been cleared or grazed as fenced off to protect stock from poison.

Western side is very degraded, extensive erosion and sedimentation, little vegetation on banks in some parts, dead yates (salt). Has been grazed previously by sheep but now by cattle. Classified as C grade but very nearly D grade in some places. Used to be 12 ft deep in pool but it is now filled with silt. In 1994,deep ripped rabbit burrows on northern bank, caused erosion.

Heller and Brown (1996) Comments: On the eastern side it adjoins a property with good vegetation. Western section of the roperty is very degraded. Mallee Shrubland (0%) and Riverine (20%). Overall condition 'good'. Very good in mallee, more degraded on the river. No livestock at present, but previously on the river. Ground cover is poor in the riverine section. Salinity evident in small areas. Banks of the river are eroded. Overall comments; river degraded, this section full of exotic grasses which dominate understorey. Numerous rabbits.

Recommendations:
Fence off western section, with wide buffers.
Fence off and revegetate three southern tributaries.
Revegetate both banks.
Rabbit control.

Flood levels: Flood in 1988, extensive loss of topsoil from surrounding paddocks resulting in heavy silting of the creek and the damage is now evident.

Previous restoration works: Eastern section is always been fenced off due to the presence of poison plants. South of the creek, is a tributary of Devils Swamp catchment which has had extensive fencing and revegetation works. This was a definite priority before Devils Creek. Contour banks.

Why restoration done? Presence of poison pea plant.

Any lessons learnt? Improvement seen? Noticeable difference when the sheep were removed. Salinity has not increased and improvements are evident in some parts.

Future management plans: Would like to fence off both banks of creek and also three tributaries which are heavily eroded, followed by revegetation. Interested in removing silt in channel

Piezometers: One located in Devils Swamp catchment, south of Devils Creek.

LOCATION 1490 MAP SHEET: DEVILS CREEK 3

Catchment: Devils Creek

Key issues: Salinity.

Condition: Eastern section is fenced off, it was grazed about 8 years ago. Steep banks, with some erosion. Sedimentation in the channel. Revegetation from 10 years ago is in good condition. Classified as C grade.

Western section is only fenced on one side. The understorey is sparse (rabbits and sheep), and erosion of old tracks is evident. Good vegetation in some parts. Understorey is dominated by sedges. Classified as C grade due to siltation in parts and erosion of old tracks. If fenced off regeneration should occur, provided rabbits are also controlled.

Heller and Brown (1996) Comments: Riverine shrubland and mallee shrubland. Overall condition of remnant 'modified'. Regeneration is not happening due to rabbits. Livestock have access to the southern side but do not greatly impact. Species diversity is fairly low but overall appearance is acceptable. Weeds are fairly localised as sedges predominate on slopes of the river. Ground cover is small and the shrub layer is lacking; very open mallee. Evidence of disturbance through previous grazing and stocking. Probably good if rabbits are removed. Introduced grasses could be a problem. Small amount of salinity and some soil movement along the creek. Degraded mainly through rabbit activity.

Recommendations:
Fence off western section.
Rabbit control.
Restrict stock access.

Use of river: Dumping of sheep carcasses on anthills.

Previous restoration works: Revegetation in the eastern section 10 years ago is fenced off. South of Devils Creek on this location, a tributary of Devils Swamp catchment has been fenced off and revegetated. This was an urgent priority.

LOCATION 1491 MAP SHEET: DEVILS CREEK 3

Catchment: Devils Creek

Key issues: Salinity.

Condition: Eastern section has been fenced since 1959 and is in excellent condition except for the perimeter where weeds have encroached, (blown in by wind). Mallee Shrubland, classified as A grade.

Middle section is partially fenced on the northern side, sheep have access to the southern side of the creek. Vegetation still in reasonably good condition, weeds are present in the understorey, there is little regeneration, classified as B grade.

Western section is fenced off part-way on the northern side but there is no fence on the southern side. Excellent Moort thicket, Yates and Melaleucas. Some Yates have died recently, due to salt. Wild oats and other weeds are present. Rabbit problem. Saline, samphires present. Classified as B grade.

Heller and Brown (1996) Comments: Riverine/Melaleuca Shrubland (20%) and Mallee Shrubland (80%). Overall condition is 'good'. River section is fairly good, Mallee old and grazed. No regeneration. Basically no ground cover but many species, are assumed to be eaten out. Tree layer present, small shrubs have disappeared, mainly poison. Many rabbits. Dense Melaleuca thickets along the river. Few trees, sand areas extremely thick with rabbits.

Recommendations: Carry out proposed fencing, revegetation and perennials.
Restrict stock access.
Rabbits.

Anecdotal recordings: Used to be near-fresh, yabbies present in early years. Has definitely got saltier.

Flood levels: Floods scoured out the south side. Floods cause more erosion and increases the amount of water coming down and new channels forms.

Use of river: Used to water stock, but is now too salty.

Historical stories: Landowner was around when initial War Service Land Settlement Scheme was initiated and was concerned then with salt. Noticed decline in the creek quality four years after clearing.

Previous restoration works: Fenced out eastern section, and parts of the creek to the west. Eastern section fenced in 1959.

Why restoration done? Poison pea plant present and landowner could foresee value of conservation.

Any lessons learnt? Improvement seen? Cleared too much native vegetation and salt problems have arisen. Willing to revegetate large areas of land to address and control salinity.

Future management plans: Fence out the creek, revegetate encroaching saline land, establish lucerne pastures to combat rising water tables.

Perennials: Has planted lucerne in the past, is planning to establish lucerne pastures higher up in the landscape to combat rising water tables and stop encroaching salinity that is occurring downslope in the creekline.

LOCATION 1492 MAP SHEET: DEVILS CREEK 2

Catchment: Devils Creek

Key issues: Salinity.
Sedimentation/silting up of channel.

Condition: The Southern tributary varies in condition. The Western section is fenced one side and not the other. The vegetation is Mallee and Yate, with a few dead Yates in the creekline (lerp, salt, inundation?). Little sedimentation. Classified as B up to the crossing. The middle section is classified as A, it has never been cleared and stock have never grazed the area. A few weeds present on the perimeter but the mallee scrub is only slightly disturbed. The fence exists but needs replacing with trees toppling it in some places. The eastern section of the southern tributary is unfenced and free for sheep to graze, with weeds present in the understorey on the perimeter of the vegetation. Classified as B.

Heller and Brown (1996) Comments: Yate/melaleuca shrubland, riverine yate/melaleuca and casuarina woodland. Overall condition 'modified'. There are old yates dying in some areas and some huge and very old melaleucas present. Unfenced in parts. Absence of medium shrubs and low shrubs. Some sheep grazing. Creek spreads out; banks eroded; deposition on tributaries off farm. Not highly degraded. Little regeneration throughout. Grazing pressures, if removed, would result in an increase in remnant vegetation condition and health.

Recommendations: Carry out proposed fencing.
Restrict stock access.

Anecdotal recordings: Change in water quality, more saline. Mosquitoes breed in stagnant pools over summer.

Flood levels: Flood in 1988, caused erosion, loss of fences, washed out crossings.

Use of river: Sheep graze and shelter in the vegetation.

Previous restoration works: Revegetation and fencing.

Why restoration done? Fenced off vegetation as poison plant present.

Any lessons learnt? Improvement seen?
Revegetation has returned cover to the ground which will prevent erosion.

Future management plans: Proposed fencing and is interested in removing silt in channel.

Perennials: Saltbush planted years ago is dying.

LOCATION 1476 MAP SHEET: DEVILS CREEK 2

Catchment: Devils Creek

Key issues: Salinity.
Sedimentation/ silting up of channel

Condition: The Northern tributary is in varied condition. The upper section is fenced, has been revegetated with saltbush and other native species but lacks an understorey, with the saltbush starting to die out. It is fenced and the creek is silted up. This is classified as C up to the stock crossing. Below the stock crossing it isn't fenced but a large amount of vegetation remains with a wide buffer zone. The vegetation community is mallee scrub. The creek is full of silt. Classified as B, due to the good condition of the vegetation which has few weeds present. Below the next stock crossing, the vegetation is pristine, with few weeds and slight disturbance. It is fenced off and is classified as A.

Heller and Brown (1996) Comments: Mallee heath. Overall condition 'good'. Reasonable diversity. Banksia, Dryandras dying; also the low shrub layer has dead patches. Very few introduced grasses. Some signs of browsing but it is not devastating. All layers present but not dense. Some old fences and machinery dumped. General comment - adjacent creek very degraded.

Recommendations: Carry out proposed fencing.
Revegetate the Northern tributary.
Restrict stock access.

Anecdotal recordings: Change in water quality, more saline. Mosquitoes breed in stagnant pools over summer.

Flood levels: Flood in 1988, caused erosion, loss of fences and washed out the crossings.

Use of river: Sheep graze and shelter in the vegetation.

Previous restoration works: Revegetation and fencing.

Why restoration done? Fenced off vegetation as poison plant present.

Any lessons learnt? Improvement seen? Revegetation has returned cover to the ground which prevents erosion.

Future management plans: Proposed fencing and is interested in removing the silt in the channel.

Perennials: Saltbush planted years ago is dying.

LOCATION 1473 & 1475 MAP SHEET: DEVILS CREEK 1

Catchment: Devils Creek

Key issues: Salinity and rising water table.

Condition: The upper creekline was cleared, not knowing the salinity and erosion problems that would result. The south-eastern section was left vegetated with average to good stands of Casuarinas and Melaleucas present, but this and the understorey has been impacted on by sheep which graze the adjacent paddocks. Sediment buildup is apparent, with a flood plain forming. The upper creek is lacking vegetation except for grasses and samphires. Overall condition is C, due to erosion and lack of vegetation. Some natural regeneration has occurred. Landowner very keen for amelioration work, which is part of his five-year farm plan.

Heller and Brown (1996) Comments: Not surveyed.

Recommendations: Carry out proposed fencing and revegetation.
Restrict access of sheep.

Anecdotal recordings: Upper creek was cleared originally (approx. 40 years ago), as the creek appeared to start further south. As a result, the channel has become more defined in the upper section. Salinity has not encroached further into the farmland, possibly due to low stocking and revegetation on the upper slopes.

Flood levels: Flood waters have created a flood plain and eroded the upper creek.

Previous restoration works: Fenced out some sections and carried out revegetation, including use of tagasaste and other perennials. Contour banks to control surface water and stop excess water reaching creek. Has implemented rotation with perennials such as lucerne and tall wheat grass.

Why restoration done? Aesthetics and to control rising water tables and salinity.

Any lessons learnt? Improvement seen? Neighbour's property, (Location 1476), had extensive revegetation done approx. 10 years ago. Looks very impressive and aesthetically pleasing. Landowner very impressed by this, and would like similar appearance on own section of the creekline.

Future management plans: Plans to fence out the entire creekline, limit stock, and revegetate with native species, especially salt tolerants. Plans to establish lucerne, tall wheat grass or Rhodes grass and other suitable perennials in adjacent paddocks to control rising water tables. Use perennial pastures on rotation basis for feedlot sheep.

Perennials: Tagasaste present, has used lucerne in past. Plans to incorporate perennials such as lucerne, tall wheat grass and Rhodes grass into system to control rising water tables.

Piezometers: Can see the importance of piezometers as tools for monitoring groundwater and interested in drilling holes for them.

LOCATION 1474 MAP SHEET: DEVILS CREEK 1

Catchment: Devils Creek

Key issues: Erosion, salinity and rising water table.

Condition: This farm doesn't run sheep or cattle, the creekline is fenced but not likely to be grazed anyway.This is the beginning of the Devils Creek tributary. The creekline is fenced off entirely with a gap for a crossing; regeneration of vegetation has occurred. Saltbushes were planted on the upper creek, and has now spread down the creek and on the banks. The northern tributary has been revegetated 6 to 7 years ago but is not fenced. The condition on the upper creek is C due to heavy sedimentation, presence of weeds, dead Mallee and Yate trees in the creekline and lack of understorey. The understorey will regenerate but probably needs to be seeded. Human disturbance through use of motorbikes and horses.

The lower creek, closest to the road, is B grade. Weeds are present, old machinery dump, sediment in the creek. No erosion. The vegetation is dense, with native understorey dominant with few weeds. The vegetation community is not dominated by one particular species but an array of *Melaleuca cuticularis*, Sheoak, Mallee and Yate. Saltbush, Samphire and Quandong, native fruit trees present. Yate saplings and other species of seedlings and saplings at different stages.

Heller and Brown (1996) Comments: Open woodland and riverine. Overall condition 'modified'. Old and has salinity problems. Weed invasion is localised to certain areas along the banks. Woodland fairly free of weeds. Unburnt. Yates regenerating along the river. Overall not too bad, fairly old, a little bit saline.

Recommendation: Fence out southern tributary and revegetate, as proposed.

Anecdotal recordings: Salt not getting worse. Fencing off area 5 to6 years ago has led to natural regeneration of understorey, saplings and seedlings present.

Flood levels: 1988, floods carried away fibreglass drainage pipes.

Historical Stories: South Coast Highway originally went through this location but was moved further east.

Use of river: Recreation in the form of motorbike riding, horse riding and walking. Old machinery dump site (only small).

Previous restoration works: Fenced off the creekline and revegetated the upper creek and northern tributary with saltbush. Other revegetation with Tasmanian blue gum on the upper northern bank of the lower creek. Fenced off areas and natural regeneration occurred.

Why restoration done? To stop erosion and salinisation of farmland

Future management plans: Would like to fully fence southern tributary and revegetate.

Perennials: Lucerne planted 5 years ago on the south-west paddock above the creek to lower the water table. The saltbush that was planted on the upper banks has now spread through the entire creek.

Rehabilitation techniques and recommendations

The following information details recommendations for the protection and restoration of the Bremer River and Devils Creek. Specific recommendations for each location are covered in 'Foreshore condition descriptions and recommendations'. This section gives an overview of the necessary requirements to improve the environmental quality of the Bremer River and Devils Creek.

Livestock management

Uncontrolled stock access to riparian land can lead to excessive run-off, bank erosion, loss of productive land, loss of important habitat, reduced water quality, damage to in-stream ecosystems, loss of plant species, soil compaction and weed invasion (LWRRDC[4] (2), 1996).

The most important step in livestock management is to remove or control stock access to the river. This is best done by fencing out the stock and creating specific access points for crossing or watering. This will ensure minimal damage is done and enable agricultural practices to continue.

In the unfenced areas of the Bremer Catchment, livestock are negatively impacting on the riverine environment. Sheep graze the native understorey, creating the opportunity for weed invasion and causing soil disturbance which can lead to erosion. Cattle impact on the vegetation in different ways to sheep due to their size, strength and eating habits. The understorey is not grazed as low by cattle, but the soil is also disturbed by their hooves. Cattle are destructive by knocking over dead trees and disturbing the roots of live trees.

Fencing

Fencing is a riparian management technique used to control livestock and human disturbance of the river systems. The type of fencing required is determined by the site characteristics and what needs to be controlled. In the Bremer River catchment, the livestock that have access to the waterways include sheep, cattle and horses. The fencing required for each type of livestock differs.

Fences are ideally placed at least 5-10 metres back from the top of the river bank. This will allow the establishment of vegetation. Fences that are erected too close to the river channel may be undermined and lost during heavy flow or floods.

A large portion of the Bremer River and Devils Creek is fenced out, with some periodic grazing of livestock in these areas. The Water and Rivers Commission is working with the Jerramungup LCDC to encourage the fencing of all waterways.

Revegetation

Riparian vegetation is necessary to; maintain habitats, bio-filtering and ecological corridor functions of the river, combat erosion, and preserve the riverine landscape (APACE and Pen, 1995). The vegetation on the Bremer River and Devils Creek varies in condition with some areas devoid of vegetation and in need of intensive rehabilitation. Other areas that have sparse vegetation need rehabilitation. Where large buffer zones have been recently fenced out and grazed land has been incorporated into the buffer zone, weeds dominate. These areas lack native vegetation and are ideal for rehabilitation by direct seeding or seedlings.

Successful revegetation sites exist throughout the catchment where a variety of species including native trees, pine trees and salt bush have been used. These examples show that restoration work to control erosion and salinity is and can be used successfully.
Revegetation advice and information on techniques is available from the Jerramungup Landcare Service Centre and the Greening Western Australia Bushcare Support Officer located at Tambellup.

Wendy Bradshaw, Bushcare Support Officer, and Nathan McQuoid, Manager of Vegetation Services, both employed by Greening Australia WA under the Bushcare program, are in 2000, conducting direct seeding trials on Location 1483, Geoff and Therese Bell's property. The site is 1.4 ha and on sandy gravel over clay soil.

[4] *Land and Water Resources Research and Development Corporation, Canberra.*

The objectives are to:

1. contribute to revegetation of yate/mallee system.
2. use direct seeding through great plains (discs) seeders for establishment.
3. attempt a mallee system that is a common deep sandy gravel type in the area.
4. seed as early as possible, post good germination and weed control.

Salinity

Salinity is an issue for some landowners within the Bremer River catchment. Encroaching salinity affects the production capabilities of the land and threatens the economic feasibility of farming systems.

A whole catchment approach is needed when tackling the salinity issue, and involves considering techniques and changing management practices to reduce the amount of recharge. Recharge is rainfall that soaks deep into the soil and replenishes the groundwater. This causes the water table to rise (Negus, 1991).
The options available for salinity management are:

1. More intensive cropping: increases water-use on upper and middle catchment areas.
2. Perennial grasses and lucerne: high-water use plants.
3. Fodder trees: for their water use and production potential.
4. Surface water control: through contour banks or levies.
5. Agroforestry/plantations: combining forestry and agriculture for recharge control and diversification of income.
6. Increase pasture production: recharge under annual grass/clover pastures is nearly twice that under cereal or lupin crops.
7. Production from saltland: use perennial forage plants on salt-affected land. Provides surface mulch to reduce salt accumulation on the soil surface and plants use groundwater.

(Adapted from Negus, 1991).

Weed management

Weed invasion is a major issue in the Bremer River catchment and control is needed, particularly when establishing vegetation. The understorey of disturbed Yate Woodlands are dominated by weeds, and they have encroached the perimeters of pristine remnants.

The best method of weed control is prevention of establishment by ensuring minimal disturbance in native vegetation. Undisturbed native vegetation is quite resistant to weed invasion (Hussey *et al.*, 1997).
Once weeds become established there are four ways of control:

1. physical - hand-pulling or mechanical mowing, slashing, cultivating or scalping.
2. natural suppression - creating a situation where the required plants (native or cultivated) are encouraged to grow and weeds are discouraged
3. biological - the introduction of a natural predator or a disease that will destroy the weed without affecting non-target plants.
4. chemical - the use of herbicides (Hussey *et al.*, 1997).

Some useful references on weed control are given in ‘Management issues’.

Wendy Bradshaw, Bushcare Support Officer employed by Greening Australia WA under the Bushcare program, describes a few rules to be aware of when dealing with weeds.

1. Avoid bare ground. This creates a perfect place for weed seeds to blow in and proliferate.
2. Fire promotes weeds. Burning a remnant which is weed infested will only make the weeds worse as this process creates bare ground. Native plants cannot compete with the rapid growth of weeds, which then become a greater fire hazard.
3. If weed control is carried out, revegetate to prevent further weed invasion onto the bare soil.

4. Be sure that they are weeds. Many native grasses exist and may not be recognised. Only control the weeds you know and get advice on others before acting. Native grasses are often found growing with weeds. In this case, selective herbicides can be used to control the weeds and promote the native grasses such as Fuselade at the rate of 1L/ha.

5. Any disturbance which creates bare ground will promote weeds unless revegetation is undertaken in the process.

6. Weeds are better for soil health than bare ground.

Rabbit control

Rabbits are evident in the Bremer River catchment, particularly in sandy soils. Rabbits impact severely on native vegetation and hinder revegetation. Eradication is necessary and reliance on Mixamitosis and Calicivirus is not enough. If Calicivirus passes through the rabbit populations, it is recommended that follow up baiting occurs, as it doesn't affect juveniles. The best options are destroying the rabbit burrows by deep ripping, with follow up baiting. Baiting is done with One Shot 1080 Oats which can be ordered from Agriculture Western Australia[3].

Ideal outcomes

Protecting Bremer River and other waterways in the catchment

Ideal outcomes include:.....

- ✔ The entire Bremer River fenced to restrict stock access.
- ✔ Tributaries in the catchment fenced and revegetated - with a wide buffer zone of at least B grade condition.
- ✔ The quality of water draining to the Wellstead Estuary to meet or better ANZECC guidelines for pollutants and nutrients.
- ✔ Salinity levels in the river remaining stable over the long term.
- ✔ Areas in the catchment that are waterlogged or showing signs of salinisation addressed through sustainable farming practices
- ✔ Weed species, particularly invasive weeds, removed from waterways in the catchment.
- ✔ Eroding banks stabilised through revegetation, brushing, or engineering options.
- ✔ Foreshore survey maps annually updated to record the progress of protecting the Bremer River and Devils Creek. The catchment map and individual landholder maps being used to record on-going works, as the baseline to source funding and as a working tool to help guide and prioritise future works.
- ✔ A funding application submitted to help finance the on-ground works proposed in this report.
- ✔ On-ground work monitored and evaluated with a view to correct mistakes and share successful outcomes.

Protecting Wellstead Estuary

Ideal outcomes include:....

- ✔ The removal of invasive weeds along the foreshore of the Wellstead Estuary.
- ✔ Appropriately designed and constructed board walks and paths around the estuary that minimise environmental impacts and encourage further appreciation of the estuary
- ✔ The revegetation and restoration of existing degraded sites including paths that are no longer required.
- ✔ A management plan developed for the foreshore and the estuary to guide a long-term commitment for the protection of the estuarine and foreshore environment.
- ✔ A group of people interested in protecting the estuary forming an advisory group to the shire that will encourage and involve local input into the management of the estuary.
- ✔ Appropriate signage erected around the estuary to inform tourists and local community members of the values of the estuary and how they can assist in its protection.
- ✔ The Hooded Plover breeding grounds protected near the mouth of the estuary and along the coast.
- ✔ Further research on the estuaries by universities to learn more about the ecological values of the estuary.
- ✔ The existing oral history document titled *Stories of the Bremer River and Wellstead Estuary* expanded by collating more photographs and stories from original settlers and long term residents.
- ✔ Protect John Cove Recreation site through appropriate erosion control mechanisms.

5. Additional information

Case studies in river restoration

Many landholders in the Bremer River Catchment have implemented river restoration works along the river and its tributaries. To support the recommendations made in the Bremer River Foreshore Condition Report, three case study sites (see Figure 5:1) have been selected because they exemplify the benefits of river restoration works, from restricting stock access by fencing foreshores through to integrating trees into the farming landscape.

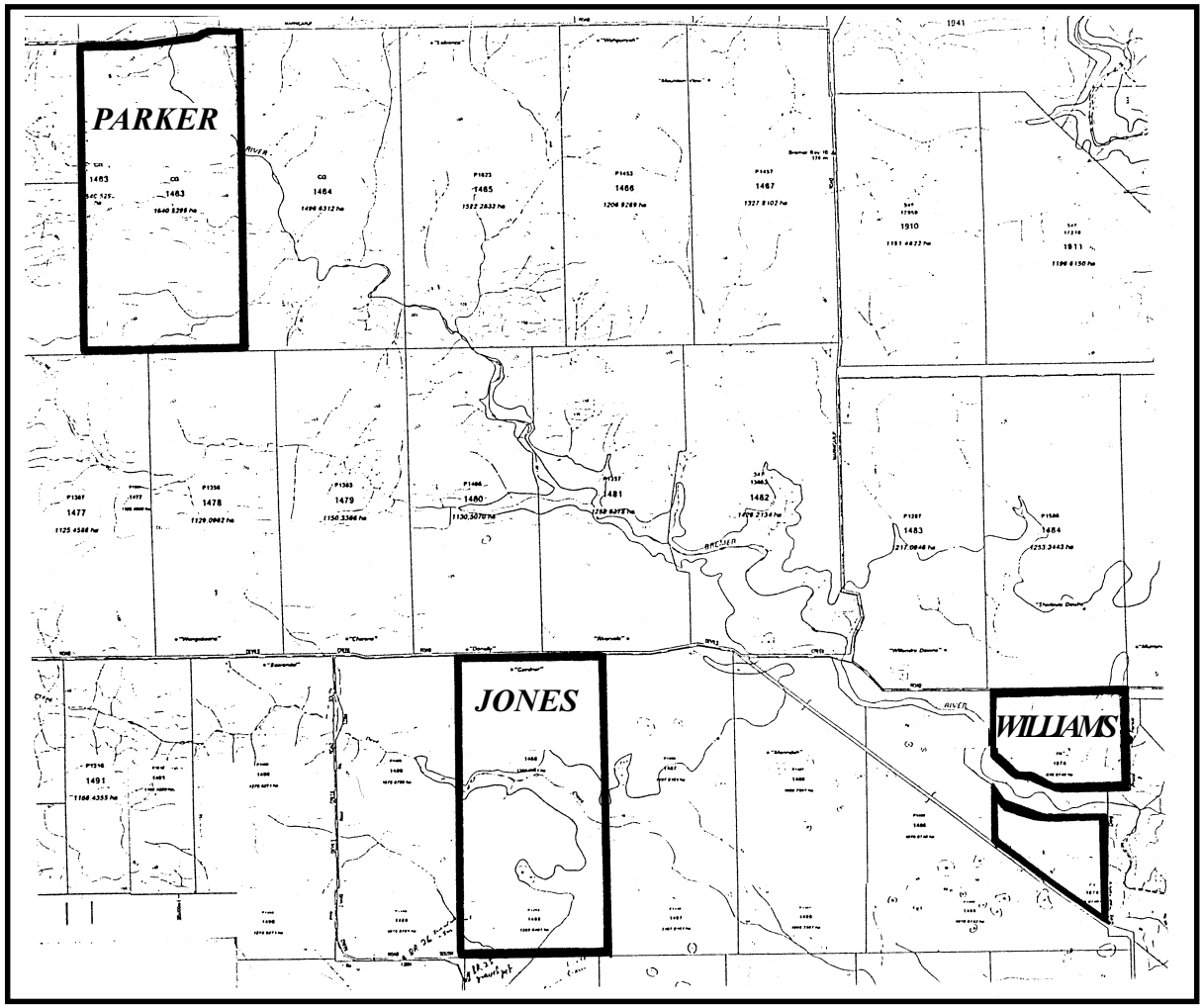


Figure 5:1. Location of the case study sites within the Bremer River Catchment

Aerial view of the Bremer River

FENCING TO PROTECT RIVERS
R & R WILLIAMS, 'Betws-Y-Coed'

Background

Ross Williams brought his conditional-purchase block (Location 1874) in 1968 and started clearing and developing the land for sheep and crops in 1975.

The Bremer river reserve separates the location with the Bremer River running through the property entering on the western boundary and flowing in a south-easterly direction where it exits at the south-eastern corner. The South West Bay River also flows through this location to the north of the Bremer River and its condition was reported in the South West Bay River Catchment Plan.

Waterway condition

The stretch of the Bremer River on this location was classified as A grade, with a few weeds present and slight disturbance around the stock crossing. The river has always been fully fenced. The South West Bay River, a minor tributary of the Bremer River, was not classified as part of this report because it has only recently been fenced, however, it was given a B grade on inspection.

The dominant vegetation communities are Mallee Shrubland and Riverine (50:50) and is clearly shown in Figure 9.2 (Heller and Brown, 1996). The riparian vegetation on this location has good species diversity. The foreshore survey of this location also in some parts identified aquatic vegetation and overhanging riparian vegetation.

The Rivercare issue

Ross was aware of the potential for erosion along the tributaries of the Bremer River and the South West Bay River because of the large amount of runoff from the neighbouring farm. The creek had flooded many times with the water reaching heights of 5 metres. It has washed away Devil's Creek Road to the north about four times. During theses floods the unfenced creek banks further upstream eroded by 2 to 3 metres.

Ross wanted to protect the waterways from sheep, and to conserve the vegetation for flora and fauna habitats. The presence of poison (*Gastrolobium sp.)* was a further reason to stop access to the river and its tributaries.

A grade foreshore condition vegetation in Bremer River

Ross Williams inspects the most recently erected fence around the swamp near the northern boundary

Ross Williams checks the river crossing in the main channel of the Bremer River

The solution

Ross, as part of his farm plan, began protecting areas of remnant bush 15 years ago when he fenced off a patch containing poison plants. He also fenced the western end of the South West Bay River in 1985. "There was land cleared up there and within three years of being cleared the creekline was showing signs of salt. They had never done anything about fencing it out and I thought well there's no point leaving all this nice bush to go like that. Obviously the salt was very close to the surface then and the natural bush was only just holding it in balance".

Ross fenced the eastern end of the creek in 1996. There is a difference in the vegetation density between the western and eastern end. He used RVPS and his own funds to carry out some of the fencing.

There are contours on the property which have reduced water flow to the lower slopes. For about three years, Paulownia trees have been planted on the property, giving slow, but significant results.

Recently, Ross has received funding from the Water and Rivers Commission to fence a wetland on the property because it was in relatively good condition but showing signs of degradation from stock access. He extended the fencing further to include a small tributary of the South West Bay River.

Outcomes and observations

Ross explained that fencing creeks and protecting riparian vegetation has been good for stock shelter both in hot and cold weather. He has also been practising no-till and has not recenlty seen any erosion of the paddocks into the creek. Ross has noticed a decrease in wind erosion on the farm. Since the creek has been protected, there is more pasture allowing stock to graze in the paddock on the east side of the South West Bay River for longer.

Differences in the vegetation density between the eastern and western lengths of the South West Bay River can be observed. There is less understorey in the more recently-fenced area, although the overstorey is healthy. Since fencing, Ross has noticed some natural revegetation in both sections of the creek. Even though the same amount of water is running off the land it is cleaner.

The Yate trees are healthy and are apparently unaffected by the lerp infestations which plague other nearby areas. Ross attributes this to his healthy riparian zone and the non-stressed yates being not susceptible to insect attack.

Future action

Under the Bremer River Catchment Demonstration Projects scheme, Ross has received a grant to complete the fencing required to protect the South West Bay River and its tributaries and the tributaries of the Bremer River on this location.

FENCING TO PROTECT RIVERS

T & C PARKER, ' The Block'

Background

Trevor and Carol Parker have owned 'The Block' for 11 years and maintained a sheep to crop ratio of approximately 40:60 during this time.

'The Block', location 1463, as required under conditional purchase, was cleared around 30 years ago, with the exception of a large area in the north-east corner through which the Bremer River flows.

The Bremer river flows in a south-easterly direction through location 1463. Kombi Creek, a minor tributary of the Bremer River, dissects the location to the south of the Bremer River and flows in an easterly direction where it joins the Bremer River in the adjacent location (1464). Two crossings are located along its length to provide access to the southern half of the property.

This location was chosen as a case study site because of the varied condition of the foreshores.

Waterway condition

The length of the Bremer River and the upper reaches of Kombi Creek on location 1463 were classified as A grade. The lower reaches of Kombi Creek (towards Bremer River) were classified as B grade.

The buffer zone surrounding the Bremer River is significantly wider than the lower reaches of Kombi Creek. This reiterates, not only the need for a buffer zone, but that a minimum width is required to ensure its effectiveness in foreshore protection and rehabilitation.

The dominant vegetation communities are Mallee Shrubland and Riverine with some small Mort thickets (*Eucalyptus platypus*) around Kombi Creek.

Rivercare Issue

Erosion and salinity are the two rivercare issues of concern to Trevor and Carol Parker.

It motivated them to carry out fencing on the 'The Block' which they purchased in 1989.

The situation

There are three areas on location 1463 that will, in discussions, highlight the advantages of fencing off waterways.

This length of the Bremer River is unique because it has always been fenced off (due to the presence of poison) and there is a wide buffer zone. Trevor and Carol fenced off the remaining length of the Bremer River in 1997 with RVPS funding. Costs were reduced by using second-hand materials.

Thirty years ago when the block, as required under conditional purchase, was cleared the Bremer River was fenced because poison pea was present Some lengths of Kombi Creek also have been doubled-fenced for 30 years.

In 1997, RVPS funding was used to fence a section of Kombi Creek (north bank, middle length of location). Recent Water and Rivers Commission funding will be used to complete fencing Kombi Creek.

This tributary was not graded as part of this report, however, Figure 15 shows that the signs of degradation are evident and comparisons between the foreshore condition of the Bremer River and Kombi Creek can be made.

Future actions

Trevor and Carol will complete fencing the entire length of Kombi Creek and have plans to fence smaller tributaries of Kombi Creek, to prevent further saline encroachment on the farmland. They may also consider revegetating some of the foreshores on their property. Trevor and Carol are proposing to fence a smaller tributary of Kombi Creek which is increasingly becoming more degraded and salt scalding is occurring on adjacent farmland.

When asked to make a comparison between the condition of the Bremer River and Kombi Creek, Carol remarked that the level and degree of weed invasion and erosion was different and the value of fringing vegetation was evident.

Fencing on the Bremer River with a dense Casuarina community in the background

Thirty-year-old fencing at Kombi Creek (looking downstream)

More recently fenced foreshore of Kombi Creek (compare the foreshore with the photo above)

REVEGETATION WITH ALLEY FARMING TO COMBAT RISING WATERTABLES AND WIND EROSION

Keith and Nita and Alex and Margaret JONES, "Gairdner Grazing Co."

Background

"G.G Co." (Location 1488) has been in the Jones family for 41 years. Half of the clearing was carried out during war service settlement in 1955 and the other half was cleared over the next 15 years, the most recent clearing was carried out in 1972. Cropping and sheep are the major landuses on this location with an average of two thirds of the arable land put into crop.

Devils Creek dissects this location entering on the western boundary and flowing in a east to south-easterly direction to exit on the eastern boundary.

A smaller tributary runs through a series of 3 swamps to join Devils Creek in the location to the west.

Waterway condition

Classification was different along the course of Devils Creek in this location. The difference relates to the soil types and the stock access. The western most part of the creek was classified as A grade. This area, containing high granite soils, has never been open to stock and as a result is a healthy riverine woodland with minimal weeds and stable foreshores.

The middle section of Devils Creek on this location, has not been grazed for around 18-20 years and has been classified as having a B grade foreshore condition due to dominance of weeds in the understorey.

The eastern section of the creek was classified as C grade and was open to stock up until around 10 years ago. The sandy soil type is easily eroded with erosion and foreshore breakaway evident. There is no shrub layer and exotic grasses make up the understorey that is low in species diversity. The trees are fairly old and there is little evidence of regeneration.

Groundwater movement can be better understood because it is monitored by using more than 20 piezometers located throughout the farm.

The Rivercare issue

The main concerns at this location are wind erosion, the rising watertable and the associated threat of salinity. The threat of loosing most of the productive land to salt was the motivation for the restoration work.

The solution

In the 1980s, the Gairdner Grazing Co began implementing land and rivercare techniques before it became fashionable. The ultimate goal was always to stop the rising water table. Fencing and revegetation constitute the bulk of the river restoration works on this location. Alley farming has also been carried out in two paddocks and contours have been used to control surface water drainage.

Approximately 15 kilometres of fencing has been erected to restrict stock access to the foreshore of Devils Creek. The eastern section of the creek has always been fenced due to the presence of poison.

Revegetation is an ongoing activity on this location with an area of approximately 25 hectares revegetated on either side of Devils Creek. Revegetation has been carried out using seedlings of various species including: Golden Wreath Wattle (*Acacia saligna*), River Red Gum (*Eucalyptus camaldunlensis*), Sugar Gum (*E. cladocalyx*), Flat-topped Yate *(E. occidentalis*), Spotted Gum (*E. maculata*) and others.

The successful selection of revegetation species according to the company's research efforts and expertise is testimony to the value of understanding the dynamics of the environment.

Special treatments include watering the seedlings with a fire unit when it has been required and weed control when required. The plants used in the revegetation have experienced good growth and have not been hampered by disease and insects. This has meant that chemical treatments have not been necessary. The areas that have been revegetated are shown in Map 12, however there has been further fencing and revegetation since the

A grade foreshore condition on Location 1488

Alley farming using **Pinus pinaster** *on Location 1488*

production of this map including the small tributary that runs through the three swamps to the south of Devils Creek and joins into Devils Creek in the adjacent location.

Alley farming has been employed on this location as a technique to prevent degradation that results from wind erosion and control the rising watertable. Normal cropping regimes have been maintained in the alleys. Tree planting on this location can be referred to as agroforestry because they are to be harvested for wood production, and will maintain a cropping regime between the alleys. The first lot of alleys was planted 10 years ago on sandy soil that was prone to blowing away. Pinasta pines were chosen for two reasons: firstly because the Jones' liked them and secondly because they are known to: grow on poor soils, be fast growing, and produce a timber that can be easily harvested. Alex says that his best canola crop grew on one of the alleys in 1999 and the protection that the trees offer has definitely reduced the amount of wind erosion. The first block of the pines is ready for harvesting this year.

The second area where alley farming has been employed was located specifically to combat the rising water table. Control and reversal of rising water tables can be effected by selectively introducing and incorporating trees into farmland (Schofield, *et al*., 1992). The second alley farming plot was put in four years ago and in each alley there are single rows of *E. occidentalis*, Southern Mahogany (Eucalyptus sp.), Ribbon Gum (Eucalyptus sp.), *E. cladocalyx* and *E. camaldunlensis* with single rows on either side of the alley of *Acacia saliga*. There are plans to harvest selected trees in these alleys, particularly the Sugar Gums which are good growing and produce good furniture wood. The trees in this plot are pruned to maintain straight timbers for furniture wood.

Alex Jones recommends incorporating trees into a farming system and says that it has its place in some soil types. "If there is a rising water table, trees have got to be a part of the solution. Drainage is another one but there is no substitute for using the water in the first place". The Gairdener Grazing Company has established more than 100 000 trees. It has not had any agency involvement or funding for landcare and rivercare restoration works. Alex Jones attributes the ability to implement these various restoration works to a high labour-to-hectare ratio. The success of the enterprise has allowed them to diversify and invest in land and rivercare.

Future action

The fencing of Devils Creek and its smaller tributaries has been completed and the company will continue to revegetate areas where it is required. Preparations to start work later this year on more fencing and revegetation to control the surface water are underway. (Figure 19).

Alley farming rows using mixed species

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