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Foreshore and Channel Assessment of Mortlock River and Mortlock River South

FORESHORE AND CHANNEL ASSESSMENT OF MORTLOCK RIVER AND MORTLOCK RIVER SOUTH

Jointly funded by

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and

Avon Catchment Council

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DEPARTMENT OF ENVIRONMENT

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Cover Photograph:
View from bridge on Mannavale Road
David Gibb

December 2005

Foreword

Jointly funded by the Natural Heritage Trust, the Department of Environment and the Avon Catchment Council, this project is a part of the Avon Rivercare Program to undertake foreshore surveys of major tributaries that flow into the Avon River.

The major objective of this project is to document the present condition of, and recommend management actions needed for, the Mortlock River and Mortlock River South through standard field surveys, in consultation with landholders and the surrounding community.

The Mortlock River and Mortlock River South catchments drain portions of the Town of Northam and the Shires of Northam, York, Cunderdin and Quairading. The foreshore and channel assessments along the Mortlock River and Mortlock River South were undertaken between March and April 2004.

The purpose is to provide baseline information to land managers in the Mortlock River and Mortlock River South catchments. It is hoped that this information will guide, encourage and assist in the sustainable planning and management of the river environment by landholders and community groups.

As a result of historical and present day agricultural land practices, most of the Mortlock River and Mortlock River South is degraded and in a poor state. A wide range of management issues have been identified which contribute to the degradation of the river. These include sedimentation, stock and vehicle access to the foreshore through lack of fencing, soil salinisation and bank erosion.

The principles for waterways management have been included to suggest ways in which the foreshore condition can be improved to provide environmental, economic and social benefit to riverside owners and interested community members.

Although this tributary has been surveyed in isolation to other major waterways, the long-term management of the riverine environment depends on an integrated catchment approach, whereby landholders within the whole catchment are responsible for working together to improve the condition of the waterways. It is hoped that the results of this report will help to create a sense of ownership of the river for the community as a whole and encourage integrated catchment management, conservation of the riverine environment and sustainable development.

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Introduction

The riparian zone adjacent to waterways acts as a natural buffer from the surrounding environment. Healthy foreshore vegetation helps to stabilise riverbanks and slows and filters water which reduces the impact of erosion and sedimentation of river pools. Riparian vegetation also provides protective cover and a suitable habitat for aquatic and terrestrial fauna.

The river valleys in the Avon region have been a focus for farming and as a consequence are often highly degraded. The major threats to the foreshore health of waterways are the loss of native vegetation or a decline in health due to weed invasion, stock grazing and vegetation clearing. The loss of riparian vegetation often leads to the destabilisation of riverbanks, leaving areas exposed to erosion during bankfull flows.

Gaining an understanding of the health and condition of river foreshores is the first step towards developing appropriate management strategies to protect and maintain these areas.

Purpose of the survey

The purpose of this foreshore survey is to collect baseline data about the current environmental condition of the Mortlock River and Mortlock River South and its surrounding environment. This information can then be used to encourage landowners to undertake waterways management strategies to improve the overall environmental health of the waterway. It is essential that landowners, the community and other stakeholders, who have a specific area of interest within a waterway, also assess the environment upstream as well as any tributaries flowing into the area. An entire catchment approach is needed. By recognising all aspects of the surrounding catchment, including past and present land uses, it will be possible to restore a waterway that will eventually meet several objectives.

Objectives of this project can be summarised as follows:

- Identify areas within the riparian environment which need future rehabilitation or conservation.
- Provide managers with data about the river to aid them with decision making, especially in prioritisation of future rehabilitation works.
- To provide baseline information from which stakeholders can monitor future changes in the riparian health.
- To inform landholders and the community about the causes of waterway degradation and;
- To provide a reliable technical basis for future project funding submissions.

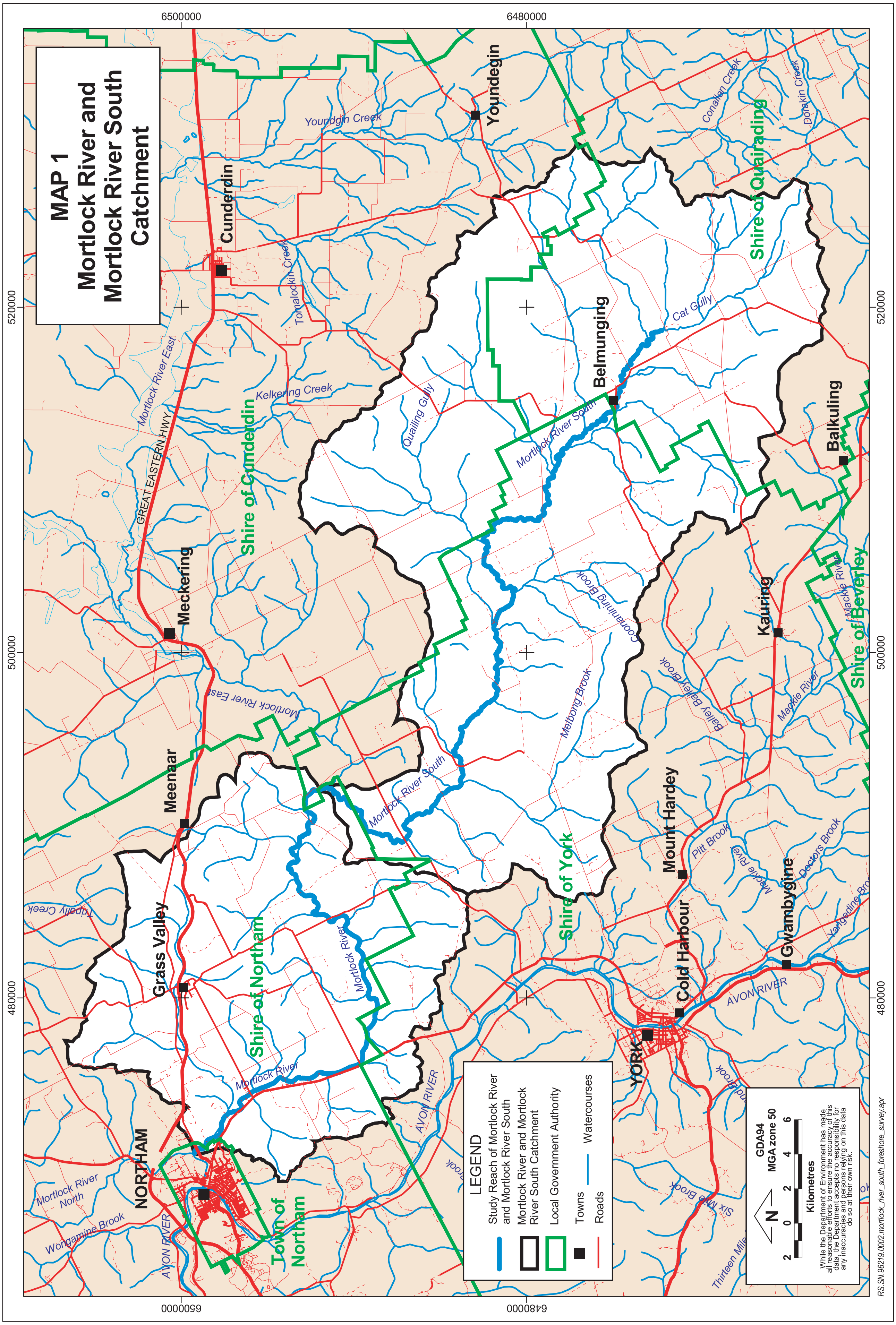
Study area

For continuity in this report, all references to the surveyed waterway will be made to the Mortlock River and Mortlock River South.

The Mortlock River System is one of the major tributaries of the Avon River. It consists of the Mortlock River and its three branches; the North, East and South. The Mortlock River North has its source at Lake Ninan, which lies approximately 6.5 km south west of Wongan Hills townsite and flows to Northam where it meets the Mortlock River (Water and Rivers Commission, 2003a). The Mortlock River South originates in the Shire of Quairading and eventually joins with the Mortlock River East near Duck Pool Reserve, 18 km ESE of Northam. The Mortlock River then meets with the Mortlock River North 2 km east of Northam and then eventually flows into the Avon River. The Avon River has its source near Wickepin and eventually becomes the Swan River at the confluence with Wooroloo Brook in Walyunga National Park. The study area is located within the boundaries of the Shire of Northam, York, Quairading and the Town of Northam. For this survey, its is assumed that the source of the Mortlock River South is 23 km NW of the townsite of Quairading, where a more defined channel system starts to form.

Map 1 shows the size of the Mortlock River and Mortlock River South catchment (3090 km^2) in relation to major towns, roads and shire boundaries.

The primary focus of this survey was the immediate environment around the foreshore and channel areas of the river. This includes the main and side channels (anabranches), floodway, flood fringe, floodplain and surrounding land uses.



Map 1. Mortlock River and Mortlock River South catchment

In addition, foreshore and channel assessments have already been completed for the Mortlock River North (WRM 39) and the Mortlock River East (WRM 41).

Historical description of the Mortlock River

Aboriginal heritage

Aboriginal people have occupied the Avon region for more than 30 000 years. From historic records, the Balardong tribe occupied all of the Mortlock River catchment. The Balardong Tribal area was bounded by Northam in the west, Brookton in the south, east to Corrigin and Kellerberrin and north to Wongan Hills and Dalwallinu. Within this area lived about 500 Aboriginal people (Stokes, 1986).

Data from the Department of Indigenous Affairs shows that there are sites of Aboriginal significance along and surrounding the Mortlock River and Mortlock River South. All of the sites are classified as containing artefacts and may contain objects connected with the traditional cultural life of Aboriginal people, past and present. Examples of these artefacts, which Aboriginal people used in everyday life could include rock structures, modified trees or quarries. Potentially rivers, estuaries, wetlands and dunes could contain all types of Aboriginal sites and may be considered places of significance (Water and Rivers Commission, 2002).

Site numbers S02649, S02648, S02650, S00091 and S01411 all are located within close proximity to the Mortlock River and Mortlock River South. Due to the sensitivity of the sites, access to specific information cannot be disclosed (Department of Indigenous Affairs, 2003).

European heritage

The Avon River, near the present town of York, was first discovered by Ensign Dale during an expedition to find new farming land in August 1830. This came to be the first settlement in the Avon region. In October 1831, new explorations and land grants northward of York produced the first signs of settlement in Northam, and Toodyay (Garden, 1992).

Henry Mortlock Ommanney first discovered the Mortlock River in 1835, when he traced the two branches to their confluence. From historical accounts the Mortlock River had a series of deep pools which were brackish and the associated salt caused it to be known locally as the Salt River (Garden, 1992).

The land use in the Mortlock River and Mortlock River South catchment is predominantly agriculture and has been since the early 1900s. Today, large-scale cereal crop farming and livestock enterprises are the primary industries in the region. Approximately 95% of the catchment has been cleared for agriculture, much of it dating from the 1920s (Public Works Department, 1984). In recent years there has been a tendency for land in the Shires of Northam and York to be subdivided into smaller lots. This is evident in the study area where landuse is varied with some livestock agistments, olive plantations and hobby farms located along the river foreshore.

Catchment description

Climate

The Mortlock River and Mortlock River South catchment experiences a Mediterranean type climate with hot dry summers and cool wet winters. Table 1 shows climatic averages for the Shire of Northam and York.

The majority of the Avon catchment falls within the Transitional Rainfall Zone (800 – 300 mm), and is subject to a broad range of climatic influences. The Mortlock River and Mortlock River South catchment lies within the 400 mm – 500 mm rainfall zones. About 70% of the annual rainfall falls during the five to six month period of May to October (Australian Bureau of Meteorology, 2002).

Table 1. Regional climatic averages

Climatic Factor	Northam	York
Average yearly rainfall (mm)	430.5	450.0
Average maximum temperature (°C)	25.2	24.8
Average minimum temperature (°C)	11.0	10.5
Average evaporation (mm/day)	4.4	Not available
Average wind speed (km/h)	8.9	9.7

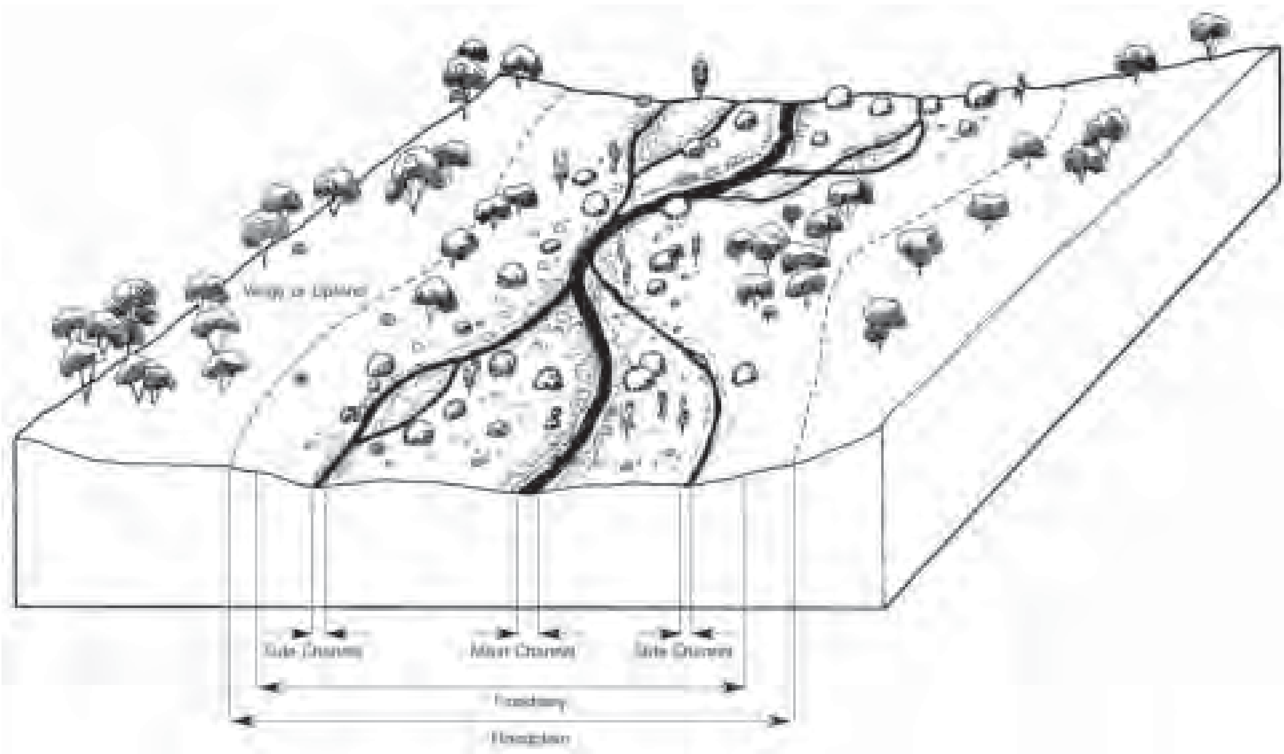


Figure 1. River floodplain cross section — Zone of Rejuvenated Drainage *(Source: Water and Rivers Commission, 2001)*

Geomorphology and soils

The Mortlock River and Mortlock River South catchment is located within the Zone of Rejuvenated Drainage. The Meckering Line to the east and the Darling Range Zone to the west (Lantzke and Fulton, undated) define the Zone of Rejuvenated Drainage. The Zone of Rejuvenated Drainage is characterised by greater dissection, or cutting into the landscape, than the Zone of Ancient Drainage to the east, thus forming steeper, narrower valleys which contain rivers and creek lines that flow every winter.

The major soil types in the Zone of Rejuvenated Drainage in the western portion of the Mortlock River and Mortlock River South catchment include sandplain soils, hillside soils and valley floor soils (Lantzke, 1993).

The sandplain soils originate from deeply weathered laterite and are characterised by having deep pale yellow sands or pale sands over gravel/loamy sand (Uf1). Hillside soils are found on the sloping country below the sandplain soils above the valley floor soils. The soil characteristics include shallow hardsetting grey sandy loam over clay and other sandy duplex soils. Hillside soils often contain rock outcrops of granite, dolerite, migmatite and gneiss and the soil surrounding these outcrops reflects the parent rock and is often red in colour (Uf1, Qb29). The valley floor soils occur at the bottom of the landscape on the floodplain of the Mortlock River. The major soil types in the valley floor include grey sand (often known as river sand), which overlies grey clay and a shallow loamy sand duplex underlain with brown medium clay. This duplex soil has the tendency to become waterlogged in wetter rainfall years (Va63).

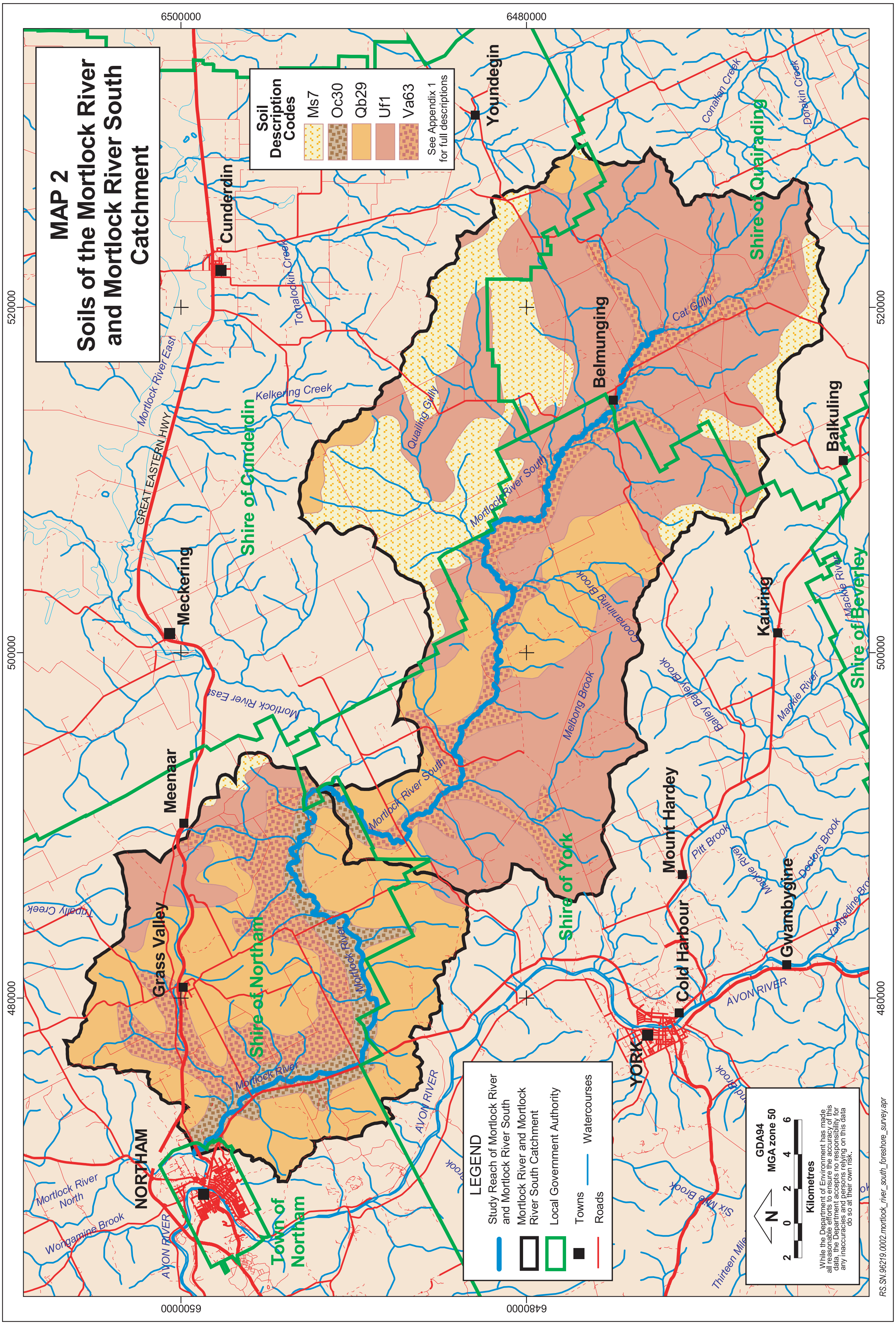
Figure 1 depicts a cross-sectional representation of the landscapes of a typical watercourse in the Zone of Rejuvenated Drainage.

Map 2 shows the distribution of soil units throughout the Mortlock River and Mortlock River South catchment, while Appendix 1 provides a description to match the soil units used.

Hydrology

The Mortlock River and Mortlock River South catchment drains the south eastern portions of the Shire of Northam, the north east of the Shire of York and the north west of the Shire of Quairading.

There are several minor tributaries which flow into the Mortlock River and Mortlock River South from the surrounding catchment. These include Grass Valley Brook, Melbong Brook, Coonanining Brook, Quailing Gully, Cat Gully, Oakover Creek, Mulukine Creek, Mount Mary Brook and Meenaar South Creek.



Map 2. Soil types of the Mortlock River and Mortlock River South catchment

The Mortlock River catchment consists of three main branches (North, East and South) which all eventually flow into the Avon River near Northam. The Mortlock River system is seasonally active and flows intermittently after heavy rainfall events, which usually means during winter, spring and early summer. In many cases the channel is well defined and basically consists of a wide and shallow floodplain.

Almost all of the catchment is cleared and in a wet year the system can contribute large volumes of flood-waters into the Avon River. Even without flood events, the waterways tend to flow strongly every year, especially in the downstream reaches.

Local groundwater levels in the Mortlock River and Mortlock River South catchment can differ in depth (metres below ground level) over tens of metres due to soil type, local geology, remnant vegetation and engineering works. A study conducted in 2001 by the South Mortlock Catchment Group showed that a majority of groundwater levels were between 0.4 m and 2 m below the surface of the soil (Wooldridge, undated). No conclusions were made from this report.

Vegetation

The Mortlock River and Mortlock River South has a variety of vegetation types due to the mosaic of the soil types that the river dissects. The floodway of the river is lined with salt and waterlogging-tolerant species which are characteristic of the waterways in the Zone of Rejuvenated Drainage. These species include Swamp sheoak (*Casuarina obesa*), York gum (*Eucalyptus loxophleba*), Flooded gum (*Eucalyptus rudis*) with occasional Needle bush (*Hakea preissii*) and Samphire (*Halosarcia* sp). Jam wattle (*Acacia acuminata*) occurs in the floodway but is mildly tolerant of salt and seasonally wet conditions.

The upper slopes of the floodway are dominated by woodland of York gum (*Eucalyptus loxophleba*), Flooded gum (*Eucalyptus rudis*), Salmon gum (*Eucalyptus salmonophloia*) with occasional Gimlet (*Eucalyptus salubris*) in areas. Sandy rises are dominated by Acorn banksia (*Banksia prionotes*), Rock sheoak (*Allocasuarina huegeliana*) over Spiked scholtzia (*Scholtzia involucrata*) and Saltbush (*Atriplex* sp).

Introduced vegetation is confined to the understorey layer and consisted of a variety of annual and perennial grasses and herbaceous plants. Agricultural weed species such as Wild oats (*Avena* sp), Barley grass (*Hordeum leporinum*), Ryegrass (*Lolium rigidum*) and Puccinellia (*Puccinellia ciliata*) are common in the riparian zone. Other minor weeds found in the riparian zone include Great brome grass (*Bromus diandrus*), Soursob (*Oxalis pescaprae*), Smooth heliotrope (*Heliotropium curassavicum*) and Pattersons curse (*Echium plantagineum*).

Catchment landuse and tenure

The landuse in the Mortlock River and Mortlock River South catchment is varied with a mix of agricultural landuses. The agricultural focus is the growing of cereal grains and other crops, sheep and less so, cattle.

Some sections of the Mortlock River and Mortlock River South lie within river reserves and are vested for the purposes of ‘Water’, ‘Resting Place for Travellers and Stock’, and ‘Camping’. These include Reserve 3073, 1355 at Kelly Pool, Reserve 1487, Flea Pool, Belmunging Pool, and Belmunging townsite reserve. Small linear sections of the river are described as unallocated crown land but the majority of the surrounding catchment is privately owned.

Historical water quality

The water quality of the Mortlock River and Mortlock River South catchment is a major factor that affects the health of the waterway and its ecosystem. Mortlock River water quality and river flows are continually monitored at the Department of Environment river gauging station 615020 at O’Driscolls Farm, in the Shire of Northam. The location of this station is on the Mortlock River, downstream of the confluence of the Mortlock River East and the Mortlock River South, subsequently water quality readings would be a combination of the two waterways. Historical water quality data from gauging station 615020 can be found in Appendix 2.

Nutrients, salinity and sediments are major pollutants of the Mortlock River and Mortlock River South and are a result of clearing and agricultural landuse. Results from the river gauging station have shown that the salinity levels in the river can vary from 61 mS/cm (hyper saline) to 4 mS/cm throughout the course of a year. The pH of the Mortlock River can range between 7.5 and 8.8, which is slightly alkaline.

Total Nitrogen and Total Phosphorus levels in the Mortlock River have been regularly monitored since 1995. Nitrogen and phosphorus are important nutrients for the growth of aquatic plants and algae. Excessive nutrients can lead to algal blooms which are a public health concern and an ecological problem in waterways. Nitrogen levels in the Mortlock River fluctuate from 1 mg/L to 2 mg/L, which is considered to be high. Phosphorus export from the catchment is high due to agricultural landuses and soils that do not retain nutrients. Phosphorus levels have fluctuated from medium amounts 0.020 mg/L to extreme levels of 2.903 mg/L. Harris (1996) suggests that 50% of the nutrients in the Avon River measured at Walyunga National Park come from the Mortlock River system (North, East and South branches).

Groundwater salinity varies considerably throughout the catchment. Perched or sandplain aquifers often have fresh to brackish groundwater but lower in the landscape around the Mortlock River and Mortlock River South channel, the groundwater salinity range can be a lot higher. A small groundwater study conducted in the upper reaches of the Mortlock River South catchment in 2001 revealed that peizometers located lower in the landscape near waterways have higher groundwater tables and higher associated salinity (Wooldridge, undated). Groundwater pH varies from highly acidic ($pH < 4$) to slightly alkaline ($pH = 7.5$). Recent data reveals that highly acidic groundwater is more widespread than initially perceived and has the potential to affect large areas of agricultural land and remnant bushland (Cummins, 2003).

Survey methods

Community awareness and involvement

A letter of introduction was sent to landholders along Mortlock River and Mortlock River South explaining the purpose of this survey. Arrangements were then made by phone for access onto properties to survey the river. Letters were also sent out to local landcare, rivercare, catchment and 'Friends' groups to allow them the opportunity to become involved in the assessment of Mortlock River and Mortlock River South.

Articles were placed in the local newspapers, such as the Avon Valley Advocate, which gave the project background and invited landholders to be involved in the survey process. ABC Radio interviews were also used to disseminate information to a wider audience in the catchment.

A draft report was prepared and released for public comment, giving landholders and community members the opportunity to respond to report findings and the broad management recommendations that have been made.

Assessment technique

A Foreshore and Channel Condition Assessment Form was adapted to standardise the field surveys and to keep the collection of data consistent. The assessment template was based on the assessment techniques developed by Pen and Scott in their 1995 publication; Stream and Foreshore Assessment in Farming Areas, with some variations included to meet the specific needs of this assessment. The survey form was divided into the following categories:

- general details;
- bank stability (presence of erosion, undercutting, slumping, subsidence and sedimentation);
- waterway features;
- vegetation health (and coverage);
- habitats (aquatic and terrestrial) ;
- habitat diversity;
- landform types;
- fencing status;
- foreshore condition assessment;
- overall stream environmental rating (stream health);
- evidence of management;
- management issues;
- ideas for management;
- vegetation;
- water quality data;
- GPS coordinates; and
- photographs

Surveys were conducted along the length of Mortlock River and Mortlock River South with survey sections determined by paddock and/or property boundaries. The length of Mortlock River was divided into 76 sections for the purpose of this survey.

Foreshore and channel assessments were conducted along the length of each river section by filling out the survey form (an example is provided in Appendix 3). In some instances, factors such as foreshore condition were averaged for the whole of a section, with best and poorest conditions recorded.

Where assessment categories referred to each side of the waterway (ie fencing status on the left or right bank), all surveys were conducted facing upstream.

The majority of assessment along Mortlock River and Mortlock River South was observational. Foreshore and channel condition was assessed whilst walking along the waterway and recorded on the survey form. Photos were taken at points of interest and will be used for future monitoring of the river and its foreshore. Landholders were also asked about changes in waterway condition and health, fauna, past landuse and management of the waterway.

Where vegetation could not be identified during field assessments, samples were taken for later identification. A *Licence for Scientific or other Prescribed Purposes* was obtained from the Department of Conservation and Land Management giving permission to collect flora for scientific and identification purposes subject to certain conditions.

The use of GPS (Magellan GPS 315) allowed for points of interest to be recorded. Locations such as section start and end points were recorded to allow for accurate display of collated data on maps. Readings also allow for accurate location of sections for future monitoring and management.

The assessment format used is comprehensive in recording foreshore and channel condition but does not require specialised knowledge or extensive technical assistance to complete. Hence, community groups, landholders and individuals, without the aid of a qualified person, can undertake assessments. The survey forms are sectionalised so that assessors can make use of sections relevant to their needs. A blank assessment form is provided in Appendix 3 that can be copied and used by the community to assess the present condition of waterways.

Bank stability

Bank stability was assessed by observing the proportion of the banks affected by erosional processes including undercutting, firebreak and track washout, subsidence, gully erosion, sedimentation and slumping. General evidence of streambank erosion includes widening streamlines, incised channels, bare soil on the top of banks, vertical banks and exposed tree roots.

Vegetation health

This section is used to provide a general description of the health and vigour of the native and exotic vegetation. This information is important as it identifies sections of river foreshore which may become unsupported by trees in the near future. The presence of native vegetation seedlings is noted as these will replace old trees in time.

A native and exotic vegetation list and the abundance of each species found, is included in this report. This is particularly important as to which native species should be used in revegetation projects and for the management of major weed species.

Foreshore assessment grading system

One of the main pieces of information collected was the foreshore condition assessment rating of each section. Both an overall rating and a 'best' and worst' rating were recorded. The overall rating of each section was determined as the average rating along the whole length of the section and was recorded as either A, B, C or D-grade. The 'best' and 'worst' ratings were respectively the highest and lowest ratings determined within the section and were recorded as A1 (pristine) through to D3 (weed-infested drain). Refer to Appendix 4 for the field guide to foreshore grades.

A-grade foreshore

This overall rating is used for river banks and floodways that are entirely vegetated with native species. Some weeds may be present but native species still dominate the understorey. There is little evidence of erosion or slumping of the channel banks, limited sedimentation, seasonal river pools and there is little evidence of human interference. This general rating is further divided to reflect the level of weed invasion and disturbance.

Rating	**Key features**
A1 Pristine	The river embankments and floodway are entirely vegetated with native species and there is no evidence of human presence or livestock damage
A2 Near pristine	Native vegetation dominates. Some introduced weeds may be present in the understorey but not as the dominant species. Otherwise, there is no evidence of human impact
A3 Slightly disturbed	Native vegetation dominates, but there are some areas of human disturbance where soil may be exposed and weeds are relatively dense (ie. local weed infestations along tracks). Native vegetation would quickly recolonise if human disturbance declined

B-grade foreshore

A general B-grade foreshore rating is given to sections where the majority of the vegetation structure is intact but where the understorey has been invaded by weeds. The sub-grades are divided based on the level of weed invasion and its affect on the regeneration of some shrubs and trees.

Rating	Key features
B1 Degraded – weed infested	Weeds have become a significant component of the understorey vegetation. Native species are still dominant but a few have been replaced by weeds
B2 Degraded – heavily weed infested	Understorey weeds are nearly as abundant as native species. The regeneration of trees and large shrubs may have declined
B3 Degraded – weed dominant	Weeds dominate the understorey, but many native species remain. Some trees and large shrubs may have disappeared

C-grade foreshore

A C-grade foreshore rating indicates that the foreshore supports only trees over weeds or pasture. As a result of the dominance of weeds in the understorey, bank erosion and subsidence occur in localised areas. The sub-grades for this rating are divided based on the amount of ground cover provided by weeds and the susceptibility of the banks to erosion.

Rating	Key features
C1 Erosion prone	Trees remain with some large shrubs or tree grasses and the understorey consists entirely of weeds (ie. annual grasses). There is little or no evidence of regeneration of tree species. River embankment and floodway are vulnerable to erosion due to the shallow-rooted weedy understorey providing minimal soil stabilisation and support
C2 Soil exposed	Older trees remain but the ground is virtually bare. Annual grasses and other weeds have been removed by livestock grazing and trampling or through humans use and activity. Low level soil erosion has begun
C3 Eroded	Soil is washed away from between tree roots. Trees are being undermined and unsupported embankments are subsiding into the river valley

D-grade foreshore

A D-grade foreshore rating indicates that there is not enough remaining vegetation to control erosion and the waterway is little more than an eroding ditch or weed-infested drain. Sub-grades are determined by the amount of vegetation present and the severity of erosion.

Rating	Key features
D1 Ditch – eroding	There is not enough fringing vegetation to control erosion. Remaining trees and shrubs act to impede erosion in some areas, but are doomed to be undermined eventually
D2 Ditch – freely eroding	No significant fringing vegetation remains and erosion is out of control. Undermined and subsided embankments are common. Large sediment plumes are visible along the river channel
D3 Drain – weed dominant	The highly eroded river valley has been fenced off, preventing control of weeds by stock. Perennial weeds have become established and the river has become a simple drain

Overall stream environmental health rating

The overall stream environmental health (OSEHR) provides an indication of stream health based on an assessment of the quality and diversity of aquatic and terrestrial habitats in the riparian zone. The completeness of the OSEHR is important for the existence and health of all types of creatures that live in the riparian zone. Each of the assessment parameters is ranked from excellent through to very poor. A numerical score has also been given to each ranking and the score system has been calculated to give more weighting to conditions which are more important to stream health, such as shade and permanent water. Refer to Appendix 7 for the full OSEHR table and explanatory information.

Survey results

Historical evidence as well as the survey results indicate that the Mortlock River and Mortlock River South and its surrounding catchment has been subjected to a wide range of disturbances, such as vegetation clearing, fire disturbance and animal grazing for a number of years. This has lead to a decline in ecosystem health and the ability of the river environment to repair itself.

Field observations indicate the main forms of degradation include a decline in fringing vegetation diversity and density, sedimentation, bank erosion, weed invasion and salinity and these are the result of current and past agricultural landuse practices.

Bank and channel stability

Bank and channel stability can be affected by surrounding soil type, the presence or absence of riparian vegetation and the velocity or force of flowing water. These factors can cause a number of associated problems which were recorded in the survey:

- undercutting;
- firebreak/track washouts;
- subsidence;
- erosion;
- gully erosion;
- sedimentation; and
- slumping.

Field assessments were used to determine an average percentage of the river section affected by the problems listed above. The rating system used is shown in Table 2.

Table 2. Rating system used to determine bank stability

Proportion (%) of River Bank Affected	Rating
0–5%	Minimal
5–20%	Localised
20–50%	Significant
> 50%	Severe

On the Mortlock River and Mortlock River South, undercutting occurred on the outside of meander bends. Large sediment deposits in the river channel have diverted water directly into the bank and caused scouring and channel widening. As a result of this, undercutting was minimal at 53% of sections and localised at 19% of sections. Evidence of undercutting along the river banks included exposed tree roots and bedrock.

River bed and bank erosion was a large issue in the Mortlock River and Mortlock River South floodway. There was localised erosion at 68% of sections, significant erosion at 18% of sections and minimal erosion at 11% of sections. Evidence to suggest erosion included vertical river banks, scouring of the river bed and exposed soil.

Sedimentation was documented at all of the sections along the survey (Figure 2). Significant sediment deposits were recorded at just under half (48%) of the sections surveyed. 35% of the river had localised sedimentation and 15% had severe (> 50%) sediment deposits. Only 1% of sections had minimal sedimentation.

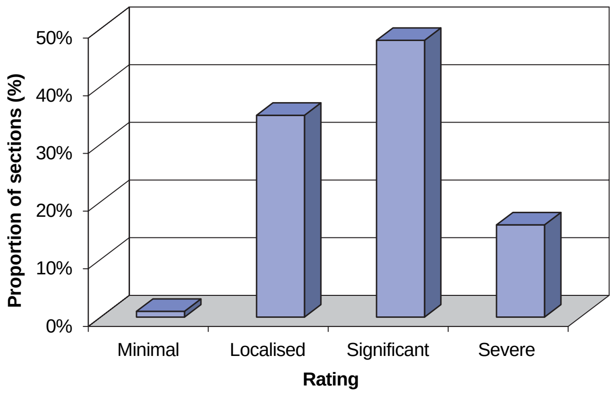


Figure 2. Bank stability – sedimentation

Other forms of bank and channel instability were noted and these included firebreak and track washouts, subsidence, gully erosion and slumping. These were all found to be minimal and do not pose an immediate threat to the river system.

Waterway features

Identifying the features of a waterway can often be a simple way of determining stream health. The presence of features such as river pools, anabranches, riffles and islands could mean that the waterway is in reasonable health. Other features such as sand slugs, dams and any other man made structure could be related to poor stream health.

Photo: Crees Road Bridge (decommissioned)

One of the major waterway features of the Mortlock River and Mortlock River South is the presence of a single channel. 80% of sections displayed only one channel for water to flow through. A further 20% of the sections had a braided channel system with numerous channels of similar size. Numerous anabranches also occurred within the floodplain of the Mortlock River and Mortlock River South. An anabranch is a secondary channel of a river, which splits from and then later joins the main channel (Lovett & Price, 1999a). Anabranches were recorded at 89% of sections. Vegetated islands are typical river features that accompany anabranches and braided channel systems and they were documented at 36% of sections.

The amount of sediment within a river system can be an indicator of river health. Excessive amounts of sediment can impact on river ecology through the filling of river pools and eventual loss of aquatic habitats. Sediment slugs along the Mortlock River and Mortlock River South were documented at 74 of the 76 sections or approximately 97% of the sections surveyed. River pools were documented at 47% of the sections. It should be noted that the survey was conducted during April and May 2004 when water levels are generally the lowest during the year.

An extensive road network in the Mortlock River and Mortlock River South catchment lead to many bridges being recorded along the survey. Bridges crossing the river were observed at 23% of sections. Many of the bridges are still in use whereas others have not been used in many years as shown in the photograph above.

Small streams and brooks leading into the Mortlock River and Mortlock River South were recorded at 32% of sections. The average rainfall in the catchment is approximately 450 mm. This combined with high runoff from the surrounding hills, which consist of impermeable bedrock of granite and dolerite, this has formed the numerous small streams which flow into the Mortlock River and Mortlock River South.

Foreshore vegetation

Native vegetation

The dominant overstorey vegetation growing on the floodplain and banks of the Mortlock River and Mortlock River South includes Swamp sheoak (*Casuarina obesa*), York gum (*Eucalyptus loxophleba*), Flooded gum (*Eucalyptus rudis*) and Swamp paperbark (*Melaleuca rhaphiophylla*). Upstream of Flea Pool reserve, Swamp

Table 3. Native vegetation occurrence and abundance

Scientific Name	Common Name	% of sites where species occured	Abundance of each species (% of occurance)		
			Low	Medium	High
Acacia acuminata	Jam wattle	61	66	31	3
Acacia meisneri	Blue wattle	1	100	0	0
Acacia microbotrya	Manna wattle	5	100	0	0
Amymea miquelii	Stalked mistletoe	3	100	0	0
Atriplex amnicola	River saltbush	5	100	0	0
Atriplex semibaccata	Creeping saltbush	38	90	10	0
Banksia prionotes	Acorn banksia	3	100	0	0
Casuarina obesa	Swamp she-oak	82	2	3	95
Cyprus gymnocaulus	Spiny flat sedge	13	80	20	0
Dianella revoluta	Blueberry lily	1	100	0	0
Erogrostis dielssii	Mallee lovegrass	3	100	0	0
Eucalyptus loxophleba	York gum	83	16	74	10
Eucalyptus rudis	Flooded gum	61	58	35	7
Eucalyptus salmonophloia	Salmon gum	3	100	0	0
Eucalyptus salubris	Gimlet	1	0	0	100
Eucalyptus wandoo	Wandoo	3	100	0	0
Frankenia pauciflora	Sea heath	4	100	0	0
Grevillea paniculata		3	100	0	0
Hakea preissii	Needle bush	54	52	45	3
Halosarcia sp.	Samphire	75	10	59	31
Jacksonia sternbergiana	Stinkwood	6	100	0	0
Juncus kraussii	Shore rush	6	83	17	0
Maireana brevifolia	Small leaf bluebush	63	30	60	10
Melaleuca brevifolia		3	100	0	0
Melaleuca rhaphiophylla	Swamp paperbark	53	62	38	0
Melaleuca uncinata	Broombush	3	100	0	0
Santalum acuminatum	Quandong	1	100	0	0
Scholtzia involucrata	Spiked scholtzia	6	100	0	0
Sporobolus virginicus	Native marine couch	23	76	24	0
Xanthorrhoea preissii	Grasstree	3	100	0	0

sheoak (*Casuarina obesa*) ceases to be the dominant overstorey species where it changes to York gum (*Eucalyptus loxophleba*). Other large trees encountered on the survey with low coverage include Gimlet (*Eucalyptus salubris*) and Salmon gum (*Eucalyptus salmonophloia*).

The middlestorey are those species which grow to approximately 4 m in height and have a bushy growth habit. Middlestorey species found in abundance on the Mortlock River and Mortlock River South floodway include needle-bush (*Hakea preissii*) and Jam wattle (*Acacia acuminata*). Species with low coverage include Stinkwood (*Jacksonia sternbergiana*), Acorn banksia (*Banksia prionotes*), Spiked scholtzia (*Scholtzia involucrata*), Grevillea paniculata and Quandong (*Santalum acuminatum*).

Table 4. Weeds species occurrence and abundance

Scientific Name	Common Name	% of sites where species occured	Abundance of each species (% of occurance)		
			Low	Medium	High
Avena fatua	Wild oats	79	5	35	60
Bromus diandrus	Broom grass	13	30	70	0
Citrullus lanatus	Pie melon	1	100	0	0
Cotula coronopifolia	Water buttons	1	100	0	0
Crassula sp.	Crassula	1	100	0	0
Cynadon dactylon	Couch	1	100	0	0
Cucumis myriocarpus	Prickly paddy melon	1	100	0	0
Echium plantagineum	Pattersons curse	1	100	0	0
Ehrharta calycina	Veldt grass	1	100	0	0
Eragrostis curvula	African lovegrass	1	100	0	0
Heliotropium curassavicum	Smooth heliotrope	1	100	0	0
Hordeum leporinum	Barley grass	65	14	70	16
Juncus acutus	Spike rush	23	59	41	0
Limonium sinatum	Perennial statice	1	100	0	0
Lolium rigidum	Rye grass	26	26	63	11
Oxalis pes-caprae	Soursob	1	100	0	0
Puccinellia ciliata	Puccinellia	27	30	60	10

Native understorey species were common throughout the survey and the species documented include samphire (*Halosarcia* sp.), Creeping saltbush (*Atriplex semibaccata*), Small leaf bluebush (*Maireana brevifolia*), Sea heath (*Frankenia pauciflora*), Native marine couch (*Sporobolus virginicus*) and River saltbush (*Atriplex amnicola*). The native sedge species found along the Mortlock River included Shore rush (*Juncus kraussii*) and Spiny flat sedge (*Cyperus gymnocaulos*). See Table 3 for native vegetation occurrence and abundance. Also refer to Appendix 6 for the York regional herbarium species list of Flea Pool Reserve located on the Mortlock River South.

Introduced vegetation

Weeds were common throughout all sections of the survey and made up a large proportion of the understorey vegetation (see Table 4). Weed species were low in diversity but high in abundance in the study area. Introduced grasses dominated the river floodway and these included Barley grass (*Hordeum marinum*), Wild oats (*Avena barbata*) and Annual ryegrass (*Lolium rigidium*). Species of low abundance and occurance included Pattersons curse (*Echium plantagineum*), Smooth heliotrope (*Heliotropium curassavicum*), Spike rush (*Juncus acutus*), Puccinellia (*Puccinellia ciliata*) and Great brome grass (*Bromus diandrus*).

Vegetation health

The native vegetation of the Mortlock River and Mortlock River South is under threat from salinity, weed invasion, stock grazing and less so, waterlogging. These environmental pressures can affect the native vegetation's ability to grow and reproduce to such a point where native vegetation diversity and abundance is in decline.

73% of sections had some sick trees with evidence such as loss of foliage or poor growth. 2% of the sections had many sick trees with extreme foliage loss or damage. 15% of the surveyed sections had some dead trees along the floodway. 2% of sections had many dead trees and evidence suggests that the trees have been dead for many years, but these are still useful habitat for invertebrates and birds.

Seedlings of native species were recorded along the survey and they occurred in only 22% of sections and in low

Photo: Weed and leaf litter removed from floodway

abundance. A majority of the species recorded included Swamp sheoak (*Casuarina obesa*) and Jam wattle (*Acacia acuminata*).

The abundance of native vegetation varied along the Mortlock River and Mortlock River South. Native vegetation was rare at 3% of sections, 83% of sections had occasional native vegetation and 14% had frequent native vegetation.

Exotic vegetation abundance was rare at 3% of sections, occasional at 11%, frequent at 78%, and abundant at 8% of surveyed sections. From these percentages, exotic species were considered to be frequent throughout the floodplain of the Mortlock River and Mortlock River South. Common weed species encountered along the banks of the Mortlock River and Mortlock River South include Annual rye grass (*Lolium rigidum*), Wild oats (*Avena barbata*), Spike rush (*Juncus acutus*), Sea barley grass (*Hordeum leporinum*) and Puccinellia (*Puccinellia ciliata*).

Vegetation cover

Along the length of the survey, vegetation cover was recorded as a patchy overstorey over a sparse middlestorey with a continuous understorey layer. Table 5 shows the proportion (%) of vegetation cover for each vegetation layer. The table showed that in 85% of sections the overstorey or dominant vegetation layer was patchy with large spaces between trees. The middlestorey vegetation was sparse in 60% and patchy in 39% of sections. The understorey layer was continuous at 71% of sections.

The overstorey and middlestorey layers consisted solely of native species, with no exotic vegetation in these two layers. Approximately 10 – 20% of species found in the understorey layer were native which translates into high (> 80%) weed abundance and diversity.

Table 5. Vegetation cover

Vegetation layer	**Proportion of vegetation cover** (%)			
	Absent (0%)	**Sparse** (< 20%)	**Patchy** (20 – 80%)	**Continuous** (> 80%)
Overstorey	0	10	85	4
Middlestorey	1	60	39	0
Understorey	4	9	16	71

A bare ground percentage was recorded for each survey section. The percentage of bare ground could influence soil and bank stability and could also change the terrestrial habitat values of the section. There were low percentages of bare ground along the survey due to high weed abundance. Bare ground was sparse (< 20%) at 56% of sections and patchy at 44% of sections.

Leaf litter was absent at 5% of sections, minimal cover at 92% and good cover at 3% of sections.

Habitat diversity

The Mortlock River and Mortlock River South displayed a moderate diversity of habitat types. Both the aquatic and terrestrial habitat types were recorded.

Aquatic animals

Abundant logs, rocks, fallen branches, leaf litter and vegetation are all important habitat types for aquatic animals. Cascades and rapids can be caused by undulating surfaces on the river bed which could include rocks, branches or consolidated sediment deposits. Cascades and rapids were noted at 26% of sections. Meanders and associated river pools are an important refuge area for aquatic animals over the summer months and were recorded at 76% of sections. Instream cobbles and rocks were recorded at only 11% of sections which may be due to an absence of rocks in the surrounding sandy soil types. 85% of sections displayed logs and branches, which are important habitat for aquatic macroinvertebrates and fish. There was a lack of instream and bank vegetation for aquatic animals. Instream and bank vegetation was present at only 4% of sections. The instream vegetation mainly consisted of samphires and some weed species.

Terrestrial animals

The Mortlock River and Mortlock River South has high habitat diversity for birds, medium habitat value for invertebrates and reptiles and a low habitat value for frogs and mammals. Terrestrial invertebrates had leaf litter and bark at 60% of sections but only 4% of sections had a variety of vegetation types. Bird roosting and nesting sites in trees or shrubs were common along the river floodway. Trees were present at 98% of sections, shrubs at 94% and rushes at 22% of surveyed sections. Frogs require dense vegetation and emergent plants for habitat and these habitat types were lacking throughout the survey. Only 1% of sections had dense vegetation and only 8% had emergent plants.

A majority of native mammals need dense protective vegetation to collect food and live in and with a low percentage of this habitat type mammals would find it difficult to survive in the riparian zone. Reptiles require a habitat with sufficient food and places to rest. Leaf litter and logs (basking sites) were recorded at 66% of the sections but there was an absence of instream and bank vegetation as reptile habitat.

During the survey, observations were made of the fauna living in the river floodplain. These included:

Birds: pacific black duck, white-faced heron, welcome swallow, kookaburra, little pied cormorant, silvereye, grey teal, dotterel, willie wagtail, ringneck parrot, Australian magpie, magpie lark, Australian raven, galah, crested pigeon, yellow-throated miner, red wattlebird, blue-breasted fairy wren, grey fantail, wedge-tail eagle, red-capped robin, sacred kingfisher and dove.

Mammals: western grey kangaroo, fox and rabbit

Reptiles: Southern pale-flecked morethia, common dwarf skink, western bearded dragon

Fish: mosquito fish (Gambusia)

Insects: ant, dragonfly, damselflies, wasp, flies, butterfly, whirligig beetle (aquatic), amphipod (aquatic) and diving beetle (aquatic)

Evidence of water depth in the Mortlock River and Mortlock River South ranges from bankfull conditions (2 metres deep) to a dry river bed. The seasonal flow of the Mortlock River and Mortlock River South represents extremes in aquatic habitat that fauna would have to adapt to. During the survey, evidence was collected on the variation in water depth. These observations include:

- Salt deposits on the river banks;
- Bank erosion;
- Terraced river banks (erosional features);
- Vegetation (samphires) distribution on the river bank;
- Debris trapped in vegetation or man made structures;
- Undercutting of tree roots; and
- Deposition of sediment on river banks and within river channel.

The annual pattern of summer drought and winter flood is the basic context for most of the river systems in the Avon

Photo: Stock (sheep) within riparian zone

region. All of the animal species which use the river are adapted to exploit episodes of drought and flood. During the winter months, river flow would increase and there would be suitable habitat for birds and aquatic fauna. During the summer months water levels fall and the river environment becomes a hostile place to live with high water temperatures and salinities. Fauna either retreats to the remaining deep river pools or leaves the area in search of permanent fresh water.

Fencing status

An assessment of the fencing along the Mortlock River and Mortlock River South showed that fencing was present in a majority of sections. Of the 76 sections surveyed, 65% had the left bank fenced and 79% had the right bank fenced. Table 6 shows the approximate fence distance from the riverbanks.

Of those sections that had fencing on the left bank, 53% was rated as good quality, 45% was moderate quality and only 2% was poor quality. Of sections that had fencing on the right bank, 40% was good quality, 50% was moderate and 10% was poor quality fencing. Refer to Appendix 5 for examples of fence condition.

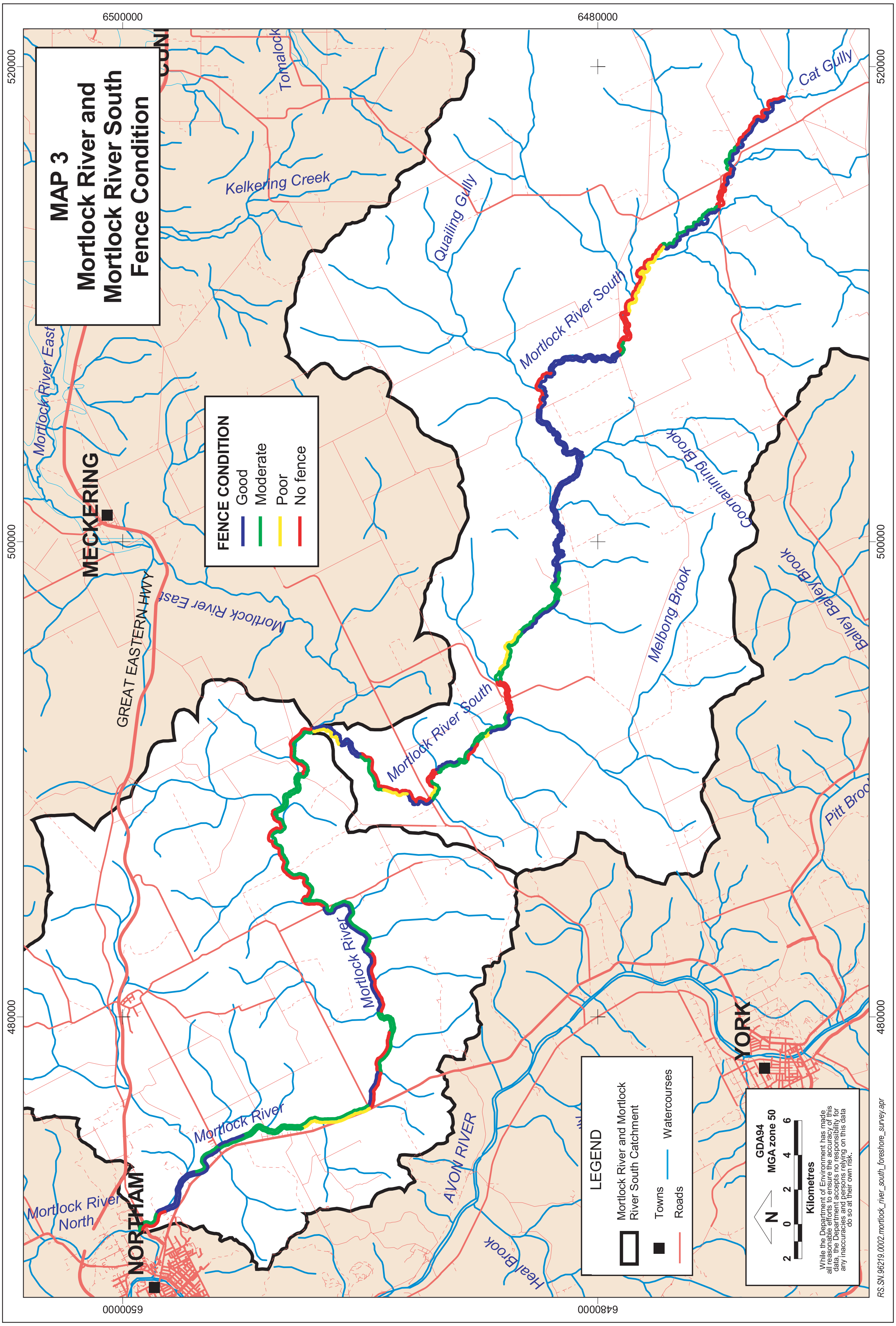
Table 6. Fence position

Distance category in metres	Proportion of sections fenced (%)	
	Left bank	Right bank
< 10	2	2
10 – 20	16	13
20 – 30	37	25
> 30	45	60

The fencing style varied throughout the survey. Ringlock, ringlock with barbed wire, single plain wires and electric fences were present along the river. See Table 7 for the presence of each fence style.

Table 7. Fence style

Fence style	Proportion of sections with fencing (%)	
	Left bank	Right bank
Ringlock with barbed wire strand	44	40
Ringlock	53	56
Electric fence	3	2
Single plain wires	0	2



Map 3. Fence condition

Stock and vehicle access

The results showed that stock had access to the river foreshore at 42% of sections. Vehicles had access to the river banks at 46% of sections and there were river crossings at 42% of the river sections.

Water quality

During the course of the survey, water quality readings could not be taken for most of the sections due to a lack of river flow. Some pools were present but flowing water is needed to take a representative sample of the river.

The water quality along the Mortlock River is monitored at the Department of Environment river gauging station 615020 O'Driscolls Farm. The gauging station is located on the Mortlock River downstream of the confluence with the Mortlock River South and the Mortlock River East. Data from this station is not specific to the Mortlock River or the Mortlock River South so it can not be expanded on in this report. Data from the gauging station dating back to 1994 can be found in Appendix 2.

Electrical Conductivity (EC) is used as a measure of dissolved salts, the most common being sodium chloride (table salt). The level of dissolved salts is referred to as salinity or Total Dissolved Salts (TDS) and is measured in milligrams per litre (mg/L) or milli-siemens per centimeter (mS/cm).

The results from the survey conducted in the months of April/May showed that the EC in the Mortlock River South was considered to be in the high saline range (20 – 40 mS/cm) (Table 8). The readings decrease during the winter months (July/August) when there is an increase in rainfall and fresh water to approximately 18 – 25 mS/cm (Ryan & Cobb, 1997).

The pH (power of hydrogen) of a watercourse is a measurement of its relative acidity or alkalinity. The pH scale ranges from 0 (acidic) to 14 (alkaline or basic) with the value of 7 indicating neutral conditions such as those of distilled water. The natural pH of water in a watercourse is dependent on the predominant landforms, soil types and vegetation present. For many watercourses in the Avon region, a pH of less than 5 or greater than 9 would indicate potential pollution problems.

pH measurements taken along the Mortlock River South during the survey indicate that the water is slightly alkaline with a pH of between 8.17 and 8.66 (Table 8). The presence of certain salts can influence the pH of watercourses. The use of inorganic phosphate fertilisers or the release of phosphate containing detergents can increase phosphate concentrations in waterbodies near to farming areas which can alter the pH of the river.

The water temperature of the Mortlock River and Mortlock River South was taken during the months of April/May and results show that temperatures are low (Table 8). The water temperature can change due to the presence or absence of native vegetation, degree of water clarity or turbidity, water depth, the time of day and season.

Table 8. Water quality results

Section number	pH	Electrical Conductivity (mS/cm)	Temperature (°C)	Location
MRS046	8.22	33.4	13.4	Upstream boundary
MRS047	8.22	31.7	14.8	Upstream boundary
MRS048	8.27	38.8	15.7	Upstream boundary
MRS049	8.17	34.1	14.8	Downstream boundary
MRS050	8.66	35.8	17.0	Upstream boundary
MRS051	8.21	35.7	15.3	Upstream boundary

Table 9. Electrical conductivity and salinity ranges

Salinity Classification	Electrical Conductivity (mS/cm)	Salinity (mg/L)
Fresh	< 1.0	< 550
Marginal	1.0 – 2.0	550 – 1 100
Brackish	2.0 – 9.0	1 100 – 4 950
Low Saline	9.0 – 20.0	4 950 – 11 000
High Saline	20.0 – 45.0	11 000 – 24 720
Hyper Saline	> 45.0	> 24 750

Disturbance

The Mortlock River and Mortlock River South channel and surrounding riparian environment are subject to a wide range of disturbance factors, which act to continually degrade the river foreshore. The major forms of disturbance encountered on the Mortlock River and Mortlock River South included stock and vehicle disturbance, feral animals, and fire. The extent of stock and vehicle access can be seen in Map 4. A summary of the major disturbances observed during the survey include:

- 46% of sections were accessible and showed evidence of vehicle disturbance;
- 42% of sections were accessible by stock;
- 31% of sections had some form of feral animal disturbance, either from diggings or warrens; and
- 42% of sections had an open river crossing.

Lateral channel movement is a significant form of disturbance which can result from sediment deposits and unstable river banks. Even though there were significant amounts of sedimentation and localised erosion, the channel appears to be stable and is able to convey most river flows without major changes to the river banks, channel bed or riparian vegetation.

The problems resulting from these disturbances include bank erosion, pollution of the waterway, weed invasion and fire. These can be summarised into:

- Bank erosion was localised (5–20%) at 68% and significant (20–50%) at 18% of sections;
- 17% of surveyed sections were affected by pollution. The main source of pollution was animal faeces.
- Weeds were noted at all sections and have a medium management priority at 14% of sections and high management priority at 82% of surveyed sections; and
- Fire had a medium management priority at 38% of sections and is a high management priority in 47% of sections.

Evidence of management

Of all foreshore sections surveyed, 90% had undergone some form of riparian management along the Mortlock River and Mortlock River South. Even though a high percentage of sections revealed some form of management, the overall impact of the management was considered to be low in terms of the ecological health of the river. Riparian management was not continuous from property to property.

The most common form of river management found along the riparian zone was fencing, with 65% of sections having fencing on the left bank and 79% having fencing on the right bank. Fencing is the most effective means of protecting riparian vegetation and encouraging regeneration.

Due to the large amount of small landholders along the Mortlock River and Mortlock River South, fence location varied in distance away from the river banks. Refer to Table 6 for fence position away from river banks. The lateral movement of the river, presence of riparian vegetation and frequency of flooding should be taken into account when locating fences along the Mortlock River and Mortlock River South.

Constructed firebreaks were common along the external fence lines that border the river floodway. Firebreaks were present in 47% of sections. In some of the surveyed sections landholders have cleared the weeds from the understorey using a scalping method as to reduce the fire risk on the property.

Along with fencing and firebreaks, revegetation was another significant form of riparian management present along the survey reach. 21% of sections had attempted and showed evidence of revegetation. Revegetating the riparian zone can help to stabilise riverbanks, provide shade and habitat for aquatic and terrestrial animals and filter out harmful nutrients and sediments.

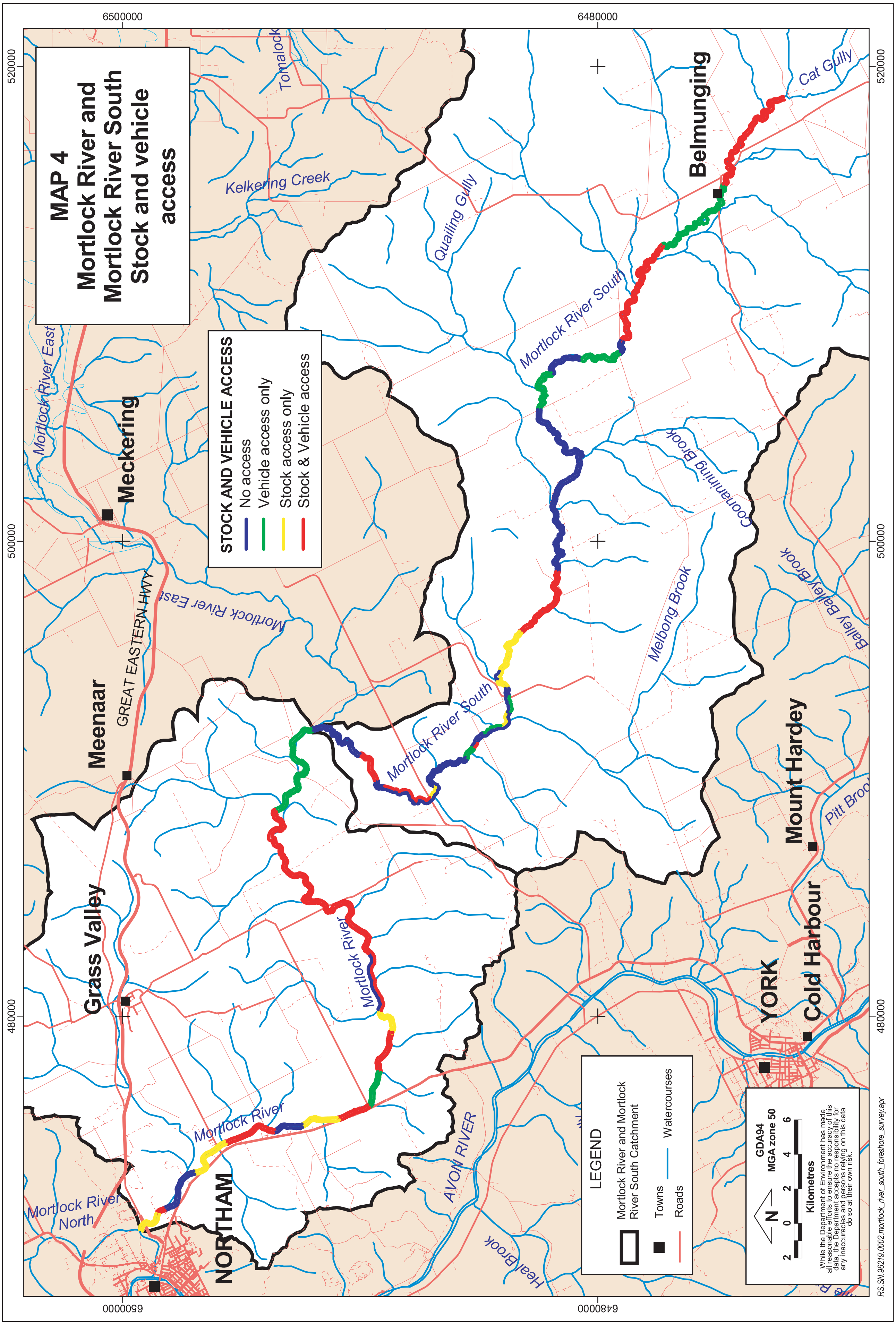
Weed control was evident in 10% of the sections and occurred where landholders had undertaken revegetation.

Priorities for management

The issues requiring management along the Mortlock River and Mortlock River South have been listed and given a priority ranking (high, medium and low). Table 10 shows the different management issues along the river with percentages of sections and level of priority. If an issue did not exist along a section of river then it was not included in the priority classification so some of the issues may not add up to 100%.

Table 10. Priorities for management

Management issue	% of surveyed sections		
	High	Medium	Low
Salinity	88	12	0
Weeds	82	14	1
Fire	47	38	10
Bank erosion	26	63	10
Livestock access	19	13	18
Sedimentation	14	48	34
Vehicle access	5	8	22
Cultural features	5	1	0
Feral animals	3	16	13
Rubbish	1	10	17
Water pollution	0	3	14
Recreation	1	3	10
Service corridors	3	3	38
Plant diseases	0	1	14



Map 4. Stock and vehicle access

The results in Table 10 indicate that the major management issues along the Mortlock River and Mortlock River South include salinity, weeds and fire and less so bank erosion, sedimentation and feral animals.

Salinity was found to be a high priority management issue in 88% of sections. Evidence of salinity included salt deposits and salt tolerant vegetation growing along the banks. Weed invasion was a high priority at 82% of sections. The grassy nature of the weeds accounted for 47% of sections having fire as a high priority management issue. Livestock access was a high priority at 19% of sections. Medium priority management issues included bank erosion in 63% of sections, followed by sedimentation at 48% of sections and feral animals at 16% of sections.

Foreshore condition

The foreshore condition assessment has been developed from observations of river system degradation throughout the south-west Australia. The system follows the general process of remnant bush degradation, with the added complication of erosion as stream banks become exposed (Pen & Scott, 1995). Refer to Appendix 6 or Survey Methods for explanatory information

General foreshore condition

A very large percentage (94%) of the surveyed sections was rated as having a C-grade general foreshore condition. C-grade is where the foreshore supports only trees over weeds or pasture, or just plain pasture and bank erosion and subsidence may be occurring, but only in isolated areas (Water and Rivers Commission, 1999).

Best foreshore condition

The best foreshore condition along the Mortlock River and Mortlock River South was a B2 rating at 3% of sections. A B2 rating is degraded but weeds are as abundant as native species and the regeneration of native species has declined due to weed invasion, erosion and disturbance from stock.

Poorest foreshore condition

The poorest foreshore condition sections on the Mortlock River and Mortlock River South can be related to past land uses and can be influenced by soil type, vegetation abundance, river fencing and disturbance. The poorest foreshore condition was rated as D2 at 3% of sections, followed by D1 at 11% of sections. There is not enough fringing vegetation in a D1 foreshore to control erosion, some trees and shrubs remain but will eventually be lost to undermining.

Overall stream environmental health rating

The Overall Stream Environmental Health Rating (OSEHR) is a system used to assess the habitat condition of streams and rivers, adapted from a Victorian model (Pen & Scott, 1995). It has been modified to give greater value to factors such as shade and the presence of permanent water which are very important to aquatic life in a region characterised by long hot dry summers. See Appendix 7 for explanatory definitions of the OSEHR.

Ratings of Excellent, Good, Moderate, Poor and Very Poor were given to a range of environmental factors associated with the river. The OSEHR was considered to be Poor in 62% of sections and Moderate in 38% of sections. Map 5 shows the OSEHR for the Mortlock River and Mortlock River South.

The results in Table 11 show that there were no Excellent ratings and low numbers of sections with Good stream cover and habitat diversity. 52% of sections had Moderate floodway and bank vegetation, 48% was considered to be Poor. 52% of sections had Moderate verge vegetation, 47%

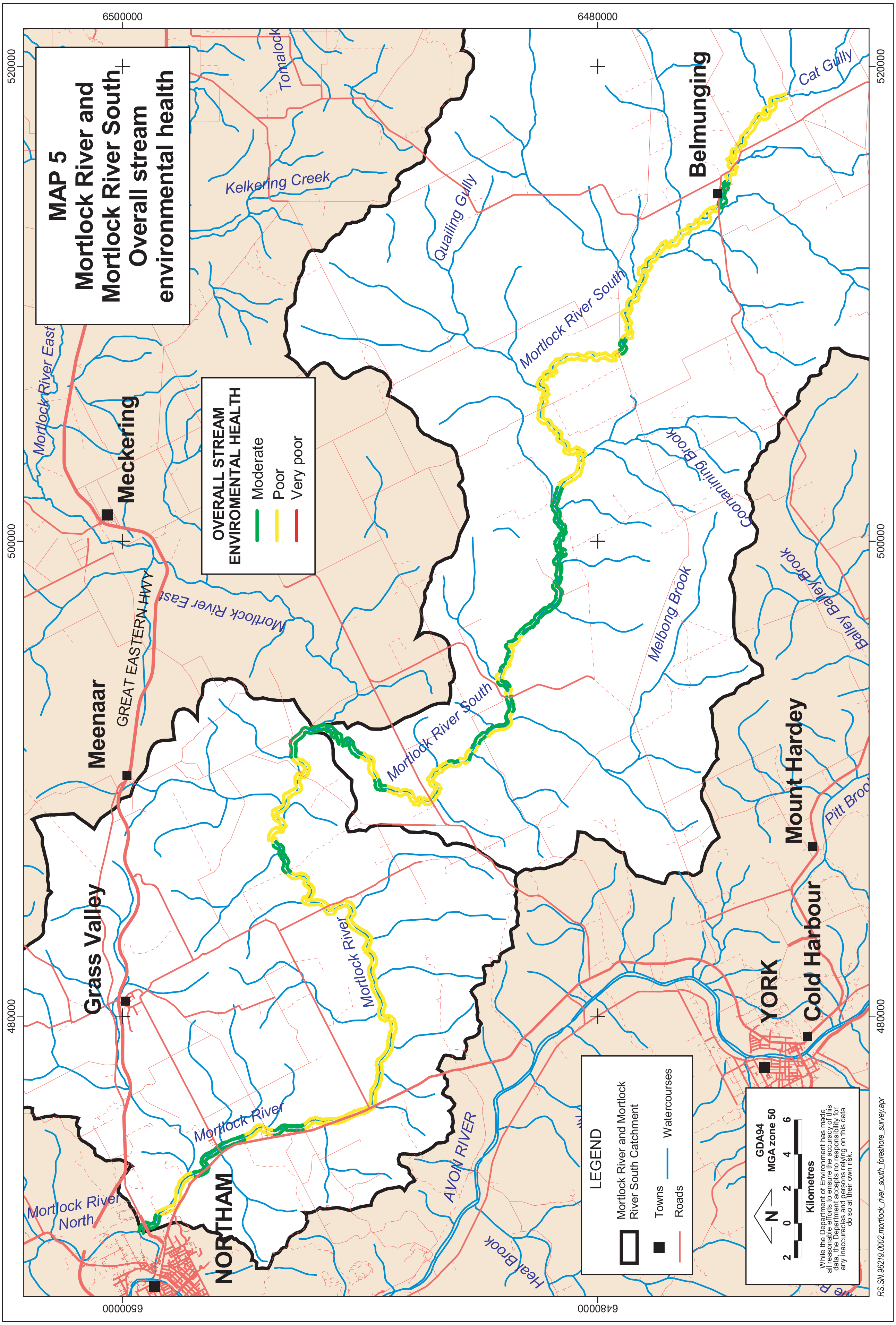
Table 11. Environmental health categories

Environmental Health Category	Proportion of sections (%)				
	Excellent	Good	Moderate	Poor	Very Poor
Floodway and bank vegetation	0	0	52	48	0
Verge vegetation	0	0	52	47	1
Stream cover	0	4	52	43	1
Bank stability and sedimentation	0	0	43	56	1
Habitat diversity	0	3	63	34	0

Photo: Typical C-grade river foreshore

Photo: Typical D-grade river foreshore

was Poor and 1% was Very Poor. Stream cover was rated as Good at 4% of sections, Moderate at 52%, Poor at 43% and Very Poor at 1%. Bank stability and sedimentation was found to be Moderate at 43% of sections, Poor at 56% and Very Poor at 1%. Habitat diversity was rated as Good at 3% of sections, Moderate at 63% and Poor at 34%.



Map 5. Overall stream environmental health

Interpretation of survey results

Bank and channel stability

The survey results show that sedimentation and less so, bank erosion are the main results of past channel instability along the Mortlock River and Mortlock River South. There were significant (20 – 50% of the section) sediment deposits at 48% of sections. The advent of large-scale clearing in the Mortlock River and Mortlock River South catchment has initiated large-scale changes in water flow and sediment movement. There has been an increase in the amount of runoff from the catchment. Increased flow has increased the erosive power of the water and the potential for erosion and bank collapse has increased. Clearing has also introduced fine silt and clay particles into the river system. These clay particles are deposited during low flows and have consolidated into hard sedimentary silt plumes which line the bed of the river in some sections (see photo below). Other sections are dominated by sandy sediments, which are mobilised during high flows.

Sediment is a natural component of the Mortlock River and Mortlock River South but the river system has excessive amounts, which has caused many problems. Sediment has filled most of the river pools, as a result of poor bank stability and degradation in the upstream catchment. These river pools provide important habitat for aquatic fauna that do not have physiological adaptations to tolerate drought during the hot, dry summers. Sediment slugs and plumes can alter the flow of water causing water to be redirected into the river banks resulting in further erosion, undercutting of trees and loss of riparian vegetation. Typically, rivers that have increased sedimentation have a less diverse macroinvertebrate fauna (Water and Rivers Commission, 2000a). Sediment can smother the rocks, logs and branches, which many macroinvertebrates use as habitat.

Along the Mortlock River and Mortlock River South, stock access to the river foreshore was evident at 42% of

Photo: Consolidated silt within river channel

Photo: Channel filled with coarse-grained (sandy) sediment

sections. Most of the sections that provided stock access to the river had no defined crossing or watering points. Some of the sedimentation problem in the Mortlock River and Mortlock River South results from bank erosion and undercutting caused by livestock trampling and removal of the vegetation cover, either exotic or native. Livestock access should be restricted so that river banks can stabilise which should reduce stream erosion and sedimentation.

Vehicles were able to access the riparian zone in 46% of sections and crossing points were also noted at 42% of sections. A majority of these crossing points were simple unconsolidated tracks across the river. Vehicle and stock traffic using these crossing points can loosen soil structure, which causes continual isolated disturbance to the banks and river bed. The exposed soil around the crossing can easily be eroded under high winter flows and could add to the sedimentation in downstream areas.

Riparian vegetation acts to reduce water velocity by increasing bank and channel ‘roughness’ or surface area. There were numerous native plant species found along the banks of the river but they were sparse to patchy in number. Species such as samphire (*Halosarcia* sp.) have colonised bare saline areas of the river banks and they also act to dissipate energy produced from flowing water. In areas where the vegetation has been cleared or is low in abundance, there is an increase in flow velocity and erosive power which combined with stock damage, has resulted in the erosion of banks and scouring of the river bed, leaving only hard sedimentary bedrock. A channel with no sediment for habitat is also detrimental to aquatic animals.

Waterway features

The present condition of the Mortlock River and Mortlock River South is reflected in the features of the waterway. The presence of features such as river pools, anabranches, riffles and islands could indicate that the river is in reasonable health. Other features such as sand slugs, dams and other man-made structures could have a detrimental effect on river health.

A single channel is common in the Zone of Rejuvenated drainage where river valleys are steeper, narrower and are defined within a floodplain of 100 metres either side of the banks. Anabranches were recorded at 89% of sections and this would indicate that in the past the river has received some large floods, which have carved out and created these side channels. Large floods in the future could cause wide scale erosion and sediment deposition due to the degraded nature of the river banks and foreshore.

In highly eroding and unstable sections of the Mortlock River and Mortlock River South, the river can carry large amounts of sediment and these were seen in small heaps within the channel or as long sediment slugs. If the sediment is excessive it will clog the channel and will often become braided into a series of channels weaving from side to side. Water can be redirected into the banks in these braided areas and can cause further bank erosion. Although there was only 20% of sections that had a braided channel system, these areas could become more degraded in the future if sediment is not stabilised.

River pools were noted at 47% of the sections. The pools provide an essential summer drought refuge, which is an integral part of the survival of many aquatic animal species. Many of the water birds recorded during the survey were located on or near a river pool. Although 47% of sections had river pools, the survey was conducted during autumn in low flow conditions. Most of these pools were less than one metre deep and would evaporate over summer. Increased sedimentation has filled most of the old permanent pools along the Mortlock River and Mortlock River South.

Riffles or cascades were only noted at 5% of sections but are a very important feature of the Mortlock River and Mortlock River South. Riffles and cascades help to oxygenate the water column, which is essential for aquatic life. Riffles also help to slow velocity and reduce the erosive power of water. Riffles can also provide habitat for aquatic macroinvertebrates and support algae in the oxygen-rich conditions.

There were numerous small streams and brooks flowing into the Mortlock River and Mortlock River South in 32% of sections. A majority of the small streams flow through agricultural land and most are unfenced and unstable. A percentage of the sedimentation problem in the Mortock River and Mortlock River South could be due to poor land management practices which has caused sediment to be washed off the land into the nearest waterway, adding to the issue in the main channel.

Foreshore vegetation

A healthy river system supports a diverse range of trees, shrubs, sedges, rushes and herbs. Foreshore vegetation acts to support the soil of the riverbank, helping to prevent erosion. In addition, riparian vegetation provides important habitat for native fauna and, through filtration, can decrease the amount of sediment and nutrients moving into the river which, in turn, maintains water quality.

The majority of the foreshore vegetation of the Mortlock River and Mortlock River South is considered to have a patchy overstorey of *Casuarina obesa*, *Eucalyptus loxophleba*, *Eucalyptus rudis* and *Melaleuca rhaphiophylla* over a sparse middlestorey of *Hakea preissii* and *Acacia acuminata* over a continuous understorey of *Atriplex semibaccata*, *Halosarcia* species and *Sporobolus virginicus*.

Many sections along the Mortlock River and Mortlock River South had sick, dying or dead trees in the riparian zone possibly due to high salinity levels. The earliest occurrence of salinity in the Mortlock River catchment was documented in 1920 with the death of aquatic vegetation. In 1928, the riparian vegetation (tea trees) in the Mortlock River East were starting to die (Sanders, 1991). Water quality snapshot readings indicate that the present salinity ranges from hyper-saline to brackish and there are few native plants that can survive the seasonal changes of salinity. The vegetation growing in the riparian zone along the Mortlock River and Mortlock River South is indicative of the present salinity levels. The Swamp sheoak or *Casuarina obesa* is the major canopy tree and was recorded at 82% of the sections. The Swamp sheoak is tolerant of higher salinity levels and also has a high tolerance to waterlogging. Salinisation has also restricted the regeneration of many native plant species with very few sections showing the presence of newly germinated seedlings. Waterlogging in the wetter months could also account for the sick, dying or dead trees found along the surveyed sections.

The disturbance of the riparian vegetation has altered the nutrient cycling within the river system. Evidence has shown that there is a low abundance of leaves, twigs and branches falling into the water, which are the main source of energy, carbon and nutrients needed to fuel the river ecosystem (Pen, 1999). The riparian vegetation also filters out harmful nutrients, which originate from the surrounding agricultural landscape. During flooding, the nutrients get deposited and trapped in the vegetation and the plants eventually assimilate the nutrients. This is better known as the flood pulse concept where there is a lateral exchange of material from floodplains to the river channel. With the absence of dense vegetation and subsequent leaves, twigs, branches and other organic matter, the vital food source which aquatic animals need to survive is no longer present and a result of this is a reduction in species diversity. Also with an absence of dense riparian vegetation, nutrients from the surrounding agricultural areas can move freely into the river and cause nutrient enrichment and subsequent algal blooms, which can kill aquatic animals.

The removal of riparian vegetation along the banks has contributed to an increase in bank erosion in some sections. The erosion has washed away the soil, which is usually reinforced by the tree roots, and has caused undercutting and channel widening.

The understorey vegetation cover is considered to be continuous with 71% of sections having more than 80% cover. Only a small percentage of that is made up of native species. Various weed species dominate the understorey along the riparian zone. The role of native understorey in the management of river systems cannot be understated. The current lack of native understorey species means that the nutrient stripping ability of the riparian zone is greatly reduced, leading to higher concentrations of nutrients entering the aquatic system and the promotion of weed species. Nutrient enrichment and consequent algal blooms have the ability to kill aquatic fauna.

Land use within the Mortlock River and Mortlock River South catchment has significantly altered the species composition and density of riparian vegetation. The riparian zone has been subjected to agricultural activities such as cereal and pasture cropping and grazing activities. These land use practices have introduced a number of perennial and annual weed species. Common agricultural weed species found along the riparian zone include Barley grass (*Hordeum leporinum*), Wild oats (*Avena fatua*), Puccinellia (*Puccinellia ciliata*) and Annual rye grass (*Lolium rigidium*). Grazing and trampling of the riparian zone has lead to the spread of these weeds, whose life cycles are short and exploit only the fresher water, which falls in winter and spring. The absence of dense understorey native vegetation combined with stock access to the river has increased weed growth and density to where it dominates the understorey vegetation. Weeds are quicker to adapt to disturbance and an increasing level of salinity has lead to the death of many less tolerant native species, leaving room for weeds to invade. Not only are these grasses major weeds, they also increase the fire risk during the summer months as they dry off and end their life cycle. It should also be noted that Spike rush (*Juncus acutus*), a major saline waterway weed in the Avon catchment, was not recorded in high abundance along the Mortlock River South but was recorded along the Mortlock River. Spike rush can dominate the understorey and spreads easily due to large amounts of viable seed. All endeavours should be made to restrict or eradicate Spike rush populations in the Mortlock River South catchment using the burning and herbicide spraying technique.

Table 12 Local species revegetation list

Growth habit	Genus/Species	Common name
Tree		
	Allocasuarina huegliana	Rock sheoak
	Banksia prionotes	Acorn banksia
	Casuarina obesa	Swamp sheoak
	Eucalyptus rudis	Flooded gum
	Eucalyptus salmonophloia	Salmon gum
	Eucalyptus salubris	Gimlet
	Eucalyptus wandoo	Wandoo
	Melaleuca rhaphiophylla	Swamp paperbark
Shrub		
	Acacia acuminata	Jam wattle
	Acacia meisnerii	Blue wattle
	Acacia microbotrya	Manna wattle
	Acacia saligna	Golden wreath wattle
	Callistemon phoeniceus	Lesser bottlebrush
	Hakea preissii	Needle bush
	Jacksonia sternbergiana	Stinkwood
	Melaleuca brevifolia	
	Melaleuca uncinata	Broombush
	Santalum acuminatum	Quandong
	Scholtzia involucrata	Spiked scholtzia
Low shrub		
	Atriplex amnicola	River salt bush
Groundcover		
	Atriplex semibaccata	Creeping saltbush
	Enchylaena tomentosa	Ruby saltbush
	Frankenia pauciflora	Sea heath
	Maireana brevifolia	Small leaf bluebush
Rushes, sedges and grasses		
	Cyprus gymnocaulus	Spiny flat sedge
	Juncus kraussii	Shore rush
	Sporobolus virginicus	Native marine couch

Overhanging trees and shrubs cast shade over the water, which assists in maintaining low water temperatures. Shade is an essential refuge for aquatic animals from the hot summer sun. Many native aquatic animals can only survive in cooler conditions and could be killed if the temperature reaches high levels. Shade also reduces the growth of aquatic plants and harmful algae which, combined with excessive nutrient levels, could cause algal blooms. In a majority of sections, the overstorey vegetation was either absent or sparse and as a result cast little shade over the river. Minimal shade could act to decrease the water quality and potential aquatic habitats of the river.

It should be noted that the vegetation surveys conducted throughout the foreshore and channel assessment are not conclusive. It is likely that there are other species present along the river and it is recommended that future assessments include two separate vegetation surveys, at differing times of the year, to determine a more accurate list of species. For an up to date list of riparian species and those recommended for use in revegetation and habitat restoration projects please refer to Table 12 or Water Note 24 Riparian zone revegetation in the Avon catchment.

Please note that some of the species listed in Table 12 were not recorded during the survey but occur naturally in riparian areas of the Mortlock River and Mortlock River South catchment and should be included in revegetation projects to increase biodiversity and habitat for animals.

Habitat diversity

The Mortlock River and Mortlock River South riparian zone was found to have only moderate habitat diversity with a reduced number of aquatic and terrestrial habitats which is indicative of the overall health of the waterway. In-stream cover is a vital habitat element for aquatic animals and is important for the maintenance of water quality within the river ecosystem. In-stream cover can consist of leaf litter, rocks, branches/logs and vegetation.

There was a lack of aquatic macrophytes (submerged plants) and there were only a few species of emergent macrophytes (rushes and sedges) which are those species which grow half in water and half on land. Spiny flat sedge (*Cyprus gymnocaulus*) was recorded at 13% of sections and Shore rush (*Juncus kraussii*) was only recorded at 6% of sections. These are the two main rush and sedge species growing along the Mortlock River and Mortlock River South. These rushes and sedges have shallow root systems, which bind the soil and reduce erosion. Rushes and sedges are also pivotal to water quality improvement with excellent nutrient stripping capability. Their growth habit means they are excellent at slowing the flow of water and trapping sediments. Dense stands of native rushes and sedges provide excellent weed control, excluding less desirable species and out-competing others (Water and Rivers Commission, 2000c). Spiny flat sedge and shore rush can tolerate fluctuations in salinity and are easily propagated for use in revegetation projects.

Leaf litter and detritus was found to be an important aquatic habitat type at 73% of sections. The leaves of native vegetation are hard and break down slowly in natural conditions and provide food and shelter for aquatic animals. Due to the absence of native vegetation in some areas, weeds dominated the riparian zone and subsequently there was less leaf litter. Weeds often have soft leaves, which break down quickly rendering them unavailable to aquatic animals for habitat and food.

Figure 3. Large woody debris habitats

Source: Water and Rivers Commission (2000d)

The presence of logs, branches and woody debris along the river was considered to be high at 86% of sections. Apart from helping to slow the flow of water, woody debris alters the flow of water, creating eddies and small isolated zones of turbulence or still water which provide 'micro-habitats' and food sources for a range of small animals and plants (Figure 3). Woody debris in the Mortlock River and Mortlock River South is particularly important because it can help to stabilise sandy or silty river beds in low flow areas. Woody debris in the river channel can also cause bank erosion due to redirection of flow into the banks. Log jams or woody debris build-up would need to be removed or repositioned before bank erosion occurs.

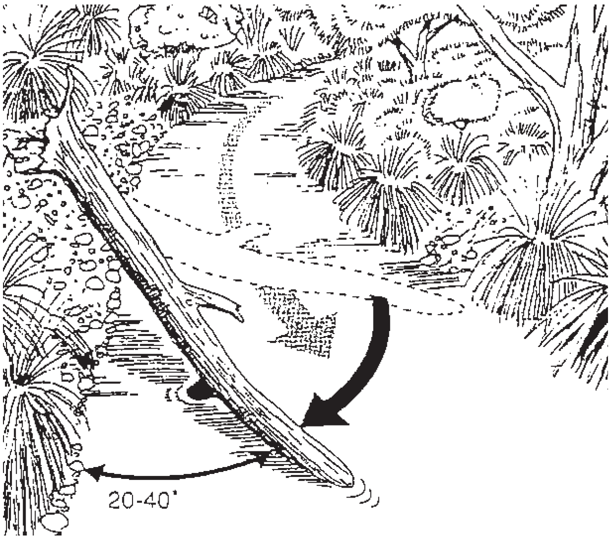


Figure 4. Correct alignment of large woody debris
Source: Water and Rivers Commission (2001b)

Instream cobbles and rocks were only recorded at 11% of sections. Due to the sedimentation problem in the Mortlock River and Mortlock River South, the rocks and cobbles that usually line the river runs have most probably been smothered and covered over by the sandy sediments. The speed at which water moves through a section of river will influence the types of aquatic animals that occur there. Cascades, rapids and riffles can make the water turbulent and can create a variety of flow conditions. They were noted at 26% of sections. These riffle zones are often turbulent and are favoured by filter feeding macroinvertebrates that are able to exploit the current for gathering food.

There is an absence of dense riparian vegetation along the Mortlock River and Mortlock River South. Dense riparian vegetation is important because it provides habitat for terrestrial invertebrates, birds, frogs, reptiles and native mammals that inhabit the river environment. Observations of the animal life along the Mortlock River and Mortlock River South showed that there was sufficient habitat for birds (trees, shrubs) and terrestrial invertebrates but there was not enough habitat to support reptiles, small mammals and frogs. These animals need dense streamside vegetation as it provides cover from predators and protected nesting sites. Although the aquatic and terrestrial habitat diversity of the Mortlock River and Mortlock River South is considered to be moderate due to land clearing and stock grazing, the existing vegetation is important on a large scale as it forms corridors which link larger patches of vegetation together. Through linkages to other reserves, the river vegetation can provide refuge during extreme conditions such as drought and fire. Revegetation with native sedges, rushes, dense low growing shrubs and a mixture of trees will create suitable habitat for the terrestrial and aquatic animals that inhabit the Mortlock River and Mortlock River South. See Figure 5 for typical habitats found along waterways.

Water quality

Water quality problems have been a prominent issue in the Mortlock River and Mortlock River South for some time. Historical and present day water quality data from the Mortlock River and Mortlock River South show that salinities are within the low to high saline range (9–45 mS/cm). The high salinity levels have placed great stress on the aquatic system, resulting in the loss of native vegetation and fauna and in some cases, the colonisation of new, invasive salt tolerant species such as barley grass. Humans, livestock, crops and soils all have varied tolerances to salt. Although sheep can tolerate salinities from 16 mS/cm to 22 mS/cm, the Mortlock River and Mortlock River South is unsuitable for drinking for most of the year, apart from high rainfall events where salt is diluted. Not only are saline soils less productive and often unusable for cultivation, they also tend to be more erodible than normal and are subject to water erosion, nutrient loss and degradation.

The pH of the Mortlock River and Mortlock River South had an average value of around 8, which is slightly alkaline. At extremely high or low pH values, the water becomes unsuitable for most organisms. A significant change in pH will affect bacteria and micro-organisms which help to purify the water and can weaken aquatic organisms which become more vulnerable to disease and parasites. As a general rule, pH values lower than 4 or greater than 9 may indicate a pollution problem in the catchment. There are a number of factors which could influence the pH of the river, and that makes it difficult to draw conclusions about what is happening in the catchment.

Phosphorus (P) and nitrogen (N) are the main nutrients responsible for the eutrophication and subsequent algal blooms in waterways. In the Mortlock River and Mortlock River South catchment, the main source of these nutrients is from runoff from the surrounding agricultural land in the form of animal manure and crop fertilisers. More readily available for plant (algae) uptake are the dissolved forms of N and P and they can bond to the surface of soil

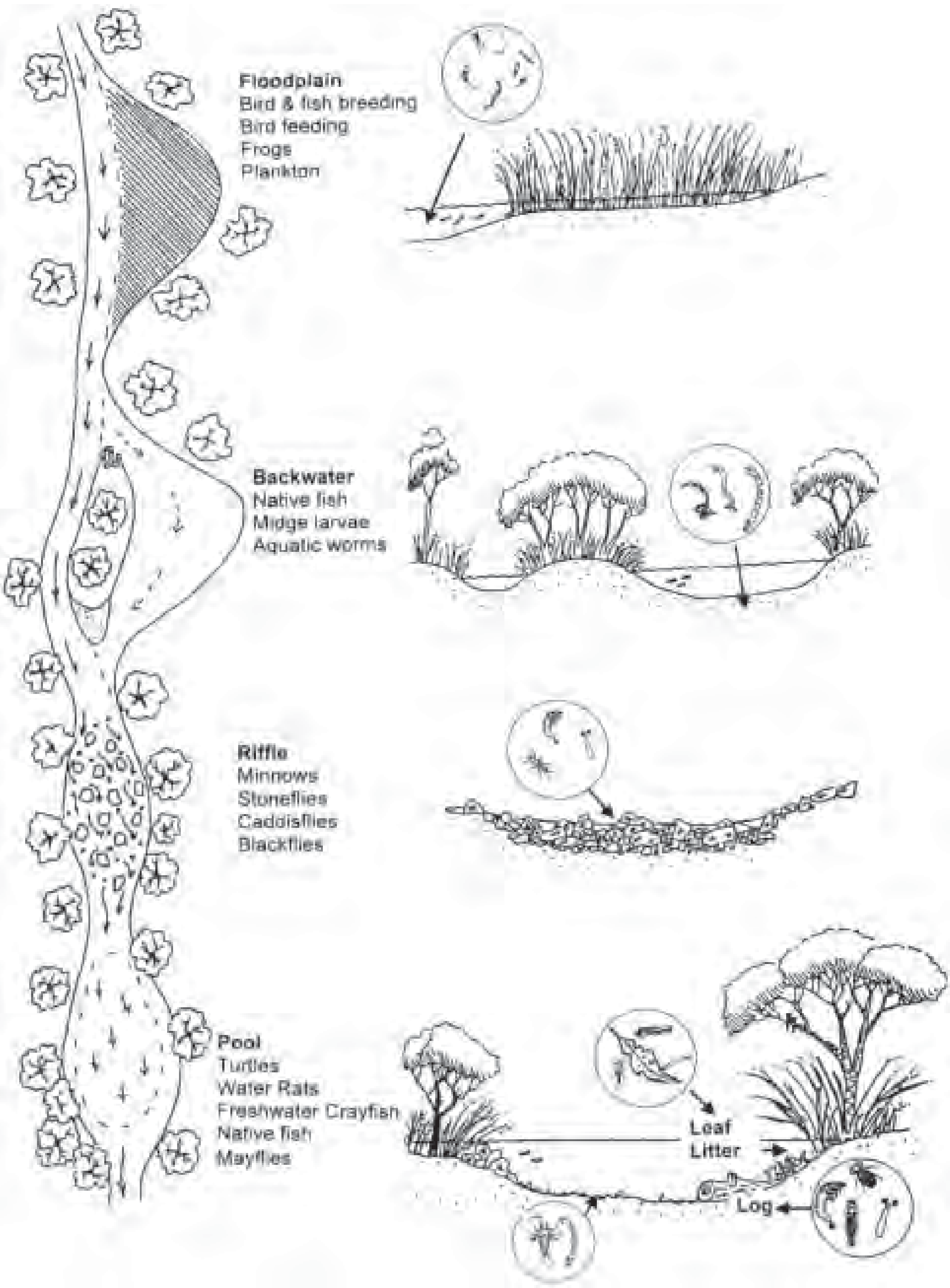


Figure 5 Habitats found along waterways *Source: Water and Rivers Commission (1998)*

particles and thus much of the N and P in the water may be associated with suspended sediment. Best practice water management techniques should be used to intercept water and sediment runoff from farms which would utilise the nutrients before the water flows into the river.

Temperature is the basic measure of how hot or cold a waterbody is. Water temperature changes over the course of the day and with the seasons. Water temperature is higher in turbid, shallow waterways with little vegetation cover and cooler where the waterway is deep, clear and shaded by surrounding vegetation. The readings for this survey were taken in April/May so low water temperatures of between 13.4 and 17.0°C were recorded. A large or sudden change from the normal temperature is significant for macroinvertebrates (water bugs) and other fauna, which have fairly narrow temperature tolerance ranges. For example, an increase in temperature speeds up the rate of chemical reactions, decreasing the amount of oxygen dissolved in the water and increases respiration, causing fauna to be less resilient to other changes in water quality. An increase in temperature further promotes algal blooms if other conditions, such as high nutrient concentrations and light intensity, are suitable.

Disturbance

The Mortlock River catchment was one of the first areas to be extensively cleared in the Avon region for agriculture. Agriculture has had a dramatic effect on the present condition of the Mortlock River and Mortlock River South. Current disturbances to the riparian zone include:

- stock access to the river banks and channel;
- uncontrolled vehicle crossings;
- feral animal disturbance; and
- frequent fires from agricultural land practices.

Stock had access to the riparian zone at 42% of sections. The introduction of stock into the riparian zone can have a number of impacts on the river environment. These include:

- reduction in the regeneration, distribution and health of native plant species;
- disturbance of sediments and river banks which leads to erosion and sedimentation;
- contribution of nutrients to the river through faeces and urine; and
- the introduction and spread of weed species.

Stock management in the riparian zone has often been neglected as it is sometimes seen to disadvantage the landholder, but there are many returns for the landowner who fences off the river and allows natural regeneration of the riparian zone. There will be reduced bank erosion, improved water quality, fewer river crossings, windbreaks for stock and reduced stock losses (Rutherfurd et al, 2000). Fencing off the riparian zone does not mean that the land cannot be used. Farmers can use the riparian zone for a river paddock for selective grazing at different times of the year. Once the riparian zone has regenerated it can be crash grazed, providing the growing and flowering season, generally spring and summer, is avoided.

Limiting river access points is one of the cheapest and simplest methods of supplying water to stock. Limited access points allow stock to drink from a short section of stream, while reducing trampling and the amount of urine and faeces deposited in the river. If constructed properly, access points require very little maintenance apart from occasional repairs after flooding.

Figure 6. Stock watering point

Source: Water Note 7
Livestock Management: watering points and pumps

Weeds were found to be a major management issue in a number of sections. The riparian zone of the Mortlock River and Mortlock River South has experienced frequent natural disturbances such as fire and flooding. When these are combined with disturbances from surrounding agricultural land-uses, weeds have a greater opportunity to invade. Grassy agricultural weeds such as Wild oats (*Avena fatua*), Barley grass (*Hordeum leporinum*), Rye

Photo: Riffle river crossing

grass (*Lolium rigidum*) and Puccinellia (*Puccinellia ciliata*) increase the fuel load, fire risk and fire intensity in the riparian zone. Frequent and intense fires in riparian areas can kill native vegetation. Due to the fast annual lifecycle of weeds, they can compete vigorously with native vegetation for resources such as fresh water and light.

Numerous rabbit and fox warrens were observed along the banks of the Mortlock River and Mortlock River South. Species such as rabbits are favoured by the disturbed conditions where native vegetation has been cleared and weed species are present. Under certain conditions, the structural integrity of the river banks could be compromised by the burrowing action and slumping or bank collapse could occur.

Evidence of management

River management along the Mortlock River and Mortlock River South is encouraged. There are a significant number of landholders and interest groups who are actively managing the river environment through a variety of means. River management can include fencing, riparian revegetation, erosion control, installation of riffles and logs, weed and fire control and sediment removal. From anecdotal evidence, the significant number of landholders who have not implemented river management techniques on their properties could be linked to a general lack of understanding and awareness about river management principles. It is also expensive to put these river management practices in place and many landholders do not have the capital to implement them. For example: it costs approximately $1 500 just for materials to fence one kilometre of river bank.

Fencing the banks of the Mortlock River and Mortlock River South can be the first step taken towards river management and 71% of sections had some form of fencing with varying condition. To accompany this high percentage of landholders that had fencing along the river, a majority was erected more than 30 m away from the banks. Fencing should be located as far away from the river banks as possible. To assist landholders in the Avon River catchment the Department of Environment developed the Avon River Basin Fencing Project. Landowners whose property lies adjacent to the Avon River or its tributaries (including the Mortlock River and Mortlock River South) are invited to express an interest in the project so that fencing materials could be allocated to them. Landowners who receive materials enter into a voluntary agreement to manage the riverine environment and maintain the fences. The project aims at fencing the Avon River and its tributaries to control livestock grazing so that natural riparian vegetation, which will control erosion and salinity and add to wildlife habitat, can regenerate.

Landholders have recognised that fire is a large issue in the catchment and from this 47% of sections had installed firebreaks around the edges of paddocks or along the inside of river fencelines. A fire in the riparian zone has the ability to spread quickly and destroy crops and farm infrastructure. Frequent burning to reduce fuel loads may also destroy old dead trees with nest hollows and reduce woody debris, which provides shelter and food for aquatic and terrestrial animals. Fire that partially or totally removes vegetation cover will affect the shading characteristics of the river. This in turn will affect aquatic habitat. The filtering capacity of the riparian vegetation will be reduced, increasing the transport of sediment and nutrients to the river (Lovett & Price, 1999a). The disturbance and initial input of nutrients and light that can result from fire will also encourage many weed species. Refer to Appendix 8 for the fire position statement of the Avon Waterways Committee.

Principles of waterways management

The need for management

The results of this channel and foreshore assessment indicate that there are many issues that need long-term management if the health of the river is to be improved. Results indicate a necessity for the implementation of appropriate integrated catchment management practices.

Water supplies in rural Western Australia are limited, and those in abundance are often affected by salinity and have limited use. The Mortlock River and Mortlock River South catchment has a limited supply of fresh to brackish water (surface and groundwater) to satisfy a wide range of competing needs, meaning that water resources need to be used and managed sustainably. A management or action plan can be used to guide sustainable land and water use, whilst at the same time looking after the riverine environment in conjunction with the economic needs of the landholders. The management or action plan can be devised for individuals or groups of properties and the catchment as a whole. The plan could include such things as:

- identification and prioritisation of potential future threats;
- indications of community and landholder needs and desires;
- actions to address management issues; and
- an implementation plan outlining recommendations for action, timeframes and responsibilities for undertaking actions.

Management of waterways and semi-rural land use should be closely related, as the interrelated nature of the two means that they have a wide range of effects on each other (Weaving, 1994). Management of Mortlock River and Mortlock River South and its surrounding catchment will not lead to the waterway being returned to its pristine, pre-European settlement condition, but will prevent further degradation and encourage the system to become healthier and more resilient in the long term.

Principles important for inland river management that are relevant to the management of Mortlock River and Mortlock River South and other tributaries throughout the Avon River catchment have been identified by Edgar (2001).

1. Natural flow regimes, (intermittent drying of the channel), and the maintenance of water quality are fundamental to the health of inland river ecosystems.
2. Flooding is essential to floodplain ecosystem processes and also makes a significant contribution to pastoral activities.
3. Structures such as dams, weirs and levees can have a significant impact on the connectivity along rivers and between the river and its floodplain.
4. The integrated management of surface and groundwater supplies is an important concept that needs to be undertaken on a catchment-wide scale.
5. Sufficient knowledge exists to ensure that water resource allocation decisions are made on a sustainable basis.
6. New developments should be undertaken only after appraisal indicates they are economically viable and ecologically sustainable. Promoting greater water efficiency is essential to achieving sustainable industries.
7. High conservation value rivers and floodplains need to be identified and, in some cases, protected in an unregulated state.
8. Rivers at risk of further degradation need to be identified, and priorities established for their rehabilitation.
9. Improved institutional and legal frameworks are needed to meet community river management aspirations.
10. With all parties making a commitment to work together, management regimes can be developed that are ecologically, economically, socially and culturally sustainable.

Management responsibilities

The purpose of this foreshore and channel survey is to provide a present condition report on the river and to encourage landholders to undertake river management activities. The successful management of a waterway entails the inclusion of the surrounding landscape. It is important to understand that the landscape components within the Mortlock River and Mortlock River South catchment are interrelated and hence need to be managed as a whole.

The river should not be managed as an entity on its own, as there are many issues throughout the catchment that contribute to the current condition. Managing the waterway on its own can be likened to treating a problem but not the cause. A catchment-wide approach should be employed with a range of objectives to improve the health of the riverine environment. There are many smaller tributaries feeding into Mortlock River and Mortlock River South that impact on the water quality, as well as sediment loads and channel and foreshore condition.

Maintaining a catchment group or ‘friends’ group for the length of the river is important to the long-term management of the waterway. Promoting the waterway as an asset to the community and encouraging community involvement in management may prove difficult as Mortlock River and Mortlock River South runs through many private landholdings. As the waterway is such a large and diverse system, small groups of landholders along the waterway and from within the surrounding catchment should be encouraged to join together to plan and implement river management actions.

The Avon Catchment Council, Avon Waterways Committee, South Mortlock Catchment Group, York River Conservation Society, York LCDC and Quairading LCDC are groups aiming to promote and coordinate integrated catchment management within the Avon River catchment for the benefit of the surrounding community. These groups have committed themselves to improving the health of the waterways and surrounding catchments, and may possess many resources and knowledge that will be useful in the future management of the Mortlock River and Mortlock River South. These groups will require strong support from government agencies, local government authorities, other catchment groups, landholders and the surrounding community if they are to contribute to the management of the whole catchment.

The Avon Natural Resource Management Strategy produced by the Avon Catchment Council has identified the Mortlock River system as a priority for management. The plan has stated an aspirational goal of: improving priority sections of major tributaries within the Avon Arc and Mortlock River system by at least one ‘foreshore condition’ class (Avon Catchment Council, 2004). For example, a C-grade foreshore must be improved to a B-grade foreshore.

Waterways management should be undertaken with the objective of resolving competition between incompatible land uses to ensure that those values that are high or irreplaceable can be maintained. Efforts should be made to maintain and enhance the quality of the water in Mortlock River and Mortlock River South and adjoining tributaries, in order to conserve ecological systems and meet the needs of present and future generations. Flexibility in the management plan is essential if it is to have the long-term ability to combine waterways conservation with agricultural practices and semi-rural lifestyles which are highly dependent on climate and other environmental factors (Clement et al. 1998).

A blank survey sheet is included in Appendix 3 for use by landholders, catchment groups or community members who are interested in assessing the condition of their waterway, to use for future monitoring and management purposes.

Anecdotal evidence suggests that landholders along Mortlock River East are aware of the benefits of long-term management of the waterway. Economics is one of the main issues hindering development of on-ground management actions. The lack of financial resources available for landholders to direct into waterways management and the management of surrounding land may mean that there is a need for government and community groups to provide support and encouragement (Coates, 1987). The ‘Fence the Avon Program’, administered by the Department of Environment is one such program that is able to give financial relief to landholders to fence waterways. The program aims at using fencing to control livestock grazing so that natural riparian vegetation, which will control erosion, salinity and add to wildlife habitat, can regenerate. Landowners whose property lies adjacent to the Avon River or its tributaries are invited to express an interest in the project so that fencing materials could be allocated to them. Landowners who receive materials enter into a voluntary agreement to erect the fence, manage the riverine environment and maintain the fences.

Management requirements

Weed management

Weeds have many negative impacts on the riverine environment. They degrade the bushland along the waterway, and are a fire hazard. Introduced species replace native vegetation or prevent the regeneration of native vegetation. They compete with native vegetation for space and water. The resulting loss of native species may lead to a change in the food and habitat source for native fauna, hence altering the food chain.

Weeds are also a fire hazard. Many weeds are winter active, meaning that they die off, or become dormant, during summer. In areas of high weed coverage the dry grasses provide a large source of fuel for fire and may increase the possibility of the spread of a wildfire along the waterway corridor.

An integrated management approach should be encouraged as the best way to deal with weeds. Weed control needs to focus on the immediate area as well as upstream areas where seeds can be easily transported downstream to susceptible areas. Information should be sought from the local LCDC, Department of Agriculture, Department of Environment or the Environmental Weeds Action Network, to develop a catchment-wide weed control strategy.

Landholders can undertake weed control by targeting the best areas and working towards the worst weed-infested areas. Focusing on invasive species as well as declared and pest plants will give a more productive outcome to weed control. Working from the edge of the weed infestation towards the centre, and removing the seed source is the most effective way to manage weed infestations. Working from upstream areas means that the likelihood of seeds and cuttings being washed downstream and recolonising in weed free areas is reduced significantly.

Weeds growing along road verges that run in close proximity to the waterway and its tributaries should also be controlled, so as to reduce the risk of spreading into surrounding riparian zones.

Some introduced species perform a useful role in rehabilitation and riverbank stabilisation. For example, couch (*Cynodon dactylon*) colonises bare areas along banks and verges and is often useful in stabilising areas that would otherwise be susceptible to erosion and undercutting. These species should be tolerated in the short term, but in the longer term they will need to be controlled before spreading too far. When undertaking weed management, weeds should only be removed from areas susceptible to erosion when revegetation is about to begin. Areas left bare for long periods will be eroded and may contribute to sedimentation within the waterway. Planting of native species to replace weed species should be considered as an option when planning for revegetation. For example, Salt water couch (*Sporobolus virginicus*) can be used to replace introduced grass species.

Riparian revegetation

The health of the bank and foreshore vegetation along a waterway is indicative of the health of the waterway. Riparian vegetation is an important component of the river ecosystem, and when salinity levels increase, for example, many plant species will die off and be replaced by more salt-tolerant species.

Vegetation along waterways should be managed with a view to improving catchment health. Riparian vegetation improves waterway health by:

- providing habitat for native fauna;
- stabilising the channel bed, banks and verge;
- providing wildlife corridors, allowing fauna to move along the river;
- providing shade over the waterway, thus providing a more favourable habitat and decreasing the likelihood of algal blooms;
- providing woody debris for habitat and bank stabilisation;
- filtering runoff from surrounding land to decrease nutrient input into the waterway; and
- protecting soils from wind and water erosion (Lovett & Price, 1999a).

Management works should be prioritised to gain the greatest benefit from the available resources. Protecting areas of good (weed free) riparian vegetation and working towards more degraded areas will be more economically viable for landholders (Lovett & Price, 1999a). It is more costly to rehabilitate a degraded area than to protect it before it becomes weed infested.

If revegetation of riparian areas takes place, it is important that stock do not have immediate access to these areas of fringing vegetation. A fence around the revegetated area (or the riparian zone) is the most effective tool to prevent livestock grazing and trampling newly revegetated areas.

Where grazing of the riparian zone is proposed, the following rules should be followed to minimise disturbance and limit the environmental and economic losses associated with an unhealthy riverine system:

- Avoid grazing the riparian zone during the germination, growing and flowering times of the native plants.
- Do not overstock the riparian zone. This will minimise the negative impact that grazing and trampling have on the productivity of this area, as well as the water quality within the river.
- Adjust stocking rates and the frequency of grazing within this zone to suit the carrying capacity of the land (Lovett & Price 1999b).

Riparian vegetation plays an important role in protecting the waterway from degradation. Vegetation along banks, verges and foreshore areas can help to regulate the hydrological processes, filter nutrients from recharge water as well as cycle nutrients, and prevent soil erosion by overland flows of water and wind (Coates, 1987).

Fire management

Annual weeds, such as grasses, dry out during the summer months and can pose a serious fire risk if not kept under control. Along the Mortlock River and Mortlock River South the vegetation exists as a corridor and, after frequent or uncontrolled fire, may be vulnerable due to the limited opportunity for native species to recolonise from surrounding areas.

An abundance of weed species that die off during summer months means that the riparian zone along Mortlock River and Mortlock River South is susceptible to fire, and hence a management plan to accommodate any risks needs to be decided upon and implemented. There are many disadvantages to fire, including risk to persons, property and livelihood, weed invasion, loss of habitat for fauna, loss of some seed, loss of peat soils and an increase in erosion. Under controlled circumstances, when risks are reduced, there are also benefits of fire to the natural system. For example, fire provides the right conditions for many native plant species to germinate and grow.

To reduce any serious threat of fire, it may be necessary to implement controlled grazing along some sections of the river. This can reduce the threat of fire to those people living and farming along the waterway. A controlled fire regime can be a useful tool in the regeneration of native species growing within the riverine environment as many species have adapted to occasional fire and benefit from it. When uncontrolled and on too frequent a basis, fire may lead to a loss of habitat, an increased susceptibility to weed invasion, and can damage assets, such as fences and revegetation areas.

If areas are burnt too frequently, there is an increased risk of weed invasion. Fire creates bare open ground which is ideal for the germination of weed species, and if fires become too frequent it is easy for weeds to out-compete native plants.

Burning of vegetation and debris along the waterway foreshore and banks should be responsive to the condition of the vegetation, but it is important to remember that leaf litter and debris contribute important habitat for terrestrial and aquatic animals, as well as protecting the soil from erosion. A set time regime should be put into place to monitor burning within the riparian zone. This will deter burning too frequently and minimise the damage caused by doing so (Lovett & Price, 1999a).

Firebreaks along foreshore verges are important to protect the fragile vegetation from unintentional fires that may result from stubble burning in surrounding paddocks. To maintain effective fire control for the riparian zone, firebreaks and fencing should be upgraded and maintained along verge areas of the foreshore. When fencing for protection of riparian vegetation the firebreak should be located on the river side of the fence, as far away from the bank as possible. A firebreak on the river side of the fence will allow easy access to this zone, and prevent stock from pushing the fence over to graze on the other side. Barbed wire fences should be used in this instance.

The Avon Waterways Committee (AWC) has developed a fire policy that sets out the objectives for bushland management along the river. The main goals are to manage the fire problem along the waterway, while minimising the threat to the river environment and to neighbours. It is also a priority to educate river neighbours and encourage landholders to take responsibility for protecting their own assets. A copy of this policy is located in Appendix 8.

Water quality

Poor water quality can significantly affect the health of the river and it's surrounding ecosystems. Land clearing associated with the agricultural development, in the catchment, has had a negative impact on the health of this waterway. Combined with current land use practices, the clearing of vegetation has increased the sediment loads and possibly the salinity levels within the river and its tributaries, adversely affecting the health of the riverine system (Schofield et al. 1988).

Restricting stock access to the river will help to improve water quality. Stock (sheep and cattle, along with goats and horses) are responsible for mobilising plant nutrients that are distributed via their faeces (Swan River Trust, 1998). Controlled access will minimise the amount of manure within the waterway and limit nutrient enrichment.

Water resource management is best approached as a part of integrated catchment management. Managing each catchment area as a whole allows the diverse range of social, economic and ecological activities that affect a particular water body to be coordinated. Water and biological resources are firmly linked within the natural environment, and disruptions to either one can have significant implications on these resources and the environment as a whole (Australian Water Resources Council, 1992).

Development

There has been minimal change of land use within the catchment of the Mortlock River and Mortlock River South since the land was cleared for agriculture in the early 1900s.

The flood regime within the Avon catchment tends to follow a 10 year cycle (Hansen, 1986). When planning development within the Mortlock River and Mortlock River South catchment, the flood regime needs to be taken into consideration so that damage caused by floods is minimised. Development within flood-prone areas should be actively discouraged.

Any existing and future landuse should be guided by Town or Shire Planning Schemes, the Department for Planning and Infrastructure and the Department of Environment, while providing for the protection and enhancement of the environment and the catchment surrounding Mortlock River and Mortlock River South.

Areas of cultural significance (both Aboriginal and European) should be recorded and protected through the Town Planning Scheme to prevent any changes to landuse that may be detrimental to these sites. It should be noted that where Aboriginal sites may be affected by proposals for development and land use change, the requirements of the Aboriginal Heritage Act, 1972 must be met (Western Australia Planning Commission, 1999). Any sites listed on the State Register of Heritage Places are protected by the Heritage of Western Australia Act, 1990, which determines certain requirements for individual sites, aiming to conserve the associated heritage values.

Large woody debris

Large woody debris (also known as snags) are branches, large limbs or whole trees which fall into the watercourse and either remain in place or move downstream where they come to rest. It is common for smaller debris and leaf litter washed downstream to accumulate at these points, providing an important habitat for many aquatic organisms. Some areas along Mortlock River and Mortlock River South have been cleared of this material due to perceived risks of flooding and bank erosion, highlighting the need to educate people to the benefits of keeping the debris within the river system, and the disadvantages of removal.

Contrary to common belief, the removal of large woody debris does not reduce flood risk and will actually lead to bank and channel erosion caused by an increased flow velocity. The increased movement of sediment through the system will result in deposition in pools and along floodplains and may lead to a decline in habitat, raised channel beds and increased threat to infrastructure such as low bridges. Reintroducing large woody debris to the system will increase river stability and provide a greater diversity of habitat for native fauna.

In areas where large woody debris has been removed, attempts should be made to add sufficient debris material to the waterway to return it to its natural load. By considering the amount of debris found in healthier parts of the river (or in waterways in close proximity under the same conditions) assumptions can be made as to how much woody debris to return to the system (Lovett & Price, 1999b).

Sediment deposition

The goal of management is to minimise sediments entering the river, to reduce the movement of excess sediment along the waterway, to stabilise the riverbanks and channels, and to remove sediments from the river at selected places.

Sediments comprise of sand and silt, which can be carried in the water column or in solution. During high river flows, both are carried down the river and deposited when the river velocity is reduced, either by natural pools, a natural obstruction, or by the drying up of the river in summer.

The installation of man-made riffles can act as sediment traps. A riffle is a designed low rock bar, or some other form of engineered structure, placed across the river at a strategic point with the aim of slowing river velocity. These structures can also become places where coarse sediments will be deposited and can later be removed by machinery. Riffles can also be used as a vehicle and stock crossing point. In some sections, landholders have constructed riffles as river crossings which inadvertently, aid in sediment deposition.

Fencing

When revegetating an area along the riparian zone it is important to exclude stock so that they do not eat and trample planted areas. Fencing is the most practical means of excluding stock. It is recommended that stock be excluded from the riparian area for at least three years to allow plants to grow and recolonise the area (Piggott et al. 1995). After this period the plants should be established and stock access, if allowed for fire reduction grazing, should be properly managed.

Controlled grazing requires fencing to confine stock to the approved grazing area and to control the intensity of grazing. Fenced areas will regenerate naturally over time, or can be replanted with native trees and shrubs. The vegetation helps to control soil erosion along the river, and provides habitat for wildlife. Riparian vegetation is an effective way of preventing sediment entering the waterway.

Fences should be erected outside the riparian zone, as far away from the bank as possible, to exclude stock from the riparian zone. This will encourage the regeneration of native tree species and the growth of ground covers that will aid in stabilising the waterway banks and verges. Fencing of the zone should follow certain parameters if it is to be of benefit to both the environment and economic pursuits of the landholder. A good management practice is to develop a firebreak inside the riparian zone to allow for easy access and to prevent stock pushing fences down to gain access to vegetation.

The type of fence used should be suited to the flood regime. For example, drop fences will drop to the ground during flood events where pressure from water and debris builds up. Using the right type of fence is economically viable, as it minimises the need for repairs. Fencing along riparian zones should be located parallel to the waterway to minimise the impact of floodwaters on the fence. Most importantly the type of fence used should be suited to the surrounding land use if it is to have the maximum benefit of protecting the water resources for future use (Lovett & Price, 1999b).

A study conducted by Bell and Priestley, (1998) showed that the benefits of riparian fencing as identified by farmers are:

- stock are safe from floods, losses greatly reduced;
- streambank and floodplain erosion causing loss of productive land is reduced;
- benefits to the stream environment (return of birds, fish and plants);
- time saved rounding up stock;
- improved property appearance and resale value; and
- improved recreation areas.

Moreover the main benefits are that the need for constant supervision is alleviated and there is more freedom to leave the property without making special arrangements. There is also less time spent chasing stock out of streams or from adjoining properties (Bell & Priestley, 1998).

When stock, especially sheep, become sick, they take refuge in the shelter of the river and are difficult to find and are often lost due to this. Generally landowners who have excluded stock from the riparian zone state that the benefits in terms of improved lifestyle, peace of mind, and responsibility for good animal husbandry are more than enough to outweigh the cost of excluding stock from the riparian zone (Bell & Priestley, 1998).

Feral animals

Field observations and conversations with landholders along Mortlock River and Mortlock River South determined that there are a high number of feral animals resident within the riparian and channel vegetation. The most common are rabbits and foxes. Feral animals take over habitats and prey on native fauna, destroy native vegetation, increase the spread of weeds, contribute to bank destabilisation and erosion through burrowing into the soil, and are often a threat to livestock being grazed along foreshore and surrounding areas.

Management of feral animals should be approached as a whole throughout the catchment. There is no use working to rid one property of pest animals only to have them migrate from surrounding properties. There is a need for cross-boundary management of feral animals to stop this happening. Baiting and trapping could be an option here. Controlling weeds will also help to deter pest animals due to a lack of food, nesting and breeding sites.

Waste disposal

Field observations determined that along some sections of the waterway it has been, and still is, commonplace to

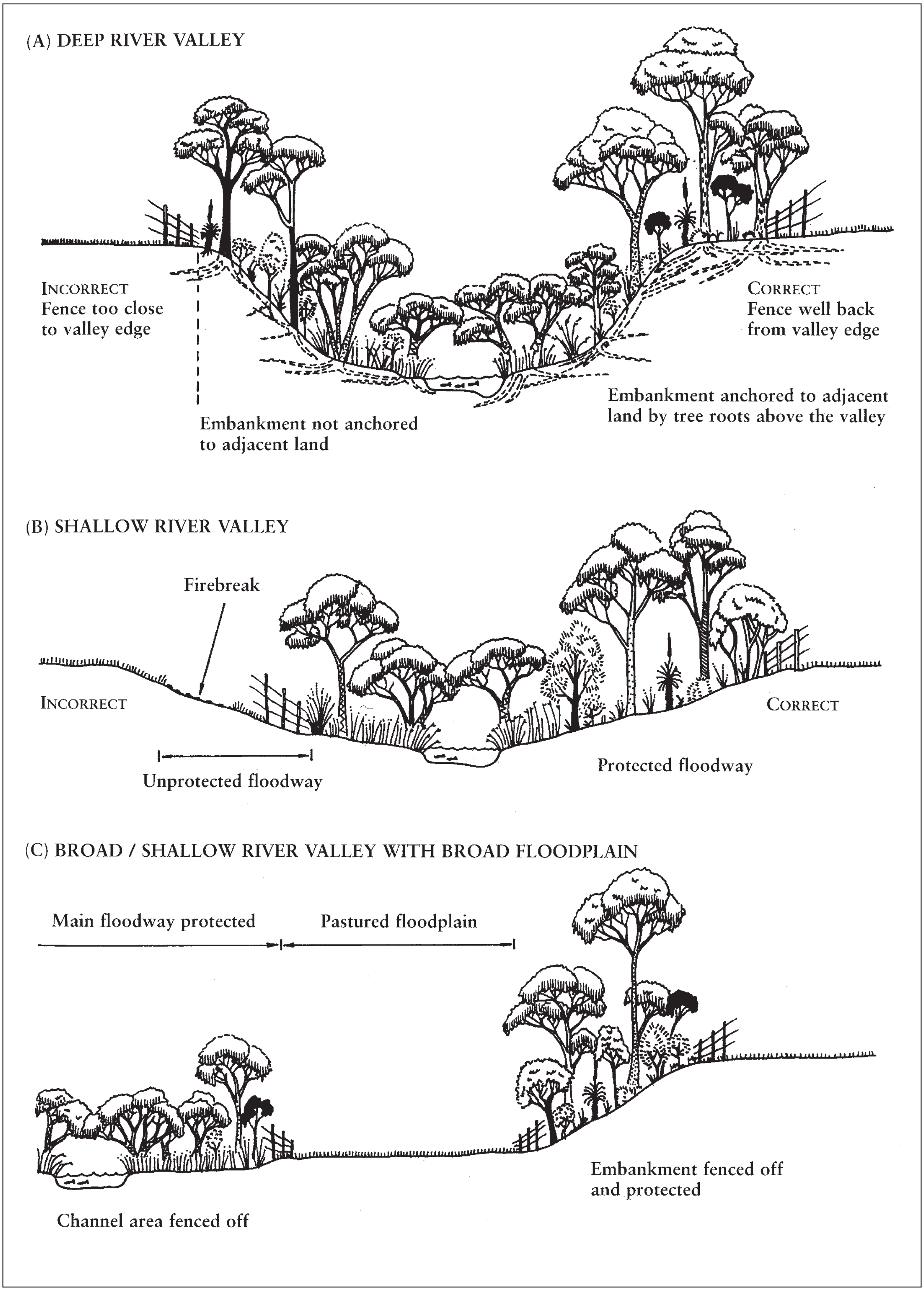


Figure 7. Correct placement of fencing along river floodway *Source: L. Pen 1999*

dispose of unwanted farm machinery, cars and chemical containers along the banks of the waterway. Refuse can cause pollution of the waterway and those into which it feeds (the Avon River) when oils, fuel and chemicals leach into the waterway and are moved downstream during periods of high flow. Landholders should be encouraged not to dump unused items near the river by educating them on the risks involved in affecting the surrounding environment.

Education and awareness

For the long-term benefit of the riverine ecosystem, measures should be taken to educate landholders in an effort to promote understanding and awareness of the significance of waterways and their management for future use. Landholders along Mortlock River and Mortlock River South were given the opportunity to take part in the foreshore and channel assessment, and it is important that involvement is on-going, especially in any future plans to improve the health of this waterway.

Catchment management and community action requires awareness of the issues, education and information, technical advice and practical support. Local government authorities, as well as relevant government and non-government agencies need to provide support to these groups, while banding together to promote issues such as waterways management, integrated catchment management and land management to community members.

There is a wealth of information already learnt and gathered from other community, catchment and 'Friends of' groups which is valuable and can be passed on through establishing networks between groups in surrounding areas. The Avon Catchment Council Information Network <www.avonicm.org.au> provides a range of resources helpful to land and waterways management.

Concluding comments

This foreshore assessment has been undertaken to provide landholders, interested community groups, local government authorities and government and non-government agencies within the surrounding catchment, with an understanding of the current condition of the Mortlock River and Mortlock River South channel and foreshore areas.

The survey process has been developed to suit the needs of the Avon region and can be used by interested individuals, groups and organisations to gain an understanding of the condition of the waterways within their community. It is hoped that this process will be useful for these people to monitor the health and condition of this waterway into the future.

By using a standard methodology to gather information it is possible to compare and contrast foreshore conditions in the same area over time, or between different sites in the same survey season. Results can then be used to prioritise management needs, determine the impact of new disturbances and assess changes in foreshore and channel condition.

This document provides the results of the foreshore assessments undertaken along Mortlock River and Mortlock River South. The main conclusion to draw from the findings is that in many ways the health of the river is suffering, both directly and indirectly, as a result of past and present land use activities.

A majority of the Mortlock River and Mortlock River South catchment is ancient, weathered and generally degraded. Historically land has been overused, but land use activities are slowly becoming ecologically sustainable in the catchment. There is hope that with a greater understanding of the condition of Mortlock River and Mortlock River South, community members will band together to try to recover some of the natural health and beauty of the waterway.

In general the Mortlock River and Mortlock River South system can be described as a C-grade system, meaning that the foreshore vegetation supports only trees over weeds or pasture. Bank erosion and subsidence may occur in some areas. The high sediment loads within the channel mean that the catchment and river-bed are unstable and in need of rehabilitation.

There is decline in the health, abundance and species diversity of native riparian vegetation growing along the banks of the Mortlock River and Mortlock River South and an increase in the abundance of weed species. The most common species of native vegetation included Swamp sheoak (*Casuarina obesa*), York gum (*Eucalyptus loxophleba*), Flooded gum (*Eucalyptus rudis*), Swamp paperbark (*Melaleuca rhaphiophylla*), Jam wattle (*Acacia acuminata*), Needlebush (*Hakea preissii*), Small leaf blue bush (*Maireana brevifolia*), Samphire (*Halosarcia* species) and Saltwater couch (*Sprobolus virginicus*). Species such as Swamp paperbark and Flooded gum have declined in health and abundance due to local salinity levels. Of the weed species dominating the understorey, Wild oats (*Avena fatua*), Barley grass (*Hordeum leporinum*), Annual ryegrass (*Lolium rigidium*) and Puccinellia (*Piccinellia ciliata*) were the most common throughout the assessment. These weeds have displaced the native understorey vegetation, decreasing the available habitats and increasing the fire risk in the riparian zone.

There was no dense riparian vegetation along the river. This has severely reduced the number of available habitats for aquatic and terrestrial animals which live in and along the Mortlock River and Mortlock River South. There was a lack of deep river pools, rocks and riffles which can be attributed to increased sediment in the channel. River sections that have a variety of habitat types are able to support a greater variety of species than sections which do not vary in character.

The major disturbances along the length of the river include stock access to the riparian zone through a lack of quality river fencing, informal vehicle crossings, feral animals and frequent fires. These disturbances have affected the riparian zone by:

- destabilising river banks and the river bed eventually causing increased erosion and sedimentation;
- spreading weed species;
- reducing native species regeneration and health; and
- reducing water quality;

There is a high degree of landholder support for riparian management along the Mortlock River and Mortlock River South. Some of the landholders have received fencing materials from the ‘Fence the Avon Program’ in the past and results can be seen in those sections with decreased disturbance in the riparian zone and the regeneration of native species. With this, weed species have also increased so careful management is needed when the riparian zone is fenced. This program is still available to landholders who own property adjacent to the Mortlock River and Mortlock River South and it is hope that the results of the assessment will be used to identify areas that need fencing and the eventual fencing of the entire river.

The Avon Natural Resource Management Strategy produced by the Avon Catchment Council identified the entire Mortlock River system as a priority for management due to its importance as a regional asset and its contribution of sediment, salinity and nutrients to the Avon River.

The plan has stated a 20 year target of: priority sections of major and minor tributaries, identified for sediment and nutrient management purposes, or for salinity control have improved by at least one ‘foreshore condition’ class by 2025 (Avon Catchment Council, 2004). For example, a C-grade foreshore must be improved to a B-grade foreshore.

The restoration of the Mortlock River and Mortlock River South is achievable within this 20 year timeframe and if managed in an integrated way will see an improvement in bank stability, water quality and vegetation cover. This will lead to an improvement in the health of the Mortlock River System and subsequently the quality of water it discharges into the Avon River.

The need exists to assess competing landuses and determine a compromise that allows for the rehabilitation and conservation of Mortlock River and Mortlock River South along with sustainable and economically viable land use practices. This will lead to many economic, environmental and social advantages both now and into the future.

Future strategies to improve the ecological health of Mortlock River and Mortlock River South need to be linked to the development of more sustainable farming systems within its catchment. If management of the riverine system is to be effective, degradation associated with Mortlock River and Mortlock River South must be treated at the cause and not the symptom.

Management of this waterway requires knowledge and understanding of what factors are present and how they are affecting, either positively or negatively, the surrounding environment. This survey provides that information so that the community can work together to initiate an integrated approach to improving the health of Mortlock River and Mortlock River South. The data collected throughout this foreshore and channel assessment is also an effective tool to monitor future changes in the stability and health of this waterway.

Glossary

Algal bloom The rapid excessive growth of algae, generally caused by high nutrient levels and favourable conditions.

Anabranch A secondary channel of a river which splits from the main channel and then later rejoins the main channel.

Bank The steeper part of a waterway channel cross section, which is usually considered to lie above the usual water level.

Bed stability When the average elevation of the streambed does not change much through time.

Carrying capacity The maximum population of organisms or the maximum pressure that an environment can support on a sustainable basis over a given period of time.

Catchment The area of land which intercepts rainfall and contributes the collected water to surface water (streams, rivers, wetlands) or groundwater.

Channelisation The straightening of the river channel by erosional or mechanical processes.

Contour farming Ploughing and planting along the contour of the land, rather than in straight lines, to help retain water and reduce soil erosion.

Debris Loose and unconsolidated material resulting from the disintegration of rocks, soil, vegetation or other material transported and deposited during erosion.

Degradation Specifically for waterways, the general excavation of a streambed by erosional processes over a number of years. Has a broader meaning of reduction in quality.

Discharge Volumetric outflow of water, typically measured in cubic metres per second.

Ecosystem A term used to describe a specific environment, e.g. lake, to include all the biological, chemical and physical resources and the interrelationships and dependencies that occur between those resources.

Electrical conductivity (EC) A measure of salinity. The higher the electrical conductivity of a stream the greater the salinity.

Electric fence Any fence design which is electrified, irrespective of whether it consists of electric tape, a single smooth electric wire or four plain wires of which two are electric.

Environment All the biological and non-biological factors that affect an organism's life.

Environmental degradation Depletion or destruction of a potentially renewable resource such as soil, grassland, forest, or wildlife by using it at a faster rate than it is naturally replenished.

Erosion The subsequent removal of soil or rock particles from one location and their deposition in another location.

Eutrophication An excessive increase in the nutrient status of a waterbody.

Evaporation A physical change in which liquid changes into a vapour or gas.

Exotic vegetation Introduced species of vegetation from other countries or from other regions of Australia (i.e. not endemic to the region).

Fabricated fence Includes rabbit netting, sheet metal and hinge joint fences.

Floodfringe The area of the floodplain, outside the floodway, which is affected by flooding. This area is generally covered by still or very slow moving water during the 100 year flood.

Floodplain A flat area adjacent to a waterway that is covered by floods every year or two.

Floodway The river channel and portion of the floodplain which forms the main flow path of flood waters once the main channel has overflowed.

Floodway and bank vegetation Vegetation which covers the floodway and bank part of the riparian zone. The vegetation which actually grows in the floodway or on the banks above the stream.

Foreshore Area of land next to a waterway.

Groundwater Water which occupies the pores and crevices of rock or soil.

Gully erosion The removal of soil by a concentrated flow with sufficient volume and velocity to cut large channels, generally more than 30 cm deep.

Habitat The specific region in which an organism or population of organisms live.

Hydrology The study of water, its properties, distribution and utilisation above, on and below the earth's surface.

Large woody debris A branch, tree or root system that has fallen into or is immersed (totally or partially) in a waterway.

Leaf litter The uppermost layer of organic material in a soil, consisting of freshly fallen or slightly decomposed organic materials which have accumulated at the ground surface.

Levee An artificial embankment or wall built to exclude flood waters, or a natural formation next to a waterway built by the deposition of silt from floodwaters.

Monitoring The regular gathering and analysing of information to observe and document changes through time and space.

Native species Species that normally live and thrive in a particular ecosystem.

Nutrients The food (elements) required by plants to grow.

Organism Any form of life.

Overgrazing Destruction of vegetation when too many animals feed too long and exceed the carrying capacity of a an area.

Pest plant Weed species that are seen as being a nuisance to the existing land use. Local government authorities can enforce the control of such a species.

pH Technically this is the hydrogen ion (H+) concentration in the water. It is the simplest measure of acidity/alkalinity.

Pollution Any physical, chemical or biological alteration of air, water or land that is harmful to living organisms.

Regeneration Vegetation that has grown from natural sources of seed, from vegetative growth, or has been artificially planted.

Riffle The high point in the bed of the stream (accumulation of coarse bed materials) where upstream of accumulations a shallow pool is formed. Downstream from the crest of the accumulation the water is often shallow and fast flowing.

Riparian zone Refers to the zone directly adjoining a waterway. Any land that adjoins, directly influences, or is influenced by a body of water.

Runoff That portion of rainfall that is not immediately absorbed into or retained by the soil e.g. overland flow.

Salinisation The accumulation of salts in soil and water which causes degradation of vegetation and land.

Sediment Soil particles, sand and other mineral matter eroded from land and carried in surface waters.

Sedimentation The accumulation of soil particles within the channel of a waterway.

Slumping The mass failure of part of a stream bank.

Snags Large woody debris such as logs and branches that fall into waterways.

Subsidence The sinking of parts of the ground which are not slope related.

Terrestrial Relating to land.

Turbidity A measure of the suspended solids in the water.

Undercutting The undermining or erosion of soil by water from underneath an existing landform (i.e. riverbank), structure (i.e fence post) or vegetation (i.e. tree).

Verge The area extending from the top of the bank to the next major vegetation or land use change.

Verge vegetation The strip of land up to 20 m from the immediate river or creek valley.

Waterlogging Saturation of soil with irrigation water or excessive rainfall, so that the water table rises close to the surface.

Water quality The physical, chemical and biological measures of water.

Weed A plant considered undesirable, unattractive, or troublesome, especially growing where it is not wanted.

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Appendix 1
Soils of the Mortlock River catchment

Soil unit	Soil unit description
Ms7	Gently sloping to gently undulating plateau areas with long and very gentle slopes and, in places, abrupt erosional scarps: chief soils are (i) on gently convex slopes of the plateau, sandy yellow earths (Gn2.21) containing ironstone gravels and with clay D horizons; (ii) on depositional slopes flanking erosional sites, yellow earthy sands (Uc5.22) sometimes with ironstone gravels at depth; (iii) on erosional ridges and slopes, leached sands (Uc2.12) containing ironstone gravels and overlying mottledor pallid-zone clays; and (iv) sandy depressions of leached sands (Uc2.22) with some (Dy) soils. Soil dominance tends to vary locally between (i) and (iii). As mapped, areas of unit Uf1 are included.
Oc30	River terraces: chief soils are hard alkaline red soils (Dr2.33). Associated are some (Dy3.43) soils; and small areas of other soils are likely. As mapped, areas of soils of unit Qb29 may be included. Occurs on sheet(s): 5
Qb29	Rolling to hilly with some steep slopes; gneissic rock outcrops common: chief soils are hard neutral red soils (Dr2.22) with others such as (Dr2.62) and (Dr3.42). Associated are (Dy3.42) soils on slopes; patches of (Ug5.37) and (Ug5.2) soils with some gilgai also on slopes; colluvial slopes of (Gn2) soils such as (Gn2.12) and (Gn2.45); and variable areas of other soils seem likely. As mapped, areas of unit Uf1 and small areas of unit Oc30 may be included.
Uf1	Undulating terrain with ridges, spurs, and lateritic mesas and buttes: chief soils on the broad undulating ridges and spurs are hard, and also sandy, neutral, and also acidic, yellow mottled soils (Dy3.82 and Dy3.81), (Dy5.82 and Dy5.81), all containing ironstone gravels. Associated are a variety of soils on the shorter pediment slopes, including (Dr2.32), (Dr3.41), (Dy2.33), and others of similar form; and dissection products of the lateritic mesas and buttes. As mapped, small areas of unit Ms7 may occupy some drainage divides, unit Va63 traverse some drainage-ways, and unit Qb29 occur in localities of deeper dissection.
Va63	Valley plains and terraces: chief soils are hard alkaline yellow mottled soils (Dy3.43). Associated are small areas of a range of soils including (Dy3.42), and (Dr5.8) and (Dy5.8), both containing laterite or large amounts of ironstone gravels; and some (Dr2.4) and (Uc2.34) soils.

Source: CSIRO, 1967

Appendix 2
O'Driscolls gauging station water quality data

Total Dissolved Solids (TDS), Conductivity and Discharge

Time and Date		TDS from insitu cond (mg/L)	Conductivity	Conductivity	Discharge (m^3/s)
		POINT	mS/cm	mS/m	INST
10:20	27.05.1994	15 672.23	28.49	2 849.50	0.168470
08:20	31.05.1994	5 940.34	10.80	1 080.06	4.327933
09:50	20.06.1994	19 747.28	35.90	3 590.41	0.302972
11:30	30.06.1994	8 724.39	15.86	1 586.25	0.345833
11:31	30.06.1994	8 724.39	15.86	1 586.25	0.345320
13:49	15.08.1994	11 788.48	21.43	2 143.36	0.691931
10:22	27.09.1994	25 084.71	45.61	4 560.86	0.012581
10:24	27.09.1994	25 084.71	45.61	4 560.86	0.012581
10:33	04.10.1994	26 632.44	48.42	4 842.26	0.006515
10:36	04.10.1994	26 632.44	48.42	4 842.26	0.006515
11:06	17.10.1994	27 056.22	49.19	4 919.31	0.014475
11:08	17.10.1994	27 056.22	49.19	4 919.31	0.014643
14:42	18.10.1994	27 766.19	50.48	5 048.40	0.006947
12:25	24.10.1994	34 061.22	61.93	6 192.95	0.000369
12:26	24.10.1994	34 061.22	61.93	6 192.95	0.000369
average		**21 602.16**	**39.28**	**3 927.67**	
14:00	23.05.1995	12 021.87	21.86	2 185.79	1.109182
14:02	23.05.1995	12 021.87	21.86	2 185.79	1.110104
11:46	07.06.1995	17 060.00	31.02	3 101.82	1.304247
11:47	07.06.1995	17 058.99	31.02	3 101.63	1.304247
10:25	12.06.1995	6 341.52	11.53	1 153.00	4.327933
10:26	12.06.1995	6 341.52	11.53	1 153.00	4.327808
12:00	17.07.1995	6 967.93	12.67	1 266.90	9.109243
12:30	24.07.1995	4 402.86	8.01	800.52	12.546374
12:33	24.07.1995	4 402.86	8.01	800.52	12.540784
09:23	31.07.1995	4 500.40	8.18	818.25	10.292497
09:24	31.07.1995	4 500.40	8.18	818.25	10.279310
09:53	01.08.1995	5 332.87	9.70	969.61	9.868502
11:09	07.08.1995	10 724.14	19.50	1 949.84	2.650021
11:10	07.08.1995	10 206.95	18.56	1 855.81	2.653160
11:15	21.08.1995	14 217.81	25.85	2 585.06	1.641797
11:16	21.08.1995	14 217.81	25.85	2 585.06	1.642675
14:00	04.09.1995	15 763.76	28.66	2 866.14	1.839876
14:01	04.09.1995	15 763.76	28.66	2 866.14	1.840989
08:49	13.09.1995	21 679.29	39.42	3 941.69	0.831245
08:50	13.09.1995	21 679.29	39.42	3 941.69	0.831245

Time and Date		TDS from insitu cond (mg/L)	Conductivity	Conductivity	Discharge (m^3/s)
		POINT	mS/cm	mS/m	INST
11:40	18.09.1995	18 883.27	34.33	3 433.32	0.397119
11:41	18.09.1995	18 883.27	34.33	3 433.32	0.396873
13:00	25.09.1995	22 961.18	41.75	4 174.76	0.130917
13:01	25.09.1995	22 961.18	41.75	4 174.76	0.130981
13:37	03.10.1995	24 669.22	44.85	4 485.31	0.063299
13:38	03.10.1995	24 669.22	44.85	4 485.31	0.063299
11:18	09.10.1995	25 977.97	47.23	4 723.27	0.043269
11:19	09.10.1995	25 977.97	47.23	4 723.27	0.043269
14:07	11.10.1995	26 642.59	48.44	4 844.11	0.038477
14:24	16.10.1995	25 346.73	46.08	4 608.50	0.025162
14:25	16.10.1995	25 346.73	46.08	4 608.50	0.025162
10:34	25.10.1995	21 791.10	39.62	3 962.02	0.139299
10:35	25.10.1995	21 791.10	39.62	3 962.02	0.139299
09:16	31.10.1995	24 968.80	45.40	4 539.78	0.052540
09:17	31.10.1995	24 968.80	45.40	4 539.78	0.052726
12:34	06.11.1995	25 684.00	46.70	4 669.82	0.026993
12:35	06.11.1995	25 684.00	46.70	4 669.82	0.026993
13:02	14.11.1995	26 315.92	47.85	4 784.71	0.012191
13:03	14.11.1995	26 315.92	47.85	4 784.71	0.012191
09:47	21.11.1995	28 239.33	51.34	5 134.42	0.004080
09:24	28.11.1995	30 912.80	56.21	5 620.51	0.001481
average		**18 151.15**	**33.00**	**3 300.21**	
12:10	08.07.1997	16 117.16	29.30	2 930.39	1.218043
12:10	12.09.1997	21 471.06	39.04	3 903.83	1.078607
13:50	10.10.1997	23 388.00	42.52	4 252.36	0.235791
11:45	06.11.1997	32 804.20	59.64	5 964.40	0.000174
average		**23 445.10**	**42.63**	**4 262.75**	
11:50	23.07.1998	13 519.99	24.58	2 458.18	2.484672
16:40	18.08.1998	18 723.56	34.04	3 404.28	0.400213
10:30	26.08.1998	22 163.79	40.30	4 029.78	0.167536
11:25	17.09.1998	22 691.75	41.26	4 125.77	0.135988
15:30	09.10.1998	25 011.67	45.48	4 547.58	0.017857
11:18	15.10.1998	25 989.17	47.25	4 725.30	0.008222
12:00	11.11.1998	37 001.73	67.28	6 727.59	0.000000
average		**23 585.95**	**42.88**	**4 288.36**	
13:02	02.06.1999	4 839.64	8.80	879.93	6.569280
09:45	20.07.1999	12 715.96	23.12	2 311.99	1.594151
11:20	17.08.1999	14 907.33	27.10	2 710.42	1.224307
15:40	26.08.1999	10 073.00	18.31	1 831.45	4.260693
12:02	14.09.1999	13 728.20	24.96	2 496.04	1.584751
11:00	14.10.1999	16 389.16	29.80	2 979.85	0.494522
14:45	03.11.1999	24 552.82	44.64	4 464.15	0.012385
12:00	09.11.1999	26 964.71	49.03	4 902.67	0.005025

Time and Date		TDS from insitu cond (mg/L)	Conductivity	Conductivity	Discharge (m^3/s)
		POINT	mS/cm	mS/m	INST
11:30	07.12.1999	25 323.54	46.04	4 604.28	0.000592
average		**16 610.48**	**30.20**	**3 020.09**	
12:07	05.01.2000	17 828.53	32.42	3 241.55	0.174134
16:20	27.01.2000	2 209.96	4.02	401.81	35.281223
12:25	02.02.2000	5 771.50	10.49	1 049.36	4.207208
13:25	09.02.2000	13 738.09	24.98	2 497.83	0.359377
11:05	29.02.2000	24 221.41	44.04	4 403.89	0.032604
11:35	30.03.2000	28 426.21	51.68	5 168.40	0.007376
12:12	26.04.2000	28 845.32	52.45	5 244.60	0.003025
12:18	23.05.2000	29 169.66	53.04	5 303.58	0.004263
13:43	21.06.2000	22 835.96	41.52	4 151.99	0.068078
15:35	10.07.2000	11 223.71	20.41	2 040.68	0.213731
12:50	19.07.2000	14 730.73	26.78	2 678.31	1.130431
12:10	15.08.2000	19 058.95	34.65	3 465.26	0.122443
12:55	12.09.2000	21 499.62	39.09	3 909.02	0.171287
12:15	10.10.2000	24 010.03	43.65	4 365.46	0.007198
14:38	18.10.2000	25 163.89	45.75	4 575.25	0.001374
average		**19 248.90**	**35.00**	**3 499.80**	
10:05	02.08.2001	7 481.16	13.60	1 360.21	2.211979
10:00	30.08.2001	22 210.85	40.38	4 038.34	0.128075
09:36	27.09.2001	26 213.61	47.66	4 766.11	0.057248
10:30	25.10.2001	20 312.72	36.93	3 693.22	0.045366
average		**19 054.58**	**34.64**	**3 464.47**	
10:25	05.07.2002	26 958.10	49.01	4 901.47	0.046222
11:27	31.07.2002	24 298.91	44.18	4 417.98	0.035468
11:45	29.08.2002	24 458.77	44.47	4 447.05	0.013453
12:26	26.09.2002	208.92	0.38	37.98	0.002821
10:22	23.10.2002	32 896.22	59.81	5 981.13	0
average		**21 764.18**	**39.57**	**3 957.12**	
14:05	20.02.2003	6 783.48	12.33	1 233.36	2.516431
12:40	28.05.2003	27 109.84	49.29	4 929.06	
12:00	03.07.2003	16 230.34	29.51	2 950.97	
10:49	05.09.2003	21 529.04	39.14	3 914.37	
12:40	03.10.2003	27 694.37	50.35	5 035.34	
15:15	23.10.2003	31 062.15	56.48	5 647.66	
11:25	05.11.2003	33 762.20	61.39	6 138.58	
11:28	12.12.2003	20 687.62	37.61	3 761.39	
average		**23 107.38**	**42.01**	**4 201.34**	

Total Nitrogen, Total Phosphorus and pH

Collected date		N (tot) {TN, pTN} (mg/L)	P (tot) {TP, pTP} (mg/L)	pH (in situ)
12:00	14.09.1994	1.514	0.113	
10:24	27.09.1994	1.940	0.177	
10:36	04.10.1994	1.656	0.167	
11:08	17.10.1994	1.927	0.156	
12:26	24.10.1994	2.518	0.187	
11:38	15.05.1995		0.160	
14:02	23.05.1995	1.791	0.119	
10:52	29.05.1995	1.119	0.057	
11:47	07.06.1995	1.373	0.152	
10:26	12.06.1995	1.947	0.152	
16:07	15.06.1995			7.840
12:00	17.07.1995	1.954	0.126	
12:30	24.07.1995	1.845	0.139	
09:24	31.07.1995	2.396	0.189	
11:10	07.08.1995	1.871	0.117	
10:37	14.08.1995	1.958	0.186	
11:15	21.08.1995	1.821	0.127	
11:28	28.08.1995	1.843	0.119	
14:00	04.09.1995	1.934	0.130	
08:49	13.09.1995	1.667	0.110	
11:41	18.09.1995	1.888	0.110	
13:00	25.09.1995	1.949	0.110	
13:37	03.10.1995	1.786	0.090	
11:18	09.10.1995	0.244	0.130	
14:25	16.10.1995	1.846	0.120	
10:34	25.10.1995	1.614	0.021	
09:16	31.10.1995	1.615	0.108	
12:34	06.11.1995	1.712	0.028	
13:02	14.11.1995	7.898	2.903	
09:46	21.11.1995	2.025	0.077	
09:24	28.11.1995	2.260	0.088	
14:07	26.06.1996	3.706	0.202	8.220
17:20	28.08.1996	1.952	0.104	
15:45	25.10.1996			8.320
14:09	09.05.1997			8.340
15:45	20.06.1997	1.194	0.070	8.310
12:10	08.07.1997			7.840
13:30	18.07.1997	1.254	0.048	8.330
12:05	06.08.1997	1.362	0.105	8.080
11:45	15.08.1997	1.284	0.096	
12:10	12.09.1997	1.446	0.143	
13:50	10.10.1997	0.131	0.166	
11:45	06.11.1997	0.214	0.069	
11:50	23.07.1998	1.146	0.097	7.810

Collected date		N (tot) {TN, pTN} (mg/L)	P (tot) {TP, pTP} (mg/L)	pH (in situ)
16:40	18.08.1998	1.881	0.097	8.400
10:30	26.08.1998	0.168	0.152	8.200
11:25	17.09.1998	0.674	0.090	8.200
15:30	09.10.1998	1.121	0.093	8.500
11:18	15.10.1998	0.876	0.123	8.500
12:00	11.11.1998	6.240	0.320	8.800
13:02	02.06.1999	2.232	0.126	7.340
13:02	02.06.1999			7.600
09:45	20.07.1999	1.700	0.077	8.000
09:45	20.07.1999			8.200
11:20	17.08.1999	1.500	0.075	
11:20	17.08.1999			7.800
15:40	26.08.1999	1.500	0.076	7.700
15:40	26.08.1999			8.200
12:02	14.09.1999	1.400	0.059	
12:02	14.09.1999			8.100
11:00	14.10.1999	1.200	0.050	
11:00	14.10.1999			8.200
14:45	03.11.1999	1.700	0.077	8.700
14:45	03.11.1999			8.400
12:00	09.11.1999	1.800	0.068	
12:00	09.11.1999			8.100
11:30	07.12.1999	2.000	0.110	
11:30	07.12.1999			8.700
12:07	05.01.2000	3.000	0.300	
12:07	05.01.2000			8.800
16:20	27.01.2000	3.100	0.110	7.200
16:20	27.01.2000			7.300
12:25	02.02.2000	2.500	0.140	
12:25	02.02.2000			7.500
13:25	09.02.2000	2.400	0.130	7.900
13:25	09.02.2000			8.200
11:05	29.02.2000	1.800	0.087	
11:05	29.02.2000			8.300
11:35	30.03.2000	1.700	0.047	
11:35	30.03.2000			8.400
12:12	26.04.2000	1.600	0.028	
12:12	26.04.2000			8.700
12:18	23.05.2000	1.500	0.044	
12:18	23.05.2000			8.600
13:43	21.06.2000	1.300	0.030	
13:43	21.06.2000			8.300
15:35	10.07.2000			8.500
15:38	11.07.2000	1.500	0.029	
12:50	19.07.2000	1.300	0.023	
12:50	19.07.2000			8.500

Collected date		N (tot) {TN, pTN} (mg/L)	P (tot) {TP, pTP} (mg/L)	pH (in situ)
12:10	15.08.2000	1.100	0.023	
12:10	15.08.2000			8.400
12:55	12.09.2000	1.300	0.060	
12:55	12.09.2000			8.300
12:15	10.10.2000			8.900
12:16	10.10.2000	1.700	0.083	
14:38	18.10.2000	1.800	0.075	
14:38	18.10.2000			9.300
08:00	01.08.2001	2.000	0.130	
10:10	01.08.2001	2.400	0.120	
10:05	02.08.2001			7.800
10:00	30.08.2001			8.400
10:12	30.08.2001	1.400	0.060	
09:36	27.09.2001			8.300
09:55	27.09.2001	1.300	0.060	
10:30	25.10.2001			8.600
10:40	25.10.2001	1.500	0.050	
10:25	05.07.2002	1.700	0.080	
10:25	05.07.2002			7.100
11:27	31.07.2002	1.400	0.060	
11:27	31.07.2002			8.400
11:45	29.08.2002	1.300	0.020	
11:45	29.08.2002			8.400
12:25	26.09.2002	1.500	0.100	
12:26	26.09.2002			8.990
10:22	23.10.2002	4.400	0.650	8.600
10:22	23.10.2002			
11:58	19.02.2003	5.800	0.460	5.900
14:05	20.02.2003	3.800	0.330	
14:05	20.02.2003			8.050
12:40	28.05.2003	1.800	0.100	
12:40	28.05.2003			8.300
12:00	03.07.2003	2.000	0.100	
12:00	03.07.2003			8.200
10:58	01.08.2003	1.400	0.030	
10:49	05.09.2003		0.030	
12:40	03.10.2003	1.300	0.110	
12:40	03.10.2003			8.430
15:15	23.10.2003			9.010
11:25	05.11.2003	1.900	0.420	
11:25	05.11.2003			9.560
11:28	12.12.2003			8.590

Source: Water and Rivers Commission (2003b)

Appendix 3 — Foreshore assessment form

Foreshore and Channel Condition Assessment Form

For property and paddock scale surveys

General Details

Recorder's Name: ………………………………………….. Survey Date: ……………………………

Tributary Name: …………………………………………. Section Number: ……………………….

Catchment Name: ………………………………………….. Length of Section: ……………………...

Sub-catchment Name: ……………………………………... Shire: ……………………………………

Nearest Road Intersection: ……………………………………………………………………………..

GPS (start of survey section) E: ……………………..…… N:…..…………………………

GPS (end of survey section) E: …………………………….. N: ……………………………

Landholder contacted: Yes ❐ No ❐
Landholder consent obtained: Yes ❐ No ❐
Landholder present during survey: Yes ❐ No ❐

Bank(s) surveyed (facing upstream)
left ❐ right ❐ both ❐

Landholder: ……………………………………………….. Contact Number: ....

Property address: ………………………………………………………………………………………

Bank Stability

Proportion of bank affected (% of survey area)	Undercutting	Firebreak/track washouts	Subsidence	Erosion	Gully erosion	Sedimentation	Slumping
0-5% Minimal							
5-20% Localised							
20-50% Significant							
>50% Severe							

Are the banks subject to any artificial stabilisation?: ❐ Yes ❐ No
Give details:

Waterways Features

❐ Single channel
❐ Braided channel
❐ Pool
❐ Wetlands
❐ Other
…………………………….

❐ Dam
❐ Groundwater
❐ Rapids (natural)
❐ Anabranch
❐ Tributary

❐ Riffles (artificial)
❐ Bridge
❐ Sand slugs
❐ Vegetated islands

Vegetation Health

❒ Looks healthy ❒ Some sick trees ❒ Many sick or dying trees ❒ Some dead trees ❒ Many dead trees

Are there any tree seedlings or saplings present?: ❒ Yes ❒ No Species: ……………………

Leaf litter: ❒ Absent ❒ Minimal cover ❒ Good cover ❒ Deep cover

Bare Ground: % cover: …………….

Native vegetation: ❒ Abundant ❒ Frequent ❒ Occasional ❒ Rare ❒ Absent

Exotic vegetation: ❒ Abundant ❒ Frequent ❒ Occasional ❒ Rare ❒ Absent

Instream cover: ❒ Leaf litter/detritus ❒ Rocks ❒ Branches ❒ Vegetation

Vegetation cover

Proportion cover	Overstorey	Middlestorey	Understorey
> 80% Continuous			
20-80% Patchy			
< 20% Sparse			
0% Absent			

Proportion of Native Species

	Proportion (%) of native species
Overstorey	
Middlestorey	
Understorey	

Habitats

Aquatic organisms

Invertebrates, reptiles and fish

❒ Cascades, rapids, riffles
❒ Meanders, pools
❒ Instream cobbles, rocks
❒ Instream logs
❒ Variety of instream and bank vegetation types

Terrestrial animals

Invertebrates

❒ Variety of vegetation types
❒ Protected basking sites (tree bark, leaf litter)

Birds (roosting/nesting sites)

❒ Trees
❒ Shrubs
❒ Rushes

Frogs

❒ Dense streamside vegetation
❒ Emergent plants/soft substrate for eggs

Reptiles

❒ Variety of vegetation types
❒ Protected basking/nesting sites (leaf litter, logs)

Mammals

❒ Dense protective vegetation

Habitat Diversity

Any data or observations on variation in water depth?

Any data or observations on water quality? (i.e. discoloured water, debris, algal blooms)

Any wildlife (or evidence of presence) observed?

Landform Types

Description/Diagram (ie. major v-shaped river valley with granite outcrops, shallow valley with low relief).

Fencing Status

Left Bank

Fence present? ❐ Yes ❐ No Fence condition: ❐ Good ❐ Moderate ❐ Poor

Fence style: ❐ Barbed wire ❐ Electric ❐ Fabricated ❐ Ringlock ❐ Plain wire

Right Bank

Fence present? ❐ Yes ❐ No Fence condition: ❐ Good ❐ Moderate ❐ Poor

Fence style: ❐ Barbed wire ❐ Electric ❐ Fabricated ❐ Ringlock ❐ Plain wire

Fence position (approximate distance [m] from river bank): LB: ……….….. RB: ……………………

Stock access to foreshore: ❐ Yes ❐ No Vehicle access to foreshore: ❐ Yes ❐ No

Crossing Point: ❐ Yes ❐ No

Foreshore Condition Assessment

A Grade Foreshore	**B Grade Foreshore**	**C Grade Foreshore**	**D Grade Foreshore**
A1 Pristine A2 Near pristine A3 Slightly disturbed	B1 Degraded – weed infested B2 Degraded – heavily weed infested B3 Degraded – weed dominant	C1 Erosion prone C2 Soil exposed C3 Eroded	D1 Ditch – eroding D2 Ditch – freely eroding D3 Drain – weed dominant

(Choose one of the above. Use Grades A, B, C or D for General condition and use sub-grades for best and poorest ratings ie A1 through to D3)

General: Best: Poorest:

Overall Stream Environmental Rating

Rating	Floodway & bank vegetation	Verge vegetation	Stream Cover	Bank stability & sediment	Habitat diversity
Excellent	15	8	8	8	6
Good	12	6	6	6	4
Moderate	6	4	4	4	2
Poor	3	2	2	2	1
Very poor	0	0	0	0	0

Surrounding landuse:

Conservation reserve (8) Urban (2) Agricultural (2)

Rural residential (4) Remnant bush (6) Commercial/industrial (1)

Total score = ☐

Score	40-55	30-39	20-29	10-19	0-9
Rating	Excellent	Good	Moderate	Poor	Very poor

Environmental rating = ………………………………….

Evidence of Management

Tick the appropriate boxes:

❒ Prescribed burning
❒ Firebreak control
❒ Fencing
❒ Nest boxes
❒ Recreational facilities (e.g. rubbish bins, BBQ's, benches)
❒ Signs
❒ Planting
❒ Weed control
❒ Erosion control
❒ Earthworks
❒ Dredging

❒ Other: ....

Management Issues

Tick the appropriate priority box for each management issue. If the issue does not exist along this section of the waterway it can be crossed out.

Issue	Priority		
	High	Medium	Low
Fire			
Disease			
Weeds			
Erosion			
Salinity			
Sediment			
Stock Access			
Vehicle Access			
Rubbish			
Pollution			

Issue	Priority		
	High	Medium	Low
Recreation			
Garden Refuse			
Service Corridors (roads)			
Crossing point			
Feral Animals			
Point source discharge			
Pumps or off-take pipes			
Dam/weir			
Cultural Features			

Ideas for Management

Tick the appropriate boxes:

❒ Prescribed burning
❒ Firebreak control
❒ Fencing
❒ Erosion control
❒ Recreational facilities (e.g. rubbish bins, BBQ's, benches)
❒ Stock crossing
❒ Planting
❒ Weed control
❒ Earthworks/riffles
❒ Dredging

❒ Other: ....

Vegetation

Plant Name	Abundance (H,M,L)	Plant Name	Abundance (H,M,L)

Water Quality Data

Sample Number	pH	Conductivity mS/cm	Temperature ºC	Location

GPS Coordinates

Coordinate	Description

Photos

Appendix 4
Field guide to foreshore condition grades

A-Grade

Foreshore has healthy native bush (i.e. similar to that found in nature reserves, state forests and national parks).

A1. Pristine—river embankments and floodway are entirely vegetated with native species and there is no evidence of human presence or livestock damage.

A2. Near Pristine—Native vegetation dominates. Some introduced weeds may be present in the understorey but not as the dominant species. Otherwise, there is no evidence of human impact.

A3. Slightly Degraded—Native vegetation dominates. Some areas of human disturbance where soil may be exposed and weeds are relatively dense (ie. along tracks). Native vegetation would quickly recolonise if human disturbance declined.

B-Grade

The foreshore vegetation had been invaded by weeds, mainly grasses and looks similar to typical roadside vegetation.

B1. Degraded—weed infested—Weeds have become a significant component of the understorey vegetation. Native species are still dominant but a few have been replaced by weeds.

B2. Degraded—heavily weed infested—Understorey weeds are nearly as abundant as native species. The regeneration of trees and large shrubs may have declined.

B3. Degraded—weed dominant—Weeds dominate the understorey, but many native species remain. Some trees and large shrubs may have disappeared.

C-Grade

The foreshore supports only trees over weeds or pasture. Bank erosion and subsidence may occur in localised areas.

C1. Erosion prone—Trees remain with some large shrubs or tree grasses and the understorey consists entirely of weeds (i.e. annual grasses). There is little or no evidence of regeneration of tree species. River embankment and floodway are vulnerable to erosion due to the shallow-rooted weedy understorey providing minimal soil stabilisation and support.

C2. Soil exposed—Older trees remain but the ground is virtually bare. Annual grasses and other weeds have been removed by livestock grazing and trampling or through humans use and activity. Low level soil erosion has begun.

C3. Eroded—Soil is washed away from between tree roots. Trees are being undermined and unsupported embankments are subsiding into the river valley.

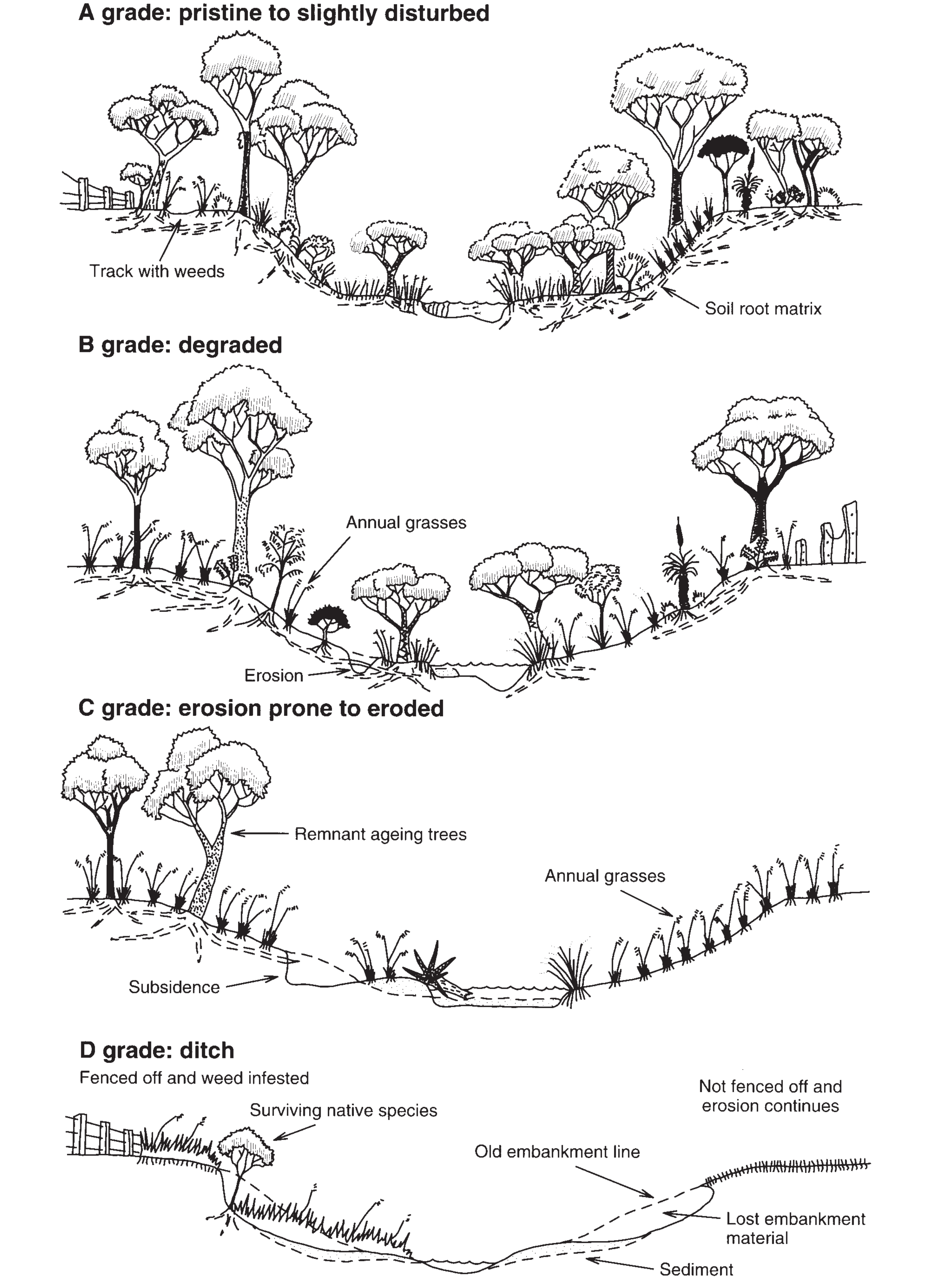
D-Grade

The stream is little more than an eroding ditch or a weed infested drain.

D1. Ditch—eroding—There is not enough fringing vegetation to control erosion. Remaining trees and shrubs act to impede erosion in some areas, but are doomed to be undermined eventually.

D2. Ditch—freely eroding—No significant fringing vegetation remains and erosion is out of control. Undermined and subsided embankments are common. Large sediment plumes are visible along the river channel.

D3. Drain—weed dominant—The highly eroded river valley has been fenced off, preventing control of weeds by stock. Perennial weeds have become established and the river has become a simple drain.



Source: Water and Rivers Commission, 1999

Appendix 5 — Examples of fence condition

Fencing Status — Examples of Fence Condition

Fence condition: POOR.

Fence condition: MODERATE.

Fence condition: GOOD.

Appendix 6
York regional herbarium list for Flea Pool Reserve (reserve 838)

River Conservation Society

YORK REGIONAL HERBARIUM SPECIES LIST

Location: Flea Pool Reserve (Res No. 838)
Lat: 31°48'02", Long:117°0'01"

Species	Collector	GR Number	Accession	Barcode	Where File
Acacia erinacea	HS104	163	980222	5251877	Flea Pool 1
Acacia multispicata	HS40	163	970341	4919238	Flea Pool 1
Allocacuarina campestris	CH525	70			Flea Pool 1
Atriplex semibaccata	CH236	105	980112		Flea Pool 1
Austrostipa elegantissima	CH235	31	980112		Flea Pool 1
Banksia prionotes	CH216	90			Flea Pool 1
Borya spherocephala	HS44	54F			Flea Pool 1
Caladenia hirta	KB32	66	200083	5680913	Flea Pool 1
Cheilanthes sp	CH297	7			Flea Pool 1
Corynotheca micrantha var. *gracillis*			M Hislop		
Dampiera spp	HS46	341			Flea Pool 2
Daviesia hakeoides ssp subnuda	CH233	165	980112 mh		Flea Pool 1
Didymanthus	CH553	105			Flea Pool 1
Drosera macrophylla	HS103	143	980222	5251486	Flea Pool 1
Eremophila spp	HS48	326			Flea Pool 2
Eucalyptus	CH328	273	990088		Flea Pool 2
Eucalyptus loxophleba	CH327	273			Flea Pool 2
Greviilea paniculata	HS50	90	980112	5098092	Flea Pool 1
Grevillea levis	HS19	90	970306	4869877	Flea Pool 1
Grevillea vestita	HS21a	90	970306	4869834	Flea Pool 1
Hakea preissii	CH524	90			Flea Pool 1
Halosarcia lepidosperma	CH558	105	K Shepherd		Flea Pool 1
Halosarcia pergranulata	CH557	105	K Shepherd		Flea Pool 1
Hibbertia enerva	HS20a	226			Flea Pool 2
Hibbertia rupicola	CH522	226	200124	5772753	Flea Pool 2
Hibbertia rupicola (S. Moore)	CH231	226	970341	4919181	Flea Pool 2
Jacksonia sternbergiana	CH523	165	200124	5772737	
Melaleuca rhaphiophylla	HS24	273	970306	4869842	
Mirbelia ramulora	CH555	165	10067	5626315	
Papilionaceae	HS47	165			
Pelargonium spp*	HS45	167			
Philotus sp.	HS43	106			
Podolepsis capillaris	CH237/298	345	980112	5098084	
Ptilotus polystachys	HS42	106			
Santalum spicatum	CH326	92			
Scholtzia ascapitata	RH3H		M Trudgeon		
Scholtzia involucrata	HS22	273	980122		
Scholtzia spp	HS102	273	980222	5251826	
Sclerolaena eurotioides	CH521/559	105	200124	5772745	
Sowerbaea laxiflora	KB33	54F	200083	5680905	
Suaeda australis	CH556	105	K Shepherd		
Waumbia densiflora	CH545	54	10085	5914647	

Appendix 7
Overall stream environmental health rating explanatory information

	Floodway and bank vegetation	Verge vegetation	Stream cover	Bank stability and sedimentation	Habitat diversity
Excellent	Healthy undisturbed native vegetation. Virtually no weeds. No disturbance.	Healthy undisturbed vegetation. Verges more than 20 m wide.	Abundant cover: shade, overhanging vegetation, snags, leaf litter, rocks and/or aquatic vegetation.	No erosion, subsidence or sediment deposits. Dense vegetation cover of banks and verge. No disturbance.	3 or more habitat zones. Some permanent water.
Good	Mainly healthy undisturbed native vegetation. Some weeds. No recent disturbance.	Mainly healthy undisturbed native vegetation. Verges less than 20 m wide.	Abundant shade and overhanging vegetation. Some instream cover.	No significant erosion, subsidence or sediment deposits in floodway or on lower banks. May be some soil exposure and vegetation thinning on upper bank and verge.	2 habitat zones. Some permanent water.
Moderate	Good vegetation cover, but mixture of native and exotic species. Localised clearing. Little recent disturbance.	Good vegetation cover, but mixture of native and exotic species. Verges 20 m or more.	Some permanent shade and overhanging vegetation. Some instream cover.	Good vegetation cover. Localised erosion, bank collapse and sediment heaps only. Verges may have sparse vegetation cover.	Mainly 1 habitat type with permanent water. OR Range of habitats with no permanent water.
Poor	Mainly exotic ground cover. Obvious site disturbance.	Narrow verges only (<20 m wide). Mainly exotic vegetation.	Channel mainly clear. Little permanent shade or instream cover.	Extensive active erosion and sediment heaps. Bare banks and verges common. Banks may be collapsing.	Mainly 1 habitat type with no permanent water.
Very Poor	Mostly bare ground or exotic ground covers (ie. pasture, gardens or weed infestations, but no trees).	Mostly bare ground or exotic ground covers (ie. pasture, gardens or weed infestations, but no trees).	Virtually no shade or instream cover.	Almost continuous erosion. Over 50% of banks collapsing. Sediment heaps line or fill much of the floodway. Little or no vegetation cover.	Stream channellised.

Living Streams Survey: Information to determine environmental ratings of streamlines. *Source: Pen and Scott, 1995*

Appendix 8
Avon Waterways Committee fire policy

Recovery Statement Number 1

FIRE

Introduction

The *Avon Waterways Committee* (AWC) is an organisation formed to assist the community and government agencies to sustainably manage the waterways within the Avon River Basin, within a framework of natural resource management. It has a mandate to continue the progression of the *Avon River Management Program*, developed by its predecessor, the *Avon River Management Authority* (ARMA).

It has resolved to evolve the policies developed by ARMA as a statutory authority into more 'user friendly' position statements, called ***Recovery Statements***, and to develop new statements for issues as they arise.

The AWC, in developing these documents, have agreed that the '*Principles of River Management*' written by the late Jim Masters OA, and other sound scientific principles will underpin each Statement. Further, they recognise that each document must be consistent with the Avon Catchment Council's *Natural Resource Management Strategy for the Avon River Basin*.

The following document is a draft *Recovery Statement* on ***'FIRE'***.

Objectives

The long-term objective of Avon Waterways Committee is to restore the natural functioning and vegetation of the Avon River and its major tributaries. Arising out of this aim, the Committee has four objectives related to fire:

- To protect riverine ecosystems from the damaging effects of uncontrolled fire:
- To use controlled fire for regeneration in accordance with management plans;
- To manage the fire hazard along the river, so as to minimise the threat of wildfires to adjoining assets and property; and
- To work cooperatively with Local Governments, Fire Brigades and neighbours with respect to fire management and development of Fire Management Plans.

Background

Fire is a natural factor in most Australian ecosystems. It can be started by lightning as well as by humans. The native bush is adapted to occasional fire; plants and animals either survive the fire, or regenerate following it. Many native plant species regenerate best after fire (although along the Avon River, regeneration events are also associated with floods).

Different types of native bush are adapted to different fire regimes. We have no knowledge of the “natural” fire regime that would have occurred in the Avon valley before agricultural development, but it can be inferred from the presence of fire-tender species such as Swamp Sheoak (*Casuarina obesa*) that fires may not have naturally occurred more frequently than every 15 or 20 years.

However, the strip of bush along the Avon River and its tributaries is no longer in its natural state. The surrounding country has been largely cleared and converted to cropland, pasture and urban development, limiting opportunity for decolonisation of burnt areas by native birds and animals.

Many weeds (especially exotic annual grasses) are thickly established in the bush, while in some places the native herbivores have been displaced by sheep.

Whilst fire is a natural factor in the bush, it can be a damaging agency in degraded bush. In particular, frequent fires enhance further weed development that in turn leads to higher annual fire hazards. Fire is a useful (indeed often essential) agent for bushland regeneration, but if it occurs too frequently, it can eliminate some native species and if it is too intense, it can burn down valuable habitat trees and accelerate erosion along the riverbanks.

Uncontrolled summer fires are also a threat to human values. Along the Avon River are several towns, minor settlements, farms, businesses, bridges, powerlines, railways, tourist sites and historic buildings. These assets need to be protected from bushfires, including fires that may start in the river system.

The AWC has no significant resources at this stage to carry out fire management programs or to fight fires. We are therefore dependent upon the assistance of local Bushfire Brigades and neighbours; equally they are dependent upon us to ensure our policies and river management plans are practical as well as visionary.

Strategies

In order to achieve its objectives, AWC will:

1. Undertake a Wildfire Threat Analysis of the river system. This will be done in conjunction with Local Authorities and experienced Bushfire Brigade personnel in each district. The purpose will be to identify all the important values that are potentially threatened by a fire starting in the river system.

2. Develop fire management plans to cover the areas of the river adjacent to identified high value sites and adjacent land as necessary. These plans will deal with issues such as access, firebreaks, fire suppression plans and hazard reduction, and will set out the various responsibilities for decision-making by those involved in doing the work which is prescribed. All plans will be undertaken with full community involvement. Final plans must be submitted to the AWC for consideration, and a recommendation will be made to the Water and Rivers Commission (WRC) for endorsement if appropriate.

3. Aim to keep fire permanently out of as much of the riverine system as possible, except where fire is used for hazard reduction, regeneration or control of weeds or feral animals under the terms of an approved management plan.

4. Allow the use of controlled fire, or selective herbicides to control annual grass fuels in areas where hazard reduction is approved to protect a high value site. In the case of controlled burning, a prescription must be prepared which specifies season and intensity of fire, the measure to be taken to ensure the fire is made safe, and that mopping up and patrolling is undertaken to protect old trees, hollow logs etc. In the case of herbicide spraying, a prescription must be prepared which specifies the frequency, chemical to be used, the rate and time of application and the measures to be taken to protect non-target species or guard against off-site effects.

   All controlled burning must be in accordance with the Bush Fires Act and meet Local Government requirements, and all prescriptions must be submitted to the AWC for consideration, and a recommendation will be made to the WRC for endorsement if appropriate.

5. Not permit uncontrolled grazing by sheep, cattle, goats, pigs or horses in the river system in areas controlled by WRC. Some limited controlled grazing may be approved during an interim period in which other hazard reduction measures are being developed. Proposals to graze WRC-controlled land must be submitted to the AWC for consideration, and a recommendation will be made to the WRC for endorsement if appropriate.

   Owners of riverine vegetation will be encouraged to phase out or limit grazing on their lands in favour of less destructive measures of hazard reduction.

   New weed invasion will be minimised by minimising all forms of soil disturbance along the river. This especially applies to roads and firebreaks, off-road vehicle use and urban development, none of which may take place along the river without approval of WRC.

6. Permit the mowing or slashing of weeds in some areas close to towns, buildings or other constructions so as to break down a tall grassy fire hazard. Prescriptions covering the proposed work must be submitted to WRC for approval.

7. Encourage neighbours to the river to make their own properties fire-safe, rather than rely on fire hazard reduction along the river. This will be achieved through education campaigns, including detailed discussion with property owners and the involvement of neighbours in the preparation of fire management plans for the river system.

   AWC will also support measures promoted by Landcare groups to minimise stubble burning on farmlands adjacent to the waterways.

8. Encourage research to be undertaken on the management of fire and on fire ecology along the Avon River. AWC wishes to recover the full suite of native plants and animals that once occurred in the bush in this area, but at the same time we wish to ensure neighbouring assets are protected. AWC will assist scientists from government agencies and universities who are prepared to work on research projects that help to achieve this aim.

9. Monitor all areas burnt. Where good regeneration of desirable species has occurred, areas will be set aside from prescribed burning for a sufficient period to enable the young plants to establish, flower and seed.

10. Strongly support volunteer Fire Brigades located along the river, to ensure they are properly equipped and organised. This support will take the form of collaborative submissions to Local Authorities and the Bush Fires Service, until we are in a position to provide direct financial support.

11. Identify potential sources of fire in or adjacent to the river system. Where there are obvious problem sites (e.g. smouldering rubbish tips) the site-manager will be approached to fix the problem. If necessary AWC will ask Local Authorities or the Bush Fire Service to enforce the Bush Fires Act to eliminate potential sources of fire.

    Open fires will not be permitted in camp grounds or other recreational areas controlled by WRC along the river during restricted or prohibited burning periods, generally between the months of September and May.

12. Seek endorsement of this Recovery Statement, and all fire management plans developed for the river system from local authorities, neighbours and relevant government agencies (especially the Bush Fire Service).

13. Ensure that all fire management plans and regimes that are developed are consistent with the ACC Natural Resource Management Strategy

Publication feedback form

The Department of Environment welcomes feedback to help us to improve the quality and effectiveness of our publications. Your assistance in completing this form would be greatly appreciated.

Please consider each question carefully and rate them on a 1 to 5 scale, where 1 is poor and 5 is excellent (*please circle the appropriate number*).

Publication title: FORESHORE AND CHANNEL ASSESSMENT OF MORTLOCK RIVER AND MORTLOCK RIVER SOUTH

How did you rate the quality of information?	1	2	3	4	5
How did you rate the design and presentation of this publication?	1	2	3	4	5

How can it be improved?

....

....

....

....

How effective did you find the tables and figures in communicating the data?	1	2	3	4	5

How can they be improved?

....

....

....

How did you rate this publication overall?	1	2	3	4	5

If you would like to see this publication in other formats, please specify. (E.g. CD)

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