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Foreshore and channel assessment of Mortlock River East

FORESHORE AND CHANNEL ASSESSMENT OF MORTLOCK RIVER EAST

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Helping Communities Helping Australia

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Cover photograph: Mortock River East [taken by David Gibb]

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 Mortlock River East and identify management actions needed through standard field surveys, in consultation with landholders and the surrounding community.

The Mortlock River East catchment drains portions of the Shires of Northam, York, Goomalling, Kellerberrin, Trayning, Mt Marshall, Wongan-Ballidu and the majority of the Shires of Cunderdin, Tammin, Wyalkatchem, Dowerin and Koorda. The foreshore and channel assessments along the Mortlock River East were undertaken between November 2003 and January 2004.

The purpose of this project is to provide baseline information to land managers in the Mortlock River East catchment. It is hoped that the 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 present day agricultural land practices, the majority of the Mortlock River East 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, weed invasion, fire risk and salinisation.

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 river owners and interested community members.

Although this tributary has been surveyed in isolation from 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 to the surrounding environment. Healthy foreshore vegetation stabilises the riverbanks, slows and filters water thus reducing the impact of erosion and sedimentation of river pools. Riparian vegetation also provides protective cover and suitable habitat for aquatic and terrestrial fauna.

The river valleys 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 causes 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 East 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, 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:

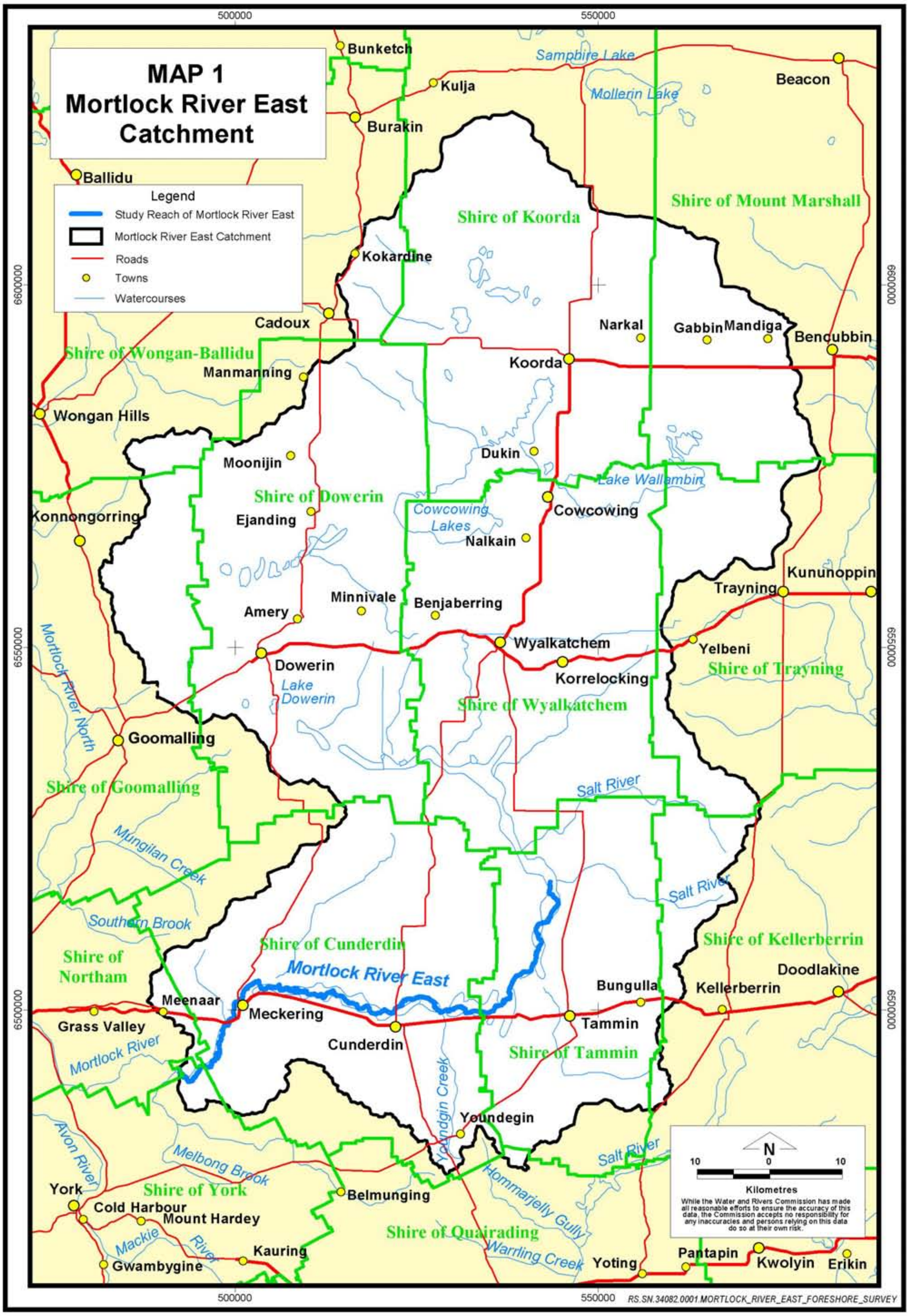
- To identify areas within the riparian environment which need future rehabilitation or conservation.
- To provide managers with data about the river to aid them in their decision making, especially in prioritisation of future works.
- To provide baseline information from which stakeholders can monitor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

Study area

The Mortlock River System is one of the major tributaries of the Avon River. It consists of the Mortlock River North, the Mortlock River East, the Mortlock River South and the Mortlock River. The Mortlock River East branch flows from the Shire of Tammin and eventually meets with the Mortlock River near Duck Pool Reserve, 18km ESE of Northam. The Mortlock River then meets with the North branch 2km east of Northam and eventually flows into the Avon River. The Avon River has its source near Wickepin and eventually becomes the Swan River near the confluence with Wooroloo Brook at Walyunga National Park. The study area is located within the boundaries of the Shires of Northam, York, Cunderdin and Tammin. During a 1:100 year flood, the Mortlock River East connects with the series of salt lakes which follow an ancient drainage line to the source of the river at the Cowcowing Lake system. For this survey, it is assumed that the source of the Mortlock River East is 13km NNW of the townsite of Tammin, where a more defined channel system starts to form.

Map 1 shows the extent of the Mortlock River East catchment (24,600km^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. Figure 1 shows a cross sectional representation of a typical watercourse in the Avon catchment.



Map 1. Mortlock River East catchment

Historical description of the Mortlock River East

Aboriginal heritage

Aboriginal people have occupied the Avon region for more than 30,000 years. Historical records show that the Balardong tribe occupied all of the Mortlock River East catchment. The present day area was bounded by Northam in the east, Brookton in the south, east to Corrigin and Kellerberrin and north to Wongan Hills and Dalwallinu. Within the makeshift boundary lived about 500 Aboriginal people (Stokes, 1986).

Data from the Department of Indigenous Affairs shows one site of Aboriginal significance along the Mortlock River East in the Shire of Cunderdin. This is significant site 5883, located along Great Eastern Highway, 8km east of the town of Cunderdin. Due to the sensitivity of the site, 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 Richard Dale on 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).

The Mortlock River was first discovered by Henry Mortlock Ommanney 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 East 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).

Catchment description

Climate

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

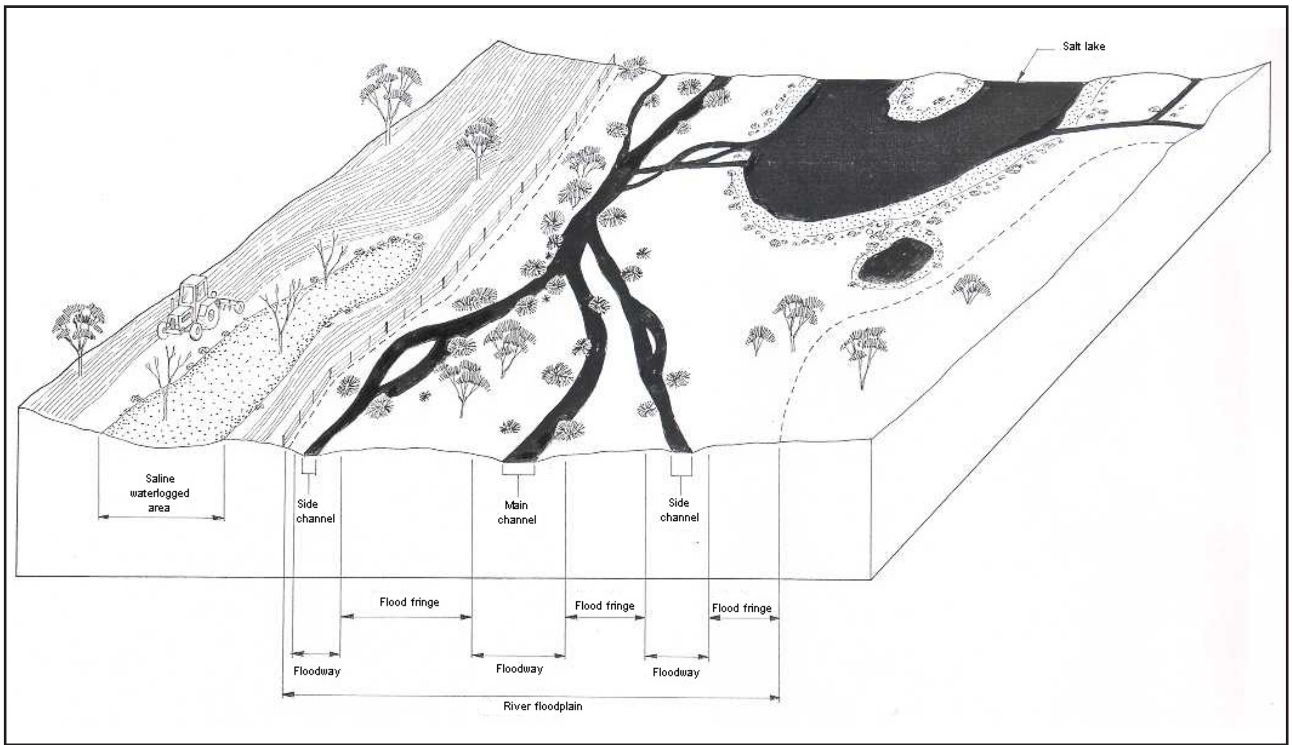


Figure 1. Cross section of a typical watercourse in the Avon catchment ***(Source: Water and Rivers Commission, 2003a).***

The majority of the Avon catchment falls within the Transitional Rainfall Zone (800–300mm), and is subject to a broad range of climatic influences. The Mortlock River East catchment lies within the 400–350mm 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	Cunderdin	Tammin
Average yearly rainfall (mm)	430.5	368.6	329.9
Average max. temperature (^{o}C)	25.2	25.1	25.0
Average min. temperature (^{o}C)	11.0	11.4	10.8
Average evaporation (mm/day)	4.4	N/A	N/A
Average wind speed (km/h)	8.9	13.2	12.3

Geomorphology and soils

Mortlock River East catchment can be divided into two physiographic regions: the Zone of Ancient Drainage and the Zone of Rejuvenated Drainage; each zone has a characteristic suite of landforms, soils and vegetation. The Zone of Ancient Drainage includes all the land east of the Meckering Line (117^{o}E longitude) and extends beyond the eastern edge of the wheatbelt (Lantzke and Fulton, undated). The landscape consists of a gently undulating plateau with wide convex divides, long gentle slopes and broad valleys that contain salt lakes at their lowest point. These chains of salt lakes are sediment-filled remnants of an ancient drainage system which now flows only in wet years. The gradients of these valleys are low, often with grades of 1:1500 or less. The Zone of Rejuvenated Drainage is defined by the Meckering Line to the east and the Darling Range Zone to the west (Lantzke and Fulton, undated). The Zone of Rejuvenated Drainage is characterised by greater dissection of 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 main channel of the Mortlock River East is easily recognisable and well defined to the west of Meckering. To the east, the channel is braided, undefined and eventually forms a series of salt lakes in the Shire of Wyalkatchem area.

The Zone of Ancient Drainage and the Zone of Rejuvenated Drainage have distinct soil types and can be divided accordingly. The majority of the Mortlock River East catchment lies within the Zone of Ancient Drainage but there is a small section to the west of Meckering that lies in the Zone of Rejuvenated Drainage.

The major soil types of the Zone of Ancient Drainage in the Mortlock River East catchment include sandplain soils, hillside soils, valley floor soils and saline soils (Lantzke, 1992).

The sandplain soils are characterised by deep pale grey/ yellow sands with some ironstone gravels or brown/ yellow sandy clay loams. They are usually found on undulating plateau or upland areas (Ms8). Hillside soils are colluvium in nature, derived from laterite in the upper slopes. These soils are characterised as duplex with a surface of shallow grey/brown sandy loam overlaying a deep brown/yellow mottled clay layer (Va66). Valley floor soils occur on the broad, flat river valleys. Gradients often have a slope of 1:1500. This soil is characterised by having a shallow grey/brown sandy clay loam over structured reddish/brown clay with lime present in some areas (Sl28). Saline soils occur on the salt lakes, channels, flats and dunes of the Mortlock River East. This soil type occurs in the lowest point of the valley floor and consists of a mixture of sand, silt and clay and is calcareous and gypsiferous in nature (SV1).

The major soil types in the Zone of Rejuvenated Drainage in the western portion of the Mortlock River East 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 often red in colour (Uf1, Qb29). The valley floor soils occur at the bottom of the landscape on the floodplain of the Mortlock River East. 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 a brown medium clay. This duplex soil has the tendency to be come waterlogged in wetter rainfall years (Va63).

Map 2 shows the distribution of soil units throughout the Mortlock River East catchment, and Appendix 1 provides a description of the soil units.

Hydrology

The Mortlock River East catchment drains the eastern portions of the Shires of Northam, Tammin and Goomalling, the north east of the Shire of York, the whole of the Shires of Cunderdin and Dowerin and the southern corner of the Shire of Wyalkatchem and Koorda.

There are several minor tributaries which flow into the Mortlock River East branch from the surrounding catchment. These include Bungulla, Youndegin, Tomalockin and Kelkering Creeks and Warrengidging Brook.

The Mortlock River consists of three branches (North, East and South) which all eventually flow into the Avon River near Northam. The Mortlock River East contributes little flow in years of average rainfall but since the catchment is predominantly cleared for agriculture it can, in wet years, contribute large volumes of water (Harris, 1996). For example in 2000, which was considered to be a wet year, the total discharge for the Mortlock River East was 35,430 megalitres. In contrast, total discharge for 2001 was 3707 megalitres (Water and Rivers Commission, 2003b). This shows the seasonal variation of flow in the river over a short period of two years.

The Mortlock River East is seasonal and only flows after heavy rainfall events which is usually during the winter and spring months. In the eastern portion of the catchment in the Shire of Cunderdin the main channel meanders across a wide floodplain, which can be up to 2.5km wide. To the west of Meckering, in the Zone of Rejuvenated Drainage, the main river channel becomes more defined and is able to carry larger volumes of water through to the Avon River. See Figure 1 for a cross sectional representation of a watercourse in the Avon catchment.

Vegetation

Native vegetation

The Mortlock River East has a variety of vegetation types due to the mosaic of the soil types that the river dissects. West of the Meckering Line the banks of the river are lined with swamp sheoak (*Casuarina obesa*), York gum (*Eucalyptus loxophleba*) and Jam wattle (*Acacia acuminata*). To the east of the Meckering Line the landscape changes to broad flat river valleys and waterlogged saline soils. The upper slopes of the wide valleys are dominated by salmon gum (*Eucaluptus salmonophloia*) and salt river gum (*Eucalyptus sargentii*). The valley floors have a mix of *Melaleuca* species, samphires (*Halosarcia* species) and saltbushes (*Atriplex* species). Vegetation communities can change over a small distance given different water depths, soil types and local salinity levels.

Introduced vegetation

Due to the proximity of the river to agricultural areas, a number of agricultural weeds dominate the catchment. Weeds such as wild oats (*Avena barbata*), annual rye grass (*Lolium rigidum*) and sea barley grass (*Hordeum leporinum*) are common throughout the river floodplain. Weeds such as spike rush (*Juncus acuta*), great broom (*Bromus diandrus*) and heliotrope (*Heliotropium curassavicum*) are also common along the river floodplain.

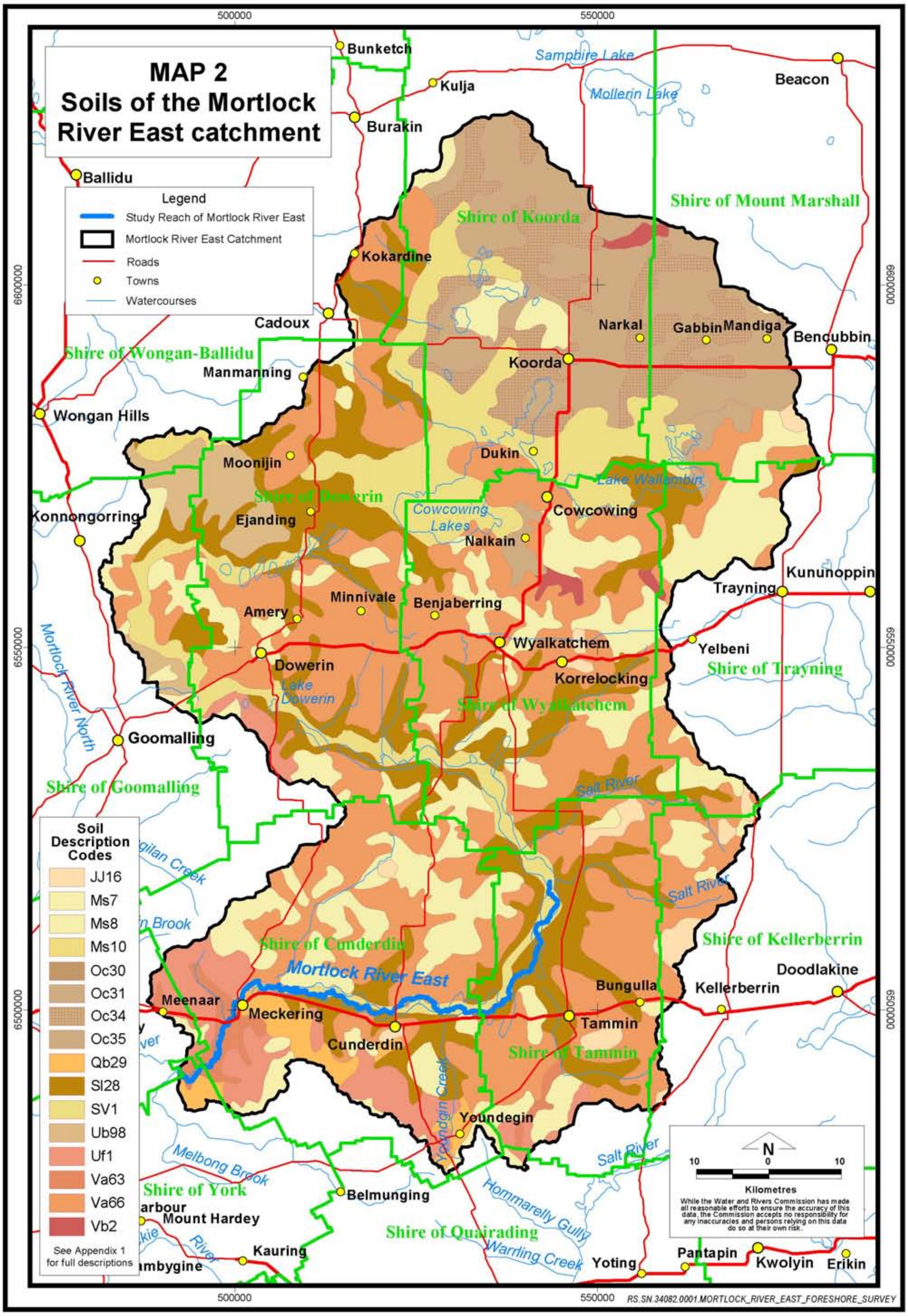
Catchment land use and tenure

The land use in the Mortlock River East catchment is varied with a mix of agricultural land uses. The agricultural focus is the growing of cereal grains and other crops, sheep and, less so, cattle.

Some sections of the Mortlock River East lie within Crown reserves (Duck Pool Reserve, Rabbit Proof Fence and the Cunderdin Agricultural College) but the majority of the catchment is privately owned.

Water quality (historical)

The water quality of the Mortlock River East catchment is a major factor that affects the health of the waterway and its ecosystem. Sanders (1991) reported that the first documented appearance of salinity was in the Mortlock River East catchment in 1920 where a study by Jim Masters recorded the death of semi-aquatic and aquatic vegetation.



Map 2. Soils of the Mortlock River East catchment

Nutrients, salinity and sediments are the major pollutants of the Mortlock River East branch due to clearing and agricultural land use. Numerous snapshots have shown that the salinity levels in the river can vary from 4500mS/m (hyper saline) to 1500mS/m (low saline) throughout the year.

Nutrients and sediment have also been monitored within the catchment and there is a strong relationship between the two. Higher suspended sediment, caused by water erosion and topsoil loss from agricultural areas, can increase the nutrient levels in the water. Warrengidging Brook, a tributary of the Mortlock River East, has shown this relationship through long-term nutrient and sediment monitoring (Water and Rivers Commission, 2001).

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 channel, the groundwater salinity can range from 4000mS/m to 7000mS/m which is in the hyper saline range (Cummins, 2003). 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 East 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 East.

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 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;
- waterways features;
- vegetation health (and coverage);
- habitats;
- habitat diversity;
- landform types;
- fencing status;
- foreshore condition assessment;
- overall stream environmental health;
- evidence of management;
- management issues;
- ideas for management;
- vegetation
- water quality data;
- GPS coordinates; and
- photos.

Surveys were conducted along the length of Mortlock River East with survey sections determined by paddock and/or property boundaries. The length of Mortlock River East was divided into 27 sections for the purpose of this survey.

Foreshore and channel assessments were conducted along the length of each river sections by filling out the survey form (an example is provided in Appendix 2). 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), surveys were conducted facing upstream.

The majority of assessment along Mortlock River East was observational. Foreshore and channel condition was assessed whilst walking along the waterway and recorded on the assessment template. 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 land use 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 2 that can be copied and used by the community to assess the present condition of waterways.

Method of analysis

A database has been set up to record information collected during foreshore and channel assessments. The database contains both numerical and written data taken directly from the survey forms. It does not include any anecdotal evidence supplied by landholders and other community sources. Only information that does not breach confidentiality has been included in this database.

Having information recorded in a database structure (as well as using a standardised assessment form) has allowed for analysis between survey sections as well as along the whole watercourse. Queries within the database structure provided efficient collation of data, which can be converted into spreadsheets for interpretation and inclusion in this report.

Five categories have been used throughout the field assessments to determine the overall stream environmental rating (see Appendix 3). The overall stream environmental health rating is used to assess the ecological value of the individual river sections and allows us to classify the health of the waterway. This rating system determines the current environmental condition of the waterway based on the six individual components listed below:

- floodway and bank vegetation;
- verge vegetation;
- stream cover;
- bank stability and sedimentation;
- habitat diversity; and
- surrounding land use.

Depending on the rating (Very Poor up to Excellent), an overall stream environmental health rating was determined for each survey section. Appendix 3 provides a table that shows each individual component based on the rating the section received.

Results of the foreshore and channel assessment have been stored in a database that has been used to correlate figures for factors such as general foreshore condition and fencing along the river. Data has been collated and is the source information from which maps have been produced. Key findings of this Mortlock River East assessment have been summarised within this report.

Survey results

Historical evidence as well as the survey results indicate that the Mortlock River East and its surrounding catchment has been subjected to a wide range of disturbances, such as vegetation clearing, animal grazing, waterlogging and salinity, 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 abundance and diversity, sedimentation, bank erosion and weed invasion.

Bank and channel stability

Bank and channel stability can be affected by surrounding soil type, 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 used in the survey:

- undercutting
- firebreak/track washouts
- subsidence
- erosion
- gully erosion
- sedimentation
- 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

Bank stability and sedimentation were also determined as part of the overall stream environmental rating. Results showed that a majority of sections were recorded as displaying erosion and sedimentation at various levels. Undercutting was recorded at only three sites along the Mortlock River East.

Where the undercutting occurred along the survey reaches, it was either localised at 7% of sections or significant at 3% of sections. Subsidence (or the sinking of the ground level that is not affected by slope) was recorded as being localised at 3% of the sites. The problem of firebreak and track washout was recorded at one site where it was a significant problem (20–50%).

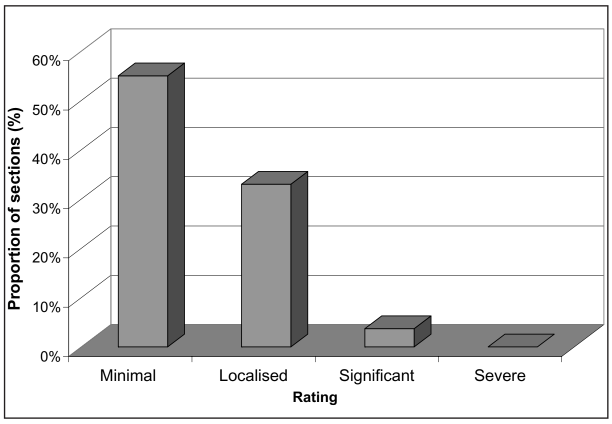


Figure 2. Bank stability – erosion (% of sections)

Figure 2 shows that 55% of all sites surveyed had minimal erosion of the riverbanks. Thirty-three percent of sections surveyed had a higher localised erosion rating and only 3% had bank significant erosion.

Gully erosion was recorded with 11% of the sites showing minimal levels and 3% showing localised levels.

Slumping was not recorded at any of the sites along the Mortlock River East.

Sedimentation in the channel was another major form of river degradation with 40% of the surveyed sections showing minimal sedimentation in the river. Forty percent of the sections had localised sedimentation while only 7% of the sections had a significant sediment problem. This can be seen in Figure 3.

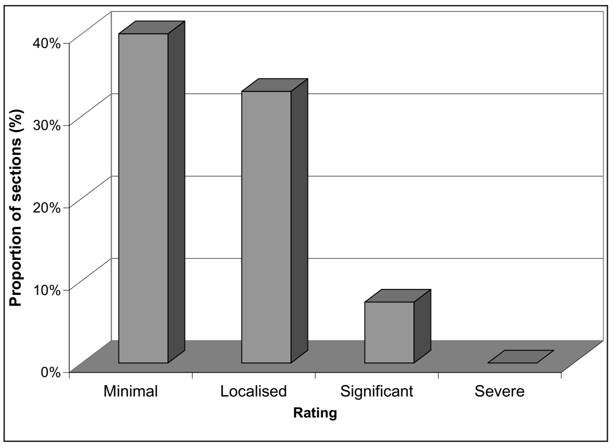


Figure 3. Bank stability – sedimentation (% of sections)

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.

The survey of the waterway features showed that 22% of the sections had a single channel and 77% had a braided channel system. To accompany the braided channel system, 70% of sections had vegetated islands within the floodway.

Only 3% of sections surveyed had a river pool. The timing of the survey was during summer where river flow is reduced and pools dry out.

Twenty-two percent of the surveyed sections had road bridges spanning the main channel. Sand slugs or sediment deposits were documented at 25% of the surveyed sites.

Foreshore vegetation

Native vegetation

The vegetation in the western sections of the Mortlock East catchment is dominated by an overstorey of swamp sheoak (*Casuarina obesa*), York gum (*Eucalyptus loxophleba*) and flooded gum (*Eucalyptus rudis*). In the east of the catchment, trees become less common and shrub species, such as salt lake honey myrtle (*Melaleuca thyoides*) and broombush (*Melaleuca uncinata*) become dominant.

The middle storey is again dominated by shrub species growing to 4m in height. These include needlebush (*Hakea preissii*), jam wattle (*Acacia acuminata*) and a variety of *Melaleuca* species.

Native understorey plants were common throughout the sections surveyed with creeping saltbush (*Atriplex semibaccata*), sea heath (*Frankenia pauciflora*) and numerous samphires (*Halosarcia* species) as the dominant species.

In the eastern part of the catchment, weed species dominated the understorey along the Mortlock River floodplain. A majority of the species with high abundance included annual or perennial grasses, which include wild oats (*Avena fatua*), sea barley grass (*Hordeum leporinum*) and annual rye grass (*Lolium rigidium*).

Vegetation health

The native vegetation along the Mortlock River East is under pressure from introduced weeds, salinity and stock grazing. Sixty-six percent of sections showed that there were some sick trees growing along the river. Eleven percent of sections showed that there were many sick trees, 11% of sections had some dead trees and 11% of sections had many dead trees. See Table 3 for native vegetation occurrence and abundance.

Tree seedlings were recorded at three sections along the Mortlock River East. The seedling species included jam wattle (*Acacia acuminata*), swamp sheoak (*Casuarina obesa*) and broombush (*Melaleuca uncinata*).

The native vegetation varied in abundance from section to section. Native vegetation was found to be rare at 3% of the sections surveyed. There was occasional native vegetation at 40% of sections and frequent native vegetation at 55% of sections.

Exotic vegetation also changed in abundance along the survey. Weeds were more frequent in the Zone of Rejuvenated Drainage and less frequent in the Zone of Ancient Drainage. Weeds were rare in 29% of sections, occasional in 22% of sections and frequent in 48% of sections surveyed. See Table 4 for weed occurrence and abundance.

The common weed species encountered along the banks of the Mortlock River East included wild oats (*Avena fatua*) which was found at 40% of sections and had a

Table 3. Native vegetation occurrence and abundance

Scientific name	Common name	% of sites where species occurred	Abundance of each species (% of occurrence)		
			Low	Medium	High
Acacia acuminata	Jam wattle	18	100	0	0
Acacia meisneri	Blue Wattle	3	100	0	0
Acacia lineolata		3	100	0	0
Acacia saligna	Golden wreath wattle	7	100	0	0
Actinostrobus pryamidalis	Swamp cyprus	3	100	0	0
Amyema preissii	Mistletoe	11	100	0	0
Aristida holathera var *holathera*	Kerosene grass	22	83	17	0
Asteraceae sp.	Everlastings	7	50	50	0
Atriplex amnicola	River saltbush	7	100	0	0
Atriplex semibaccata	Creeping saltbush	37	60	40	0
Austrostipa elegantisma	Spear grass	7	50	50	0
Banksia prionotes	Acorn banksia	3	100	0	0
Casuarina obesa	Swamp sheoak	40	18	45	36
Conostylis sp.	Cottonheads	3	100	0	0
Cyperus gymnocaulus	Spiny flat sedge	18	80	20	0
Darwinia diosmoides		7	50	50	0
Dianella sp.	Native flax	7	100	0	0
Disphyma crassifolium	Pigface	14	75	25	0
Eragrostis dielsii	Mallee love grass	3	0	100	0
Eucalyptus loxophleba	York gum	51	71	29	0
Eucalyptus rudis	Flooded gum	11	100	0	0
Eucalyptus sargentii	Salt gum	11	66	33	0
Frankenia glomerata	Cluster head frankenia	11	33	66	0
Frankenia pauciflora	Sea heath	40	45	45	10
Grevillea paniculata		7	100	0	0
Hakea preissii	Needlebush	44	91	9	0
Juncus kraussii	Shore rush	3	100	0	0
Maireana brevifolia	Small leaf blue bush	22	66	33	0
Melaleuca brevifolia		37	100	0	0
Melaleuca laterifolia	Gorada	29	62	38	0
Melaleuca thyoides	Salt lake honey myrtle	59	56	44	0
Melaleuca uncinata	Broombush	51	35	57	7
Resionaceae sp.	Southern rushes	3	100	0	0
Rhagodia drummondii	Lake fringe rhagodia	3	100	0	0
Halosarcia sp.	Samphire	92	8	36	56
Santalum acuminatum	Quandong	18	100	0	0
Scholtzia involuctata		33	77	23	0
Sporobolus virginicus	Saltwater couch	18	80	20	0

Table 4. Weed species occurrence and abundance

Scientific name	Common name	% of sites where species occurred	Abundance of each species (% of occurrence)		
			Low	Medium	High
Hordeum leporinum	Barley grass	29	12	87	0
Bromus diandrus	Great broom grass	7	50	50	0
Schinus trebinthifolia	Pepper tree	3	100	0	0
Juncus acutus	Spike rush	7	100	0	0
Limonium lobatum	Statice	3	100	0	0
Ptilotus polystachus	Mulla mulla	11	66	33	0
Puccinellia ciliata	Puccinellia	7	100	0	0
Lolium rigidium	Annual rye grass	25	0	28	72
Salsola kali	Prickly saltwort	3	100	0	0
Avena fatua	Wild oats	40	18	54	28

*Healthy foreshore vegetation (*Melaleuca thyoides, Casuarina obesa*) growing along banks*

medium abundance. Barley grass (*Hordeum leporinum*) was recorded at 29% of sections with medium abundance and annual rye grass (*Lolium rigidium*) was recorded at 25% of sections with high abundance.

Vegetation cover

Along the length of the survey, vegetation cover was dominated by a patchy middlestorey and a variety of continuous understorey plants. The overstorey only contributed a small amount to the overall vegetation cover. Table 5 shows the proportion (%) of vegetation cover of each vegetation layer. The table shows that in 44% of sections, the overstorey was absent and 44% had sparse cover (<20%). The middlestorey vegetation was sparse in 55% of sections and patchy in 45% of sections. The understorey was seen to be the dominant vegetation layer with 44% of sections having patchy (20–80%) cover and 56% of section were recorded as having continuous (>80%) cover.

The native species composition within the three vegetation layers showed that the overstorey and middlestorey were dominated by native species. All of the sites which recorded overstorey vegetation had 100% native species composition. Ninety-six percent of the sites surveyed had 100% native middlestorey species composition.

The understorey layer recorded lower percentages of native species, which would indicate that weeds have invaded and displaced native understorey species along the river and that stock have been grazing in the riparian areas for long periods of time. The lowest percentages of native understorey species were seen in the western sections (Zone of Rejuvenated Drainage) of the survey where the layer was dominated by weeds. The eastern sections (Zone of Ancient Drainage) had proportionately higher native understorey percentages of between 70–90% and were dominated by samphire communities.

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. Forty percent of sections had between 0–10% bare ground coverage. 37% of sections had bare ground covering 11–20%. Twenty-three percent of sections had higher levels of bare ground coverage of between 21–50%.

Leaf litter was absent from 48% of the sections. Minimal cover was recorded at 48% of the sections and good leaf litter cover was noted at only 4% of the sections.

Table 5. Vegetation cover

Vegetation layer (%)	Proportion of vegetation cover			
	Absent (0%)	Sparse (<20%)	Patchy (20–80%)	Continuous (>80%)
Overstorey	44	40	16	0
Middlestorey	0	55	45	0
Understorey	0	0	44	56

Habitat diversity

The Mortlock River East displayed a low diversity of habitat types throughout the surveyed sections. Both the aquatic and terrestrial habitat types were recorded.

Abundant logs, rocks, fallen branches, leaf litter and vegetation are all important habitat types for aquatic animals. Bank and instream vegetation was recorded at 62% of sections which consisted of trees, found at 62% of sections, and shrubs, found at 96% of sections. Rushes and sedges were only noted at 14% of sections surveyed.

Other aquatic habitat types included:

- meanders and pools which were recorded at 92% of sections with very little permanent water;
- instream rocks were recorded at only 7% of sections due to the sandy nature of the soil types; and
- instream logs and branches which were recorded at 40% of sections.

The terrestrial environment was recorded as having a low habitat value for invertebrates, frogs, reptiles and mammals. There was an absence of a variety of vegetation types and emergent vegetation. Protective basking sites which could be used by reptiles and invertebrates, were found at 3% of surveyed sections and dense streamside vegetation was also recorded at 3% of sections.

The Mortlock River East supports a wide diversity of wildlife. During the survey, observations were made of the fauna evident in the area. Bird species make up 78% of the total fauna found along the survey. Fauna observed along the Mortlock River East included:
Birds: Pacific black duck, ringneck parrot, white-faced heron, Australian magpie, silvereye, Australian raven, crested pigeon, welcome swallow, magpie lark, willie wag tail, oriental plover, grey butcher bird, galah, weebill, spotted harrier, mistletoe bird, laughing turtle dove, black-faced cuckoo-shrike.
Mammals: rabbits, kangaroos.
Fish: *Gambusia* (mosquito fish).
Insects: ants, grasshoppers.

The water depth in the Mortlock River East ranged from 2m to a dry river bed, observed during the course of a year. This represents extremes of aquatic habitat types and fauna which inhabit the river have to adapt to this change. During the survey evidence of the possible variation in water depth was recorded and this included:

- debris deposited on banks or in overhanging trees;
- erosion and undercutting of river banks;
- exposed tree roots;
- presence of side channels;
- sediment slugs; and
- salt deposits along banks.

Due to the seasonal variations in water depth the fauna diversity would also change with the seasons. 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 decrease, salinity increases in concentration and fauna either retreats to the few remaining deep pools or leaves the area in search of fresh water.

Fencing status

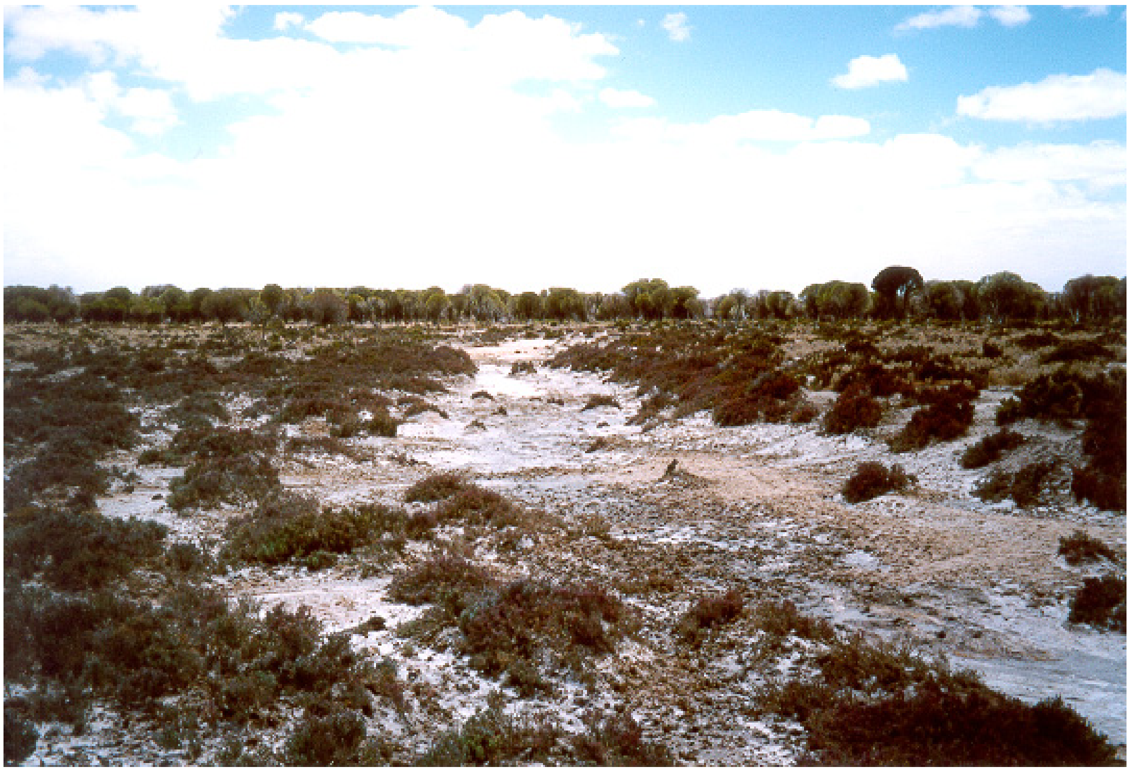
An assessment of the fencing along the Mortlock River East showed that fencing was not present in a majority of sections. Of the 27 sections surveyed 50% of the river had no fencing, 14% had only the left bank fenced, 18% had only the right bank fenced and 18% had both banks fenced. Table 6 shows the approximate fence distance from the riverbanks.

Of those sections that displayed fencing on the left bank, 7% was poor quality, 18% was moderate quality and 7% was good quality. Of sections that displayed fencing on the right bank, 11% was poor quality, 14% was moderate quality and 7% was good quality. The types of fencing documented on the survey included single wires, plain ringlock and barbed wire. Five percent of sections that were fenced had single wire construction. Sixty-eight percent had a plain ringlock fence and 27% had barbed wire fencing.

The results showed that stock had access to the river foreshore along 70% of the surveyed sections. Vehicles had access to the riparian zone along 88% of sections and there were river crossing points at 74% of sections surveyed.

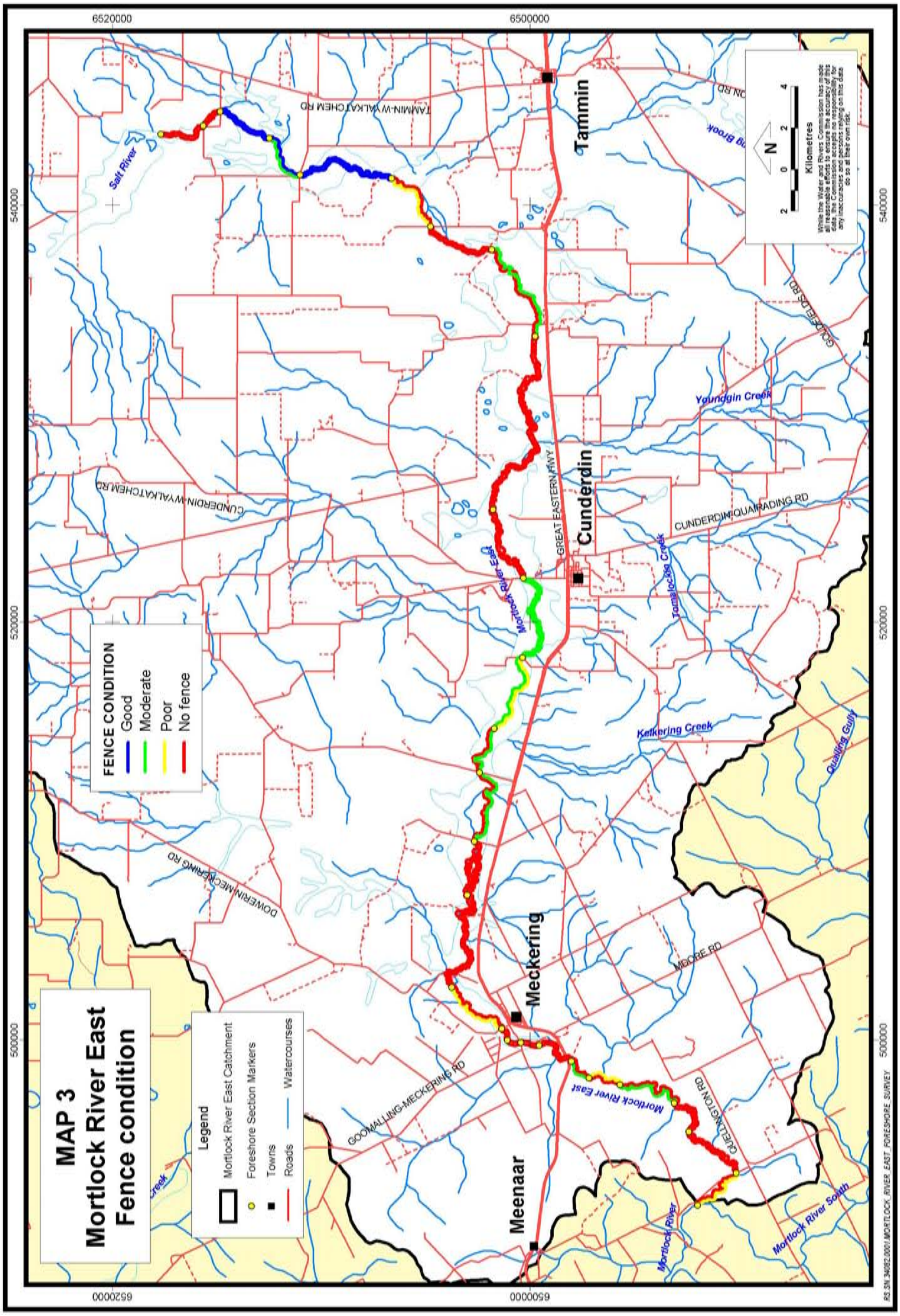
Table 6. Fence position from riverbank

Distance category in metres	Proportion of sections in each category (%)	
	Left bank	Right bank
<10	0	0
10–20	14	8
20–30	8	0
>30	12	30
No fence	66	62



Numerous stock tracks within river channel

Unfenced (left side of photo) and fenced (right side of photo) river sections



Map 3. Fence condition

Water quality

During the course of the foreshore assessment the water quality of the Mortlock River East could not be measured due to the lack of river flow. Some pools were present but flowing water is needed to take a representative sample of the river.

Water quality along the Mortlock River is monitored at a Department of Environment gauging station DR8770 O'Driscolls Farm. The gauging station is located on the Mortlock River, downstream of the confluence of the east and south branches. The data recorded from the station is not specific to the Mortlock River East so it can not be expanded on in this report. As a matter of interest, some data from DR8770 dating back to 1994 has been included in Appendix 7.

Conductivity is a measure of a range of dissolved salts, the most common being sodium chloride (table salt). The level of sodium chloride is referred to as salinity or Total Dissolved Salts (TDS) and is measured in milligrams per litre (mg/L) or millisiemens per metre (mS/m).

Results from the Avon Catchment Water Quality Snapshot Survey during June, July and August 1997, show that the electrical conductivity was classified as between low saline and high saline. The lowest reading was at site AS26 (lower Mortlock River East) with 2200mS/m and the highest reading was from the same site with 4000mS/m (Ryan & Cobb, 1999).

Recent electrical conductivity measurements were taken along the Mortlock River East during a water quality snapshot in winter 2003. Salinity readings along the Mortlock River East were between 22,095mg/L and 24,914mg/L. This can further be expressed as electrical conductivity of between 4002mS/m and 4529mS/m. These readings indicate that the water is in the high saline to hyper-saline range. See Table 7 for electrical conductivity classifications.

The pH of a watercourse is a measurement of its relative acidity or alkalinity. The pH scale ranges from 0 (acidic) to 14 (alkaline) 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 and soil types present. For all watercourses, a pH of less than 5 or greater than 9 would indicate potential pollution problems.

The pH measurements of the Mortlock River East have been intermittent and were recorded in snapshots in 1990 and 2003. During the winter of 1990 the pH reading was 8.15, which is within normal range. During the 2003 water quality snapshot, the pH levels in the Mortlock River East were measured at five sites. The average pH for the five sites was 8.3, which again is within the normal pH range of 5–9.

As a part of the 1997 snapshot, phosphorus (P) and nitrogen (N) levels were documented. Low to moderate levels of P were found with concentrations ranging from 0.047mg/L to 0.085mg/L. Moderate to high levels of N were found in the Mortlock River East with levels ranging from 1.1mg/L to 2.3mg/L. An excess of nutrients can lead to possible eutrophication and a 'bloom' in the growth of aquatic plants and algae, leading to severe dissolved oxygen depletion and consequent stress on the river system.

Table 7. Electrical conductivity and salinity ranges

Salinity classification	Electrical conductivity (mS/m)	Salinity (mg/L)
Fresh	<100	<550
Marginal	100 – 200	550 – 1100
Brackish	200 – 900	1100 – 4950
Low Saline	900 – 2000	4950 – 11000
High Saline	2000 – 4500	11000 – 24720
Hyper Saline	>4500	>24750

Foreshore condition

General foreshore condition

A large percentage (85%) of the 27 sections surveyed were rated as having a C-grade foreshore. C-grade foreshores are defined by the area supporting trees/ shrubs over weeds or pasture. Bank erosion and subsidence may be occurring, but only in isolated areas (Water and Rivers Commission, 1999).

Eleven percent of the sections were found to have a B-grade foreshore which means both sides of the waterway have been invaded by weeds, mainly grasses, and support a higher density of native vegetation. Three percent of the sections surveyed were given a D-grade foreshore. D-grade foreshores are classified as little more than an eroding ditch and are in great need of stabilisation and restoration. See Appendix 4 for detail of foreshore grades.

A C-grade section along the Mortlock River East in the Ancient Drainage zone

A D-grade foreshore along the Mortlock River East in the Rejuvenated Drainage zone

Best foreshore condition

The best foreshore condition along the Mortlock River East varied throughout the survey. Three percent of sections had the highest B3 rating. The majority of the sections (74%) had a foreshore grade of C1 followed by C2 with 14% and C3 with 3%. Three percent of sections were found to have a best rating of D1.

Poorest foreshore condition

The poorest foreshore condition can be related to the past landuse practices and can be influenced by soil type, vegetation abundance, presence of fencing and animal grazing. The poorest foreshore conditions were rated as C1 in 37% of surveyed sections, C2 in 33% of sections and C3 in 3% of sections. D1 rating was given to 22% of sections and D2 for 3% of surveyed sections.

Overall stream environmental health rating

The Overall Stream Environmental Health Rating (OSEHR) is a system used to assess the environmental 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.

Ratings of Excellent, Good, Moderate, Poor and Very Poor were given to a range of environmental factors. The overall stream environmental health was considered to be poor in 94% of sections. Map 4 shows the overall stream environmental ratings for the Mortlock River East.

Results displayed in Table 8 show that there were no Excellent or Good ratings for any of the environmental health categories. Thirty-three percent of sections surveyed had a rating of Moderate for floodway and bank vegetation, 62% were Poor and 5% were Very Poor floodway vegetation. Twenty-six percent of sections had Moderate verge vegetation and 74% of sections had Poor verge vegetation. Sixty percent of sections had Very Poor stream cover while 33% were Poor and 7% had Moderate stream cover. Seven percent of sections had Moderate stream cover

Bank stability and sedimentation was found to be Moderate at 78% of sections and was found to be Poor at 22% of sections. Habitat diversity was rated as Poor at 94% of sections with only one habitat type found. Moderate and Very Poor habitat diversity were each found at 3% of surveyed sections.

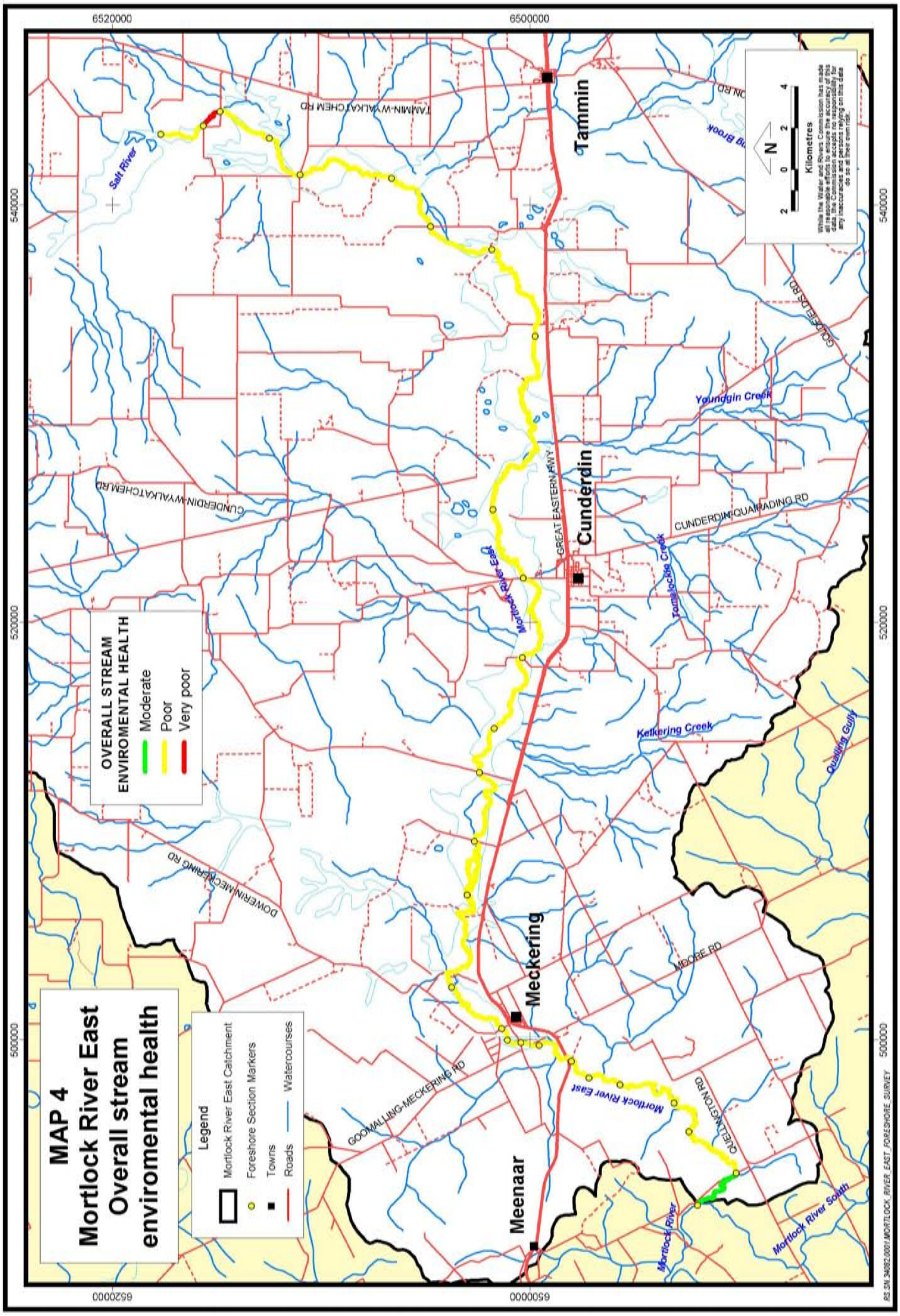
Disturbance

The Mortlock River East channel and surrounding riparian environment are subject to a wide range of disturbance factors which continually degrade the river foreshore. The major forms of disturbance include stock and vehicle access to the river channel, weed invasion, feral animals, and rubbish dumping. A summary of the major disturbances observed during the survey include:

- 100% of sections contained weed species;
- 85% of sections were accessible by vehicles and 74% of sections had informal vehicle and stock crossing points;
- 70% of the surveyed sections were accessible by stock;
- 22% of surveyed sections were affected by pollution. The main source of pollution was animal manure;
- 18% of sections had rubbish dumped in the riparian zone;
- 11% of sections had evidence of earthworks in and around the river channel; and
- 3% of surveyed sections had evidence of feral animal activity.

Table 8. Environmental health categories

Environmental health category	Proportion of sites (%)				
	Excellent	Good	Moderate	Poor	Very Poor
Floodway and bank vegetation	0	0	33	62	5
Verge vegetation	0	0	26	74	0
Stream cover	0	0	7	33	60
Bank stability and sedimentation	0	0	78	22	0
Habitat diversity	0	0	3	94	3



Map 4. Overall Stream Environmental Health Rating

Anecdotal evidence suggests that during summer, landholders use the riparian zone for grazing stock. Some landholders use it for a few months, others all year round. Those areas which are grazed all year round are under continual pressure from trampling and stock damage. Some landholders also ‘crash graze’ the river foreshore to control weeds and to reduce the summer fire hazard in the riparian zone.

Evidence of management

Seventy percent of all foreshore sections surveyed had undergone some form of management along the Mortlock River East riparian zone. Even though a high percentage of sections revealed some form of management, the overall impact of the management was considered to be low because the management practices were not continuous from property to property.

The most common form of river management was fencing, with 33% of sections having fencing just on the left bank. 37% of sections had fencing only on the right bank. 18% of surveyed sections had fencing on both sides of the river. Forty-eight percent of sections, in 2003, had no form of fencing along the Mortlock River East. Observations showed that paddocks in crop had no fences which separate the river from faming land.

Due to the broad flat floodplain of the Mortlock River East, fences were located further away from the river channel, sometimes more than 30m. For sections that had fencing on the left bank, 14% were located 10–20m away from the riverbanks. 7% were located 20–30m away and 11% were located more than 30m away. For sections that had fencing on the right bank, 7% of fences were located 10-20m away from the riverbanks and 29% were located more than 30m away.

Along with fencing, revegetation was the only other form of management along the Mortlock River East. Thirty-seven percent of sections had attempted revegetation along banks of the river. Revegetating the riparian zone can help to stabilise riverbanks, provide shade and habitat for aquatic animals and filter out harmful nutrients and sediments.

Priorities for management

The management issues of the Mortlock River East have been listed and given a priority ranking (High, Medium, and Low). Table 9 shows the different management issues along the river with percentages of sections and level of priority.

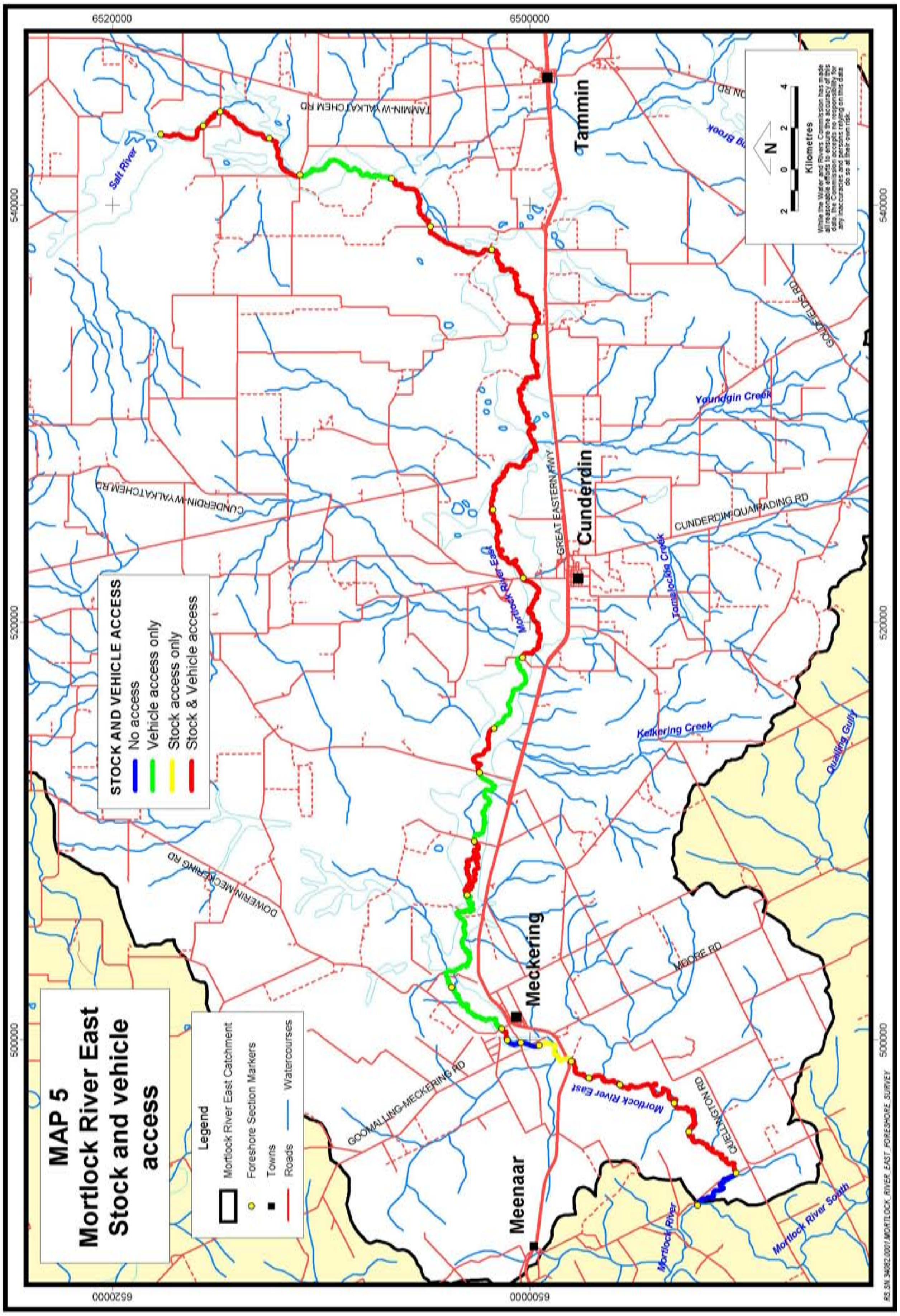
Levee banks were the most common form of earthworks within the riparian zone

Table 9. Priorities for management

Management issue	% of surveyed sections		
	High	**Medium**	**Low**
Salinity	100	0	0
Weeds	40	25	35
Live stock access	37	29	34
Fire	25	16	59
Cultural features	22	0	78
Pollution	14	7	79
Bank erosion	7	40	53
Vehicular access	7	22	71
Rubbish	0	18	82
Recreation	3	0	97
Pumps/Off-take pipes	7	0	93
Dam/Weir	3	0	97
Service corridors	0	3	97
Feral animals	0	3	97

The results in Table 9 indicate that the major management issues along the Mortlock River East include salinity, weeds, livestock access to the riparian zone and fire.

Salinity was found to be a high priority management issue in 100% of sections. Evidence of salinity included salt deposits along the banks and salt tolerant native vegetation (samphires). Weeds and livestock access had a high priority for management at 40% and 37% respectively. Fire was the other high priority management issue at 27% of surveyed sections. Medium priority management issues included bank erosion in 40% of sections, followed by livestock access and weeds at 29% and 25% of sections respectively.



Map 5. Stock and vehicle access

Interpretation of survey results

Channel stability

The survey results show that bank erosion and sedimentation are the main forms of channel instability along the Mortlock River East. The results show there was stock access to the river in 70% of the sections. Typically, severe degradation does not begin until livestock regularly enter the riparian zone to graze. Livestock trample the native vegetation, eat out the more palatable species, compact the soil and distribute weed species through their manure.

Throughout the survey it was also common to find cropping along the edge of the riparian zone. Cropping areas can contribute large amounts of sediments and nutrients into the river from cleared paddocks. There is increased runoff due to the lack of vegetation. In cropping and grazing areas, there has been a change in the water cycle. Where water previously infiltrated into the soil, it now flows overland, transporting soil as it moves.

Localised to significant sediment deposits or sand slugs were largely recorded in the Zone of Rejuvenated Drainage. The sections were characterised by having a meandering channel with a variety of flow conditions. The area was also classified as having poor bank stability and localised erosion. Sediment was deposited in the areas of low flow in and around vegetation and woody debris or snags and on the inside of meander bends. Sediment deposits can cause water to be redirected into the banks, which can cause further erosion, channel widening and possible damage to infrastructure, which include pumps, fences, bridges, culverts and vegetation.

Vehicles were able to access the riparian zone at 85% of the sections surveyed. Uncontrolled vehicle crossing points were also noted at 74% of sections. A majority of the crossing points were simple 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 point can easily be eroded by higher winter flows and can add to the sedimentation problem in other areas.

The local vegetation surrounding the river plays an important role in bank stability. The floodway and bank

Cropping to the edge of the riparian zone vegetation was mainly classified as being moderate or poor with narrow verges of less than 20m wide consisting of a mixture of native and exotic vegetation. Vegetation prevents bank erosion by anchoring the riverbanks in place with the large roots of trees and shrubs. The finer roots of shrubs, sedges and rushes effectively stabilise the riverbanks by binding sediments within the gaps of the larger trees.

Vegetation acts to reduce water velocity by increasing bank roughness. The main vegetation type found in the survey was samphires (*Halosarcia* species), which not only colonise bare saline land but also act to dissipate energy produced from flowing water. In areas where vegetation has been cleared from the banks, there has been an increase in flow velocity and erosive power which has resulted in the erosion of banks and scouring of the river bed, leaving only hard sedimentary bedrock.

Waterway features

The present condition of the Mortlock River East is reflected in the features of the waterway. Results show an absence of a number of typical river features such as riffles and permanent river pools. These river features are not common in the Zone of Ancient Drainage due to flat broad river floodplains, braided channel systems and weathered soil types. It must be noted that there is a change in the waterway features from the Zone of Ancient Drainage to the Zone of Rejuvenated Drainage.

Only 3% of surveyed sections had river pools. Constant bank erosion and sediment input from farming areas has caused the pools to gradually fill up with sediment. The slow water velocity flowing through the pool can cause sediments to be deposited, in turn reducing its depth.

Sediment deposits were recorded at 25% of the sections, all within the Zone of Rejuvenated Drainage, west of the Meckering Line. The sections had a higher percentage of rocks, logs and branches, which affect the roughness of the river bed and banks. Branches and logs reduce flow velocities and can cause sediment to be deposited in slugs. The absence or removal of branches and logs in the majority of sections has caused an increase in flow velocity in some areas. This has resulted in bank erosion and subsequent sedimentation in areas of low flow.

The low percentage of sections displaying riffles or rapids is indicative of the soil types and landforms of the area. The majority of the Mortlock River East system is in the Zone of Ancient Drainage and is characterised by broad, flat, weathered river valleys. Because the landscape is flat and broad in the Zone of Ancient Drainage water moves through the Mortlock River East slowly and with less velocity than in the Zone of Rejuvenated Drainage, which has a higher sloping landscape and erosive power. The main soil type within the riparian environment is a depositional clay/silt soil with small pebbles. These particles are not large enough to create the riffle or mixing effect. The most effective sites for water oxygenation are cascades and rapids where the bubbling and frothy turbulent flow creates a vast surface area over which aeration can occur.

Habitat diversity

The Mortlock River East riparian zone was found to have low habitat diversity with a number of vital habitats missing from the aquatic and terrestrial environment, 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 general absence of in-stream cover along the sections due to the absence of dense riparian vegetation.

In-stream leaf litter and twigs often collect in the deep pools or in areas of still or low flowing water and form important habitat and food for a range of aquatic organisms from bacteria to juvenile aquatic insects to native fish. In-stream leaf litter was absent from all sections of the survey. This could be due to the seasonal flow conditions and filling of river pools with sediment. Overhanging riparian vegetation can also trap leaf litter and deposit it into the river. In the Zone of Ancient Drainage, the river valley is dominated by samphires and small shrubs which do not contribute large amounts of leaf litter to the river. In the Zone of Rejuvenated Drainage the overstorey was either absent or patchy, therefore also contributing little leaf litter to the river. 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 have dominated the riparian zone. Weeds often have soft leaves, which break down quickly rendering them unavailable to aquatic animals for habitat and food.

The presence of logs, branches and woody debris along the river was patchy but a greater density was found in the Zone of Rejuvenated Drainage where there was a higher occurrence of trees lining the river. 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' for a range of small animals and plants.

There is no dense riparian vegetation along the Mortlock River East. Riparian vegetation is important because it provides a range of habitats for many animals that inhabit the river environment. Observations of the animal life along the Mortlock River East showed that there was sufficient habitat for birds (trees, shrubs) but there were no 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 East is considered to be poor 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.

Foreshore condition

The general foreshore condition of the Mortlock River East has been rated as C-grade. This indicates that there has been a high level of disturbance along the riparian environment. Such a decrease in foreshore condition can be attributed to:

- surrounding agricultural land use practices;
- spread of weeds due to continual disturbance of the riparian zone by uncontrolled stock grazing and fire;
- a decrease in water quality and an increase in water quantity within the river system; and
- a lack of integrated waterways management practices.

The historical land use in the Mortlock River East catchment can be linked to a general lack of community understanding about integrated river management on a long term basis. From anecdotal evidence, landholders do not have the time and capital to effectively manage the river environment on their property. The management practices which have been undertaken, such as fencing and revegetation, are only small scale and vary in condition from paddock to paddock.

Foreshore vegetation

A healthy river system will support a diverse range of trees, shrubs, sedges, rushes and herbs. The 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 can decrease the amount of sediment and nutrients moving into the river which, in turn, maintains current water quality.

The riparian or foreshore vegetation along the sections of the Mortlock River East surveyed was in most areas represented by a intermittent layer of canopy trees of swamp she-oak and York gum over weeds or samphire-dominated river flats with thickets of *Melaleuca* species.

Many sections along the Mortlock River East had sick, dying or dead trees in the riparian zone and all of the sections had evidence of salinity. The earliest occurrence of salinity in the Mortlock River East catchment was documented in 1920 with salt on the land. In 1928, the riparian vegetation (tea trees) in the Mortlock River East was starting to die (Sanders, 1991). Water quality snapshot readings indicate that the present salinity can range from hyper saline to low saline 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 East is indicative of the present salinity levels. The swamp sheoak or *Casuarina obesa* was the major canopy tree and was recorded at 44% of the sections. The swamp sheoak is tolerant of higher salinity levels and also has a high tolerance to waterlogging but it was not found to the east of the Meckering Line. Salinisation has also restricted the regeneration of many native plant species with very few sections showing the presence of newly germinated seedlings.

The river sections in the Zone of Ancient Drainage have poor drainage, are relatively flat, have deep clay soils and are subject to waterlogging for most of the year. This area was dominated by samphire communities, which have a very high tolerance of salinity and waterlogging. 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. With the absence of dense vegetation along the waterway, nutrients can move freely into the river and can 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 caused undercutting and channel widening.

The land use within the Mortlock River East catchment has significantly changed the species composition 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*) 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 in the western sections of the survey, has increased weed growth and density to where it dominates the understorey vegetation. Survey sections to the east of the Meckering Line showed a lower occurrence of weeds. This area is dominated by samphire (*Halosarcia* species) communities, which are adapted to high water salinity and waterlogging. This makes it an extreme and uninhabitable environment for most weeds to colonise and survive.

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 extreme levels. Shade also reduces the growth of aquatic plants and harmful algae which, combined with excessive nutrient levels, could form 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. This could act to decrease the water quality and potential aquatic habitats of the river.

Disturbance

The Mortlock River East was one of the first catchments to be extensively cleared in the Avon region. Early pressures which increased the rate of clearing were the supply of wood for fuelling water pumping stations and the need for good agricultural land. Agriculture has had a dramatic effect on the present condition of the river environment. Current disturbances to the river include:

- stock access to the riverbanks and channel;
- broad scale farming practices;
- weed invasion of the floodplain;
- uncontrolled vehicle access to and across the river; and
- fire in the riparian zone.

Stock and vehicles had access to the river at 70% and 88% of sections respectively. Landholders use the riparian zone as a summer grazing area for stock but anecdotal evidence suggests it is used for only a few months of the year. Others use stock in the riparian zone to reduce the fire hazard caused by grassy weeds.

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 weeds.

Weeds were found to be a major management problem in a number of sections. The riparian environment along the Mortlock River East experiences frequent natural disturbances such as fire and flooding. When these are combined with disturbances from the surrounding agricultural land uses, weeds have a greater opportunity to invade. Grassy agricultural weeds such as wild oats (*Avena fatua*), barley grass (*Hordeum leporinum*) and annual rye grass (*Lolium rigidium*) can 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 cycle of weeds, they can compete vigorously with native vegetation for resources such as fresh water and light.

Evidence of management

River management along the Mortlock River East is considered to be poor. There were some landholders 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 or 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 1km of riverbank.

Fencing the banks of the Mortlock River East can be the first step taken towards river management. To assist landholders in the Avon River catchment the Department of Environment, with funding from the Natural Heritage Trust and Avon Catchment Council, developed the Avon River Basin Fencing Project. Landowners whose property lies adjacent to the Avon River or its tributaries (including the Mortlock River East) 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.

The major form of management along the Mortlock River East was fencing. Fencing is the most effective way of managing the riparian zone. The degree and condition of the fencing varied from property to property which indicates that upgrades in fencing condition are done only when necessary. Half of sections surveyed had fencing erected along the river, which assists to control access to the banks and channel which in turn reduces disturbance and promotes regeneration of local plants. Examples of fence condition can be seen in Appendix 6.

Thirty-seven percent of landholders have undertaken revegetation in the riparian zone. Revegetation was found to be a management practice which was cheap and easy to carry out. Planting trees and shrubs has been undertaken in some areas as a part of the solution to land degradation and loss of water quality. The species used to revegetate the riparian zone were adapted to excessive waterlogging and salinity, two of the main reasons for the decline in abundance of native species.

Principles of waterways management

The need for management

The results of this channel and foreshore assessment indicated 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 East 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, 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 East 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 East 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 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 East 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 East 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 East runs through mainly 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, Dowerin/Goomalling LCDC and the Cunderdin/Tammin LCDC are community groups aiming to promote and coordinate integrated catchment management within the Avon River catchment for 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 this waterway. 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 draft Avon NRM Strategy produced by the Avon Catchment Council has identified the Mortlock River system as a whole 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 East 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 2 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).

Management requirements

Weeds 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 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 grass (*Cynadon 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 erode 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 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 East 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 East 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 crop and pasture 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) have developed a fire policy that sets out the objectives for bushland management in and 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 5.

Water quality

Poor water quality can significantly affect the health of the river and its 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 they distribute 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 East 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 East 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 the 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 East.

Areas of cultural significance (both Aboriginal and non-Aboriginal) 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 become accumulated at these points, providing an important habitat for many aquatic organisms. Some areas along Mortlock River East 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 sand (the heavy, coarse fraction which is mostly carried in the water column), and silt (the finer fraction which is carried in solution). Both are moved down the river channels to be deposited when the river velocity is reduced, either by natural pools, a natural obstruction, or by the drying up of the river in summer.

A riffle is an engineer-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 easiest and cheapest means of excluding stock. It is recommended that stock be excluded from the planted 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, therefore losses are 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. 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 East 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, they 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 to have them migrate from surrounding properties. There is a need for cross boundary management of feral animals to stop this happening. Surveys show that feral animal control (baiting) is already in practice along some areas of the waterway and surrounding landholdings. 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 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 East 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 require 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 East 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 East. 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 East 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 East, community members will band together to try and recover some of the natural health and beauty of the waterway.

In general Mortlock River East is described as a C-grade system, meaning that the foreshore vegetation supports only trees over weeds or pasture. Bank erosion and subsidence may also occur in localised areas. The high sediment loads within the channel mean that the system is very mobile and unstable and is in need of rehabilitation.

There is a lack of native plants and an abundance of weeds in the Zone of Rejuvenated Drainage. The most common native vegetation include trees and shrubs, with swamp sheoak (*Casuarina obesa*), York gum (*Eucalyptus loxophleba*) and numerous species of tea tree (*Melaleuca*) being the most prevalent. Of the weed species invading the groundcover, wild oats (*Avena barbata*), barley grass (*Hordeum leporinum*) and annual rye grass (*Lolium rigidium*) were the most commonly observed during this assessment. Native samphire species (*Halosarcia*) also dominated the floodplain and channel of the Mortlock River East in the Zone of Ancient Drainage.

The major disturbances along the length of this watercourse are weeds as well as stock access to the riparian zone. Observations determined that the issues in greatest need of management were weed invasion, stock access, sedimentation and salinisation of the waterway and surrounding land.

The need exists to assess competing landuses and determine a compromise that allows for the rehabilitation and conservation of Mortlock River East 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 East 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 East 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 East. 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.

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

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.
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.
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 20m 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.

Appendix 1

Soils of the Mortlock River East

Soil unit descriptions

JJ16	Broken terrain characterized by rock outcrops (granitic bosses and tors) which may cover very large areas within the unit: shallow and often stony or gritty sandy soils (Uc4.11), (Uc4.33), and (Uc4.22) form a soil scree around the areas of bare rock. Associated are small areas of many other soils, such as (Dr2.62) and (Gc2.22); their occurrence reflects the chemistry of the individual rock outcrop. As mapped, small areas of units Va66 and Ms8 are included.
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 mottled or 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).
Ms8	Gently sloping to gently undulating plateau areas or uplands with long and very gentle slopes and, in places, abrupt erosional scarps: chief soils are (i) on depositional slopes, sandy yellow earths (Gn2.21 and Gn2.22) containing some ironstone gravels, and yellow earthy sands (Uc5.22) often with ironstone gravels at depths below 6-7ft; and (ii) on erosional ridges and slopes, ironstone gravels (KS-Uc4.11) together with (Uc4.11) and (Uc2.12) (both containing ironstone gravels), all underlain by hardened mottled-zone material by depths of 12-24 in. Soil dominance tends to vary locally between (i) and (ii) but overall the soils of (i) seem to have a slight dominance over the soils of (ii). Associated are smaller areas of other soils, such as (Dy3.82) containing ironstone gravels in its surface horizons.
Ms10	Gently sloping to gently undulating plateau areas or uplands with long and very gentle slopes and, in places, abrupt erosional scarps: chief soils on depositional slopes are sandy, acidic, and neutral yellow earths (Gn2.21, Gn2.22, Gn2.25, and Gn2.35) and yellow earthy sands (Uc5.22), all containing some ironstone gravels or underlain by indurated ironstone gravel pans. Associated on erosional ridges and slopes are (Uc2.12), (Uc2.21), and (Uc4.11) soils all containing some ironstone gravels and underlain by indurated ironstone gravel pans or hardened mottled-zone materials. This unit is similar to unit Ms8 but seems to have a greater variety of yellow earth soils which, however, could be more extensive in some areas of unit Ms8 than present data indicate.
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.
Oc31	Broad flat valleys: chief soils are hard alkaline red soils (Dr2.33) with acid clay strata below about 5-6ft depth. Associated are small areas of other soils including gilgai formations along drainage-ways. As mapped, small areas of units Vb2, Sl28, DD9, and Va66 are included.
Oc34	Broad flat valleys: chief soils are hard alkaline red soils (Dr2.33). Associated are red earths (Gn2.13 and Gn2.12). Other soils may occur, including (Dr2.43), (Db2.43), (Dy3.43), (Gc1.22), (Gc1.12), and some (Ug5.2) with gilgais. Small areas of unit Vd7 occur at the head of some valleys.
Oc35	Gently undulating to rolling terrain with some ridges and uneven slopes and with the variable presence of lateritic mesas and buttes; some granitic rock outcrops: chief soils are hard alkaline red soils (Dr2.33), (Dr2.63), (Dr2.73) with variable areas of (Dy) soils such as (Dy3.43), (Dy3.83), (Dy3.42), and (Dy3.41). Associated are some (Dr2.22) soils; patches of soils of unit Ms8; and some (Gn2.12) soils on slopes especially in the more northern and eastern areas of the unit.

Appendix 1 (continued)

Soil unit descriptions

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.
Sl28	Broad flat valleys with small clay pans and salt-lake remnants in some localities: chief soils are hard alkaline yellow soils (Dy2.43 and Dy2.33) underlain by acid lateritic clays below depths of from 2 to 4 ft. Associated are small areas of (Dy5.43) soils in sandy localities; (Ug5.22) soils in areas where some low gilgai microrelief is present; some (Dy3.43) soils, especially in western valleys; and other soils on lunettes and dunes some of which are gypseous. As mapped, small areas of units Oc31, Vb2, DD9, and Va66 are included.
SV1	Broad flat valleys with small clay pans and salt-lake remnants in some localities: chief soils are hard alkaline yellow soils (Dy2.43 and Dy2.33) underlain by acid lateritic clays below depths of from 2 to 4 ft. Associated are small areas of (Dy5.43) soils in sandy localities; (Ug5.22) soils in areas where some low gilgai microrelief is present; some (Dy3.43) soils, especially in western valleys; and other soils on lunettes and dunes some of which are gypseous. As mapped, small areas of units Oc31, Vb2, DD9, and Va66 are included.
Ub98	1 Hilly with granitic and gneissic rock outcrops: chief soils are hard neutral yellow mottled soils (Dy3.4). Small areas of other soils are likely. As mapped, small areas of unit Ms8 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. As mapped, areas of adjoining units are included.
Va66	Gently undulating to rolling terrain with some ridges and uneven slopes; and with the variable presence of lateritic mesas and buttes and granitic tors and bosses: chief soils are hard alkaline yellow mottled soils (Dy3.43) and hard alkaline red soils (Dr2.33), (Dr3.33), and (Dr2.43), either of which may be dominant locally. Associated are a variety of soils, notably (Dy) soils such as (Dy3.82 and Dy3.83) and (Dr) soils such as (Dr3.32). Acid lateritic strata are common below 4-5 ft. As mapped, lateritic mesas and buttes of unit Ms8 soils are a constant feature, as are small granitic bosses and tors of unit JJ16 and minor valleys of units Sl28, Oc31, and Vb2. Western occurrences of this unit have some features transitional to unit Uf1, especially the larger areas of (Dy3.82) soils.
Vb2	Upper reaches of broad gently sloping valleys: chief soils are hard alkaline yellow mottled soils (Dy3.83) and (Dy3.43) and leached yellow earths, possibly (Gn2.55), both containing siliceous hardpans in the subsoil as well as variable amounts of ironstone gravels. Associated are small areas of other soils including shallow yellow earths (Gn2.2) often only 24 in. thick and overlying truncated (Dy) or (Gn2) soils. As mapped, small areas of units Oc31 and Sl28 may be included.

Source: CSIRO, 1967

Appendix 2
Tributary 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

Appendix 2 (continued)

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

Appendix 2 (continued)

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

Appendix 2 (continued)

Foreshore Condition Assessment

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

Appendix 2 (continued)

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			
Stock Access			
Vehicle Access			
Rubbish			
Pollution			

	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
- ❒ Erosion control
- ❒ Earthworks/riffles
- ❒ Dredging

❒ Other: ....

Vegetation

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

Appendix 2 (continued)

Water Quality Data

Sample Number	pH	Conductivity mS/cm	Temperature ºC	Location

GPS Coordinates

Coordinate	Description

Photos

Appendix 3

Overall Stream Environmental Health Rating

Living Streams Survey: Information to determine environmental ratings of streamlines

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

Source: Pen and Scott, 1995

Appendix 4
Foreshore Assessment Grading System

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 (i.e. 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 human 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

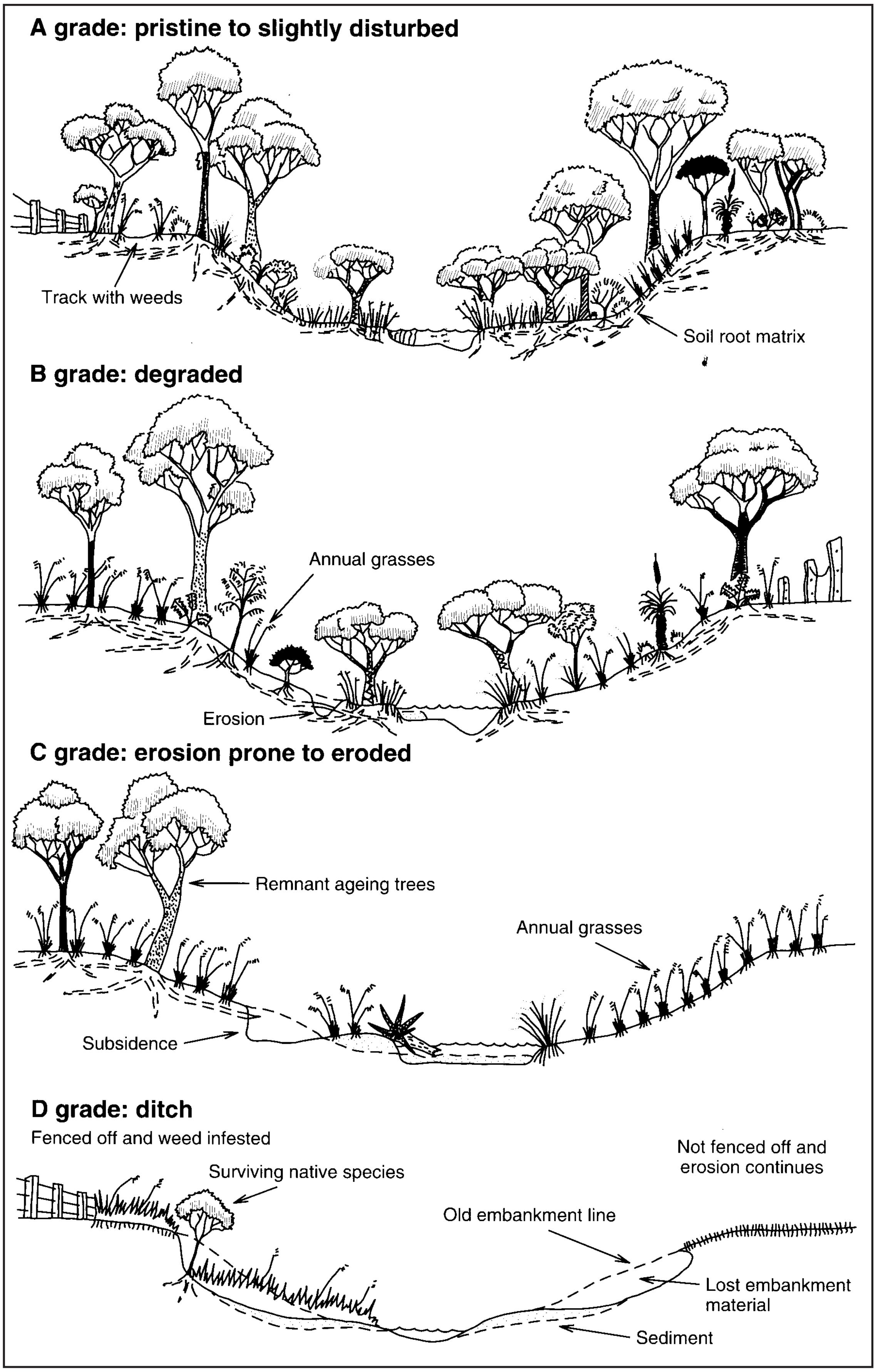
The stream is little more than an eroding ditch or a weed infested drain.

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.

Appendix 4 (continued)



Appendix 5

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.

Appendix 5 (continued)

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.

Appendix 5 (continued)

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

Appendix 6

Examples of fencing condition

Fencing status – examples of fence condition

Fence condition: POOR

Fence condition: MODERATE

Fence condition: GOOD

Appendix 7

Water Quality Data – O'Driscolls Gauging Station

Total Dissolved Solids (TDS), Conductivity and Discharge

Time & Date POINT	TDS from insitu cond (mg/l) mS/cm	Conductivity mS/m	Conductivity INST	Discharge (m3/s)
10:20 27/05/1994	15672.22859	28.49496107	2849.496107	0.168469512
08:20 31/05/1994	5940.338668	10.80061576	1080.061576	4.327933013
09:50 20/06/1994	19747.27849	35.90414271	3590.414271	0.302971721
11:30 30/06/1994	8724.386262	15.86252048	1586.252048	0.345832921
11:31 30/06/1994	8724.386262	15.86252048	1586.252048	0.345320172
13:49 15/08/1994	11788.4779	21.43359618	2143.359618	0.691930753
10:22 27/09/1994	25084.70592	45.60855622	4560.855622	0.01258121
10:24 27/09/1994	25084.70592	45.60855622	4560.855622	0.01258121
10:33 04/10/1994	26632.44282	48.42262331	4842.262331	0.006515192
10:36 04/10/1994	26632.44282	48.42262331	4842.262331	0.006515192
11:06 17/10/1994	27056.22214	49.19313116	4919.313116	0.014475335
11:08 17/10/1994	27056.22214	49.19313116	4919.313116	0.014643027
14:42 18/10/1994	27766.19347	50.48398813	5048.398813	0.006947248
12:25 24/10/1994	34061.21505	61.9294819	6192.94819	0.00036883
12:26 24/10/1994	34061.21505	61.9294819	6192.94819	0.00036883
average	21602.1641	39.276662	3927.6662	
14:00 23/05/1995	12021.87027	21.85794595	2185.794595	1.109181554
14:02 23/05/1995	12021.87027	21.85794595	2185.794595	1.110103544
11:46 07/06/1995	17059.99847	31.01817904	3101.817904	1.304246508
11:47 07/06/1995	17058.99074	31.0163468	3101.63468	1.304246508
10:25 12/06/1995	6341.523464	11.53004266	1153.004266	4.327933013
10:26 12/06/1995	6341.523464	11.53004266	1153.004266	4.327807668
12:00 17/07/1995	6967.933814	12.66897057	1266.897057	9.109242796
12:30 24/07/1995	4402.855265	8.005191391	800.5191391	12.54637429
12:33 24/07/1995	4402.855265	8.005191391	800.5191391	12.54078444
09:23 31/07/1995	4500.401032	8.18254733	818.254733	10.29249701
09:24 31/07/1995	4500.401032	8.18254733	818.254733	10.2793104
09:53 01/08/1995	5332.868603	9.696124733	969.6124733	9.868502194
11:09 07/08/1995	10724.14339	19.49844252	1949.844252	2.650020885
11:10 07/08/1995	10206.9477	18.55808673	1855.808673	2.653160054
11:15 21/08/1995	14217.81355	25.85057008	2585.057008	1.641796953
11:16 21/08/1995	14217.81355	25.85057008	2585.057008	1.642675043
14:00 04/09/1995	15763.75899	28.66137999	2866.137999	1.839875996
14:01 04/09/1995	15763.75899	28.66137999	2866.137999	1.840988942
08:49 13/09/1995	21679.28822	39.41688768	3941.688768	0.83124545
08:50 13/09/1995	21679.28822	39.41688768	3941.688768	0.83124545
11:40 18/09/1995	18883.26633	34.33321151	3433.321151	0.397119438
11:41 18/09/1995	18883.26633	34.33321151	3433.321151	0.396872579
13:00 25/09/1995	22961.17525	41.74759136	4174.759136	0.130916668
13:01 25/09/1995	22961.17525	41.74759136	4174.759136	0.130980949

Appendix 7 (continued)

Time & Date POINT	TDS from insitu cond (mg/l) mS/cm	Conductivity mS/m	Conductivity INST	Discharge (m3/s)
13:37 03/10/1995	24669.2169	44.85312163	4485.312163	0.06329852
13:38 03/10/1995	24669.2169	44.85312163	4485.312163	0.06329852
11:18 09/10/1995	25977.97193	47.23267623	4723.267623	0.043268922
11:19 09/10/1995	25977.97193	47.23267623	4723.267623	0.043268922
14:07 11/10/1995	26642.58703	48.44106733	4844.106733	0.038476679
14:24 16/10/1995	25346.72931	46.08496237	4608.496237	0.025162269
14:25 16/10/1995	25346.72931	46.08496237	4608.496237	0.025162269
10:34 25/10/1995	21791.1019	39.62018527	3962.018527	0.139299248
10:35 25/10/1995	21791.1019	39.62018527	3962.018527	0.139299248
09:16 31/10/1995	24968.79772	45.39781403	4539.781403	0.052540146
09:17 31/10/1995	24968.79772	45.39781403	4539.781403	0.05272616
12:34 06/11/1995	25683.99814	46.69817843	4669.817843	0.026992733
12:35 06/11/1995	25683.99814	46.69817843	4669.817843	0.026992733
13:02 14/11/1995	26315.9176	47.84712292	4784.712292	0.012190812
13:03 14/11/1995	26315.9176	47.84712292	4784.712292	0.012190812
09:47 21/11/1995	28239.33042	51.34423712	5134.423712	0.004080044
09:24 28/11/1995	30912.79762	56.20508659	5620.508659	0.001480597
average	18151.1456	33.0020829	3300.20829	
12:10 08/07/1997	16117.15769	29.30392307	2930.392307	1.218043018
12:10 12/09/1997	21471.06043	39.0382917	3903.82917	1.078606604
13:50 10/10/1997	23387.99948	42.52363542	4252.363542	0.235791196
11:45 06/11/1997	32804.19708	59.64399469	5964.399469	0.000174371
average	23445.10367	42.62746122	4262.746122	
11:50 23/07/1998	13519.99212	24.58180386	2458.180386	2.484672384
16:40 18/08/1998	18723.56244	34.0428408	3404.28408	0.400212946
10:30 26/08/1998	22163.79053	40.29780097	4029.780097	0.167536417
11:25 17/09/1998	22691.75303	41.25773279	4125.773279	0.135987637
15:30 09/10/1998	25011.67433	45.4757715	4547.57715	0.017856745
11:18 15/10/1998	25989.17417	47.25304395	4725.304395	0.008222405
12:00 11/11/1998	37001.7294	67.27587163	6727.587163	0
average	23585.95372	42.88355221	4288.355221	
13:02 02/06/1999	4839.635546	8.799337357	879.9337357	6.569279948
09:45 20/07/1999	12715.95772	23.11992313	2311.992313	1.59415061
11:20 17/08/1999	14907.32637	27.10422976	2710.422976	1.22430742
15:40 26/08/1999	10072.998	18.31454182	1831.454182	4.260693052
12:02 14/09/1999	13728.20317	24.96036939	2496.036939	1.584750882
11:00 14/10/1999	16389.16022	29.79847314	2979.847314	0.494522325
14:45 03/11/1999	24552.81736	44.64148611	4464.148611	0.012385088
12:00 09/11/1999	26964.71117	49.02674759	4902.674759	0.005024602
11:30 07/12/1999	25323.54333	46.04280605	4604.280605	0.000591594
average	16610.48365	30.20087937	3020.087937	
12:07 05/01/2000	17828.5315	32.41551181	3241.551181	0.174133536
16:20 27/01/2000	2209.960167	4.018109395	401.8109395	35.28122297
12:25 02/02/2000	5771.500109	10.49363656	1049.363656	4.207207699
13:25 09/02/2000	13738.09146	24.97834811	2497.834811	0.359376549

Appendix 7 (continued)

Time & Date POINT	TDS from insitu cond (mg/l) mS/cm	Conductivity mS/m	Conductivity INST	Discharge (m3/s)
11:05 29/02/2000	24221.40703	44.03892188	4403.892188	0.032604293
11:35 30/03/2000	28426.20559	51.68401016	5168.401016	0.007376066
12:12 26/04/2000	28845.31754	52.44603189	5244.603189	0.003024864
12:18 23/05/2000	29169.66433	53.03575332	5303.575332	0.00426312
13:43 21/06/2000	22835.96237	41.51993157	4151.993157	0.068077984
15:35 10/07/2000	11223.71312	20.40675113	2040.675113	0.213730632
12:50 19/07/2000	14730.73154	26.78314826	2678.314826	1.130430878
12:10 15/08/2000	19058.95089	34.65263797	3465.263797	0.122442547
12:55 12/09/2000	21499.61886	39.0902161	3909.02161	0.171287477
12:15 10/10/2000	24010.02608	43.65459287	4365.459287	0.007197627
14:38 18/10/2000	25163.88597	45.75251995	4575.251995	0.001374119
average	19248.90444	34.99800807	3499.800807	
10:05 02/08/2001	7481.157878	13.60210523	1360.210523	2.211978611
10:00 30/08/2001	22210.84713	40.38335842	4038.335842	0.128075273
09:36 27/09/2001	26213.61179	47.66111234	4766.111234	0.057247673
10:30 25/10/2001	20312.71906	36.93221647	3693.221647	0.045365988
average	19054.58396	34.64469812	3464.469812	
10:25 05/07/2002	26958.09946	49.0147263	4901.47263	0.046221535
11:27 31/07/2002	24298.91402	44.17984367	4417.984367	0.035467586
11:45 29/08/2002	24458.7707	44.47049218	4447.049218	0.013452544
12:26 26/09/2002	208.9152992	0.379845999	37.98459986	0.002820792
10:22 23/10/2002	32896.22499	59.81131817	5981.131817	0
average	21764.18489	39.57124526	3957.124526	
14:05 20/02/2003	6783.484909	12.33360893	1233.360893	2.516431224
12:40 28/05/2003	27109.84319	49.29062399	4929.062399	
12:00 03/07/2003	16230.34298	29.50971452	2950.971452	
10:49 05/09/2003	21529.03597	39.14370177	3914.370177	
12:40 03/10/2003	27694.36836	50.35339701	5035.339701	
15:15 23/10/2003	31062.15286	56.47664155	5647.664155	
11:25 05/11/2003	33762.197	61.38581273	6138.581273	
11:28 12/12/2003	20687.62196	37.61385811	3761.385811	
average	**23107.3809**	**42.01341983**	**4201.341983**	

Appendix 7 (continued)

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	

Appendix 7 (continued)

Collected Date	N (tot) {TN, pTN} (mg/L)	P (tot) {TP, pTP} (mg/L)	pH (in situ)
11:45 06/11/1997	0.214	0.069	
11:50 23/07/1998	1.146	0.097	7.810
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

Appendix 7 (continued)

Collected Date	N (tot) {TN, pTN} (mg/L)	P (tot) {TP, pTP} (mg/L)	pH (in situ)
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
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

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