Government of **Western Australia**
Department of **Water**

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Foreshore and channel assessment of Christopher Brook

Water resource management series

Report No. WRM 52
November 2008

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This project is funded by the Avon Catchment Council and the State and Australian Governments through the Natural Heritage Trust and the National Action Plan for Salinity and Water Quality.

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November 2008

ISSN: 1326-6934 (pub)
ISSN: 1835-3592 (pdf)

ISBN: 978-1-921468-51-3 (pub)
ISBN: 978-1-921468-52-0 (pdf)

Acknowledgements

This report was prepared by Lucy Sands (BlueSands Environmental) for the Department of Water, Northam.
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The following people are acknowledged for their assistance and knowledge during the project:

- Kate Gole (Department of Water, Northam) for her assistance during the preparation of the survey, development of the Microsoft Access database, advice and report editing
- landholders adjacent to the river for their permission to access the river and for their interest and information
- Viv Read (Viv Read & Associates) for his assistance during the survey
- Bernard Kelly and Martin Revell (Department of Water, Northam) for report editing and project support
- Hamish Wallace for map production and GIS support.

Cover photo: River Pool, Christopher Brook
(Photo: Lucy Sands)

Unless otherwise stated, all photograph taken by Lucy Sands or Viv Read.

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Executive summary

The foreshore and channel assessment of Christopher Brook provides information on the current condition of this waterway and highlights the issues and areas that require specific management.

Christopher Brook is thought to be a relatively fresh waterway in the Dale River subcatchment of the Avon River catchment. In the past, there have been some hydrogeological investigations of the adjacent Kokedin Creek catchment, which revealed that the source of this relatively fresh water was possibly perched, unconfined groundwater.

The information obtained during the Christopher Brook survey supports these investigations. Snapshot water quality samples, observations of landform and anecdotal evidence all suggest that the source of this relatively fresh water is likely to be the groundwater seeps on the tributaries in the lower to middle reaches of the brook. These tributaries are located on the down gradient side of large sand lenses, which are acting as perched aquifers and discharging groundwater into the tributaries.

In addition to these important fresh water sources, these tributaries support areas of good quality riparian vegetation, some of which are fenced remnant bushland and some of which have been actively revegetated by local landowners.

Agricultural land uses dominate the Christopher Brook catchment which, along with much of the Wheatbelt, was subject to widespread clearing decades ago. Clearing and unrestricted stock access has lead to a decline in the health and diversity of plant species in the riparian zone, especially along the main channel. Weeds dominate the understorey and there is active erosion along most of the main channel. This erosion is particularly noticeable in sections with no fringing vegetation, where erosion is progressively consuming valuable farmland.

There are widespread infestations of sharp rush (*Juncus acutus*) along Christopher Brook. These infestations should be cause for concern for local landowners, as not only do they make accessing the waterway difficult but they can also be a symptom of saline, waterlogged soils.

Christopher Brook is displaying signs of deteriorating health that are similar to other waterways in the western Wheatbelt. However, Christopher Brook is unique in that it has sources of relatively fresh water and tributaries that have pockets of vegetation in near pristine condition.

Therefore, it is important to understand the hydrogeology of the sand lenses on these tributaries, including how they are recharged and what can be done to protect their water quality.

Christopher Brook has a relatively low proportion of fencing, and restricting stock access by fencing has environmental and economic benefits. Not only will it reduce erosion, allow regeneration and improve water quality but it will also improve property appearances, reduce the amount of land lost to erosion and provide a windbreak for stock.

This report makes general and specific recommendations to improve the health of Christopher Brook, and it is hoped these will engage landowners interest and stimulate action to protect this valuable asset.

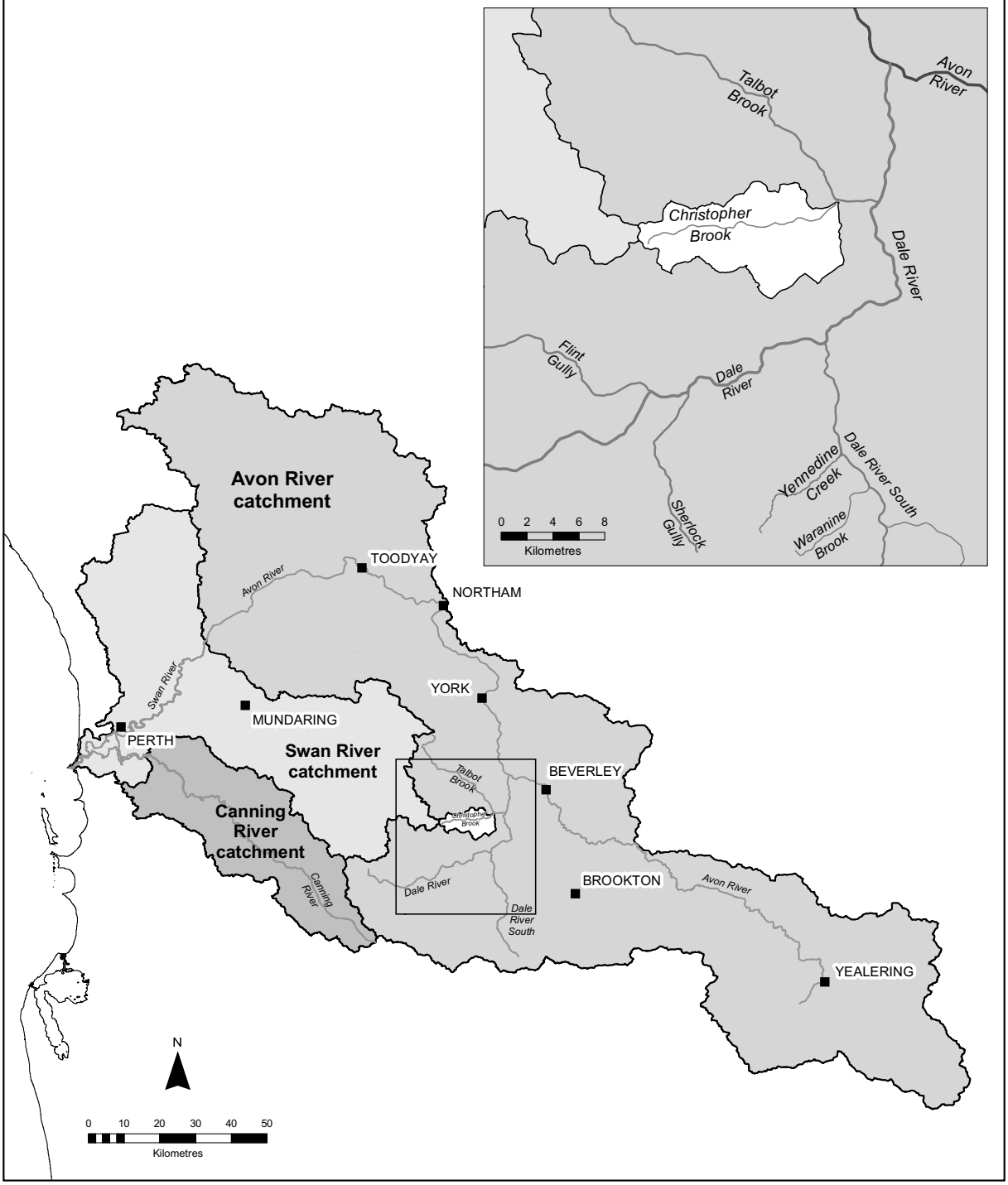
1 Introduction

Foreshore and channel assessments have been completed for a number of waterways in the Avon River catchment, including the nearby Dale River and Talbot Brook (Department of Water, 2006; Water and Rivers Commission, 2002a). These assessments are designed to provide a consistent approach to collecting baseline information to assist in future management of these waterways.

The purpose of the assessment was to:

- collect baseline information on the current condition, health, past and current management practices and threatening processes relating to Christopher Brook that will allow changes in condition and health to be measured.
- provide this information to waterway managers, including landowners, the community and organisations.
- highlight issues and areas that require urgent management.
- engage landowners interest in the causes of degradation and possible management techniques to overcome these issues.

Map 1
Location of the Christopher Brook catchment within the Avon River catchment



Legend

- Towns
- Watercourses
- Christopher Brook catchment boundary

SOURCES

DoW acknowledges the following datasets and their Custodians in the production of this map:
Hydrography, Linear (heirarchy) - DOW - 2006
Hydrography, Linear (heirarchy) - WRC - 2003
Hydrography Subcatchments - DOW - 2007
Towns - DLI - 2001

Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum:GDA 94
Projection: MGA Zone 50

Project Information
Requestee: Kate Gole
Map Author: Hamish Wallace
Task ID:6886
Filename J:\gisprojects\Project\B_Series\B4216\0001\mxd\MAP01_Christopher_Brook_catchment_location_A4.mxd
Date: March 2008

Department of Water
Government of Western Australia

This map is a product of the Department of Water, and was printed on March 2008

This map was produced with the intent that it be used for Christopher Brook Foreshore Reporting at the scale of 1:1,400,000

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, the Department accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

2 Description of Christopher Brook

2.1 Location, land use and tenure

Christopher Brook is located approximately 20 km south-west of the town of Beverley, in the Dale River catchment, which is a significant subcatchment of the larger Avon River catchment. Christopher Brook flows in an easterly direction towards its confluence with Talbot Brook, near the York-Williams Road, within the Shire of Beverley. Map 1 shows the location of Christopher Brook in relation to the Avon River catchment.

Christopher Brook is a unique waterway, in that it is one of a few relatively fresh waterways in the Avon River catchment. These fresh water inflows appear to originate from the tributaries in the middle and lower reaches of this waterway and, in turn, supply Talbot Brook and the Dale River with important fresh water inflows.

Christopher Brook and its tributaries flow through eight privately owned land holdings, most of which are used for stock grazing and/or cropping. There are a few smaller land holdings located on the tributary (CBTrib001) that flows in a northerly direction alongside the York-Williams Road (Map 2). Most of these smaller land holdings are also used for stock grazing.

2.2 Landform and soils

The Avon River basin has three distinct drainage zones. Christopher Brook lies within the zone of rejuvenated drainage. This zone includes the land between the Darling Range, to the west, and the Meckering Line, to the east.

This zone is characterised by a more undulating landscape than the zone of ancient drainage (which encompasses much of the central and eastern Wheatbelt) with defined drainage lines that flow every winter. The average rainfall within the zone is 375–550 mm/year (Lantzke and Gulton, undated).

The Christopher Brook catchment is characterised by gently undulating hills and relatively broad valley floors, which narrow towards its headwaters.

A number of soil landscape units exist within the Christopher Brook catchment, as outlined in Table 1.

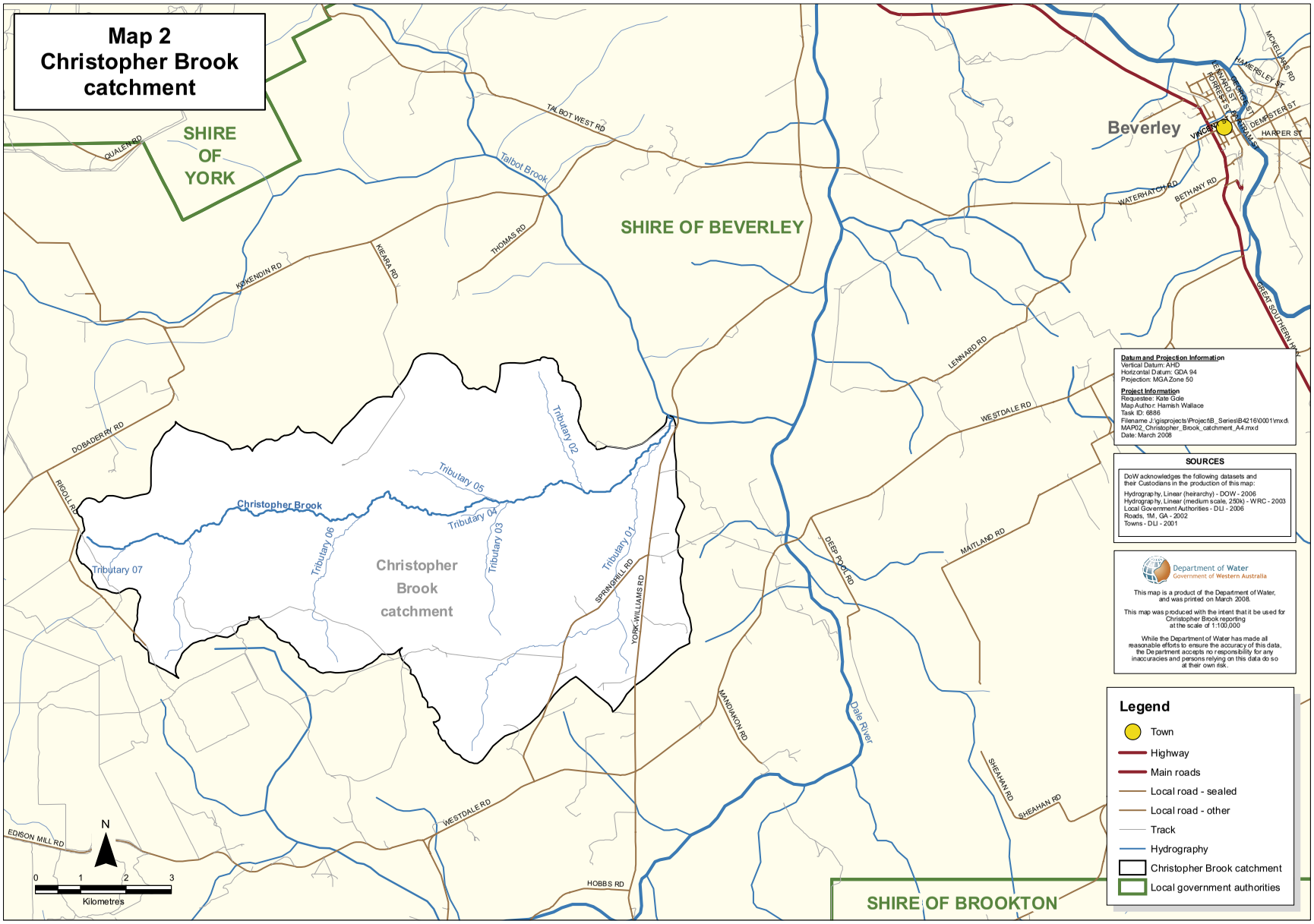

Map 2
Christopher Brook catchment
SHIRE OF YORK
SHIRE OF BEVERLEY
SHIRE OF BROOKTON
Beverley
Talbot Brook
Christopher Brook
Tributary 01
Tributary 02
Tributary 03
Tributary 04
Tributary 05
Tributary 06
Tributary 07
Christopher Brook catchment
TALBOT WEST RD
QUALEN RD
KOKENDIN RD
KIERARA RD
THOMAS RD
DOBADERRY RD
RIGOLL RD
WESTDALE RD
EDISON MILL RD
HOBBS RD
SPRINGHILL RD
YORK-WILLIAMS RD
DEEP POOL RD
MANDIAKON RD
Dale River
MAITLAND RD
SHEAHAN RD
LENNARD RD
WATERHATCH RD
BETHANY RD
HAMERSLEY ST
DEMPSTER ST
HARPER ST
VINCENT ST
MCKELLARS RD
GREAT SOUTHERN HWY
N
0 1 2 3
Kilometres
Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA Zone 50
Project Information
Requestee: Kate Grde
Map Author: Hamish Wallace
Task ID: 6886
Filename J:\gisprojects\Project\B_Series\B4216\0001\mxd\MAP02_Christopher_Brook_catchment_A4.mxd
Date: March 2008
SOURCES
DoW acknowledges the following datasets and their Custodians in the production of this map:
Hydrography, Linear (heirarchy) - DOW - 2006
Hydrography, Linear (medium scale, 250k) - WRC - 2003
Local Government Authorities - DLI - 2006
Roads, TM, GA - 2002
Towns - DLI - 2001
Department of Water
Government of Western Australia
This map is a product of the Department of Water, and was printed on March 2008.
This map was produced with the intent that it be used for Christopher Brook reporting at the scale of 1:100,000
While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, the Department accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.
Legend
Town
Highway
Main roads
Local road - sealed
Local road - other
Track
Hydrography
Christopher Brook catchment
Local government authorities

Table 1 Soil landscape units, landforms, main soil types and vegetation types found in the Christopher Brook catchment. (Adapted from Lantzke & Fulton, undated)

Landscape unit	Landform	Main soil types	Dominant vegetation
York	Irregular, often hilly country where waterways have dissected the lateritic profile to expose bedrock	Loamy sand, clay loam, rock outcrop	York gum (*Eucalyptus loxophelba*) and jam (*Acacia acuminata*) woodland
Maitland	Swamps and poorly drained areas that occur within broad valley floors	A variety of undetermined swampy soils	Paperbark (*Melaleuca* sp.), rushes (*Juncus* sp.) and low scrub.
Sheahan	Gently undulating hill slopes	Pale sands over gravel/loamy sand	*Banksia* sp., tea tree (*Leptospermum* sp.), Christmas tree (*Nuytsia floribunda*) and some marri (*Corymbia calophylla*)
Dale	Flats and broad tributary valleys. Slopes are usually less than 1%. Low lying areas are prone to waterlogging	Sandy valley duplex, loamy sand valley duplex	White gum (*Eucalyptus wandoo),* flooded gum (*Eucalyptus rudis*), some tea tree (*Leptospermum* sp.) and jam (*Acacia acuminata*)
Steep Rocky Hills	Steep hills which contain large areas of outcrop, slopes range from 10% to more than 30%	Rock outcrop, loamy sand, sandy loams, clay loams	Marri (*Corymbia calophylla*), jam (*Acacia acuminata*), York gum (*Eucalyptus loxophelba*) grasstree (*Xanthorrhoea* sp.) and white gum (*Eucalyptus wandoo)*

2.3 Climate

The Christopher Brook catchment has a Mediterranean climate, characterised by hot, dry summers and cool, wet winters. The closest, most representative, weather station is located at Beverley, approximately 20 kilometres north-west.

At this station, average yearly rainfall is 420 mm, with June and July being the wettest months and December the driest (Table 2).

Table 2 Average monthly and annual rainfall for Beverley (Australian Bureau of Meteorology, 2007)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual average
Average rainfall (mm)	12	13	16	24	54	80	78	60	36	24	15	10	420

2.4 Historical water monitoring

There is limited water quality data available for Christopher Brook. No stream gauging station exists on this waterway. Data is limited to two snapshot samples taken approximately 350 metres upstream from its confluence with Talbot Brook in 2006 and 2007. Water quality data for Talbot Brook is also limited to the 2006 and 2007 snapshot results. The snapshot results are outlined in Table 3.

Table 3 Snapshot results for Christopher and Talbot Brook (Department of Water, 2008)

Waterway	**Sampling location**	**Month/year**	**pH**	**Salinity*** (mS/m)	**Total phosphorus** (mg/L)	**Total nitrogen** (mg/L)
Christopher Brook	~350 m upstream of Talbot Brook	September, 2006	7.56	460	0.75	0.025
		September, 2007	7.78	403	n/a	n/a
Talbot Brook	York-Williams Road Bridge	September, 2006	7.92	976	0.88	0.008
		September, 2007	7.78	403	n/a	n/a

** A salinity classification table is presented in Table 12*

2.5 Tributaries

There are 15 tributaries flowing into Christopher Brook. Of these, seven are considered to be major tributaries. Major tributaries were initially determined from aerial photography based on their approximate catchment area. These preliminary observations were then confirmed by field observations of channel width and depth and flow discharge. The remaining eight are minor tributaries that flow intermittently during rainfall events, capturing overland flow. None of the major tributaries are known to be named.

3 Foreshore and channel assessment method

3.1 Focus of the foreshore and channel

The foreshore and channel assessment looked at the condition of the foreshore and channel areas of the Christopher Brook floodplain. Figure 1 shows a cross section of a typical waterway in the Avon River catchment and the terms used to describe it. Definitions of the floodplain, floodway and verge can be found in the glossary.

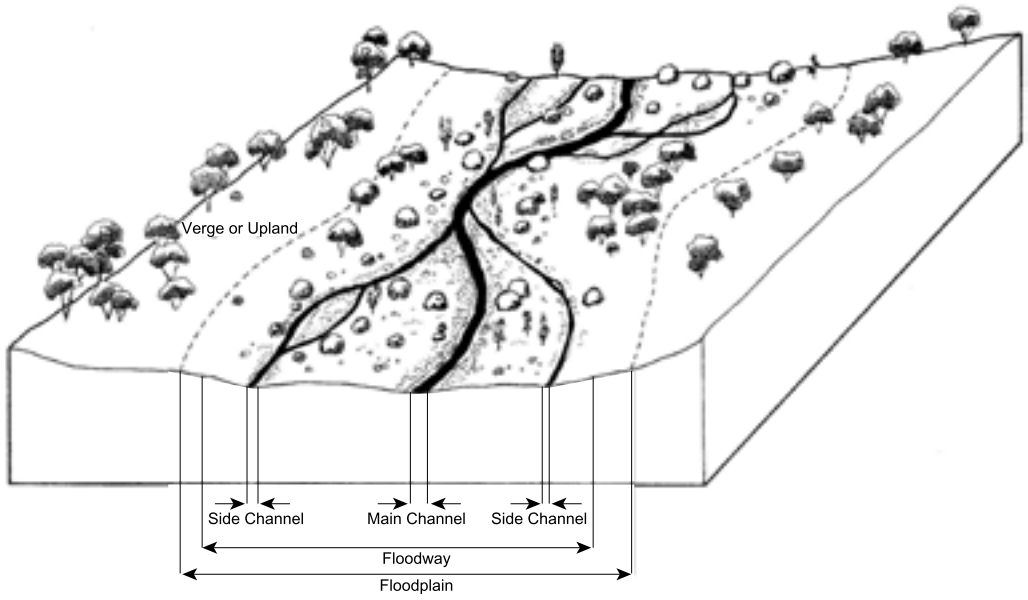


Figure 1 *Cross section of a typical river valley in the Avon River catchment*

3.2 Survey preparation

Prior to undertaking the foreshore and channel assessment, a letter was sent to landowners along Christopher Brook explaining the purpose of the field assessment. Each landowner was then contacted by phone, prior to the assessment, to gain access to the waterway.

Landowners were invited to be present during the assessment to better understand the assessment process and provide information on historical recreational use, waterway features and past and current river management practices.

The foreshore and channel assessment was planned using 1:30 000 cadastre maps and 1:10 000 aerial photographs. These maps were used to identify roads, property boundaries, fence lines, tributaries and significant landforms that helped to plan approximate survey sections, which were later confirmed during the assessment.

3.3 Foreshore and channel assessment method

The current foreshore and channel assessment method used in the Avon River catchment has been adapted by the Department of Water from the *Stream foreshore assessment for farming areas* developed by Pen and Scott (1995). The method, as it was applied to Christopher Brook, is described below and it is also detailed in *Foreshore and channel assessment in the Avon River catchment* (Department of Water, 2007).

3.3.1 Definition of survey sections

The foreshore and channel assessment of Christopher Brook commenced at its confluence with Talbot Brook, walking upstream, towards its headwaters. Both banks were assessed and the left and right banks were determined by facing upstream.

The river was divided up into 20 sections, the boundaries of which were usually defined by paddock boundaries (see Map 3). The river was surveyed up to the top of its headwaters near a bushland reserve (Crown Reserve 47883), along Rigoll Road.

In addition to the 20 sections assessed in the main channel, seven significant tributaries were also assessed (see Map 3). Four of the seven significant tributaries of Christopher Brook were assessed for their entire length because they were considered to have important hydrological and ecological significance to Christopher Brook. These four tributaries were also divided up into sections, usually defined by paddock boundaries and given a unique code. For example, CBTrib001 was divided up into six sections and was coded CBTrib001-A, CBTrib001-B and so forth. The remaining tributaries were surveyed for 200–500 metres.

3.3.2 Foreshore and channel assessment form

To standardise the collection of field data, for each survey section the following information was recorded on the foreshore and channel assessment form (Appendix 1):

- GPS coordinates using a Garmin GPS 76 (see section 3.3.3)
- bank stability and erosion (see section 3.3.4)
- waterway form and features (see section 3.3.5)
- vegetation health, including identification of native and weed species (section 3.3.6)
- habitat quality and diversity, including identification of native and introduced fauna (section 3.3.7)
- water quality (section 3.3.8)
- fence condition and stock access (section 3.3.9)
- foreshore condition rating (section 3.3.10)

- overall stream environmental health rating (section 3.3.11)
- management issues, evidence of management and management recommendations (section 3.3.12).

A photographic record was also taken during the assessment, some of which are included in this report. The remaining photos are on file at Department of Water, Northam.

3.3.3 Bank stability

Erosion is a naturally occurring process even in pristine waterways. However, in waterways that are in good condition erosion is generally only present on meander bends. Badly eroded banks and sediment slugs indicate poor waterway condition and result from a lack of fringing vegetation to protect and stabilise banks, and trampling of banks by livestock.

During the survey bank stability was assessed by observing the proportion of the banks within each survey section affected by erosional processes including undercutting, firebreak and track washout, subsidence, gully erosion, sedimentation and slumping (Table 4).

Table 4 Rating system used to determine bank stability

Percentage of riverbank affected	Rating
0–5%	Minimal
5–20%	Localised
20–50%	Significant
>50%	Severe

These processes are explained below and some are illustrated by photos 1, 2 and 3. Photo 1 shows the bank of an unfenced section of the brook where undercutting is occurring as a result of the channel incising (becoming deeper). The photo also shows sediment deposition, which in this case has occurred on the inside of the meander bend. Photo 2 shows the process of undercutting too, where a dead tree root has become exposed as a result of undercutting. This photo also illustrates the process of headcutting, which is occurring in the channel itself. Sedimentation is also shown in photo 3. In contrast, photo 4 shows a well-vegetated, stable stream channel on one of the brook's tributaries.

Undercutting occurs on vertical banks where an increase in flow velocity causes the channel to incise. The scouring action of the water against the banks causes the banks to become undercut. Eventually the undercut bank, with no support from below, will collapse. This process is called slumping. Subsidence is another form of bank collapse where flows saturate banks and cause them to collapse under the

added weight of the water (Pen, 1999).

Washouts occur where sandy soils are exposed on the floodplain, usually along tracks and firebreaks. During floods these areas are scoured out and the scour grows in size with each successive flood. Washouts can also occur when the main channel becomes clogged with sediment and debris and flood flows are unable to move through the channel. Instead, flows move across the floodplain eroding vulnerable areas (Pen, 1999).

Gully erosion refers to the formation of a relatively deep channel (>30 cm) where once there was only a shallow depression. A common way gullies form is through headcutting. Headcutting is where a stream erodes upstream from a point and occurs where the slope of the channel suddenly increases. The flow velocity consequently increases, scouring the soil over the face of the slope (Pen, 1999).

Sedimentation is a process where sediments settle out of the water column in areas where the flow velocity decreases such as on the inside of meander bends, in river pools and upstream of riffles. Erosional process cause sediments to become mobile in the water column, therefore a waterway with unstable banks and significant erosion will often have a high level of sedimentation. Sediment can also be washed in from upstream sections, tributaries or can enter via overland flow.

Photo 1 *Bank undercutting on a meander bend of Christopher Brook. The arrow indicates the former depth of the channel bed. Also note the sediment deposit on the inside bend.*

Photo 2 *An exposed dead tree root along an unfenced tributary of Christopher Brook.*

Photo 3 *Sediment deposit in Christopher Brook*

Photo 4 *Well vegetated, stable banks along a tributary of Christopher Brook*

3.3.4 Waterway form and features

The presence of waterway features such as deep pools, riffles, anabranches, large woody debris and wetlands provide an indication of waterway health. These waterway features provide a variety of habitats and a high occurrence indicates a generally healthy waterway. Features such as dams, sediment slugs, bridges and crossings are often present as a result of human use or disturbance and may relate to poor waterway health.

The presence of the following natural and constructed waterway features in each survey section were recorded:

- waterway form, including channel form, channel depth and width and the presence of vegetated islands and sediment slugs
- pools
- riffles
- large woody debris
- wetlands
- groundwater seeps

- tributaries
- constructed features such as dams, crossings and bridges

Waterway form

Waterway form refers to the path the waterway makes over the landscape and takes into account floodplain form. Waterway form is determined by flow, sediment load, landscape gradient, soil types and vegetation.

Understanding form helps to recognise how a waterway behaves and subsequently, how it is influenced by a variety of factors (i.e. land uses, climate change, and restoration) and assists in river management (Water and Rivers Commission, 2002b).

For each survey section whether the channel was straight, braided or anabranching was recorded. As it is possible for waterway form to change within a survey section, for some sections more than one form may have been noted. Braided channels divide and rejoin around small, unstable sediment bars or islands. These small islands may be vegetated and during peak flows can be covered with water. Anabranching channels divide and converge around larger, stable islands that are only inundated during large flood events (Water and Rivers Commission, 2002b).

As they are related to channel form, the presence of vegetated islands and sediment slugs within survey sections was also noted.

Pools and riffles

Pools and riffles are important waterway features, providing a variety of habitats and flow conditions within waterways. They often occur together in pool-riffle sequences, where pools form upstream and downstream of riffles.

Deep river pools provide a source of permanent water for aquatic and terrestrial fauna, particularly important in summer months when the remainder of the channel is dry.

Riffles are high points in the channel bed where water becomes turbulent as it passes over accumulated coarse material such as rocks, woody debris or pebbles. Riffles are an important waterway feature, as they provide important habitat for aquatic invertebrates and juvenile fish. Riffles also help oxygenate the water column, as the turbulent water increases its contact with the air, allowing oxygenation of the water (Pen, 1999).

The presence or absence of deep pools and natural and constructed riffles in each survey section was recorded.

Large woody debris

Large woody debris includes fallen trees, logs, branches and twigs and is also

referred to as snags. Woody debris is essential to the functioning of waterways. It slows the flow of water and provides a range of flow conditions. It stabilises the bed and banks of waterways, offering protection from erosion and provides an energy source for instream food webs.

Waterways that have woody debris present are often found to have a greater number of river pools, which enable algae and submerged plants to grow. These in turn strip the water column of nutrients, thereby reducing the nutrient load being transported downstream (Water and Rivers Commission, 2000d).

The presence or absence of large woody debris in each survey section was recorded.

Wetlands

A wetland can be defined as an area of seasonally, intermittently or permanently inundated land and can be flowing or static and fresh, brackish or saline. Examples of wetlands include rivers, streams, lakes and swamps. For the purposes of this assessment however, wetlands are defined as seasonally or intermittently inundated depressions within the floodplain that tend to be connected to the main channel of Christopher Brook only during peak flow events. They are covered during peak flows and retain water as the flows subside. They also fill from local surface runoff and groundwater seeps.

Groundwater seeps

Groundwater seeps are areas where groundwater discharges at the surface. They can be located on hillslopes or in the lowest parts of the landscape – valley floors. They can also be found at the base of sand lenses, which are areas of deep sandy soils. Where groundwater is relatively fresh, seeps can improve the quality (salinity) of streamflow however saline groundwater seeps can increase streamflow salinity. The presence of groundwater seeps was noted for each section.

Tributaries

Tributaries can influence downstream water quality. They can be a source of fresh or saline water and also sediment. Tributaries entering each survey section were noted.

Constructed features

The survey assessed the number of constructed features along the waterway including dams, constructed riffles, crossings (stock and vehicle) and bridges.

3.3.5 Vegetation assessment

Vegetation health and structure is linked to waterway health and plays a key role in bank stability. Vegetation health and structure were assessed to identify sections of foreshore that may become unsupported in the future. A visual assessment of vegetation health was made and recorded as – healthy, some sick trees, many sick or dying trees, some dead trees or many dead trees. Vegetation structure was assessed by estimating the crown cover for each structural layer (overstorey, middlestorey and understorey). An estimation of the percentage of native species compared to weed species was made.

Native and weed species were identified. While a detailed flora survey was not undertaken, an effort was made to identify the common native and introduced species in each section to give an indication of the diversity of plant species in the riparian zone, provide a species list for future riparian revegetation projects and identify weed species impacting on riparian vegetation. Regeneration of native species was also noted.

3.3.6 Habitat diversity

A wide diversity of aquatic and terrestrial habitats is necessary for waterways and riparian zones to support a diversity of flora and fauna species. Information was collected during the survey on whether different habitats, such as pools, instream rocks and logs, protected basking sites and a variety of vegetation types, were present.

Signs and sighting of native and introduced fauna species were recorded. Recording the presence of introduced species, including sightings, tracks and scats, is undertaken to provide information for future management of the waterway. Recording of native fauna species was mostly limited to bird sightings and is undertaken to give an indication of the habitat value of the riparian vegetation along the brook.

3.3.7 Water quality

For each survey section water quality parameters, including pH, temperature and electrical conductivity (salinity), were tested using an MC81 metre. General observations were also made about turbidity (water clarity). Samples were collected at the start of each section and parameters measured immediately.

3.3.8 Fencing and stock access to the riparian zone

Waterways provide stock with drinking water, shade and feed. However, stock can do enormous amounts of damage to fringing vegetation and banks and can foul water supplies. The control of livestock is the single most important management activity in the riparian zones of rural areas and the most effective way of achieving this is by fencing (Pen, 1999).

Fence condition and stock access to the riparian zone was recorded. Fence condition was recorded as follows:

- good – relatively new and expected to remain stock-proof with minor maintenance for >30 years
- moderate – fence is stock-proof but will need maintenance or replacement within 10–20 years
- poor – fence is barely stock-proof and will need to be replaced within 5 years or
- no fence.

Photos in Appendix 2 show examples of good, moderate and poor fence condition.

Signs of stock or vehicle access, such as gates and/or stock tracks, were also recorded.

3.3.9 Foreshore condition grade

The foreshore condition grade indicates the level of waterway degradation by characterising the foreshore in terms of vegetation structure, the balance between native and weed species and bank stability. Both an overall rating and best and worst rating were recorded for each survey section.

The overall or general foreshore grade for each section was determined as the average grade along the length of the section and was recorded as A-grade (pristine) through to D-grade (eroding ditch). The best and worst grades were respectively the highest and lowest ratings determined within the section and were recorded as A1 (pristine) through to D3 (weed-infested drain). A description of each foreshore grade and sub-grade is provided below and a diagram of the four grades is presented in Appendix 3.

A-grade foreshore

For a section to be rated as A-grade, the riparian zone must be entirely vegetated with native species (Photo 5). Some weeds may be present but native species still dominate the understorey and there is little or no evidence of disturbance from human activities or introduced animals. This general rating is further divided to reflect the level of weed invasion and disturbance.

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

B-grade foreshore

A general B-grade foreshore rating is given to sections where the majority of the vegetation structure is intact but where the understorey has been invaded by weeds (Photo 6). The sub-grades are divided based on the level of weed invasion and its affect on the regeneration of some shrubs and trees.

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

Photo 5 *An A-grade reach on a tributary of Christopher Brook*

Photo 6 *A B-grade reach of Christopher Brook*

Photo 7 *A C-grade reach of Christopher Brook*

Photo 8 *A D-grade reach of Christopher Brook*

C-grade foreshore

A C-grade foreshore rating indicates that the foreshore supports only trees over weeds or pasture (Photo 7). As a result of the dominance of weeds in the understorey, bank erosion and subsidence occur in localised areas. The sub-grades for this rating are divided based on the amount of ground cover provided by weeds and the susceptibility of the banks to erosion.

Rating	Key features
C1 Erosion prone	Trees remain with some large shrubs 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 foreshore

A D-grade foreshore rating indicates that there is not enough remaining vegetation to control erosion and the waterway is little more than an eroding ditch or weed-infested drain (Photo 8). Sub-grades are determined by the amount of vegetation present and the severity of erosion.

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

3.3.10 Overall environmental stream health rating

Each section was given an overall environmental stream health rating to give an indication of stream health based on an assessment of the quality and diversity of riparian zone habitats.

The overall environmental stream health rating for each section was based on an assessment of the following factors:

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

Each of the factors (with the exception of landuse) was rated from excellent to poor (Table 5) and numerical score for each factor was determined. Scores were weighted to give more importance to those factors, such as shade and permanent water, that are more important to stream health. The overall environmental stream health rating was then derived from the summation of the individual scores (Appendix 4).

A rating of excellent indicates a healthy stream that has all three vegetation layers (understorey, middlestorey and upperstorey) present, providing a variety of habitat types, shade and protection to the banks from erosion. On the other end of the scale a rating of very poor indicates an unhealthy stream that is highly degraded, with little or no vegetation, little habitat value and continuous bank erosion and sedimentation.

Table 5 Scores for the stream health rating

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

3.3.11 Management issues

Management issues, including fire risk, weed invasion, erosion, salinity, stock access and rubbish dumping, were identified for each survey section. These were prioritised (high, medium or low) for action. Any management undertaken by landholders, such as fencing and revegetation, were also noted and further management suggestions are given.

3.4 Information analysis

On completion of the assessment, the results were entered into a Microsoft Access database. The database has been designed and created by the Department of Water to record data from multiple foreshore and channel assessments for analysis and interpretation to assist in future river management.

Queries run in Microsoft Access were then analysed in Microsoft Excel to provide the results presented in chapter 4.

4 Findings from the Christopher Brook foreshore survey

This chapter presents the results from the foreshore survey and a discussion of their meaning.

4.1 Bank stability

Undercutting, sedimentation and bank slumping are the main forms of erosion and bank instability along the main channel of Christopher Brook (Table 6). Undercutting has occurred where the channel has incised and streamflow has undercut the banks. Eventually the banks have collapsed into the channel (a process called slumping). Undercutting was localised in 45 per cent and significant in 55 per cent of sections in the main channel. Slumping was localised in 70 per cent and significant in 15 per cent of sections.

In the main channel, 90 per cent of sections had significant sedimentation. In contrast, 13 per cent of tributary sections had significant sedimentation, indicating that the source of sediment in the main channel was probably from the main channel itself or via overland flow, as the majority of the catchment is cleared and used for agriculture.

The tributaries were relatively stable, with the majority of assessed sections having minimal or no erosion (Table 7). Only 7 per cent of sections had significant undercutting and an additional 7 per cent were affected by severe undercutting. Erosion was limited to the unfenced tributary sections which had unrestricted stock access. The remaining tributary sections had dense fringing vegetation, some of which were hydraulically connected to groundwater seeps.

Table 6 Percentage (%) of sections rated under each bank stability rating in the main channel (total number of sections = 20)

Rating*	Erosion process					
	Undercutting	Track washout	Subsidence	Gully erosion	Sedimentation	Slumping
Minimal		65	50	70	5	15
Localised	45	35	50	30	5	70
Significant	55				90	15
Severe						

** Refer to section 3.3.3 for descriptions of the bank stability ratings*

Table 7 Percentage (%) of sections rated under each bank stability rating in tributary sections (total number of sections = 15)

Rating*	Erosion process					
	Undercutting	Track washout	Subsidence	Gully erosion	Sedimentation	Slumping
Minimal	60	87	93	87	40	80
Localised	26	13	7	13	47	20
Significant	7				13	15
Severe	7					

** Refer to section 3.3.3 for descriptions of the bank stability ratings*

4.2 Waterway form and features

A summary of the waterway features observed along Christopher Brook is provided in Table 8.

Table 8 Summary of waterway features for Christopher Brook and its tributaries

Waterway feature	Percentage (%) of sections on main channel with feature present (n=20*)	Percentage (%) of sections on assessed tributaries with feature present (n=15*)
Waterway form		
Single channel	95	93
Braided channel	35	13
Anabranch	30	7
Vegetated island	10	7
Sediment slugs	95	67
Natural features		
Deep pool	45	20
Natural riffle	60	13
Large woody debris	75	73
Wetlands	15	20
Groundwater seep	35	80
Tributary	45	7
Constructed features		
Constructed riffles	10	0
Crossing	65	20
Dam	5	0
Bridge	0	0

** n denotes total number of survey sections*

4.2.1 Waterway form

The floodplain in the main channel was relatively broad (60 m) near its confluence with Talbot Brook and then became narrower (20–30 m) towards its headwaters. The channel width generally became narrower towards the upper reaches of the main channel, although there were sections where the channel broadened out considerably. This was mainly due to lateral erosion where the banks are progressively eroding and collapsing into the channel. Channel depth ranged from 1–3 metres in the lower reaches. The middle to upper reaches were shallower, having a depth less than 1 metre.

The survey results show that in the majority (95 per cent) of survey sections along the main channel, Christopher Brook had a defined single channel. However, within 35 per cent of survey sections the channel form changed from single to braided. Thirty per cent of sections had anabranches. Anabranches were more common in the middle reaches, where the valley floor was broad. Many of these anabranches have been cut off from the main channel due to the level of incision in Christopher Brook, which is significant in the lower to middle reaches.

Anabranches that are connected to the main channel during high flow or flood events serve an important hydrological and ecological function. For much of the drier months these side channels are similar to the rest of the floodplain and are important for nutrient cycling and provision of habitat (Department of Water, 2006). Anabranches that are connected to the main channel (where the channel is not incised) provide an important source of carbon and energy to the waterway during peak flow or flood events.

4.2.2 Pools and riffles

Along Christopher Brook, 40 per cent of sections contained deep pools that would hold water over the summer months. River pools were more common in the mid to lower reaches of the waterway, where the channel was wider and deeper and had greater volume of flow (Photo 9). Twenty per cent of tributary sections had deep pools, fewer in comparison to the main channel, but a large proportion of tributary sections had broad seepage areas rather than defined channels.

Naturally occurring riffles were present in 60 per cent of sections in the main channel and 13 per cent of tributary sections. Some of these riffles were created by accumulated woody debris, some by calcrete pavement intrusion and others were the classic cobble and pebble stone variety. There were a few farm crossings constructed with rock which also act as riffles and sediment traps, although these are not considered to be naturally occurring so they were included as crossings (see section 4.2.7).

Photo 9 *A deep pool on a meander bend in the downstream reaches of Christopher Brook*

4.2.3 Large woody debris

Christopher Brook had a high percentage of sections in the main channel (75 per cent) and tributaries (73 per cent) with woody debris present. In most cases, those sections with no woody debris also had minimal fringing vegetation and high levels of erosion.

4.2.4 Wetlands

Wetlands were uncommon along the main channel of Christopher Brook, with only 15 per cent of sections having wetlands in the floodplain. In the lower reaches one section (CB001) had a wetland, which had been disconnected from the main channel due to the level of channel incision in this section. The remaining wetlands occurred in the upper reaches (CB017 and CB019) where the valley floor was relatively broad and the wetlands would be connected to the main channel during peak flow events. These wetlands were also fed by groundwater seeps.

Wetlands were found in 20 per cent of tributary sections, which were all fed by groundwater seeping from the base of sand lenses. These wetlands contained healthy, regenerating remnant vegetation which was fenced from stock.

4.2.5 Groundwater seeps

There are numerous groundwater seeps in the Christopher Brook catchment. Along the main channel 35 per cent of sections had groundwater seeps, which were dominant in the upper reaches. Groundwater seeps in the upper catchment were often a result of groundwater discharging into the valley floor. In the lower reaches groundwater seeps were observed along the channel embankment. These may have once discharged into the bed of the main channel but due to the level of incision in the lower reaches they now discharge along the bank.

Groundwater seeps were observed in 80 per cent of tributary sections, throughout the catchment. These groundwater seeps were a result of groundwater seeping from the base of sand lenses, with the exception of CBTrib006, where groundwater was discharging into the valley floor.

4.2.6 Tributaries

The major tributaries of Christopher Brook were assessed as part of the survey and the results are discussed in the relevant sections of this report. The locations of the surveyed tributaries are shown on maps 2, 3, 4 and 5. Table 9 summarises the significant threats and assets of these tributaries.

Table 9 Tributaries with significant threats or assets

Tributary	Threat(s)	Asset(s)
Tributary 1	• Downstream – little vegetative cover, channel incision, bank erosion, sharp rush (*Juncus acutus*) • Upstream – some sharp rush (*Juncus acutus*) invasion	• Upstream –near pristine sections supporting vegetation in excellent health which is providing a diversity of habitats • Low salinity
Tributary 2	• Lack of fringing vegetation • Bank erosion and sedimentation	• Some revegetation undertaken • Partially fenced upstream
Tributary 3	• Upstream of groundwater seep, the channel has little vegetative cover and significant sharp rush (*Juncus acutus*) infestation	• Low salinity • Relatively fresh groundwater seep • Down and mid-stream sections support very good vegetation and habitat
Tributary 4	• Significant weed invasion, particularly sharp rush (*Juncus acutus*) • Lack of over and mid storey vegetation	• Relatively fresh groundwater seep • Minimal erosion
Tributary 5	• Sharp rush (*Juncus acutus*) infestation in middle reaches • Erosion and bank undercutting in downstream section	• Near pristine section supporting excellent vegetation and habitat • Relatively fresh groundwater seep

Tributary	Threat(s)	Asset(s)
Tributary 6	• Sharp rush (*Juncus acutus*) infestation • Salinity risk • Sedimentation and undercutting	• Healthy stand of wandoo (*Eucalyptus wandoo*) on verge • Close to remnant vegetation (south of channel)
Tributary 7	• Lack of understorey	• Deep pools • Close to bushland reserve along Rigoll Road

4.2.7 Constructed features

The survey recorded the presence of constructed features along the waterway including dams, riffles, crossings and bridges.

There was only one dam adjacent to the main channel, which was located approximately 30 metres away from the channel and appeared to be causing minimal impact. No roads cross the main channel of Christopher Brook and there are no bridge crossings.

Farm crossings were present in 65 per cent of sections in the main channel and 20 per cent of sections in the assessed tributaries. This included two culvert crossings, one in the main channel (associated with a farm access road) and the other along CBTrib001 (crossing for Springhill Road). Some of the farm crossings were informal stock crossings and others were created as vehicle crossings. Erosion was evident at many of these farm crossings and very few were stabilised with field stone, resulting in erosion of the channel bed and banks.

4.3 Vegetation assessment

Dense, healthy fringing vegetation is integral to a healthy waterway. Fringing vegetation provides bank stability, habitat, instream shade and woody debris which provides energy to the stream ecosystem. It also filters sediment and nutrients, slows the velocity of flow and protects adjacent land from erosion, especially during flood events.

Fringing vegetation can be degraded by clearing, stock access, erosion, weed infestation, disease, pest attack, change to flow conditions and fire (Photo 10).

Information about vegetation health was also recorded as part of the stream environmental health rating (see section 4.7). These results are presented below, along with other information about vegetation structure, health and species composition collected during the survey.

4.3.1 Vegetation health and structure

A mixture of overstorey (trees), middlestorey (shrubs) and understorey plants (herbs, sedges and rushes) are important for bank stability and habitat diversity. A dense

Photo 10 *Effects of stock access on native vegetation. Cattle have stripped the bark from this swamp paperbark* (Melaleuca rhaphiophylla).

covering of native understorey plants such as sedges, rushes and herbs provide an excellent buffer to the banks during high flow events and have the ability to strip nutrients and sediment from instream and overland flows.

Survey results for the stream health rating indicate that 60 per cent of the floodway vegetation along Christopher Brook was in moderate condition. However, the majority of the verge vegetation was in poor (50 per cent) to very poor (30 per cent) condition. This indicates that along most of Christopher Brook, there is only a thin narrow strip of vegetation supporting the channel. The floodplain of Christopher Brook is largely cleared, with few to no native species remaining, as a result of clearing for agriculture.

During the survey the proportion of native species in the overstorey, middlestorey and understorey was recorded. Along the main channel, the proportion of native species in the understorey was low, with only one section having more than 10 per cent of native species in the understorey. The understorey along most of the main channel is dominated by agricultural weeds.

The tributary sections had a higher occurrence of native species in the understorey. In 47 per cent of sections, natives made up more than 10 per cent of species in

the understorey, with some of the A-grade sections having up to 95 per cent of the understorey being native species.

In addition to the vegetation health information that contributes to the stream health rating, an assessment was made on the overall health of vegetation within the foreshore area. The presence of dead trees and/or foliage loss may be an indication of disease, insect attack, heat stress, waterlogging, salinity or stock pressures.

The vegetation appeared healthy in 30 per cent of sections in the main channel. There were signs of declining health in 30 per cent of sections, mostly as a result of stock access and jarrah leaf miner (*Perthida glyphopa*) affecting the flooded gums (*Eucalyptus rudis*). However, the flooded gums (*Eucalyptus rudis*) along Christopher Brook do not appear to be as severely affected by jarrah leaf miner (*Perthida glyphopa*) as those along nearby Talbot Brook.

In 40 per cent of sections there were some dead trees. However, there was also healthy, regenerating vegetation present in many of these sections. In some cases the trees could have been stressed by one or a number of pressures and the more susceptible individuals died.

The health of vegetation along the tributaries was similar to the main channel. Forty per cent of sections had healthy vegetation. This was particularly evident along CBTrib003 and CBTrib005, which are fenced and drain separate fresh groundwater seeps. Foliage loss was noted in 20 per cent of sections and the remaining 40 per cent of sections had some dead trees, mostly noticeable along unfenced tributary sections.

4.3.2 Native plant species

There were 23 native plant species identified in the riparian zone along the main channel of Christopher Brook (Table A.5.1 in Appendix 5). The overstorey was dominated by flooded gum (*Eucalyptus rudis*) and wandoo (*Eucalyptus wandoo*). Marri (*Corymbia calophylla*) was only found in the middle reaches and York gum (*Eucalyptus loxophelba*) only occurred in the upper reaches.

The middlestorey was dominated by swamp paperbark (*Melaleuca rhaphiophylla*) in the lower reaches, whilst jam (*Acacia acuminata*) and golden wreath wattle (*Acacia saligna*) occurred throughout. Swamp sheoak (*Casuarina obesa*) and swamp cypress (*Actinostrobus pyramidalis*) were limited to sections that had been revegetated by landholders.

The understorey had fewer native species, comprised solely of sedges and rushes. Pithy sword sedge (*Lepidosperma longitudinale*) was the dominant native sedge in downstream reaches of the main channel, whilst *Baumea preissii* and *Lepidosperma costale* were restricted to a few sections in the middle reaches.

Twenty native plant species were identified on the surveyed tributaries (Table A.5.1

in Appendix 5). Flooded gum (*Eucalyptus rudis*) and wandoo (*Eucalyptus wandoo*) were the dominant overstorey species, with York gum (*Eucalyptus loxophelba*) occurring in some mid to upstream tributaries.

The middlestorey species found along the tributaries were similar to those found on the main channel, with swamp paperbark (*Melaleuca rhaphiophylla*), golden wreath wattle (*Acacia saligna*) and jam (*Acacia acuminata*) being the most dominant. Swamp cypress (*Actinostrobus pyramidalis*) and swamp banksia (*Banksia littoralis*) were restricted to sandy seepage areas.

There were two tributary sections and two sections in the main channel that had the richest species diversity, all having 12 native plant species present. The vegetation was a good mixture of trees, shrubs, sedges, rushes and groundcovers, all healthy and providing support to the banks and diverse habitat.

4.3.3 Regeneration of native species

Regeneration of native species is critical to ensure there is adequate replacement of the species that die as a result of natural or human disturbances (i.e. disease, fire, erosion, grazing). Regeneration will only be successful if disturbances are limited during the plants' critical growth period

Regeneration was evident in 85 per cent of sections in the main channel and 60 per cent of tributary sections. Regeneration was more frequent in areas with limited stock access and sections with no stock access usually had two or more species regenerating.

Dominant regenerating trees and shrubs included:

- flooded gum (*Eucalyptus rudis*)
- swamp paperbark (*Melaleuca rhaphiophylla*)
- wandoo (*Eucalyptus wandoo*).

4.3.4 Weed invasion

Weeds are a problem in waterways because they generally do not provide suitable habitat for native animals, they lack the ability to effectively bind the banks as their roots are shallow, and they do not provide woody debris to the channel. Weeds can also quickly colonise disturbed areas or sediment deposits, altering the morphology of the channel and diverting flow into adjacent banks, causing lateral erosion. Their ability to propagate rapidly enables them to dominate and simplify natural ecosystems (Environmental Protection Authority, 2007).

Weeds also cause economic losses in agriculture as they reduce yields, contaminate crops, poison stock, reduce livestock carrying capacity, downgrade wool and taint milk (Hussey *et al.*, 1997).

Weeds were present in all sections of the main channel and tributaries, although some tributary sections had minimal weed invasion. Seventeen species were identified during the survey. Dominant species included sharp rush (*Juncus acutus*), soursob (*Oxalis pes-caprae*), cape tulip (*Homeria spp*) and Guildford grass (*Romulea rosea*). It should be noted that this is a snapshot of weeds present at the time of the survey (September 2007) and that it is possible there are some weeds lying dormant at that time of the year. If this is the case, these weeds were not identified during the survey. A list of species identified during the survey can be found in Table A.5.2 in Appendix 5.

Sharp rush (*Juncus acutus*) was particularly invasive in the channel and in damp seepage areas of the floodplain. Section CB017 was almost impossible to access due to the infestation of sharp rush (*Juncus acutus*).

4.4 Habitat diversity

The habitat requirements of aquatic and terrestrial animals vary greatly in a river system, with some being able to utilise the entire waterway and others being restricted to localised areas, such as pools or riffles.

Aquatic habitat diversity usually increases when there are a variety of waterway conditions and features, such as fast and slow moving water, shaded and exposed areas, sandy and rocky beds, shallow and deep water and inundated floodplains or anabranches.

Terrestrial habitat diversity is directly related to the species diversity of riparian vegetation, a variety of under, mid and upperstorey species providing a variety of micro habitats for birds, reptiles, frogs and mammals.

4.4.1 Aquatic habitat and animals

Observation of aquatic species was limited to sightings or calls (for species such as frogs). No formal sampling, such as netting, was undertaken.

Two frog species were observed during the survey, including the motorbike frog (*Litoria moorei*) and quacking frog (*Crinia occipitalis*) in both the main channel and tributary sections. It is highly likely that there is a greater diversity of aquatic species in Christopher Brook, as the aquatic habitat in many sections is suitable to a variety of aquatic macroinvertebrates and fish species.

In the main channel, aquatic habitats (see Table 10) were dominated by meanders and shallow to deep pools in the main channel. These features were present in 95 per cent of sections. The deeper pools provide important summer refuge for aquatic and terrestrial animals but were less frequent than the shallow pools. There were also 75 per cent of sections that had instream logs and 70 per cent of sections had instream rocks or boulders, many of which were either exposed calcrete pavement or occasional granite boulders.

Aquatic habitats in the tributary sections varied to those in the main channel and were dominated by instream logs (80 per cent) and emergent plants (80 per cent). This is partially due to the waterway form (morphology) of the tributary channels. The mid and upstream sections of four of the seven surveyed tributaries were flat seepage areas with poorly defined channels. Therefore these sections had no pools, riffles or instream rocks. However, most of these sections were densely vegetated with a variety of native plant species, providing excellent habitat for aquatic macroinvertebrates, frogs and terrestrial species.

4.4.2 Terrestrial habitat and animals

Trees and shrubs were the dominant terrestrial habitat (see Table 11), with 100 per cent of sections in the main channel having trees and 90 per cent of sections having shrubs. Eighty per cent of sections in the main channel had rushes, although in many cases this was dominated by sharp rush (*Juncus acutus*), an invasive weed.

Birds were the dominant terrestrial animal identified during the survey. Along the main channel, 23 different bird species were identified. In contrast, 26 different species were identified along the tributary sections. Considering the length of tributary sections surveyed was 8.5 km compared to 16.5 km of the main channel, the tributaries had a richer diversity of bird species. Bird species diversity was richest in those tributary sections having dense fringing vegetation supported by groundwater seepage. A list of bird species found during the survey can be found in Table A.5.4 in Appendix 5.

Other native animals observed included one brushtail possum (*Trichosurus vulpecular*), an echidna (*Tachyglossidae sp.*), two reptile species and western grey kangaroos (*Macropus fuliginosus*).

Table 10 Aquatic habitat diversity recorded on Christopher Brook

Aquatic habitat	**Percentage (%) of sections along the main channel** (n=20*)	**Percentage (%) of sections along the tributaries** (n=15*)
Aquatic invertebrates, reptiles and fish		
Riffles	60	33
Meanders, pools	95	53
Instream rocks, boulders	70	33
Instream logs	75	80
Variety of instream and bank vegetation	40	33
Frogs		
Emergent plants (frogs)	40	80

** n denotes total number of survey sections*

Table 11 Terrestrial habitat diversity recorded on Christopher Brook

Terrestrial habitat	Percentage (%) of sections, along the main channel (n=20*)	Percentage (%) of sections along the tributaries (n=15*)
Terrestrial invertebrates		
Variety of vegetation types	5	27
Protected basking sites	85	60
Birds		
Trees	100	80
Shrubs	90	67
Rushes	80	67
Reptiles		
Variety of vegetation types	10	40
Protected basking/nesting sites	75	53
Mammals		
Dense protective vegetation	25	40
Frogs		
Dense riparian vegetation	15	47

** n denotes total number of survey sections*

4.4.3 Introduced animals

Introduced animals can be a nuisance to landowners and place additional pressures on riparian vegetation and native animals. European red foxes (*Vulpes vulpes*) were observed in 25 per cent of sections of the main channel, mostly in the downstream sections and then again in the headwaters, near the bushland reserve along Rigoll Road.

In the main channel, European wild rabbits (*Oryctolagus cuniculus*) were observed in 30 per cent of sections, mostly in the upper reaches of the waterway.

European red foxes (*Vulpes vulpes*) and European wild rabbits (*Oryctolagus cuniculus*) were both present in 27 per cent of tributary sections.

4.5 Water quality

It should be noted that the water quality results are indicative only and are a snapshot of water quality on the day samples were taken. Other snapshot samples were taken in 2006 and 2007, the results of which are discussed in section 2.4. Long-term water quality data is unavailable for Christopher Brook.

The downstream sections of Christopher Brook were brackish to moderately saline, ranging between 300–490 mS/m. After section CB008, salinity levels rose considerably and peaked at 890 mS/m, before falling again in the headwaters to 300 mS/m (Figure 2).

To help with a comparison of different units of measurement, a salinity classification is presented in Table 12.

Although the results are only indicative, they support comments made by landowners. Local landowners believe that the downstream sections of Christopher Brook are relatively fresh (for the Avon River catchment) and that the middle and downstream tributaries are the source of this relatively fresh water.

The snapshot results support this anecdotal evidence. The electrical conductivity readings for the tributaries CBTrib003, CBTrib004 and CBTrib005 range from 110–230 mS/m, which is classified as being marginal to brackish (see Table 12). These three tributaries converge with the main channel within 400 metres of each other in section CB008. It is upstream of this convergence where the salinity of the main channel was noted to rise sharply.

Although the tributaries in the middle reaches are quite short in length, they appear to drain water from the down gradient side of large sand lenses. In hydrological terms, sand lenses can hold large volumes of fresh water, acting like a blanket of fresh water overlying clay (perched groundwater). This fresh water gradually drains out of these lenses, annually recharged by rainfall (Hundi, pers. comms.).

The snapshot results also indicate that the pH of Christopher Brook and its tributaries was neutral (pH 7) or very marginally acidic, with the lowest pH reading of 6.89 recorded close to granite outcrops in CBTrib007. The turbidity (clarity) of the water during the survey was generally good, although some suspended sediment was observed at crossing points.

Table 12 Salinity classification table

Classification [1]	mg/L [1]	mS/m [2]	grains/gallon [2]
Fresh	0–500	0–91	0–35
Marginal	500–1 000	91–182	35–70
Brackish	1 000–2 000	182–364	70–140
Moderately saline	2 000–5 000	364–909	140–350
Saline	5 000–10 000	909–1 818	350–700
Highly saline	10 000–35 000	1 818–6 363	700–2 450
Brine	>35 000	>6 363	>2 450
Sea water	35 000	6 363	2 450

[1] *Mayer et al, 2005* [2] *Department of Fisheries*

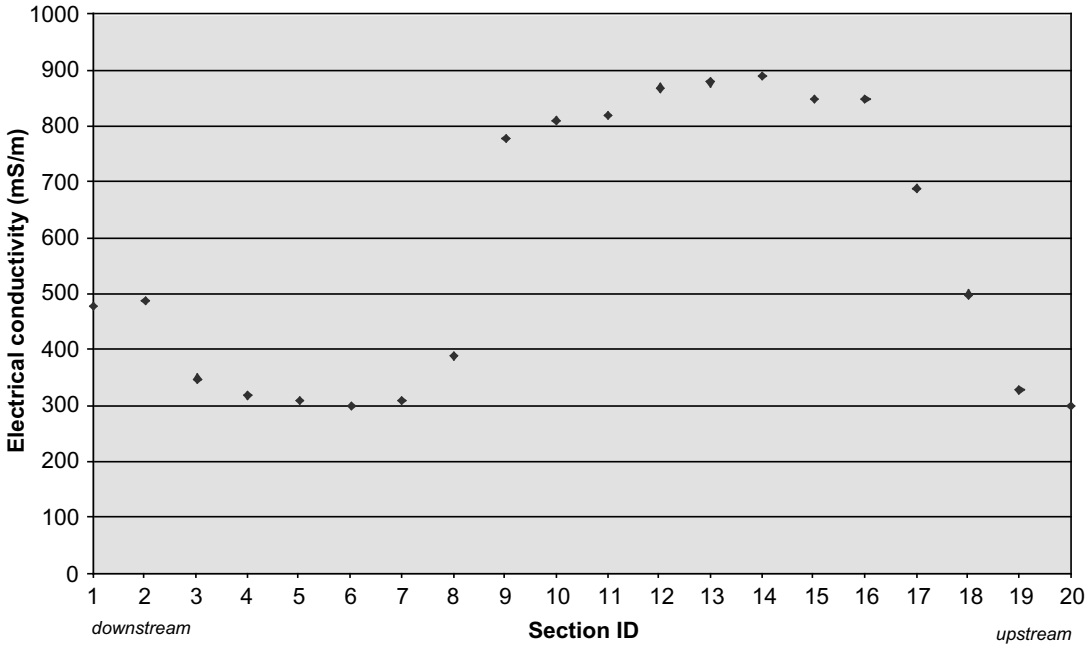


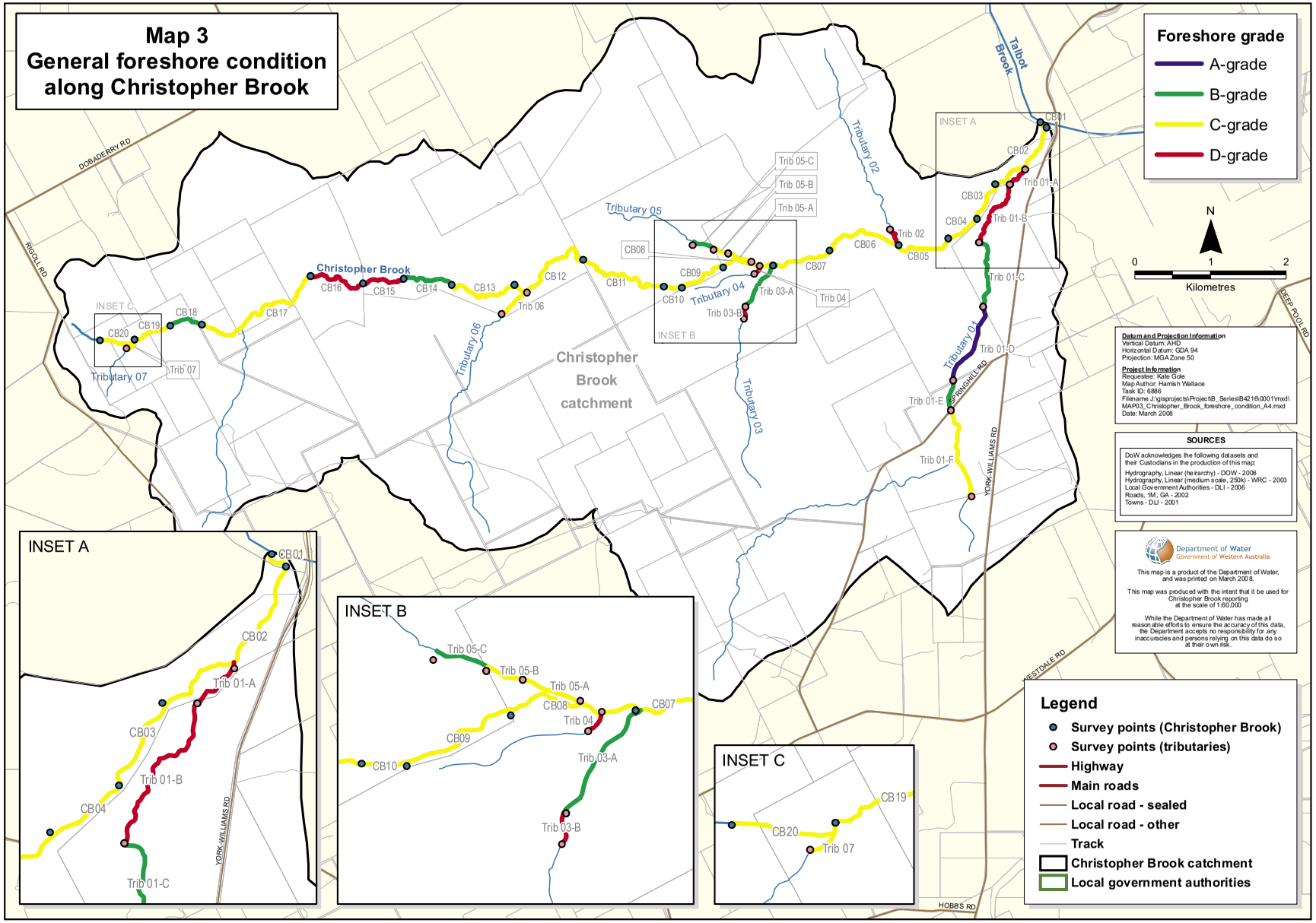
Figure 2 *Salinity levels recorded in the main channel Christopher Brook, September 2007*

4.6 Foreshore condition

4.6.1 General foreshore condition

The condition of the main channel of Christopher Brook was generally worse than that of its major tributaries (Map 3). Of the approximately 16.5 km of the main channel that was surveyed, 82 per cent was rated as C-grade foreshore, 10 per cent as D-grade and 8 per cent as B-grade. None of the main channel was rated as A-grade (Table 13).

The entire length of four major tributaries was surveyed, as was 200–500 metres of three additional tributaries. The total length of tributaries surveyed was approximately 8.5 km. In contrast to the main channel, some parts of the tributaries were in 'near pristine' condition with 18 per cent of the 8.5 km being rated as A-grade foreshore and 25 per cent as B-grade. Tables 13 and 14 summarise the general condition ratings for Christopher Brook and its major tributaries.


Map 3
General foreshore condition along Christopher Brook
Foreshore grade
A-grade
B-grade
C-grade
D-grade
Christopher Brook
Christopher Brook catchment
Talbot Brook
Tributary 01
Tributary 02
Tributary 03
Tributary 04
Tributary 05
Tributary 06
Tributary 07
Trib 01-A
Trib 01-B
Trib 01-C
Trib 01-D
Trib 01-E
Trib 01-F
Trib 02
Trib 03-A
Trib 03-B
Trib 04
Trib 05-A
Trib 05-B
Trib 05-C
Trib 06
Trib 07
CB01
CB02
CB03
CB04
CB05
CB06
CB07
CB08
CB09
CB10
CB11
CB12
CB13
CB14
CB15
CB16
CB17
CB18
CB19
CB20
INSET A
INSET B
INSET C
DOBADERRY RD
RIGOLL RD
DEEP POOL RD
YORK-WILLIAMS RD
SPRINGHILL RD
WESTDALE RD
HOBBS RD
N
0
1
2
Kilometres
Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA Zone 50
Project Information
Requestee: Kate Gole
Map Author: Hamish Wallace
Task ID: 6886
Filename J:\gisprojects\Project\B_Series\B4216\0001\mxd\MAP03_Christopher_Brook_foreshore_condition_A4.mxd
Date: March 2008
SOURCES
DoW acknowledges the following datasets and their Custodians in the production of this map:
Hydrography, Linear (heirarchy) - DOW - 2006
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Local Government Authorities - DLI - 2006
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Department of Water
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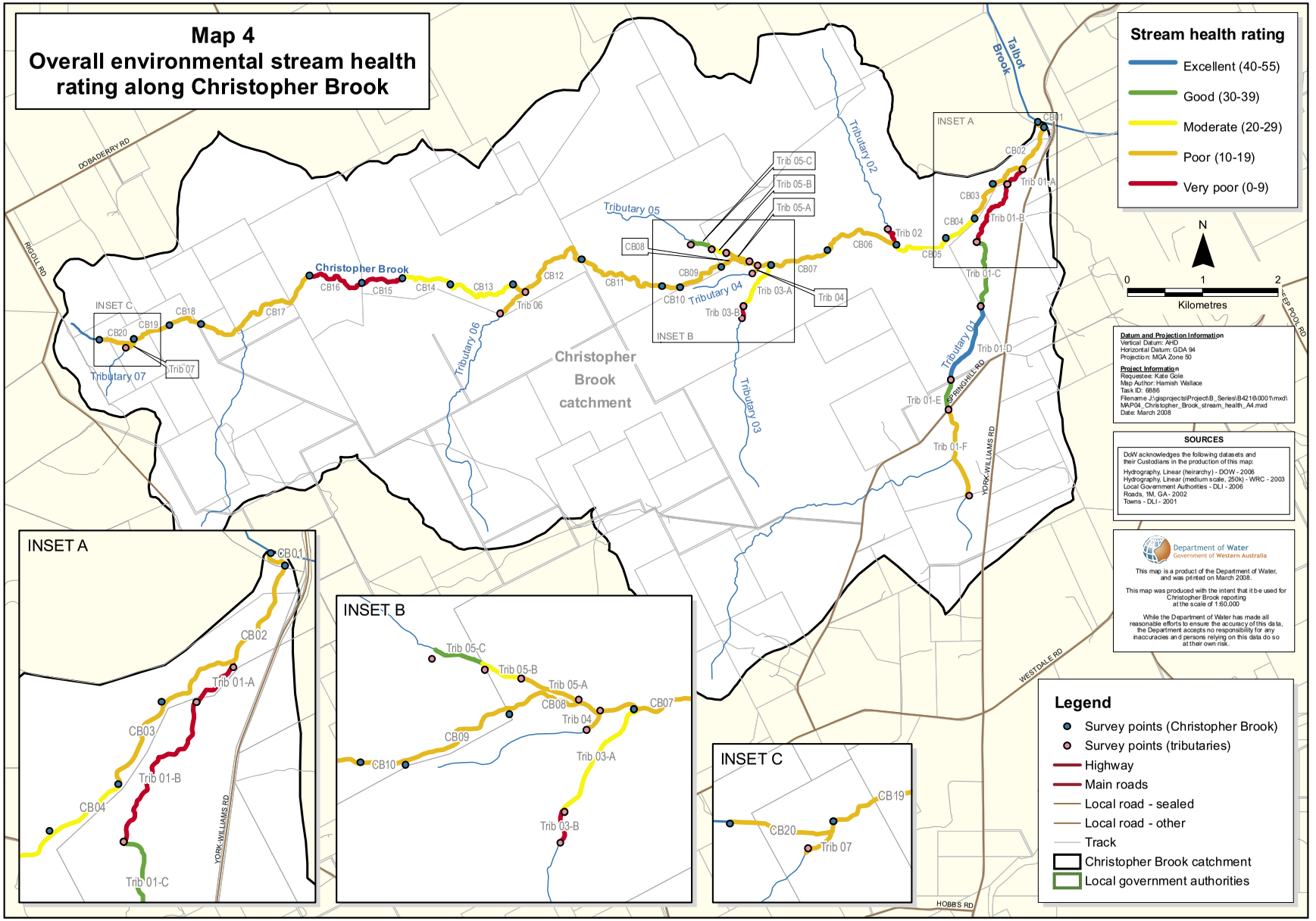
Legend
Survey points (Christopher Brook)
Survey points (tributaries)
Highway
Main roads
Local road - sealed
Local road - other
Track
Christopher Brook catchment
Local government authorities


Map 4
Overall environmental stream health rating along Christopher Brook
Stream health rating
Excellent (40-55)
Good (30-39)
Moderate (20-29)
Poor (10-19)
Very poor (0-9)
Christopher Brook
Talbot Brook
Tributary 01
Tributary 02
Tributary 03
Tributary 04
Tributary 05
Tributary 06
Tributary 07
Christopher Brook catchment
INSET A
INSET B
INSET C
CB01
CB02
CB03
CB04
CB05
CB06
CB07
CB08
CB09
CB10
CB11
CB12
CB13
CB14
CB15
CB16
CB17
CB18
CB19
CB20
Trib 01-A
Trib 01-B
Trib 01-C
Trib 01-D
Trib 01-E
Trib 01-F
Trib 02
Trib 03-A
Trib 03-B
Trib 04
Trib 05-A
Trib 05-B
Trib 05-C
Trib 06
Trib 07
DOBADERRY RD
RIGOLI RD
SPRINGHILL RD
YORK-WILLIAMS RD
WESTDALE RD
HOBBS RD
KEP ROOL RD
N
0
1
2
Kilometres
Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA Zone 50
Project Information
Requestee: Kate Gole
Map Author: Hamish Wallace
Task ID: 6886
Filename J:\gisprojects\Project\B_Series\B4216\0001\mxd\MAP04_Christopher_Brook_stream_health_A4.mxd
Date: March 2008
SOURCES
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Hydrography, Linear (heirarchy) - DOW - 2006
Hydrography, Linear (medium scale, 250k) - WRC - 2003
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Legend
Survey points (Christopher Brook)
Survey points (tributaries)
Highway
Main roads
Local road - sealed
Local road - other
Track
Christopher Brook catchment
Local government authorities

Table 13 General condition of the main channel of Christopher Brook

Grade	**Total length** (km)	**Percentage (%) of sections** (n=20*)
A-grade foreshore	–	–
B-grade foreshore	1.3	8
C-grade foreshore	13.6	82
D-grade foreshore	1.6	10
Total	16.5	100

** n denotes total number of survey sections*

Table 14 General condition of the assessed tributaries of Christopher Brook

Grade	**Total length** (km)	**Percentage (%) of sections** (n=15*)
A-grade foreshore	1.6	19
B-grade foreshore	2.1	25
C-grade foreshore	2.6	30
D-grade foreshore	2.2	26
Total	8.5	100

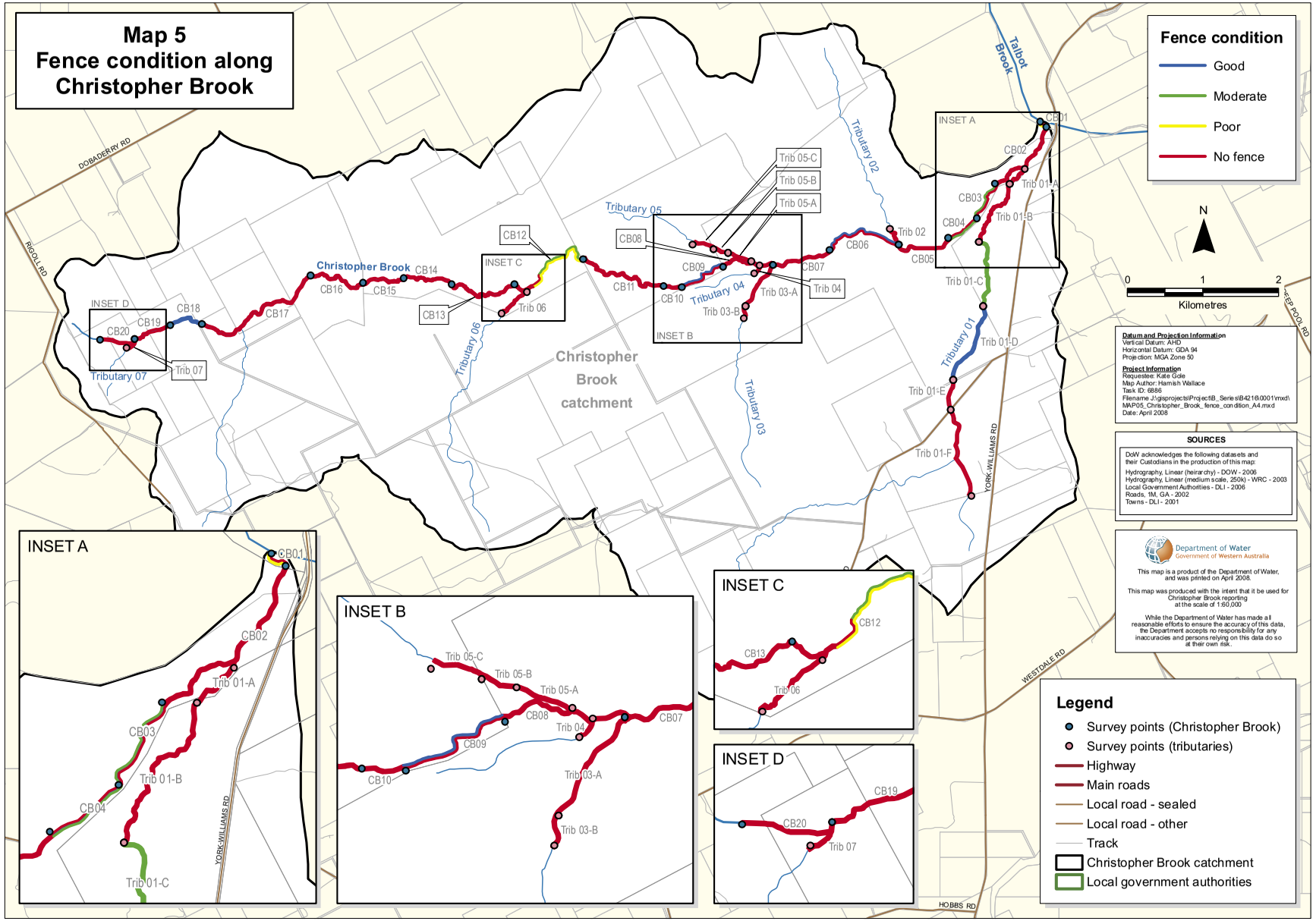
** n denotes total number of survey sections*

4.6.2 Best and poorest condition

The best foreshore rating is the highest possible rating within each section and may be limited to part of the section. In the main channel, the best foreshore rating was B2, recorded for 5 per cent of sections. In this area the overstorey was healthy, and consequently there was good bank stability, but there was also significant weed infestation. The next best rating was B3, which was allocated to 25 per cent of sections along the main channel. These sections were in reasonable health, but weeds dominated the understorey.

The poorest foreshore rating is the lowest rating within each section. In the main channel the poorest rating recorded was D2, recorded for 10 per cent of sections. In these areas, there was no fringing vegetation remaining to support the banks and the banks were being consumed by erosion.

The fenced sections of the tributaries, located in the lower to mid reaches of Christopher Brook, were the best in the catchment. These areas have relatively fresh groundwater seeps which, according to local landowners, provide year-round fresh to brackish water flows into Christopher Brook. These seepage areas also support healthy and diverse native vegetation. Parts of two tributary sections were rated as being A2, which means that they are in near pristine condition. Native vegetation is dominant in these areas and there is very little human disturbance, other than a few weeds.


Map 5
Fence condition along Christopher Brook
Fence condition
Good
Moderate
Poor
No fence
N
0
1
2
Kilometres
Christopher Brook catchment
Christopher Brook
Tributary 01
Tributary 02
Tributary 03
Tributary 04
Tributary 05
Tributary 06
Tributary 07
Talbot Brook
Trib 01-A
Trib 01-B
Trib 01-C
Trib 01-D
Trib 01-E
Trib 01-F
Trib 02
Trib 03-A
Trib 03-B
Trib 04
Trib 05-A
Trib 05-B
Trib 05-C
Trib 06
Trib 07
CB01
CB02
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CB16
CB17
CB18
CB19
CB20
INSET A
INSET B
INSET C
INSET D
DOBADERRY RD
RIGOLI RD
YORK-WILLIAMS RD
WESTDALE RD
HOBBS RD
DEEP POOL RD
Datum and Projection Information
Vertical Datum: AHD
Horizontal Datum: GDA 94
Projection: MGA Zone 50
Project Information
Requestee: Kate Gole
Map Author: Hamish Wallace
Task ID: 6886
Filename J:\gisprojects\Project\B_Series\B4216\0001\mxd\MAP05_Christopher_Brook_fence_condition_A4.mxd
Date: April 2008
SOURCES
DoW acknowledges the following datasets and their Custodians in the production of this map:
Hydrography, Linear (heirarchy) - DOW - 2006
Hydrography, Linear (medium scale, 250k) - WRC - 2003
Local Government Authorities - DLI - 2006
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Legend
Survey points (Christopher Brook)
Survey points (tributaries)
Highway
Main roads
Local road - sealed
Local road - other
Track
Christopher Brook catchment
Local government authorities

In contrast, the tributary sections that were unfenced were in poor condition and D2 was the lowest rating allocated to one tributary section. This area had no fringing vegetation. Consequently the banks were eroding and the channel was deeply incised. The poorest rating of D2 was on a downstream reach of same tributary that was allocated the best rating of A2 (CBTrib001).

4.7 Overall stream environmental health rating

The overall environmental stream health ratings for each survey section are presented on Map 4 and in tables 5 and 6.

Along the main channel of Christopher Brook, there were no sections rated as excellent or good. The majority of the main channel was assessed to be in poor environmental health, with 11.8 km (72 per cent of sections) falling into this category (Table 15). This was primarily due to the lack of healthy, dense riparian vegetation, the presence of weeds in the understorey and the level of erosion which has lead to a decline in stream cover and habitat diversity.

There were some sections (18 per cent) of the main channel that were assessed to be in moderate environmental health. Although there was some erosion and weed invasion in these sections, they had good vegetation cover, which provided a variety of instream and terrestrial habitats.

All of the sections along the main channel had agricultural land uses abutting the waterway, which can lead to a decline in waterway health from unrestricted stock access.

The health of 1.6 km (19 per cent) of the assessed tributaries was rated to be in excellent environmental health and 1.3 km (15 per cent) was in good health (Table 16). These tributary sections had dense, healthy vegetation, minimal to no weeds and stable banks, which provided excellent quality terrestrial and aquatic habitat. However, 2.7 km (32 per cent) tributary sections were rated to be in poor and 1.9 km (22 per cent) was in very poor condition.

Table 15 Overall stream environmental health rating of the main channel of Christopher Brook

Rating	**Total length** (km)	**Percentage (%) of sections** (n=20*)
Excellent	0	–
Good	0	–
Moderate	3.1	18
Poor	11.8	72
Very poor	1.6	10
Total	16.5	100

** n denotes total number of survey sections*

Table 16 Overall stream environmental health rating of the assessed tributaries of Christopher Brook

Rating	**Total length** (km)	**Percentage (%) of sections** (n=15*)
Excellent	1.6	19
Good	1.3	15
Moderate	1.0	12
Poor	2.7	32
Very poor	1.9	22
Total	8.5	100

** n denotes total number of survey sections*

4.8 Fencing and access to the channel

4.8.1 Presence and condition of fencing

Waterways provide stock with drinking water, shade and feed. However, stock can do enormous amounts of damage to fringing vegetation and banks and can foul water supplies. The control of livestock is the single most important management activity in the riparian zones of rural areas and the most effective way of achieving this is by fencing (Pen, 1999).

During the survey, the presence and condition of fencing was assessed along both banks in each section (Map 5). Approximately 16.5 km of the main channel was surveyed, of which 1.5 km (9 per cent) of the left bank and 3.8 km (23 per cent) of

the right bank was fenced, although only 1 km (6 per cent) of this was fenced on both sides (see Table 17).

The position of fencing is such that most of the main channel is contained within farm paddocks, usually used for stock grazing for some part of the year, with the fence line making the boundary fence of the paddock. In most cases the fence was positioned 20 metres or more away from the channel.

Twenty four per cent of tributary sections were fenced both sides, usually as part of a large bush block. There were no tributary sections that were only fenced on one side (see Table 18).

Appendix 6 provides detail on the length and condition of fencing along each section. Most of the fencing was in moderate to good condition, with only 2 km (5 per cent) being rated as poor.

Landowners interested in fencing Christopher Brook or its tributaries may be eligible to receive fencing materials through the Avon Fencing Project. For more information see section 5.3.

Table 17 Presence of fencing along the main channel

	Length (km) fenced	**Percentage (%) fenced** (n=20*)
Left bank only	1.5	9
Right bank only	3.8	23
Both sides	1.0	6
Total fenced	5.3	
Total length surveyed	16.5	–

** n denotes total number of survey sections*

Table 18 Presence of fencing along tributary sections

	Length (km) fenced	**Percentage (%) fenced** (n=15*)
Left bank only	0.0	0
Right bank only	0.0	0
Both sides	2.0	25
Total fenced	2.0	25
Total length surveyed	8.5	–

** n denotes total number of survey sections*

Photo 11 *Stock access down this steep embankment is exposing the soil to erosion. Left unmanaged, this bank will eventually erode into the channel.*

4.8.2 Access to the foreshore

Stock and vehicle access to the foreshore was recorded during the survey. Eighty five per cent of the survey sections along the main channel and 80 per cent of tributary sections are accessible by stock, although stock access in some sections is well managed and there is minimal damage to the riparian zone. However, some sections are heavily stocked and this is compromising the health of riparian vegetation and leading to bank instability (Photo 11).

There are few road crossings on Christopher Brook or its tributaries. The main channel has one farm access road crossing and CBTrib001 has a crossing for Springhill Road. All other service roads are located 2 km or more from the main channel. Therefore, to access all their paddocks, landowners must utilise farm crossings. Farm crossings were present in 65 per cent of sections in the main channel and 20 per cent of tributary sections, although some of these sections had multiple crossing points, usually formed by stock taking a preferred pathway across the brook.

Most of Christopher Brook appears to be actively used in current farm management practices, either as a source of water for stock or source of feed.

4.9 Management issues

Erosion and sedimentation, weed invasion and salinity were identified as priority management issues in most survey sections on both the main channel and tributaries.

Erosion, sedimentation and weed invasion are the result of catchment clearing, unrestricted stock access and the surrounding agricultural land use. Salinity problems are the result of widespread catchment clearing that has changed the catchment water balance, resulting in the water table rising and salts being brought to the surface.

These management issues are discussed further in chapter 5. Descriptions of each survey section, including specific management recommendations, are included in Appendix 7.

4.10 Summary of findings

The main findings from the foreshore and channel assessment of Christopher Brook and its tributaries are summarised below.

4.10.1 Main channel

The main findings for the main channel of the brook are as follows:

- The general foreshore condition rating for most of the main channel was C-grade.
- The overall environmental stream health rating for most of the main channel was poor.
- The management issues identified as a high priority were erosion, sedimentation, salinity and weeds
- Sedimentation and undercutting were the main forms of erosion.
- There is significant infestation of sharp rush (*Juncus acutus*), with some sections being almost inaccessible due to the infestation.
- Only 38 per cent of the waterway is fenced and 85 per cent of sections are accessible by stock.
- Snapshot water quality results indicate that the downstream reaches have low salinity levels, followed by a sharp increase in middle reaches, immediately upstream of the convergence of three relatively fresh tributaries.
- There were 23 native plant species were identified along the main channel.
- There were 23 bird species were identified along the main channel.

4.10.2 Tributaries

The main findings for the tributaries are as follows:

- The general foreshore condition rating varied between A-grade and D-grade, with some sections being rated as near pristine.
- The overall environmental stream health rating for most of the tributaries was poor to very poor, however there were some sections that were in good to excellent health.
- The management issues identified as a high priority were erosion, sedimentation, salinity and weeds
- Groundwater seeps are present in four out of seven surveyed tributaries, most of which appear to supply relatively fresh water to Christopher Brook.
- Undercutting is a significant problem in some sections.
- Some sections were fenced as part of a large bush block and had not had stock access for decades. Other sections were heavily grazed.
- There were 20 native plant species identified along the tributary sections.
- There were 26 bird species identified along the tributary sections.

5 Management advice for Christopher Brook

A number of management issues were identified during the survey. This section provides some information on the most appropriate way in which to manage them. Waterways management advice is also available by contacting the Department of Water's Northam office on (08) 9690 2600.

Christopher Brook is known to provide relatively fresh flows to Talbot Brook, and consequently to the Dale River. Local anecdotal evidence suggests this relatively fresh water originates from the tributaries in the middle and lower reaches of the brook. Information collected during the survey, including snapshot water quality samples and observations of landform, suggests that relatively fresh groundwater is seeping from sand lenses and discharging into these tributaries and then into Christopher Brook.

These groundwater seeps also support significant areas of good quality remnant vegetation. The survey has identified some of these tributary sections as being in near pristine condition.

In addition, there are sections along Christopher Brook where landowners have undertaken extensive revegetation. Most of these sections are in very good condition and little management, other than weed control, is required to maintain and improve these sections. However, landowners should be aware of their importance and continue their good management by excluding or restricting stock access.

The waterways of the Avon River catchment have been significantly modified since European settlement. There are few waterways in the catchment that still have relatively fresh water flows and also few that are regarded to be in near pristine condition. Therefore, it is important to protect the remaining assets of Christopher Brook and where possible, improve assets that are degrading.

It is not envisaged that Christopher Brook will be returned to a pristine or pre-European state. However, the results of this survey will assist landowners and river managers to understand the assets and main threats to the waterway and how to manage them. This will help to ensure Christopher Brook is more resilient and able to recover from potential threats and disturbances it may face in the future.

5.1 General management advice

While each issue of concern is discussed separately, Table 19 gives some general management suggestions for each general foreshore rating. Appendix 7 provides a description and specific management recommendations for each survey section.

Additional information and practical advice on river management can be found in the *Field guide to managing waterways in the Avon Wheatbelt* available from the Department of Water, Northam (Viv Read & Associates, 2008).

Table 19 General management suggestions for each foreshore rating (adapted from Water and Rivers Commission, 2001)

A-grade – pristine to slightly disturbed	A-grade foreshores require minimal management such as: • removal or realignment of large woody debris where it is causing localised erosion • removal of isolated occurrences of weeds • fence maintenance to exclude livestock • control of feral animals • establishment and maintenance of fire breaks and access tracks
B-grade – weed infested to weed dominant	Management of B-grade foreshores requires a bit more effort than for A-grade rated foreshores and includes: • removal of minor weed invasions and ongoing control of widespread weed problems • removal or realignment of large woody debris where it is causing localised erosion • management of stock access to control weeds without damaging native vegetation and streambanks
C-grade – erosion prone to eroded	Management activities for C-grade foreshores are more difficult due to the higher degree of degradation. However, the following activities can help maintain and restore value to the river section: • use of large woody debris to protect banks from erosion • revegetation with local native species to stabilise banks and provide habitat • stabilisation of sediment slugs with local native species • managing stock access and stocking rates to jointly control widespread grassy weeds and maintain vegetation on streambanks to protect them from erosion
D-grade – eroding ditch to simple drain	It is very costly to restore D-grade foreshore areas. Priorities for management include: • revegetation in localised areas initially using fast-growing species then in-filling with slower growing plants • implementing strategies to slow water flow, for example using large woody debris and riffles • undertaking localised weed control in and around revegetation areas • managing stock access and stocking rates to jointly control widespread grassy weeds and allow maintain sufficient vegetation cover on streambanks to protect them from erosion

5.2 Catchment and farm management

Good catchment management is paramount to the health of the waterway and has benefits to landowners. *Farming for the Future* is a program run by the Department of Agriculture and Food that promotes sustainable farming practices. The program supports individuals and industry groups to develop sustainable farm practices and includes the following areas:

- farm economic and social sustainability (e.g. business plans)
- natural resource sustainability (e.g. salinity management, soil and land management)
- biosecurity (e.g. pest and weed management) (Department of Agriculture and Food, 2008).

More information on Farming for the Future, including a self-assessment tool, can be found on the Department of Agriculture and Food's website link <www.agric.wa.gov.au/content/SUST/f4fhomepage.htm#why>.

5.3 Stock control and fencing

Christopher Brook has some near pristine sections along its tributaries. These sections have been fenced and stock excluded for decades.

Landowners are often concerned about fencing riparian zones, with the most frequent comments being that the area will become weed infested and present a significant fire risk. Some landowners also feel that the riparian area provides good grazing and is the only source of water for stock. Although valid, these concerns can be overcome and fencing the riparian zone has a number of benefits both to landowners and the environment including:

- reduced stock losses from flooding
- improved bank stability from protected fringing vegetation
- reduced land lost to erosion
- provision of a windbreak for stock
- improved water quality
- improved property appearance and resale value
- improved habitat for native fauna (Department of Water, 2006).

Landholders are encouraged to fence the riparian zone and restrict stock access except for crash grazing to control weeds and the subsequent fire risk. Crash grazing is where stock are allowed to graze in riparian zones for short periods to suppress the weed mass. They are removed before they start to damage native vegetation. The following guidelines should be followed if fenced riparian zones are to be grazed:

- only graze riparian areas when soil is relatively dry and the bulk of the vegetation is dormant
- avoid grazing during the growing, flowering and germination seasons of native vegetation, which typically means spring and summer
- adjust stocking rates and frequency of grazing to suit the sensitive nature of the land (Department of Water, 2006).

Landholders interested in fencing Christopher Brook or its tributaries may be eligible to receive fencing materials through the Avon Fencing Project. The Avon Fencing Project, funded by the Avon Catchment Council and Department of Water, provides ringlock, posts and strainers to fence priority riparian areas. Materials are limited. Contact the Department of Water's Northam office on (08) 9690 2600 to register your interest.

5.3.1 Location of fences

The placement of fencing is an important factor that must be carefully considered. Incorrect placement of fencing may lead to the fence, and your investment, being washed away. When determining fence placement, you need to know a little about the potential flood level and flood frequency of your waterway.

Fences can be constructed to resist flood damage by constructing them with the least vertical height that gives adequate stock control. Posts should also be located as close together as possible and set firmly into the ground. Fences crossing waterways also require regular maintenance to prevent damage from accumulating woody debris (Department of Water, 2006).

Christopher Brook has a shallow river valley, with a fairly well defined floodway. The most appropriate location of fences would be at the edge of the floodplain, as outlined in Figure 3. As a general guide, this would be approximately 30 metres or more away from the channel. However, if there are areas of good quality vegetation or salt scalds nearby, fences may be best located further away from the channel to encompass these areas.

5.3.2 Stock crossings

Stock crossings are important along Christopher Brook, as the main channel is wholly contained within large private land holdings and crossing the channel is necessary for landholders to access all paddocks. However, many of the stock crossings along the waterway are causing erosion and sedimentation downstream, mostly because they are located where the bed is soft, the banks are too steep or they are located on a meander bend.

The correct placement of crossing points is important to minimise erosion, protect fringing vegetation and also protect stock. Crossing points should be located on a straight stretch of the waterway, preferably where the bed is naturally high and the banks are not too steep. If the bed is soft, it should be hardened up with rock or field stone (not gravel as this will be washed away). Rocky crossings can also act as riffles and help to trap sediment and provide habitat for aquatic fauna. Ideally, crossing points should be fenced to restrict stock access to the rest of the channel (see Figure 4).

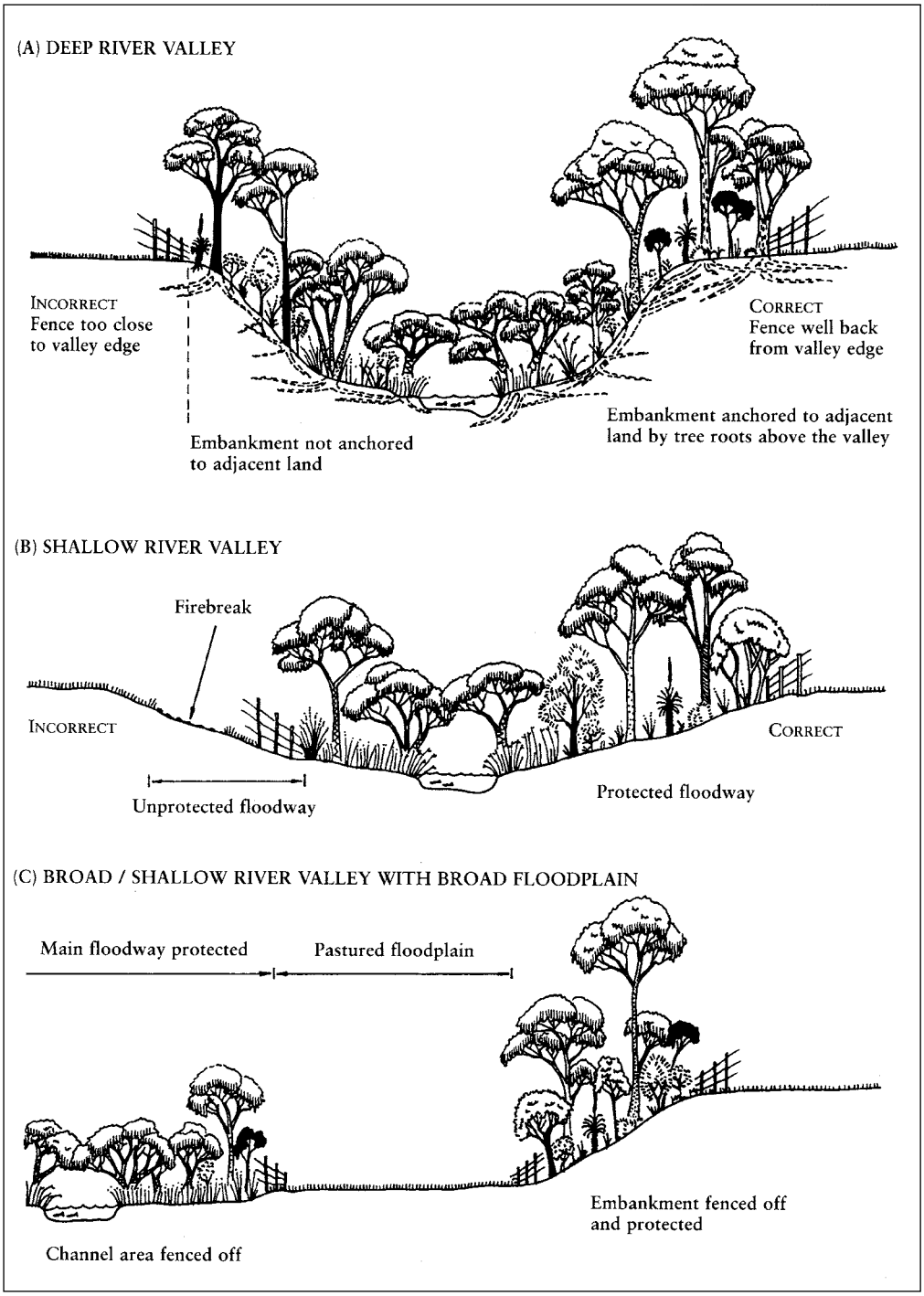

Figure 3 *Ideal fence placement along river floodways (adapted from Pen, 1999)*

5.3.3 Stock watering points

Providing off-stream stock watering points (Figure 5) is the best option to minimise damage to the riparian zone, however it is not always practical. Properly designed stock watering points along riparian fence lines provide a number of benefits to stock and the waterway, including by improving water quality by limiting erosion and

nutrient enrichment, providing cleaner water to stock and reducing erosion of the bed and banks. When relocating or constructing stock watering points the following points should be considered:

- place the access point on the inside of a meander bend;
- create an access ramp (1:6 gradient) which is stabilised with field stone;
- fence both sides and the end of the ramp to restrict stock accessing the channel; and
- start the ramp at least 1 metre back from the top of the bank (Water and Rivers Commission, 2000c).

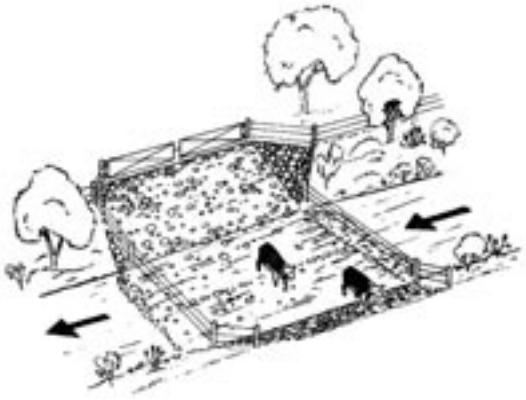

Figure 4 *Basic geometry of a livestock crossing (adapted from Water and Rivers Commission, 2000b)*

Figure 5 *On-stream stock watering point (adapted from Water and Rivers Commission, 2000b)*

5.4 Erosion and sediment control

Most of Christopher Brook is eroding and this should be of concern to landowners. Bank erosion caused by undercutting and slumping is consuming valuable farmland and, left untreated, the problem will worsen and cause adverse impacts downstream. Failure to manage erosion early may require landowners to fence off much larger areas of valuable farmland in the future in an effort to protect crops and grazing land.

Sedimentation in the brook, a result of the erosion problem, is also a problem. Excess sediment is smothering aquatic habitat and filling river pools.

Sedimentation can also contribute to localised flooding and deflect flows into banks causing further erosion (Department of Water, 2006).

The principle forms of erosion and sedimentation along Christopher Brook and its tributaries stem from previous land clearing and unrestricted stock access. Unrestricted stock access has led to the decline of fringing vegetation, especially native understorey species, whose roots effectively bind and protect the banks from erosion.

Photo 12 *Bank stabilisation using large woody debris along a tributary of Christopher Brook. This tributary receives minor flows but the log would be more secure if the butt was buried into the bank.*

The most effective means of slowing and preventing further erosion and sedimentation of Christopher Brook is to restrict stock access by fencing. This will enable the bed and banks to recover from disturbance and allow natural regeneration

to occur. In some sections that have severe erosion, the use of appropriately placed large woody debris can offer protection to exposed banks (Photo 12). Logs should be installed against the outer bank, pointing downstream at an angle of approximately 30º. The butt of the log should be buried up to one metre into the bank to secure it against high flows (Water and Rivers Commission, 2000d).

Once an area is fenced landowners may need to manage the weed burden, recommendations for which are made in section 5.6. Some sections will also require assistance in re-establishing native vegetation as there may be minimal vegetation to enable natural regeneration and the current seed store may be unviable (see section 5.5).

Channel incision is a problem in the lower reaches of Christopher Brook. The most effective means of managing this instability is to stabilise the channel bed by re-creating riffles with rock or woody debris. Riffles can also be constructed to double as stock and vehicle crossing points, an important consideration as Christopher Brook has few formal vehicle crossings. Riffles are also effective in oxygenating the water, slowing flow velocity and trapping sediment. Sediment accumulates behind the riffle and vegetation can be established on the flanks, stabilising the banks (Water and Rivers Commission, 2000d).

Riffles are relatively easy to construct but care must be taken to ensure their correct placement. Riffles should be placed on a straight stretch of river or at a crossover point in the middle of a meander. They should also be placed on a natural high point of the channel. Riffles should be constructed in a ‘V’ shape, with the lowest point in the centre of the channel (Water and Rivers Commission, 2000d). Care should also be taken to ensure the height of the riffle will not obstruct flows, otherwise it could deflect flows into the bank and wash out the construction.

A worthwhile reference for anyone interested in riffles or bank stabilisation is *Stream stabilisation* (Water and Rivers Commission, 2000d).

Assistance in undertaking bed and bank stabilisation works is available through the Department of Water’s Northam District Office.

5.5 Revegetation of the riparian zone

Healthy waterways are a valuable asset to landowners and are worth managing and protecting. The fringing vegetation along Christopher Brook is relatively healthy and most sections have a diversity of trees and shrubs. Improving the diversity and quality of this fringing vegetation, especially the understorey, has a number of benefits to landowners and the environment including:

- improved bed and bank stability
- improved water quality through the trapping of sediment and uptake of nutrients
- aesthetic and recreational benefits

- provision of shade and shelter for stock
- provision of fodder during times of drought (with careful management of stock numbers)
- localised lowering of water tables which may reduce the movement of salt into the waterway
- shading streams
- Enhancing biodiversity and providing aquatic and terrestrial habitats (Price, *et al.*, 2005).

Revegetating the riparian zone is only worthwhile if the area has been restricted to stock (see section 5.3). Planning your revegetation project is also important to maximise success. Assistance in planning and undertaking riparian revegetation projects can be sought from Department of Water, Northam by contacting (08) 9690 2600.

Steps to consider when planning your revegetation project are as follows:

- determine which area requires attention first. The general rule of thumb is to protect the best areas first and work towards the more degraded areas
- consider areas where there is potential for natural regeneration. It is much easier to protect existing native vegetation than to replant it. Where native species remain and are healthy enough to flower and produce viable seed, natural regeneration is the best, and cheapest, way to revegetate
- determine if site preparation is required, such as fencing, erosion control or weed removal, which are usually best undertaken during drier months
- if the area is quite degraded (i.e. D-grade rating), then initial plantings should consist of fast growing species, which could be followed up with slower growing species in subsequent years
- choose your species wisely. Your choice of species depends on your reasons for revegetating and site conditions. For example, you would choose different species to control erosion than you would to increase biodiversity. Consideration of salt and waterlogging tolerant species should also be given, as there are areas of Christopher Brook where these threats are apparent (Price, *et al.*, 2005, Department of Water, 2006).

Native species that have proved popular in revegetation projects and/or have naturally regenerated along Christopher Brook include swamp sheoak (*Casuarina obesa*), jam wattle (*Acacia acuminata*), golden wreath wattle (*Acacia saligna*), wandoo (*Eucalyptus wandoo*), harsh hakea (*Hakea prostrata*) and pithy sword sedge (*Lepidosperma longitudinale*). See Appendix 8 for further information on species that may be suitable for riparian revegetation.

A worthwhile reference for anyone interested in revegetation is *Riparian plants of*

the Avon catchment: a field guide, available from the Avon Catchment Council and Department of Water, Northam.

5.6 Weed control

Annual agricultural weeds are dominant in the understorey along many rural waterways and Christopher Brook is no exception. Weeds often have shallow roots and are unable to provide bank stability the same way as deep rooted native species. Weeds reduce habitat diversity for native animals, pose a significant fire risk and reduce the regeneration of native species.

Weed control can be a daunting task, but prevention is the key. It is easier to manage a small scale weed problem than a significant infestation. Common methods of weed control include chemical control, stock grazing, mechanical removal and hand removal.

The type of weed control you use will depend on the location, type of weeds, time of year and existing vegetation. It is typically best to target smaller infestations first. Sometimes a number of techniques can be the most effective way of eliminating significant infestations. Some examples are listed in Table 20.

Advice on the management of riparian weeds is available from Department of Water's Northam office by contacting (08) 9690 2600. The Department of Agriculture and Food can also provide assistance with weed identification and management advice.

Table 20 Possible control methods for weed removal

Method	Techniques	Advantages	Disadvantages	Things to consider
Hand removal	Pulling or digging weeds by hand	Erosion is localised and kept to a minimum	Labour intensive	Best done when the soil is damp
Mechanical	Brushcutters, chainsaws, tractor slashers, mowers	Can be suitable for large areas	Inappropriate use can lead to erosion	
Chemical		Can cover large areas Very effective for some species	Risk of contamination to the waterway	Always read instructions on the label and wear protective clothing. Chemicals can harm aquatic animals and pollute waterways, choose a suitable chemical that will not harm aquatic ecosystems or choose another control method
Grazing	Allowing stock to periodically graze the fenced riparian zone	Reduces weed biomass Source of feed during drought	Unsuitable for high quality bushland/ riparian areas Stock can easily damage native vegetation and erode banks	Maintain low stocking rates for short periods during late spring and summer Avoid stocking riparian areas when native species are flowering and regenerating
Solarisation	Plastic sheeting	Effective for small areas	Difficult to use if there is native vegetation among weeds Need to leave plastic on for 2–3 weeks which is difficult in some areas	This technique uses plastic sheeting to kill the weed mass. Plastic should be in direct sunlight and the soil should be damp

Landowners also have an obligation to remove weeds that are declared under the *Biosecurity and Agriculture Management Act 2007 (WA)*. During the survey, one declared plant species, one-leaf cape tulip (*Homeria flaccida*), was found along most of the waterway. This species is declared as Priority 1 throughout Western Australia, which prohibits the movement of plants or their seeds within the state.

5.6.1 Control of sharp rush

A particularly invasive species, sharp rush (*Juncus acutus*), was identified during the survey. Although this not a declared plant species in Western Australia, it is in other Australian states, due to its invasive nature and ability to colonise large areas of valuable farmland.

This species has been mistaken for a native rush by many landowners and, as such, has been left untreated. Photos 13 and 14 illustrate the growth form and seed heads of sharp rush (*Juncus acutus*). There are some sections along Christopher Brook where the infestation of sharp rush makes it virtually impossible to access the channel.

Sharp rush (*Juncus acutus*) is tolerant of saline and waterlogged conditions and once established it covers large areas and out-competes almost all other vegetation. Infestations can become impenetrable to livestock and humans, preventing access to water. The sharp spines can be dangerous to children (as they are at eye level) and if the spines penetrate the skin it can cause adverse reactions in some people.

Infestations can also provide an effective shelter to introduced animals, and when growing in channels, can seriously obstruct water flow, causing flooding (Department of Primary Industries, 2008).

Removal of sharp rush (*Juncus acutus*) is usually more successful if using an integration of methods including mechanical removal and chemical control. However, before carrying out any control, consideration should be given to potential soil erosion as the rhizomatous root mat of this species can cover large areas. If you require advice, or would like assistance in developing a weed removal plan for a large infestation of sharp rush (*Juncus acutus*), contact the Department of Water, Northam on (08) 9690 2600.

*Photo 13 Sharp rush (*Juncus acutus*)*

*Photo 14 Sharp rush (*Juncus acutus*) seed head.*

(Photos: K. Gole, Department of Water)

5.7 Salinity and nutrient management

The cause and impacts of dryland salinisation are well known throughout the Wheatbelt. It is estimated that everyday in Western Australia the equivalent of 19 football ovals of land are lost to dryland salinity (Environmental Protection Authority, 2007).

Although extensive dryland salinisation is predominant in the mid to north-western areas of the Wheatbelt, local hydrogeology, land form and soil types influence salinity risk (Environmental Protection Authority, 2007).

Christopher Brook is known to provide relatively fresh inflows to Talbot Brook and consequently, the Dale River. However, it cannot be assumed that this catchment is not at risk of salinisation. Sharp rush (*Juncus acutus*) is a symptom of saline, waterlogged areas and significant infestations exist along Christopher Brook. There are also salt scalds in the paddocks adjacent to the mid to upper reaches of the main channel.

The groundwater seeps that exist along Christopher Brook and its tributaries are currently considered by locals to provide a source of relatively fresh water. In 1998, hydrogeological investigations were initiated by the Kokedin Creek Catchment Group for the adjacent Kokedin Creek catchment, which has similar landform and soils type characteristics to Christopher Brook. Groundwater seeps are also common in the Kokedin Creek catchment and it appears that most of this discharge is driven by perched aquifers and unconfined groundwater flow (Interra Pty. Ltd., 1998).

The hydrological investigations in Kokedin Creek catchment were to be expanded to a groundwater monitoring program. This program was to provide local landowners with information regarding the factors controlling the distribution of salinity in the catchment. Although the groundwater monitoring bores were installed and monitoring occurred, the results were not analysed or reported.

There is limited information on the hydrogeology and water quality of these groundwater seeps. If these seeps are indeed providing an important source of relatively fresh water, then there is a need to understand how and where they are recharged and what should be done to protect them (i.e. fencing and revegetating upstream areas that may be the recharge points).

It is recommended that the hydrological investigations commenced by the Kokedin Creek Catchment Group are reinstated and expanded to include additional sites in the Christopher Brook catchment. Surface water quality monitoring in Christopher Brook would also assist in obtaining a greater understanding of the sources of relatively fresh water in this catchment.

While there were no point sources of pollution and/or nutrients observed along Christopher Brook, agricultural land uses dominate the catchment. Fertiliser and pesticide runoff commonly enter waterways in agricultural areas. Unrestricted stock access along much of the waterway also means that stock foul the water with their

wastes. This can be more concentrated during summer when there is minimal flow and stock spend more time grazing the riparian zone which offers shade, feed and cooler conditions.

Restricting stock access to the riparian zone will not only prevent stock from fouling the water, it will also allow fringing vegetation to recover and regenerate. A well vegetated riparian zone can remove sediment and nutrients from overland runoff and flow within the stream.

5.8 Fire management

Fire is an important natural feature that shapes the Australian landscape. However, along many waterways the structure of plant communities has changed considerably and the understorey is often dominated by annual agricultural weeds that add to the fuel load.

In the rural landscape, waterways often represent a significant proportion of the remaining remnant native vegetation. Therefore, uncontrolled fires in riparian zones can significantly damage fringing vegetation, destroy habitat, impact on food supplies for native animals and expose the area to erosion and weed infestation. Fires can also damage fences and pose a risk to stock and farm infrastructure.

Although intense fires are damaging, fire can be a useful management tool in appropriate circumstances. For example, some native plants require smoke, intense heat or ash to germinate and carefully controlled fires can be useful in stimulating the germination of these species. Fire can also be useful in reducing the weed burden, especially in heavily infested areas. However, extreme care should be taken when undertaking controlled burns in riparian zones and the use of fire should be considered in consultation with the relevant fire authority and the Department of Water, Northam.

Firebreaks and access to the riparian zone are important, especially along Christopher Brook, as there are no service roads crossing the main channel. When fencing the riparian zone, firebreaks should be located on the river side of the fence, allowing easy access to the area and preventing stock from pushing through fences to graze the riparian zone (Department of Water, 2006).

The Avon Waterways Committee has developed a fire policy that outlines objectives for fire management along the Avon River and its tributaries (Appendix 9).

5.9 Introduced animal control

There were two introduced animals observed along Christopher Brook, namely the European red fox (*Vulpes vulpes*) and European wild rabbits (*Oryctolagus cuniculus*). Feral cats (*Felis catus*) were not observed along the waterway but they were observed along Talbot Brook during its assessment in 2002 (Water and Rivers

Commission, 2002a). Feral cats (*Felis catus*) tend to be wary of humans so it is possible they are also in this catchment.

The European red fox (*Vulpes vulpes*) has played a major role in the decline of a number of native animals, including ground-nesting birds, reptiles, small to medium sized mammals and some threatened species since their introduction in the 1800s. They also prey on newborn lambs, posing an economic threat to sheep farmers (Department of the Environment and Heritage, 2004a).

European wild rabbits (*Oryctolagus cuniculus*) compete with native wildlife, damage vegetation and degrade the land. They effect the success of revegetation projects, eat seedlings and rabbit warrens can cause erosion along waterways.

The most effective methods of fox and rabbit control appear to be baiting, fencing and shooting. Biological control of rabbits has proved effective in some areas of Australia, although it seems to be more effective when followed up with more traditional methods such as baiting or digging up warrens (Department of the Environment and Heritage, 2004b). However, care should be taken when digging up warrens near waterways, to limit the potential of erosion.

Table 21 summarises the problems caused by introduced animals and the possible methods of control.

Table 21 Problems and control of introduced animals (Department of Environment and Heritage, 2004 a to d).

Feral animal	Problems	Control methods
European wild rabbit (*Oryctolagus cuniculus*)	• Ringbarks trees • Prevents regeneration of native plants • Competes with stock and native fauna for food	• Destroying warrens • Shooting • Poisoning • Trapping • Biological control using myxoma virus or calicivirus
European red fox (*Vulpes vulpes*)	• Preys on native fauna • Preys on livestock including lambs and poultry	• Shooting • Baiting
Feral cat (*Felis catus*)	• Preys on native fauna • Preys on livestock such as poultry • Carry infectious diseases	Control is difficult as feral cats do not readily take baits or approach traps. They are difficult to shoot as they are wary of humans
Feral pig (*Sus scrofa*)	• Compete with native fauna for food • Destroy native vegetation and destabilise river banks by trampling and wallowing • Kill livestock • Damage crops • Carry infectious diseases	• Trapping • Shooting

Glossary

Acid(ic)	See pH.
Alkaline	See pH.
Anabranching channel	Diverging and converging channel separated by relatively large, stable islands that are only inundated in flood events.
Alluvium	Sediment deposited by flowing water.
Aquifer	A layer of rock or soil capable of receiving, storing and transmitting quantities of water.
Braided channel	Diverging and converging channel separated by relatively small, unstable bars or sediment slugs which are frequently covered by in-channel flows.
Catchment	The area of land which intercepts rainfall and contributes the collected water to a common point through surface and groundwater.
Confluence	Flowing together or intermingling, for example where a tributary joins the main river channel.
Channel incision	Where the bed of the channel is eroded downwards, creating a deeper channel and steep banks
Debris	Loose and unconsolidated material resulting from the disintegration of rocks, soil, vegetation or other material transported and deposited during erosion
Discharge	Volumetric outflow rate of water, typically measured in cubic metres per second. Applies to both groundwater and surface water.
Discharge area or zone	Area where groundwater discharges to the surface.
Ecosystem	A biological community of interacting organisms and their physical environment.
Electrical conductivity	A measure of salinity. The higher the electrical conductivity of soil or water the greater the salinity.
Erosion	The subsequent removal of soil or rock particles from one location and their deposition in another location.
Floodplain	A broad, flat, low-lying area of land within the valley floor that is inundated during a 100-year flood. Includes the floodfringe and floodway.

Flood – 100 year	The 100-year flood has a statistical probability of occurring, on average, once every 100 years. The 100-year flood level is the contour to which this flood will rise.
Floodfringe	The area of the floodplain, outside of the floodway, that is affected by flooding.
Floodway	The river channel and portion of the floodplain which forms the main flow path for flood waters once the main channel has overflowed.
Foreshore	Area of land next to a waterway.
Groundwater	Water which occupies the pores and crevices of rock or soil.
Groundwater seep	Seeps occur where the groundwater meets the surface. This can be the result of a bedrock high (where the bedrock is close to the surface), dolerite dyke, at the base of a sand rise or where the slope changes.
Habitat	The physical and biological environment on which a particular species depends for its survival.
Hydrogeology	The study of the occurrence and movement of groundwater in the soil and rocks of the Earth's crust
Hydrology	The study of water, it’s properties, distribution and utilisation, above, on and below the earth’s surface.
Introduced species	A general term used to describe species that are not native to the region.
Large woody debris	A branch, tree or root system that has fallen into or is immersed (totally or partially) in a waterway.
Macroinvertebrates	Aquatic invertebrates (animals without backbones) that are retained on a 0.25 mm mesh net and therefore big enough to be seen with the naked eye.
Natural resource management	The ecologically sustainable management of the land, water, air and biodiversity resources for the benefit of existing and future generations.
Nutrient load	The amount of nutrient (usually nitrogen and/or phosphorus) reaching a waterway over a given time period from its catchment area.
pH	The concentration of hydrogen ions in solution that indicates the acidity or alkalinity in water. A pH value of 7 is neutral, above 7 is alkaline and below 7 is acidic.

Recharge	Volumetric inflow rate of water to an aquifer, typically measured in cubic metres per second.
Recharge area or zone	An area through which water percolates to replenish (recharge) an aquifer. Unconfined aquifers are recharged through rainfall. Confined aquifers are recharged in specific areas where water leaks from overlying aquifers, or where the aquifer rises to meet the surface.
Remnant vegetation	An area of vegetation remaining after a major disturbance, such as land clearing.
Riffle	High points in the channel represented by bedrock bars, accumulations of rock or woody debris.
Riparian zone	The riparian zone includes the floodplain and adjacent verge. The width of the riparian zone varies greatly, from 10s of metres to kilometres, depending on the type of waterway and its catchment.
Riparian vegetation	Vegetation growing within the riparian zone.
River basin	The area drained by a waterway and its tributaries (see Catchment).
Runoff	Water that flows over the soil surface when rainfall is greater than the infiltration capacity of the soil. Flow in waterways results from rainfall runoff.
Salinity	A measure of the total soluble (dissolved) salts in water. Commonly measured in terms of total dissolved salts (TDS) in milligrams per litre (mg/L), or electrical conductivity, in millisiemens per metre (mS/m) or millisiemens per centimetre (mS/cm). Water resources are classified as fresh, marginal, brackish or saline on the basis of salinity.
Salinisation	An increase in the concentration of soluble salts in soil or water.
Sand lense	An area of deep, sandy soils. Where these areas are in contact with finer-textured soils, such as clays, seeps often occur. This is where water contained within the sand lense moves downslope and flows out at the bottom of the lense. These seeps can be fresh or saline.
Sediment	Sand, clay, silt, pebbles and organic matter carried and deposited by wind or water.

Sedimentation	The process by which sediment is deposited, for example in waterways.
Sediment load	The amount of sediment reaching a waterway over a given time period from its catchment area. Also refers to the amount of sediment being transported by a waterway.
Sediment slug	An accumulation of sediment within a waterway formed where the flow velocity slows to the point where there is not enough energy to continue to carry the sediment suspended in the water column, for example on meander bends and river pools.
Slumping	The process by which undercut, unsupported banks collapse. The result of the undercutting.
Subsidence	Another form of bank collapse where flows saturate banks and they collapse under the added weight of the water
Surface water	Water flowing or held in waterways such as creeks, rivers and wetlands.
Terrestrial	Relating to land (as opposed to water).
Turbidity	A measure of how cloudy water is. Turbid water is caused by sediment or other pollutants.
Tributary	A waterway that flows into a larger waterway.
Undercutting	Occurs on vertical banks where streamflow scours sediment from the toe (bottom) of the bank.
Verge	Upland area adjacent to the floodplain.
Water quality	The physical, chemical and biological measures of water.
Waterlogging	Excess water close to the soil surface.
Watertable	Saturated level of unconfined groundwater. Wetlands in low-lying areas may be surface expressions of groundwater.
Waterway	Surface water bodies, including streams, rivers, lakes, wetlands, estuaries, coastal lagoons and inlets. Can be seasonally or permanently inundated.

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Appendix 1 Foreshore and channel assessment form

For property and paddock scale surveys

General details

Recorder's name: …….. Survey date: ……

Tributary name: …….Section number: …DRS ……

Catchment name: Avon River Length of section: ……...

Sub-catchment name: ……... Shire:……

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

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

Landholder contacted: Yes ❒ No ❒ Bank(s) surveyed (facing upstream)
Landholder consent obtained: Yes ❒ No ❒ Left ❒ Right ❒ Both ❒
Landholder present during survey: Yes ❒ No ❒

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

Property address: ……

Bank stability

Proportion of bank affected (% of survey area)	Undercutting	Firebreak/track washouts	Subsidence (sinking of soil)	Gully erosion	Sedimentation	Slumping (mass movement)
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
❒ Deep pool
❒ Wetlands
❒ Groundwater seep
❒ Natural riffle
❒ Anabranch
❒ Tributary
❒ Large woody debris
❒ Vegetated island
❒ Constructed riffles
❒ Sediment slug
❒ Crossing
❒ Dam
❒ Bridge
❒ Other
……
……

Channel width (m) ..... Channel depth (m).....

Vegetation health

❒ Looks healthy ❒ Some sick trees (some foliage loss) ❒ 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 (native and weeds)

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

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

Birds (roosting/nesting sites)
- ❒ Trees
- ❒ Shrubs
- ❒ Rushes

Frogs
- ❒ Dense fringing vegetation
- ❒ Emergent plants/soft substrate for eggs

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

Mammals
- ❒ Dense protective vegetation

Water quality

pH……

Salinity (ms/m)……

Temperature (ºC)……

Comments on water quality:

Fencing status

Fence section 1

Start……E Start……..N End……..……E End…….……..N

Left bank ❒ Right bank ❒

Fence condition: ❒ Good ❒ Moderate ❒ Poor ❒ No fence

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

Approximate distance [m] from main channel: ❒ <10m ❒ 10-20m ❒ 20-30m ❒ >30m

Fence section 2

Start……E Start……..N End……..……E End…….……..N

Left bank ❒ Right bank ❒

Fence condition: ❒ Good ❒ Moderate ❒ Poor ❒ No fence

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

Approximate distance [m] from main channel: ❒ <10m ❒ 10-20m ❒ 20-30m ❒ >30m

Fence section 3

Start……E Start……..N End……..……E End…….……..N

Left bank ❒ Right bank ❒

Fence condition: ❒ Good ❒ Moderate ❒ Poor ❒ No fence

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

Approximate distance [m] from main channel: ❒ <10m ❒ 10-20m ❒ 20-30m ❒ >30m

Fence section 4

Start……E Start……..N End……..……E End…….……..N

Left bank ❒ Right bank ❒

Fence condition: ❒ Good ❒ Moderate ❒ Poor ❒ No fence

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

Approximate distance [m] from main channel: ❒ <10m ❒ 10-20m ❒ 20-30m ❒ >30m

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

Crossing Point: ❒ Yes ❒ No

Foreshore condition rating

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 health 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

Tributary assessment

Tributary survey section number: ……..

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

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

General foreshore rating: ……..

Comments:

Evidence of management

Tick the appropriate boxes:

❒ Prescribed burning
❒ Firebreak control
❒ Fencing
❒ Weed control
❒ Revegetation
❒ Erosion control
❒ Sediment management
❒ Other:……..

Management issues

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

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

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

Ideas for management

Tick the appropriate boxes:

❒ Firebreak control
❒ Fencing
❒ Erosion control
❒ Stock/vehicle crossing
❒ Revegetation
❒ Weed control
❒ Riffles
❒ Sediment management
❒ Other: …….

Native plant list

Introduced plant list

Native fauna list

Introduced fauna list

GPS coordinates

Coordinate	Description

Photos

Photo number	Description

Appendix 2 Examples of fence condition ratings

Fence in poor condition

Fence in moderate condition

Fence in good condition

(Photos: K. Gole, Department of Water)

Appendix 3 Foreshore grading system

A-grade – Foreshore has healthy native bush 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 replace 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.

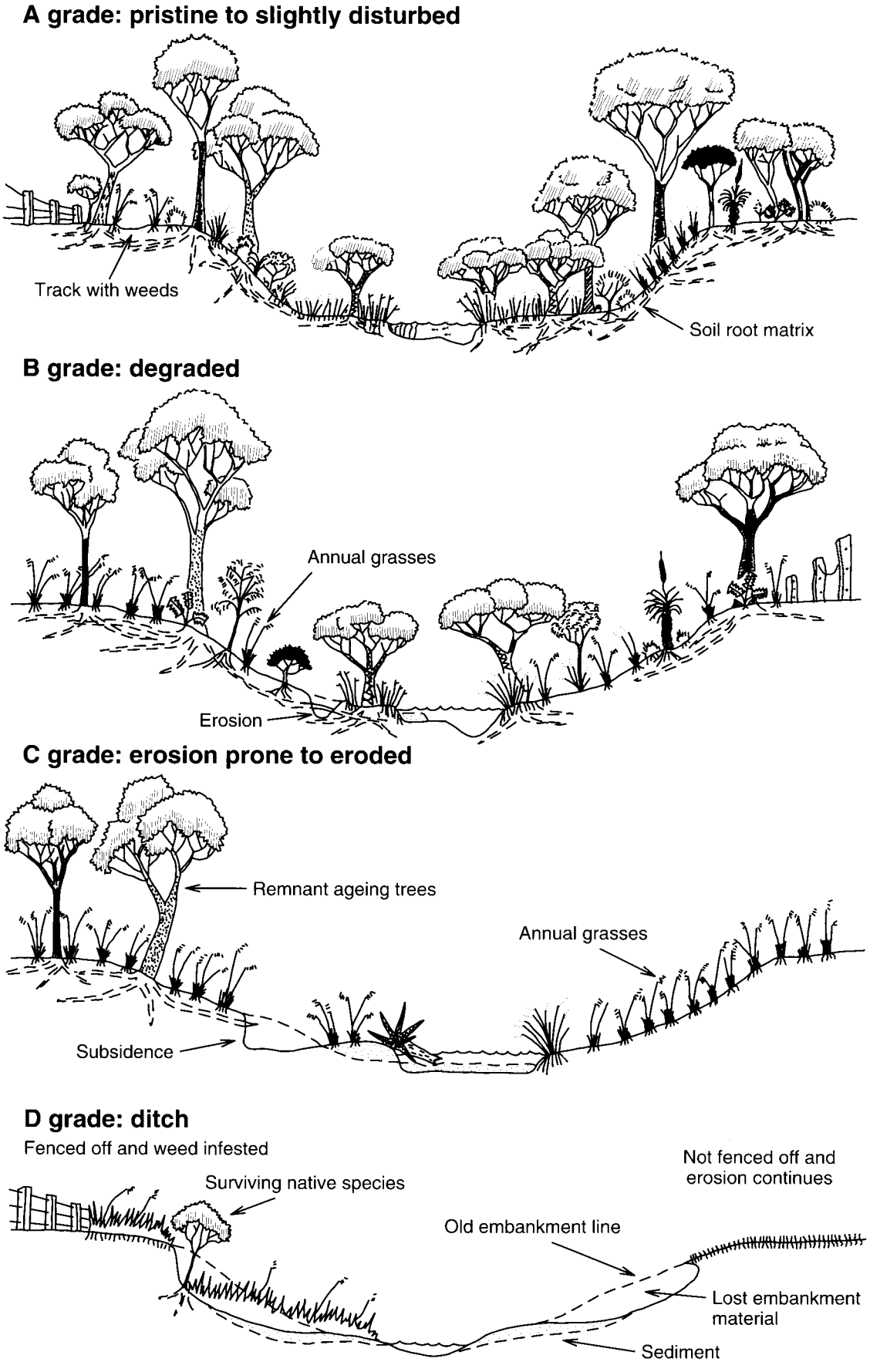
C3. Eroded – Soil is washed away from between tree roots. Trees are being undermined and unsupported embankments are subsiding into the river valley.

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.



Adapted from Water and Rivers Commission, 1999

Appendix 4 Factors and scoring for determining the stream health rating

	Floodway and bank vegetation	Verge vegetation	Stream cover	Bank stability and sedimentation	Habitat diversity
Excellent	Healthy undisturbed native vegetation. Virtually no weeds. No disturbance. **(15 points)**	Healthy undisturbed vegetation. Verges more than 20 m wide. **(8 points)**	Abundant cover: shade, overhanging vegetation, snags, leaf litter, rocks and/or aquatic vegetation. **(8 points)**	No erosion, subsidence or sediment deposits. Dense vegetation cover of banks and verge. No disturbance. **(8 points)**	3 or more habitat zones. Some permanent water . **(6 points)**
Good	Mainly healthy undisturbed native vegetation. Some weeds. No recent disturbance. **(12 points)**	Mainly healthy undisturbed native vegetation. Verges less than 20 m wide. **(6 points)**	Abundant shade and overhanging vegetation. Some instream cover. **(6 points)**	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. **(6 points)**	2 habitat zones. Some permanent water. **(4 points)**
Moderate	Good vegetation cover, but mixture of native and exotic species. Localised clearing. Little recent disturbance. **(6 points)**	Good vegetation cover, but mixture of native and exotic species. Verges 20 m or more. **(4 points)**	Some permanent shade and overhanging vegetation. Some instream cover. **(4 points)**	Good vegetation cover. Localised erosion, bank collapse and sediment heaps only. Verges may have sparse vegetation cover. **(4 points)**	Mainly 1 habitat type with permanent water, OR range of habitats with no permanent water. **(2 points)**
Poor	Mainly exotic groundcover. Obvious site disturbance. **(3 points)**	Narrow verges only (< 20 m wide). Mainly exotic vegetation. **(2 points)**	Channel mainly clear. Little permanent shade or instream cover. **(2 points)**	Extensive active erosion and sediment heaps. Bare banks and verges common. Banks may be collapsing. **(2 points)**	Mainly 1 habitat type with no permanent water. **(1 point)**
Very poor	Mostly bare ground or exotic groundcovers (i.e. pasture, gardens or weed infestations, but no trees). **(0 points)**	Mostly bare ground or exotic groundcovers (i.e. pasture, gardens or weed infestations, but no trees). **(0 points)**	Virtually no shade or instream cover. **(0 points)**	Almost continuous erosion. Over 50% of banks collapsing. Sediment heaps line or fill much of the floodway. Little or no vegetation cover. **(0 points)**	Stream channellised. **(0 points)**

Scores for surrounding landuse:

Conservation reserve	**(8 points)**	Rural residential	**(4 points)**	Agricultural	**(2 points)**
Remnant bush	**(6 points)**	Urban	**(2 points)**	Commercial/ industrial	**(2 points)**

Adapted from Water and Rivers Commission 1999, Planning and Management: Foreshore condition assessment in farming areas of south-west Western Australia*, River Restoration Report No. RR3.*

Appendix 5 Plants and animals identified during the survey of Christopher Brook

Table A.5.1 Native plants identified during the survey

Common name	Scientific name
Tree	
Flooded gum	*Eucalyptus rudis*
Marri^	*Corymbia calophylla*
Swamp paperbark	*Melaleuca rhaphiophylla*
Swamp sheoak	*Casuarina obesa*
Swamp banksia	*Banksia littoralia*
Wandoo	*Eucalyptus wandoo*
York gum	*Eucalyptus loxophelba sub. loxophelba*
Shrub	
Pea flower	*Gastrolobium sp.*
Golden wreath wattle	*Acacia saligna*
Grass tree	*Xanthorrhoea preissii*
Harsh hakea	*Hakea prostrata*
Jam	*Acacia acuminata*
	Melaleuca adnata
Mohan	*Melaleuca viminea sub viminea*
Needlebush	*Hakea pressii*
Pea flower	*Gastrolobium sp.*
Prickly moses^	*Acacia pulchella*
Swamp cypress	*Actinostrobus pyramidalis*
Rushes and sedges	
	Baumea pressii
Knotted clubrush*	*Ficinia nodosa*
	Lepidosperma costale
River twigrush*	*Baumea riparia*
Pale rush^	*Juncus pallidus*
Pithy saw sedge	*Lepidosperma longitudinale*
Spiny flat sedge^	*Cyperus gymnocaulos*
Aquatic	
Filamentous green algae	

* Found only on tributaries
^ Found only on main channel

Table A.5.2 Introduced plants identified during the survey

Common name	Scientific name
Fern	
Tree fern*	*Sphaeropteris cooperi*
Herb	
Cape tulip	*Homeria spp*
Capeweed	*Arctotheca calendula*
Corkscrew	*Erodium botrys*
Flatweed	*Hypochaeris spp*
Four o'clock	*Oxalis purpurea*
Guildford grass^	*Romulea rosea*
Narrowleaf lupin^	*Lupinus angustifolius*
Soursob	*Oxalis pes-caprae*
Waterbuttons	*Cotula coronopifolia*
Grass	
Barley grass	*Hordeum leporinum*
Love grass^	*Eragrostis spp*
Rye grass*	*Lolium sp.*
Salt-water couch	*Paspalum vaginatum*
Wild oats	*Avena fatua*
Rushes and sedges	
Bulrush	*Typha orientalis*
Sharp rush	*Juncus acutus*

* Found only on tributaries ^ Found only on main channel

Table A.5.3 Animals identified during the survey

Common name	Scientific name
Native mammals	
Brushtail possum^	*Trichosurus vulpecula*
Echidna*	*Tachyglossidae spp.*
Western grey kangaroo	*Macropus fuliginosus*
Amphibians	
Motorbike frog	*Litoria moorei*
Quacking frog	*Crinia georgiana*
Reptiles	
Unidentified goanna	*Varanid spp.*
Western blue-tongued skink^	*Tiliqua occipitalis*
Introduced mammals	
European red fox	*Vulpes vulpes*
European wild rabbit	*Oryctolagus cuniculus*

* Found only on tributaries ^ Found only on main channel

Table A.5.4 Bird species identified during the survey

Common name	Scientific name	Habitat type**	Conservation status**
Bird species			
Australian magpie	*Gymnorhina tibicen*	Woodland	Farmland
Australian magpie-lark	*Grallina cyanoleuca*	Woodland	Farmland
Australian raven	*Corvus coronoides*	Farmland	Farmland
Australian ringneck	*Barnardius zonarius*	Farmland	Farmland
Black-faced cuckoo-shrike^	*Coracina noveahollandiae*	Woodland	Farmland
Black-shouldered kite	*Elanus notatus*		
Brown honeyeater*	*Lichmera indistincta*		
Brown quail*	*Coturnix ypsilophora*		
Crested pigeon	*Ocyphaps lophotes*	Farmland	Farmland
Elegant parrot*	*Neophema elegans*		
Galah	*Eolophus roseicapilla*	Woodland	Farmland
Great egret	*Ardea alba*		
Grey fantail	*Rhipidura fuliginosa*	Woodland	Remnant Dependant
Grey teal	*Anas gracilis*	Farmland	Farmland
Grey-shrike thrush*	*Colluricincla harmonica*	Woodland	Remnant Dependant
Laughing kookaburra	*Dacelo novaeguineae*		
Martin spp^	*Hirundo spp*		
Pacific black duck	*Anas superciliosa*		
Red-capped parrot^	*Purpureicephalus spurius*		
Red wattlebird*	*Anthochaera carunculata*	Woodland	Remnant Dependant
Rufous treecreeper^	*Climacteris picumnus*	Woodland	Priority
Silvereye*	*Zosterops luteus race chloronotos*		
Splendid fairy-wren	*Malurus splendens*		
Spotted pardolote	*Pardalotus punctatus*		
Wedge-tailed eagle	*Aquila audax*		
Weebill	*Smicronis brevirostris race occidentalis*	Woodland	Remnant Dependant
Western gerygone*	*Gerygone fusca*	Farmland	Remnant Dependant
Western thornbill	*Acanthiza inornata*		
White-browed scrubwren*	*Sericornis frontalis*		
White-faced heron^	*Egretta novaehollandiae*	Farmland	Farmland
Willie wagtail	*Rhipidura leucophrys*	Woodland	Farmland

* Found only on tributaries
^ Found only on main channel

** Greening Australia Western Australia, 1994

Appendix 6 Fencing information for surveyed sections of Christopher Brook

Table A.6.1 Length and condition of fencing for each surveyed section

Section	**Left Bank Fence** (m)	**Right Bank Fence** (m)	**Length of Section** (m)
Main Channel			
CB001		190 (P)	190
CB002			1100
CB003		600 (M)	600
CB004	470 (M)		470
CB005			900
CB006		1100 (G)	1100
CB007			800
CB008			800
CB009		650 (G)	650
CB010			350
CB011			1300
CB012	400 (P)	700 (M)	1350
CB013			1050
CB014			650
CB015			620
CB016			1000
CB017			1950
CB018	600 (G)	600 (G)	600
CB019			550
CB020			420
Total	**1 470**	**3 840**	**16 450**
Tributaries			
CBTrib001-A			290
CBTrib001-B			1100
CBTrib001-C	450 (M)	450 (M)	450
CBTrib001-D	1600 (G)	1600 (G)	1600
CBTrib001-E			400
CBTrib001-F			1200
CBTrib002			200
CBTrib003-A			750
CBTrib003-B			300
CBTrib004			300
CBTrib005-A			400
CBTrib005-B			200
CBTrib005-C			450
CBTrib006			500
CBTrib007			250
Total	**2 050**	**2 050**	**8 390**

Fence condition – (G) = good, (M) = moderate, (P) = Poor

Appendix 7 Description and management options for each surveyed section

Table A.9.1 Description and management options for each surveyed section of Christopher Brook (main channel)

Section	General foreshore grade	Overall environmental stream health rating	Section description	Management options
CB001	C-grade	Poor	This section is relatively short but contains two significant meanders. Bank erosion is evident and the channel is deeply incised with steep banks. A small depression/ wetland exists on the left bank but it is doubtful that it has received flow from the main channel for some time, due to the depth of incision in the channel. This section was rated to be in poor condition. There is no regeneration of native vegetation and the understorey is exclusively weeds, including sharp rush (*Juncus acutus*). The right bank is fenced, although the fencing requires repair or replacement. There is a significant sediment deposit in Talbot Brook, directly opposite the confluence of Christopher Brook. This may be partially caused by sediment deposition from Christopher Brook. Tannin staining (caused by the leaching of organic substances from native vegetation) appears to be evident in Christopher Brook but not so obvious in Talbot Brook.	• This section appears to be a small paddock which would benefit from replacing the fencing on the right bank and maintaining low stocking rates to suppress weed growth and encourage natural regeneration. • There are a few occurrences of sharp rush (*Juncus acutus*) in this section which should be controlled.
CB002	C-grade	Poor	This section has areas of calcrete pavement that are exposed along the banks and in the channel, forming small cascades and waterfalls. There is a short anabranch on the right bank, and the confluence of the first tributary (DRSTrib001) is located at the end of this anabranch. The channel is deeply incised, demonstrated by some exposed tree roots. The channel is well shaded in some sections, although the instream vegetation is dominated by sharp rush (*Juncus acutus*) and bulrush (*Typha orientalis*). Fringing vegetation is limited to that growing within or immediately adjacent to the channel and the channel is unfenced. This section was rated to be in poor condition.	• Although stock access is obviously managed, fencing the waterway so that it is not part of a paddock would enable the waterway to recover. Stock could still be allowed access to suppress weeds and reduce the fire risk, so long as access to the channel is carefully managed. • Sharp rush (*Juncus acutus*) and bulrush (*Typha orientalis*) dominate the channel and should be progressively removed and replaced with native rushes.

Section	General foreshore grade	Overall environmental stream health rating	Section description	Management options
CB003	C-grade	Poor	There a number of meanders in this section and the channel braids for approximately 150 metres. This section was rated to be in poor condition as there is a significant amount of sedimentation and the understorey is dominated by weeds. There are a few isolated patches where wandoo (*Eucalyptus wandoo*) is regenerating. Sharp rush (*Juncus acutus*) is not as dominant in this section. The right bank is fenced.	• Fence left bank to limit stock access and encourage natural regeneration.
CB004	C-grade	Moderate	There are no significant meanders in this section. The channel braids for approximately 100 metres and the island is well vegetated with swamp paperbark (*Melaleuca rhaphiophylla*), although weeds dominate the understorey. This section was rated to be in moderate condition. The channel is well shaded by a mixture of flooded gum (*Eucalyptus rudis*), wandoo (*Eucalyptus wandoo*) and swamp paperbark (*Melaleuca rhaphiophylla*), all of which are healthy and regenerating. Exposed calcrete pavement and woody debris in the channel provided a mixture of instream habitats. The right bank is fenced.	• Fence left bank to limit stock access and encourage natural regeneration. • There is an informal stock crossing (E 479564 N6439609) which would benefit from being made into a formal crossing with fencing and large rocks to stabilise the soft bed.
CB005	C-grade	Moderate	A number of deep pools exist in this section, some of which are located on meander bends. The banks are steep along much of this section. This section is unfenced and cattle have caused some damage to the banks and swamp paperbarks (*Melaleuca rhaphiophylla*). There is abundant shade and instream habitat and the flooded gums (*Eucalyptus rudis*) and swamp paperbarks (*Melaleuca rhaphiophylla*) are regenerating. The confluence of the second major tributary (CBTrib002) is at the end of this section. This section was rated to be in moderate condition.	• This section is in reasonable condition but is at risk of deteriorating due to stock access. Fencing the channel would allow natural regeneration to occur and stock could still be allowed periodic access to suppress weed growth. • In the proposed fence line, construct a crossing point at the current location (E478955 N6439456). • Remove sharp rush (*Juncus acutus*).

Section	General foreshore grade	Overall environmental stream health rating	Section description	Management options
CB006	C-grade	Poor	There is a significant anabranch that extends up to 150 m south of the main channel, which has moderately sloping banks, vegetated only by annual grasses. This anabranch would have carried a significant volume of flow prior to the incision of the main channel, but now only holds runoff from the adjacent paddock. The banks in much of this section are exposed calcrete pavement, with some of the bank having a 90º gradient. There is very little fringing vegetation remaining to support the banks and some large wandoos (*Eucalyptus wandoo*) are at risk of collapsing into the channel due to undercutting. The channel is deeply incised and dominated by bulrush (*Typha orientalis*), with patches of pithy sword sedge (*Lepidosperma longitudinale*) and sharp rush (*Juncus acutus*). This section was rated to be in poor condition.	• Fencing the main channel and anabranch and revegetating as one management unit would significantly improve this section and provide improved conservation value to this waterway. • In the proposed fence line, construct a crossing point at a suitable location. • Sharp rush (*Juncus acutus*) and bulrush (*Typha orientalis*) dominate the channel and should be progressively removed and replaced with native rushes.
CB007	C-grade	Poor	There are a few deep pools in this section and an anabranch at the start of the section, which would only carry water in high flow events. There is a fresh groundwater seep in the floodway, in the middle of the section. There is a significant amount of sediment in the channel which is infested with sharp rush (*Juncus acutus*). The banks along much of the section are eroding and slumping into the channel, exposing the calcrete pavement which is a dominant sub-soil feature in the middle sections of this catchment. One minor tributary occurs in this section, which is dominated by sharp rush (*Juncus acutus*). This section was rated to be in poor condition.	• Fence both banks to limit stock access. • In the fence line, construct a crossing point and harden the bank up with field stone to create a rocky riffle. • Sharp rush (*Juncus acutus*) and bulrush (*Typha orientalis*) dominate the channel and should be progressively removed and replaced with native rushes.

Section	General foreshore grade	Overall environmental stream health rating	Section description	Management options
CB008	C-grade	Poor	Three significant tributaries enter the main channel in this section. Each of the tributaries have well-vegetated subcatchments that drain groundwater seepages. The fringing vegetation in this section is quite diverse and some species are regenerating. However, the verges are still quite narrow (less than 20 metres) and the paddock is used for cattle grazing. The channel has significant sedimentation and undercutting but is stable in some sections and dominated by the native sedge *Baumea pressii*. This section was rated to be in poor condition, although its score (18) was close to being moderate (20–29 is moderate).	• Fence both banks to limit stock access. • In the fence line, construct a crossing point at the current location (E 477074 N 6439242) and harden the bank up with field stone to create a rocky riffle. • Remove sharp rush (*Juncus acutus*).
CB009	C-grade	Poor	This section is similar to the previous section and was also rated to be in poor condition (also scoring 18 points). This section has no tributaries and more species are regenerating here than in the previous section. Sharp rush (*Juncus acutus*) is dominant. The banks are stable with only localised undercutting but the channel still has significant sedimentation, possibly washed in from upstream. Salinity levels recorded during the survey increased considerably in this section and remained high upstream, indicating that the tributaries in section CB008 provide significant quantities of lower salinity water.	• Maintain low stocking rates or fence banks if intending to use paddock for stock grazing. • Progressively remove sharp rush (*Juncus acutus*).
CB010	C-grade	Poor	This is a short section where the main channel starts to meander in a north-west direction. The section is unfenced, although the stocking rates appear to be well managed. The banks in this section are moderately sloping with only localised undercutting and slumping. However, there is still significant sedimentation of the channel, which is again lined with regenerating sharp rush (*Juncus acutus*). The fringing vegetation is comprised mainly of trees with few native shrubs or sedges and rushes present. This section was rated to be in poor condition.	• Maintain low stocking rates or fence banks if intending to use paddock for stock grazing. • Progressively remove sharp rush (*Juncus acutus*).

Section	General foreshore grade	Overall environmental stream health rating	Section description	Management options
CB011	C-grade	Poor	This section is highly sinuous, with a number of significant meanders. The channel is lined with sediment, the banks are exposed and undercutting is significant. Granite intrusions can be found in this section, with one area creating a natural riffle. This section is unfenced, and although current stocking rates are low, it appears it may have been heavily stocked in the past due to the limited amount of fringing vegetation. This section was rated to be in poor condition.	• Maintain low stocking rates or fence banks if intending to use paddock for stock grazing. • Ripping and direct seeding could be trialled to assist in the regeneration process. • Progressively remove sharp rush (*Juncus acutus*).
CB012	C-grade	Poor	This section has a significant meander pattern. There is a large meander at the start of the section that is experiencing severe erosion and, if left unmanaged, will continue to erode into the adjoining farmland. There is an anabranch, which is cut off from the main channel, mid-way through the section. The majority of the section has little fringing vegetation and the channel is lined with sharp rush (*Juncus acutus*). However, there has been an attempt at fencing the channel and revegetation, although some of the planting has not been successful. This may be due to salinisation, as salt scald is apparent immediately north-west of this revegetation site. Exposed calcrete pavement provides some natural riffles toward the end of the section. The sixth major tributary (CBTrib006) flows into the main channel in this section. This section was rated to be in poor condition.	• Replace fencing around revegetated area and extend along remainder of section. • Trial ripping and direct seeding or plant seedlings of salt tolerant species to assist with regeneration. • In the fence line, construct crossing points at the current locations (E474642 N6439404 & E473868 N6438934) and harden up with field stone. • Progressively remove sharp rush (*Juncus acutus*) and replace with native rushes to enhance biodiversity.

Section	General foreshore grade	Overall environmental stream health rating	Section description	Management options
CB013	C-grade	Moderate	The valley floor is broad and the channel narrows considerably in this section. An anabranch exists in this section and is still connected to the main channel. Sharp rush (*Juncus acutus*) dominates the banks and has possibly contributed to the incision of the channel, with high flows cutting down into the channel, rather than the bank, which is stabilised by the weed. Fringing vegetation is healthy, regenerating and diverse and verges are more than 20 m wide in some areas. Although this section is unfenced, the stocking rates appear to be well managed. This section was rated to be in moderate condition.	• Maintain low stocking rates or fence banks if intending to use paddock for stock grazing. • Progressively remove sharp rush (*Juncus acutus*) and replace with native rushes to enhance biodiversity.
CB014	B-grade	Moderate	This section had significant regeneration of native tree species. Fringing vegetation is healthy and there is a diversity of native shrubs and sedges present. Verges are 20 metres or more along much of this section. The channel is similar to the previous section, being incised and lined with sharp rush (*Juncus acutus*). There is a patch mid-way through the section where sharp rush (*Juncus acutus*) has invaded the floodway. This section was rated to be in moderate condition.	• Progressively remove sharp rush (*Juncus acutus*) and replace with native rushes to enhance biodiversity.
CB015	D-grade	Very poor	This section is a contrast to the previous section, as it has almost no fringing vegetation. This has lead to significant erosion of the channel. The channel is incised and lateral erosion is also evident. The broad valley floor continues. At the start and end of this section there is some revegetation, although it is providing little bank stability and the fencing requires replacement. There are a number of farm crossings and sharp rush (*Juncus acutus*) occurs in the channel. This section was rated to be in very poor condition.	• Fencing the channel and excluding stock for 5 years (with crash grazing to control weeds) would allow natural regeneration to occur. This would enable the banks to stabilise and slow or possibly halt the lateral erosion, which will eventually consume valuable adjacent agricultural land. • Trial ripping and direct seeding or plant seedlings of rapidly-growing, salt tolerant species to assist with regeneration. • Remove sharp rush (*Juncus acutus*). • In the fence line, construct crossing points at the current locations (E472229 N6439036 & E472100 N6439085) and harden up with field stone.

Section	General foreshore grade	Overall environmental stream health rating	Section description	Management options
CB016	D-grade	Very poor	This section is similar to the previous section, with very little fringing vegetation and a significant degree of erosion. There is a large block of revegetation at the start of the section which extends 50-150 metres north of the channel but it is providing little stability to the bank. There are a number of contour banks that appear to have been installed to manage surface water from adjacent paddocks. This section was rated to be in very poor condition.	• Fencing the channel and excluding stock for 5 years (with crash grazing to control weeds) would allow natural regeneration to occur. This would enable the banks to stabilise and slow or possibly halt the lateral erosion, which will eventually consume valuable adjacent agricultural land. • Trial ripping and direct seeding or plant seedlings of rapidly-growing, salt tolerant species. • Remove sharp rush (*Juncus acutus*). • In the fence line, construct crossing points at the current locations (E472229 N6439036 & E472100 N6439085) and harden up with field stone.
CB017	C-grade	Poor	The channel narrowed considerably in this section but is significantly infested with sharp rush (*Juncus acutus*). This made it difficult to access parts of this section, as the sharp rush is up to 100 metres thick. There has been a significant amount of planting in this section, including swamp sheoak (*Casuarina obesa*), jam (*Acacia acuminata*) and golden wreath wattle (*Acacia saligna*), all which have survived and are regenerating. As with the previous section, there are a number of contour banks that have been installed to manage surface water. This section was rated to be in poor condition.	• There is a significant amount of sharp rush (*Juncus acutus*) in this section, which should be progressively removed and replaced with native rushes to enhance biodiversity. • Maintain low stocking rates for weed suppression.

Section	General foreshore grade	Overall environmental stream health rating	Section description	Management options
CB018	B-grade	Poor	This is a short section which is part of a 25 hectare revegetation site, which was planted in the 1980s. The area is fenced and has no stock access, which has contributed to a high survival rate of seedlings. In some parts, the channel is incised and undercutting is occurring, although the sharp rush (*Juncus acutus*) is providing some bank stability. There is one minor tributary in this section, which is in similar condition to the main channel. The valley floor is steeper in this section which is close to the headwaters. Salinity levels recorded during the survey were lower in this and the remaining upstream sections, possibly due to groundwater seepages and the well-vegetated headwaters.	• There is a significant amount of sharp rush (*Juncus acutus*) in this section, which should be progressively removed and replaced with native rushes to enhance biodiversity.
CB019	C-grade	Poor	The valley floor is steep in this section and the channel is poorly defined in some parts, being a sequence of seeps rather than a defined channel. The channel then reforms upstream. Fringing vegetation is patchy and the infestation of sharp rush (*Juncus acutus*) continues through this section. Although this section is unfenced it appears to be used predominately for cereal cropping. Salt scald is evident in the floodplain and in adjacent paddocks. This section was rated to be in poor condition.	• Maintain low stocking rates or fence banks if intending to use paddock for stock grazing. • Progressively remove sharp rush (*Juncus acutus*) and replace with native rushes to enhance biodiversity. • Plant native species tolerant to salinity and waterlogging to control salt scald extending into valuable farmland.
CB020	C-grade	Poor	This section is where Christopher Brook first forms a channel, although it is poorly defined in parts. Upstream there is a bushland reserve and numerous granite outcrops. Despite recent rains, there was limited flow in this section. Some small pools exist but are possibly the result of seepage. The seventh major tributary (CBTrib007) formed part of the headwaters in this section.	• Maintain low stocking rates or fence banks if intending to use paddock for stock grazing.

Table A.9.2 Description and management options for each surveyed section of major tributaries flowing into Christopher Brook

Section	General foreshore grade	Overall environmental stream health rating	Section description	Management options
CBTrib001 This is a significant tributary of Christopher Brook, which extends approximately 5–6 km to the south. This tributary flows through a large block of native vegetation near the corner of Springhill Rd and York-Williams Rd. This tributary has been divided into six sections for the purposes of this survey.				
CBTrib001-A	D-grade	Very poor	This section is significantly degraded. Fringing vegetation is limited to a few individuals of wandoo (*Eucalyptus wandoo*), which is not regenerating. Sharp rush (*Juncus acutus*) dominates. The left bank is stable due to extensive calcrete but the right bank is less stable due to the presence of alluvial soils. This section is unfenced and was rated to be in very poor condition.	• Fence both banks to limit stock access. • Assist natural regeneration by revegetating tributary with suitable native species. • In the fence line, construct a crossing point and harden the bank up with field stone to create a rocky riffle. • Sharp rush (*Juncus acutus*) dominates the channel and should be progressively removed and replaced with native rushes.
CBTrib001-B	D-grade	Very poor	This section is similar to the previous section. It is significantly degraded by limited fringing vegetation and there is a dominance of sharp rush (*Juncus acutus*) that has recently regenerated. The landowner has designed some effective surface water banks and is stabilising the banks with large logs. There is an anabranch along the right bank, which is not vegetated. This section is unfenced and was rated to be in very poor condition.	• Fence both banks to limit stock access. • Assist natural regeneration by revegetating tributary with suitable native species. • In the fence line, construct a crossing point and harden the bank up with field stone to create a rocky riffle. • Sharp rush (*Juncus acutus*) dominates the channel and should be progressively removed and replaced with native rushes.
CBTrib001-C	B-grade	Good	This section was rated to be in good condition and is a significant contrast to the previous two sections. It appears to be a relatively fresh groundwater seepage area, which may have increasing salinity. There has been active revegetation by the landowner of Melaleuca and Eucalypt species and native sedges and rushes are regenerating naturally. However, it was noted that swamp cypress (*Actinostrobus pyramidalis*) is in decline.	• The landowner should be congratulated for their extensive efforts to revegetate this area. Little needs to be done in this section to maintain or improve its value, other than remove the sharp rush (*Juncus acutus*) before it spreads.

Section	General foreshore grade	Overall environmental stream health rating	Section description	Management options
CBTrib001-D	A-grade	Excellent	This section comprises an extensive area of relatively fresh groundwater seepage. The condition of vegetation improves in this area, becoming dense with high species diversity, significant regeneration and little weed invasion, although some sharp rush (*Juncus acutus*) is present. Some areas of this section can be defined as being 'near pristine'. The aerial photograph for this area shows a treeless patch, which is in fact a seepage area which probably has detained winter surface water (Photo CBTrib001-4 10). There has been a deep drain constructed (>10 years ago) adjacent to the boundary fence. This is discharging very little groundwater flow into the tributary. The deep drain is unlikely to provide significant benefits but is unlikely to be causing significant harm. This section was rated as being in excellent condition and has high conservation value.	• The landowner has retained and improved the conservation value of this area. Again, little needs to be done in this section to maintain its value, other than remove sharp rush (*Juncus acutus*) before it spreads.
CBTrib001-E	A-grade	Good	At the start of this section there is remnant vegetation in a fresh groundwater seepage area which is healthy and regenerating. At the time of the survey there was no streamflow upstream from the seepage area despite recent rains. A small road culvert indicates there is probably minimal flow at this site even during winter. Several water supply dams ('soaks') have been constructed within the vegetation, which probably provides a reliable farm water supply. This section was rated as being in good condition.	• The native vegetation at the start of this section is in good condition and if stock are excluded from the area, it should regenerate naturally and spread towards Springhill Road.

Section	General foreshore grade	Overall environmental stream health rating	Section description	Management options
CBTrib001-F	C-grade	Poor	This section is mostly cleared agricultural land, with little fringing vegetation, although there is a small patch of remnant vegetation mid-way through the section. Although the channel is cleared, there is limited erosion. Some streamflow is also captured in a farm dam at the end of this section (photo CBTrib001-6 08). This section was rated to be in poor condition.	• As a minimum, the patch of remnant vegetation should be fenced and stock excluded to allow natural regeneration to occur. Extension of the vegetation along the length of the section would provide an important ecological linkage to the remnant bushland to the north.
CBTrib002	D-grade	Very poor	There is a waterfall and a significant pool at the confluence of this tributary with the main channel. The confluence is located in an area where there is a large amount of exposed calcrete. It is possible that the waterfall was created when the main channel became incised, starting off as gully erosion and progressing as far as the hard rock would allow. The channel of this tributary is narrow and has little fringing vegetation other than annual grasses for the first 300 metres. Beyond this point, there has been some revegetation of the banks as it flows around the base of a large, cleared hill.	• Fence both banks to control stock access. • Revegetate with species tolerant to salinity and waterlogging, especially in first 300 metres.
CBTrib003 This tributary has been divided into two survey sections.				
CBTrib003-A	B-grade	Moderate	This section was rated to be in moderate condition. The channel and banks are well-vegetated, predominately with a diversity of native species. Weeds are comprised mainly of annual grasses, although there are some occurrences of bulrush (*Typha orientalis*) and sharp rush (*Juncus acutus*). A large freshwater wetland exists towards the end of this section. The wetland is discharging water into the tributary, which is in turn supplying freshwater inflows to Christopher Brook. The wetland appears to occur at the eastern side of a well-vegetated sand lens.	• Maintain low stocking rates and fence wetland and the adjacent remnant vegetation around the sand lens to exclude stock. This wetland seepage area is providing important freshwater input into this tributary. The quality of this supply could be compromised if stock access is unmanaged.

Section	General foreshore grade	Overall environmental stream health rating	Section description	Management options
CBTrib003-B	D-grade	Very poor	A fence line delineates the first and second sections of this tributary and a dramatic change in condition. This section was rated to be in very poor condition, as there is little native fringing vegetation, other than a few flooded gums (*Eucalyptus rudis*) and a single swamp paperbark (*Melaleuca rhaphiophylla*) at the start of the section and an isolated patch of knotted clubrush (*Ficinia nodosa*). It appears that the wetland area to the north of this section is unfenced.	• Fencing this section and revegetating with suitable native species would provide a valuable ecological linkage between tributaries CBTrib001, CBTrib003, CBTrib004 and CBTrib005 (there is a large area of remnant vegetation in a neighbouring property that could link CBTrib001 and this tributary). • Remove sharp rush (*Juncus acutus*).
CBTrib004	D-grade	Poor	This tributary is located close to CBTrib003 and drains the north eastern side of the large sand lens. A defined channel only exists for approximately 200 metres, after which it dissipates into a waterlogged floodplain. There is little native fringing vegetation and sharp rush (*Juncus acutus*) dominates along this tributary. There are a large number of dead trees, possibly lost to waterlogging. This section is unfenced and was rated to be in very poor condition.	• Sharp rush (*Juncus acutus*) dominates the channel and should be progressively removed and replaced with native rushes so as to limit erosion. • Revegetate area with species tolerant to waterlogging.
CBTrib005 This tributary has been divided into three survey sections.				
CBTrib005-A	C-grade	Poor	The first section runs parallel to the main channel until it meets three unused aquaculture ponds, which are located off stream. These ponds have never been stocked but the landowner indicated they are frequently used by turtles. There is a significant amount of undercutting at the beginning of this section and exposed calcrete along the banks. This section is unfenced. This section was rated to be in poor condition.	• Fence both banks to limit stock access and encourage natural regeneration. • Sharp rush (*Juncus acutus*) dominates the channel and should be progressively removed and replaced with native rushes so as to limit erosion.

Section	General foreshore grade	Overall environmental stream health rating	Section description	Management options
CBTrib005-B	C-grade	Moderate	This section is well vegetated with the native rush *Baumea preissii* but had little overstorey vegetation along the channel. This section was waterlogged and had a few groundwater seepage areas away from the channel. Sharp rush (*Juncus acutus*) occurs in this section but is not as dominant as in the previous section. This section was rated to be in moderate condition.	• Remove sharp rush (*Juncus acutus*) before it spreads.
CBTrib005-C	B-grade	Good	This section was rated to be in good condition. The channel dissipates into a large, vegetated seepage area after approximately 300 metres, which extends to the base of a large pine plantation. The landowner indicated that this section had been fenced from stock for a number of decades. Although there is a dominance of sharp rush (*Juncus acutus*) at the beginning of this section, this is quickly replaced with a diversity of native rushes, shrubs and trees. The vegetation is healthy and dense, providing important habitat for animals. At the time of the survey, frogs, an echidna and a number of bird species were observed in this section.	• The landowner has retained and improved the conservation value of this area. Little needs to be done in this section to maintain its value, other than remove the sharp rush (*Juncus acutus*) before it spreads.
CBTrib006	C-grade	Poor	This tributary drains an area of salt affected land to the south of the main channel. The channel is well vegetated for the first 150 metres, but is then quickly replaced by a dominance of sharp rush (*Juncus acutus*). There is a significant amount of sedimentation apparent and localised undercutting and slumping. This tributary was rated to be in poor condition.	• Fence both banks to limit stock access and encourage natural regeneration. Assist regeneration by planting species tolerant to salinity and waterlogging. • Sharp rush (*Juncus acutus*) dominates the channel and should be progressively removed and replaced with salt-tolerant native rushes.

Section	General foreshore grade	Overall environmental stream health rating	Section description	Management options
CBTrib007	C-grade	Poor	This is a short tributary which encompasses part of the headwaters of Christopher Brook. Consequently the channel is poorly defined after approximately 150 metres. There is a dominance of wandoo (*Eucalyptus wandoo*) and flooded gum (*Eucalyptus rudis*) in this section, with no middle storey and a dominance of weeds in the understorey, although very few sharp rush (*Juncus acutus*) are present. This section was rated to be in poor condition.	• Fence both banks to limit stock access and encourage natural regeneration. • Remove sharp rush (*Juncus acutus*) before it spreads.

Appendix 8 Plant species suitable for revegetation

Table A.8.1 Native species suitable for revegetation along the Dale River and its tributaries (Department of Environment, 2004; Water and Rivers Commission, 1997a; Water and Rivers Commission, 1997b)

Species	Preferred site and soil conditions and propagation information
Rushes and sedges	
Bare twigrush (*Baumea juncea*)	Prefers light soils with fairly constant moisture along streambanks and floodways. Moderately tolerant to waterlogging and mildly salt tolerant.
Coast saw sedge (*Garnia trifida*)	Occurs on most soils types on fresh to saline floodways. Moderately water logging and very salt tolerant. Propagated from creeping stems.
Finger rush (*Juncus subsecundus*)	Grows on moist and seasonally wet floodway soils. Can be direct seeded.
Jointed twigrush (*Baumea articulata*)	Suitable for heavy and sandy soils on streambanks and floodways. Can withstand prolonged inundation up to 1 m. Transplant using creeping stems.
Pithy sword sedge (*Lepidosperma longitudinale*)	Tolerates a wide range of water levels including inundation as well as being mildly drought tolerant. Not salt tolerant, prefers fresh waterways and sandy soils. Propagated by rhizomes during winter or spring using 10cm-long pieces with good roots and leaves.
Shore rush (*Juncus krausii*)	Suitable for streambanks, seeps and floodways. Very tolerant to waterlogging and salinity. Easily propagated by seed and by transplanting creeping stems.
Spiny flat sedge (*Cyperus gymnocaulos*)	Suitable for most soil types on streambanks and seeps, especially in disturbed areas or waterways with high nutrient levels. Moderately salt tolerant but does not tolerate inundation for very long.
Ground cover	
Creeping saltbush/ berry saltbush (*Atriplex semibaccata*)	Suitable for a wide variety of fresh to slightly saline soils across the landscape including floodfringes and floodways. Slightly waterlogging and salt tolerant. Can be grown from tubestock or direct seeded.
Sea heath (*Frankenia pauciflora*)	Grows in sands and lighter soils in floodways and winter-wet areas. Very salt and waterlogging tolerant. Can be grown from tubestock.
Grasses	
Kerosene grass (*Aristida holathera*)	Grows on sands, loams and gravels on floodfringes and the drier parts of floodways. Does not tolerate waterlogging but is slightly salt tolerant. Can be grown from tubestock or direct seeded.
Native marine couch (*Sporobolus virginicus*)	Suitable for lighter soils on streambanks and floodways. Very tolerant to waterlogging and moderately salt tolerant. Easily propagated by transplanting creeping stems.

Shrubs	
Astartea (*Astartea fascicularis*)	Grows on alkaline sands near watercourses, wetlands and seasonally wet depressions. Can be grown from cuttings taken in autumn or direct seeded.
Golden wreath wattle (*Acacia saligna*)	Grows on a variety of soil types on floodfringes and floodways. Can be planted from tubestock or direct seeded. Seed needs scarification and heat treatment for uniform germination.
Jam wattle (*Acacia acuminata*)	Grows on a variety of soil types, especially red loams, on floodfringes and drier floodways. Slightly waterlogging and salt tolerant. Plant as tubestock or direct seed. Seed needs scarification and heat treatment for uniform germination.
Manna gum (*Acacia microbotrya*)	Occurs on a wide range of soil types on floodways and floodfringes. Slightly waterlogging and salt tolerant. Plant from tubestock or direct seed. Seed needs scarification and heat treatment for uniform germination.
Mohan (*Melaleuca viminea sub viminea*)	Grows in a variety of soil types in floodways. Moderately salt and waterlogging tolerant. Can be grown from tubestock or direct seeded.
Robin redbreast bush (*Melaleuca lateritia*)	Grows on floodway soils. Can be grown from cuttings and direct seeded.
Swamp banksia (*Banksia littoralis*)	Grows within floodfringes but is not tolerant of prolonged waterlogging and inundation. Can be grown readily from seed collected in autumn and late winter and direct seeded.
Swamp paperbark (*Melaleuca rhaphiophylla*)	Suitable for a variety of floodway soils. Extremely tolerant of waterlogging and mildly salt tolerant. Plant tubestock or direct seed.
Swamp sheoak (*Casuarina obesa*)	Suitable for a variety of floodway soils. Very salt and waterlogging tolerant. Plant tubestock or direct seed.
Trees	
York gum (*Eucalyptus loxophelba sub. loxophelba*)	Suitable for a variety of soil types including floodfringes and the drier parts of floodways. Does not tolerate waterlogging or salt. Plant tubestock or direct seed.
Flooded gum (*Eucalyptus rudis*)	Suitable for most soil types in winter-wet depressions, floodways and floodfringes. Very tolerant of waterlogging and moderately salt tolerant. Plant tubestock or direct seed.

Appendix 9 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 Programme*, 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 principals 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 wildfire's 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 crop land, pasture and urban development, limiting opportunity for recolonisation of burnt areas by native birds and animals.

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

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

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

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

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

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

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

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

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

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

10. AWC will 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. Potential sources of fire in or adjacent to the river system will be identified. Where there are obvious problem sites (eg, 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. AWC will 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. AWC will ensure that all fire management plans and regimes that are developed are consistent with the ACC Natural Resource Management Strategy

Review

The Recovery Statement will be reviewed annually.

Alan Cole

Chairman

Avon Waterways Committee

August 2007

www.water.wa.gov.au

ISBN 978-1-921468-51-3 (pbk)
ISBN 978-1-921468-52-0 (pdf)