A River Management Plan for the Light Catchment

Jason VanLaarhoven, Glen Scholz, Laura Phipps and Diane Favier

Knowledge and Information
Department of Water, Land and Biodiversity Conservation

September 2004

Report DWLBC 2004/17

Government
of South Australia

Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation
Level 11, 25 Grenfell Street, Adelaide
GPO Box 2834, Adelaide SA 5001

Telephone	National	(08) 8463 6800
	International	+61 8 8463 6800
Fax	National	(08) 8463 6999
	International	+61 8 8463 6999
Website	www.dwlbc.sa.gov.au	

ISBN 0-9752098-3-3

VanLaarhoven, J., Scholz, G., Phipps, L. & Favier, D. 2002. “A River Management Plan for the Light Catchment”. South Australia. *Department of Water, Land and Biodiversity Conservation. Report,* DWLBC 2004/17.

Foreword

South Australia's water resources are fundamental to the economic and social wellbeing of the State. Water resources are an integral part of our natural resources. In pristine or undeveloped situations, the condition of water resources reflects the equilibrium between rainfall, vegetation and other physical parameters. Development of surface and groundwater resources changes the natural balance and causes degradation. If degradation is small, and the resource retains its utility, the community may assess these changes as being acceptable. However, significant stress will impact on the ability of a resource to continue to meet the needs of users and the environment. Degradation may also be very gradual and take some years to become apparent, imparting a false sense of security.

Management of water resources requires a sound understanding of key factors such as physical extent (quantity), quality, availability, and constraints to development. The role of the Resource Assessment Division of the Department of Water, Land and Biodiversity Conservation is to maintain an effective knowledge base on the State's water resources, including environmental and other factors likely to influence sustainable use and development, and to provide timely and relevant management advice.

Bryan Harris

Director, Knowledge and Information

Department of Water, Land and Biodiversity Conservation

CONTENTS

Page No.

CONTENTS (cont'd)

Page No.

CONTENTS (cont'd)

Page No.

CONTENTS (cont'd)

Page No.

CONTENTS (cont'd)

Page No.

List of Tables

Page No.

List of Figures

Page No.

List of Plates

Page No.

List of Maps

List of Appendices

Executive Summary

The Mid North Rivers Management Planning Project (MNRMPP) was initiated by the Environment Protection Agency in response to local community concerns about water resources and watercourse management issues in the Mid North Region of South Australia. With a transfer of riverine management functions, the project was handed over to the Department of Water, Land and Biodiversity Conservation in 2003 for completion.

The project aims to achieve healthy rivers through better watercourse management and determination of environmental water requirements.

The objectives of the project are to:

- develop river management plans that incorporate recommendations for watercourse management and an assessment of environmental water requirements;
- integrate watercourse management actions of landholders and key stakeholders;
- integrate watercourse management and environmental water requirement issues into other regional and district planning and implementation strategies;
- increase community understanding of watercourse management and environmental water requirement issues.

The project began in May 1998 and is developing river management plans for the Wakefield, Broughton and Light rivers in the Mid North of South Australia.

This report relates to the Light River, which is located approximately 50 km north of Adelaide and has a catchment area of 1820 km^2.

Water resource development within the catchment amounts to a small number of farm dams predominantly for stock and domestic use. The number of dams has only increased slightly over the past decade and this level of development has not significantly impacted on flows within the catchment.

The Light River system has been dramatically modified by the impacts of European settlement and associated land use changes. Riverine habitats have been altered through the clearance of native riparian and floodplain vegetation, the loss of in-stream complexity due to incision and deposition of sediment, stock grazing, and the introduction of exotic plants and animals. Vegetation clearance and agricultural development have also resulted in an altered flow regime for the watercourses within the Light catchment.

The environmental condition of the system varies considerably across the catchment but the assessment of watercourse condition and environmental water requirements showed that the overall ecological health of the Light catchment is degraded. Despite this, there are a number of areas of significant ecological value.

Two snapshot fish surveys conducted within the catchment found only low numbers of native fish in all areas except the estuary where large numbers and a diverse range of native fish were observed. The results of the surveys suggest that the Light catchment is in poor condition in relation to fish populations. A combination of low flows, high exotic fish numbers and loss of habitat are likely to be the major reasons for low native fish numbers in the region.

Macro-invertebrates collected from the system were predominantly taxa that are tolerant of a broad range of environmental conditions, are good colonisers, and are common and widespread in South Australia. The number of taxa recorded was significantly lower than for the other Mid North catchments — the Wakefield and Broughton, as well as for the Gawler just south of the Mid North Region. A lack of habitat and high salinity levels are probably major contributors to lower macro-invertebrate diversity but the high salinity levels may be a natural feature of this system and the Light catchment may never have supported a diverse population of macro-invertebrates.

The ecology of many watercourses within the Light catchment is highly dependent on groundwater-fed baseflows and permanent pools. These areas of permanent surface water are of particular importance as refugia in dry periods.

The Light catchment has only one gauging station from which flow statistics can be quantified and environmental water requirements verified. This lack of data, along with the variability of the system, has imposed significant limitations on the process of identifying environmental water requirements. Therefore those identified should be considered to be a 'first estimate'. A process of monitoring and further research is required to further refine and verify the findings of this plan.

Flows in the Light catchment appear to support both the ecological functioning and physical processes of the river system but, according to the limited gauging data, some environmental water requirements appear to be only just being met. This understanding of the environmental water requirements of the Light catchment will contribute to future water resource planning to address water needs of the environment, amongst other issues.

Improved watercourse management and meeting environmental water requirements, are both needed to address the degraded condition of the riparian zone of watercourses within the Light catchment. The watercourse management priorities outlined in the plan were developed based on the data collected and in consultation with local landholders; separate priorities for watercourse management have been developed to reflect the sometimes different views of science and the community.

The identified watercourse management issues in order of ecological priority on a whole of catchment basis follow. They also strongly reflect those of the community.

1. Conservation of important riparian habitats
2. Protection of remnant vegetation
3. Rehabilitation of good riparian vegetation
4. Control of weeds
5. Revegetation and rehabilitation of areas of poor native vegetation
6. Poor bank stability
7. Gully erosion/gully heads
8. Control of exotic trees
9. Structural works causing or threatened by erosion
10. Erosion heads.

These watercourse management priorities, and the options outlined in the plan, can be used by the community and key stakeholder organisations for both practical and strategic planning, and to set priorities for individuals or groups seeking funding for on-ground works.

The watercourses of the Light catchment will degrade, or continue to degrade further, unless action is taken to improve the management of these systems. The following eleven management recommendations for the watercourses within the Light catchment are discussed in this report, along with suggested actions and key partners required to achieve these recommendations:

1. Integrate stakeholder approaches to watercourse management in the Light catchment.
2. Develop management plans to control the impact of development on the health of the river system.
3. Implement the watercourse management priorities and strategies identified in this management plan.
4. Protect ecosystems of high ecological value.
5. Develop an exotic tree and weed control strategy targeting watercourses within the catchment.
6. Develop an integrated revegetation strategy that incorporates the plans of regional stakeholders.
7. Develop guidelines to help stakeholders and landholders conduct watercourse management works.
8. Develop management guidelines to help stakeholders to assess and minimise the effects of activities that impact on riverine environments.
9. Develop a risk assessment strategy to identify potential point source and diffuse pollution impacts within the catchment.
10. Further monitor the watercourses within the Light River system to adequately assess the resources and system health.
11. Develop an eradication program for exotic fish.

Improved management of the Light River system requires an integrated approach that combines flow, land and watercourse management.

CHAPTER 1 INTRODUCTION

1.1 The Mid North Rivers Management Planning Project

The Mid North Rivers Management Planning Project (MNRMPP) evolved from community consultation meetings conducted in 1996 by South Australia's Department of Environment and Natural Resources (now Department for Environment and Heritage (DEH)), in partnership with the Clare Valley Water Resources Planning Committee. At these meetings landholders expressed concerns about watercourse condition, water quality, stream flows and the lack of an integrated, catchment-wide approach to water resource management. These concerns were supported by the Department of Primary Industries and Resources SA (PIRSA), soil conservation boards, local government, and animal and plant control boards.

The project aimed to maintain and improve the health of the Wakefield, Broughton and Light rivers by determining environmental water requirements and planning for better watercourse management. A project team was formed in the Environment Protection Agency (EPA) to produce a river management plan for each of these three rivers including this one for the Light River. With a transfer of riverine management functions, the project was handed over to the Department of Water, Land and Biodiversity Conservation in 2003 for completion.

The specific objectives of the MNRMPP are to:

- develop river management plans that incorporate recommendations for watercourse management and an assessment of environmental water requirements;
- integrate watercourse management actions of landholders and key stakeholders;
- integrate watercourse management and environmental water requirement issues into other regional and district planning and implementation strategies;
- increase community understanding of watercourse management and environmental water requirement issues.

The project, which began in May 1998, was funded by the Natural Heritage Trust and DEH. Key local stakeholder organisations provided advice and direction through a project reference group comprising representatives from:

- PIRSA;
- Clare Valley Water Resource Planning Committee;
- soil conservation boards;
- local government;
- animal and plant control boards;
- Department for Water Resources (now Department of Water, Land and Biodiversity Conservation (DWLBC));
- DEH.

The long-term outcomes of the project for the Wakefield, Broughton and Light Rivers include improved health and diversity of riverine ecosystems, reduced erosion and sedimentation, improved water quality, and reduced stock and weed management problems.

1.2 A river management plan for the Light catchment

1.2.1 PURPOSE OF THE PLAN

The river management plan for the Light catchment is a decision making tool for landholders and key stakeholders with an interest in river management. The plan aims to:

- provide baseline information on the condition and function of riverine ecosystems;
- provide strategic direction for river management in the catchment;
- facilitate the integration of river management objectives with other regional plans and strategies;
- increase community understanding of river management issues.

The plan can be applied at a local, subcatchment scale as well as at a regional, catchment scale. It has been structured to meet the needs of landholders who have a watercourse running through their property and those of stakeholder organisations involved with long-term and day-to-day planning affecting the Light River and its tributaries.

The plan targets watercourse management needs locally by assessing the condition of the watercourse, identifying management issues and developing options for watercourse management based on ecological priorities. It also addresses landholder and stakeholder priorities at a subcatchment scale. It provides valuable information for water resource allocation and management by scientifically assessing the water requirements for water dependent ecosystems along the Light River and its tributaries. The plan also discusses catchment-scale issues and provides recommendations based on catchment wide water management requirements.

1.2.2 CATCHMENT LOCATION AND DESCRIPTION

The Light catchment is located in the Mid North region of South Australia, approximately 50 km north of Adelaide and encompasses an area of approximately 1820 km^2. It is one of the largest catchments wholly contained within South Australia.

The Light River starts in the Northern Mount Lofty Ranges above the junction of Tothill Creek near Waterloo. It flows south to past Marrabel to Hamilton, before flowing in a westerly direction past Hansborough before again flowing south to the junction with St Kitts Creek. It then flows in a westerly direction past Kapunda, Hamley Bridge and Mallala, before discarding to the sea between Dublin and Two Wells. Its main tributaries are Tothill Creek, Julia Creek, Freshwater Creek, Stockwell Creek, Allen Creek, Ross Creek, Fannel Creek and the Gilbert River (Map 1.1).

Most of the catchment is used for dryland agriculture, with cereal, grain legume and canola cropping, as well as sheep and cattle grazing. In recent years low grazing returns have seen a swing to intensive cropping. This has placed increased pressure on the soil (Lower North Soil Conservation Board 2001).

Unlike the Broughton and Wakefield catchments, the Light catchment has limited water resource development. This is largely due to the lower volumes of flow within the catchment and a groundwater system characterised by naturally low well yields and high salinities. Historically, watercourses in the catchment have been used to water stock. The few dams are mostly in the upper areas of the catchment and little groundwater is extracted.

Despite minimal water use the watercourses have been modified considerably by land use practices such as vegetation clearance and grazing. This has affected the physical condition and ecological values of the watercourses, and recreational and agricultural use. Catchment-scale planning to identify and develop a strategic direction for rehabilitation and management of the Light River and its tributaries is essential to help protect water quality and sustain natural riverine ecosystems.

1.2.3 POLICY AND PLANNING CONTEXT

The need to ensure the long-term integrity of rivers and wetlands as functioning ecosystems has been widely recognised at State and national levels. In 1994, the Council of Australian Governments (COAG) endorsed a strategic framework to introduce important water reforms. Under this agreement, providing water for the environment is legally recognised as an essential component of any water allocation system and any future water resource developments are required to be ecologically sustainable.

The *National Principles for the Provision of Water for Ecosystems* — produced by the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) and the Australia and New Zealand Environmental and Conservation Council (ANZECC) in 1996 — provide a basis for considering environmental water requirements as part of water allocation decisions.

The policies endorsed through the COAG Water Reform Agenda and the *National Principles for the Provision of Water for Ecosystems* are reflected in South Australia's *Water Resources Act 1997* which provides an important legal framework for water resource and watercourse management in South Australia. The object of the Act recognises, among other things, the need to protect water dependent ecosystems and their biodiversity.

Water resources and watercourses are managed through various statutory water management plans and other powers. The *State Water Plan 2000* (Department for Water Resources and State Water Plan Steering Committee 2000a,b) sets the strategic direction for water resource management in South Australia. All other water management plans must be consistent with the *State Water Plan*, including:

- catchment water management plans prepared by catchment water management boards;
- water allocation plans for prescribed water resources prepared by catchment water management boards or water resources planning committees;
- local water management plans prepared by local councils.

The *State Water Plan* outlines statewide policies for managing the health of water dependent ecosystems, including water for the environment and watercourse management.

The integrated management of waterbodies and associated water dependent ecosystems is intended to maintain or improve the condition of these systems, to ensure the long-term integrity of their ecological functions and dependent biodiversity, and to achieve their ecologically sustainable use, including the highest value use of water (Department for Water Resources 2000a).

The plans developed by the MNRMPP are an important step in achieving this goal for the Wakefield, Broughton and Light River systems. The plans describe the environment water requirements for these systems and identify watercourse management issues, priorities and management options based on the assessment of river condition, landholder and stakeholder consultation and technical input from river management specialists. The plans are not statutory documents but are important decision making tools and sources of information for government agencies, regional organisations, community groups and landholders. For example, they will provide valuable information for the development of statutory water management plans under the *Water Resources Act 1997*, even though there is no legal obligation to produce such a plan.

1.2.4 ENVIRONMENTAL WATER REQUIREMENTS

A catchment is made up of a range of water dependent ecosystems such as estuaries, lakes, wetlands, rivers and streams. All of these systems require water to maintain their physical features (e.g. channel shape, water quality), their communities of plants and animals and associated ecological processes. Environmental water requirements can be defined as '… descriptions of the water regimes needed to sustain the ecological values of aquatic ecosystems at a low level of risk' (ARMCANZ and ANZECC 1996).

The minimal level of water resource development and flow regulation in the Light River system has left the water regime in a largely unmodified condition. This largely natural flow regime can be protected with appropriate planning and development guidelines.

Determining environmental water requirements therefore involves identifying those flows or features of the natural flow regime that are most important for maintaining or improving the condition of water dependent ecosystems. It is not only the quantity of water that is important, with the following also being important for maintaining physical river features, plants and animals, and ecological processes:

- water quality;
- the frequency, duration and velocity of flows;
- variability of flows;
- seasonal patterns and timings of flows;
- the length of low flow or no flow periods.

The environmental water requirements of water dependent ecosystems in the Light River system have been identified by the MNRMPP and are outlined in Chapter 6 and Appendix B of this plan. However, identifying environmental water requirements is only one step in ensuring that the water needs of the environment are actually met. Providing water to the environment is part of a complex water allocation and management process that must balance social, economic and environmental needs. These competing needs may place constraints on the provision and effectiveness of environmental water requirements.

In South Australia a goal of providing water for the environment is to sustain and, where necessary, restore ecological processes, habitats and biodiversity of water dependent ecosystems (Department for Water Resources and State Water Plan Steering Committee 2000a). This goal cannot be achieved if the water is not being provided to an environment that has been degraded. The health of riverine ecosystems is dependent not only on meeting environmental water requirements but also on protecting water quality, maintaining and rehabilitating habitat and biodiversity, and using good land and watercourse management practices.

1.2.5 WATERCOURSE MANAGEMENT

Watercourse management refers to management practices, including watercourse stabilisation and rehabilitation measures, which are required to address threats to river health. Such threats may include accelerated bed and bank erosion, poor water quality, stock and weed management problems, and loss of habitat and biodiversity.

Watercourses and the riparian zone are sensitive zones that often require a different management approach from other areas of the landscape (Bell and Priestley 1998). In the past there has been little focus on the importance and appropriate management strategies for watercourses and riparian lands. There has been a tendency to treat rivers and creeks as drains — removing water from surrounding land. More recently, however, the importance of healthy watercourses has been recognised in preventing erosion, providing food and shelter for aquatic animals, maintaining biodiversity, protecting water quality, maintaining agricultural productivity, and for their recreation and aesthetic values.

Many landholders with watercourses running through their property are genuinely concerned about managing that watercourse well. However, a lack of time, money and technical knowledge are often impediments to better management of watercourses. The MNRMPP process brought landholders and key stakeholders in the community together to discuss their concerns and successes in managing the watercourses. The project team assessed the condition of watercourses throughout the catchment and then used this information to identify watercourse management issues. This information was then used in community meetings to explain the issues, and discuss management priorities and on-ground solutions.

Significant watercourse management issues are discussed in Chapter 7 and in more detail for each subcatchment of the Light catchment in Chapters 8–11. Priorities and options for management are also outlined in Chapters 8–11. These subcatchment management priorities and options can be used by the community as practical property planning tools, as a guide to develop management priorities and as support for individuals or community groups seeking funding assistance for on-ground works such as state revegetation grants and Natural Heritage Trust funds.

1.2.6 COMMUNITY AND STAKEHOLDER INVOLVEMENT

Several key stakeholder organisations have watercourse, water resource or land management responsibilities that directly or indirectly affect the watercourses within the Light catchment. For example, soil conservation boards, through their district plans, have the ability to implement land management measures that help prevent degradation of watercourses. Map 1.2 illustrates the different local government bodies whose jurisdiction lies within the Light catchment. State Government agencies such as DEH, DWLBC and PIRSA also have river and land management responsibilities. The legal rights and responsibilities of those different stakeholder organisations for river management are discussed further in Appendix D.

These different responsibilities make it difficult to achieve a coordinated and integrated approach to water resource and watercourse management in the catchment. In addition, no one organisation has overall responsibility for implementing the management options recommended in this plan. To overcome this, a key objective of the planning process was to integrate watercourse management and environmental water requirements into the regional and district plans and implementation strategies of stakeholder organisations. The project reference group played a key role in ensuring this integration.

Ultimately, landholders with property adjacent to a watercourse are in the forefront of improving the health of the river system. Rivers will be better managed only if these landholders, stakeholder organisations and the wider community understand the importance of improved water resource and watercourse management and have an opportunity to individually influence management actions. The MNRMPP conducted a comprehensive community and stakeholder involvement process to raise awareness and to involve all potential users of the plan throughout the planning process. Landholders and stakeholders were involved in identifying watercourse management issues and determining priorities for management as well as contributing valuable local information, such as rainfall and flow records. Key stakeholders were also consulted to determine their information needs on water resource and land management issues that affect the river system.

1.3 Using the plan

Opportunities and examples of how landholders, community groups and stakeholders can use and integrate the information contained in the plan are outlined in Table 1.1. The plan can provide advice and information about watercourse management problems, priorities and potential solutions and can be used by landholders and community groups to access funding for on-ground works. The plan offers river management information that can assist stakeholders with operational and strategic planning. At an operational level, the watercourse management priorities identified in the plan can help stakeholder groups plan work program priorities. The plan can assist with strategic planning providing baseline information and a technical basis for decisions.

Table 1.1 Target audiences and uses of the information provided by the plan

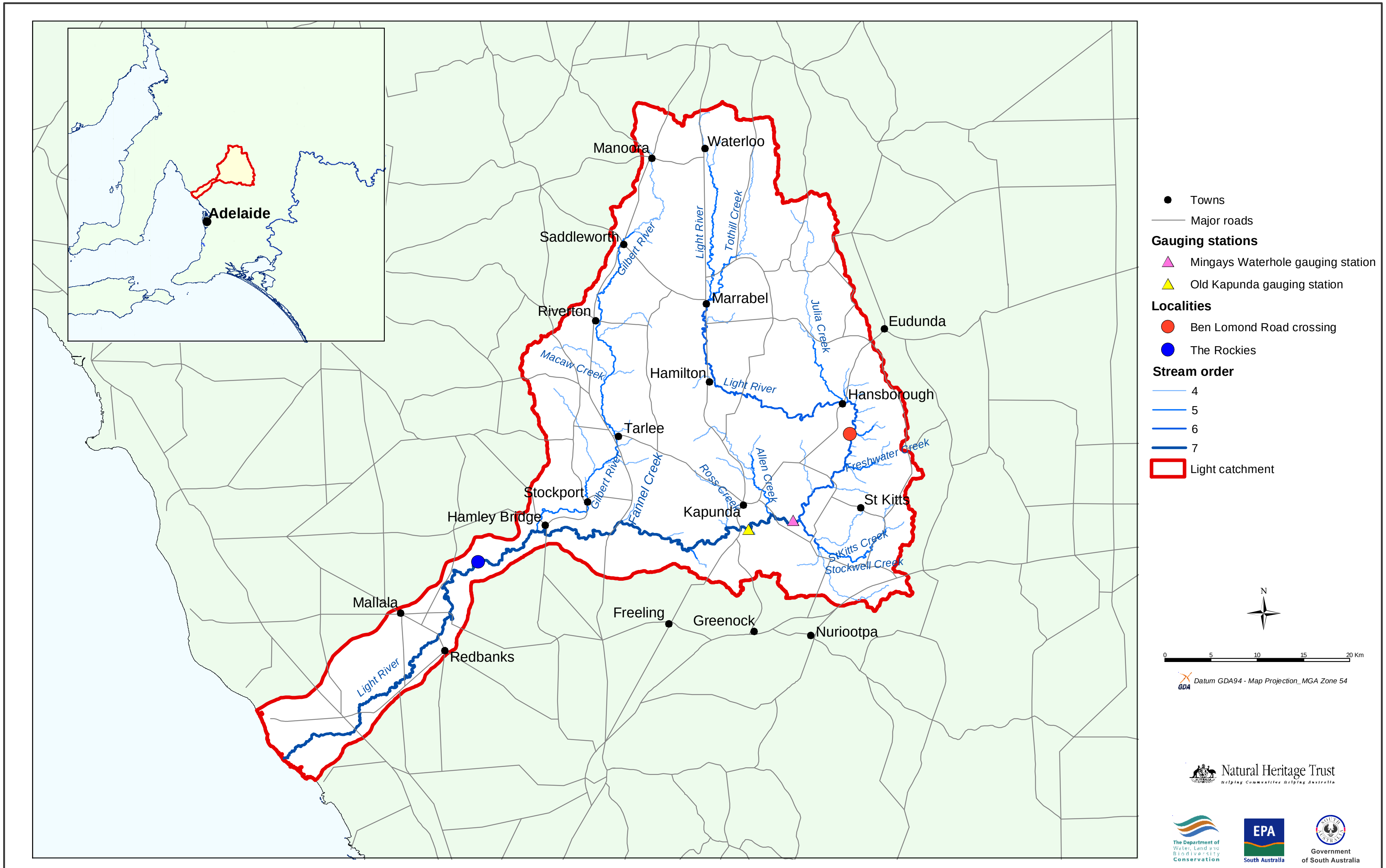
Target audiences	Information uses
Landholders and community groups (e.g. Landcare groups, Waterwatch groups)	• Identification and location of watercourse management issues at a subcatchment and catchment level • Options for improving watercourse management practices • General catchment and subcatchment information • Supporting documentation for funding applications
Local government Councils of Light, Clare and Gilbert Valley, Goyder, Wakefield, Mallala and Barossa	• Decision making on development applications • Local water management planning under the *Water Resources Act 1997* • Plan amendment reports • Management of river based assets e.g. bridges, culverts and public reserves/council land adjacent to watercourses • Flood mitigation • Stormwater drainage
Soil conservation boards Lower North Soil Conservation Board	• Information on the impact of land management practices on riverine environment • Integration into review of Soil Conservation Board district plans • Access to funding for and implementation of on-ground riparian works
Animal and plant control boards Lower North, Burra Eudunda Robertstown and Adelaide Plains Animal and Plant Control Boards	• Integration into district plans and weed control work programs • Location and extent of watercourse weeds
Mid North Regional Development Board	• Integration into regional development plans
INRM Committee Northern and Yorke Agricultural District	• Baseline information on the water resources and condition of the riverine environment • Committee has priorities and recommendations for management and monitoring
PIRSA	• Property management planning and extension advice • Technical river management information
DEH	• State of the Environment reporting • Monitoring of water quality and ecosystem health • Biodiversity planning

Target audiences	Information uses
DWLBC	• State of the Environment reporting • State Water Plan policies, reporting and monitoring • Water management plans e.g. water allocation plans
SA Water	• Impacts of structures e.g. weirs

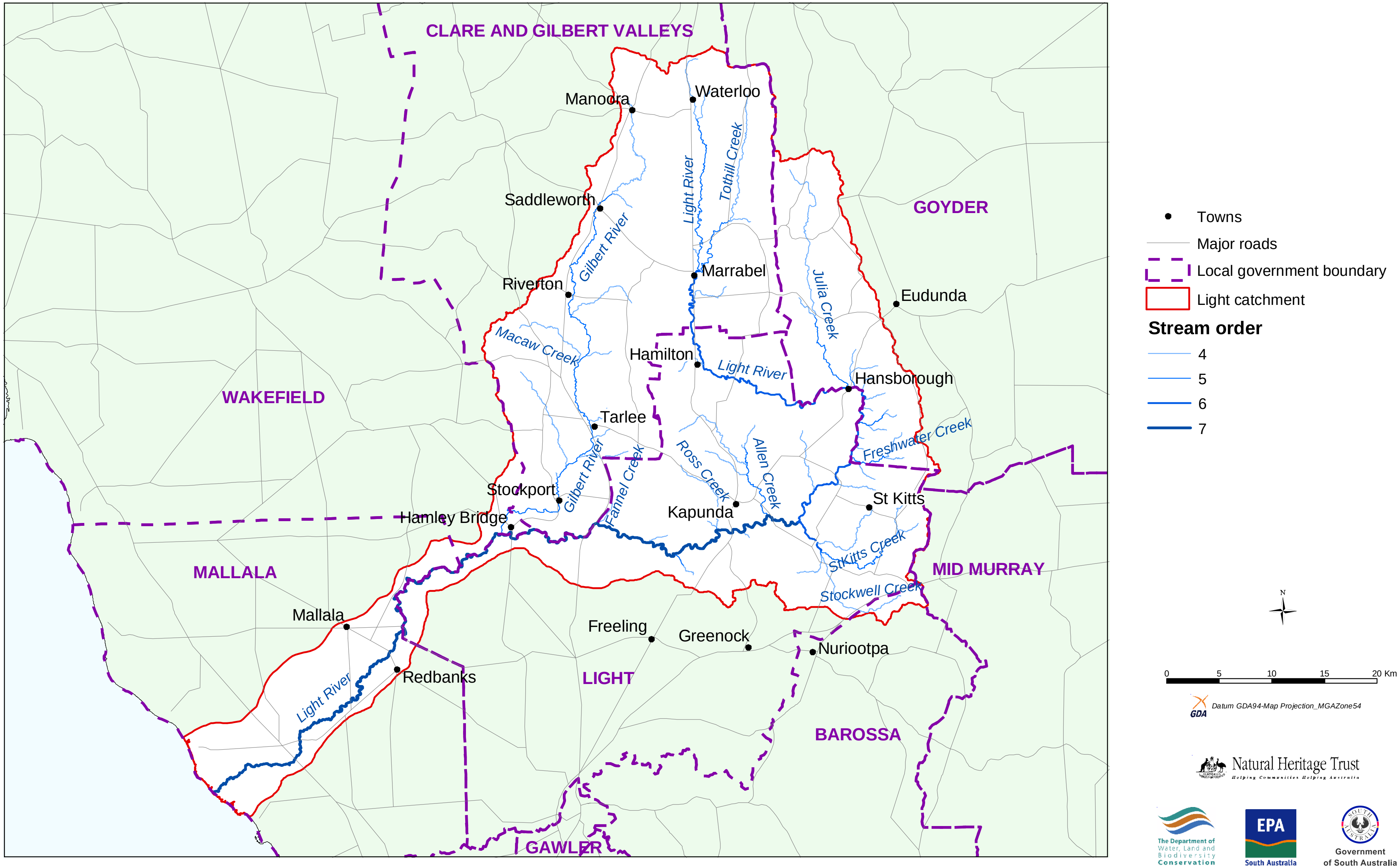
1.4 Navigating the plan

The three sections of the plan enable it to be easily used by a wide range of community members and stakeholders with different management needs and capabilities. Those interested in the overall condition of the catchment can refer to Chapters 1–7. For more detailed information on subcatchments refer to Chapters 8–11. For more additional information on the ecology, geomorphology, legal responsibilities and information gaps refer to the appendices. A glossary is included at the end of the report.

- *Chapter 1 Introduction:* background information on the MNRMPP, an introduction to the plan and background on the Light catchment.
- *Chapter 2 Introduction to river processes:* brief overview of river processes and concepts to help explain the more technical sections of the plan.
- *Chapter 3 Project methodology:* methods used to consult with the community, identify watercourse management issues and determine environmental water requirements.
- *Chapter 4 Community consultation:* results of the community consultation process, and community concerns and priorities.
- *Chapter 5 The Light catchment:* general background and overview of the hydrology, geomorphology and ecology of watercourses within the Light catchment.
- *Chapter 6 Environmental water requirements:* discussion of environmental water requirements for the ecological and geomorphological components of the Light River system.
- *Chapter 7 Watercourse management issues:* discussion of the nature, location and management strategies for watercourse management issues for the Light catchment.
- *Chapters 8–11 Subcatchment management:* outline of key ecological and geomorphological characteristics of each subcatchment; discussion of the watercourse management priorities and strategies for watercourse management in each subcatchment; discussion of environmental water requirements for each geomorphic zone within the subcatchments.
- *Chapter 12 Recommendations for the Light catchment:* recommendations for the management of watercourses throughout the Light catchment.



Map 1.1: Location of the Light catchment



Map 1.2: Local government boundaries in the Light catchment

CHAPTER 2 INTRODUCTION TO RIVER PROCESSES

2.1 Introduction

This chapter provides general reference information on river ecosystem components and processes and explains commonly used terms.

2.2 Structure and function of river ecosystems

A river is a dynamic, living system with complex physical and biological processes that are constantly undergoing change. A good understanding of these processes is crucial to sound river management. There are five interacting elements that determine the structure and function of river ecosystems: physical features (e.g. channel shape), water quality, water quantity, condition of the riparian zone and of the floodplain, and the plants and animals living in the stream (Rutherford et al. 1999). A change to any of these elements can have a significant effect upon other parts of the system. Thus, when addressing a river management problem it is essential to ensure that the remedy employed does not cause problems elsewhere.

2.2.1 PHYSICAL CHARACTERISTICS AND HABITATS

Flow regimes and geomorphic processes such as erosion, sediment transport and deposition play an important role in determining in-stream, riparian and floodplain environments. The material transported and deposited by rivers in the channel, and in the riparian zone and floodplain, forms key physical features that are the basis of river habitats. Some typical physical features found in the in-stream environment (see Figure 2.1) include benches, bars, pools, riffles and runs (Brierley et al. 1996). Different features offer different opportunities for plants and animals.

Habitats are places where animals and plants live. Habitat types within the in-stream environment can include deep pools, shallow riffles, aquatic plants, woody debris and large rocks. Different habitats will favour different types of animals and plants. For example, the types of animals present in a shallow riffle will tend to differ from those present in a deep pool. Certain plants such as the common reed (*Phragmites australis*) prefer areas of still or slow moving water; other aquatic plants thrive in shallow running water (Gooderham and Jerie 1999).

Many animals require a variety of different habitats for day-to-day life or for different stages of their lifecycle. The ability to move freely between different habitats is important. For example, some species of freshwater fish use estuaries to breed and then migrate upstream for adult growth. On a day-to-day basis, fish may also need areas for feeding, areas to shelter from predators and refuges from flood or drought. Aquatic insects also use different habitats during their lifecycles. For example some mayfly species live among cobbles in fast flowing water as nymphs, spend their adult stage in riparian vegetation and then return to the stream to lay their eggs (Gooderham and Jerie 1999).

A watercourse with a diverse number of habitats will generally support a greater range and number of organisms than a less complex watercourse. One of the impacts of European settlement and associated land use change, has been the simplification of riverine habitats by, for example: clearance of riparian vegetation; channelisation, incision and deposition of sediment causing loss of in-stream complexity; and dam construction causing loss of flow variability (Gooderham and Jerie 1999).

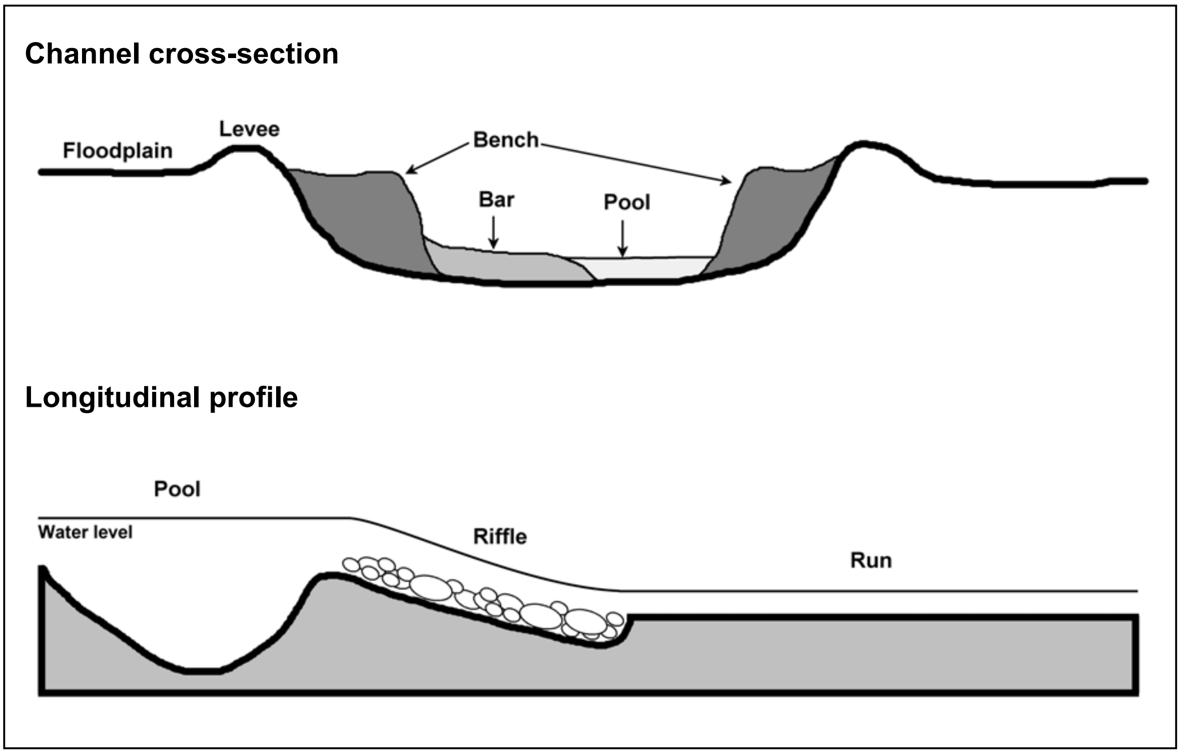


Figure 2.1 Schematic cross-section and longitudinal profile of a watercourse showing common physical features

2.2.2 WATER QUALITY AND TEMPERATURE

Water quality is vital for maintaining the health of aquatic ecosystems. Plants and animals can tolerate a certain range of water quality but outside that range their ability to survive is diminished greatly. If water quality declines, sensitive organisms will be lost while more tolerant organisms, including fish such as the introduced eastern gambusia (*Gambusia holbrooki*), will tend to dominate. Water quality can be affected by adjacent land use, the presence of livestock, the capacity of the riparian zone to act as a buffer and provide shade, sewage effluent, urban stormwater pollution and industrial wastewater (Gooderham and Jerie 1999).

Water temperature is a lifecycle control factor of aquatic and terrestrial invertebrates that use the stream for all or part of their lifecycle. Changes to water temperature give environmental cues that can trigger different parts of an animal's lifecycle. For example, aquatic insects emerge from the river in warmer water temperatures. If the water temperature changes dramatically (e.g. through the removal of the riparian vegetation that provides shading) then temperature sensitive species will not survive.

2.2.3 WATER REGIME

The water regime has a direct effect on plants and animals through the cycle of flood and drought, as a cue for migrations and lifecycle changes, and by providing connections with floodplain habitats. For example, reeds and rushes may rely on a period of low flow to establish on the bank of a watercourse and river red gums (*Eucalyptus camaldulensis*) can require periods of flooding for regeneration. The water regime is also an important factor determining the physical shape and character of a watercourse and thus maintaining in-stream habitats (Gooderham and Jerie 1999).

Rivers in semi-arid climatic zones such as the Light River are characterised by a high degree of variability in water regimes over time and over the different areas of the catchment. The native plants and animals in the watercourse have had to adapt to these cycles of drought and flood. It is this variability that maintains the biodiversity of these riverine ecosystems (Thoms 1998). The range and variability of flows are just as important within a system as the volume of flows. The timing, extent, frequency, duration, depth, and the rate of rise and fall of flow events are also important. A change to one or more of these components of the water regime is generally marked by a reduction in habitat complexity and, consequently, in the diversity of plants and animals.

Streamflow may have a baseflow component provided by groundwater discharge. In low rainfall areas, this baseflow is likely to be vital to the composition and maintenance of in-stream and riparian ecosystems by supporting their vegetation during dry seasons (Hatton and Evans 1998). Groundwater in-flows can play an important role in maintaining water quality and quantity.

Shallow groundwater can also support riverine ecosystems. In-stream, riparian and wetland vegetation may depend to varying degrees on shallow groundwater to sustain growth during dry periods. For example, river red gums along inland rivers often depend on shallow groundwater for survival (Hatton and Evans 1998). Fauna that have the ability to spend part of their lifecycle below the river bed (hyporheic fauna) require subsurface flows.

2.2.4 RIPARIAN ZONE AND FLOODPLAIN

The riparian zone is generally defined as the ribbon of land adjacent to, and influenced by, a watercourse (Figure 2.2). This zone is a critical link between terrestrial and aquatic ecosystems. Riparian vegetation includes the terrestrial vegetation adjacent to the stream as well as aquatic and semi-aquatic plants on the edge of the stream bank. Riparian vegetation plays a critical role in the ecology of the river by providing organic matter and habitat, acting as a filter for sediment and pollutants, protecting banks from erosion, providing shade, and influencing channel shape and flow (Kapitzke et al. 1998).

The floodplain — land adjacent to the watercourse that is flooded regularly — also plays a significant role in the ecology of the river environment. When inundated the floodplain provides a habitat for macro-invertebrates and for fish spawning. As the flood recedes, leaf litter and other detritus, which are important as sources of food and nutrients, are transported into the watercourse (Gooderham and Jerie 1999).

Some riparian and floodplain plants require periods of flooding for survival and for regeneration. Incision of a watercourse can lead to a dramatic change in the flooding regime, which can alter riparian and floodplain vegetation communities and affect the animals that rely on that vegetation (Gooderham and Jerie 1999).

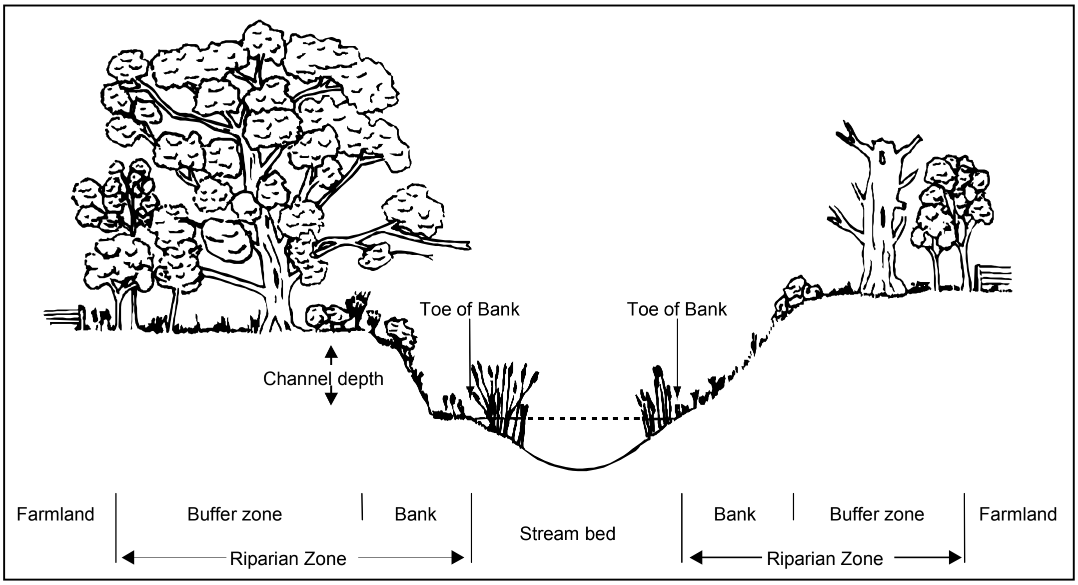


Figure 2.2 Typical cross-section of a watercourse showing the location of the riparian zone

2.2.5 IN-STREAM PLANT AND ANIMAL COMMUNITIES

In-stream plants (aquatic and semi-aquatic species) are an essential component of the river ecosystem. They provide food and habitat for fish, birds and invertebrates, act to stabilise sediment, improve water quality and reduce flow velocities and erosion potential (Kapitzke et al. 1998). In-stream animals can be very diverse and include species of invertebrates (e.g. snails, worms, shrimps and insects) and vertebrates (e.g. fish, amphibians, reptiles, birds and mammals). Within the river ecosystem, animals and plants use each other for food, shelter and recycling of waste matter (Gooderham and Jerie 1999). A food web is a simple way of describing the flow of nutrients and interactions between plants and animals in a community (Figure 2.3).

Algae and plants form the basis of the food web. They produce their own energy from sunlight and raw chemicals, and provide food for other organisms. In the in-stream environment, aquatic and semi-aquatic flowering plants (macrophytes) and algae are an important source of food for herbivores. Plants along the riverbanks also provide large amounts of organic matter (leaf litter and woody debris) to the in-stream ecosystem (Gooderham and Jerie 1999).

Herbivores occupy the next level in the food web. Within watercourses, there are two basic types: ‘scrapers’ that graze on algae and decomposers such as fungi and bacteria; and ‘shredders’ that consume plant leaves and stems, and old or dead plant material or detritus. The latter group includes invertebrates such as aquatic snails, freshwater crayfish and the larvae of insects.

Above the herbivores in the food web are the predators. These are usually larger invertebrates and animals such as fish, frogs, lizards and birds. All parts of the food web need to be supported for a healthy ecosystem (Gooderham and Jerie 1999).

2.3 Characteristics of a healthy river

A healthy river or watercourse ecosystem is generally defined as one with a community of plants and animals and associated ecosystem processes that are comparable to the natural or undisturbed habitats of the region (Karr and Dudley 1981). A healthy river or watercourse will contain a diversity of plants and animals, a significant proportion of which will be intolerant of degraded conditions, such as poor water quality and lack of habitat diversity (Gooderham and Jerie 1999). The type of plant and animal species present can be a good indicator of river health. The presence of a variety of sensitive species indicates that the river is in good condition; the predominance of species tolerant of degraded conditions indicates poor river condition. Fish and macro-invertebrates are often used as indicators of river health.

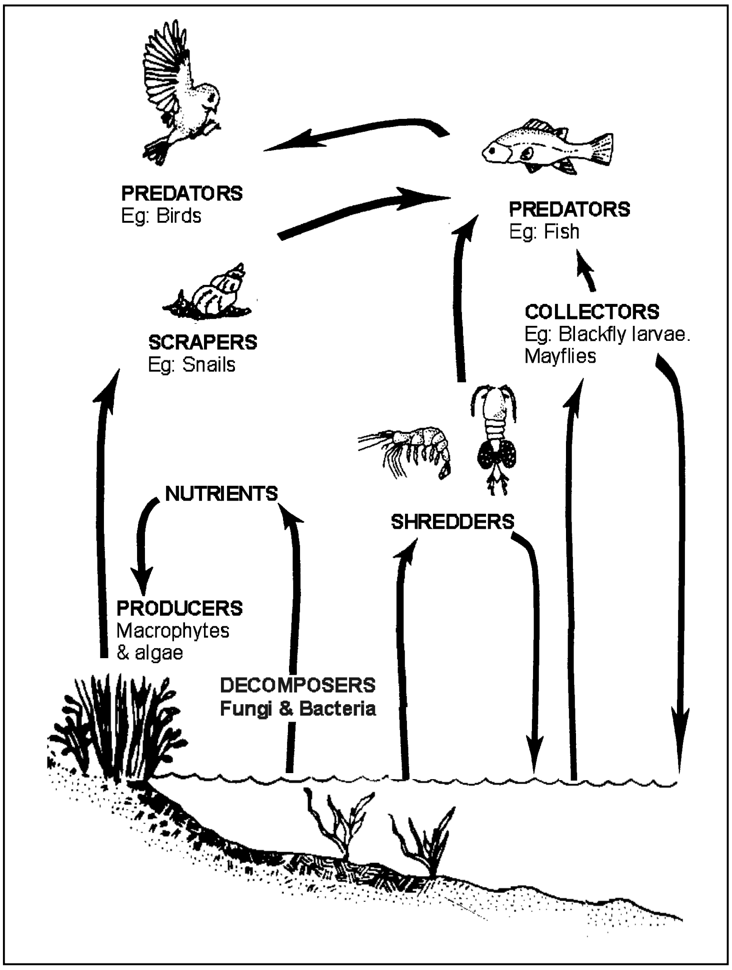


Figure 2.3 **The interactions between plants and animals in a community with arrows showing nutrient flows (adapted from Gooderham and Jerie 1999)**

In general, the health of a river ecosystem relies on a balance between the water regime, physical characteristics and processes, and ecology. Three key relationships can be drawn between these factors. The water regime (e.g. flow depth, velocity, energy) affects the shape and structure of the river and floodplain. River shape and structure, in turn, determine the type of physical habitat available and, consequently, the type of animal and plant communities. River shape and structure, and the nature of the river ecosystem also influence the water regime (e.g. in-stream vegetation increases the channel complexity, reduces flow velocities and traps sediment).

CHAPTER 3 PROJECT METHODOLOGY

This chapter presents an overview of the river management planning process for the Light catchment and outlines the methods used to identify watercourse management issues, determine environmental water requirements and consult with the community.

3.1 Overview of the planning process

The MNRMPP planning process (Figure 3.1) had three key components: assessing watercourse management priorities and options; determining environmental water requirements; and involving the community and key stakeholders. The process of community and stakeholder involvement was concurrent with, and an integral part of, determining watercourse management priorities and options, and assessing environmental water requirements for the Light River system.

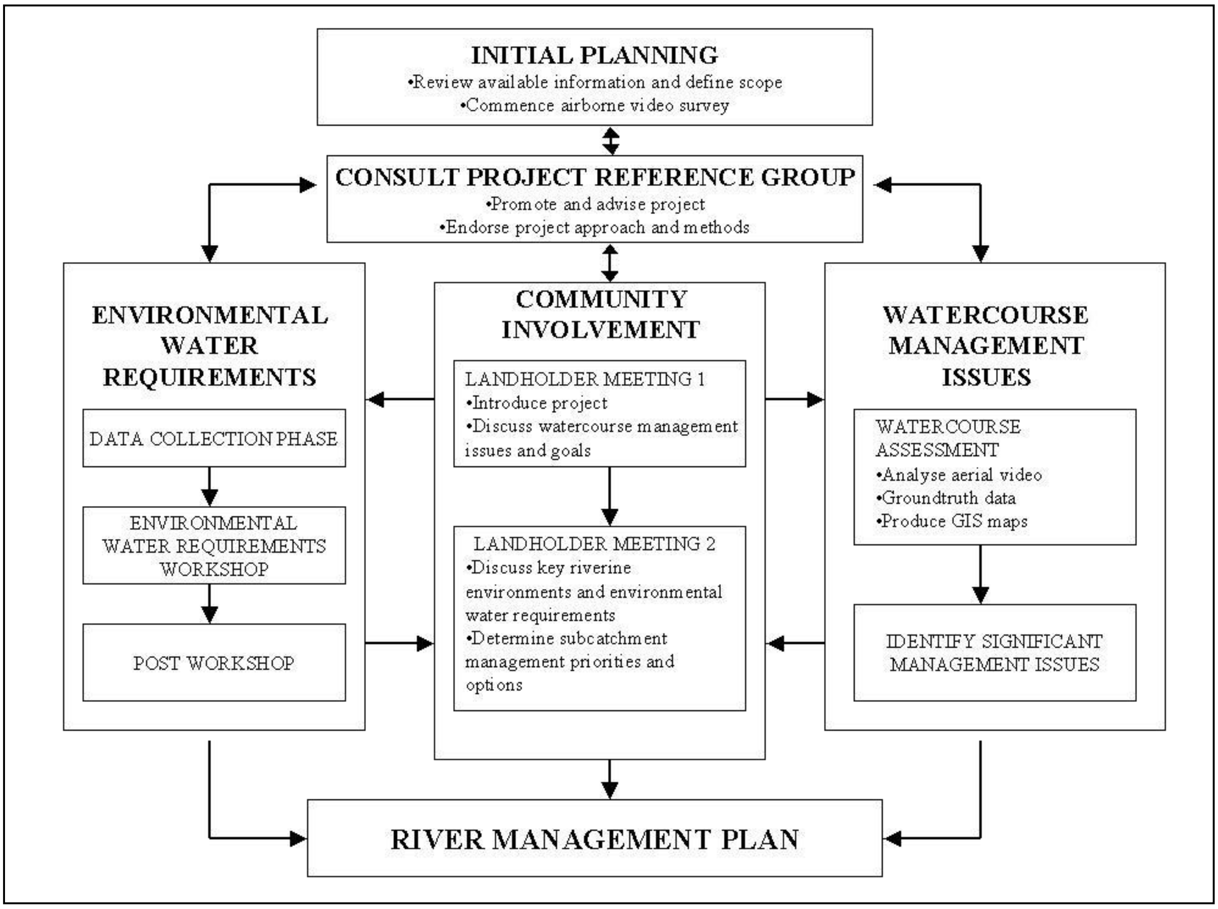


Figure 3.1 Light catchment management planning process

Assessment of the Light catchment began with an airborne video survey of the watercourse corridor and its main tributaries in June 1999. The project team analysed the video to determine the current condition of the watercourses. This data was used to produce maps of watercourse condition for discussion at community consultation meetings, to identify watercourse management issues and to select representative sites for assessment of environmental water requirements.

Key stakeholders, through representation on the project reference group, facilitated involvement of stakeholder organisations in the project and ensured their organisations and the project team exchanged information and advice.

The assessment of the watercourse condition and the environmental water requirements were integrated with the community consultation and involvement. A series of community meetings provided landholders with the opportunity to:

- identify what they considered to be the key watercourse management issues along their section of watercourse
- contribute their local knowledge on the condition of the watercourses in the Light river system
- consider the outcomes of the assessments of river condition by the project team and prioritise management issues
- understand the catchment processes at work by viewing the management of the river in a 'big picture context' rather than just at their property level.

Data was collected and interpreted for assessing environmental water requirements after the first community meetings; landholders provided valuable local knowledge of rainfall, flows and changes over time. The project team commissioned field studies and technical reports on the geomorphology, vegetation, ecology, and fish and macro-invertebrate populations across the catchment. The former Department for Water Resources assessed and modelled hydrological data and the EPA's Frog Census program supplied data on frog populations. The team, in consultation with the ecologist and geomorphologist on the scientific panel, conducted detailed habitat assessments at representative sites throughout the catchment.

The scientific panel of experts considered this information and determined the water requirements for maintaining the ecological health of the river and its major tributaries. The information was also used to present an overview of key riverine environments, catchment hydrology and environmental water requirements at the second series of community meetings.

The project team then began collecting and interpreting data to assess watercourse conditions. It considered the issues and concerns raised at the initial community meetings as part of this process. Watercourse management issues for each subcatchment and potential management options were discussed at the second series of community meetings when landholders had the opportunity to participate in determining management priorities.

The final stage in the planning process was preparation of the river management plan for the Light catchment. A draft version was reviewed by the project reference group and members of the scientific panel, as well as by a DEH and DWLBC internal review panel before the final plan was produced.

3.2 Community and stakeholder involvement

3.2.1 THE PROJECT REFERENCE GROUP AND STAKEHOLDER INVOLVEMENT

Key stakeholder organisations were involved primarily through the project reference group. The group, comprising local representatives of soil conservation boards, animal and plant control boards, local government, the Clare Valley Water Resources Planning Committee, PIRSA, DEH, and the former Department for Water Resources met monthly. It provided a local advisory role to the project team and facilitated the integration of river management information into the plans and work programs of their organisations. The group also promoted the project to their organisations and to the wider community. Members of the organisations were invited to attend the community meetings held by the project team.

3.2.2 COMMUNITY INVOLVEMENT

The process of community involvement was adapted from that used successfully by the Riparian Zone Management Project in the Mount Lofty Ranges (Department of Environment and Natural Resources 1997a,b). All landholders with property adjacent to a fourth order or larger watercourse (see Section 3.3.1) were contacted by mail and invited to be involved in the project, particularly by attending community meetings for information and participation. The wider catchment community was informed of the progress of the project through radio interviews, and articles and advertisements in local newspapers and community newsletters.

To facilitate community involvement and watercourse assessment, the catchment was divided into four subcatchments on the basis of drainage, property boundaries, land use and social networks. These subcatchments were: Upper Light, Mid Light, Gilbert and Lower Light (Map 3.1).

This arrangement had a number of advantages. Landholders within each subcatchment had similar management issues and concerns, and consultation at this level enabled greater focus on local issues. The small numbers involved in each subcatchment encouraged more landholder involvement.

Time constraints meant that only two rounds of community consultation were held in each subcatchment instead of the three held in the Wakefield and Broughton catchments. Eight separate meetings were held throughout the Light catchment and their outcomes are presented in Chapter 4.

Meeting 1

The first round of community meetings was held on 31 October and 1 November 2000. The aims of the initial community meetings were to inform participants about the project, discuss the data collection methods, and identify watercourse management issues of importance to local landholders. Participants were asked the following questions:

- What is the condition of watercourses in your subcatchment?
- What do you see as the watercourse management issues in your subcatchment?
- What condition would you like the watercourses in your subcatchment to be in, in 10–20 years?
- What are the barriers to better watercourse management?

Through a simple voting process, participants were able to identify the watercourse management issues of most importance to them and identify key barriers to better watercourse management. Feedback from the meeting was provided to all key stakeholders, riverine landholders and meeting attendees. Community responses to these questions are discussed in Chapter 4.

Meeting 2

Upon completion of the assessment of environmental water requirements, landholders and community members were invited to attend the second round of meetings in February 2001. The purpose of these meetings was to present landholders with an overview of the geomorphology, ecology and hydrology of the catchment and to discuss key riverine environments and their environmental water requirements. Key management issues identified through the watercourse assessment process conducted by the project team were also presented. The importance of each issue and options for management were discussed along with general principles for determining priorities for management. Landholders were given the opportunity to vote on their priorities for watercourse management in their subcatchment. This information assisted the project team to develop watercourse management priorities and options for each subcatchment of the Light catchment based on community and environmental priorities.

As it was not possible for all landholders to attend this final meeting, a summary of the outcomes of the voting process and the priority list of issues outlined in this document were mailed to every landholder for them to comment on.

3.3 Watercourse assessment methods

3.3.1 WATERCOURSE SURVEY

The watercourse survey was designed to provide a rapid assessment of the bio-physical condition of the larger watercourses in the catchment. The survey method used aerial video to make an initial visual assessment of watercourse condition. This assessment data was then interpreted to identify significant management issues.

The project focused on fourth order and larger watercourses as defined by the Strahler stream ordering system (Strahler 1964). In this system, unbranched watercourses originating at a source are termed first order streams. When two watercourses of the same order join, a stream of that order plus one is formed. Time and resource constraints limited the scope of the project to these larger watercourses. In total, more than 536 km of watercourses were surveyed (see Map 3.1).

The airborne video survey used a Seeker Seabird observation plane with a video camera installed under the passenger side of the plane. Flights were undertaken on fine, sunny days as cloud cover severely reduced the clarity and resolution of the video. The plane flew at approximately 1000–1500 feet above ground, a height that provided good resolution of watercourse parameters while enabling the navigator and pilot to easily track the watercourses. A video recorder captured the colour image as well as corresponding global positioning system (GPS) data. The GPS data was also recorded by an onboard laptop computer and later downloaded to a geographic information system (GIS).

Data was coded from the aerial video onto 1:20 000 base maps produced using ESRI ArcInfo and ArcView GIS. Watercourse parameters that were assessed were:

- density and type of riparian and in-stream vegetation coverage;
- location and density of exotic trees and weeds;
- large scale bed and bank erosion;
- channel features e.g. incision and channelisation;
- baseflow and pools;
- stream works e.g. bridges, culverts;
- adjacent land use.

The base maps of the surveyed watercourses included GPS points to aid the location of video image data. The coding methods used to analyse the video image were adapted from methods used previously by the Riparian Zone Management Projects (Department of Environment and Natural Resources 1997a,b).

The data taken from the video was verified by two weeks of groundtruthing in the field and further refined through consultation with landholders. The corrected data was entered into ArcInfo GIS and then converted to ArcView GIS coverage for storage, display and analysis. The GIS coverage created from coding of the aerial videos was used to produce maps of watercourse condition (Maps 5.5–5.8 and 5.10–5.11).

3.3.2 SCOPE AND LIMITATIONS

The aerial video flights, analysis of the videos and groundtruthing, completed between June 1999 and February 2001, represent a 'snapshot' of the condition of the larger watercourses of the Light catchment at this time.

Overall, airborne video survey provided a rapid and cost effective method for obtaining an overview of watercourse condition and habitat types across the Light catchment. However, this technique has limitations. The difficulties associated with flying a meandering watercourse mean that only an estimated 90% of the watercourses surveyed were captured on video. In addition, in areas of dense vegetation it was not possible to observe all watercourse parameters. On-ground surveying could not be conducted in some of these areas, in which case the parameters were classified as unobserved.

Riparian weeds were particularly difficult to assess and the survey was biased towards detecting weeds such as boxthorn and artichoke which have distinct growth or colour patterns that can be detected by air. In addition, density classes were based on crown cover and, as such, may not have always been a good indication of the severity of the weed infestation.

Due to the difficulty in identifying weeds along some reaches of the Light River, officers from the Lower North Animal and Plant Control Board conducted a ground survey of boxthorn and artichoke along the Light River from Redbanks to Allen Creek.

3.3.3 IDENTIFYING AND PRIORITISING WATERCOURSE MANAGEMENT ISSUES

The project team used data from the survey of watercourse condition to identify significant management issues along the surveyed watercourses. In determining these issues, the main focus was on ecological rehabilitation prospects. With this as a management goal it is often more effective to protect natural remnants than to focus effort on badly degraded watercourses (Rutherford et al. 1999). Overall, prevention is generally more effective, easier to implement and less costly than repairing damage caused. To determine the significant management issues for watercourses across the catchment, the project team used a set of general principles and guidelines (see Section 7.8) that, in brief, were:

- protect important assets such as riverine habitat or remnant vegetation
- protect or rehabilitate streams in the best general condition before those in poor condition; stop deterioration first rather than repairing damage caused
- consider the scale of the problem — issues that may be significant at a property level may not be significant at a catchment scale
- consider the impacts of the issue on upstream and downstream reaches
- consider the costs of management action against the ecological benefits.

After the key management issues for each subcatchment were identified, presented at the second community meetings and voted on, the project team produced tables highlighting priority management issues and management strategies for each subcatchment of the Light catchment (Tables 8.2, 9.2, 10.2 and 11.2).

The results of the watercourse assessment and the significant management issues identified are discussed on a catchment basis in Chapter 7 and shown on Map 7.1. These issues have been divided into three main categories: conservation, vegetation management and channel stability. Chapters 8–11 contain discussions of issues specific to each subcatchment.

3.4 Assessment of environmental water requirements

The current base practice for assessing environmental water requirements in Australia is to conduct multidisciplinary studies involving panels of specialist scientists. The extent of new data collection and investigations depends on the study timeframe and resources (Arthington 1998). The 'Scientific Panel Habitat Assessment Method' employed in this study was an adaptation of this generic approach to suit the following requirements:

- meet data, time and resource constraints
- be applicable to unregulated, ephemeral river systems
- provide a whole of catchment understanding of the river's physical and ecological components, processes and functions
- develop flow benchmarks where future changes could be modelled and subsequent impacts quantified
- incorporate community input.

The method was based on classifying the river system into river process (geomorphic) zones. The underlying assumption was that each zone would have a unique assemblage of river morphologies and physical habitats. The ecological components and processes for these zones also differed. Data was collected on representative habitats within these zones and studies of fish, frog and macro-invertebrate populations undertaken at sites across catchment. Recorded and modelled hydrological data was obtained for the different zones. A multidisciplinary scientific panel was assembled to review the data and use their professional knowledge and expertise to determine the critical flow parameters for each river geomorphic zone.

The approach was based on the following ecological and management principles:

- maintain the natural variability in connections between habitats
- maintain the natural variability in carbon/food sources
- maintain/improve the physical and ecological condition of the Light River
- maintain the natural variability of flows (level, duration, frequency, seasonality)
- maintain the system's natural biodiversity and where appropriate restore biodiversity values in degraded areas
- do not give human constructed structures/habitats priority over natural habitats (in terms of flows and managing the river system)
- prioritise areas of better biological and physical condition.

The method involved three essential phases: initial data collection, the scientific panel workshop and a post-workshop analysis of data (Figure 3.2).

3.4.1 DATA COLLECTION PHASE

Most data collection for assessing environmental water requirements for the Light River system for fourth order and larger watercourses was carried out between September 2000 and May 2001.

Scientific panel catchment tour

Members of the multidisciplinary scientific panel (Table 3.1) inspected the Light catchment in October 2001 to observe the river and its tributaries first hand, and exchange ideas and observations.

DATA COLLECTION PHASE

1. Assemble scientific panel
2. Undertake scientific panel catchment field trip
3. Identify river geomorphic zones
4. Complete field work:
   - representative habitat survey
   - fish survey
   - macro-invertebrate survey
   - community knowledge
5. Model hydrology

↓

ENVIRONMENTAL WATER REQUIREMENT WORKSHOP

1. Identify links between fish, macro-invertebrates, frogs vegetation, physical habitat and water regime for each zone
2. Identify key environmental water requirements (flow levels, duration, frequency, seasonality)
3. Identify management issues, knowledge gaps and monitoring needs

↓

POST-WORKSHOP

1. Model hydrology to compare recommended requirements with recorded flow data
2. Assess technical reports on links between geomorphology, ecology and environmental water requirements
3. Refine recommended environmental water requirements for each geomorphic zone

Figure 3.2 Process for determining environmental water requirements

Identification of river geomorphic zones

The major watercourses in the Light catchment were subdivided (Brizga 2001) into 20 geomorphic zones (Section 5.4, Map 5.4, Table 5.4) on the basis of:

- major tributary confluences;
- geology;
- natural channel and floodplain morphology;
- key landform units (e.g. the Light River delta and estuary);
- water resource development;
- channel incision.

The key features and characteristics of each zone are outlined for each subcatchment in Chapters 8–11.

Table 3.1 Members of the scientific panel

Participant	Field of expertise/role	Organisation
*Dr Sandra Brizga	Geomorphologist	S Brizga & Associates Pty Ltd
*Lance Lloyd	Ecologist	Lloyd Environmental Consultants
*Chris Madden	Biologist — Macro-invertebrate (Monitoring River Health Initiative)	Australian Water Quality Centre, SA Water
*Paul McEvoy	Biologist — Macro-invertebrate (Monitoring River Health Initiative)	Australian Water Quality Centre, SA Water
Michael Hammer	Biologist — Fish	The University of Adelaide
*Bruce Murdoch	Hydrologist	DWR (now DWLBC)
*Steve Walker	Herpetologist	EPA
Peter Goonan	Aquatic biologist	EPA
*Diane Favier	Project Team	EPA
*Glen Scholz	Project Team	EPA
*Jason VanLaarhoven	Project Team	EPA
*Jane Bradley	Project Team	EPA

* participated in scientific panel catchment tour

Data collection

Habitat surveys

Field surveys at sites representative of the main physical habitats within each geomorphic zone recorded longitudinal and cross-section profiles, and collected data on the parameters: landuse, channel/floodplain disturbance, floodplain and riparian zone width, baseflow characteristics, channel features, in-stream debris, substrate and floodplain, riparian and in-stream vegetation. Levels were recorded on the cross-sections to delineate physical and ecological features that might respond to various flows (e.g. flow levels covering in-stream benches and levels inundating river red gums on the floodplain). Photographs recorded each site.

Ecological studies

Ecological studies were commissioned by the project to collect and analyse data on key indicators (such as vegetation, fish, macro-invertebrates and frogs) across the catchment. The technical reports produced from these studies were then used by the scientific panel to determine the water requirements of key dependent ecosystems and by the project team to assess the health of watercourses throughout the catchment.

Ecologists from the Monitoring River Health Initiative (MRHI) analysed macro-invertebrate data from 64 samples collected from 20 MRHI sites in the Light catchment between 1994 and 1999. The data was initially analysed for the type of species present, species richness, abundance and distribution (Venus et al. 2000). It was also run through a predictive computer model (AusRivAS) to assess the relative health of each site (Venus et al. 2000). A technical report was produced with information on macro-invertebrate species diversity and distribution, river condition and recommendations on the water requirements of macro-invertebrate species in the Light catchment.

A one-off survey of fish populations combined with rapid macro-invertebrate sampling at seven MRHI sites in the Light catchment was conducted in December–January 1999. The resulting technical report contained information on native fish populations, an index of the biotic integrity of the river at the survey sites and a discussion of the water requirements of fish populations (Hicks and Sheldon 1999). An additional fish survey in December 2000 assessed several new sites within the catchment (Hammer 2001).

Information on frog populations and lifecycle requirements was gathered through the Frog Census program managed by the EPA.

PIRSA Rural Solutions was commissioned to study pre-European riparian vegetation associations in the Light catchment. This study used field assessments and information provided by Planning SA on remnant vegetation to determine the likely extent of pre-European vegetation associations. This information, together with the rehabilitation and revegetation requirements for each association, was included in a technical report (Brown and Kraehenbuehl 2000).

Community information

Information such as rainfall records, flood records, general observations relating to river flows and historical data was sought from local landholders. It supplemented the limited rainfall and gauged stream flow information available for the catchment.

Hydrological data and modelling

A basic assessment of the hydrology of the Light catchment was made using modelled flow information on rainfall, catchment characteristics and farm dams obtained from the National Land and Water Resources Audit (2000) for the period 1978–1997. This information, along with rainfall data over 1884–1997, was used in a simple hydrological model to determine the variability of flow over the extended period. This was then used to characterise the hydrology of the Light catchment, and to estimate the discharge from the system.

There are two stream flow gauging stations that have or are currently operated in the Light catchment, one near Kapunda and the other at Mingays Waterhole. The Kapunda gauging station operated from 1973 until 1989, and the gauging station at Mingays Waterhole has been in use from 1985 to present. A composite of flow recorded by these two stations was created. This data was used to obtain detailed information on flows, their frequency, duration, peaks and return periods, baseflow and flow sequences in the immediate area of these gauging stations.

Cross-sections and long profiles were surveyed at five sites throughout the catchment: on the Light River at Gordon Road crossing, downstream of Peters Road crossing, Ben Lomond Road crossing, near Hamilton, and on the Gilbert River at Tarlee (Appendix B; Figures B.1–B.5). This was done to enable the calculation of flow and velocity estimates using the slope area method. Due to spatial effects, only sites in close proximity to the gauging stations were able to have detailed hydrological information assessed. These sites were below Peters Road crossing and at the Ben Lomond Road crossing.

3.4.2 ASSESSMENT OF ENVIRONMENTAL WATER REQUIREMENTS

An ecologist reviewed the reports provided by the biologists (macro-invertebrate and fish surveys) and assessed field data to determine the environmental water requirements for the ecological components of the river system. These key ecological functions were related to specific flow levels, frequencies and durations. They were assessed for sites representative of each geomorphic zone (Lloyd 2001).

The geomorphologist outlined the catchment geomorphology, identified the characteristics of different geomorphic zones and discussed the flow parameters for important geomorphic processes at each representative site (Brizga 2001).

The hydrologist outlined the catchment hydrology and identified the flow volumes corresponding to the key flow levels identified on cross-sections taken at five sites throughout the catchment (Figures B.1-B.5) using the slope area method. Two of these sites (Ben Lomond Road crossing and Peters Road crossing) were in close enough proximity to the gauging stations to allow the determination of actual flow frequencies and durations (Murdoch 2001).

The project team reviewed the three reports and produced environmental water requirement tables integrating the three components. For each zone, the important flow bands and associated key ecological and geomorphic functions (e.g. migration of fish/scouring of pools), and frequency, duration and seasonal flow requirements were listed. At sites close to the gauging station, hydrological information was used to compare the environmental water requirements with the current flow regime.

Through the process of linking these components, the project team identified specific knowledge gaps. A workshop session was held to seek clarification from the scientific panel on a range of questions identified by the project team.

The tables outlining the environmental water requirements for each river geomorphic zone of the Light River system were refined based on the technical information provided at the workshop. These tables were reviewed and accepted by the panel participants (Appendix B, Tables B.1–B.21). A simplified discussion of the important flow bands for each zone, including key ecological and geomorphological functions, can be found in Chapters 8–11.

3.4.3 LIMITATIONS AND ASSUMPTIONS

The assessment of environmental flow requirements represents a simplification of a complex ecological system based on the best data and knowledge then available. The requirements determined are only estimates because knowledge of the ecology and flow relationships within the Light catchment is limited. These estimated requirements do, however, provide an initial and important basis for protecting the natural values of the catchment’s streams and wetland habitats.

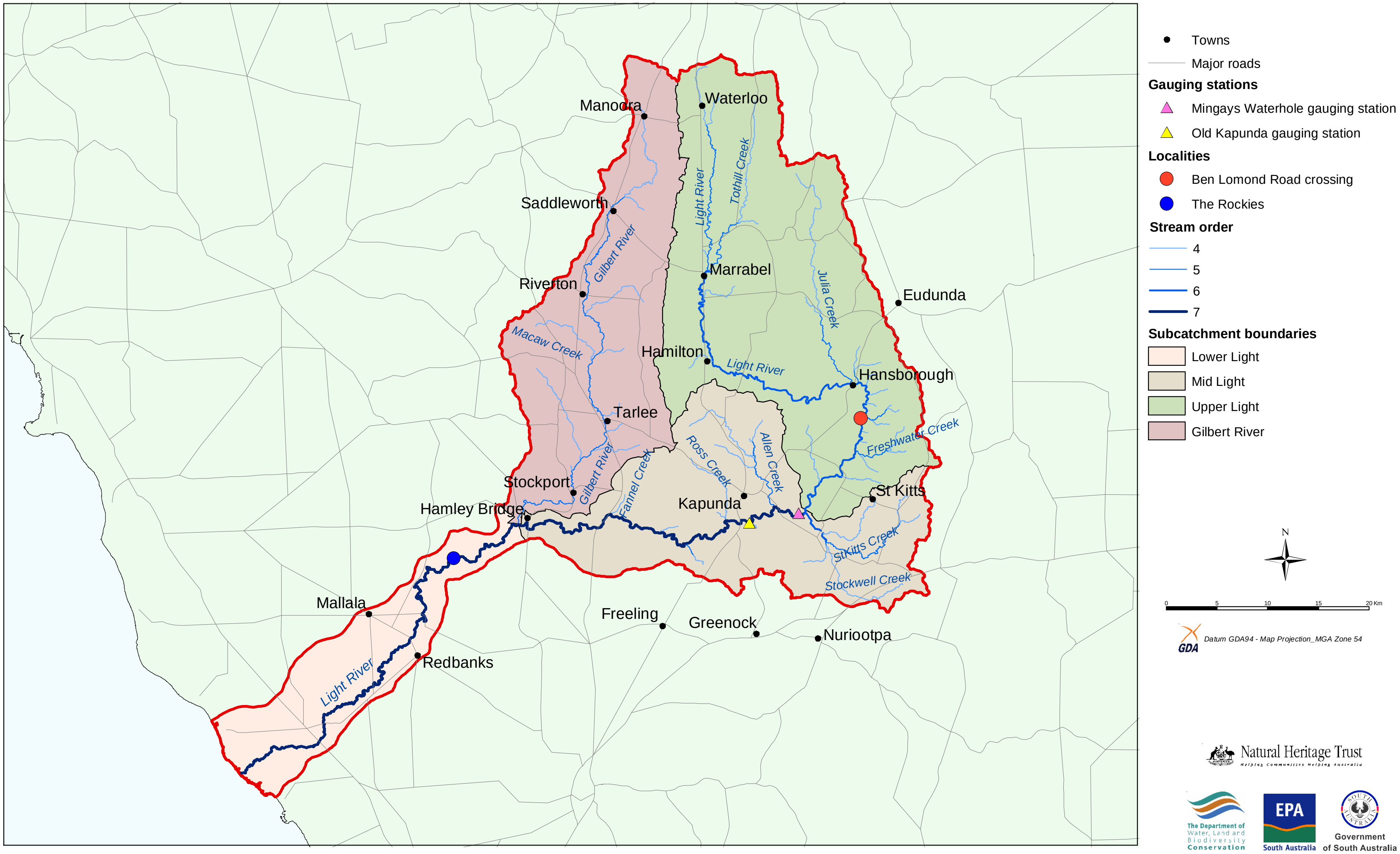
Many of the estimates of required flow frequency and duration were determined based on the requirements of fish. Fish are usually the most sensitive indicator to change and it is assumed that if fish requirements are met then most other ecological requirements are also being met.

The approach to describing environmental water requirements and their importance attempts to link key functions with a particular flow band. This is often a simplification as different flows may be significant for particular functions. For example, sediment transport is mainly driven by high flows but smaller flows also have an influence. Similarly, the functions of different flow bands change depending on the form of the channel. A flow event that reaches bankfull in a shallow channel may only reach a mid flow level in a narrow, deeply incised channel.

Similarly, environmental water requirements are described in terms of key components of the water regime (extent and depth, frequency, duration and seasonal factors). This does not take into account other features of the water regime that may be important (variability, the rates of rise and fall of a flow event, time since the last flow event and the sequence of flow events).

3.5 Summary

The methods used to assess watercourse conditions, determine management priorities and strategies, assess environmental water requirements, and involve the community and key stakeholders, have been summarised in this chapter. Further details for the methods used in the technical studies which supported this plan can be found in the technical reports produced by Hicks and Sheldon 1999, Venus et al. 2000, Brown and Kraehenbuehl 2000, Lloyd 2001, Brizga 2001 and Murdoch 2001.



Map 3.1: Surveyed watercourses and subcatchments in the Light catchment

CHAPTER 4 COMMUNITY CONSULTATION

4.1 Introduction

This chapter presents an overview of the outcomes of the community consultation process outlined in Chapter 3. Details of the local community's views on issues and watercourse condition for each subcatchment are discussed in Chapters 8-11.

Improved watercourse management will be achieved if the local catchment community develops an ownership of the management problems and the solutions. This will only occur if the community understands the importance of improved river management and if individuals can influence management actions.

Landholders, community members and key stakeholders within the Light catchment were consulted (Section 3.2) on a subcatchment basis to determine local watercourse issues, their vision for an improved watercourse environment and the challenges they may face in managing the watercourse. During the course of the project 465 landholders and stakeholders were contacted by mail and 224 people attended community meetings.

4.2 Management issues, barriers and goals

At the first meeting landholders responded to four main questions (Section 3.2.2).

4.2.1 CURRENT CONDITION

Perceptions of the current condition of watercourses in the catchment varied depending on which subcatchment the respondent's land was situated. Some believed the watercourses in their subcatchment were in good condition, although a lack of rainfall and a decrease in flows were considered to be impacting on water quality and river health. Other watercourses were considered to be in poor condition due to the lack of vegetation, rising salinity and erosion.

Two common observations were noted across the catchment: there was less flow in the system than in the past and pools were drying up; and the density of reeds in the Light River system had increased greatly.

It was also noted that the adoption of conservation farming practices such as contour banking and minimum tillage had improved land management across the catchment reducing runoff and soil erosion. Stock grazing had also decreased, which had reduced erosion and pollution within the watercourses.

4.2.2 ISSUES

Issues of concern and their importance differed among the subcatchments (see Chapters 8–11). However, a number of issues emerged as being common and important to people across the entire catchment:

- decreasing river flow;
- lack of native vegetation;
- degraded water quality;
- erosion;
- weeds;
- increased growth of reeds;

- increasing river salinity;
- flooding;
- reduction in level of watertable and pools, and the drying up of springs.

The degraded condition of the watercourse was of concern to many landholders throughout the catchment including declining water quality, erosion, weeds and reeds. Of most concern was the decrease in surface flows, and springs and waterholes drying.

4.2.3 VISION FOR FUTURE CONDITION

In response to the question of how they would like the watercourses to be like in 10–20 years, most landholders wanted a general improvement of present condition including:

- improved river flows and fewer reeds;
- improved health of the river system, including more native vegetation and wildlife;
- improved water quality;
- control of exotic flora and fauna along watercourses;
- a sustainable balance between development and maintaining a healthy riverine environment.

Landholders also expressed the need for increased community and government support and the need to maintain control of the management of their land.

4.2.4 BARRIERS TO SUCCESS

The most important barriers to watercourse management identified by landholders were:

- lack of community awareness, knowledge and information about how the river functions and how to improve management;
- lack of funds to address watercourse management issues and the extensive time and paperwork involved in the funding application process;
- the problem of economic viability versus environmental management including conflicts between agricultural use and environmental needs;
- lack of time to address watercourse management;
- lack of integrated catchment management and a lack of coordination and communication between organisations and individuals involved in river and water resource management;
- lack of social and regulatory consequences for poor watercourse management;
- outside impacts including upstream management impacting on downstream health;
- growing demands on water resources throughout the area.

4.3 Local knowledge

At meetings and through individual discussions, landholders and stakeholders provided valuable local knowledge that greatly assisted the identification of management issues and the assessment of environmental water requirements. In particular, landholders' rainfall and flood records were invaluable in understanding the catchment hydrology because many watercourses lacked hydrological data.

4.4 Achieving action on the ground

The results of the community consultation indicated that most people were aware of problems along their watercourses and would like to see the condition of their watercourses improved. Major barriers such as lack of knowledge, funds and support, no integrated management and conflicting uses need to be addressed in order to achieve changes on the ground.

CHAPTER 5 THE LIGHT CATCHMENT

5.1 Introduction

This chapter discusses the hydrological, geomorphological and ecological components of the Light River system, and the interaction between these components. It also reviews the ecological assets of the catchment, the potential impacts of changes to the flow regime on the health of the river system and discusses recommendations for the protection of the water dependent ecosystems.

The discussion in this chapter is based on field surveys by the project team, a literature review and findings from reports commissioned for the project on the following topics:

- biotic survey (Hicks and Sheldon 1999)
- riparian rehabilitation and revegetation (Brown and Kraehenbuehl 2000)
- environmental water requirements of macro-invertebrates (Venus et al. 2000)
- geomorphology and environmental water requirements (Brizga 2001)
- field data for additional sites in the Light catchment (Hammer 2001)
- environmental water requirements and ecology (Lloyd 2001)
- environmental water requirements: hydrology (Murdoch 2001)

Specific information on issues and environmental water requirements for the four subcatchment areas of the Light catchment is discussed in detail in Chapters 8–11.

5.2 Current and historical landuse and land management

Landuse and land management has undergone dramatic changes since European settlement, which have significantly altered watercourses within the Light catchment. The following brief account of the changes in landuse and land management since European settlement has been sourced from the Lower North Soil Conservation Board District Plan (Soil Conservation Council 2001).

Rail links to Adelaide opened the region up to cereal cropping in the 1860s and this remains the dominant landuse today. The valleys and lower slopes of the highlands were quickly developed for farming with the pre-European open grassland and open woodland vegetation of the region presenting few problems to agricultural development. Areas of dense mallee scrub in the Light catchment restricted agricultural development until the invention of the scrub roller and stump jump plough in 1876.

The standard practice of ‘a roll, a burn and a stump jump plough’ of developing mallee country resulting in the loss of significant tracts of native vegetation. The use of the wheat–fallow system, which was standard practice between the 1870s and 1940s, involved intensively cultivated fallows of 9–10 months or longer and stubble burning.

This practice depleted organic matter reserves, damaged soil structure and left soils exposed to wind and rain erosion. In some areas, the breakdown in soil structure caused a surface seal to develop. The resulting increased runoff rate caused widespread sheet and gully erosion, and is likely to have caused the significant watercourse incision evident in many areas of the catchment today.

Farming practices improved during the 1940s with the adoption of the Ley farming system, involving the rotation of crops with improved pastures (barrel medic and subclover). The value of improved pasture species was soon realised and, together with high wool prices, the practice led to an increase in sheep and wool production, and in many cases surpassed cropping in net value.

Contour banking has been used to control water erosion in the hilly cereal districts of the catchment since 1945. The original banking systems were designed to intercept and hold excess water and to ensure that as much water as possible soaked into the soil, while safely redirecting excess water, and preventing gully erosion and siltation downstream.

The use of other recent land management practices such as minimum tillage and stubble retention has also helped to manage soil erosion and reduce surface runoff, as well as resulting in increased yields.

The main landuse within the Light catchment today is the cropping of cereals, grain legumes, and canola, sometimes coupled with grazing. In recent years there has been an increase in more intensive cropping rotations due to low grazing returns. Increased vegetation cover on cropping land and reduced grazing along watercourses has resulted in a general improvement in watercourse condition.

5.3 Hydrology

5.3.1 RAINFALL

Rainfall from the coast across the plains to the low undulating areas around Hamley Bridge varies from 350 to 450 mm per year. The remainder of the catchment in the Northern Mount Lofty Ranges receives from 450 mm to just over 500 mm per year, with regions of higher rainfall in the higher relief areas (Map 5.1).

The Light catchment has a reliable winter rainfall pattern with most of the total annual rain falling between June and September. However, total annual rainfall is extremely variable from year to year: at Kapunda it ranges between 362 mm and 654 mm in 80% of years.

Thunderstorms are common between December and March, and can deliver high rainfall quantities in short periods of time. These summer events are very variable between years (B Murdoch, pers comm 2001), and are localised and therefore patchy across the catchment.

5.3.2 GROUNDWATER

Little information is available on the groundwater systems that support permanent pools and baseflow within the Light River system. Michael Cobb (Water Search Pty Ltd) provided the following information.

East of an approximate north–south line through Hamley Bridge are hard-rock groundwater systems with some shallow alluvial areas at the northern end of the Barossa Valley alluvial system. Most rock types are siltstones, shales and slates with low well yields and generally high salinities limiting these resources to stock water use. Relatively thin bands of sandstone, quartzite and marble can provide higher yields of irrigation quality water but they are small areas of limited geographic extent.

To the west of Hamley Bridge lies the St Vincent sedimentary basin, forming a layer-cake sequence of aquifers and aquitards. The unconfined aquifer (watertable) influences flows in the Light River and is generally quite saline. The deeper confined aquifers that are used by Virginia irrigators provide better quality water but the salinity is still too high for irrigation.

Landholder consultation has indicated that historically the baseflow in the lower reaches of the Light River around Port Wakefield Road flowed permanently but, over the last 10–20 years, has ceased to flow over drier seasons. Landholders also suggested that this may be due to extensive pumping of groundwater on the Adelaide Plains at Virginia. However, this is unlikely as there is very little interaction between the two aquifers. The loss of flow is more likely to be due to a combination of recent low annual rainfall and a change in land management practices leading to a reduction in groundwater recharge.

5.3.3 SURFACE FLOW

Generally there are two aspects of runoff: storm flows produced by high intensity rainfall; and flow produced by overall winter rainfall. Runoff occurs when the soil profile is sufficiently saturated so that further rainfall cannot be absorbed or when the rate of rainfall exceeds the rate at which the soil can absorb water. On an annual catchment scale, rainfall of greater than 450 mm is required to suitably saturate the catchment in order to generate significant flows in the Light River (Figure 5.1). Rainfall events in July, August and September on an already 'wet' catchment result in significant runoff and stream flow (Figure 5.2).

Most watercourses within the Light catchment cease to flow in summer and autumn, with the main channels drying back to permanent pools (Map 5.2). Some sections of watercourses dry up completely, including the lower reaches of the Light River south of Mallala.

Only two stream flow gauging stations have operated in the Light catchment. The Kapunda gauging station recorded data from 10 May 1973 to 29 May 1989, and the Mingays Waterhole gauging station, still in use on the Light River east of Kapunda, has recorded data since 11 July 1985. Consequently, little is known of the flow characteristics for the ungauged watercourses and the in-stream losses and gains of the catchment as a whole.

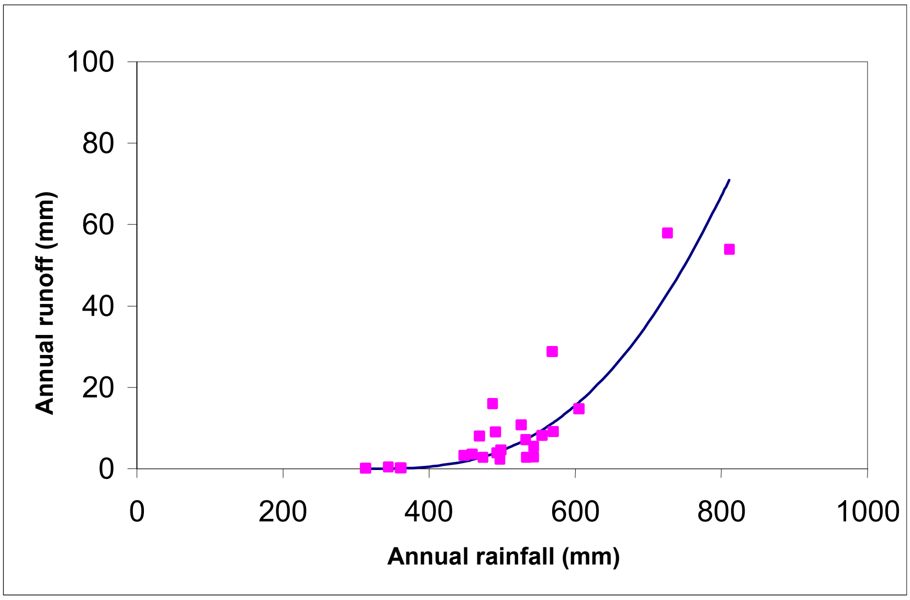


Figure 5.1 Annual relationship between surface runoff driven flow (minus the baseflow component) in the Light River at Mingays Waterhole and rainfall recorded at Kapunda

Areas of permanent groundwater driven baseflow have been identified along the lower reaches of the Gilbert River, the upper reaches of Julia Creek and along the Light River from the junction with St Kitts Creek extending approximately 15 km downstream. Based on gauging information (1985 – 2000), baseflow on the Light River at Mingays Waterhole has never ceased, even following drought years (Murdoch 2001). This indicates that baseflow is relatively secure in the Light catchment, unless significant groundwater extraction occurs in the baseflow source areas.

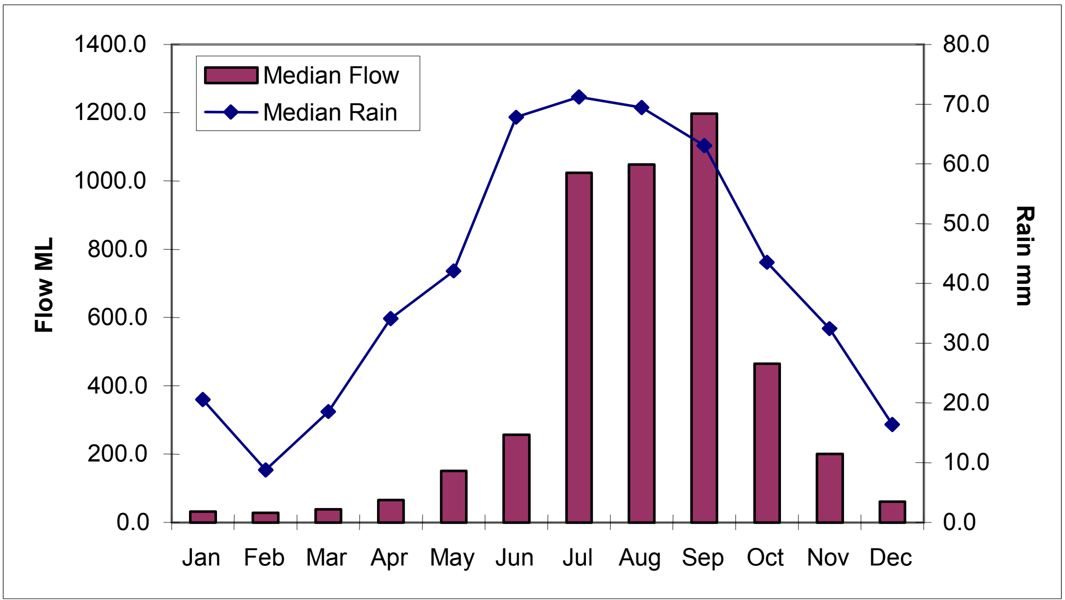


Figure 5.2 Monthly median flow in the Light River at the Mingays Waterhole gauging station and Kapunda monthly median rainfall (1978–1997 data)

5.3.4 HYDROLOGICAL FEATURES

Hydrological flows assessment in the Light catchment has been derived from data collected at the Kapunda and Mingays Waterhole gauging stations and from modelling of Light catchment flow characteristics by the Department for Water Resources (now Department of Water, Land and Biodiversity Conservation) (Murdoch 2001).

Mingays Waterhole is located on the Light River in the middle of the catchment (Map 3.1). Caution needs to be applied when extrapolating hydrological data to areas distanced from the gauging station. Flows in various regions throughout the catchment will give differing levels of inundation due to varying channel shape and in-stream features, such as deep pools, rocky outcrops, and vegetation type and density. However, this assessment can be used as an indication of the flow characteristics of the Light catchment.

Flow volume

The mean annual volume of flow from the upper Light catchment to Mingays Waterhole, based on the period 1978–1997, is 12,100 megalitres (ML), with a median of 7,500 ML (Murdoch 2001).

The estimated mean annual Light River flow just downstream of the Gilbert River junction at Hamley Bridge, is 22,400 ML and the median flow is 14,800 ML. The mean and median adjusted flows (flow with the impact of farm dams removed) are 24,300 and 16,730 ML per year respectively. Based on modelling data, the construction of farm dams has resulted in an approximate 8% reduction in the mean annual stream flow volume in the Light River.

Farm dams in the Light catchment have an estimated total capacity of 3,000 ML and capture on average 1,900 ML per year of which 1,100 ML is used annually (Murdoch 2001). As illustrated in Figure 5.3, farm dams are not considered to significantly impact on stream flow in the Light catchment. However, it is possible in smaller reaches that farm dam development may be starting to impact on environmental water requirements. Areas that appear to have greater dam development include the area around Stockwell and, to a lesser degree, in the area south-west of Hamilton extending north along the Light River. These areas should be monitored to determine if excessive impacts are resulting from this level of development.

Modern conservation farming practices, such as contour banking and minimum tillage, have increased soil moisture storage, and thus reduced the amount of runoff within the catchment compared to earlier periods of European settlement. These practices would also reduce watercourse flows.

The section downstream of the fault line at Redbanks is thought to be a losing reach (the flow is not confined to the stream bed and contributes to groundwater). Realistic estimations of flow to the estuary are not possible due to the lack of groundwater and gauging station information.

Extraction rates of groundwater within the catchment for agricultural purposes has not been significant because the high level of salt in the watertable renders the water unsuitable for current irrigation purposes. On a catchment basis, the current level of farm dams does not significantly reduce the volume of surface flow, therefore flow volumes within this river system can be considered relatively close to natural levels.

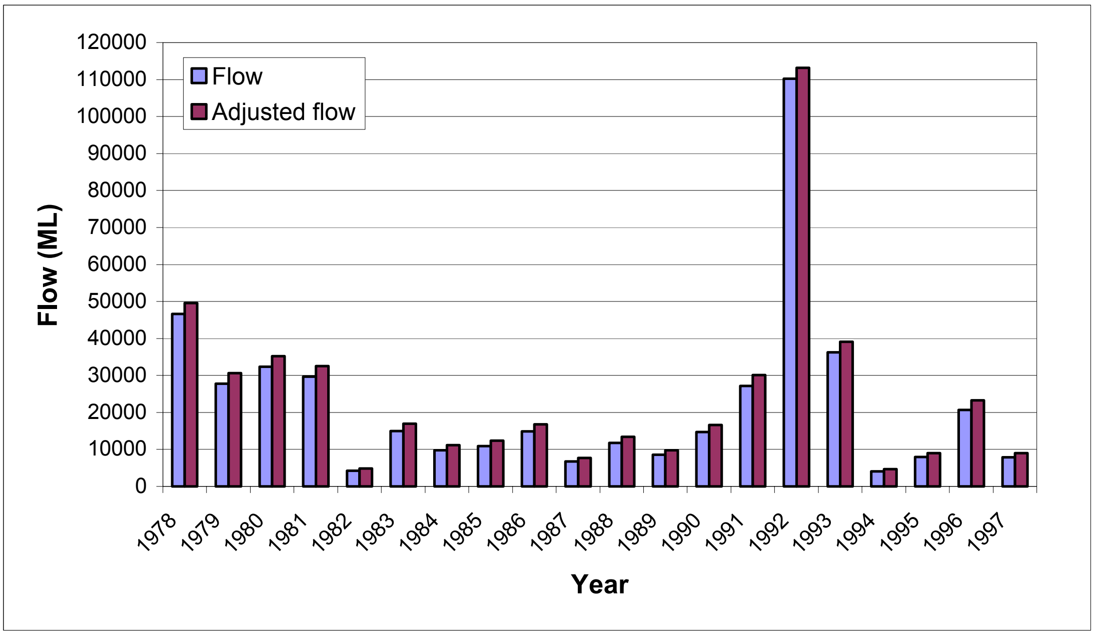


Figure 5.3 Estimated annual flow (adjusted flow has the impact of farm dams removed) in the Light River downstream of the junction of the Gilbert and Light rivers (Hamley Bridge)

Flow variability

Characteristics of flow variation in the Light catchment can be determined by assessing the flow statistics. The seasonal pattern is well defined with the annual variability in flow volume strongly correlated to rainfall events in winter and spring (Figure 5.4). In the catchment the period from July to October contains the flow events that will provide the most significant ecosystem responses.

The variability is best shown using the 10th and 90th percentiles. The closer the flow volumes at these percentiles, the lower the variability. Assessment of these parameters shows that the variation in flow volume is high and large flow events are unreliable (Figure 5.4).

The monthly flow pattern has not been greatly altered by existing levels of water resource development. Future flow management strategies will need to ensure that the natural flow variability of streams is maintained, as features of these regimes act as biological cues for many animals and plants.

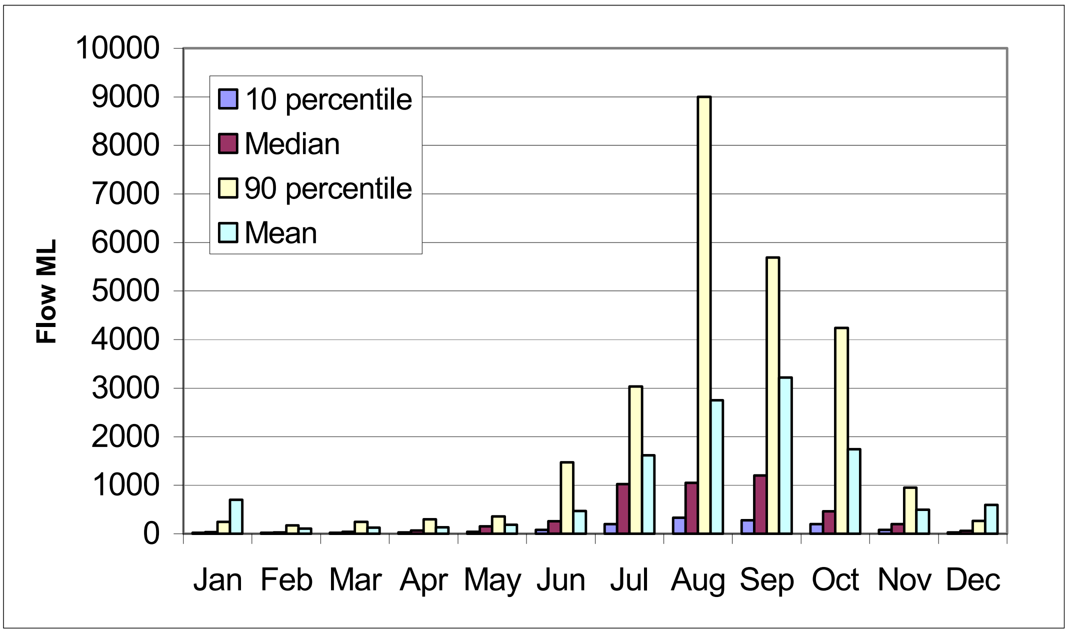


Figure 5.4 Monthly flow variability in the Light River at Mingays Waterhole (1978–1997 data)

Flow duration

Although flow peaks can stimulate environmental responses, the duration of flows at specific levels determines the magnitude of physical change and the success of ecological recruitment and establishment. Figure 5.5 is a representative example of flow durations in the Light River for events exceeding 10 cumecs (m^3/sec) in the reach between Mingays Waterhole and Kapunda.

This figure illustrates that large flow events, around 10 cumecs, are of very short time duration, in some instances lasting only a couple of hours. After the flow event peaks, there is a rapid decrease in flow volume down to the baseflow level within approximately three to four days.

Figure 5.6 is a representative example of the flow duration for higher flow events. A flow greater than 50 cumecs occurs one year in every three based on an annual exceedence probability (AEP). After the flow event peak, again, there is a rapid decrease in flow volume down to the baseflow level within approximately four to five days. To sustain flows over a longer duration (above the baseflow level) a sequence of events needs to occur similar to that shown in Figure 5.5.

Assessment of the hydrological data for Mingays Waterhole shows that a flow sequence of greater than 10 cumecs occurring for at least two days, sustained at a flow level above 2 cumecs has the following probabilities.

- three day run, 1:2 event (AEP)

- five day run, 1:3 event (AEP)
- nine day run, 1:6.5 event (AEP).

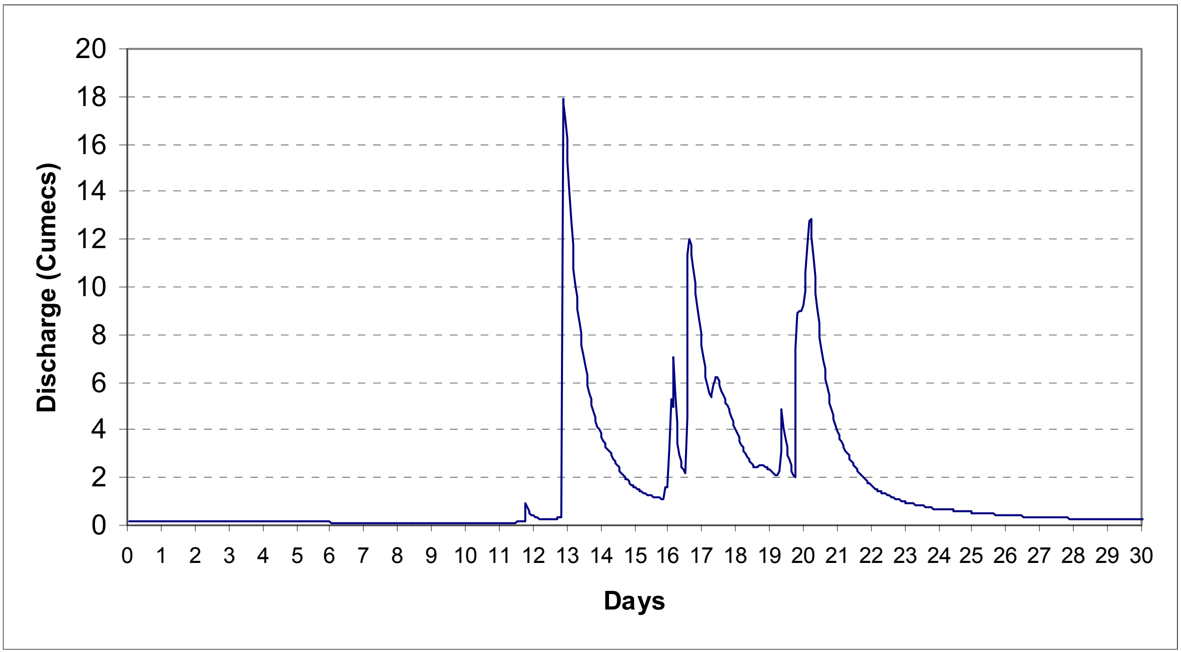


Figure 5.5 Flow sequence for September 1986

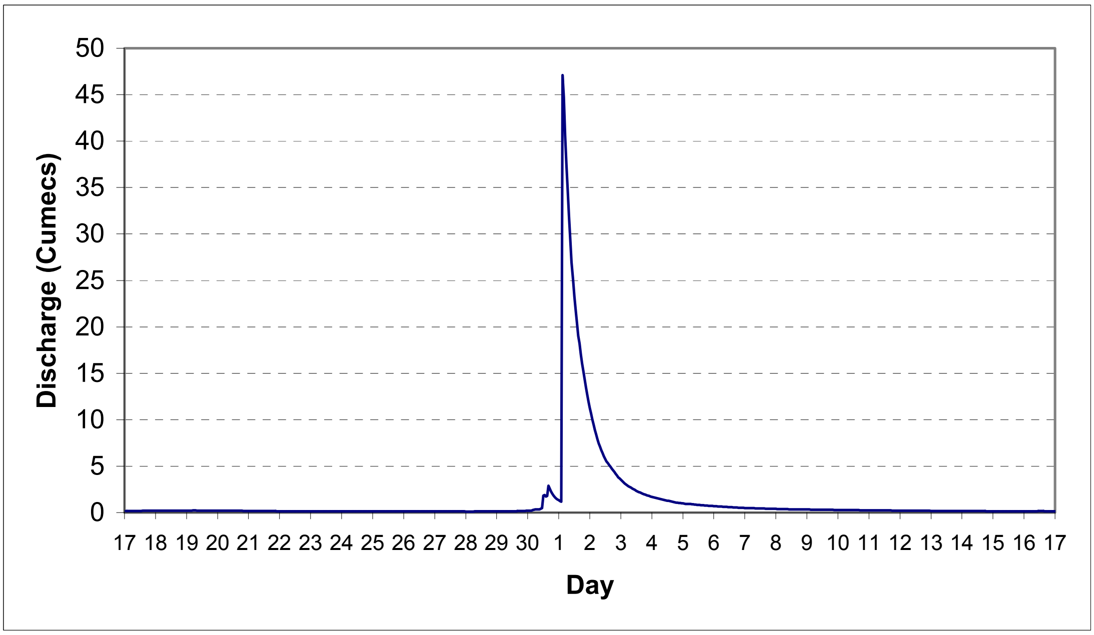


Figure 5.6 Flow sequence (48 cumec) for September-October 1996

In comparison to pre-European conditions, for most of the reaches in the Light River system the flow peak has probably increased and the flow duration shortened due to vegetation clearance and the subsequently higher rainfall runoff rates within the catchment. This is particularly significant at Mingays Waterhole which is in close proximity to the cleared streams of the eastern slopes of the northern Mount Lofty Ranges.

When considering ecosystem responses to flow, it is the combination of the frequency, duration and seasonality of flows in relation to the inundation of specific habitats (e.g. pools, riffles, benches and floodplains) that is important. The key findings from the assessment of flow data indicate that significant flow events for the Light River are of a relatively short duration with the timing and frequency of these events being critical for ecological functioning.

5.3.5 WATER QUALITY

Information on water quality within the Light catchment is limited. The only detailed water quality measures are from one location — Mingays Waterhole gauging station on the Light River — with readings beginning in 1985. Results of the ambient water quality monitoring in the Light catchment can be seen in Table 5.1 (adapted from Environment Protection Agency 1998).

Overall, water quality can be described as moderate to good based on the classification used by the Environment Protection Agency (1998). Two exceptions to this are high total zinc concentrations and very high salinity levels, which may be natural catchment features.

Table 5.1 Water quality indicators at the Mingays Waterhole gauging station (GS505532), Light River

Water quality characteristics (all values in mg/L unless specified)		Mean ± confidence interval	Median	10^{th} percentile	90^{th} percentile	No. of samples	Water quality classification*
Nutrients	-Oxidised nitrogen	0.076 ± 0.060	0.020	0.006	0.180	24	Moderate
	-TKN	0.597 ± 0.142	0.480	0.300	0.914	24	Good
	-Total phosphorus	0.020 ± 0.005	0.018	0.009	0.035	24	Good
	-Soluble phosphorus	0.0052± 0.0004	0.005	0.005	0.005	23	-
	-Dissolved organic carbon	5.3 ± 1.0	4.1	2.9	9.32	24	Good
Physical	-pH (pH units)	8.1 ± 0.1	8.1	7.9	8.2	24	Good
	-Temperature (deg C)	16.7 ± 2.1	17.0	11.0	23.0	22	-
	-Dissolved oxygen	9.1 ± 1.0	8.9	5.7	11.9	19	Moderate
Clarity	-Turbidity (NTU)	4.7 ± 2.5	1.8	0.8	12.2	24	Good
Heavy	-Total copper	0.006 ± 0.002	0.005	0.005	0.006	24	Good
Metals	-Total lead	0.0010± 0.0001	0.001	0.001	0.001	24	Good
	-Total zinc	0.143 ± 0.037	0.112	0.056	0.252	24	Poor
	-Soluble zinc	0.126 ± 0.030	0.096	0.049	0.234	24	-
	-Total iron	0.222 ± 0.102	0.120	0.082	0.503	24	Good
	-Total aluminium	0.245 ± 0.143	0.101	0.064	0.543	24	-
	-Soluble aluminium	0.063 ± 0.015	0.056	0.032	0.075	24	Good
Salinity	-actual (μS/cm)	8214 ± 1012	9275	4258	10100	24	Poor
	-estimated (mg/l)	5093 ± 627	5751	2640	6262	24	Poor

* Based on limited data

The major sources of zinc within the Light River environment are likely to be from particles released from the weathering and erosion of rocks and sediments (ANZECC and ARMCANZ 2000), septic tank effluent disposal schemes (STEDS) that flow into the system, and runoff of fertilisers that contain zinc (P Goonan, pers comm 2001).

Zinc is an essential element for both plants and animals but can be toxic in high concentrations. Zinc toxicity is influenced by water hardness and pH and can affect both fish and invertebrates. It can therefore impact upon the composition of aquatic communities. Some organisms may bio-accumulate zinc, particularly filter feeding molluscs.

The soluble forms of zinc are more toxic than particulate forms but there are no guidelines for soluble zinc for the protection of aquatic ecosystems. Given this, any level of soluble zinc that equals or exceeds that of total zinc guidelines will be a concern in terms of its potential impacts upon aquatic communities.

If high zinc levels are a result of pollution, aquatic organisms sensitive to zinc could be excluded from the system. However, it is most likely that high zinc levels are a natural characteristic of water quality in the Light River system (M McLaughlin, pers comm 2001) and thus the species composition would include aquatic organisms tolerant of high zinc levels.

Salinity measurements from Mingays Waterhole indicate that the Light River system has a highly variable salinity range, from the saline groundwater and ephemeral nature of the river system. As discussed by Murdoch (2001) the baseflow in the catchment has a relatively high salinity range, generally 2,400 µS/cm (1440 mg/L) to 12,000 µS/cm (7,200 mg/L), (Table 5.2). Median baseflow is 6,000 mg/L in summer and 4,200 mg/L in winter.

The high stream salinity that appears to be a feature of the Light catchment is probably due to two processes: the input of naturally saline groundwater as baseflow and the concentration of salinity in permanent pools through evaporation.

Table 5.2 Flow bands and related salinity levels

Flow bands	Flow range (cumecs)	Salinity (mg/L)	Median (mg/L)
Summer baseflow	0–0.04	5,100–7,200	6,000
Winter baseflow	0.05–0.7	1,440–6,000	4,200
Low flow	0.1–3	540*–4,800	n.a.
Mid flow	3–10	n.a.	330*
High flow	> 10	n.a.	300*

* based on limited data

High salinity levels were found to be a significant issue along Tothill Creek in the Upper Light subcatchment and vegetation clearance in the local catchment has probably been a contributing factor. Before the vegetation was cleared, transpiration and rainfall capture by perennial vegetation would have kept groundwater levels and the accumulation of salts below the root zone. The shallow rooted, seasonal pastures and crops now in the area allow more water to bypass the root zone and recharge the groundwater. The groundwater level has thus risen far enough to discharge into watercourses and low-lying areas (Evans 1994).

In dry periods pools will increase in salinity as salts concentrate through the process of evaporation. Surface flows are thus important to flush pools and prevent the build up of salts. In winter, increased baseflows and rainfall runoff act to dilute and freshen in-stream flow.

Animals and plants have varying tolerance levels to salinity. Macro-invertebrate species diversity is significantly reduced when water salinity levels exceed 6,000 mg/L (Hicks and Sheldon 1999). Even though the Light catchment may be a naturally saline system, any significant increase in salinity may disadvantage the more salt sensitive species, thereby causing changes in the animal and plant community composition.

5.3.6 FLOW BANDS

Flow bands are used to describe key features of various flow regimes (see Table 5.3). They are useful for describing key environmental water requirements for geomorphological and ecological processes (see 5.4.3 and 5.5.6).

Table 5.3 Key hydrological features of various flow regimes

Flow band	Description
Groundwater table	Groundwater intersects the stream bed and expresses itself as permanent water in the low lying parts of the stream bed. There is no flow but the stream bed and pools are kept permanently wet.
Baseflow	There are two aspects of baseflow — permanent and seasonal pulse flow. Permanent baseflow is that part of the flow regime that is constantly flowing, often at a very low level and driven by groundwater. The seasonal pulse baseflow is that part of the flow regime which is expressed with a sharp rise following seasonal rain.
Low flow	Low flows lie between seasonal baseflow and mid flows, and are mostly derived from surface flows but can have a significant baseflow component. Flows tend to be frequent and have a long duration.
Mid flow	Mid flows are typically those that cover the bed of the stream and up to about half the height of reeds in the stream or on the stream edge. Some of the lowest in-channel benches may be flooded, creating further habitat.
High to bankfull flows	High flows are those that generally fill ¾ of the channel to bankfull within the stream and may marginally spill onto the floodplain. All in-stream benches are inundated creating further habitat for macro-invertebrates, plants and fish.
Overbank flow	Flows greater than bankfull and inundating the floodplain, if it exists.
Catastrophic flow	These large, infrequent floods cause significant stream bed and channel rearrangement, and alter or reset the habitat.

5.3.7 IMPACTS ON FLOW REGIME

Vegetation clearance and agricultural development have had significant effects on watercourses and flow regimes in the Light catchment. Surface flows and groundwater levels are likely to have risen in response to the vegetation clearance following settlement.

Subsequent decreases in both surface flows and baseflow is most likely caused by significant improvements in land management such as contour banking, minimum tillage, reduced stocking and improved pasture management. All act to reduce the amount of runoff and soil erosion generated within the catchment. Many of these practices increase soil moisture retention and further study is necessary to assess their full impact on runoff.

Water diversions in the catchment are predominantly for stock and domestic use from a small number of farm dams that have only slightly increased in numbers over the past decade (National Land and Water Resources Audit 2000). These do not impact significantly on flows throughout the catchment.

Since European settlement the processes of watercourse incision and sediment deposition have altered the natural physical shape of the watercourses in many reaches. This has caused changes in flow velocity and flow levels within areas of the channel.

Sedimentation has resulted in an increase in the distribution of dense reed beds of common reed (*Phragmites australis*) in a number of watercourses and has probably altered stream flow hydraulics. Dense stands of common reed are likely to resist flow in smaller events, and may cause minor flooding; during larger events they are generally bent horizontal, greatly decreasing hydraulic resistance and allowing higher velocity flows.

5.4 Geomorphology

5.4.1 GEOMORPHOLOGICAL FEATURES OF THE LIGHT CATCHMENT

Geomorphology encompasses those features and processes that determine the shape, form and physical habitats found along a watercourse. These features include geology and landform, and processes such as sediment transport and erosion.

The Light catchment has two distinct landscape features: the hills and valleys of the Mount Lofty Ranges; and the flat coastal plains. These large-scale features control the drainage system of the catchment influencing the channel form and behaviour of the watercourses. The Light River topography showing the separation of the hills and valleys from the flat coastal plains is shown in Map 5.3.

The Light River flows through the hills and valleys of the Mount Lofty Ranges from its beginning at Waterloo, through to the junction with the Gilbert River at Hamley Bridge; the flat coastal plains extend from this point to Gulf St Vincent.

The influences of geology and landscape features can be seen in the behaviour of the Light River and its major tributaries. The Light River begins near Waterloo and flows southward, parallel to the north–south alignment of the Mount Lofty Ranges, down to Hamilton. It then flows eastward, and perpendicular to the alignment of the Mount Lofty Ranges towards Hansborough. Tothill Creek and Julia Creek also follow the north–south alignment of the ranges, and join the Light River at Marrabel and Hansborough respectively.

After flowing past Hansborough, the Light River turns south to south-west, and again follows the alignment of the Mount Lofty Ranges. St Kitts Creek flows through the Mount Lofty Ranges onto the Barossa Valley plain then joins the Light River. The Light River then flows westward, until it reaches the junction with the Gilbert River. The Gilbert River begins around Manoora, and flows parallel to the folding of the Mount Lofty Ranges through the Gilbert Valley, until it reaches Stockport, where it cuts across the ranges, and joins the Light River at Hamley Bridge.

The stream valleys of the Mount Lofty Ranges vary from wide and shallow along the Gilbert River and Upper Light, through to the confined and deep along the Light River between Kapunda and Hamley Bridge.

The coastal plains can be divided into three main sections:

1. Upper plains (Pinkerton Plains) — extend from Hamley Bridge to the Redbanks fault.
2. Lower plains — extend from Redbanks fault to approximately 4 km inland from coast.
3. Coastal — extend from approximately 4 km inland to the Light River estuary.

The Light River in the upper and lower plains consists of a single deep channel, often lined with a narrow riparian strip of river red gum (*Eucalyptus camaldulensis*), that contains flows in all but very large flow events. The Light River in the upper plains has cut down to bedrock, and it is this that differentiates it from the lower plains.

The Light River in the coastal section flows over stranded beach ridge deposits and shelly silts and sands, overlain in places by intertidal and swamp deposits. The river in this section breaks into a number of smaller channels, and floods approximately every four years, entering Gulf St Vincent through numerous tidal channels.

5.4.2 GEOMORPHIC ZONES IN THE LIGHT CATCHMENT

The Light catchment has been divided into 20 geomorphic zones (Map 5.4; Table 5.4.), based on characteristics such as underlying geology, channel and floodplain characteristics, key landforms, channel incision and hydrology. The physical and hydrological characteristics of each zone distinguish it from other areas of the river system and influence the plants and animals found there.

Details of the physical and ecological environments of the geomorphic zones within the different subcatchments of the Light catchment are discussed in Chapters 8–11.

5.4.3 GEOMORPHOLOGICAL PROCESSES AND FLOW BANDS

All catchment watercourses have intermittent or ephemeral reaches and flows are characterised by a high degree of variation between years. As a result, geomorphological processes are also episodic with little erosion and sedimentation in most years but high rates of erosion and sedimentation during infrequent major flood events (Brizga 2001).

A number of geomorphological functions have important environmental water requirements and are briefly described below. For more detail see Appendix A.

Maintenance of wetted habitat

Maintenance of wetted habitat such as pools, riffles, rock bars and macrophyte beds are important for sustaining vegetation, aquatic habitat and connectivity between pools. In-stream features, bed and bank stability, and vegetation influence flow hydraulics and affect erosion and deposition processes.

Groundwater level to medium flows are the most important flows in maintaining wetted habitat conditions. However, higher flows also play a role in maintaining wetted habitat.

Sediment transport

If sediment is not transported it builds up in one location, which can lead to loss of in-stream habitats and structural diversity, and a raised stream bed; it can favour some vegetation species such as the common reed. Sedimentation can lead to the encroachment of vegetation into the flow channel. The loss of channel capacity can be a contributing factor in the development of avulsions (alteration of channel course). Sediment delivery to the estuary is an important process in maintaining the estuarine environment.

Actual key flow magnitudes will depend on sediment sizes (e.g. medium to high flows for sand, high flows for gravel). In terms of total volumes of sediment transported, large floods are of key significance because they generally transport the largest volumes of sediment.

Riffle maintenance

Removal of sediments from riffle substrates is an important process as it prevents the covering over and the filling of the pores between the riffle substrates. Riffles are important habitat areas for a number of animals such as aquatic macro-invertebrates and fish.

Fine sediment and organic material may accumulate on riffles during low flow periods. High flows remove fine sediments from riffle surfaces and interstices.

Table 5.4 Geomorphic zones of the Light catchment

Subcatchment and river/stream	Zone	Zone location/description (see Map 5.4)	Zone differentiation criteria
Lower Light subcatchment – Light River	1	Coast to upstream end of estuary	Tidal influence
	2	Upstream of estuary to downstream of Redbanks	Non-tidal: broad floodplain
	3	Redbanks to Jarmin Road crossing	More narrow floodplain confined between higher terraces
	4	Jarmin Road crossing to Gilbert River junction	Narrow valley incised into the Pinkerton Plains; major in-flow from the Gilbert River
Mid Light subcatchment – Light River	5	Gilbert River junction to 2 km downstream of Peters Road crossing	Confined valley in bedrock; upstream of Gilbert River junction
	6	Peters Road crossing to St Kitts Creek junction	Includes gorge sections of the Mid Light River; major in-flow from St Kitts Creek
Upper Light subcatchment – Light River	7	St Kitts Creek junction to Julia Creek junction	Confined valley; upstream of St Kitts Creek junction; major in-flow from Julia Creek
	8	Julia Creek junction to Tothill Creek junction	Wider, unconfined valley; upstream of Julia Creek junction; major in-flow from Tothill Creek
	9	Upstream of Tothill Creek junction	Upstream of Tothill Creek junction
Gilbert subcatchment – Gilbert River	10	Light River junction to Saddleworth	Extensive reed beds
	11	Upstream of Saddleworth	No reed beds
Gilbert subcatchment – Macaw Creek	12	Macaw Creek	Upstream of Light River junction
Mid Light subcatchment – Ross Creek	13	Ross Creek	Upstream of Light River junction
Mid Light subcatchment – Allen Creek	14	Allen Creek	Upstream of Light River junction
Mid Light subcatchment – St Kitts Creek	15	St Kitts Creek	Upstream of Light River junction
Mid Light subcatchment – Stockwell Creek	16	Stockwell Creek	Upstream of St Kitts Creek junction
Mid Light subcatchment – St Kitts Tributary	17	Northern St Kitts tributary	Upstream of St Kitts Creek junction
Upper Light subcatchment – Eastern Hill tributaries	18	Eastern hill tributaries feeding into the Light River	Group of streams upstream of Light River junction
Upper Light subcatchment – Julia Creek	19	Julia Creek	Upstream of Light River junction
Upper Light subcatchment – Tothill Creek	20	Tothill Creek	Upstream of Light River junction

Channel maintenance

This function is important for maintaining the physical structure of the river and stream channels and the habitats within.

Bankfull flows or the flows larger than bankfull (if they are confined on top of the channel or in the near-channel area) are important for stream structural maintenance.

Pool scouring

Permanent pools are a major feature of the Light catchment, and serve as refuge areas for a number of animals during the drier months and times of no flow. Scouring the sediment from these pools is therefore an important function in maintaining these areas.

Pools are subject to progressive infill with organic matter and sediment during low to medium flow periods. Large floods may potentially scour out pools, depending on local hydraulic conditions.

Structural (habitat) resetting

Structural resetting is an important process in which the physical structure of the channel is reshaped and reformed, creating new habitats. During habitat resetting flow events boulders can be moved and turned, large quantities of sediment moved, and trees, branches and other plant debris transported.

Overbank flows, especially major flood events, are important. The key factor is the erosiveness of flows over the floodplain surface and in overflow channels.

5.4.4 IMPACTS ON STREAM GEOMORPHOLOGY

Watercourse geomorphology across the hill and valley areas of the catchment has significantly changed since European settlement. These changes have been a response to widespread clearing of vegetation, increased runoff volume and velocity, and direct interventions such as the construction of dams, weirs and road fords (see Map 5.5).

Typically channel adjustment includes deepening and widening of watercourse channels, raising of bed levels due to sedimentation and changes in channel course. Deepening and widening has resulted in sections of the watercourse becoming unstable, and prone to erosion. Map 5.6 shows the bed and bank stability of watercourses within the catchment.

Watercourses dominated by the common reed are widespread in the upper and middle reaches of the catchment (Map 5.7). This is mainly as a response to increased levels of sedimentation within the watercourse (see Section 7.6.1).

The Light River has retained a relatively natural channel form in the plains zone, although the riparian vegetation has been reduced to a narrow line of trees. The estuary remains in a good natural condition (L Lloyd and S Brizga, pers comm). The rates of sediment deposition at the estuary are probably reaching lower, more natural levels since improved land management practices have reduced erosion upstream and sediment-trapping reeds have proliferated.

Dams and weirs alter downstream flow regimes and hence sediment supply and transport. This will impact on natural geomorphological processes and alter channel structure and form.

While there are fewer farm dams located throughout the Light catchment than in the Broughton and Wakefield catchments in the Mid North, they will have similar impacts on the smaller streams on which they are located: trapping sediment and altering the pattern of flows and sediment transport.

There are two major weirs within the Light catchment, one located on the Gilbert River at Riverton and the other on the Light River at Hamley Bridge. The construction of the weir at Hamley Bridge has resulted in the accumulation of sediment upstream. Failure of the weir would lead to the rapid release of sediments, infilling pools and channels downstream and leading to a loss of aquatic habitats. These factors need to be taken into account in the management and maintenance of this weir. The weir at Riverton is used to form a recreational lake within the township. The lake is large and, while it most probably traps sediments, the level of impact is unknown.

5.4.5 GEOMORPHOLOGY SUMMARY

The significant changes in watercourse geomorphology across the hill and valley areas of the Light catchment since European settlement have been a response to widespread clearing of vegetation, increased runoff volume and velocity, and direct interventions such as the construction of dams, weirs and road fords.

The plains zone has retained a relatively natural channel form in the Light catchment, although the riparian vegetation has been reduced to a narrow line of trees. The estuary remains in a good natural condition.

The extent and rate of channel change — which is dependent on a range of factors — influences the rate of erosion, deposition and the types of habitats (such as pools, riffles and runs, flood runners, floodplains and tributaries) found within the Light River system.

There is a close relationship between geomorphology and ecology. Vegetation associations adapt to physical habitat structures, which are created and maintained by geomorphological processes (e.g. sedges on a sand bar). The vegetation in turn affects flow velocities and thereby influences the erosion and deposition processes.

The geomorphic flow requirements for the Light River system are presented in Appendix B.

5.5 Ecology

5.5.1 RIVERINE VEGETATION

Watercourse vegetation includes plants that grow in the stream channel (in-stream zone) and plants that grow on the banks of the channel (riparian zone). These plants generally prefer conditions of high soil moisture and have an ability to withstand flooding hence their location along the watercourse. Different associations of plants occur along and across a watercourse based on soil type, soil moisture availability, flow dynamics and flooding regimes.

The existing location, structure and density of riparian vegetation along the surveyed watercourses of the Light catchment is shown in Map 5.8. They can be compared with the location and extent of watercourse vegetation likely to have occurred before European settlement (Map 5.9) as determined by Brown and Kraehenbuehl (2000).

Current condition

Six key vegetation communities were identified in the Light catchment: riverine forests and woodlands, riverine shrublands, mangrove forests, samphire marshes, sedgelands (Map 5.8) and reedbeds (Map 5.7; Table 5.5). These communities are described below, along with the distribution of exotic trees (Map 5.10) and woody weeds (Map 5.11), which impact upon these communities. Detailed information on vegetation flow requirements including frequency, duration and seasonality can be found in Appendix C.

Table 5.5 Condition and type of riparian vegetation in the Light catchment

Riparian vegetation type	Length (km)	Percentage of surveyed watercourse
Dense[a] native tree overstorey (closed forest)	16.4	3.1
Mid-dense[b] native tree overstorey (open forest)	66.5	12.4
Sparse[c] native tree overstorey (woodland)	55.2	10.3
Dense[a] native shrub overstorey (closed shrubland)	1.1	0.2
Mid-dense[b] native shrub overstorey (shrubland)	6.4	1.2
Sparse[c] native shrub overstorey (open shrubland)	6.6	1.2
Annual grasses with or without a very sparse[d] overstorey of trees/shrubs (includes cropping)	191.3	35.7
Sedgelands	135.1	25.2
Chenopod shrubland	1.6	0.3
Mangrove forest	1.3	0.2
Samphire shrubland	2.0	0.4
Revegetation	14.1	2.6
Unsurveyed	38.9	7.3

[a] >70% canopy cover; [b] 30–70% canopy cover; [c] 10–30% canopy cover; [d] <10% canopy cover

Riverine forests and woodlands

Riverine forests and woodlands were observed along 138.1 km (25.8%) of surveyed watercourses (Map 5.8, Table 5.5).

Brown and Kraehenbuehl (2000) found that river red gum (*Eucalyptus camaldulensis*) forests historically extended along the Light River from the estuary through to its junction with St Kitts Creek. The study also suggests that river red gum extended along St Kitts Creek itself, and one of its major northern tributaries, as well as along the Gilbert River between Riverton and Saddleworth.

The historical distribution of river red gum is not dissimilar to the current distribution but the width and density of the tree distributions has probably decreased. This is particularly evident in the narrow, dense river red gum distributions in the lower reaches of the Light River, and the sparse, wider distributions along the middle reaches. Isolated patches of river red gum also exist along the floodplain of Stockwell Creek, and existed throughout the area historically.

Riverine forests dominated by river red gums depend on flooding for recruitment, establishment and maintenance. Overbank and floodplain flows in winter–spring are required to enable major recruitment events at least every 10–50 years. Activities that reduce the frequency of overbank flow events, such as in-stream structural works, incision and altered flow regimes, will impact on river red gum forest and woodland populations.

South Australian blue gum (*Eucalyptus leucoxylon*) is believed to have existed along all of the tributaries of the Gilbert River, the northern tributaries of the mid-Light River (Fannel, Ross and Allen creeks), Julia Creek, the tributaries of the Light River north of Hamilton and Tothill Creek.

This distribution of South Australian blue gum is greatly diminished from the pre-European state. The vegetation survey of the Light River only picked up significant stands along Ross and Allen creeks, and patches along Macaw, Fannel, and Tothill creeks.

A southern cypress pine (*Callitris gracilis*) and peppermint box (*Eucalyptus odorata*) open woodland once existed along the eastern hill tributaries of the Light River between St Kitts and Hansborough but this has been almost completely cleared. The area is now dominated by annual grasses. These woodland species rely on rainfall for recruitment, establishment and maintenance and have no stream flow requirements.

Riverine shrublands

Riverine shrublands were observed along 14.1 km (2.6%) of surveyed watercourses (Map 5.8, Table 5.5). The shrublands of the Light catchment mostly comprise short leaf honey myrtle (*Melaleuca brevifolia*).

According to Brown and Kraehenbeuhl (2000), before European settlement these shrublands existed along the banks of the Gilbert River from Hamley Bridge to just south of Riverton, as well as along the upper Light River around Hamilton. There are only very small stands of this shrub left in these areas. According to landholder evidence, the short leaf honey myrtle was cleared from along the lower reaches of the Gilbert River to allow stock and horse access to water, and the actions of large floods also had an impact.

Short leaf honey myrtle is a shrub that normally occurs along the edges of lagoons and streams, and is likely to require permanent access to water such as permanent pools, or baseflow. It is unknown whether flooding is required to maintain this species.

Mangrove forests and samphire marshes

Mangrove (*Avicennia marina*) forests are located at the Light River estuary and cover approximately 1.3 km (0.2%) of surveyed watercourses. Samphire (*Sarcocornia* sp., *Halosarcia* sp.) marshes occur on the tidal flats and cover approximately 2 km (0.4%) of surveyed watercourses within the Light catchment (Map 5.8, Table 5.5).

Mangrove forests provide important breeding grounds and habitat for fish, birds and macro-invertebrates and protect the coastline from the erosive influence of the marine environment. Samphire marshes provide organic matter to the estuary food chain, filter sediment from land-based runoff and are an important habitat for insects, small vertebrates and birds (New South Wales Government 1992; Rose and McComb 1995).

Regular seasonal flows that connect the river to the estuary are required to transport sediment, nutrients and organic matter. The sediment maintains the mudflats that support the mangrove forests. The nutrients and organic matter provide a valuable food source for estuarine plants and animals. Although the distribution of samphire marshes is largely influenced by tidal inundation, river flooding also plays a role (Murray et al. 1995).

According to landholder evidence, the Light River connects with the estuary most years during winter and spring. There is no connection under baseflow conditions, as the connecting channel is ephemeral. Bankfull to overbank flows are important for sediment transport to the estuary. Overbank to extensive floods are also important, as during these events the Light River floods out onto the low lying samphire marshes and discharges through the numerous tidal streams along the coast.

Sedgelands

Sedgeland vegetation associations in varying condition cover approximately 135.1 km (25.2%) of surveyed watercourses within the Light catchment (Map 5.8, Table 5.5). These communities largely comprise rushes (*Juncus* spp.), sea club-rush (*Bolboschoenus cadwellii*) and sedges (*Cyperus* spp.).

The distribution and composition of sedgeland communities depends on soil moisture and surface water levels. Where there is permanent water or the watertable is close to the surface, the lower bank and in-stream vegetation is typically a sedgeland or rushes and sedges in association with a reedbed (closed herbland) dominated by the common reed (*Phragmites australis*).

The distribution of these sedgelands is similar to the historic distribution. This association was found along the Light River west and north of halfway between Hansborough and Hamilton, and along Stockwell Creek. Currently, the association still exists along the Light River but is much sparser along Stockwell Creek.

Regular low flows that inundate channel bars and low banks are required to ensure recruitment, establishment and growth of sedgeland species. One or several low flow events are required every 1–2 years to maintain soil moisture levels (Lloyd 2001).

Reed beds

Reed beds are a significant feature of the Light catchment and exist along 206.9 km (38.6%) of watercourses (Table 5.5).

The in-stream reedbeds (macrophyte beds) of the Light catchment consist of a range of plants such as common reed (*Phragmites australis*), sea rush (*Juncus kraussii*), sea club-rush (*Bolboschoenus cadwellii*) and spiny flat-sedge (*Cyperus gymnocaulos*). Aquatic macrophytes tend to dominate areas that are characterised by permanent baseflow and/or shallow groundwater combined with high sediment loads and lack of shade.

Associations dominated by the common reed with fringing sedgeland species, have a very similar distribution today as in pre-European times. According to Brown and Kraehenbuehl (2000), prior to European settlement this association dominated the in-stream section of the Gilbert River, Julia Creek, and the Light River above its junction with St Kitts Creek through to half-way between Hansborough and Hamilton. Today, this association extends further downstream along the Light River from its junction with St Kitts Creek to south-east of Kapunda (Map 5.7).

Macrophyte beds provide food and shelter for fish, frogs, macro-invertebrates and birds such as ducks, waterfowl, and the clamorous reed warbler (*Acrocephalus stentoreus*). They also reduce water velocity along the edges of channels, reducing erosion and increasing the duration of flooding (Boulton and Brock 1999).

Macrophyte beds require groundwater or baseflows to maintain an almost permanently wetted environment. Annual low flows that increase the area of wetted habitat are important for germination, recruitment and establishment (Lloyd 2001).

More detailed descriptions of water requirements for vegetation including frequency, duration and seasonality can be found in Appendix C.

Exotic trees

Exotic trees — or introduced tree species — were observed along 28.1 km (5.2%) of surveyed watercourses with species including olive (*Olea* spp.), pine (*Pinus* spp.), pepper-tree (*Schinus areira*) and desert ash (*Fraxinus rotundifolia*). Olive trees were the only exotic tree that occurred along a significant length of watercourse, and were found along both Ross and Allen creeks (Map 5.10).

Exotic trees were identified as a significant watercourse management issue along sections of watercourses within the Light catchment. This issue is discussed in Chapter 7.

Woody weeds

Riparian weeds are introduced plant species that impact on the health of watercourse ecosystems. Due to the survey methods used (discussed in Chapter 3) only the larger woody weeds and wild artichoke (*Cynara cardunculus*) could be identified and accurate identification tended to be limited to areas that did not have a mid-dense or dense overstorey canopy cover.

Riparian weeds were found along 123 km (22.9%) of surveyed watercourses; dense to medium density infestations affected approximately 11.8 km (2.2%). Weed species that were detected include wild rose (*Rosa* spp.), wild artichoke, African boxthorn (*Lycium ferocissimum*) and gorse (*Ulex europaeus*). Both wild artichoke and gorse are proclaimed plants in the area and must be controlled and eradicated. Wild rose is not a proclaimed plant within the Light catchment. African boxthorn was found along extensive areas of the Mid Light and Lower Light River, and Ross and Allen creeks.

Sparse wild rose was widespread throughout the upper reaches of the Light River north of Hamilton, as well as along sections of Allen and St Kitts creeks. Extended reaches infested with wild artichoke were found in the lower Light River downstream of Hamley Bridge. Stretches of watercourse infested with dense gorse were discovered along the upper reaches of the Light River, and along a tributary of St Kitts Creek (Map 5.11).

Some areas infested with riparian weeds were identified as significant watercourse management issues and are discussed further in Chapter 7.

5.5.2 FISH

Fish are particularly sensitive to changes in their environment and are good indicators of watercourse condition. The diversity, abundance and distribution of fish populations in a river will be largely determined by the flow regime, habitat type and condition, water quality, food supply and levels of predation and competition (Mosley 1983; Cambray et al. 1989 cited by Hicks and Sheldon 1999).

Current condition

Two fish surveys in the Light catchment recorded seven species of native fish (Hicks and Sheldon 1999; Hammer 2001). The species found were flathead gudgeon, blue spot goby, small-mouthed hardyhead, common jollytail, mountain galaxias, and the wholly estuarine yellow-eyed mullet and flat-tail mullet.

The common jollytail was by far the most widespread native fish in the system. It was observed along the Light River at Hamley Bridge, The Rockies, Pinkerton Plains, Main North Road crossing, Mingays Waterhole gauging station, Hansborough bridge and at Hamilton (Table 5.6). Observations by Hammer (2001), indicate that the common jollytail is also present along Julia Creek at the Hanson Road crossing, as well as along Maryvale Creek.

The next most widespread was the flathead gudgeon, which was found at the beginning of the estuary and at The Rockies. Mountain galaxias were only found at Hansborough bridge.

The Light River near the estuary had the richest community of native fish and the highest numbers in the catchment. This area also included fish that are restricted to salt water. Yellow-eyed mullet, flat-tail mullet, small-mouthed hardyhead, flathead gudgeon and blue spot goby were found at this site.

Exotic species captured within the catchment were goldfish, eastern gambusia and European carp. Eastern gambusia was by far the most numerous of all fish caught within the catchment. Table 5.6 shows fish recorded and their distributions throughout the catchment.

Table 5.6 Expected (E) and observed (O) fish species in the Light catchment

Species		Site*																							
		December 2000								February 1999															
Common name	**Scientific name**	1		2		3		4		5		6		7		8		9		10		11		12	
Native species		*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*
Yellow-eyed mullet	*Aldrichetta forsteri*	■	■																						
Flat-tail mullet	*Liza argentea*	■	■																						
Small-mouthed hardyhead	*Atherinosoma microstoma*	■	■																						
Flathead gudgeon	*Philypnodon grandiceps*	■	■	■	■	■		■		■		■		■		■		■		■				■	
Blue spot goby	*Pseudogobius olorum*	■	■	■						■		■		■		■		■		■				■	
Pouched lamprey	*Geotria australis*	■		■		■		■		■		■		■		■		■		■		■		■	
Shortheaded lamprey	*Mordacia mordax*	■		■		■		■		■		■		■		■		■		■		■		■	
Congolli	*Pseudaphritis urvillii*	■		■						■		■				■		■		■				■	
Common jollytail	*Galaxias maculatus*	■		■	■	■		■	■	■	■	■	■	■	■	■		■	■	■	■			■	
Mountain galaxias	*Galaxias olidus*			■		■		■										■		■	■				
Climbing galaxias	*Galaxias brevipinnis*							■										■		■		■		■	
Australian smelt	*Retropinna semoni*									■						■									
Non-native species		*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*	*E*	*O*
Eastern gambusia	*Gambusia holbrooki*				■		■				■		■		■		■		■		■				■
Goldfish	*Carassius auratus*		■		■										■				■						
European carp	*Cyprinus carpio*				■		■																		

* 1. Estuary; 2. Lower Light at The Rockies; 3. Mid Light downstream of Peters Road; 4. Light River at Hamilton (Hammer 2001). 5. Light River at Pinkerton Plains; 6. Light River at Hamley Bridge weir; 7. Light River at Main North Road crossing; 8. Light River at Kapunda bridge; 9. Light River at Mingays Waterhole gauging station; 10. Light River at Hansborough bridge; 11. Julia Creek near Nash Road crossing; 12. Gilbert River at Hannafords Road (Hicks and Sheldon 1999).

The numbers and diversity of native fish recorded were very low. There were fewer native species than were expected based on a review of fish species ranges (Lake 1978; Allen 1989; Harris 1995; McDowell 1996). Local landholders along the Light River have noticed a decrease in the abundance and diversity of native fish in recent decades.

Native fish account for 22% of fish numbers within the Light catchment but if the fish numbers for the estuary are omitted then this proportion drops to 2.8%. The most abundant fish captured was the introduced eastern gambusia which accounted for 96.9% of fish numbers above the estuary.

The results of the fish surveys suggest that, in terms of native fish populations, the Light catchment is in poor condition. This may be due to a number of factors including competition, habitat degradation, poor water quality, and poor breeding and migration opportunities (Hicks and Sheldon 1999).

None of the fish species recorded have critical habitat requirements; generally they are robust and tolerate a broad salinity range. However, the blue spot goby is susceptible to predation and requires good vegetation to provide cover. Mountain galaxias are able to survive in pools over summer. Common jollytails are migratory fish but are able to survive and breed in landlocked populations; this is the likely case in the Light catchment due to the lack of suitable migratory flows (Lloyd 2001).

The presence of large number of eastern gambusia at most sites sampled may be indicative of some level of habitat degradation as these fish can live in environments unsuitable for native fish. They have a very wide range of tolerances to temperature, salinity (up to twice that of seawater) and can survive very low oxygen levels (McDowell 1996).

Eastern gambusia inhabit the shallow margins of slow moving waterbodies and exclude small native fish from this zone by fin nipping, forcing them to seek deeper water. Fin nipping also removes the protective mucous coating of native fish, leaving them susceptible to infection and decreasing their chances of catching food. Eastern gambusia also compete with small native fish for resources and space and have the ability to build their population up rapidly (Hicks and Sheldon 1999).

Other exotic species present throughout the catchment but not recorded in surveys include redfin perch, brown trout and rainbow trout. Brown and rainbow trout are released annually mainly into pools throughout the Light River system by the South Australian Fly Fishers Association (I Fitzgerald, pers comm 2001). Trout are released under Department of Fisheries permit conditions. Redfin, brown trout and rainbow trout are all predatory species, and can have a significant impact on native fish populations (Zaret 1980; Fletcher 1986; Lloyd 1987 cited by Lloyd 2001). Galaxids are one species that are significantly affected by interaction with trout, as they occupy similar habitats.

Currently, there is insufficient information on fish populations and distributions throughout the catchment to pinpoint the causes of low native fish numbers and diversity. It is considered, however, to be a combination of a sub-optimal flow regime, interaction with exotic species and loss of habitat.

Further studies into the fish of the catchment are required to determine more accurately the influence of flow regime and other environmental factors on native fish in the Light catchment.

Actions that can be taken to improve the health of native fish populations in the Light catchment include:

- re-establishing natural riparian vegetation along cleared sections of the river to improve habitat quality (will probably also promote higher diversity and abundances of macro-invertebrates which will act as a food source for native fish species);
- stabilising bed and banks to protect fish habitat (i.e. prevent excessive sedimentation);
- removing or controlling exotic fish species;
- ensuring the application of pesticide spray in the vicinity of watercourses does not impact upon native plants and animals.

More detailed descriptions of water requirements for fish including frequency, duration and seasonality can be found in Appendix C.

5.5.3 AQUATIC MACRO-INVERTEBRATES

Aquatic macro-invertebrates are animals that live in water, lack a backbone and can be seen with the naked eye. They include insects (adult and larvae), snails, worms and crustaceans. Aquatic macro-invertebrates are key species in the maintenance of river ecosystems. They break down vegetation and waste matter, releasing nutrients, and they provide an important food source for many other animals.

The diversity and number of macro-invertebrates in a watercourse are determined by flow regime, habitat availability and water quality. Some species are particularly sensitive to salinity, pollution and habitat change. Macro-invertebrates thus provide important information on flow patterns, watercourse conditions and environmental water requirements.

Current condition

More than 155 macro-invertebrate species have been recorded from the Light catchment. Macro-invertebrates collected from the system were predominantly species that tolerate a broad range of environmental conditions, are good colonisers, and are common and widespread in South Australia.

The numbers and diversity of species found within the Light catchment is significantly lower than for the nearby Gawler, Wakefield and Broughton River catchments, which had approximately 240 species.

The most common macro-invertebrates found within the catchment were round worms (Nematoda), snails (Hydrobiidae), aquatic worms (Oligochaeta), amphipods (*Austrochiltonia* spp. and Eusiridae), shrimps (*Paratya australiensis*), springtails (Collembola), biting midge larvae (Ceratopogonidae), and non biting midge larvae (*Procladius* spp., *Paralimnophyes* spp., *Cladotanytarsus* spp., *Tanytarsus* spp. and *Chironomus* spp.). Blackfly larvae (*Simulium ornatipes*) need flow to survive and were collected in more than half of the samples taken from riffle habitats.

Several species that were found in the catchment are uncommon in South Australia. Protecting biodiversity and conserving habitats where these species are found is an important management consideration.

The scavenger waterbeetle (*Sternolophus marginicollis*) lives in still water and is rare in the south of Australia. This beetle was collected from the Gilbert River at Stockport.

The water boatman (*Diaprepocoris barycephala*) is a wetland species preferring macrophyte stands and is not commonly collected from streams. The species was collected from Julia Creek near the Nash Road crossing. It is likely that the shallow pools that overlie the bedrock at this site, and the associated populations of aquatic macrophytes, provide important habitat in the maintenance of this species in the area.

There are several groups of macro-invertebrates that are noticeably more rare or absent from the Light catchment but which occur in higher numbers in other similar catchments in the area, such as Gawler, Wakefield and Broughton. These include mayflies, stoneflies, non biting midges, dragonflies, damselflies, true flies (Dixidae) and caddisflies.

Some of these animals require tall riparian vegetation as shelter during their adult stage. The absence of this habitat in most areas of the catchment may be a reason for the absence of some species. Another likely explanation for the lower diversity of macro-invertebrates is high salinity levels in the range 2,883–11,532 mg/L, with most sites recording salinity levels in excess of 4,960 mg/L.

Three introduced organisms were found in the Light catchment. An introduced snail, *Physa acuta*, was found in low numbers at several sites within the catchment. Julia Creek near the Nash Road crossing was the only site where these snails occurred in high numbers. Another introduced snail, *Potamopyrgus antipodarum,* was recorded throughout the catchment but not in large numbers. An introduced proboscis worm was also found at the Mingays Waterhole gauging station. Information on the interaction and impacts of these exotic species with native species is lacking.

The results of the macro-invertebrate study indicate that the sites sampled in the Light catchment range from being significantly impaired, through to being in a least disturbed reference condition. Three sites —the Light River at the Mingays Waterhole gauging station, Kapunda bridge and Julia Creek near the Nash Road crossing — were found to be in a 'least disturbed' condition for macro-invertebrate communities.

Five sites —the Light River on the Pinkerton Plains, Hansborough bridge, east of Hamilton at the Tarnma Road crossing, the Gilbert River at Stockport and the Hannafords Road crossing — were found to be 'impaired'.

The high salinity levels of the Light catchment, which may be a natural feature, may never have allowed a diverse macro-invertebrate population, and the lower number of families found may be a natural feature of the catchment.

Management of the Light catchment should aim to protect aquatic habitats that support a diversity of macro-invertebrates. This includes maintenance of permanent flow where it occurs, and improved habitat and water quality at the sites with 'impaired' biodiversity.

More detailed descriptions of water requirements for macro-invertebrates including frequency, duration and seasonality can be found in Appendix C.

5.5.4 FROGS

The Light catchment provides habitat for a variety of frog species (Table 5.7) identified as a part of the annual EPA Frog Census. Most identified species are common and widespread across South Australia with the possible exception of Bibron's toadlet, the distribution of which is insufficiently known.

Table 5.7 Frog species of the Light catchment

Common name	Scientific name
Common froglet	*Crinia signifera*
Eastern banjo frog	*Limnodynastes dumerili*
Spotted grass frog	*Limnodynastes tasmaniensis*
Brown tree frog	*Litoria ewingi*
Bibron's toadlet	*Pseudophryne bibroni*

Only small numbers of frogs have been recorded for the area during the Frog Census. This may suggest poor conditions for frogs or there may be seasonal variation in the frog populations that has not been detected from the September census (S Walker, pers comm 2001). Further surveys in other months would be valuable in answering these questions.

Important habitats for frog species include rivers and creeks, permanent pools, ponds, reedbeds, swamps and shallow flood-out areas. Emergent and submerged aquatic plants provide important shelter and breeding areas for frogs. For example, species such as the eastern banjo frog and brown tree frog lay their eggs attached to floating or emergent vegetation. Frogs feed mainly on terrestrial macro-invertebrates, such as flying insects, millipedes, slaters and ants (Walker, pers comm 2001).

Frogs prefer still or slow flowing water. They tend to use the water's edge for habitat but can breed on the floodplain or shallow flood-out areas when floodwaters extend out that far or if there is sufficient rainfall to provide suitable habitat, such as shallow pools (Lloyd 2001). The species recorded in the Light catchment generally breed after winter–spring rains, with the exception of Bibron's toadlet which breeds from late summer through to early spring.

More detailed descriptions of water requirements for frogs including frequency, duration and seasonality can be found in Appendix C.

5.5.5 SUMMARY OF THE IMPACTS ON ECOLOGICAL SYSTEMS IN THE LIGHT CATCHMENT

A number of land and river management practices, the most significant being land clearance and the grazing of understorey species, have impacted on native riparian vegetation. Other impacts include cropping, altered flow regimes and invasion by exotic trees (Map 5.10) and weeds (Map 5.11). Exotic trees and woody weeds are discussed in more detail in Chapter 7.

Both unrestricted grazing and altered flow regimes can have significant impacts on the regeneration of overstorey and understorey species. Grazing impacts, by not allowing the growth of seedlings, and altered flow regimes can impact by not providing the required conditions for germination and recruitment of seeds and young plants.

It is estimated that riverine forests, woodlands and shrublands have been reduced to less than 50% of their pre-European lateral extent (Map 5.9). The condition of the remaining forests, woodlands, and shrublands varied across the catchment but all have been modified to some degree. In many areas a narrow band of overstorey vegetation still remains intact, but the understorey vegetation has been significantly altered by factors such as past clearance, grazing and weed invasion.

Native fish abundance and diversity in the system appears to have decreased in recent decades. Development within the region has had a negative impact upon the riverine environment. The subsequent losses of in-stream habitat, predation from exotic species and poor water quality (sedimentation, pollution and potentially rising salinity) have added stress to native fish and macro-invertebrates populations, reducing and possibly eliminating the more sensitive species. Frog populations may be similarly affected but more information is required.

5.5.6 FLOW BANDS AND ECOLOGICAL PROCESSES

Flows within the Light River system can be categorised into a number of bands based on the flow requirements of plants and animals. These flow bands and their ecological functions are discussed below.

Groundwater

As the streambed intersects the watertable it forms a permanent pool in the low-lying parts of the streambed. There is no flow but the streambed and pools are permanently wetted (Figure 5.7).

Groundwater maintains pools for aquatic biota and provides water for low-lying reedbed and sedgeland communities.

Baseflow

There are two types of significant baseflow: permanent and seasonal pulse flow. In the Mid North agricultural region, groundwater levels driven by wet years generally increase baseflows over the following two years (Murdoch 2001).

Baseflows are important for creating and maintaining riffle habitats and connecting pools to allow some movement of aquatic flora and fauna between local habitats. They also maintain water quality by increasing oxygenation and by diluting or flushing salts that have accumulated in the system through dry periods.

Low flow

Low flows are derived from surface runoff adding to the baseflow up to a level that covers the stream bed and in-stream bars (Figure 5.7).

These flows inundate shallow habitat and are important for both submerged and emergent plants. This environment is also important for the breeding and recruitment of macro-invertebrates and frogs; it provides fish with the resources to grow and enables fish larvae to successfully recruit into the population. The transport and processing of nutrients and organic matter is an important function of low flows.

Mid flow

Mid flows generally cover the entire bed of the watercourse and up to a level of about half reed height (Figure 5.7). Some of the lowest in-channel benches may be flooded, creating further habitat.

These flows can be critical for maintaining viable fish populations in the river system. They increase the amount of resources and habitat available in the aquatic environment. If they persist for more than 5–7 days they can provide good conditions for fish spawning and hatching as well as providing a good environment for newly hatched fish larvae to develop and recruit into the population. These flows also connect reaches and allow fish to move upstream and downstream. Flows at this level water riparian shrubs and trees, maintaining the vegetation and enabling seedlings to establish.

High–bankfull flow

High flow has been defined as ranging from mid flow through to bankfull flow (Figure 5.7). At bankfull flow level all benches within the watercourse are inundated creating large areas of resource rich habitat for macro-invertebrates, frogs, plants and fish. High flows can stimulate large events of fish breeding and spawning, and, if supported by sustained flooding of the low lying habitat areas, fish larvae are able to develop and recruit, which significantly increases fish populations. Flows at this level flood the in-channel riparian vegetation and can result in significant germination and growth events.

Flows of this magnitude provide important channel maintenance functions including the transporting and depositing sediment, maintaining channel form, and scouring pools. These flows flush riffle substrates and remove sediments which improves habitat conditions for macro-invertebrate and fish species.

A bankfull flow in a natural uneroded reach of a watercourse generally occurs every one to two years (Leopold and Wolman 1957). However, bankfull capacity varies considerably along and among watercourses of the Light catchment.

Overbank flow and catastrophic flow

Overbank flows are greater than bankfull and activate floodplain processes (Figure 5.7). They inundate floodplain habitats including lowland depressions, flood runners, billabongs and samphire flats. These events stimulate a large increase in ecological productivity. They provide for the germination, establishment and maintenance of floodplain vegetation, such as river red gums. These floodplain areas also provide ideal habitat for the spawning events and the recruitment of fish larvae.

Large floods are important for the transport of nutrients and organic matter longitudinally (upstream to downstream) and laterally (between the floodplain and the river). They also reset habitats by moving gravel bars, boulders and logs, and scour pools. Catastrophic flows are extreme flood events. These are important for the major structural change of the river channel, habitat resetting, and the transport of sediment, nutrients and organic matter to the estuary.

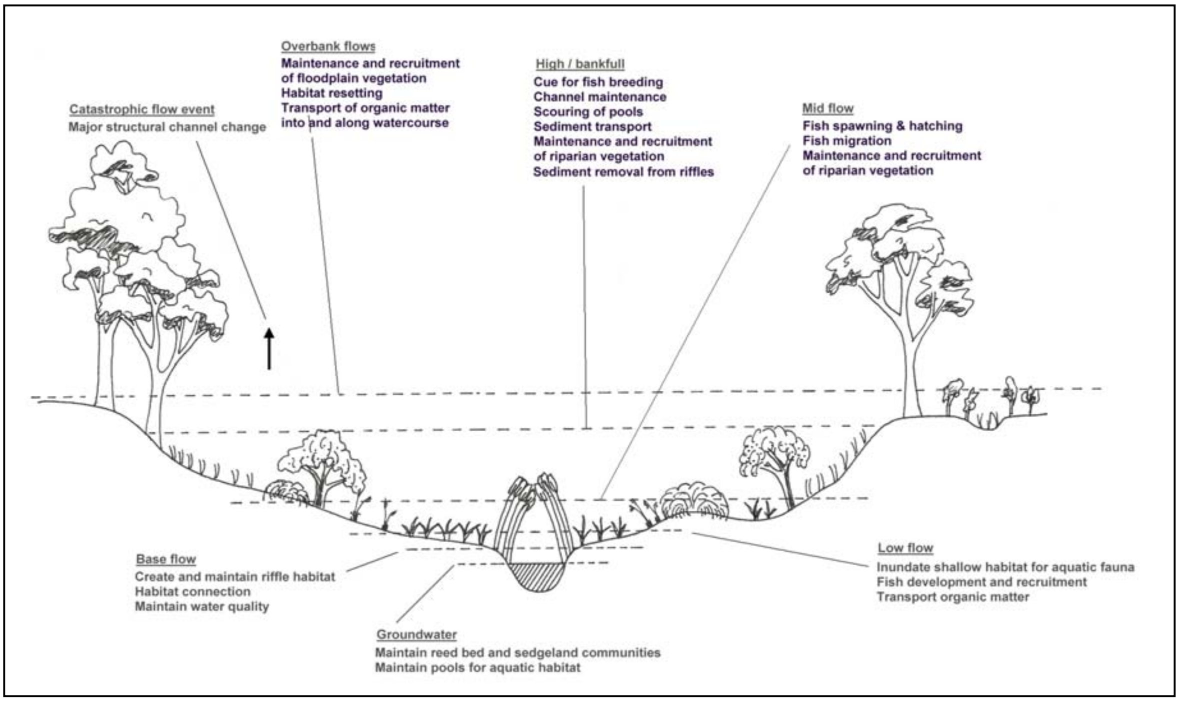


Figure 5.7 Typical flow bands and functions within the Light River system

In most watercourses of the Light catchment, stream incision has resulted in less frequent floodplain inundation. The ecological value of overbank flows is also limited as the floodplain has largely been cleared of natural vegetation and the flood runners levelled for agricultural development.

5.5.7 ECOLOGICAL SUMMARY

The life history of the plants and animals inhabiting the aquatic, riparian and floodplain environments of river systems is dependent on the flow regimes that maintain these habitats. Each habitat within the aquatic ecosystem is associated with a community of plants and animals. Some species have a wide range of environmental tolerances and are distributed across a wide range of habitats, while others are more sensitive to environmental conditions and occupy more specific habitats.

Habitats and specific flow regimes affect the life histories of plant and animal species. Assessing the links between the ecology, geomorphology and flow can identify the important processes within the riverine ecosystem. Important ecological responses to flows include fertilisation or spawning cues, the recruitment of seedlings or larvae, and the maintenance and the growth of plant and animal populations.

The inundation of habitats, and timing and duration of flows can influence these populations over the short and long term.

- Optimum flow regimes ensure population growth of a species.
- Sustaining flow regimes maintain populations at current levels.
- Minimum survival flow regimes enable short-term survival but, over longer time periods, will result in species decline, possibly leading to loss within the system.

The Light River system is an ephemeral river system. Periods of very low flows lead to the reduction of populations and the loss of some species, with higher flows allowing species to recover and recolonise. The variable flow regime is a natural characteristic of the Light River and must be considered in determining the environmental flow requirements of the system.

The present state of the physical and ecological character of the Light catchment is a result of dramatic landuse and land management changes, and vegetation clearance during the period since European settlement. A large proportion of the watercourses within the Light catchment now lack native vegetation and only small areas of native vegetation remain. The physical stream condition has also degraded due to the processes of erosion and sedimentation. This has resulted in areas of poor stream stability and a loss of habitat.

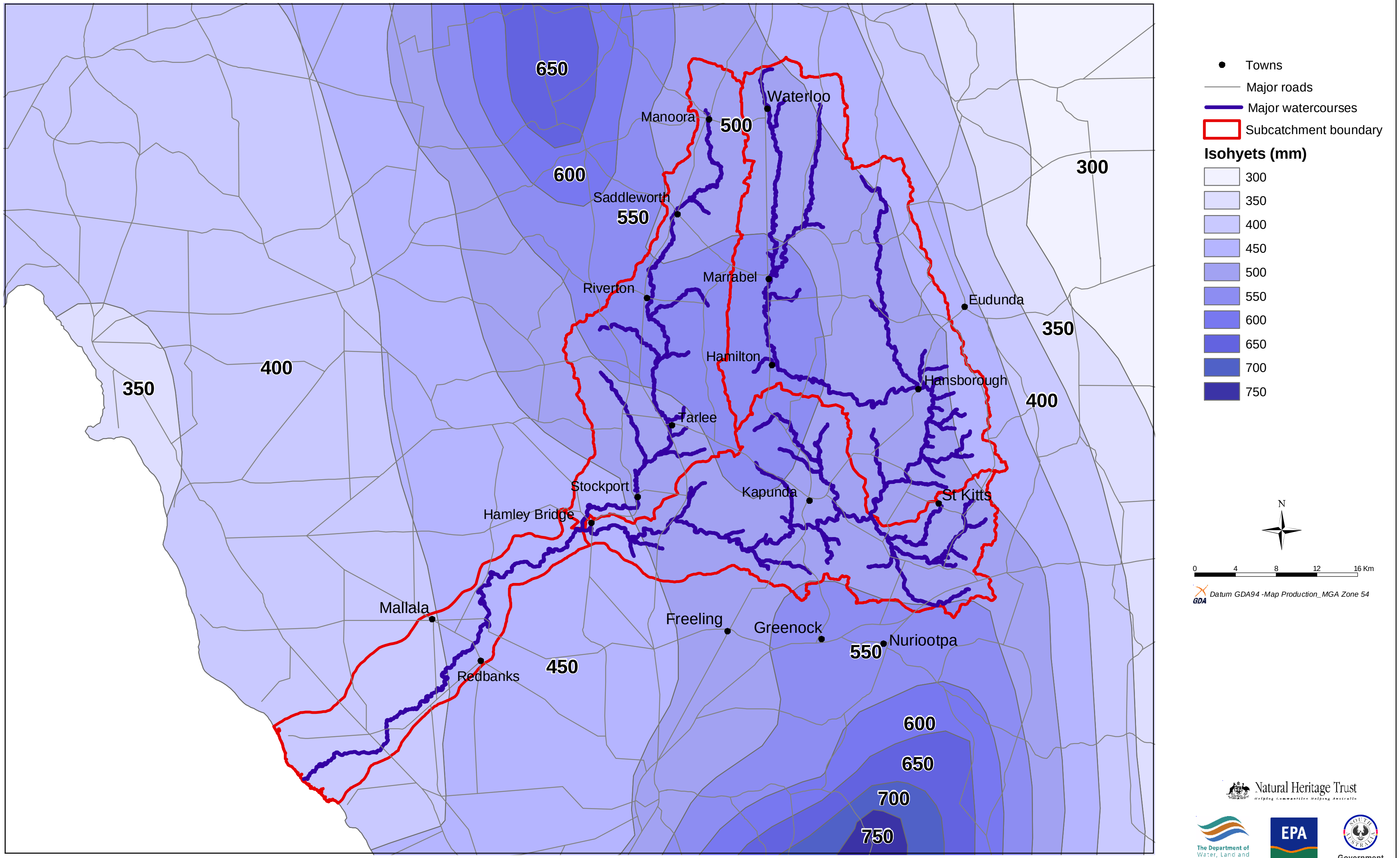
Restoring riparian vegetation will improve the in-stream environment by creating habitats, increasing biodiversity and reducing erosion by slowing runoff velocity and providing a more stable aquatic system.

Animal life within the catchment has also been impacted upon by these changes. Aquatic macro-invertebrates are much less diverse within the catchment than in other catchments in the Mid North. This is likely to be due to a number of factors, including a lack of habitat diversity and poor water quality, particularly elevated salinity levels.

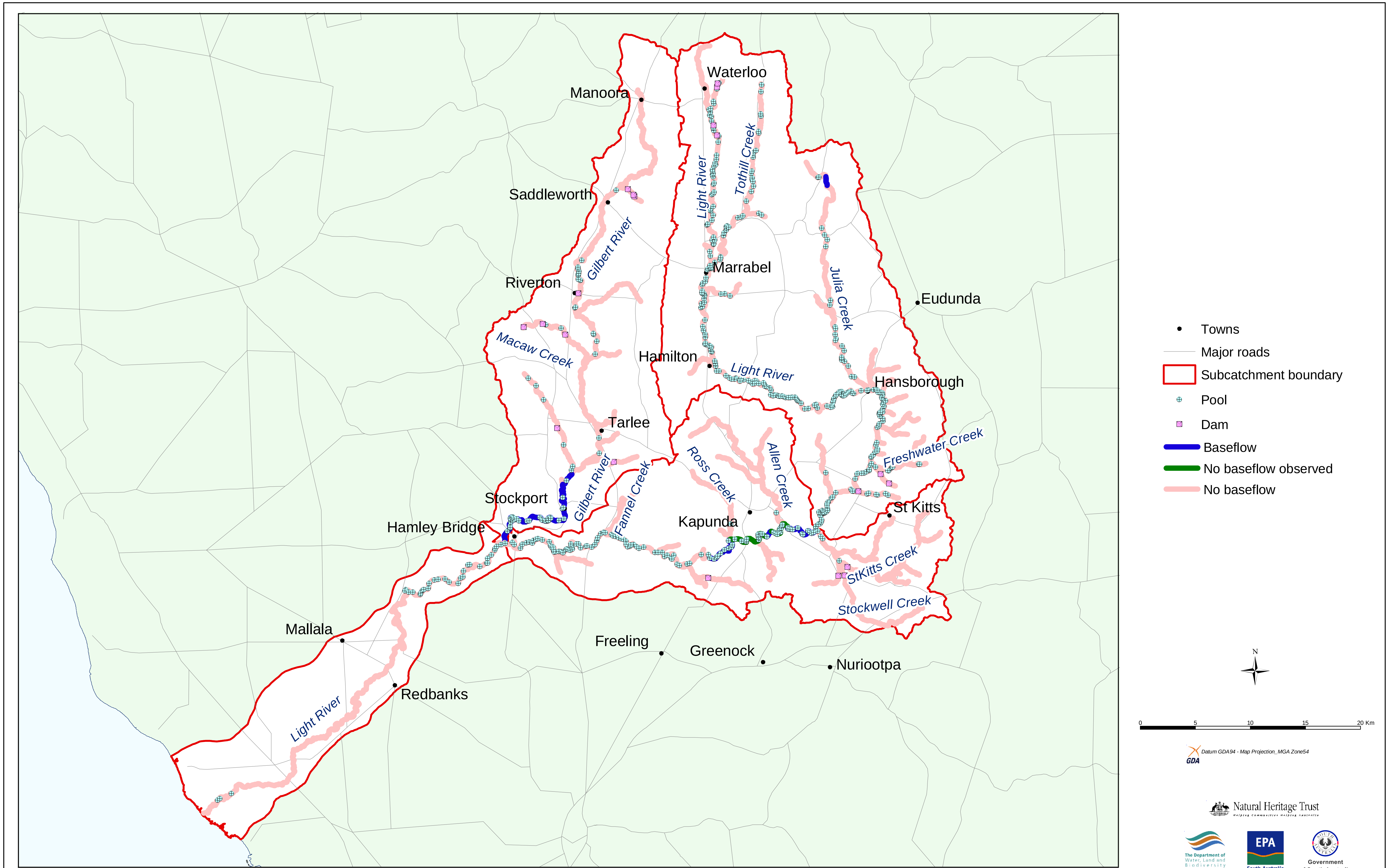
A survey of fish within the catchment has revealed that the catchment is in poor condition. This may be due to a number of factors including competition, habitat degradation, poor water quality, and poor breeding and migration opportunities.

The estuarine area and the low-lying floodplains with permanent pools and remnant vegetation have a high degree of ecological value and are recognised as key sites in the Light catchment. Without these refuge areas the ability of the river ecology to recover from unfavourable events such as drought, would be significantly reduced. These areas need to be protected and enhanced through sympathetic management practices such as controlling stock access, encouraging natural regeneration, controlling exotic species.

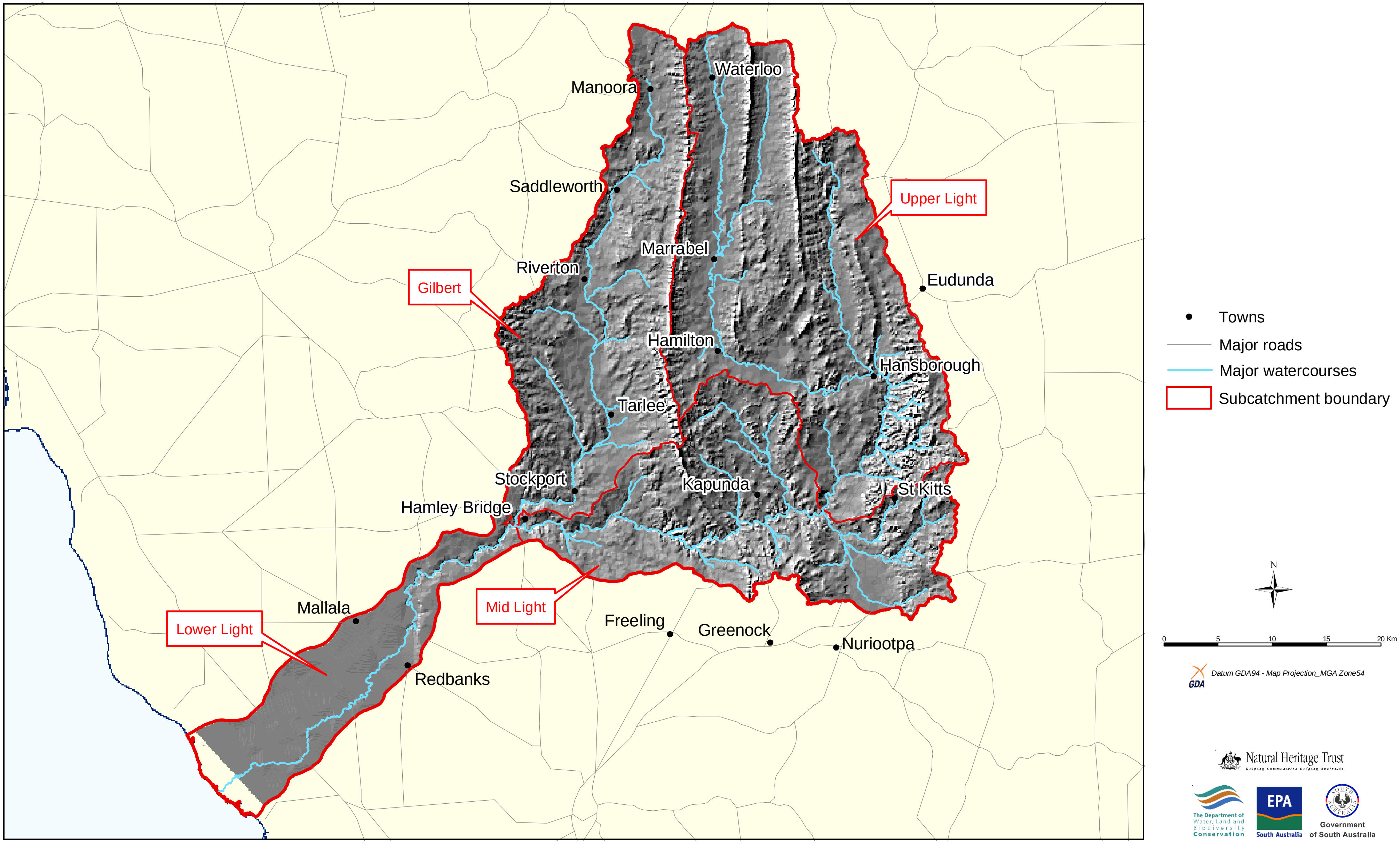
A summary of the flow requirements for specific plants and animal communities in the Light River system is presented in Appendix C. These flow requirements are preliminary and based on best available data and expert opinion (Lloyd 2001). They provide an initial basis for identifying the ecological implications of flow regime change, and development of flow management strategies to protect the natural values of the catchment's aquatic and riparian habitats. Further assessment and monitoring of these flow requirements are necessary to refine these measurable targets as a process for adaptive management.



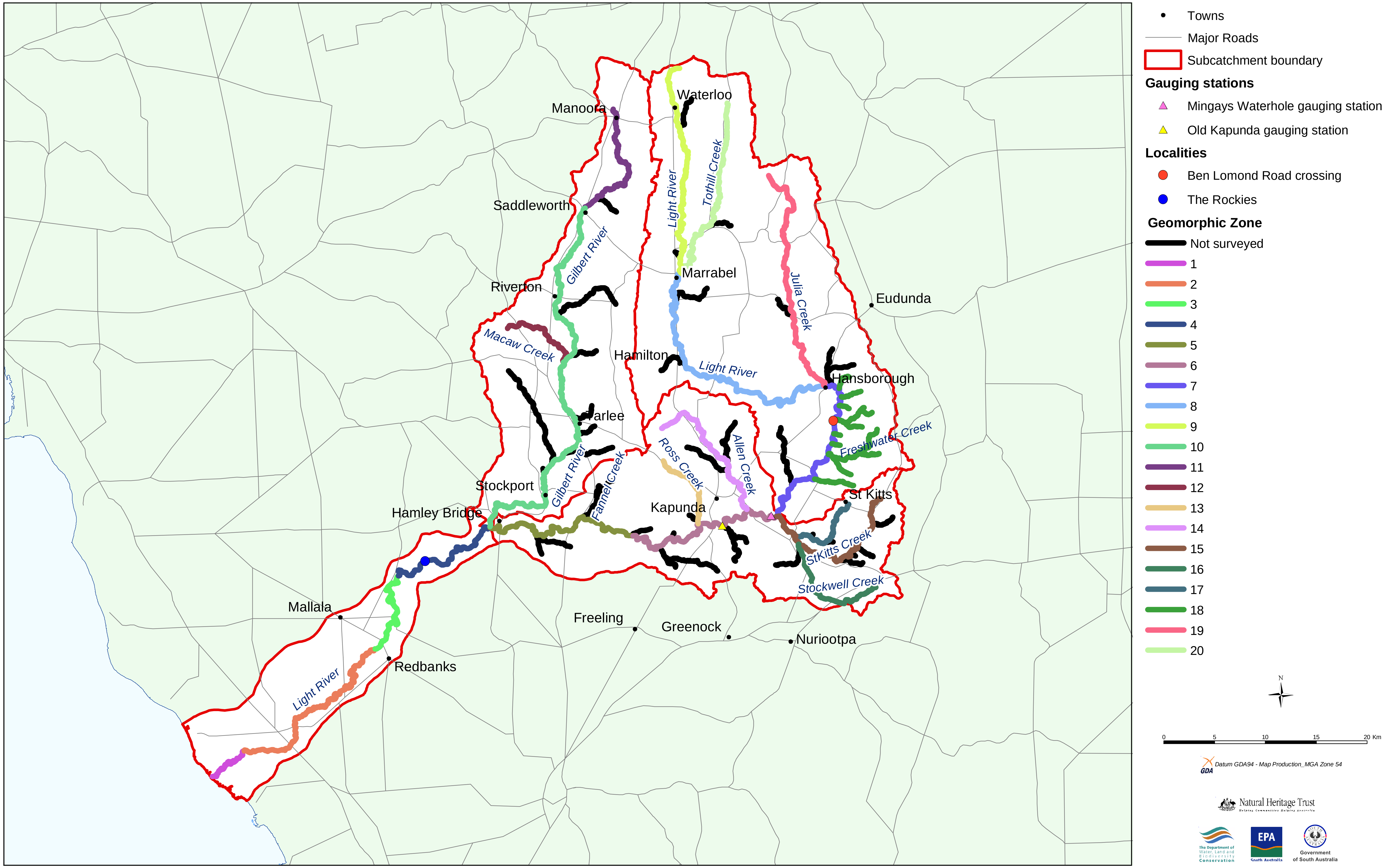
Map 5.1: Annual rainfall in the Light catchment



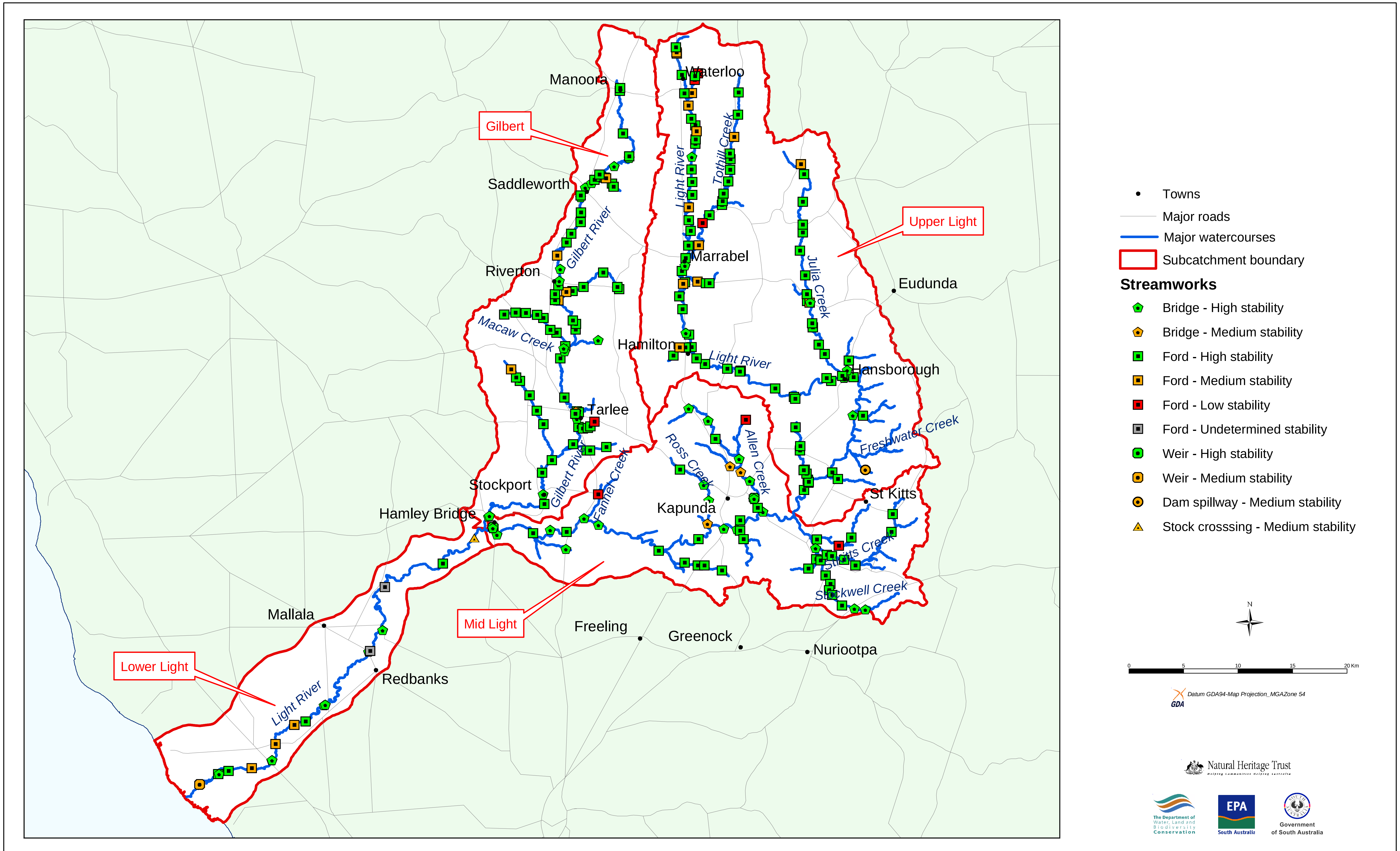
Map 5.2: Permanent pools, instream dams, and baseflow in the Light catchment



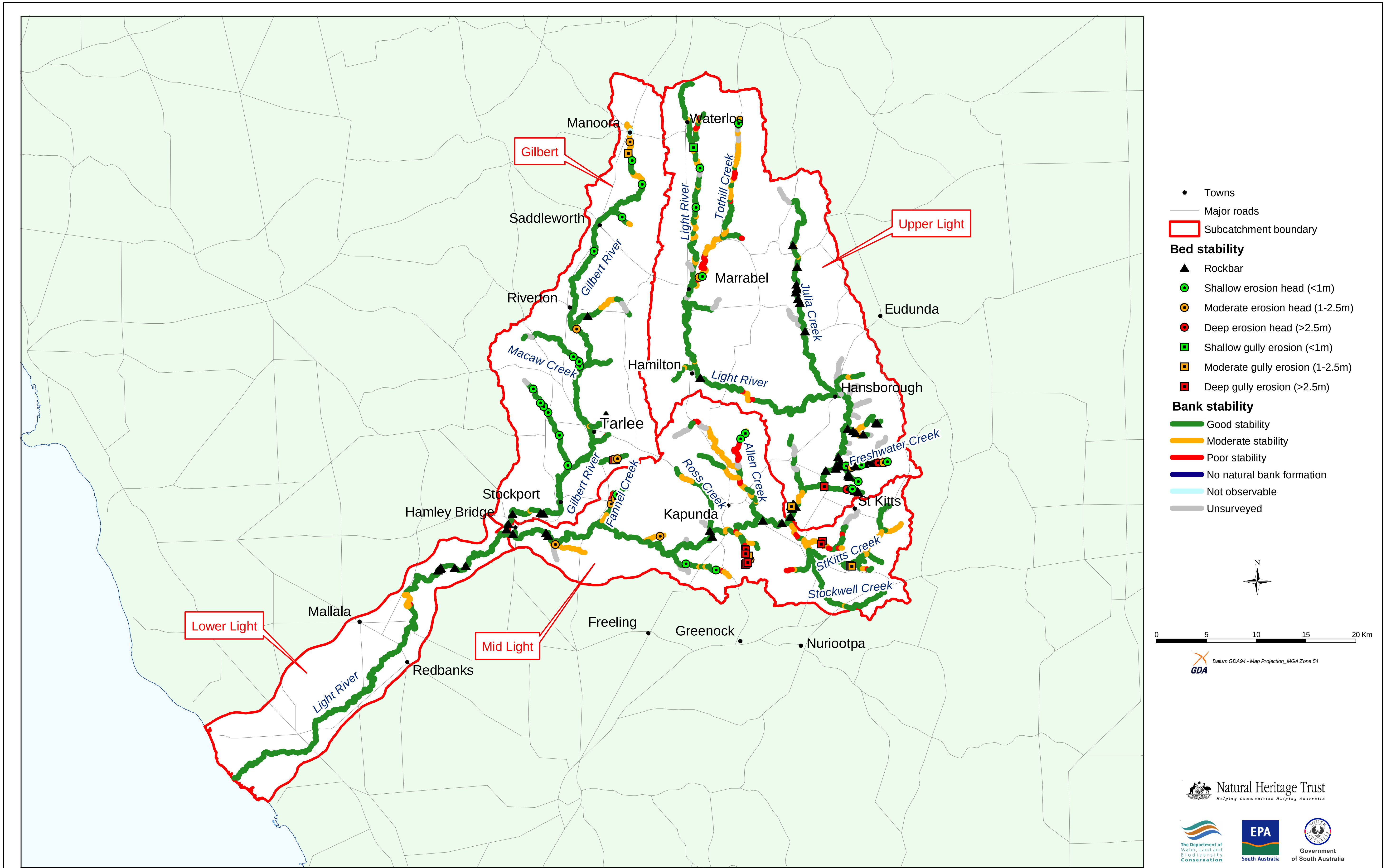
Map 5.3: Topography of the Light catchment



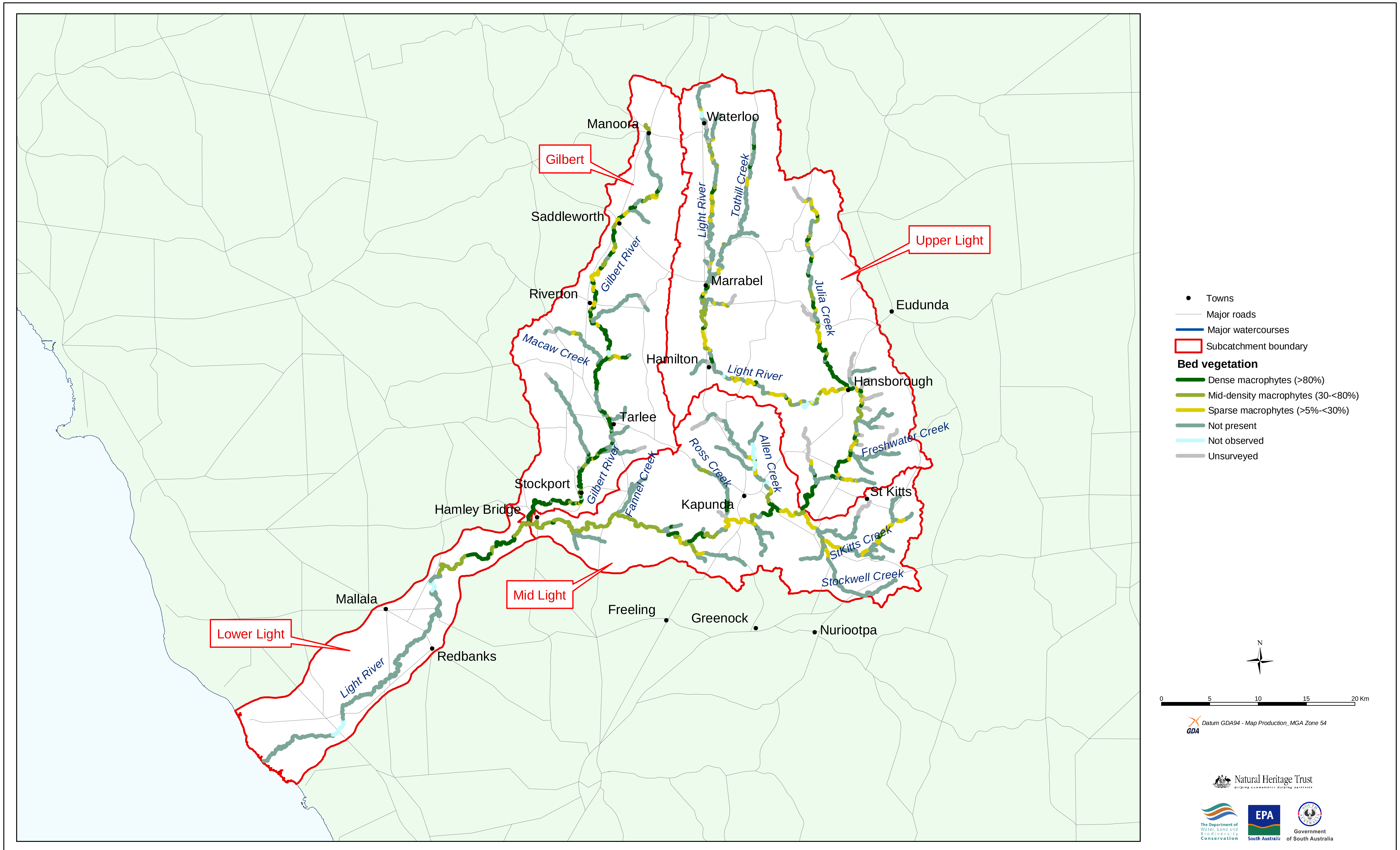
Map 5.4: Geomorphic Zones of the Light catchment



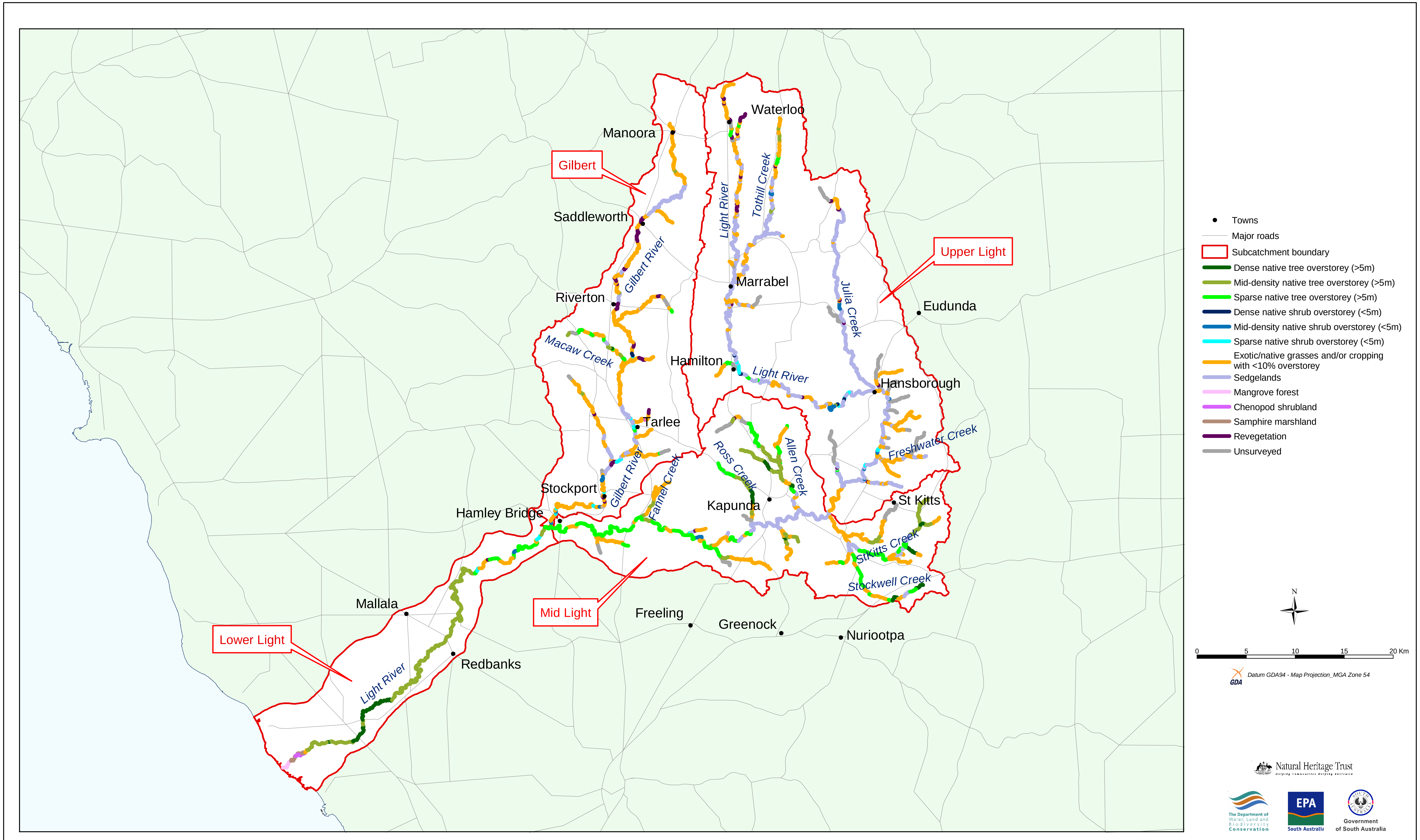
Map 5.5: Structural works along watercourses in the Light catchment



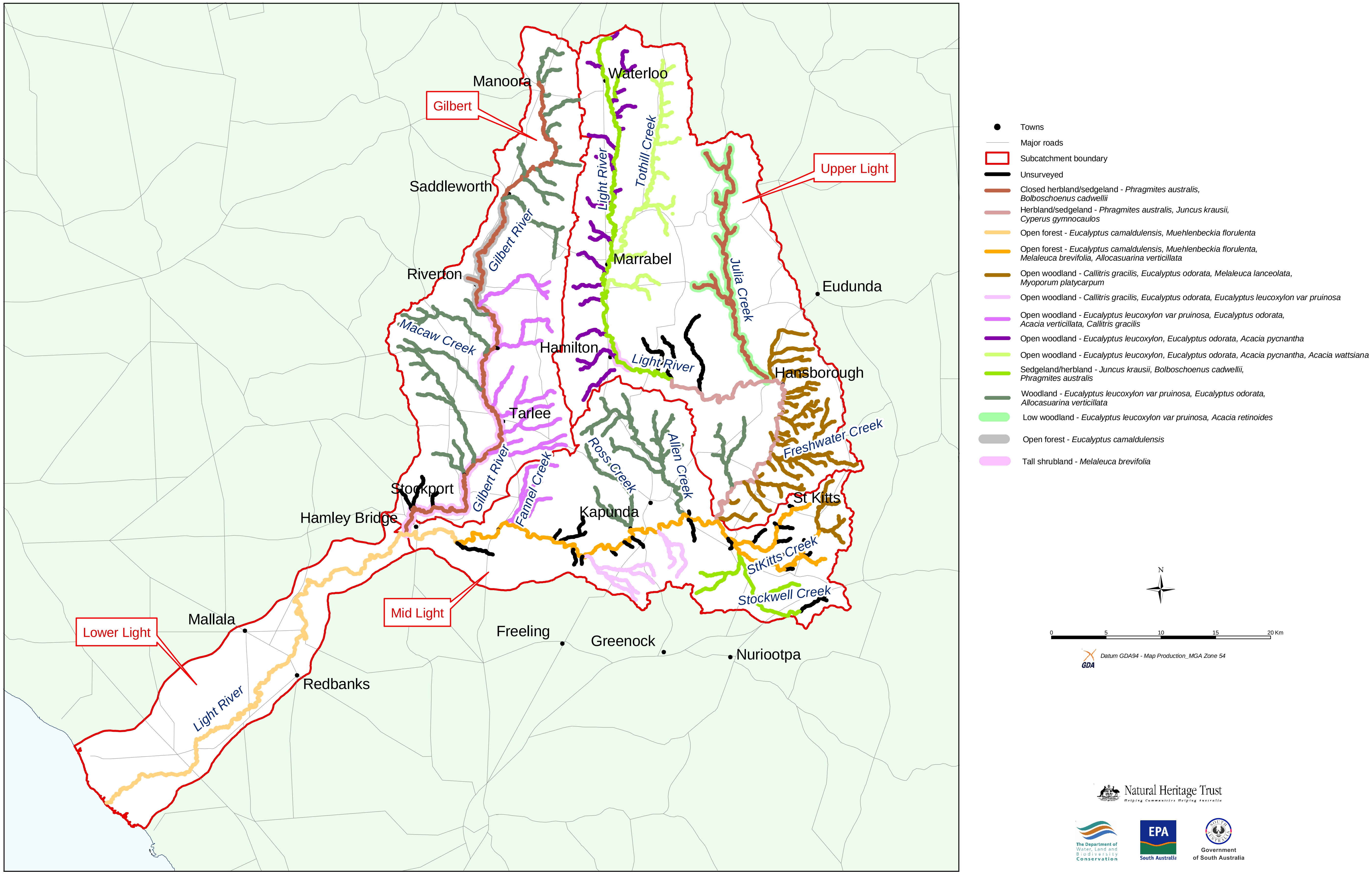
Map 5.6: Bed and bank stability in the Light catchment



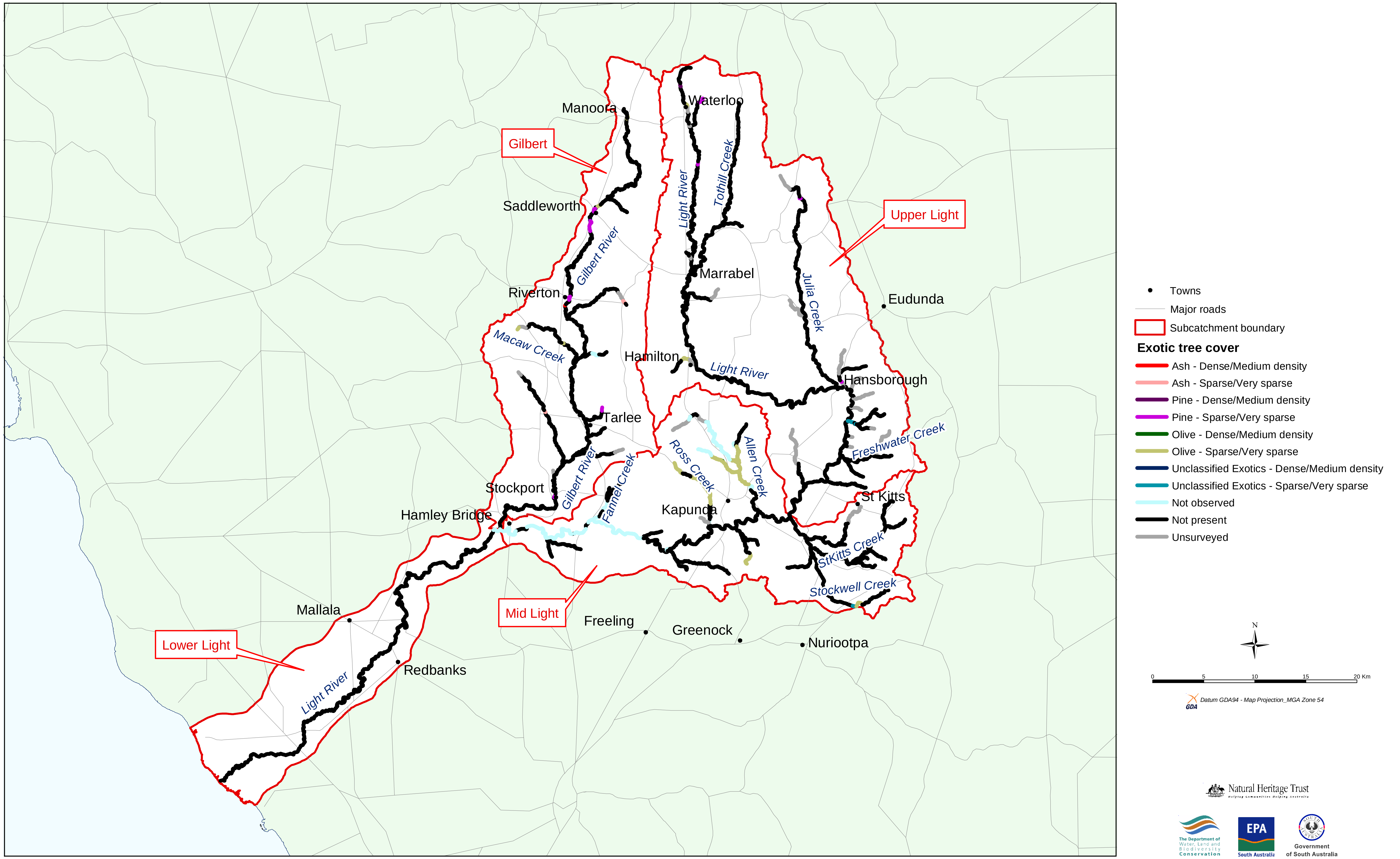
Map 5.7: Extent of reedbeds along watercourses of the Light Catchment



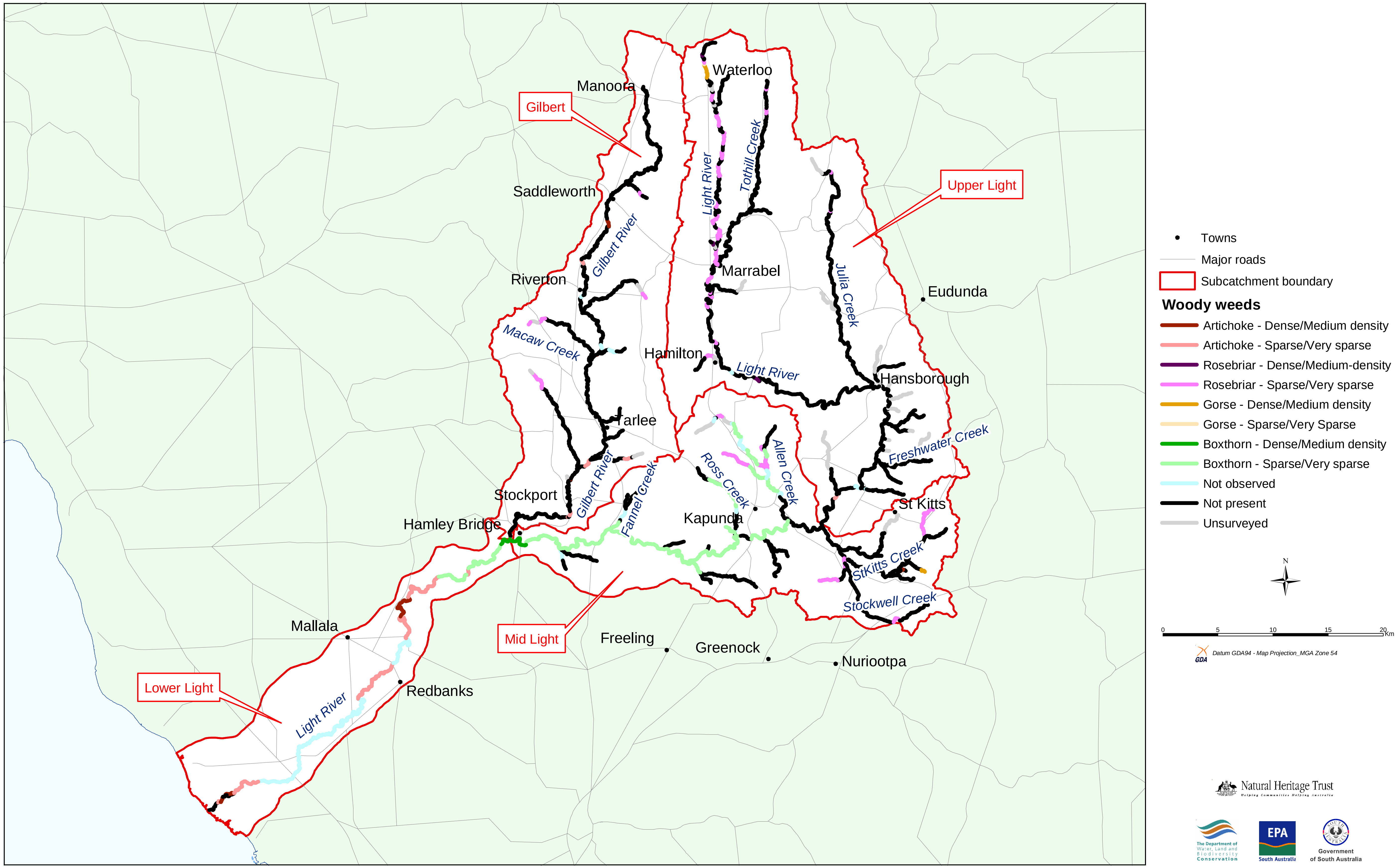
Map 5.8: Riparian vegetation along watercourses in the Light catchment



Map 5.9: Pre-european vegetation along watercourses of the Light catchment



Map 5.10: Exotic trees in the Light catchment



Map 5.11: Woody weeds in the Light catchment

CHAPTER 6 ENVIRONMENTAL WATER REQUIREMENTS

6.1 Introduction

Environmental water requirements (EWRs) are water regimes needed to sustain the physical and ecological values of water dependent ecosystems at a low level of risk. Determining EWRs involves the assessment of the interactions between hydrology, hydrogeology, geomorphology and ecology. An example is the interaction between flow regime and habitat that stimulates fish spawning events.

The purpose of establishing EWRs for watercourses within the Light catchment is to provide baseline information for the protection of the water dependent ecosystems and their biodiversity.

For each of the 20 geomorphic zones within the Light catchment, an ecological site was selected as a representative of that zone and assessed to determine its EWRs. The EWR information is presented in tables in Appendix B (Tables B.1–B.21) as: key flow bands, flow band description, key ecological and geomorphological functions, and flow frequency, duration and seasonality. Appendix B also contains a discussion on these tables. The tables do not provide a complete description of all flows but rather the flow bands identified as critical for an understanding of EWRs. These indicators can be used to assess the ecological and geomorphological implications of flow regime change through natural events or resource development.

Of these 20 geomorphic sites, only two — Light River downstream of Peters Road crossing (10 km downstream from the old Kapunda gauging station, Zone 6, Map 5.4, Figure B.2), and at Ben Lomond Road crossing (12 km upstream from Mingays Waterhole, Zone 7, Map 5.4, Figure B.3) — were in close proximity to the operating gauging station at Mingays Waterhole, and the decommissioned gauging station near Kapunda. Therefore assessment of the recorded flow data could only be extrapolated to these two ecological sites to determine if the required flow frequencies and durations actually occur under natural conditions.

The site below Peters Road crossing better reflects the environmental features of other reaches in the Light catchment and will be the only site discussed in this chapter. This will serve as an example of processes on a catchment level, and of how the determined EWRs (Appendix B) can be interpreted and used.

All flow statistics used were derived from Murdoch (2001).

6.2 Environmental water requirements based upon the assessment of the site below Peters Road crossing

The following assessment discusses the EWRs for the site below Peters Road crossing (Zone 6, Map 5.4, Figure B.2) and its relationship to the catchment as a whole. The details of the EWR assessment below Peters Road crossing is shown in Table 6.1. Further information on how these tables were formulated is in Appendix B.

Groundwater

At the site below Peters Road crossing, the groundwater level is maintained at a high enough level in relation to the stream bed surface to ensure that the deep pools are permanently filled with water.

These permanent pools provide a refuge for plants and animals through dry seasons and years.

A feature of the Light catchment is the large number of permanent pools maintained by groundwater.

Baseflow

The composite record of flow information from the Kapunda and Mingays Waterhole gauging stations shows that baseflow has flowed continuously over 26 years of recorded monitoring (1974 – 2000). This is probably due to the groundwater welling up from contact with the rock bars in the riverbed. The baseflow in the site downstream of Peters Road crossing has flowed continuously for the last 14 years with the exception of the year 2000–2001 when it ceased to flow in the summer months (I Nairn, pers comm 2001).

The critical function for baseflow below Peters Road crossing is the maintenance of riffles and the creation of habitats. These riffle zones support a diversity of macro-invertebrates when activated by flows. For most generalist macro-invertebrate species inhabiting the Light River system, lifecycles can be completed in two weeks to three months; one month of flow will sustain the majority of these populations. Specialist macro-invertebrate species such as caddis flies (*Cheumatopsyche*) require extended periods of flowing water to complete their lifecycles. At the site below Peters Road crossing the long duration of baseflow enables the full lifecycle functions of most riffle dwelling macro-invertebrates.

There are significant areas of permanent baseflow in the upper reach of Julia Creek, the lower reach of the Gilbert River and in the main stem of the Light River around Kapunda.

Low flow

Low flow levels of 1.2 cumecs at the site below Peters Road crossing are significant for inundating in-stream benches, bars and connecting pools. Adult fish are primarily dispersed through movement from drought refuges to reactivated habitats following increased flow. Some smaller species such as gudgeons complete their lifecycles within an area of a few kilometres (Young 2001). If flows at these levels endure they provide fish such as galaxias with an opportunity to migrate over significant distances upstream and downstream.

In river systems with optimum flows, the common jollytail (*Galaxias maculatus*) migrates downstream to the margins of river estuaries to lay its eggs. The fry spend 5–6 months at sea and then migrate up freshwater streams and develop into adults (McDowell 1996). Migration of common jollytail between the permanent pools at The Rockies and the estuary has been estimated by Lloyd (pers comm 2001) to take approximately one to two months. Flows that allow these migration events to occur need to take place once every year for optimum breeding and at a minimum of once every three years to sustain the fish population.

Modelling of this data shows that flows maintained at this level or above for at least seven days will occur in one year out of every 1.9 years, based on an annual exceedence probability (1 in 1.9 AEP). Flows of a duration of at least two weeks will occur in one year out of every 6.5 years (AEP).

This information suggests that this flow regime does not last long enough to allow common jollytail to reliably migrate between the estuary and the main area of permanent pools. This indicates that populations of common jollytail in the Light catchment are landlocked. Findings by Pollard (1971) and Mc Dowell (1996) noted that landlocked populations will adopt a breeding behaviour of migration upstream into flooding rivers to spawn.

The limited duration of these flow levels also suggests that fish populations in the upstream areas of the catchment may only be able to move within a localised area in most years.

Bankfull flow

Bankfull flows, estimated to be 9.1 cumecs at the site downstream of Peters Road crossing are significant for inundating the benches and depressions within the channel, and providing a large amount of food and habitat for plants and animals. Successful adult fish development and spawning depends on environmental stimuli such as water temperature, day length and a rise in water level. The optimum time for most fish species is around spring. Recruitment of fish larvae depends on suitable habitat, water quality, food resources and prevention of losses from predation.

The common jollytail was the most widespread native fish identified in the Light catchment. It has more critical flow requirements than other native fish species identified within the catchment. Therefore the stated flow requirements relate to this species.

The bankfull flow level is significant for the hatching and spawning of the common jollytail. This species lays its eggs on terrestrial vegetation inundated by a full tide or a high flow. The eggs remain dry for approximately two weeks and hatch on the next successive full tide or high flow. For successful recruitment, fish larvae and juveniles need to remain in shallow inundated areas and flood runners for a minimum of two weeks to enable them to develop in an environment relatively free from predators.

Modelling of flows at this level for one day followed by a successive flow approximately two to three weeks later at the same or higher level occurs in one year out of every 2.9 years (AEP). Flows at this level are unreliable for spawning and hatching events and the duration of flows at a suitable lower flow level are not likely to occur for a long enough duration (two weeks) to provide good recruitment events at this site. This also indicates that watercourses in the Light catchment are likely to be marginal for some species of fish.

Overbank flows

Overbank flows, estimated to be 26 cumecs at the site downstream of Peters Road crossing are significant for the complete inundation of the floodplain to the toe of the terrace. Inundated floodplains are well suited as nursery habitats due to the combination of abundant food, a large range of habitats and low predation rates.

Although fish reproduction and recruitment occurs without access to floodplain environments, current evidence (Young 2001) suggests that inundation of these ecosystems provides the major recruitment events that rebuild populations depleted through a run of unfavourable seasons.

Modelling of flows at the overbank level for one day followed by a successive flow at the same or higher level approximately two to four weeks later occurs in one year out of every 6.5 years (AEP). The information from the assessment of bankfull flows suggests that the site evaluated at below Peters Road crossing is unfavourable as a significant fish recruitment area, particularly for galaxias.

It can be concluded that significant recruitment of galaxias and other fish are most likely to occur at sites that have a shallower channel profile and a more level floodplain. However the duration of flows even at 1.2 cumecs is minimal and is unlikely to provide optimal fish recruitment conditions.

Large to catastrophic flood

At the site downstream of Peters Road, extensive flood-out events are associated with flows of greater than 30 cumecs. Very large floods are important for channel maintenance functions such as the scouring of pools and the resetting of habitats through movement of boulders, gravel beds and logs.

The natural flow frequency for a large flood event such as the one recorded on 25 December 1999 of 350 cumecs happens in one year out of every 20 years (AEP). This natural frequency is required to maintain natural processes but the loss of indigenous riparian vegetation may mean that the floodplain is more susceptible to erosion than under natural conditions, therefore greater scouring of the channel and floodplain may occur.

6.3 Discussion

In general, the hydrological findings from the assessment of gauging station data supports the ecological findings for the site below Peters Road crossing. These findings have specific relevance to the site, and extrapolating actual flow frequency and duration data to other areas of the catchment will be misleading as these will vary from site to site.

Based on general hydrological principles in the reaches upstream of Mingays Waterhole the peak flows will generally be smaller and the durations shorter. From downstream of Mingays Waterhole to the Gilbert River junction the peaks will slowly attenuate. Due to the addition of flow from the Gilbert River, downstream of the junction the duration and magnitude of the peak and the tail of the sustaining flows will generally be greater. Further downstream the peak flow will once again become smaller and the duration substantially longer. The main caution in the lower reach is that this area, for the majority of the time, is a losing reach, where surface flows seep into the watercourse bed and contribute to groundwater. During the drier periods, lower flows do not reach the estuary.

Although information on the flows and ecological responses in the Light catchment is preliminary, general statements can be made about the system.

- Flow data from the gauging station indicates that significant flow events have rapid recession rates, with limited flow duration that in turn limits significant ecological responses that require longer durations.
- Based on the rate of flow recession, fish migration is generally limited to local movement and migration.
- The large distance between the permanent pools at The Rockies and the estuarine zone, means that flows of the required height and duration do not occur with enough frequency to enable migratory fish species to regularly move between these two zones. Therefore it is considered that estuarine connectivity is not an essential process in the maintenance of fish populations in the mid to upper Light catchment.
- The survey site downstream of Peters Road crossing, although reasonable for estimating flows, was not a high value ecological site.
- Due to the limited flows in this river system, sites of high ecological value will occur in areas of permanent pools and lower lying wetland areas, such as around the entrances of tributaries rather than along large zones of the river system.
- Based on the ecological features defined by Lloyd (2001), the river system appears to be naturally sub-optimal for the recruitment of some fish species (e.g. *Galaxias maculatus*) especially in the higher reaches of the river system.

Table 6.1 Environmental water requirements for the site downstream of Peters Road crossing

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Groundwater	Fills permanent pools	• **Maintain pools for aquatic flora and fauna** • **Maintain reedbed communities**	Permanent	Permanent	Permanent with fluctuations all year round
Baseflow **0.1** cumec in winter (exceeded in 50% of Augusts)	Shallow flow over runs and riffles	• **Maintain riffles and create habitats** • Maintain water quality e.g. nutrients, salinity, dissolved oxygen	**M** / 1:1 Seasonal increase in flow level Actual flow frequency **1:1.02**	2 weeks – 3 months (max for full ecological functioning) Sustain. 1 mth Actual flow frequency **1 month = 1:1.3**	Autumn spring
Low flow 2.76 m at survey site **1.17** cumec	Inundates in-stream bench and connects pools	• **Fish migration** • **Fish development and recruitment** • **Breeding and recruitment of macro-invertebrates and frogs** • **Inundate shallow habitat for frogs, macro-invertebrates and fish** • **Habitat connection for local flora and fauna** • **Maintain water quality e.g. nutrients, salinity, dissolved oxygen**	**Fi** / 1:1–1:5 Sustain. 1:3 Optimum 1:1 Actual flow frequency **1:1.1**	1–2 months Sustain. 1 month Actual flow frequency **7 days = 1:1.9** **14 days = 1:6.5**	Late winter–spring
Bankfull 4.28 m at survey site **9.1** cumec	Inundates *Juncus* spp. and lignum; waters *Melaleuca brevifolia*	• **Galaxias fish spawning and hatching** • **Fish spawning and hatching** • **Large scale fish development and recruitment** • **Maintenance and recruitment of riparian vegetation** • **Transport nutrients** • Sediment transport	**Fi** / 1:1–1:5 Sustain. 1:3 Actual flow frequency **1:1.5**	1–2 days followed by an event of 1 day up to 2–3 weeks later Actual flow frequency **1:2.9** (for 2 events at 1 day duration)	Late winter–spring

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Overbank 5.63 m at survey site **26** cumec	Overbank flow inundating inner floodplain to toe of terrace	• **Large scale galaxias spawning and hatching.** • **Large scale fish redistribution** • **Large scale frog breeding and recruitment** • **Maintenance and recruitment of floodplain vegetation** • **Channel maintenance** • **Removal of sediments from riffle substrate** • **Sediment transport** • Transport nutrients	**Fi** / 1:3–1:10 Sustain. 1:5 Actual flow frequency **1:2.1**	1–2 days, followed by an event of 1 day up to 2–3 weeks later. Actual flow frequency **1:6.5** (for 2 events at 1 day duration) A follow up flow at a significant level for 2–4 weeks will provide optimum conditions for successful development and recruitment Actual flow frequency This pattern has not occurred during the recording period	Late winter–spring
Large to catastrophic flood 9.5–11.3 m at survey site >26–350 cumec	Large scale flood event above toe of terrace	• **Scouring of pools** • **Habitat resetting** • Channel maintenance • Sediment transport	**G** / Natural estimated >1:5 Actual flow frequency **>1:2.1–1:20**	Natural estimated hours–days	n.a.

** The following text symbols in the frequency columns represent the key functions for that flow band based on assumptions determined from the tables in Appendices A and C:

Fi — fish
V — vegetation
M — macro-invertebrate
G — geomorphological

AEP: Annual exceedence probability derived from Log Pearson Type 3 distribution frequency analysis (annual series).
AEP (estimated) Estimated annual exceedence probability using tabulated information.
For a cross-section of this site see Figure B.2 in Appendix B.

6.4 Conclusion

The assessment of EWRs has provided management directions for maintaining and improving the health of the Light catchment. The discussion below is revisited in Chapter 12 and has been used to provide recommendations and actions for river management in the Light catchment.

Significant rainfall runoff flow events provide the greatest proportion of the flow volume in the catchment, and also stimulate the most significant ecological responses. The short duration of these flow events is the greatest limiting factor for aquatic ecosystems (see Section 5.3.4). Surface flows within this range that are driven by rainfall events are of low salinity and have the potential to be targeted for development.

Recent investigations suggest that there may be an increased risk of geomorphological and ecological changes if the relevant flow statistics deviate from natural by more than approximately 20–30%, although there are likely to be variations in sensitivity between flow statistics and river systems (Brizga 2000). As a general principal, the greater the deviations from the natural flow regime, the greater the risk of significant change.

According to Murdoch (2001), the current total water capture from dams within the Light catchment is approximately 8% of the adjusted flow (the sum of the flow and the estimated volume captured by farm dams). However, a large increase in dams, such as an expansion of the wine industry into the Stockwell and Hamilton areas may capture a substantial amount of the local surface runoff. This is particularly significant during the early autumn and winter rains where dams have the highest potential to store water. This can delay the initial wetting up process of the streams, reduce the period of flow, and increase the salinity level in pools (more regularly than naturally occurs), significantly affecting the health and diversity of local aquatic biota.

To protect these ecosystems an assessment of the potential impact of farm dams is required and, if necessary, a management plan to control water resource development in the area should be developed.

Groundwater and baseflows are very important for the health of ephemeral river systems. Groundwater systems need to be protected to ensure an availability of habitat, and maintenance of water quality and aquatic ecosystems.

Further flow information is required to obtain a greater understanding of the EWRs of the whole river system. Improvement of the gauging station at Mingays Waterhole is required and the installation of new gauging stations is recommended to determine flow characteristics in the lower Light River near the estuary and in the Gilbert River. Lower cost data loggers at rated sites are recommended to monitor flow characteristics at St Kitts Creek, the upper Light River and above Redbanks to help identify and quantify surface water to groundwater interaction (recommendation 10, Chapter 12).

Monitoring programs need to be designed and implemented to determine the effectiveness of these programs.

CHAPTER 7 WATERCOURSE CONDITION AND MANAGEMENT ISSUES IN THE LIGHT CATCHMENT

7.1 Introduction

The project team's survey of the current condition of fourth order and larger watercourses in the Light catchment led to the identification of a number of significant watercourse management issues. This chapter discusses the nature and location of management issues throughout the Light catchment and potential management strategies for each issue.

The principles used by the project team to prioritise watercourse management issues on a catchment basis are also discussed in this chapter. On a subcatchment level watercourse management issues have been prioritised on both ecological and local community values and are discussed in Chapters 8–11.

7.2 Watercourse condition assessment

The assessment survey used aerial video and groundtruthing (see Chapter 3 for details) to record information on:

- native riparian vegetation — structure and density;
- bed vegetation — reed bed (macrophyte) density;
- bank stability;
- bed stability;
- exotic trees;
- exotic weeds;
- baseflow, permanent pools, dams;
- stream works stability — bridge, ford, stock crossing, weir, dam spillway.

Maps displaying the current condition for each of these parameters are located in Chapter 5. Information on the extent (km) and coverage (%) for these parameters are also located in Chapter 5 and in Table 7.1. This information was used to identify the following watercourse management issues.

7.3 Conservation management issues

Protecting watercourses with high conservation values is an important priority for management. It is much more effective, in terms of cost and ecological benefits to protect these areas than to manage them poorly and then rehabilitate them (LWRRDC 2000). The benefits of protection and management include maintaining and improving the biodiversity of the region as well as protecting a natural asset. These areas are often the only surviving remnants of the original watercourse habitats. They not only have high conservation and ecological values but also have high recreation, aesthetic and community values (e.g. The Rockies in the Lower Light). Managing and protecting areas of important riverine habitat was voted a high priority by landholders in three of the four subcatchments at community meetings (see Chapters 4 and 8–11).

7.3.1 PROTECTION OF IMPORTANT RIVERINE HABITAT

Within the Light catchment, areas of important riverine habitat are characterised by a diversity of in-stream and riparian vegetation, a range of in-stream physical habitats, (such as pools, riffles and channel bars) and, typically, permanent or semi-permanent water (Plate 7.1). These areas usually have high biodiversity values, are important refuges for organisms during harsh periods and provide a stable environment for recolonisation.

Areas of important riverine habitat (Map 7.1) identified throughout the Light catchment included:

- mangrove and samphire estuary environments at the Light River estuary;
- permanent pools in The Rockies area and upstream of Hamley Bridge;
- remnant open forest and sedgeland, riffles, rockbars, and permanent baseflow and pools along the Light River downstream of the junction of Ross Creek;
- permanent pools, riffles and reedbeds through the gorge downstream of Peters Road crossing;
- pools, reedbeds and rockbars along the Light River 3 km upstream of Hamley Bridge.

Plate 7.1 Important riverine habitat in the Mid Light subcatchment

Maintaining and enhancing these areas may require management of livestock to ensure minimal impact on the local environment. Management strategies may include fencing, removing and controlling threatening exotic trees and weeds, managing threats such as sediment deposition from erosion upstream and ensuring that the natural pattern of stream flows are maintained. Regular monitoring is also required to detect any developing problems or deterioration.

7.3.2 PROTECTION OF REMNANT VEGETATION

Areas of remnant vegetation support a diverse range of plant and animal communities and provide valuable seed reserves which can re-establish vegetation downstream (Plate 7.2). As most of the riparian vegetation across the catchment has been cleared or modified, these areas have a high ecological value; they may often be the only significant remnants.

Remnant vegetation sites requiring protection (Map 7.1) include:

- South Australian blue gum and peppermint box woodland on a tributary of Allen Creek, which is threatened by woody weeds and exotic trees;
- open woodland of peppermint box and southern cypress pine at the headwaters of St Kitts Creek;
- river red gum open forest and sedgelands along the Light River downstream of the junction of Ross Creek;
- stands of short leaf honey myrtle along the lower reaches of the Gilbert River and middle reaches of Upper Light River between Hamilton and St Kitts.

Plate 7.2 Remnant vegetation in the Mid Light subcatchment

Some remnants of vegetation currently have some level of protection from clearing and grazing. Management of remnant vegetation requires the identification and control of threats from within the reach, such as grazing and exotic weed invasion and threats from upstream or downstream such as erosion heads.

7.4 Vegetation management issues

Healthy watercourse vegetation is an essential element of a healthy riverine ecosystem. Well-vegetated banks slow surface runoff, which helps prevent sediments, pollutants and nutrients from entering the watercourse. Vegetation stabilises and protects the bed and banks from the erosive force of water. The vegetation provides shade, lowers water temperatures and regulates algal growth. Leaves and branches are both important food sources and habitats for aquatic and terrestrial animals (Davies and Bunn 1999). Healthy watercourse vegetation also enhances recreational and aesthetic values (LWRRDC 2000).

7.4.1 IMPROVING OR MAINTAINING AREAS OF GOOD NATIVE WATERCOURSE VEGETATION

Improving river health requires areas of good watercourse vegetation to be maintained and improved. A number of areas in the catchment contain vegetation in moderate to good condition (Map 7.1), which has been impacted by degrading processes such as vegetation clearance, invasion of exotic species and pressure from livestock grazing (Plate 7.3). In general, these sites will continue to deteriorate unless there is active management to revegetate and control threats.

Most of this vegetation is fragmented and lacks diversity in terms of structure (grasses, shrubs and trees) on the banks and floodplain. Typically, areas of good watercourse vegetation fall into two categories: reaches with a healthy native overstorey (typically >30% coverage) and a degraded understorey; and reaches with diverse in-stream vegetation but with degraded riparian vegetation (overstorey and understorey layers). An example of the former is a forest with a healthy eucalyptus overstorey but lacking shrub understorey layer because of clearance or grazing. An example of the latter is an area with in-stream reeds and sedges but missing overstorey trees or shrubs along the banks. In many of these areas, where a part of the vegetation structure has been removed, weed species such as African boxthorn, wild rose and wild artichoke have become established.

Areas of eucalypt forest/woodland in good condition but with modified understorey are located along:

- lower Light River extending from downstream of The Rockies to the estuary;
- Light River from downstream of Kapunda to Hamley Bridge;
- Macaw Creek;
- upper reaches of Tothill Creek;
- Allen Creek;
- Stockwell Creek, St Kitts Creek and surrounding tributaries.

Areas with good in-stream vegetation but degraded native vegetation on the banks occur along:

- upper reaches of the Gilbert River above Saddleworth and around some of the tributaries around Tarlee;
- middle reaches of Tothill Creek;
- Stockwell Creek, St Kitts Creek and surrounding tributaries.

Management of grazing in the riparian zone and removal of invasive weeds together with encouraging natural regeneration and/or revegetation will improve the condition of these areas. Management requires ongoing maintenance to ensure weeds and vermin do not impact on any rehabilitation works or further degrade the site.

Plate 7.3 Native watercourse vegetation with a good canopy but lacking understorey in the Mid Light subcatchment

7.4.2 POOR NATIVE WATERCOURSE VEGETATION

The most common watercourse management issue in the catchment was a lack of, or the degraded condition of, native watercourse vegetation (Map 7.1, Plate 7.4). Poor native watercourse vegetation occurred along 43.4% of surveyed watercourses. Clearance, cultivation within or in close proximity to the riparian zone and stock grazing are major contributors to the loss of native watercourse vegetation.

A lack of native vegetation indicates poor ecological health of both land-based and water dependent ecosystems (Figure 7.1). In general, introduced plant species such as annual grasses and weeds do not provide the riparian zone with the vegetative cover required to stabilise watercourse soils and banks. Sediment and nutrients are easily mobilised downstream, thereby reducing water quality; sedimentation of pools can lead to an increase in reed growth. Areas lacking native vegetation provide little food or shelter for native birds and animals. A lack of vegetation cover over permanent water increases water temperatures, which can promote algal growth and creates unsuitable conditions for in-stream flora and fauna (Davies and Bunn 1999).

Poor native watercourse vegetation was an issue that affected all watercourses in the Light catchment. Particularly large sections of poor native watercourse vegetation were identified along:

- Gilbert River
- Macaw Creek
- Tothill Creek

- Upper Light River
- Julia Creek
- Freshwater Creek
- Stockwell Creek.

Revegetation is necessary to improve areas of poor native watercourse vegetation. This can be achieved by controlling stock access to the riparian zone (e.g. with fencing). With removal of stock most areas will naturally regenerate but, to support this process, the additional vegetation may be established through direct seeding or tube stock planting.

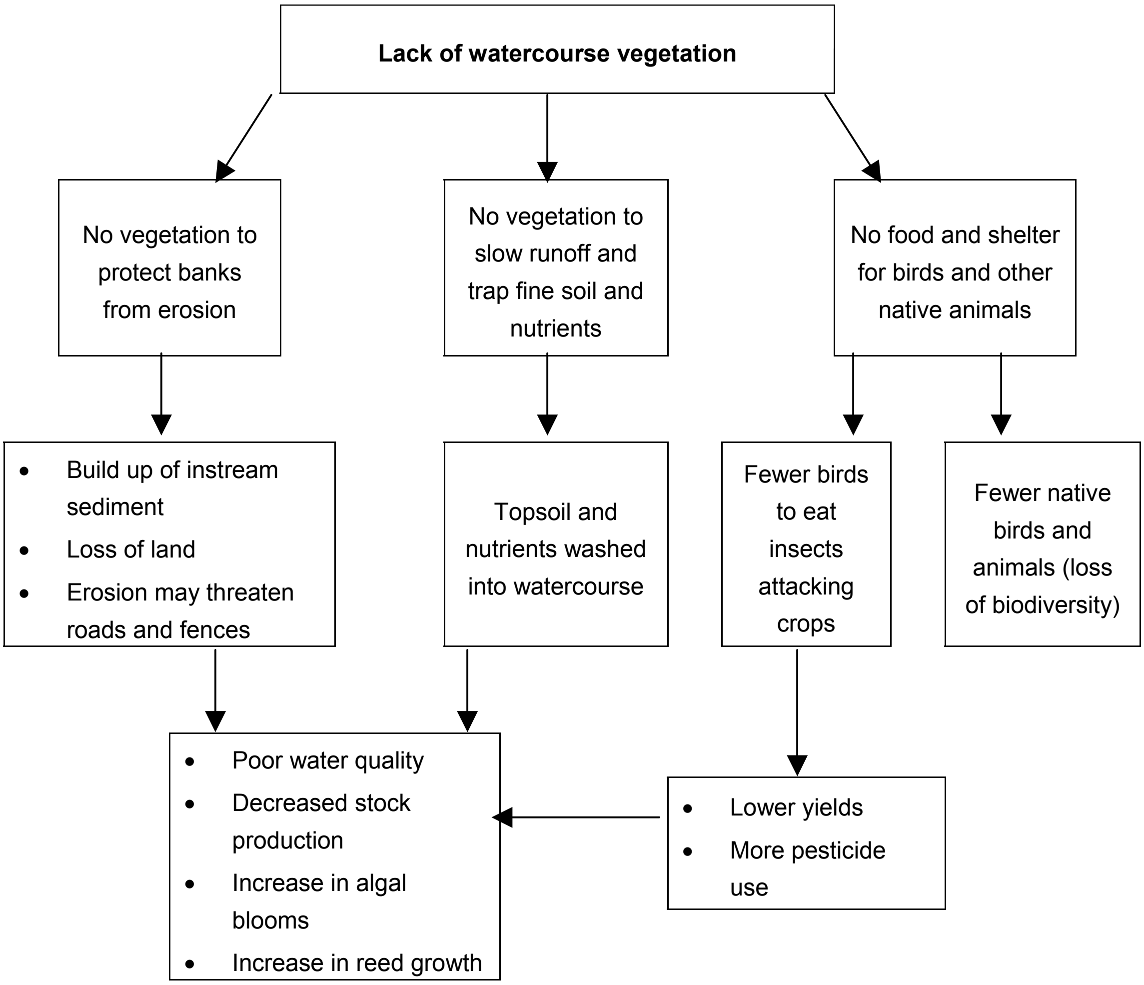


Figure 7.1 Impacts of lack of native watercourse vegetation

7.4.3 RIPARIAN WEEDS

Watercourses act as an effective conduit for the spread of weeds. Weed invasion into natural ecosystems is one of the major threats to biological diversity. Weed species compete strongly with native plant species and do not provide a full range of food and habitat requirements for native animals. Most weed species do not effectively stabilise watercourse banks and many provide a refuge for vermin. Weeds can also impact on agricultural production in areas adjacent to the riparian zone.

Plate 7.4 Poor native vegetation in the Gilbert subcatchment

In determining whether riparian weeds were a significant management issue along watercourses of the Light catchment, consideration was given to the density of plant coverage, invasiveness of the weed, proclaimed status of the weed, threat to the integrity of native vegetation and length of watercourse affected.

The four major weeds that were found to be a problem along watercourses in the Light catchment (Map 7.1) were wild artichoke, gorse, African boxthorn and wild rose (not proclaimed as a weed).

Wild artichoke was identified as a management issue along:

- Gilbert River
- Lower Light including the upper estuary.

Gorse (Plate 7.5) was identified as a management issue along:

- St Kitts Creek
- Upper Light River.

African boxthorn was identified as a management issue along:

- Light River in the Mid Light subcatchment, Allen and Ross creeks, extending down along the Light River through the Lower Light subcatchment to upstream of Redbanks;
- freshwater side of the Light River estuary.

Wild rose was identified as a management issue along:

- Upper Light River
- Julia Creek
- Tributaries north of Kapunda (including Allen Creek)
- St Kitts Creek and tributaries
- Stockwell Creek
- Gilbert River
- Macaw Creek.

Plate 7.5 Gorse choking the watercourse

Weed management involves removal and/or poisoning (using herbicides registered for use along waterways). It is also important to improve the site so that weeds do not return by:

- retaining a cover of vegetation which shades out weeds and is wide enough to maintain integrity (30–50 m);
- avoiding disturbance to the riparian zone.

7.4.4 EXOTIC TREES

Introduced tree species can spread rapidly in a watercourse environment, out-competing local species and establishing themselves in inappropriate areas such as the bed of a stream.

Exotic trees growing along watercourses can cause a number of problems. Where trees form dense thickets the normal flow of the watercourse can be obstructed causing erosion and flooding problems. Exotic trees tend to cast a dense shade that prevents undergrowth; as a consequence plant and habitat diversity is reduced. The deciduous leaf drop in late autumn produces a sudden increase in organic material, resulting in high numbers of bacteria which rapidly break down organic material releasing large quantities of nutrients. In the process they can deoxygenate the water leading to macro-invertebrate and fish kills.

In general, exotic trees provide a much poorer habitat than native species and do not meet the food and shelter requirements of many native aquatic and terrestrial insects and other animals. Biological monitoring in South Australia has shown that the number and diversity of aquatic insects and fish are greatly reduced under exotic trees compared with native vegetation.

Exotic trees were present at a few sites throughout the Light catchment (Map 7.1; Plate 7.6). In the upper Light River and Gilbert River there were a few sites with sparse pine and olives. In Allen and Ross creeks sparse olives were identified. No significant stands of exotic trees were found in the Lower Light subcatchment.

Plate 7.6 Olives in a watercourse in the Mid Light subcatchment

Removal of exotic trees along watercourses is necessary to improve ecological health but these trees play some role in stabilising a watercourse and providing habitat to native animals where other suitable habitat is limited. Thus exotic trees should removed in small areas at a time so the stream is not completely bare in the transition stage; and removal should be closely followed by revegetation. Advice should be sought before attempting to remove or control exotic trees.

7.5 Managing and rehabilitating watercourse vegetation

Managing and rehabilitating watercourse vegetation can have many benefits, including contributing to healthy riverine ecosystems, providing wildlife habitat, bed and bank stability, controlling nuisance plants and protecting water quality. In the catchment, management and rehabilitation is likely to require a combination of natural regeneration, revegetation, and grazing and weed management. Many aquatic and semi-aquatic species such as sedges, reeds and rushes will re-establish quickly and naturally once grazing pressure is removed and weeds controlled (Myers 1999). Native shrubs and trees are less likely to regenerate naturally and may have to be planted or seeded directly.

7.5.1 RIPARIAN BUFFER STRIPS

Watercourse vegetation can be a buffer to slow runoff and can trap sediment and nutrients. The effectiveness of vegetation depends on the width, the form of vegetation and the slope of the land (Pen 1999). For example, grasses and low shrubs are a more effective buffer than trees. Planting vegetated buffer strips of 10–50 m width has achieved nutrient filtration rates of 50-100% (Pen 1999). Buffer strips can be grazed as long as it is controlled to maintain groundcover and prevent damage to the soil surface.

Many areas in the catchment are cultivated and cropped right to the edge of the watercourse. A buffer strip of grasses along the watercourses in these areas could help to reduce sediment and nutrient loads substantially. The cultivation of shallow watercourses also has the potential to accelerate erosion and transport sediment and nutrients downstream. Maintaining a perennial cover of grasses would reduce this potential and promote filtration.

7.5.2 REVEGETATION AND NATURAL REGENERATION

Sound technical advice and a planned revegetation program are essential. Specific information on appropriate species and planning should be sought from local revegetation officers. The following factors will maximise benefits:

- Have a clear set of objectives for management — restoring habitat, reducing erosion, improving water quality or a combination of these — as different approaches may be required to achieve different objectives (LWRRDC 2000).
- Have an understanding of the original vegetation structure and composition to help select appropriate species — local indigenous species are obviously the most suitable for the site.
- Ensure structural diversity by planting a range of species, including aquatic plants, reeds, rushes, sedges, grasses, shrubs and trees in appropriate locations.
- Implement initial and ongoing weed and exotic tree control and grazing management practices.
- Select techniques appropriate for the site and resources such as natural regeneration, direct seeding or tubestock planting (LWRRDC 2000).
- Revegetate a band at least 10–15 m wide measured from the top of the watercourse bank; generally, a minimum width of 10 m is required to effectively to filter sediments and nutrients from the catchment runoff.

In revegetating watercourses in the catchment, particular consideration must be given to the composition of the original vegetation. For example, it would not be appropriate to plant tree and shrub species if the original vegetation was grassland. Where possible, indigenous plant species which occur naturally in an area should be used because of their intrinsic role in the river ecosystem. Native plant species will help to maintain or re-establish habitat for wildlife and to protect stream banks from erosion. They are also better adapted to local conditions and have a higher survival rate. Planting indigenous species will help to preserve plant species that may be locally rare or endangered and provide new seed banks for local species (Carr et al. 1999). Map 5.9 shows the estimated pre-European distribution of vegetation associations and species throughout the catchment and is a useful guide for revegetation.

It is important to select the right plant for the right location within the riparian zone (Figure 7.2). Aquatic and semi-aquatic species, sedges, reeds and rushes play the critical role in bank stability by holding and protecting the toe of the bank. Native shrubs and grasses are found on the banks and floodplain. Larger trees should be planted on the upper banks and floodplain zone.

The bed and banks of a watercourse must be stabilised before attempting revegetation or vegetation management. At the same time, vegetation can be part of the solution for erosion issues. Well-planned revegetation, especially on the toes and mid-section of the bank can greatly assist in stabilising eroding channels.

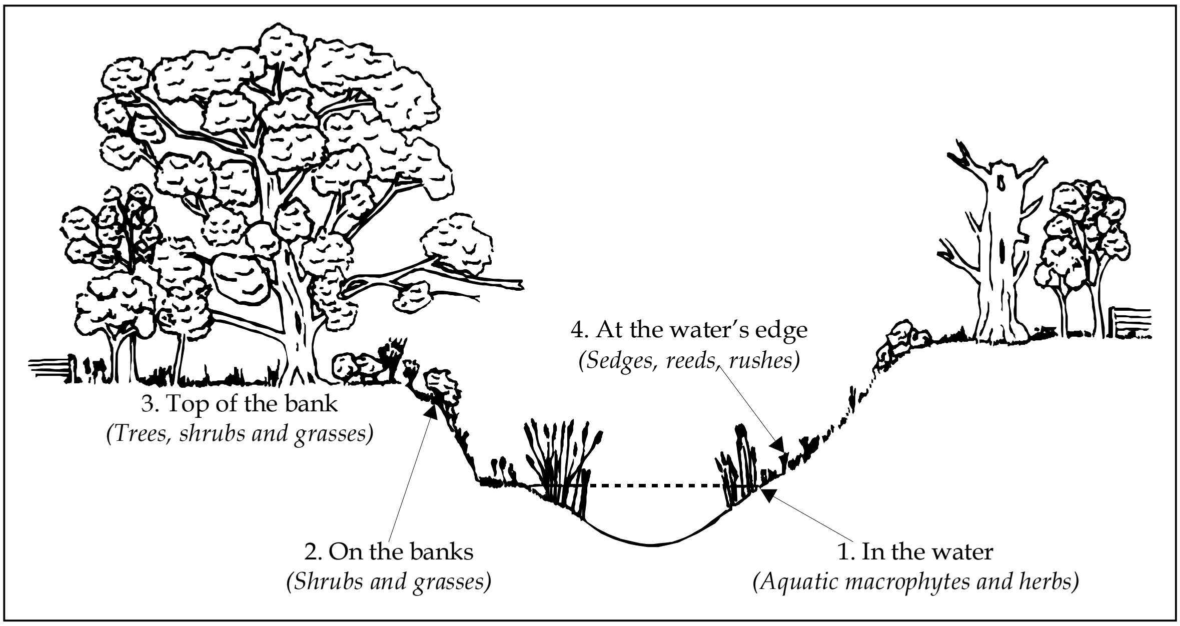


Figure 7.2 Planting zones for riparian vegetation

7.5.3 MANAGEMENT OF LIVESTOCK

Reducing or excluding livestock access can have a dramatic effect on the recovery of watercourse vegetation and channel stability. Long-term monitoring by landholders has indicated slow recovery within two years and significant recovery to a state approaching the natural state of the stream within eight years (Bell and Priestley 1998).

To lessen the impact of livestock, the timing, duration and intensity of grazing along the watercourse needs to be controlled. Fencing and an alternative water supply are the most obvious means of control. Electric fencing is an inexpensive and low maintenance option. Where fencing is not an option, it is possible to limit the time stock spend in the riparian zone by other means such as locating alternative watering points away from the stream (Bell and Priestley 1998).

In fencing a watercourse, consider locating the fence well away from the stream and parallel to the direction of flow. Where this means large areas are excluded, controlled grazing management of the zone may be necessary, for example limiting the time spent in the riparian zone and restricting grazing to late autumn–winter. Fences across the direction of flow are inevitable and there are several flood resistant fencing options, the simplest including suspension fences and drop down fences (Bell and Priestley 1998).

Some of the benefits of controlling stock access to the riparian zone include:

- reduced bed and bank erosion;
- better grazing management;
- healthier riparian environment;
- improved water quality;
- improved recreation and aesthetic values (Bell and Priestley 1998).

Some of the disadvantages are the costs involved if a substantial length of fencing or a number of alternative watering points are required.

7.5.4 WEED MANAGEMENT

Weed control and ongoing management are essential to protect and maintain a healthy riparian zone. Importantly, weed control should be linked with a program of revegetation. Where weed coverage is particularly dense it may be necessary to undertake a 2–3 year program of weed control before revegetation. Effective weed control is essential for establishing plants when revegetating (Carr et al. 1999). Weeds can be controlled by methods such as spot spraying and removal by hand or mechanically. The technique chosen will depend on the type of weed species, the site and the density of the infestation.

Care should be taken when controlling or removing weeds. Where native vegetation is lacking, some weeds such as boxthorn can act as protective refuges for small native birds. Care should be taken not to initiate erosion when removing weeds by disturbing the bed or banks of a watercourse. To minimise impacts on aquatic flora and fauna, use only herbicides registered for use near watercourses (e.g. Roundup Biactive®).

For dense infestations, the best strategy is to control or remove manageable sections over a period of time (as opposed to mass removal) followed by an organised program of revegetation. Advice should always be sought from the local animal and plant control boards on recommended methods of control.

Important ongoing weed management options over the long term include maintaining an intact native vegetation canopy to shade out weed species and preventing or minimising disturbance to the ground and riparian vegetation such as that caused by stock grazing. Minimising disturbance limits the opportunities for weeds to invade.

7.5.5 EXOTIC TREE MANAGEMENT

Exotic trees must be controlled to prevent further invasion along the watercourse. Long-term planning is critical. Control strategies will vary depending on the type of species (ability to spread and cause damage), the density and extent of distribution, the site and the ease of removal. A small number of a highly invasive tree species may require immediate removal, while a large extent of densely growing trees would require a long-term and staged control program.

To maximise the environmental benefits of removing exotic trees, it is important to replace the trees with suitable vegetation in a staged process. Where a watercourse is heavily infested, the mass removal of trees at one time can initiate erosion, increase light levels and water temperatures, and impact upon birds and animals that use the trees for their habitat. Importantly, time is required to establish native riparian vegetation.

Control methods will depend on the tree species. Methods include poisoning by injecting herbicide and then cutting down the tree when dead; cutting down the tree and immediately painting the stump with undiluted herbicide; or cutting down the tree, allowing the stump to reshoot and spraying the regrowth with herbicide. Only use herbicides recommended for use near watercourses. Timing is important. Poisoning is most effective during the growing period of October–April.

7.6 Watercourse stability issues

The natural process of erosion can be greatly accelerated by human activities that alter stream flows and disturb the stream channel. Such activities include land clearance, stock access, channel modifications (such as channelisation, excavation of stream channels and in-stream infrastructure). The steepness of the banks, soil type and whether the banks and bed are vegetated are important factors in determining the stability of a watercourse.

Erosion can cause channel deepening and widening, the destruction of physical habitats, threats to in-stream structures and increased sediment loads, which impact on downstream water quality and aquatic habitats.

7.6.1 POOR BANK STABILITY AND BANK EROSION

Poor bank stability indicating active bank erosion (Plate 7.7), is a management issue identified mostly along the upper reaches of tributaries (Map 7.1). There are a number of factors which can contribute to accelerated bank erosion, including removal of vegetation, stock grazing, bed lowering (e.g. by upstream movement of an erosion head), channelisation, obstructions to stream flow and changes to the flow regime.

Significant areas of poor bank stability and active bank erosion were located along many of the tributaries flowing into the Light River including Tothill Creek, Stockwell Creek, Fannel Creek and Allen Creek, a tributary of the Gilbert River south of Tarlee and the upper Light River (Map 7.1). These tributaries and the smaller third order streams at the footslopes of hills have high erosion rates and are major contributors of sediment into the system.

Plate 7.7 Poor bank stability along the Light River: the banks are lacking vegetation and actively eroding.

Areas of poor bank stability are usually eroding from the toe and in most cases revegetation can be a solution. For extreme cases of erosion engineering solutions on their own or accompanied by revegetation may be necessary. Engineering structures provide a solid base for establishing vegetation. Revegetating banks is important for slowing overland flow, which can be a significant contributor to erosion. Careful planning is necessary before attempting erosion control management.

7.6.2 EROSION HEADS AND GULLY EROSION

Bed erosion is generally initiated at a downstream point by activities that lower or disturb the bed of the watercourse. This is generally caused by in-stream excavation, channelisation or an increase in the volume or velocity of flow within the channel. As the erosion event travels upstream it takes the form of a locally high gradient or a 'waterfall' (an erosion head or nick point) (Carter 1995). When the erosion head passes a tributary or side gully, these areas will also undergo bed deepening as they adjust to the new bed level.

Bed erosion can cause overall deepening and widening of the watercourse. Bank erosion follows the passage of an episode of bed deepening and, in general, banks will continue to erode and widen until they adjust to a new stable slope. The eroded sediment that is carried downstream can infill the channel which may increase flooding and reed growth and smother important aquatic habitats.

Erosion heads associated with active bed erosion were identified as significant management issues at a number of sites across the Light catchment (Map 7.1). Areas of significant bed and bank erosion that were considered to be watercourse management issues occur along:

- Fannel Creek;
- a tributary south of Kapunda;
- Freshwater Creek.

These watercourses are high risk areas for erosion because of their steep gradients and the unconsolidated alluvial sediments over which flow occurs.

Gully erosion tends to occur on long, steep slopes adjacent to the main watercourse and is associated with active erosion heads that form incised gullies extending out from the main watercourse. These gullies are likely to considerably deepen and widen in heavy rainfall events. Often there is little vegetation along these slopes to slow flows, protect the soil and impede these erosion processes. Gully erosion was identified along:

- the tributaries in the St Kitts Creek area;
- a tributary south of Kapunda.

Erosion heads and gully erosion can be managed by planting grasses and bushes densely on both sides of the gully, larger plants less densely further away from the channel and sedges in the centre of the gully floor. The vegetation slows overland runoff into the gully and traps sediment in the gully itself; this reduces further bed deepening. Restricting stock access to the actively eroding gully by fencing off the area will also reduce erosion.

7.6.3 IN-STREAM STRUCTURAL WORKS

Bed and bank erosion can result in damage to in-stream man-made structures. At the same time, poorly aligned or designed bridges, culverts and weirs can initiate erosion (Plate 7.8). Culverts that are under-capacity for a flood discharge of the watercourse can result in upstream flooding and damage as water flows over the structure. Poorly aligned structures can redirect stream flow into a bank thereby causing bank erosion. Structures that fail to reduce the energy of water flow can cause scour holes and bank erosion downstream.

Structures causing or threatened by erosion were identified as a significant management issue at only a few sites throughout the catchment (Map 7.1):

- a tributary of Allen Creek;
- a tributary of the upper Light River, South of Waterloo;
- the lower reaches of Tothill Creek;
- Fannel Creek;
- a tributary of the Gilbert River in Tarlee.

In-stream structures that are being damaged by upstream erosion can be protected by targeting the erosion process upstream. Structures that are causing in-stream erosion due to poor alignment can be removed and better structures installed. Providing strength to the stream by revegetation and restricting stock access will also be of benefit in reducing erosion.

Plate 7.8 Culvert in the Mid Light subcatchment undermined by erosion processes

7.6.4 CHANNELISATION AND LEVEE BANKS

Channelisation refers to the alteration of the natural course of a watercourse (such as realignment, straightening or deepening). It is generally associated with agricultural drainage or flood control (Kapitzke et al. 1998). Levees are commonly constructed along watercourses to reduce overbank flooding. Typically these modifications increase the velocity and volumes of flow within the watercourse channel often initiating bed and bank erosion (Kapitzke et al. 1998).

Two areas of channelisation were identified in the Light catchment: along Stockwell Creek and along the Gilbert River. Levees were observed along a reach of Stockwell Creek.

Channelisation and levees are a contributing factor of stream incision in the Light catchment: water velocity increases because the flow is confined. The naturally steep gradients of the footslopes of hills, and the generally unconsolidated sediment over which flow occurs make them particularly susceptible to incision.

Channelisation and the construction of levees can have a significant impact on watercourse habitats, and aquatic plants and animals. In areas of the Light catchment the natural watercourse has been straightened and deepened to drain water from low lying, frequently inundated areas supporting sedgeland environments and river red gum flats. This can lead to reductions in the frequency of the overbank flooding required to maintain these ecosystems.

Management of channelised watercourses may require erosion control and revegetation. The river will naturally erode and deposit sediment as a process in readjusting to a natural meander pattern.

7.6.5 NO SIGNIFICANT WATERCOURSE MANAGEMENT ISSUE

Some areas have no significant ecological value, the vegetation cover is adequate or, if current management practices were continued, there would be little adverse affect on the condition of the watercourse. Examples include exotic grasslands and undefined, shallow, dry grassy channels.

In the Light catchment several sites along watercourses had no significant management issue (Map 7.1). These areas do not require active management but their condition should be monitored.

7.6.6 MANAGEMENT OF EROSION ISSUES

All erosion issues can be controlled but erosion control works are generally expensive. Careful comparison should be made of the costs and the benefits that will be gained. Fencing to restrict stock and revegetation with local indigenous plants is often the most cost-effective means of controlling bed and bank erosion. Well-vegetated watercourses are much more resistant to erosion.

Vegetation alone may not be sufficient where erosion threatens a high value asset (such as an area of high conservation value or in-stream infrastructure), the watercourse is very unstable or the area has high flow velocities. In these situations complementary engineering solutions should be considered. It is important to understand the nature of the site and the erosion processes at work and to target management strategies appropriately. For example, most bank erosion is associated with active erosion at the ‘toe’ of the bank. Control strategies need to target this location. If stream works are being considered to control erosion, it is important to seek professional advice and to be aware that council approval may be required.

Bank erosion can be controlled by dealing with the cause first — remove any obstructions and then stabilise and protect the bank by revegetation and, where necessary, soft engineering techniques such as alignment fences or rocks positioned at the base or toe of the bank.

Bank erosion control methods work by reducing flow velocities adjacent to the bank and increasing the erosion resistance of the bank. For example, in-stream and riparian vegetation reduces flow velocities by resisting flow and strengthens the bank by binding soil with root systems. Emergent aquatic plants can play an important role by binding soil and trapping sediment at the toe of the bank.

Depending on the severity of the erosion, erosion heads and bed erosion can be controlled through the construction of grade control structures and/or revegetation. Grade control structures such as rock chutes and drop weirs halt the migration of the erosion head and stabilise the bed enabling in-stream vegetation to become established. In many cases minor bed erosion can be controlled through revegetation and allowing in-stream vegetation to regenerate.

Erosion heads can also be naturally controlled by becoming 'locked up' in control structures such as rock bars, bridges and fords, or the root mass of trees. These structures act as a form of grade control, stopping movement of the erosion head upstream. In such cases, care must be taken when removing trees or repairing in-stream structures to avoid triggering a new episode of bed deepening.

7.7 *Other processes as a potential cause or symptom of watercourse management issues*

Other processes can be a potential cause or symptom of watercourse management problems and should be considered for watercourse management. Other issues in the Light catchment are outlined below.

7.7.1 REEDS

Landholders in the catchment have observed that the distribution of common reed (*Phragmites australis)* is more extensive than in the past. They are concerned that excessive growth of these reeds is causing siltation and has obstructed the normal flow of the watercourse as well as decreasing the size of permanent pools, covering riffles and restricting stock access to good quality drinking water.

This species is native and is a natural part of the river ecosystem (Plate 7.9) but its excessive growth can be a symptom of past disturbance and/or poor land management. It prefers fine sediment, high levels of nutrients and much light. Large amounts of topsoil and nutrients entering the watercourse from surrounding paddocks, sediment being deposited from upstream erosion, lack of any vegetative cover to shade the watercourse and decreased stocking rates provide an ideal environment for it to proliferate.

Reeds are common throughout the entire Light catchment, generally associated with waterholes and notably downstream of eroding sections of the watercourse.

Management of reeds requires careful consideration of the costs and benefits of doing so. These plant communities provide habitat for aquatic macro-invertebrates, frogs and birds. In addition they stabilise the bed and banks of the watercourse and trap sediment in the system, preventing its release further downstream. These factors need to be considered in any management actions. It is also important to note that reeds, rushes and sedges are native and their removal may require approval under the *Native Vegetation Act* 1991.

Revegetation can be an important long-term reed control method. Shading in the watercourse has been shown to be a significant factor in controlling the growth of reed beds. For example, stands of water plants were shown to increase significantly at sites where the forest cover was less than 50% (Canfield and Hoyer 1988). Burning and grazing reeds are currently used as short-term control methods. However, these methods can have negative impacts on the ecology of the river system; for example, waterbirds use reedbeds as nesting sites in spring to early summer and the methods used may simply encourage stronger growth the following year. Such active management can result in the release of trapped sediments. Also, some species handle burning better than others and will come to dominate the system.

Plate 7.9 Reeds in the Light River at Hansborough

For eroded areas, the growth of reed beds can be a stage in the recovery process of the river system. It is likely that over time the bed of the stream will stabilise and sediment will build up on the banks of the watercourse. The flow of the stream will begin to be confined to a smaller channel and the process will start to form a series of pools in narrow reaches of the watercourse. Through this transition the reed beds will be replaced by sedges and grass species, which will increase habitat diversity. The time required for this transition to occur is specific to the conditions of the site in question; it may take 10 years, it may take 100 years. Revegetating banks and floodplains and undertaking river rehabilitation works may encourage this process.

7.7.2 DRYLAND SALINITY

Dryland salinity becomes a problem when broad scale clearance of deep-rooted perennial vegetation results in increased recharge and rising groundwater tables. When the groundwater table rises close to the surface, the rise of water through the soil leads to soil salinisation and waterlogging. This process is known as dryland salinity. Rising groundwater can also result in greater movement of saline groundwater into watercourses causing increased salt levels in stream water, which can cause salt scalds in dry periods (Plate 7.10).

Salinity was a significant problem along the upper reaches of the Light River, along Tothill Creek and Fox Creek. The Tothill Range has a cover of native vegetation that has been grazed and the understorey has been virtually destroyed. During heavy rain the high runoff from steep slopes runs down to the foot slopes where it accumulates on perched watertables (Evans 1994).

Plate 7.10 Saline watercourse: Tothill Creek in the Upper Light catchment

Rehabilitation of saline sites firstly requires careful assessment. In some locations minimising recharge by protecting existing vegetation or planting deep-rooted perennial vegetation can be an important management strategy. On land that has become saline, removal of stock and revegetation with native salt tolerant, high water use plants can lower the watertable. Revegetating these areas to their original condition may no longer be possible and use of species adapted to saline conditions may be necessary.

7.8 Determining watercourse management priorities

7.8.1 WATERCOURSE MANAGEMENT PRINCIPLES

Following the identification of watercourse issues, the project team determined priorities for each issue based on using specific principles for best management for ecological health. These were adapted from Department of Environment and Natural Resources (1997a) and Rutherford et al. (1999).

Protect important assets

Protecting or enhancing areas of good quality riverine habitat or remnant vegetation should be given highest priority. These areas may be rare and maximum benefit for river health and biodiversity will be gained for a minimum of effort.

Condition

Protect or rehabilitate streams in the best general condition before those in poor condition. They will also be easiest to fix and benefits will be maximised for the effort expended. It is easier to halt deterioration than to repair extremely degraded reaches.

Connectivity

Control the impacts on downstream or upstream reaches. If a degraded area is likely to impact on a reach in good condition it should be considered a priority for action.

Scale of impact

Assess the potential impacts of an issue on maintaining a stable, 'healthy' watercourse and the consequences of 'doing nothing'. All issues were evaluated on a subcatchment basis rather than a property by property basis (i.e. if an issue was addressed, what would be the benefit to river health at a subcatchment level). Issues that may be considered serious on a property by property basis may not necessarily be so on a subcatchment basis. In addition, some issues will require treatment at a 'reach' or subcatchment level rather than on an individual property basis.

Benefit vs cost

Most rehabilitation will invariably have a range of potential solutions. Funds for on-ground works are always limited, so it is important to maximise the net benefits to the riverine environment, the landholder and to the wider community. Any rehabilitation work should be guided by the desire to maximise the number and extent of the benefits from such work. For example, an erosion head can be controlled by installing a rock chute, or by fencing and revegetating. The first option is expensive and will only control erosion; the second will cost little and will potentially provide a greater range of benefits (e.g. erosion control, habitat, water quality and aesthetics).

7.8.2 PRIORITISATION OF ISSUES

Using these principles, the following management issues were identified in order of catchment priority (Table 7.1). Map 7.1 displays the location and extent of these issues. The reasons for the prioritisation of each issue are discussed below.

Table 7.1 Key watercourse management issues within the Light catchment

Watercourse management issue	Length (km)	% of total length of watercourse surveyed	Catchment management priority
Important riverine habitat	22.1	4.1	High
Remnant vegetation	11.1	2.1	High
Good native watercourse vegetation	131.9	24.5	High
Riparian woody weeds	36.9	6.9	High
Poor native watercourse vegetation	233.6	43.4	Medium
Poor bank stability	19.5	3.6	Medium
Gully erosion/gully heads	1.4	0.3	Medium
Exotic trees	21.9	4.1	Low
Structural works causing or threatened by erosion	6 sites	n.a.	Low
Erosion heads	7 sites	n.a.	Low
No significant management issue	22.2	4.1	n.a.

Important riverine habitat and remnant vegetation

Protection of areas of good habitat should be given highest priority. Such areas usually have high biodiversity, are important refuges and provide a valuable seed bank. Conservation of remnant vegetation is always preferable to re-establishing new vegetation: little cost and effort is needed to produce considerable ecological benefit. Protection should involve identification of threats from other reaches. Conservation of these areas would involve fencing off to manage stock, including buffers of native vegetation if possible. Woody weeds and weeds such as annual grasses that reduce understorey regeneration should also be controlled.

Maintaining and improving areas of good native vegetation

Areas with riparian vegetation in relatively good condition still have either good overstorey and poor understorey vegetation, or poor overstorey and good understorey. These sites have a high recovery potential but require intervention such as revegetation and control of threats such as stock grazing and weeds.

Erosion heads and poor bank stability

When appropriate, erosion heads and poor bank stability should be treated as a single issue, as poor bank stability is often the consequence of a passing episode of bed deepening. Unrestricted stock access to a watercourse can also cause widespread bank erosion. The greater the grazing pressure and length of watercourse affected, the greater the potential impact.

When determining the significance of erosion issues, consideration should be given to severity, location in the catchment (i.e. impacts downstream or upstream, erodability of bed or banks) and proximity to a high value capital asset (such as areas of high conservation value or in-stream infrastructure including bridges and culverts). In addition to revegetation, it may be necessary to stabilise the watercourse (i.e. minimise bed and bank erosion).

Weeds and exotic trees

Weeds and exotic trees are detrimental to the ecological health of the watercourse and can cause and/or mask erosion problems. In determining the importance of this issue, consideration should be given to the density of plant coverage, the invasiveness of the plant species, the proclaimed status of the weed, the threat to the integrity of native or remnant vegetation and the length of watercourse affected.

Poor native watercourse vegetation

Native vegetation in poor condition and generally lacking both native overstorey and understorey species is detrimental to the ecological health of the river. It contributes to loss of habitat, susceptibility to erosion, higher water temperatures and increased flow velocities. These sites have little chance of recovering by themselves and require active management intervention, usually fencing and revegetation. Consideration should be given to the length of watercourse affected.

Structural works

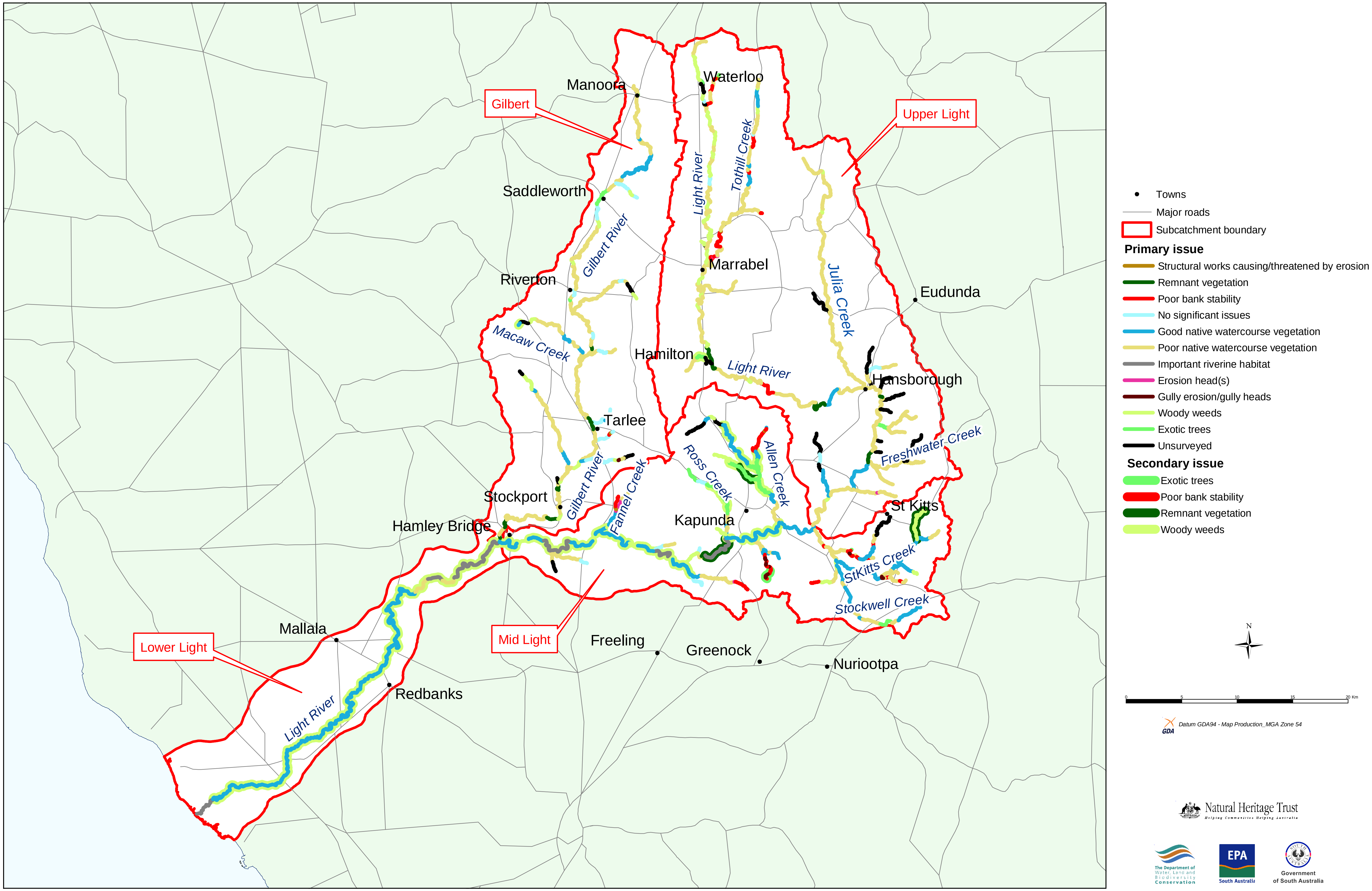
Structural works such as bridges, fords, culverts and channels, can be threatened by erosion processes or, if badly designed and installed, cause erosion problems. When determining the significance consider the stability and value of the structure and/or the severity of the impact on the bed or banks of the watercourse.

No significant watercourse management issue

At some sites no significant issues were identified, the potential for impact was low or management of the issue required a property management planning approach. Examples include exotic grasslands, undefined grassy channels and cultivated watercourses.

7.9 Summary

Of the watercourse management issues identified by the MNRMPP for the Light catchment, protection of remnant vegetation and important riverine habitat was identified as the most important issue for management. This was followed by improving/maintaining good watercourse vegetation, poor watercourse vegetation, control and removal of woody weeds and exotic trees, managing areas of poor bed and bank stability, and structural works causing or threatened by erosion. Other issues discussed were reeds, high salinity, channelisation and levee banks. Management recommendations are outlined in Chapter 12.



Natural Heritage Trust

EPA South Australia

Government of South Australia

Map 7.1: Watercourse management issues along watercourses in the Light catchment

CHAPTER 8 LOWER LIGHT SUBCATCHMENT

8.1 Introduction

This chapter provides detailed information on environmental water requirements and watercourse management issues specific to the Lower Light subcatchment of the Light catchment.

A brief description of the geomorphology and ecology of the subcatchment is followed by a discussion of the environmental water requirements needed to maintain ecological health of watercourse environments in the subcatchment. A discussion of the key watercourse management issues, including priorities and strategies for management, closes the chapter.

The Lower Light subcatchment (Maps 3.1 and 8.1) begins downstream of the junction of the Gilbert River and Light River, and includes the main channel of the Light River and its estuary extending to the mouth of the Light River.

8.1.1 COMMUNITY ISSUES

In October 2000, a preliminary community consultation meeting highlighted issues important to landholders within the Lower Light subcatchment. This information provided direction to the project team in identifying watercourse management issues within the subcatchment.

The major concerns of landholders were:

- the lack of flows including surface water and groundwater;
- weeds including wild artichoke, fennel, caltrop, tree tobacco, castor oil plant, radish, horehound and Bathurst burr.

Other issues identified at community meetings included:

- possible rising salinity of the river and surrounding land;
- effluent from the Hamley Bridge STEDS overflowing and leaching into the river;
- lack of vegetation on the riverbanks linked with a loss of bank stability;
- pollution of the river;
- reeds restricting the flow of the river.

The project team assessed the subcatchment in December 2000. They gathered information on the condition of watercourses and identified watercourse management issues which were then presented and prioritised at a second landholder consultation meeting.

8.2 Subcatchment description

8.2.1 GEOMORPHOLOGY AND VEGETATION

The vegetation associations discussed in this assessment of the relationship between geomorphology and vegetation, are historical generalisations based on work by Brown and Kraehenbuehl (2000) for the Mid North Rivers Management Planning Project. For a more detailed pre-European vegetation association description see Map 5.9.

The subcatchment lies on sedimentary coastal plains and can be broken up into three main sections.

The upper section coincides with geomorphic zones 3 and 4 (Map 5.4), and extends from the Redbanks fault to Hamley Bridge. Through this area the river has cut down to the bedrock and has a series of permanent pools known locally as The Rockies. The vegetation community consists of river red gum (*Eucalyptus camaldulensis)* open forest over lignum (*Muehlenbeckia florulenta),* common reed (*Phragmites australis)* and spiny flat-sedge (*Cyperus gymnocaulos)* along the stream. Land clearance has left the vegetation in poor condition with the understorey significantly reduced or absent in much of the area. Common reeds have also increased in the streambed, probably as a result of siltation from the cleared land and upstream erosion. It is likely that riffle habitat has reduced and is continuing to reduce through sedimentation. Some revegetation and natural regeneration is taking place and will improve the habitat value of the area.

In the middle section, the Light River flows from the permanent pools section to the lower plains section, which extends from the Redbanks fault to 4 km inland of the coast (geomorphic zone 2). This section of the river is characterised by a deep channel with a wide floodplain that flattens out nearer to the coast.

The riparian vegetation community in this section consists of forest dominated by river red gum over lignum, common reed and spiny flat-sedge. The vegetation remains relatively intact, with some invasion by exotics. Its extent has been reduced by past clearing and cropping practices to a narrow strip along the Light River surrounded by pasture and crop species. Despite this the river appears stable with few signs of erosion. Low grazing pressure and previous flows have resulted in regeneration of river red gums and *Myoporum* spp. The in-stream environment is classified as 'sparse sedges and grasses' dominated by common reed at the toe of the banks, with no submerged aquatic plants.

The final section of the Lower Light subcatchment is the estuary (geomorphic zone 1), which extends from approximately 4 km inland to the sea. The river changes from a deep freshwater channel upstream to a narrow, shallow box shaped channel with a series of tidal channels. Two permanent pools link the freshwater section of the river to the estuary. The geology of the Light River estuary consists of silts and sand deposits.

The vegetation of the Light River estuary consists of low shrubby vegetation: lignum and African boxthorn (*Lycium ferocissimum*) in the upper areas changes to samphire flats in the outer intertidal zone of the lower reaches, which changes to mangrove forest which extends to the mouth of the river. African boxthorn and wild artichoke (*Cynara cardunculus*) are a problem in the upper reaches of the estuary but the samphire flats and mangrove forest are in close to pristine condition, giving the estuary high ecological value. The estuary area is deemed Crown land and access by the public is limited, which has maintained the excellent condition of the area.

8.2.2 FISH

Fish populations in the Light catchment were assessed in summer 1998 (Hicks and Sheldon 1999) and in summer 2000 (Hammer 2001). Three sites in the Lower Light subcatchment were surveyed for fish: the upper end of the Light River estuary; the permanent pools on the freshwater side of the Light River estuary; and the permanent pools at The Rockies (Table 8.1).

These sites were chosen because of their location along the river and their suitability for supporting fish populations, including a range of aquatic habitats.

The index of biotic integrity (IBI) rates the relative biological condition of fish populations. Only one site — upstream of The Rockies — was tested for IBI and was rated as being in poor condition in relation to fish population.

Table 8.1 Numbers* of fish species identified or observed at the four sites in the Lower Light subcatchment

Fish species	Site identification			
	Light estuary**	Pools upstream of estuary**	The Rockies#	Pool upstream of The Rockies#
Native species				
Yellow-eyed mullet (*Aldrichetta forsteri)*	10	1		
Small-mouthed hardyhead (*Atherinosoma microstoma*)	2,500	1		
Common jollytail *(Galaxias maculatus*)			10	8
Flat-tail mullet (*Liza argentea*)	20			
Flathead gudgeon (*Philypnodon grandiceps*)		22	58	
Blue spot goby (*Pseudogobius olerum*)	15	67		
Subtotal	2,545	91	68	8
Alien species				
Goldfish (*Carassius auratus*)		4	10	
European carp (*Cyprinus carpio*)			2	
Eastern gambusia (*Gambusia holbrooki)*			15	615
Subtotal			27	615
Total	2,545	95	95	623
IBI rating	n.a.	n.a.	n.a.	poor

*The numbers in this table are the sum of the number of fish captured and those observed during the survey.
**Hammer 2001; #Hicks and Sheldon 1999

The species recorded at the estuary site reflected that of a typical estuarine environment. The abundance and diversity of species encountered indicated a quite healthy environment (Hammer 2001). The estuary was identified as a suitable source for species to re-enter the catchment. Estuarine species were also found in the upstream saline pools. No exotic species were found in the estuary but four goldfish were found in nearby pools upstream.

Eastern gambusia was recorded at The Rockies site, along with several goldfish and two European carp. The low populations of exotic species at The Rockies, and hence lower competition rates, suggest that this site may act as a important refuge for native fish species, particularly when the lower section of the Light River dries during summer months.

During suitable winter and spring flows, native fish may be able to move between The Rockies and the estuary and from upstream reaches down to The Rockies but hydrological modelling suggests that this is likely to be an infrequent event. A weir construction at The Rockies may be a migration barrier to the more sedentary species such as flathead gudgeons and blue spot gobies (Hammer 2001).

The permanent pool sampled upstream of The Rockies was in poor condition, with eight common jollytail and 615 eastern gambusia present. The site recorded higher salinity than other sites in the catchment which may be a contributing factor for the poor assemblage of native fish. The degraded vegetation of this site further contributed to the degraded native fish population.

For an overview of fish distributions throughout the catchment see Section 5.5.2. For further information on flow requirements of fish see Chapter 6, and Appendices B and C.

8.2.3 MACRO-INVERTEBRATES

Macro-invertebrates were sampled at one site in the Lower Light subcatchment in autumn and spring of 1994, 1995 and 1997 as part of the Monitoring River Health Initiative (MRHI) — a national program to assess macro-invertebrate populations as indicators of the health of watercourses.

The one survey site — located at a permanent pool above The Rockies at Pinkerton Plains — was selected due to its location on the river and the presence of permanent water. Edge, riffle and macrophyte zones were sampled.

Of the seven survey sites within the Light catchment, this site recorded the lowest species richness of macro-invertebrates. With the use of AusRivAS modelling, the site was classified as being in an 'impaired' condition.

Edge and riffle samples from the site contained fewer families than were predicted, and fewer sensitive families were present than was expected. Water boatmen (Corixidae), midge larvae from the Ceratopogonidae family and Tanypodinae subfamily were missing from edge samples taken at the site. The site had the greatest number of taxa missing from those expected: six from the edge samples in 1994 and 11 from the riffle samples for both 1994 and 1995. Five of the 11 taxa missing from the site in 1994 are very common in watercourses.

Poor water quality is believed to be a major contributor to the poor macro-invertebrate condition of the site. Salinity of the water at this site was among the highest of the seven sites sampled (5431–9920 mg/L), and probably above the tolerances of some macro-invertebrates. High salinity may be a natural feature of the watercourse and further research along the Lower Light River is needed to determine the cause of the high salinity levels.

Other water quality factors, lack of suitable habitat, and/or predation by exotic fish may be factors causing the poor health of the site. All need further investigation.

For an overview of macro-invertebrate distributions see Section 5.5.3. For further information on flow requirements of macro-invertebrates see Chapter 6, and Appendices B and C.

8.3 Environmental water requirements

8.3.1 ENVIRONMENTAL WATER REQUIREMENT SITES AND IMPORTANT FLOW BANDS

The Light catchment was broken up into zones based on similar geomorphological features (see Section 5.4.2 and Map 5.4) many of which have physical and ecological functions maintained by river flow. Flow bands have been used to distinguish important functions and processes that occur at various flow heights (or range of heights). For each geomorphic zone in the subcatchment a specific site was selected to identify as closely as possible the environmental water requirements (EWRs) that were important for that particular zone. These sites, their flow bands and their functions are discussed in the following sections.

For each function and process there are requirements for flow height, duration, frequency and seasonality. These have been identified for each zone based on the ecological and geomorphological requirements outlined in Chapter 6, and Appendices A, B and C.

8.3.2 FLOWS AND ENVIRONMENTAL WATER REQUIREMENT PROCESS OVERVIEW

Watercourses within the Light catchment are classified as semi-arid streams. These are characterised by low volumes of water with occasional large flows during periodic larger storm events that have high rainfall intensity and are generally of short duration.

The most important flow related features in this subcatchment are the permanent pools maintained by groundwater, the riffle zones created by seasonal low flows and the Light River estuary which relies on mid to bankfull level flows for deposition of sediment. Low to mid flows may be important in this subcatchment for migration of fish throughout the catchment. Higher flows are important for fish breeding.

Flow bands considered important for maintaining riverine environments in each zone are described below. A more detailed description of EWRs including the recommended frequency, duration and seasonality of flows is provided in Appendix B.

Zone 1: Light River estuary

The Light River estuary extends from the mouth of the Light River 4 km inland and is characterised by a shallow, narrow main channel with mangrove forest and samphire flat vegetation communities (Plate 8.1).

Plate 8.1 The Light River estuary, showing the main channel with associated healthy samphire and mangroves

Estuarine environments are influenced by tidal and river flows and are important because they link freshwater, brackish and saline aquatic habitats. River flows reach the estuary annually between late winter and spring. Low to mid flows are important for linking the river with the sea, providing sediment and nutrients, and allowing organisms such as fish to breed and migrate.

Tidal flow: Tidal flow within the estuary is important for transporting fine sediments and nutrients within the zone to maintain samphire and mangrove communities. The flow also provides food and habitat resources for fish, invertebrates and other estuarine organisms.

Low flow: As the river dries out in summer, the flows do not reach the mouth. Low river flows connect the river with the sea. This flushing flow maintains water quality by transporting nutrients, salts and dissolved oxygen through the zone. Nutrients and dissolved organic matter from upstream are also transported into the zone. Low flows are particularly important as they allow fish development and recruitment, and, in suitable conditions, fish migration.

Mid flow: Mid flows increase the area of habitat available for spawning and hatching of fish within the estuary, and if mid flows follow sufficient overbank flows this flow band will allow large scale fish development and recruitment.

Bankfull–overbank flow: These flows flood the samphire flats and mangrove forests in this zone, and significantly increase the area of habitat available for breeding for organisms including fish.

Zone 2: Light River 1.5 km downstream of Port Wakefield Road crossing to the downstream extent of Redbanks

This zone extends from 4 km inland to downstream of Redbanks and is characterised by a narrow, deep channel with a wide floodplain (Plate 8.2). The open forest vegetation appears healthy with lignum and regenerating river red gums, which indicates that flows have in the recent past been sufficient to meet the flow requirements of these plants. The river flows through this zone from winter to late spring.

Plate 8.2 Light River, upstream of Port Wakefield Road, showing the relatively deep, dry channel and healthy riparian vegetation

Groundwater: In the lower reaches of this zone groundwater is important for maintaining pools that provide fish habitat.

Low flow: Low flows inundate the channel and connect the estuary with the upstream permanent pools including The Rockies. These flows maintain water quality and transport nutrients and organic matter through the zone. Low flows also water in-stream sedgeland communities, provide habitat for frogs, macro-invertebrates and fish, and allow fish to migrate. These flows are also important for the development and recruitment of fish.

Mid flow: Mid flows inundate river red gum and lignum, which allow fish to breed by providing habitat. These flows also maintain and allow recruitment of riparian vegetation.

High–bankfull flow: High to bankfull flows are important for the maintenance and recruitment of riparian vegetation (esp. lignum). They are also important for geomorphological functions including transport of sediment, channel maintenance and scouring of pools (Plate 8.3).

Overbank and extensive flood-out: These flows inundate the floodplain and provide habitat for macro-invertebrates and frogs. Plants including river red gum are watered and can reproduce. The high velocities associated with these flows are also important for geomorphological functions such as habitat resetting of the river.

Plate 8.3 The Lower Light River 1 km downstream of Port Wakefield Road crossing: a rapidly receding bankfull flow event following heavy rains in August 2001

Zone 3: Light River, downstream of Redbanks to downstream of The Rockies

This zone, extending from downstream of Redbanks to downstream of The Rockies, is characterised by a deep narrow channel confined between an old terrace. The open forest in this zone has regenerating river red gums and healthy lignum (Plate 8.4), which indicate the zone has had sufficient flows in the recent past to maintain their health. The zone is inundated by river flows from late winter to summer and reduces to a series of temporary pools in summer.

Plate 8.4 The Light River near Redbanks in summer with a completely dry, relatively deep channel and healthy riparian vegetation

Low flow: Low flows inundate the dry channel which provides shallow habitat for frogs, macro-invertebrates and fish, creates and connects temporary pools for movement of aquatic flora and fauna, maintains water quality, and transports nutrients and organic matter. They also water in-stream sedges and allow breeding of frogs and macro-invertebrates, as well as development and recruitment of fish. Most importantly, they allow fish to migrate throughout the system.

Mid flow: Mid flows inundate river red gums and surrounding plants, providing habitat for fish spawning and hatching.

High–bankfull flow: These flows completely fill the channel (up to 10 m deep in some places). This maintains riparian vegetation including lignum and allows for recruitment. These flows also provide habitat for fish, macro-invertebrates and frogs through flooding of riparian vegetation. The geomorphological functions of these flows include habitat resetting, channel maintenance, scouring of pools and transport of sediment.

Overbank and extensive flood-out: These flows inundate the floodplain and the old terrace, which is most important for maintaining and aiding in the recruitment of floodplain vegetation including river red gums. They also provide habitat for macro-invertebrates and frogs. The high velocity of these flows can cause major structural channel change and reset habitats.

Zone 4: Light River, downstream of The Rockies to the Gilbert River

This zone is characterised by a series of groundwater fed permanent pools (Plate 8.5) and riffle habitats, which are inundated from late winter to summer by river flows.

Plate 8.5 The Light River at The Rockies, showing one of the many permanent pools with abundant reeds and good riparian vegetation

Groundwater: Groundwater is important for keeping pools filled all year round. This provides habitat for aquatic flora and fauna and maintains reed bed communities.

Low flow: Low flows connect pools and inundate riffles in this zone and also connect with upstream and downstream zones. This provides additional habitat and allows the breeding and recruitment of macro-invertebrates and frogs as well as movement of these animals. Low flows also enable fish to migrate upstream and downstream from this zone and is also important in their development and recruitment.

Mid flow: Mid flows inundate additional habitat and maintain riparian vegetation, as well as transport nutrients, organic matter and sediment through the zone. Most importantly, mid flows allow fish spawning and hatching to occur and allow large-scale fish redistribution and recruitment.

High–bankfull flow: These flows completely inundate the reeds and cover benches. Large-scale fish spawning and hatching may take place. These flows are also very important for maintaining and recruiting riparian vegetation such as lignum. Geomorphological functions of these flows include riffle cleaning, channel maintenance and scouring of pools.

Overbank and extensive flood-out: With inundation of the floodplain, plants including river red gum are able to reproduce. Habitat is also created for macro-invertebrates, frogs and fish. The high velocities of these flows are also important for transporting sediment, nutrients and organic matter from this zone to the estuary.

8.4 Watercourse management issues: priorities and strategies

8.4.1 SIGNIFICANT WATERCOURSE MANAGEMENT ISSUES

Ensuring environmental water requirements are being met will not result in a healthy river system unless the ecosystems dependent on these water requirements are maintained and protected. The project team assessed the current condition of the lower Light River and, in consultation with landholders, identified significant watercourse management issues.

Following is a brief description of the key watercourse management issues identified for the Lower Light subcatchment. The locations of these issues within the subcatchment can be found in Map 8.1.

Important riverine habitat

Important riparian habitat exists along 11.4 km (19.2%) of the Lower Light subcatchment. The estuary and The Rockies were identified as areas of important riverine habitat. The estuary system is in close to pristine condition, with no weeds and healthy intact samphire flats and mangrove forest communities. Healthy populations of fish were also found in the estuary. Estuaries are ecologically diverse systems that are important nursery areas for a variety of organisms including fish. The estuary area does not require any active management to improve it. This area is Crown land, which has helped ensure its protection.

The Rockies area, although not in a pristine condition represents important riverine habitat due to the permanency of the pools which provide refuge for fish when the lower reaches of the Light River dries in summer. The area has a diverse range of habitats, including pools, riffles and reedbeds. A number of native fish species were found in this zone, and the low proportion of exotic species further enhances its ecological importance.

It is highly recommended that the permanent pools in this area be protected and monitored and that threats and control problems such as weeds and exotic fish be identified. The revegetation and weed control already taking place along the banks of the area are important management strategies for the future; the overstorey and understorey provides habitat and shades the water, which will reduce reed growth. Revegetated slopes will also trap sediment before it enters the river.

Sedimentation in this zone is probably reducing riffle habitat and encouraging reed growth. Management of erosion upstream in the catchment is important for reducing sediment deposition in this area. This area has high value to the community, which increases the importance of protecting and improving it.

Good native watercourse vegetation

Good native watercourse vegetation extends along the majority of the Lower Light subcatchment (44.3 km or 74.9%). The area extending from the estuary to Redbanks was classified as having good native watercourse vegetation, with woody weeds being a secondary management issue. The vegetation has been reduced to a narrow strip along the banks of the watercourse, which is surrounded by cropping and grazing. The condition of riparian vegetation is relatively good but has been modified by human activities. Most of this area has riparian vegetation with mid density native tree overstorey; a small area of dense native tree overstorey at Port Wakefield Road crossing extends a few kilometres upstream.

Along this section revegetation to improve the understorey would significantly improve the value of the riparian zone. Some natural regeneration is already occurring in sections and must be protected. Control of weeds along this section will significantly improve the value of this area. Benefits of any rehabilitation will be high, as this region is an important wildlife corridor between the two areas of important riverine habitat: the estuary and permanent pools upstream.

Woody weeds

Weeds are considered a secondary issue along a significant proportion of the lower Light River. African boxthorn and wild artichoke were dense in the lower reaches of the Light River, just above the estuary. African boxthorn also grows sparsely along the river extending from upstream of Redbanks into significant riparian areas of the Mid Light subcatchment. Significant dense stands were identified along the river in the Hamley Bridge area.

Wild artichoke was growing sparsely around the Mallala area. It was also found growing between areas of important riverine habitat around the Pinkerton Plains permanent pools. It is important to control weeds in this subcatchment especially in the upper reaches where African boxthorn and wild artichoke threaten to degrade significant stretches of important riverine habitat which support a diverse range of animal and plant life.

Poor native watercourse vegetation

Poor native watercourse vegetation was classified as a key management issue along 3.5 km (6.0%) of the Lower Light subcatchment and was identified in two sections, one either side of the important riverine habitat identified between Redbanks and Hamley Bridge. The vegetation in these areas lack native overstorey and understorey species. This is a possible reason for the poor abundance and diversity of macroinvertebrate and native fish communities in this area, and the high proportion of introduced fish species, especially eastern gambusia.

Poor bank stability

A small area of poor bank stability was identified in the Redbanks area, where the channel is actively eroding. It is possible that this is the river naturally taking another course and no active management is required.

8.4.2 WATERCOURSE MANAGEMENT ISSUES NOT PRIORITISED

The community was also concerned about other issues. These are not specifically addressed as they were not within the scope of the project but they are briefly discussed here.

Reeds in watercourse

Reeds were considered an issue by landholders within the Lower Light subcatchment. Significant areas of dense reeds were found upstream of Redbanks, extending into the Mid Light subcatchment growing in the permanently wetted channel. The area is generally lacking significant bank vegetation, which naturally traps sediment and shades the watercourse. With the lack of vegetation the reeds thrive in the watercourse.

Revegetation of the banks and slopes in the Lower Light subcatchment is recommended to reduce sedimentation of the river upstream and from adjacent banks. Revegetation will also gradually shade the river and discourage the growth of reeds. Management of the catchment upstream to reduce sedimentation is also important to provide benefits to the Lower Light subcatchment.

8.4.3 WATERCOURSE MANAGEMENT PRIORITIES

Table 8.2 lists the significant watercourse management priorities for the Lower Light subcatchment and outlines strategies for management. High, medium and low priorities have been set largely in terms of how much improvement in watercourse health is possible relative to the input of money and effort required. Consequently, an issue considered a low priority is not insignificant but simply one that may not require immediate attention or may require a large input of resources to address. A more detailed discussion of the principles and guidelines used to set priorities is outlined in Section 7.8.

Community priorities for management are also listed and are based on votes placed by landholders at a meeting held at Mallala on Thursday, 1 March 2001. As management of many of these issues will largely be the responsibility of landholders, regional organisations and the local community, these priorities give an indication of community views and interests in undertaking river rehabilitation works.

8.5 Summary

The Lower Light subcatchment extends from the estuary to permanent pools near Hamley Bridge, and is an ecologically important subcatchment. It is influenced by, and itself influences, what occurs throughout the watercourses of the catchment, both by receiving flows from upstream and being the connection to the estuary and the sea.

The geomorphology consists of sedimentary plains in four main zones: the permanent pools on bedrock, the deep channel within an old terrace, the channel within a wide floodplain and the sedimentary estuarine zone. The flows change from permanent groundwater fed pools in the north to ephemeral streams to the south. The vegetation varies from upstream open forest to samphire flats and mangrove swamps at the coast. With the exception of the estuary, riverine vegetation has been modified along the entire lower reach to a narrow strip, much of which lacks understorey vegetation.

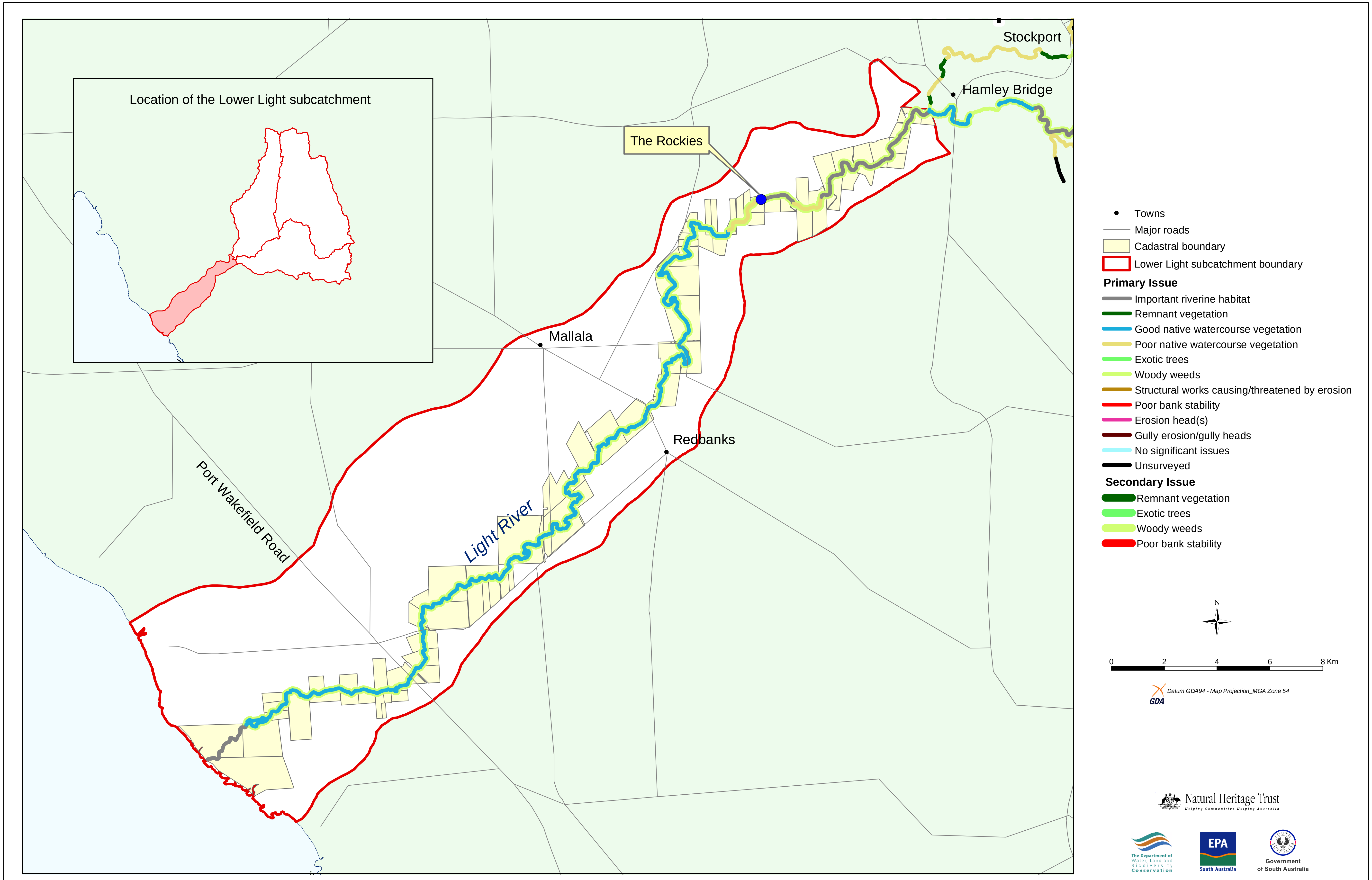
The fish populations at The Rockies were found to be relatively healthy, with two native species and relatively lower numbers of exotic fish compared to other areas of the subcatchment. These results emphasise that this is an important refuge for native fish when the lower reaches seasonally dry. The habitat upstream of The Rockies lacks native vegetation, and the native fish assemblage has low abundance and diversity, while the numbers of exotic fish are high. The fish assemblage at the estuary appears healthy with several expected species present.

Macro-invertebrates were only sampled at one site within the Lower Light subcatchment, at a permanent pool upstream of The Rockies. The study found that the macro-invertebrate community is the least healthy in the catchment with many of the expected common species not present. This reflects the degraded nature of the site. Several possible reasons for low macro-invertebrate diversity are possible, including high stream salinity, other water quality factors, lack of suitable habitat and predation by exotic fish.

Five watercourse management issues were identified along the lower Light River: important riverine habitat, good native watercourse vegetation, lack of native watercourse vegetation, woody weeds and poor bank stability. The community was also consulted and prioritised the issues they deemed important. These priorities were: removing and controlling riparian weeds, improving or maintaining areas of good native vegetation threatened by degrading processes, protecting important riverine habitat, and addressing the lack of native vegetation.

Table 8.2 Management priorities, recommendations and strategies for the Lower Light subcatchment

Management recommendation (length)	Management strategies	Sub-catchment health priority	Community priority
Protect important riverine habitat (11.3 km)	• Manage stock to avoid damage to vegetation and allow natural regeneration • Remove and control weeds and limit the opportunity for weeds to invade • Monitor the sites regularly	High	Medium
Improve/maintain areas of good native vegetation threatened by degrading processes (44.3 km)	• Revegetate and/or encourage natural regeneration • Manage stock to avoid damage to vegetation and allow natural regeneration • Remove or control weeds and limit the opportunity for weeds to invade • Monitor the site regularly	High	High
Remove/control riparian weeds (including African boxthorn and wild artichoke) (59.5 km)	• Use techniques such as removal by hand, spraying, burning or mechanical (the technique chosen will depend on the site and the density of the infestation; care is needed to prevent disturbance to watercourse bed and banks) • Control by: - regular spot spraying or removal by hand (use herbicides recommended for use near a waterway) - shading out weeds by retaining canopy cover and avoiding disturbance to the natural vegetation - excluding stock to prevent disturbance to ground and riparian vegetation • Allow natural regeneration or revegetate with locally native species to re-establish habitat, prevent erosion and allow riparian shading	Medium	High
Revegetate areas lacking native watercourse vegetation (3.5 km)	• In areas where flooding is not a major issue, revegetate with a full range of locally native plants including groundcovers, grasses, shrubs and trees • In areas prone to flooding issues, leave a vegetated buffer strip between cultivated areas and the watercourse — at the very least, a good continuous grass cover • Manage stock to avoid damage to vegetation and to encourage natural regeneration	Low	Low
Manage areas of poor bank stability (0.2 km)	• Restrict stock access to the site • Monitor the changes to the bank over time • Seek professional advice	Low	Low



Map 8.1: Significant watercourse management issues in the Lower Light subcatchment

CHAPTER 9 GILBERT SUBCATCHMENT

9.1 Introduction

This chapter provides detailed information on watercourse condition, environmental water requirements and watercourse management issues specific to the Gilbert subcatchment of the Light catchment.

A brief description of the geomorphology and ecology of the subcatchment is followed by a discussion of the environmental water requirements needed to maintain the ecological health of watercourse environments in the subcatchment. The chapter concludes with a discussion of the key watercourse management issues, including priorities and strategies for management.

The Gilbert River (Maps 3.1 and 9.1) begins at the footslopes of the upper Gilbert Valley near Manoora, and flows southward through the townships of Saddleworth, Riverton, Tarlee and Stockport before flowing into the Light River at Hamley Bridge. Major tributaries of the Gilbert River include Macaw Creek and Dry Creek.

9.1.1 COMMUNITY ISSUES

In October 2000, a preliminary community consultation meeting held at Riverton highlighted issues important to landholders within the Gilbert subcatchment. This information provided direction to the project team in identifying watercourse issues in the subcatchment.

The major concerns of landholders were:

- the lack of water flowing down the river, and the drying up of pools and springs;
- growth of reeds which hold back water, increase sedimentation and can cause flooding;
- watercourse erosion downstream of Manoora and upstream of Riverton;
- lack of native vegetation and the loss of animal habitats.

The project team assessed the subcatchment in December 2000. They gathered information on the condition of watercourses and identified watercourse management issues. These issues were then presented and prioritised at a second landholder consultation meeting.

9.2 Subcatchment description

9.2.1 GEOMORPHOLOGY AND VEGETATION

In the following discussion of the relationship between geomorphology and vegetation, the vegetation associations discussed are historical generalisations, based on work undertaken by Brown and Kraehenbuehl (2000) for the Mid North Rivers Management Project. For a more detailed pre-European vegetation association description see Map 5.9.

The uppermost reaches of the Gilbert River, between Manoora and Saddleworth, flow through alluvial soils of variable width. The river channel in this northern most section is a single defined channel, which in some areas has moderate stability and is devoid of vegetation. Downstream, towards Saddleworth, the channel becomes a very wide, undefined flooding channel, dominated by sedgeland plants.

Common reed (*Phragmites australis*) reedbeds appear south of this flood-out area, and extend at various densities throughout most of the Gilbert River. Before European settlement, the in-stream vegetation of the Gilbert River was classified as a closed herbland/sedgeland consisting of common reed and sea club-rush (*Bolboschoenus cadwellii*). However, land clearance, increased overland flow and sedimentation from past agricultural practices have created a habitat more favourable to the common reed to the point where it now dominates the system. This is particularly evident in the wetter areas of the river, such as those around Riverton, and south of Tarlee.

Dense reedbeds act as sediment traps, raising the bed of the channel. This was noticeable in a couple of locations where new road culverts had been built on top of older culverts. Raising of the riverbed, combined with the effects of reeds holding back floodwaters have caused flooding problems for many owners of agricultural land.

South of Saddleworth the valley and channel morphology is varied. In some places the channel is situated at the base of a narrow valley in bedrock, in others there is a small channel bordered by a wide floodplain. The channels are shallow to moderate in depth, and the bed and bank of the channel is stable.

Further downstream, the Gilbert River becomes a braided channel fringed with dense sedgeland plants. These areas, likely to be frequent flood-out areas, are located north of Tarlee and south of Stockport.

Most of the riparian vegetation of the Gilbert River south of Saddleworth has been cleared over years of agricultural development and the watercourse is generally in very poor condition. The riparian zone is dominated by annual grasses and has little remaining native vegetation.

Upstream of Tarlee, permanent pools are sparse; downstream of Tarlee there is permanent baseflow and the number of permanent pools increases markedly.

In some areas there is evidence of current and historic channel excavation such as south of Riverton. Excavation was probably carried out to control flooding by removing reedbeds and associated sediments. The Gilbert River appears to have recovered from this excavation well (S Brizga, pers comm 2001).

A large lake has been created in Riverton by constructing a large rock weir that acts as a barrier to the downstream movement of nutrients and sediments.

Before European settlement the riparian vegetation between Saddleworth and Riverton was characterised as an open forest of river red gum (*Eucalyptus camaldulensis*); below Riverton it was a tall shrubland of short leaf honey myrtle (*Melaleuca brevifolia*). Today, the only example of the river red gum open forests in this area is in a revegetation project in Winkler Park, just south of Saddleworth. The small sections of remnant short leaf honey myrtle shrubland found south of Tarlee have high conservation status.

The change in the instream vegetation from short leaf honey myrtle shrubland to a watercourse dominated by common reed has altered the channel hydraulics, and changed sedimentation and erosion rates.

The surveyed tributaries of the Gilbert River are mostly dry grassy channels of shallow to moderate depth. The only stability issues identified were in the eastern tributaries south of Tarlee and included some gully erosion and a ford with poor stability.

Riparian vegetation of tributaries is generally in poor condition, with some areas of good sedgeland in Dry Creek, and some eucalypt woodlands along Macaw Creek. Prior to European settlement the vegetation along the tributaries was characterised as a South Australian blue gum (*Eucalyptus leucoxylon*) and peppermint box (*E. odorata*) woodland.

9.2.2 FISH

An survey of fish populations in the Light catchment in the summer of 1998 (Hicks and Sheldon 1999) assessed only one site within the Gilbert subcatchment — a permanent pool on the Gilbert River at the Hannaford Road crossing between Riverton and Saddleworth. Other permanent pools and areas of permanent baseflow exist within the catchment, particularly in the lower reaches, but were not surveyed as a part of this study.

The only fish species that was recorded at this site was the exotic eastern gambusia (*Gambusia holbrooki*), of which 20 individuals were recorded (Table 9.1). The index of biotic integrity (IBI), which rates the relative biological condition of fish populations, based on this finding indicates that this survey site is in very poor condition (Hicks and Sheldon 1999).

Table 9.1 The number of each species identified or observed at the four sites in the Upper Light subcatchment (Hicks and Sheldon 1999)

Fish species	Hansborough bridge site
Exotic species	
Eastern gambusia*(Gambusia holbrooki)*	20
IBI rating	Very poor

The lack of native fish at this site may be due to poor habitat or the presence of exotic predators. The habitat consists of a channel that is straight, narrow and deeply incised with reed growth dominant along all edges. It also lacks shallow areas in which native fish may find refuge from exotic predators.

Native fish may also be absent due to the lack of suitable flows which are necessary for species to recolonise the area from other populations further downstream after local extinctions. The presence of a weir at Riverton acts as a major barrier for recolonisation of native fish from the lower Light River and estuary into the upper reaches of the catchment.

It is recommended that further studies are carried out to determine the presence of fish populations in the lower reaches of the Gilbert River, particularly in areas with permanent baseflow.

For an overview of fish distributions throughout the catchment see Section 5.5.2 and Table 5.6. For further information on flow requirements of fish see Chapter 6, and Appendices B and C.

9.2.3 MACRO-INVERTEBRATES

Two sites in the Gilbert River subcatchment have been sampled as part of the Monitoring River Health Initiative (MRHI), a national program to assess macro-invertebrate populations as an indicator of the health of watercourses across South Australia. The sampling was carried out in autumn and spring in 1994, 1995 and 1997.

Sites in the Gilbert River subcatchment were chosen to represent as much of the Light catchment as possible, and to have permanent water, relatively low levels of in-stream impacts, and include a number of in-stream habitats.

Two sites were chosen within the Gilbert River subcatchment: one in the northern reaches, at the Hannaford Road crossing between Riverton and Saddleworth; and one at Stockport. Both riffle and edge habitats were found and surveyed at Stockport. The lack of riffle habitat at Hannaford Road, meant sampling was restricted to the edge habitat.

According to the AusRivAS modelling results for these sites, the Gilbert River is in a 'mildly impaired' condition.

The riffle habitat at Stockport appears to provide poor habitat for macro-invertebrates. They were not populated by the net spinning caddis fly *Cheumatopsyche* sp. and blackfly larvae were only present in the spring samples. This may be due to a lack of suitable flow throughout the year and at the time of sampling in autumn the black fly larvae had not yet been able to colonise the site. These two macro-invertebrates are known to act as keystone species within stream invertebrate communities (McEvoy and Madden 1999) and their absence will greatly influence the dynamics of nutrient processing, water quality and macro-invertebrate populations.

Despite these findings, a scavenger beetle larvae (*Sternolophus marginicollis*) rare to this area was found at the Stockport site.

It is not possible at present to be certain whether the 'impaired' ecology of the Gilbert River is due to an altered environment, flows or poor water quality. There is no information on the status of macro-invertebrate populations in the river in the winter season or in variations over a long time scale (greater than five years).

It is possible that these reaches function differently to other sections of the catchment, with water flow being much more variable in time, which in turn affects the flow responsive macro-invertebrate populations.

For an overview of macro-invertebrate distributions see Section 5.5.3. For further information on flow requirements of macro-invertebrates see Chapter 6, and Appendices B and C.

9.3 Environmental water requirements

9.3.1 ENVIRONMENTAL WATER REQUIREMENT SITES AND IMPORTANT FLOW BANDS

The Light catchment was broken up into zones based on similar geomorphological features (see Section 5.4.2 and Map 5.4) many of which have physical and ecological functions maintained by river flow. Flow bands have been used to distinguish important functions and processes that occur at various flow heights (or range of heights). For each geomorphic zone in the subcatchment a specific site was selected to identify as closely as possible the environmental water requirements (EWRs) that were important for that particular zone. These sites, their flow bands and their functions are discussed in the following sections.

For each function and process there are requirements for flow height, duration, frequency and seasonality. These have been identified for each zone based on the ecological and geomorphological requirements outlined in Chapter 6, and Appendices A, B and C.

9.3.2 FLOWS AND ENVIRONMENTAL WATER REQUIREMENTS PROCESS OVERVIEW

Watercourses within the Light catchment are classified as semi-arid streams. These are characterised by low volumes of water with occasional large flows during periodic larger storm events that have high rainfall intensity and are generally of short duration.

The most important flow related features in this subcatchment are the permanent pools and sedgelands that are maintained by groundwater, the permanent riffle zones maintained by baseflow and low flow, and remnant stands of short leaf honey myrtle that are maintained by low flows.

The weir at Riverton will impact upon these important flows, as it will act to delay flows from proceeding downstream until the Riverton Lake has filled.

Flow bands considered important for maintaining riverine environments in each zone are described below. A more detailed description of environmental water requirements including the recommended frequency, duration and seasonality of flows is provided in Appendix B.

Zone 10: Gilbert River upstream of Hamley Bridge to Saddleworth

Major environments in this zone include permanent pools, dense reedbeds, remnant stands of short leaf honey myrtle (Plate 9.1), and areas of permanent baseflow below Stockport. No fish surveys were undertaken in this zone, so it is unknown if flows are required to maintain fish populations in this area.

Plate 9.1 Zone 10 of the Gilbert River, a representative view of dense common reed with fringing sedges and individuals of short leaf honey myrtle in the distance

Groundwater: Groundwater is very important in this zone to maintain permanent pools and provide soil moisture to support in-stream reedbeds.

Seasonal baseflow–low flow: These regular flows maintain water quality in pools by flushing through salts and nutrients. They are also particularly important for watering remnant stands of short leaf honey myrtle.

Mid–high flow: These flows begin to increase the habitat area available to frogs and macro-invertebrates, allowing greater breeding events. These flows are also important for watering riparian sedges and reedbeds.

Overbank flow: The main importance of these large flows is in the maintenance of the channel shape and structure by performing functions such as scouring pools and transporting sediments. These flows are important to allow fish movement into these areas, and further upstream.

Zone 11: Gilbert River at Saddleworth to upper reaches

Major environments in this zone include wide sedgelands, in-stream reedbeds and dry grassy channels (Plate 9.2).

Plate 9.2 Zone 11 of the Gilbert River, a representative view of sparse common reed intermixed with sedgeland species

Groundwater: Groundwater is very important in this zone as it provides soil moisture to support in-stream reedbeds and sedgelands.

Mid–high flow: These flows are important for moving nutrients and organic matter through the system.

Overbank flow–extensive flood-out: These large flows are important in maintaining the channel form and function of the upper Gilbert River.

Zone 12: Macaw Creek

This tributary of the Gilbert River has a range of in-stream and riparian environments. Some areas of the in-stream zone are filled with reedbeds, while others are dry grassy channels. The riparian zone ranges from annual grasses to sedgelands, and also includes areas of eucalypt woodland.

Flow bands considered important for maintaining riverine environments in this zone are described below. These flow bands have been used to develop the environmental water requirements for this zone of the Light catchment. A more detailed description of environmental water requirements including the recommended frequency, duration and seasonality of flow is provided in Appendix B.

Groundwater: Groundwater is very important in this zone as it maintains permanent pools and provides soil moisture to support in-stream reedbeds.

Low flow: These regular flows maintain water quality in pools by flushing salts and nutrients. They also begin to inundate shallow areas that are suitable for the breeding of frogs and macro-invertebrates.

Bankfull flow: These flows are important to perform geomorphological functions, such as maintaining the channel form, as well as transporting sediments, nutrients and organic matter.

Overbank flow: These flows break out of the banks of the watercourse, water the riparian eucalypts and allow recruitment of river red gum.

9.4 Watercourse management issues: priorities and strategies

9.4.1 SIGNIFICANT WATERCOURSE MANAGEMENT ISSUES

Ensuring environmental water requirements are being met will not result in a healthy river system unless the ecosystems dependent on these water requirements are maintained and protected. The project team assessed the current condition of the major watercourses within the Gilbert River subcatchment and, in consultation with landholders, identified and located significant watercourse management issues.

Following is a brief description of the key watercourse management issues identified for the Gilbert River subcatchment. The locations of these issues within the subcatchment can be found in Map 9.1.

Remnant vegetation

Significant stands of remnant short leaf honey myrtle shrubs occur along the lower reaches of the Gilbert River between Tarlee and Hamley Bridge, and along 4.6 km (4.1%) of the surveyed watercourses. These areas contain vegetation similar to that expected to be in the area before European settlement, and are also important as seed sources for recolonisation and revegetation. These shrubland areas also add another layer of complexity to the riverine habitat, and are important for supporting animal species that have limited access to that habitat throughout the rest of the subcatchment.

Good native watercourse vegetation

Areas of native vegetation in good condition occur along 10.3 km (9.2%) of the surveyed watercourses within this subcatchment. These areas have been modified by degrading process such as stock grazing and land clearance. Areas of sedgeland in good condition are found in the upper reaches of the Gilbert River, above Saddleworth, and to lesser extents along some of the tributaries around Tarlee. Eucalyptus woodlands in good condition but lacking understorey vegetation were found along Macaw Creek.

The areas that are in good condition have a higher habitat value, especially for birds and macro-invertebrates, than more degraded areas of the watercourse but their value is diminished because of their limited extent. Simply rehabilitating these isolated patches of vegetation may have limited benefit unless the lack of native vegetation upstream and downstream of these sites is addressed.

Areas lacking native watercourse vegetation

The most widespread issue affecting ecosystem health along the Gilbert River is poor riparian native vegetation, which affects 69.1 km (61.7%) of the surveyed watercourses in the Gilbert River subcatchment. In some areas, the practice of cropping right to the top of banks means there is little riparian vegetation remaining. Due to the shallow character of sections of the Gilbert River, fencing to encourage natural regeneration and/or revegetation is sometimes difficult due to the greater risk of flooding to surrounding cropland and flood damage to fences.

Woody weeds

Riparian weeds were considered to be a significant management issue along 7.8 km (7%) of the surveyed watercourses in this subcatchment. The weed species observed included wild artichoke (*Cynara cardunculus*) and wild rose (*Rosa* spp.), which were scattered sparsely throughout the subcatchment.

Exotic trees

The removal of exotic trees was identified as a key watercourse management issue along 2.5km (2.2%) of the surveyed watercourses of the Gilbert subcatchment. This issue was considered to be a low priority for local landholders. Pine (*Pinus* spp.) and olive (*Olea* spp.) trees were identified as significant management issues at Saddleworth, and a number of other exotic tree species were identified in the parklands at Riverton. Exotic trees have low habitat value, they impact on river biodiversity and can spread rapidly along a watercourse.

Poor bank stability and structural works causing or threatened by erosion

Poor bank stability, structural works causing or threatened by erosion, and gully erosion were also identified as management issues within the Gilbert River subcatchment. Poor bank stability affected 0.2 km (0.2%) of the surveyed watercourses; only one case of gully erosion and one unstable structural work in the form of a road crossing were found. All of these issues occurred in the eastern tributaries of the Gilbert River, south of Tarlee.

Their very limited extents make poor bank stability and structural works causing or threatened by erosion low priorities for management. They will have low impacts on the overall ecological health of the Gilbert River subcatchment.

No significant management issue

Areas with no significant watercourse management issues were found along 13.4 km (12%) of the surveyed watercourses within the Gilbert River subcatchment. Typically these areas were naturally dry grassy channels, with irregular flow, and will not change significantly if management practices are unaltered.

9.4.2 WATERCOURSE MANAGEMENT ISSUES NOT PRIORITISED

The community was also concerned about other issues. These are not specifically addressed as they were not within the scope of the project but they are briefly discussed here.

Reeds in watercourse

The presence of significant stretches of watercourse dominated by the common reed was a concern for the landholders within the Gilbert River subcatchment. Reedbeds are a natural feature of the environment but can dominate systems that have been disturbed by practices such as burning and grazing. The common reed will also grow very well in areas that have elevated levels of nutrients and fine sediments that may occur due to a lack of riparian vegetation that in a balanced system would filter runoff from the surrounding land. Catchment clearing often contributes to greatly increased sediment and nutrient loads in watercourses.

9.4.3 WATERCOURSE MANAGEMENT PRIORITIES

Table 9.2 lists the significant watercourse management priorities for the Gilbert River subcatchment and outlines strategies for management. High, medium and low priorities have been set largely in terms of how much improvement in watercourse health is possible relative to the input of money and effort required. A low priority issue is not insignificant; it simply may not require immediate attention or may require a large input of resources to address. A more detailed discussion of the principles and guidelines used can be found in Chapter 7.

Community priorities for management are also listed and are based on votes placed by landholders at a meeting held at Riverton on Wednesday, 28 February 2001. As management of many of these issues will largely be the responsibility of landholders, regional organisations and the local community, these priorities give an indication of community views and degree of support for undertaking river rehabilitation works.

9.5 Summary

The watercourses of the Gilbert River subcatchment currently encompass a variety of environments — *Eucalyptus* woodlands along some tributaries, sedgelands in the upper reaches, reedbeds throughout the catchment and areas of important remnant shrublands in the lower reaches.

The majority of watercourse environments have been significantly modified and the biodiversity of the system is low, and particularly lacking in native watercourse vegetation. No native fish were recorded during a limited survey of the Gilbert River. Further studies need to be carried out to determine the true state of native fish in the subcatchment. The Gilbert River was rated as being 'mildly impaired' in terms of macro-invertebrate diversity, which is probably due to the lack of suitable habitats and flows.

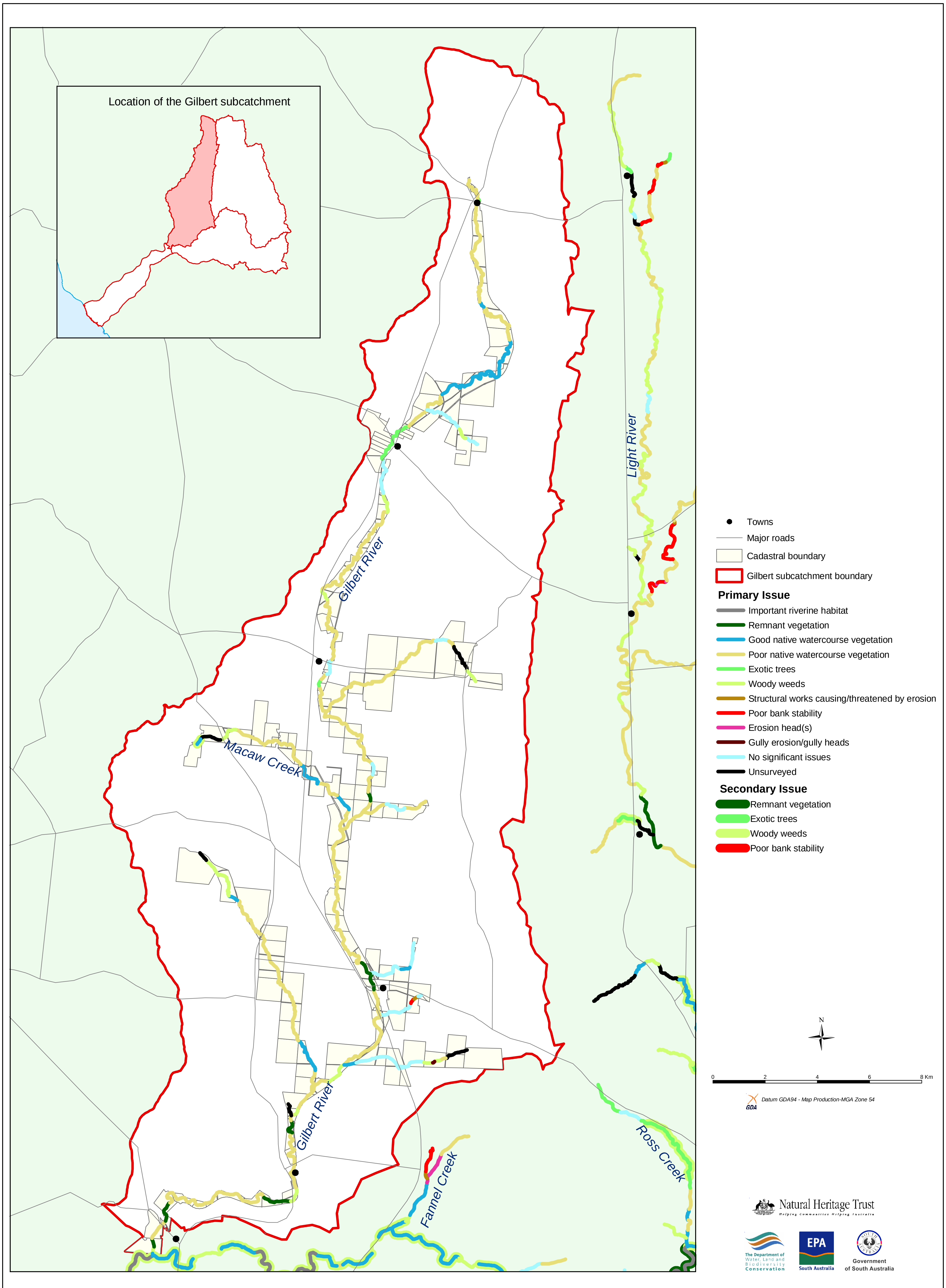
It is recommended that permanent pools and continuous baseflow be protected in the sections of the river where they occur. Permanent flow is particularly important for ensuring the health and diversity of flow obligate macro-invertebrate species. The health and diversity of native fish and aquatic plants that may exist in the lower reaches, will depend on these permanent aquatic habitats.

Vegetation clearance and cultivation to the edge of watercourses is the key impact on riverine ecosystems within this subcatchment. Management of this impact is very important and the highest priority issues include the protection and maintenance of remaining remnant habitats and environments in good condition, revegetation of areas lacking native vegetation and management of riparian weeds.

Table 9.2 Management priorities, recommendations and strategies for the Gilbert subcatchment

Management recommendation (length)	Management strategies	Sub-catchment health priority	Community priority
Protect remnant vegetation (4.6 km)	• Manage stock to avoid damage to vegetation and allow natural regeneration • Remove and control weeds and limit the opportunity for weeds to invade • Monitor the site regularly	High	High
Improve/maintain areas of good native watercourse vegetation (10.3 km)	• Revegetate and/or encourage natural regeneration • Manage stock to avoid damage to vegetation and allow natural regeneration • Remove or control weeds and limit the opportunity for weeds to invade • Monitor the site regularly	High	High
Revegetate areas lacking native vegetation (69 km)	• In areas where flooding is not a major issue, revegetate with a full range of locally native plants including groundcovers, grasses, shrubs and trees • In areas prone to flooding, leave a vegetated buffer strip between cultivated areas and the watercourse — at the very least, a good continuous grass cover • Manage stock to avoid damage to vegetation and to encourage natural regeneration	High	High
Remove/control woody weeds (species observed include wild rose and wild artichoke) (7.8 km)	• Use hand removal, spraying, burning or mechanical techniques (the technique chosen will depend on the site and the density of the infestation; care is needed to prevent disturbance to watercourse bed and banks) • Control by: - regular spot spraying or removal by hand (use herbicides recommended for use near a waterway) - shading out weeds by retaining canopy cover and avoiding disturbance to the natural vegetation - excluding stock to prevent disturbance to ground and riparian vegetation • Allow natural regeneration or revegetate with locally native species to re-establish habitat, prevent erosion and allow riparian shading	Medium	Medium

Management recommendation (length)	Management strategies	Sub-catchment health priority	Community priority
Remove/control exotic trees (2.5 km)	• Remove by cutting down and/or poisoning with a suitable herbicide (the technique used will depend on the species and its location) • Do not remove all trees in a heavily infested area at the one time • Replace exotic vegetation with suitable native species	Low	Low
Manage areas of poor bank stability (0.2 km)	• Restrict stock access and revegetate for long term stabilisation; choose areas where vegetation has most chance of establishing • Choose native species useful for erosion control e.g. grow at the toe of the bank, produce a dense root mat and can handle flooding • Assess the need for engineering works (e.g. rock riprap, gabions, battering) where erosion threatens a high value asset or is severe; seek professional advice • If bank erosion is due to bed deepening (erosion head), control bed deepening processes before attempting to stabilise bank erosion	Low	Medium
Manage structural works causing or threatened by erosion (1 site)	• Monitor site to determine if erosion is active • Ensure structural works, such as culverts, fords and bridges, are located on a straight and stable part of the watercourse, are correctly aligned, have secure footings and are designed to handle the flow capacity of the watercourse • Assess the need for erosion control works (e.g. rock chutes, drop structures) together with revegetation where erosion threatens a high value asset or is severe; seek professional advice	Low	Low
Manage side gully erosion/gully heads (1 site)	• Monitor site to determine if erosion is active • Revegetate for long term stabilisation; choose areas where vegetation has most chance of establishing • Assess the need for erosion control works (e.g. rock chutes, drop structures) together with revegetation where erosion threatens a high value asset or is severe; seek professional advice	Low	Medium



Map 9.1: Significant watercourse management issues in the Gilbert subcatchment

CHAPTER 10 MID LIGHT SUBCATCHMENT

10.1 Introduction

This chapter provides detailed information on environmental water requirements and watercourse management issues specific to the Mid Light subcatchment of the Light catchment.

A brief description of the geomorphology and ecology of the subcatchment is followed by a discussion of the environmental water requirements needed to maintain ecological health of watercourse environments in the subcatchment. The chapter concludes with a discussion of the key watercourse management issues, including priorities and strategies for management.

The Mid Light subcatchment (Maps 3.1 and 10.1) includes the area from the junction of the Light River and St Kitts Creek through Kapunda to the junction of the Light and Gilbert rivers at Hamley Bridge. Major tributaries in this subcatchment include St Kitts Creek, Stockwell Creek, Allen Creek, Ross Creek and Fannel Creek.

10.1.1 COMMUNITY ISSUES

In October 2000, a preliminary community consultation meeting highlighted issues important to landholders within the Mid Light subcatchment. This information provided direction to the project team in identifying watercourse management issues in the subcatchment.

The major concerns of landholders were:

- exotic trees and weed (olive (*Olea* sp.), African boxthorn (*Lycium ferocissimum*), wild artichoke (*Cynara cardunculus*), caltrop (*Tribulus terrestris*), nightshade (*Solanum* spp.) infestations along the watercourses
- bed and bank erosion along the watercourses.

Other issues identified at community meetings included:

- flood damage
- rubbish in the river
- nitrate pollution from septic tank effluent disposal schemes
- lack of riparian vegetation along the watercourses
- pest wildlife (rabbits and foxes) harbouring within the banks of the river
- proliferation of reeds causing sedimentation of the pools and watercourse.

The project team assessed the subcatchment in December 2000. They gathered information on the condition of watercourses and identified watercourse management issues. These issues were then presented and prioritised at a second landholder consultation meeting.

10.2 Subcatchment description

10.2.1 GEOMORPHOLOGY AND VEGETATION

The vegetation associations discussed in this assessment of the relationship between geomorphology and vegetation, are historical generalisations based on work by Brown and Kraehenbuehl (2000) for the Mid North Rivers Management Planning Project. For a more detailed pre-European vegetation association description see Map 5.9.

The tributaries to St Kitts Creek begin on the east face of the hills around the township of St Kitts. These tributaries are characterised by steep slopes and skeletal soils that have the ability to erode significantly once the vegetation is cleared. As St Kitts Creek enters the flat plains it shows signs of incision and bank erosion before flowing into the Light River.

The vegetation association at the headwaters of St Kitts Creek is an open woodland dominated by southern cypress pine *(Callitris gracilis)* and peppermint box *(Eucalyptus odorata).* Lower down the slope the vegetation association along St Kitts Creek and the tributary above changes to an open forest dominated by river red gum *(Eucalyptus camaldulensis*) and lignum *(Muehlenbeckia florulenta).* The upper slope area of St Kitts Creek is in good condition, while the lower slope areas are in a degraded condition due to a lack of native vegetation.

The tributary to the north of St Kitts Creek has been extensively cleared and shows signs of significant bed and bank erosion. These eroded areas contribute a significant amount of sediment to reaches downstream, causing siltation of the bed and pools.

Stockwell Creek flows towards St Kitts Creek from the south, and at the footslopes of the hills has become incised. The stream then flows across the flat river red gum plains of the Barossa Valley and ends up as a broad shallow sedgeland. Here the stream is characterised as a small shallow watercourse with an extensive flood-out area. This watercourse has been modified through extensive removal of river red gum from the floodplain, channelisation over most of the stream length and sections of levee's constructed to prevent flooding.

The Light River in this subcatchment flows from the junction of St Kitts Creek past Kapunda to Hamley Bridge. The river is characterised as initially flowing through a steep sided valley with a minor floodplain. The creek then flows through a confined valley just below the Peters Road crossing. Areas of incision in the higher sloped areas have resulted in the deposition of silt into the river system. The features of these reaches are pools, rockbars and reed beds with riffles occurring only within the section above Peters Road crossing.

The vegetation historically associated with this stretch of the Light River is an open forest dominated by river red gum and lignum. Most of the river red gum forest has been removed particularly around the Kapunda area. Local history acknowledges that river red gum was removed in the early days of settlement to provide fuel for the Kapunda smelters. Over the last 40 years there has been significant re-establishment of river red gums within this region (A Scholz, pers comm).

Fannel Creek, Ross Creek, Allen Creek and the creeks further south are all smaller tributaries that flow into the Light River. They flow through valleys cut into bedrock. The valley width and form are variable: in some places it is deep and confined; in others it is a broad depression. Most of the heads of the streams show evidence of incision and erosion, contributing sediment downstream to the Light River. The features of these reaches are grassy channels, sedges and reed beds. Permanent pools only occur at the lowest reaches of Ross and Allen creeks.

The vegetation association of the northern tributaries, Fannel Creek, Ross Creek and Allen Creek was historically an open woodland dominated by South Australian blue gum *(Eucalyptus leucoxylon)* and peppermint box. The southern tributaries were in an open woodland dominated by southern cypress pine and peppermint box. All these tributaries show significant loss of native vegetation with weeds and exotic trees prevalent in Ross and Allen creeks.

10.2.2 FISH

Fish populations in the Light catchment were assessed in summer 1998 (Hicks and Sheldon 1999) and in summer 2000 (Hammer 2001). Survey sites in the subcatchment were selected at Hamley Bridge, Main North Road crossing, downstream of Peters Road crossing, Kapunda bridge and Mingays Waterhole (Table 10.1).

These sites were selected due to their location along the river, the presence of large permanent pools, a range of aquatic and terrestrial vegetation and a range of habitats. None of the tributaries were sampled as at the time of sampling, they contained few permanent pools and no baseflow.

Table 10.1 The number of each species identified or observed at the four sites in the Light catchment

Fish species	Site identification				
	Hamley Bridge*	Main North Road*	Peters Road crossing**	Kapunda bridge*	Mingays Waterhole*
Native species					
Common jollytail *(Galaxias maculatus)*	13	23			36
Galaxias sp. **Observed**					20
Subtotal	13	23	—	—	56
Exotic species					
Goldfish *(Carassius auratus)*		1			1
European carp (*Cyprinus carpio*)			1		
Eastern gambusia *(Gambusia holbrooki)*	955	193	123	265	157
Eastern gambusia observed	1000	500		5000	500
Subtotal	1955	694	124	5265	658
Total	1968	717	124	5265	714
IBI rating	Poor	Poor	n.a.	Poor	Fair–poor

*Hicks and Sheldon 1999 and **Hammer 2001

The index of biotic integrity (IBI), which rates the relative biological condition of fish populations, rated the site at Mingays Waterhole between poor and fair. The sites at Hamley Bridge, Main North Road, and Kapunda bridge were rated as poor. The site below Peters Road crossing was surveyed at a later time by Hammer (2001) and not given an IBI rating but the absence of native fish and presence of exotic fish suggests this site is in very poor condition.

As shown in Table 10.1 the only identified native fish species recorded in the Mid Light subcatchment was the common jollytail, recorded at the Hamley Bridge, Main North Road bridge and Mingays Waterhole sites. No native fish were recorded in the gorge below Peters Road crossing or at Kapunda bridge. One European carp (*Cyprinus carpio*) was recorded within the gorge. High numbers of eastern gambusia were recorded at all sites which can be an indication that the habitat is degraded; these fish represent a significant threat to native fish species.

The weir at Hamley Bridge presents a migration barrier for fish. Sedentary species such as the blue spot goby *(Pseudogobius olorum)* and the flathead gudgeon *(Philyphyton grandiceps)* would have difficulty moving past the weir. Gudgeons have no climbing ability and blue spot gobys can only negotiate small structures (around 30 cm) if the surface is wet

(Hammer, pers comm 2001). Neither species was observed in any of the sites above Hamley Bridge weir, but were found below the weir in the Lower Light subcatchment. Galaxid species would be able to negotiate this weir during low flows.

Weir environments provide a relatively poor environment for smaller native fish. Apart from being a movement barrier, scouring downstream and ponding upstream of weirs creates an open predation zone for birds and larger fish (Hammer, pers comm 2001).

Removal of the weir may also produce problems as a large amount of sediment is now stored in the zone behind the structure and if mobilised may bury habitats and fill pools further downstream. Options such as reducing the height of the weir or providing a low flow bypass would improve fish movement upstream and downstream.

There is also a weir on Allen Creek at the Kapunda Road crossing which is also of sufficient height and slope to present a barrier to fish movement. No fish sampling was conducted at this site but it is recommended that any future fish surveys include sampling upstream and downstream of this weir to determine fish populations.

The permanent pools below Peters Road crossing seemed suitable for native fish although none were recorded (Hammer 2001). The only fish recorded at this site was European carp. This species has recently become established in the Light River and may be contributing to the ecological degradation of the watercourses due to its feeding habits, particularly in reaches that contain small isolated pools.

The issue of European carp in the Light River is of significant concern. An investigation into the removal or control of the distribution of European carp is recommended.

For an overview of fish distributions throughout the catchment see Section 5.5.2 and Table 5.6. For further information on flow requirements of fish see Chapter 6, and Appendices B and C.

10.2.3 MACRO-INVERTEBRATES

The Monitoring River Health Initiative (MRHI) — a national program being used to assess macro-invertebrate populations as an indicator of the health of watercourses across South Australia —sampled for macro-invertebrates at three sites in the Mid Light subcatchment in autumn and spring in 1994, 1995 and 1997.

Sites in the Mid Light subcatchment were chosen to represent as much of the Light catchment as possible, to have permanent water and relatively low levels of in-stream impacts, and to include a number of in-stream habitats.

The chosen sites were located on the Light River at Kapunda bridge and at the gauging station at Mingays Waterhole. Both riffle habitats and edge habitats were sampled.

The site at Kapunda bridge was sampled in 1994 and 1995, and was found to be in 'reference condition' (near unimpacted condition), based on the AusRivAS modelling results. It had a deep pool with fringing macrophytes, and a cobble and silt substrate. This environment provides cover, and is a particularly good habitat for the freshwater shrimp (*Paratya australiensis*), which was found in large numbers at this site.

The site at Mingays Waterhole on the Light River was sampled in 1994, 1995 and 1997, and was also found to be in 'reference condition'. It has a deep pool over a bedrock base with areas of boulder, cobble and silt substrate. An uncommon freshwater snail from the family Hydrobiidae was recorded at the site. An introduced proboscis worm was also found.

Not much variation in macroinvertebrate numbers was recorded between seasons or between years at either of these sites. This is probably because permanent flow provides the large pools with relatively constant conditions throughout the year.

According to the AusRivAS data, these two sites were among the three healthiest in the catchment. Maintaining flow in these areas will ensure the habitats supporting the macro-invertebrates are protected.

For an overview of macro-invertebrate distributions see Section 5.5.3. For further information on flow requirements of macro-invertebrates see Chapter 6, and Appendices B and C.

10.3 Environmental water requirements

10.3.1 ENVIRONMENTAL WATER REQUIREMENT MONITORED SITES AND IMPORTANT FLOW BANDS

The Light catchment was broken up into zones based on similar geomorphological features (see Section 5.4.2 and Map 5.4) many of which have physical and ecological functions maintained by river flow. Flow bands have been used to distinguish important functions and processes that occur at various flow heights (or range of heights). For each geomorphic zone in the subcatchment a specific site was selected to identify as closely as possible the environmental water requirements (EWRs) that were important for that particular zone. These sites, their flow bands and their functions are discussed in the following sections.

For each function and process there are requirements for flow height, duration, frequency and seasonality. These have been identified for each zone based on the ecological and geomorphological requirements outlined in Chapter 6, and Appendices A, B and C.

10.3.2 FLOWS AND ENVIRONMENTAL WATER REQUIREMENT PROCESS OVERVIEW

Watercourses within the Light catchment are classified as semi-arid streams. These are characterised by low volumes of water with occasional large flows during periodic larger storm events that have high rainfall intensity and are generally of short duration.

The most important water dependent features in this subcatchment are within the Light River. These features are: permanent pools maintained by groundwater, riffle zones maintained by low flows and river red gum forests maintained by overbank flows.

St Kitts Creek and its tributaries, Fannel (Pine), Ross and Allen Creeks are all characterised by steeper slopes. Consequently the flows are flash events (high velocity, short duration). Stockwell Creek and parts of the southern tributaries have a lower gradient, and experience periodic flows that flood-out over the floodplain; they are characterised by lower peak events and a longer duration span. The Light River within this subcatchment is characterised by regular reliable low flow events with higher flows approximately 4–5 times per year. The flow peaks are lower and the durations more drawn out due to the lower velocity of flow and the increased size of the channel and inner floodplain.

Flow bands considered important for maintaining riverine environments in each zone are described below. A more detailed description of environmental water requirements, including the recommended frequency, duration and seasonality of flows, is provided in Appendix B.

Zone 5: Hamley Bridge to downstream of Peters Road crossing

This zone extends from the junction of the Light and Gilbert rivers, to downstream of Peters Road crossing and is characterised by a shallow river within a confined valley (Plate 10.1).

Environments within this zone include permanent pools with interconnecting cobble riffles, wide flooding sedgelands, and/or reedbeds dominated by the common reed (*Phragmites australis*). Significant numbers of native fish were identified within this zone.

Plate 10.1 Zone 5 of the Light River at Hamley Bridge; a representative view of a shallow river within a confined valley

Groundwater: These flows are important for maintaining the reed bed communities and permanent pools for aquatic flora and fauna.

Baseflow: These flows are needed to create and maintain riffle habitats and sedgeland communities. These flows also maintain water quality by flushing pools, cycling nutrients and increasing dissolved oxygen. Shallow areas are inundated increasing habitat size and provide connectivity between pools for the movement of macro-invertebrates, frogs and fish.

Low flow: These flows inundate the benches and associated lignum and short leaf honey myrtle (*Melaleuca brevifolia*). Flows at this level are large enough to allow fish to move upstream and downstream. Fish are recruited and develop. Organic matter and nutrients are transported and cycled.

Mid–bankfull flow: At bankfull level the benches and flood runners are inundated. This provides a large area of aquatic habitat and food resources that encourages fish spawning and hatching. These flows also facilitate large scale fish redistribution, development and recruitment. These flows also maintain and assist the recruitment of riparian vegetation; they also have sufficient power to perform a number of important geomorphological functions such as maintaining channel shape and form by removing sediments from riffle substrates, and moving sediments through the system.

Overbank flow: Overbank flows completely inundate the channel plain and its flood runners. These flows allow large scale fish spawning and hatching through flooding of floodplain resources. Floodplain vegetation (especially river red gum) is maintained and recruited. These flows also 'reset' the watercourse habitat by shifting sediments, scouring pools, moving large woody debris, and turning over and moving the rocky substrate.

Zone 6: Peters Road crossing to junction with St Kitts Creek

This zone extends from Peters Road crossing to the junction of the Light River and St Kitts Creek. It is characterised by a narrow valley with minor local floodplain (Plate 10.2).

The zone contains a wide diversity of habitats with areas of good vegetation cover. Environments within this zone include permanent pools with reedbeds dominated by the common reed, rockbars and riffle zones. The permanent pools are maintained by the watertable and winter baseflow in some areas. The range of habitats, large number of pools and areas of permanent baseflow support significant fish populations.

Plate 10.2 Zone 6 of the Light River at Fords bridge; a representative view of a narrow valley with minor local floodplains

Groundwater: Groundwater is important for maintaining reedbed communities and permanent pools for aquatic flora and fauna.

Baseflow: These flows produce shallow flows that create and maintain riffle habitats and reedbed communities. The flows maintain water quality by flushing pools, cycling nutrients and increasing dissolved oxygen.

Low flow: These flows inundate the in-stream benches and connect pools. Flows at this level are large enough to allow fish to move and migrate upstream and downstream. The inundated shallow habitats allow macro-invertebrates, frogs and fish to recruit and develop.

Bankfull flow: Bankfull flows inundate lignum and sedges, and water short leaf honey myrtle. This provides a large area of aquatic habitat and food resources that encourage fish spawning and hatching. These flows also maintain and assist the recruitment of riparian vegetation. Organic matter and nutrients are transported and cycled.

Overbank flow: These flows inundate the inner floodplain to the toe of the terrace. Flows at this level are important for large scale fish spawning and hatching events, and for the maintenance and recruitment of floodplain vegetation. They also provide important channel maintenance processes such as transport of sediment, scouring of pools and the resetting of habitats.

Zone 13: Ross Creek

Ross Creek runs north-west of Kapunda and meets the Light River approximately 2 km downstream of the Kapunda to Gawler bridge. Its valley width and form is variable: some areas are characterised by deep and confined valleys (Plate 10.3), and others areas are broad and shallow.

Plate 10.3 Zone 13 in Ross Creek at Ross Creek bridge; a representative view of a deep and confined valley

Large reaches of dry grassy channel characterise Ross Creek. There are two areas of reedbeds maintained by groundwater: one below the headwaters of the stream and the other near the junction of the Light River. There is only one permanent pool at the lower end of the creek.

Groundwater: Groundwater is important for maintaining reedbed communities. It also supports permanent pools which in turn supports aquatic flora and fauna.

Low flow: These flows are important for maintaining water quality by flushing the reedbed areas, reducing salinity and increasing dissolved oxygen levels. They are also important for transporting nutrients and for the breeding and recruitment of macro-invertebrates and frogs.

High flow: High flows are important for transporting sediment, resetting habitat by moving instream objects such as logs and branches, and scouring reedbeds and pools.

Zone 14: Allen Creek

Allen Creek runs north of Kapunda and meets the Light River just downstream of the Kapunda to Truro bridge. The valley width and form is variable, with some areas characterised by incision within confined valleys and others being broad and shallow (Plate 10.4).

The main features within this zone are large areas of dry channel with reedbeds maintained by groundwater occurring sporadically along the main channel. The eastern tributary appears to add significant levels of sediment into the creek due to incision and erosion. There are three permanent pools at the lower end of the creek: above and below the weir on the Kapunda to Truro Road, and 1 km downstream from the weir.

Plate 10.4 Zone 14 in Allen Creek upstream of the Kapunda to Truro bridge; a representative view of a broad and shallow valley

Groundwater: Groundwater is important in low-lying areas for maintaining reedbed and sedgeland communities and the permanent pools that support aquatic flora and fauna.

Low flow: Up to a third bankfull flows are important for maintaining water quality by flushing the reed bed areas, reducing salinity and increasing dissolved oxygen levels. They are important for transporting nutrients and organic matter and inundating shallow habitat for the breeding and recruitment of frogs and macro-invertebrates.

High–overbank flow: Within the broad, shallow areas of the creek these flows are important for maintaining and recruiting river red gums and floodplain vegetation. In the more confined areas of the stream these flows are important for the scouring of pools and for resetting habitat by moving objects such as logs and branches. Throughout the stream these flows maintain channel form and transport sediment.

Zone 15: St Kitts Creek

St Kitts Creek flows from the south-west into the Light River upstream of Mingays Waterhole. The channel form varies from a broad and shallow valley to an incised channel (Plate 10.5).

The main features within this zone are large areas of reedbeds that are maintained by groundwater. There is only one permanent pool, located at the junction of Stockwell Creek and the Light River.

Plate 10.5 Zone 15 in St Kitts Creek at the property of A Scholz; a representative view of a broad and shallow valley

Groundwater: Groundwater is important for maintaining reedbeds and supporting aquatic flora and fauna within permanent pools.

Low flow: These flows inundate the low-lying in-stream benches, maintain sedgeland communities and provide habitat for macro-invertebrates and frogs. These flows maintain the water quality by flushing salts and increasing dissolved oxygen. Nutrients and organic matter are transported downstream.

High–overbank flow: Flows at this level are aligned to the river red gum line along the creek. These flows are important for the maintenance and recruitment of river red gum and floodplain vegetation.

Zone 16: Stockwell Creek

Stockwell Creek flows from the south-west onto the flat plains of the Barossa Valley and terminates as a sedgeland near its junction with St Kitts Creek. The channel form varies from an incised channel near the foothills to a shallow undefined channel that is channelised in areas along the broad valley floor.

The main feature of this zone is a shallow dry channel supporting small areas of sedgelands. An extensive community of river red gum was historically supported within the associated floodplain (Plate 10.6).

Plate 10.6 Zone 15 in Stockwell Creek at Ebenezer Rd; a representative view of a shallow undefined channel within a river red gum floodplain

Low flow: These small flows will maintain the sedgeland communities in the lower depressions.

Overbank flow: Overbank flows are a characteristic feature of this small shallow creek. These flows are important for maintaining and recruiting river red gums and floodplain vegetation. They provide pools for the breeding and recruitment of macro-invertebrates and frogs as well as leaching accumulated salts through soil profile. These flows also transport sediments, nutrients and organic matter.

Zone 17: St Kitts tributary

St Kitts tributary flows into St Kitts Creek from the north. The channel form varies from an incised eroding channel below the drop structure near the Watunga– St Kitts Road crossing, to a shallow channel above the crossing (Plate 10.7).

The main feature of this zone is a dry grassy channel with isolated areas of sedges.

Plate 10.7 Zone 15 in the St Kitts tributary above Watunga–St Kitts Road crossing; a representative view of a shallow channel

Low flow: These small flows will maintain the sedges in the lower depressions of the creek.

Overbank flow: These flows are important for the maintenance and recruitment of river red gums and floodplain vegetation. They are also important for transporting sediments, nutrients and organic matter down stream. Accelerated erosion may occur from high flows if the in-stream environment below the dropdown structure remains unstable.

10.4 Watercourse management issues: priorities and strategies

10.4.1 SIGNIFICANT WATERCOURSE MANAGEMENT ISSUES

Ensuring environmental water requirements are being met will not result in a healthy river system unless the ecosystems dependent on these water requirements are maintained and protected. The project team assessed the current condition of the major watercourses within the Mid Light subcatchment and, in consultation with landholders, identified and located significant watercourse management issues.

Following is a brief description of the key watercourse management issues identified for the Mid Light subcatchment (see Map 10.1 for locations).

Important riverine habitat

The three major areas of important riparian habitat in the Mid Light subcatchment cover an area of approximately 10.8 km (6.3%). The first area is on the Light River directly downstream of the junction with Ross Creek and extends 5 km downstream. It is significant because it contains a diverse range of features such as permanent baseflow, riffle zones, rockbars, permanent pools, reedbeds, sedgelands, areas of good remnant vegetation and a watercourse in a good stable condition. Further downstream around the Peters Road crossing the features are permanent pools, riffles, reedbeds, good overstorey vegetation cover and a watercourse in stable condition. The last major area is on the Light River 3 km upstream of Hamley Bridge extending for a further 3 km upstream. This area is significant because it contains a large number of permanent pools, rock bars, reedbeds, areas of good overstorey vegetation and a watercourse in stable condition.

Remnant vegetation

There are three major areas of remnant vegetation in the Mid Light subcatchment, with combined primary and secondary issue areas, covering an area of approximately 9.7 km (5.7%). The first area is located at the headwaters of St Kitts Creek and supports an open woodland dominated by peppermint box and southern cypress pine and has a good cover of native grasses. The Light River downstream of Ross Creek is an area that supports two vegetation associations in good condition. These are an open forest dominated by river red gum and lignum, and sedgelands dominated by sea rush *(Juncus kraussii)* and spiny flat-sedge *(Cyperus gymnocaulos).* The southern tributary of Allen Creek supports woodland dominated by South Australian blue gum and peppermint box with a good cover of native grasses. This area is threatened by olives.

Good native watercourse vegetation

The majority of the watercourses in this subcatchment (65 km (38%)) are covered by good native watercourse vegetation, including open forests, woodlands and sedgelands, primarily along the Light River and St Kitts Creek.

Exotic trees

Exotic trees as an issue occur over 16.6 km (9.7%) of the subcatchment. Olives are the main problem species in the subcatchment. The areas impacted are the mid and upper reaches of Ross Creek, the mid reaches of Allen Creek and the upper reach of a small tributary flowing north between these two creeks. An unidentified exotic tree species occurs within a small section of Stockwell Creek at Stockwell. Olive have been removed within a small section of Ross Creek.

Woody weeds

Riparian woody weeds are a key management issue over 16.6 km (9.7%) of the subcatchment. Wild rose is the most significant weed in the subcatchment, occurring in the mid and upper reaches of Allen Creek, and the upper reaches of St Kitts Creek, Stockwell Creek and a western tributary of St Kitts. Wild artichoke and gorse (*Ulex europaeus*) are found in the middle reaches of St Kitts Creek. The control of gorse is the highest priority due to its potential to spread throughout the watercourses. The control of wild rose in the upper reaches of St Kitts Creek is a high priority as this will improve the quality of the remnant vegetation site. Areas of sparse African boxthorn were identified through Allen and Ross creeks, extending down through the Light River into the Lower Light subcatchment.

Poor native watercourse vegetation

Poor native watercourse vegetation occurs over 34.7 km (20.3%) of the subcatchment. The lack of native vegetation is most significant in the tributaries flowing into the Light River. The absence of vegetation can increase the potential for bed and bank erosion causing sedimentation problems downstream. Significant natural regeneration of river red gum has occurred within the Light River over the past 40 years (A Scholz, pers comm 2001).

Poor bank stability

Poor bank stability as a key management issue occurs over approximately 11.2 km (6.5%) of the subcatchment. Poor bank stability is most prevalent at the headwaters of many of the tributaries flowing into the Light River from the footslopes of hills where slopes are high and the bed material is unconsolidated. Consequently these areas have high erosion rates and contribute a large amount of sediment into the river system. Significant erosion was also observed in associated smaller order streams but these were not surveyed for the project due to time and resource constraints.

Erosion heads

Erosion heads in the subcatchment are mainly located in the tributaries along the footslopes of hills. Most of these erosion heads are stable to moderately stable. Unstable erosion heads are located in the upper reaches of Fannel Creek and at one site in a tributary south of Kapunda.

Gully erosion/gully heads

Gully erosion and gully heads are also mainly located in the tributaries along the footslopes of hills: in a tributary south of Kapunda, St Kitts Creek and within a tributary of St Kitts Creek. Most of these sites are unstable and are contributing to the sedimentation of the river system.

10.4.2 WATERCOURSE MANAGEMENT ISSUES NOT PRIORITISED

The community was also concerned about other issues. These are not specifically addressed as they were not within the scope of the project but are briefly discussed here.

Reeds in watercourse

The proliferation of the common reed is believed to be restricting the flow of the river and causing sedimentation of pools. Reedbeds are a natural feature of the environment but can dominate systems that have been disturbed by practices such as burning and grazing. The common reed will also grow very well in areas that have elevated levels of nutrients and fine sediments that may occur due to a lack of riparian vegetation that in a balanced system would filter runoff from the surrounding land. Catchment clearing often contributes to greatly increased sediment and nutrient loads in watercourses.

Elevated nutrient levels

The community expressed concerns over elevated levels of nitrates in the river system due to overflow from septic tank effluent disposal schemes at Hamley Bridge and Kapunda.

Flooding

Loss of infrastructure, impact on agricultural crops and soil erosion caused by flooding was also a concern.

10.4.3 WATERCOURSE MANAGEMENT PRIORITIES

Table 10.2 lists the significant watercourse management issues for the Mid Light subcatchment and outlines strategies for management. High, medium and low priorities have been set largely in terms of how much improvement in watercourse health is possible relative to the input of money and effort required. Consequently, a low priority issue is not insignificant but simply one that may not require immediate attention or may require a large input of money and time to address. A more detailed discussion of the principles and guidelines used for determining priorities can be found in Section 7.8.

Community priorities for management are also listed and are based on votes placed by landholders at a meeting held at Kapunda on Wednesday, 28 February 2001. As management of many of these issues will largely be the responsibility of landholders, regional organisations and the local community, these priorities give an indication of the community views and interests in undertaking river rehabilitation works.

10.5 Summary

The most ecologically significant features in the Mid Light subcatchment are within the Light River itself. These features are: the permanent pools maintained by groundwater, the riffle zones maintained by low flows and the red gum forests maintained by overbank flows.

A macro-invertebrate assessment showed that two sites, Kapunda bridge and Mingays Waterhole, were among the three healthiest in the catchment. This is probably because permanent flow provides the large pools with relatively constant conditions throughout the year. Protecting flow in these areas will ensure the habitats supporting the macro-invertebrates are maintained.

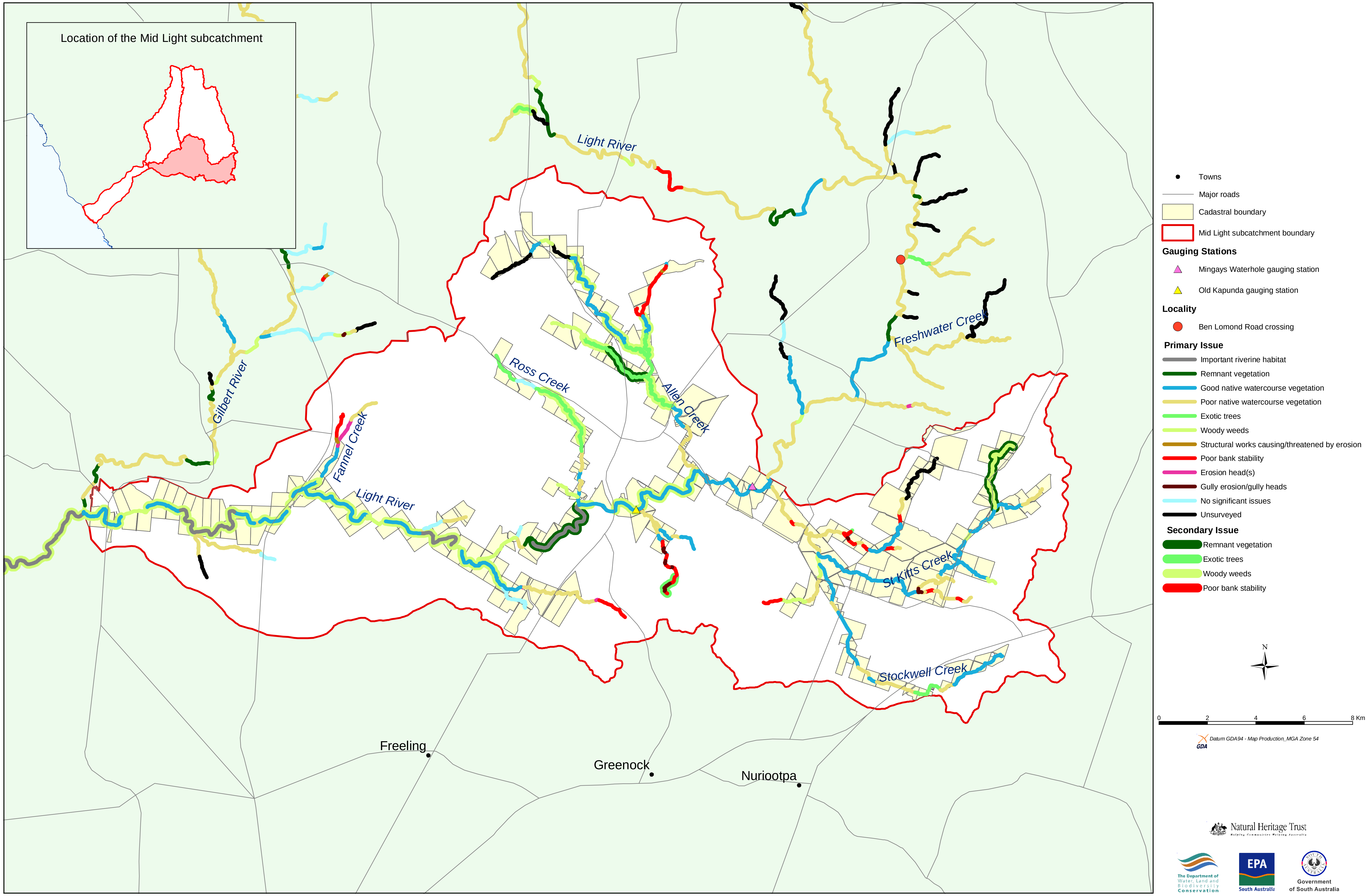
The IBI for fish populations rated between poor and fair. The only identified native fish species recorded in the Mid Light subcatchment was the common jollytail. A European carp was recorded at one site and high numbers of eastern gambusia were recorded at all sites in the subcatchment. A significant threat to the ecological health of the river system is the potential spread of European carp. The weirs at Hamley Bridge and at Allen Creek present a migration barrier for fish and act as a predation zone for birds and larger fish.

The community priorities for issues in the Mid Light subcatchment were consistent with the ecological priorities determined by the project team. The highest priority issues include the protection and maintenance of good riverine habitat, remnant vegetation and areas of good native vegetation, and the removal or control of exotic trees and woody weeds.

Table 10.2 Management priorities, recommendations and strategies for the Mid Light subcatchment

Management recommendation (length)	Management strategies	Sub-catchment health priority	Community priority
Protect important riverine habitat (10.8 km)	• Manage stock to avoid damage to vegetation and allow natural regeneration • Remove and control weeds and limit the opportunity for weeds to invade • Monitor the sites regularly	High	High
Protect remnant vegetation (0.7 km)	• Manage stock to avoid damage to vegetation and allow natural regeneration • Remove and control weeds and limit the opportunity for weeds to invade • Monitor the site regularly	High	High
Improve/maintain areas of good native vegetation threatened by degrading processes (65.3 km)	• Revegetate and/or encourage natural regeneration • Manage stock to avoid damage to vegetation and allow natural regeneration • Remove or control weeds and limit the opportunity for weeds to invade • Monitor the site regularly	High	High
Remove and control exotic trees (olives) (16.6 km)	• Remove trees by cutting down and/or poisoning with a suitable herbicide (technique used will depend on the species and its location) • Do not remove all trees in a heavily infested area at the one time • Replace exotic vegetation with suitable native species	Medium	Medium
Remove/control riparian weeds (species observed include wild rose, gorse and artichoke) (9.1 km)	• Remove with hand, spraying, burning or mechanical techniques (technique chosen will depend on the site and the density of the infestation.; care is needed to prevent disturbance to watercourse bed and banks) • Control by: - regular spot spraying or removal by hand (use herbicides recommended for use near a waterway) - shading out weeds by retaining canopy cover and avoiding disturbance to the natural vegetation - excluding stock to prevent disturbance to ground and riparian vegetation • Allow natural regeneration or revegetate with locally native species to re-establish habitat, prevent erosion and allow riparian shading	Medium	Medium

Management recommendation (length)	Management strategies	Sub-catchment health priority	Community priority
Revegetate areas lacking native watercourse vegetation (41.3 km)	• In areas where flooding is not a major issue, revegetate with a full range of locally native plants including groundcovers, grasses, shrubs and trees • In areas prone to flooding, leave a vegetated buffer strip between cultivated areas and the watercourse — at the very least, a good continuous grass cover • Manage stock to avoid damage to vegetation and to encourage natural regeneration	Medium	Medium
Manage areas of poor bank stability (11.2 km)	• Restrict stock access and revegetate for long term stabilisation; choose areas where vegetation has most chance of establishing • Choose native species useful for erosion control (e.g. grow at the toe of the bank, produce a dense root mat and can handle flooding) • Assess the need for engineering works (e.g. rock riprap, gabions, battering) where erosion threatens a high value asset or is severe; seek professional advice • If bank erosion due to bed deepening (erosion head) control bed deepening processes before attempting to stabilise bank erosion	Medium	Medium
Manage erosion head (1 site)	• Monitor site to determine if erosion is active • Revegetate for long term stabilisation; choose areas where vegetation has most chance of establishing • Assess the need for erosion control works (e.g. rock chutes and drop structures) together with revegetation where erosion threatens a high value asset or is severe; seek professional advice	Medium	Low
Manage gully erosion/ gully heads (1 site: 1.3 km)	• Fence and revegetate or allow natural regeneration for long term stabilisation; choose areas where vegetation has most chance of establishing • Assess the need for erosion control works (e.g. rock chutes, drop structures) where erosion threatens a high value asset or is severe; seek professional advice	Low	Low



Map 10.1: Significant watercourse management issues in the Mid Light subcatchment

CHAPTER 11 UPPER LIGHT SUBCATCHMENT

11.1 Introduction

This chapter provides detailed information on environmental water requirements and watercourse management issues specific to the Upper Light subcatchment of the Light catchment.

A brief description of the geomorphology and ecology of the subcatchment is followed by a discussion of the environmental water requirements needed to maintain the ecological health of watercourse environments in the subcatchment. The chapter concludes with a discussion of the key watercourse management issues, including priorities and strategies for management.

The Upper Light subcatchment (Maps 3.1 and 11.1) includes the headwaters of the Light River, and extends down to the junction of the Light River with St Kitts Creek. The Upper Light subcatchment includes two major tributaries, Tothill and Julia creeks.

11.1.1 COMMUNITY ISSUES

In October 2000, a preliminary community consultation meeting highlighted issues important to landholders within the Upper Light subcatchment. This information provided direction to the project team in identifying watercourse management issues in the subcatchment.

The major concerns of landholders were:

- increased salinity, particularly in Tothill Creek
- increased dense reedbeds that trap rubbish and cause flooding by choking the creek
- lack of native vegetation along watercourses
- watercourse erosion, especially in the tributaries.

The project team assessed the subcatchment in December 2000. They gathered information on the condition of watercourses and identifying watercourse management issues. These issues were then presented and prioritised at a second landholder consultation meeting.

11.2 Subcatchment description

11.2.1 GEOMORPHOLOGY AND VEGETATION

This section discusses the relationship between geomorphology and vegetation. The vegetation associations discussed are historical generalisations, based on work by Brown and Kraehenbuehl (2000) for the Mid North Riverine Management Project. For a more detailed pre-European vegetation association description see Figure 5.9.

The uppermost reaches of the upper Light River consist of a narrow valley carved into bedrock that grades into a wider alluvial channel approximately halfway between Waterloo and Marrabel. From this point down to the junction of the Light River and Julia Creek, the channel and valley alternate between these two forms.

The Light River downstream of its junction with Julia Creek flows through a narrow, steep-sided valley carved into bedrock, with floodplains dominated by sedgeland species. Several cobble/boulder riffles occur in this area, along with several rockbars.

Permanent pools are found throughout the whole length of the upper Light River except for the upper most reaches near Waterloo.

The upper reaches of the Light River that flow over a bedrock bed, lack native vegetation and are dominated by annual grasses and wild rose (*Rosa* sp.). As the channel flows out of this confining valley, and into the wider alluvial sections, riparian sedges begin to appear. These riparian sedges persist, in varying levels of health, throughout the rest of the Light River as it flows through this subcatchment.

Historically, the vegetation along the upper Light River from Waterloo down to its junction of the with St Kitts Creek was characterised as herbland/sedgeland dominated by sea rush (*Juncus kraussii*), sea club rush (*Bolboschoenus cadwellii*) and common reed (*Phragmites australis*). Areas of riparian short leaf honey myrtle (*Melaleuca brevifolia*) were historically dominant around Hamilton itself, and remnant stands of honey myrtle shrubland still exist today scattered between Hamilton and Hansborough.

The tributaries of the upper Light River above Hamilton were characterised as open woodland, dominated by South Australian blue gum (*Eucalyptus leucoxylon*) and peppermint box (*Eucalyptus odorata*).

The tributaries that arise in the Northern Mount Lofty Ranges and flow westward to join the Light River between Hansborough and St Kitts consist of steep rocky channels that have been extensively eroded to bedrock, which for some areas is the natural state of these watercourses.

These watercourses and the surrounding land have little to no remaining native vegetation, and are likely to be a major source of sediment to downstream reaches during heavy rainfall events. What little native vegetation remains consists of sedgeland species and is mostly found in the upper reaches.

Historically, the vegetation of these eastern tributaries was characterised as open woodland dominated by southern cypress pine (*Callitris gracilis*) and peppermint box.

Tothill Creek and Julia Creek appear to have been incised since European settlement, and erosion at many sites is being held in place by drop structures associated with road crossings.

The lower reaches of Tothill Creek south of Michalanney Road feature a broad valley with alluvial deposits, while the upper section flows through bedrock. Most of the creek has moderate to poor bank stability, with little in-stream vegetation. The majority of the riparian vegetation is in poor condition and consists mostly of a thin strip of sedgeland species.

High salinity levels are a feature of the Tothill Creek, and are likely to be a contributing factor to the lack of vegetation of the watercourse. In turn, it is likely that the inability for vegetation to establish itself due to high salinities is causing or contributing to the erosion that is occurring within the Tothill Creek area. The Tothill Landcare group is revegetating areas of the watercourse with salt tolerant species in an attempt to rehabilitate the watercourse and has had significant success.

Historically, the vegetation along Tothill Creek and its tributaries were characterised as open woodland dominated by South Australian blue gum and peppermint box. Only limited areas of eucalypt woodland still exist, and are scattered throughout the upper reaches of Tothill Creek.

Julia Creek has good bank stability and the creek flows alternately through broad alluvial valleys containing floodplains, and narrow valleys carved into bedrock. Several permanent waterholes exist along the watercourse, with the greatest number found in the downstream reaches.

There is very little remaining native vegetation left along the riparian zone of Julia Creek, and what remains consists largely of a thin strip of sedgeland species. The in-stream vegetation consists of scattered stretches of the common reed, and varies from sparse in the upstream reaches to more dense reedbeds in the lower sections.

Historically, the in-stream vegetation of Julia Creek and its tributaries were characterised as a closed herbland/sedgeland dominated by the common reed and sea club rush, with a riparian zone characterised as a low woodland dominated by South Australian blue gum and wirilda (*Acacia retinodes*).

11.2.2 FISH

Fish populations in the Upper Light subcatchment were assessed in the summer of 1998 (Hicks and Sheldon 1999) and in the summer of 2000 (Hammer 2001). Two sites with permanent pools were chosen for the fish survey during the 1998 sampling: on the Light River at Hansborough bridge and on Julia Creek at the Nash Road crossing. In 2000, two permanent pools on the Light River at Hamilton were sampled (Hammer 2001).

Table 11.1 shows fish numbers sampled from both the 1998 and 2000 samples. For the 1998 samples at Hansborough bridge, Hicks and Sheldon conducted an index of biotic integrity (IBI) which rates the relative biological condition of fish populations. and gives an indication of watercourse health in relation to the surveyed fish populations. The site at Hamilton was surveyed at a later time by Hammer (2001) and not given an IBI rating; it is likely to be classified as being in poor condition in relation to the fish population.

Table 11.1 Number of each species identified or observed at the four sites in the Upper Light subcatchment

Fish species	Site identification		
	Hansborough bridge*	**Julia Creek***	**Hamilton****
Native species			
Common jollytail (*Galaxias maculatus*)	16	0	10
Mountain galaxias (*Galaxias olidus*)	28	0	0
Subtotal	44	0	10
Exotic species			
Goldfish *(Carassius auratus)*	0	0	9
Eastern gambusia*(Gambusia holbrooki)*	137	0	50
Observed eastern gambusia	500	0	2000
Subtotal	637	0	2059
Total	681	0	2069
IBI rating	Fair–poor	n.a.	Poor[#]

*Hicks and Sheldon 1999; **Hammer 2001; [#]estimated IBI rating

No fish were recorded in Julia Creek during the 1998 sampling. The sampling site consisted of a small pool and was the least saline of the sites sampled. The lack of fish may be due to the small size of the pool which would have a higher chance of local extinctions. Along with the irregular connectivity with the Light River, this means that there is a lower chance of recolonisation.

Opportunistic observations during 2000 at a small pool downstream of Hansen Road on Julia Creek found one native fish, the common jollytail, and 51 exotic fish — one goldfish and 50 eastern gambusia. This site is closer to the Light River and may be more readily recolonised after local extinction events.

At Hansborough, of the 681 fish captured only 6.5% were native. Of the native fish caught, 16 were common jollytails and 28 were mountain galaxias. Hansborough was the only site where mountain galaxias were found in the Light catchment.

The remaining 637 fish recorded at this site were the exotic eastern gambusia. Results of the IBI based on this finding indicate that this survey site is in fair to poor condition (Hicks and Sheldon 1999).

The survey conducted in 2000 on the Light River at Hamilton recorded 69 fish of which there were 10 common jollytails, nine goldfish, and 50 eastern gambusia. In shallow areas not sampled, eastern gambusia was observed in numbers of 1000–2000 individuals.

Mountain galaxias were expected to be found at this site. Their absence may be due to elevated salinity levels of the water, which disadvantages mountain galaxias and favours the common jollytail. Also, the sites sampled only offer small patches of suitable habitat, which limits population sizes and increases the chances of local extinctions.

No IBI was calculated for this site but as the fish numbers and species found were similar to other areas, it would probably be classified as being in poor condition for fish populations.

For an overview of fish distributions throughout the catchment see Section 5.5.2 and Table 5.6. For further information on flow requirements of fish see Chapter 6, and Appendices B and C.

11.2.3 MACRO-INVERTEBRATES

The Monitoring River Health Initiative (MRHI) — a national program being used to assess macro-invertebrate populations as an indicator of the health of watercourses across South Australia —sampled macro-invertebrates at three sites in the Upper Light subcatchment in autumn and spring in 1994, 1995 and 1997.

Sites in the Upper Light subcatchment were chosen to represent as much of the Light catchment as possible, to have permanent water and relatively low levels of in-stream impacts, and to include a number of in-stream habitats.

The sites in the Upper Light subcatchment were located on the Light River at Hansborough bridge, and at the Tarnma Road crossing east of Hamilton, and on Julia Creek at the Nash Road crossing. No riffle habitats were present at any of these sites, therefore only edge habitats were sampled.

The site at Hansborough bridge on the Light River was sampled in both 1994 and 1995, and was found to be ‘mildly impaired’ based on the results of the AusRivAS model. This may be due to a lack of habitat diversity.

The deep pool at the site has fringing macrophytes, and a cobble and silt substrate. This environment provides cover and is a particularly good habitat for the freshwater shrimp (*Paratya australiensis*), which was found in large numbers at this site.

Little variation in taxon numbers was recorded between seasons or between years. This is probably because the large pool remains relatively constant throughout the year.

The Tarnma Road crossing site on the upper Light River has a long, shallow pool with fringing macrophytes, and a silt, clay and detritus substrate. The site was only sampled in 1997. Overall the site was found to be 'mildly impaired' based on the results of the MRHI surveys.

Results suggest that water quality is a contributing factor to the site being classified as 'mildly impaired'. Very different results were recorded in the spring and autumn samples: in autumn the site was classified as 'impaired'; in spring it was in 'reference condition' (near unimpacted).

One of the major differences between the spring and autumn samples was the salinity results. The autumn sample had the highest salinity reading recorded for any site in the Light catchment (11,532 mg/L) but the spring sample had one of the lowest salinity readings (3,522 mg/L). Fifteen more taxa were recorded in spring than in the autumn sample. This is likely to be a natural cycle with higher salinities in autumn due to the concentration of salts resulting from increased evaporation rates and reducing pool sizes, and lower salinities in spring due to the flushing of pools from spring rains and increased baseflow.

The Nash Road crossing site has a number of pools in bedrock, each around 40–50 cm deep, with fringing macrophytes. This site was classified as being in 'reference condition' and had the highest recorded macro-invertebrate richness for any sample from the Light catchment.

The healthy macro-invertebrate community found at this site is probably due to a combination of factors. The site has a stable bedrock channel, groundwater input, the richest macrophyte community sampled by the MRHI with nine species and the lowest salinity levels. The highest number of the exotic snail (*Physa acuta)* was also found at this site but the effect that this species has on native macro-invertebrates is unknown. Observations by MRHI personnel suggest that the presence of these snails does not indicate degradation or poor water quality.

Eleven more families were captured in spring than in autumn. This increase in taxa may be due to the flush of water from winter rain, which enables completion of animal lifecycles. The rains would also maintain water quality by flushing pools.

For an overview of macro-invertebrate distributions see Section 5.5.3. For further information on flow requirements of macro-invertebrates see Chapter 6, and Appendices B and C.

11.3 Environmental water requirements

11.3.1 ENVIRONMENTAL WATER REQUIREMENT MONITORED SITES AND IMPORTANT FLOW BANDS

The Light catchment was broken up into zones based on similar geomorphological features (see Section 5.4.2 and Map 5.4) many of which have physical and ecological functions maintained by river flow. Flow bands have been used to distinguish important functions and processes that occur at various flow heights (or range of heights). For each geomorphic zone in the subcatchment a specific site was selected to identify as closely as possible the environmental water requirements (EWRs) that were important for that particular zone. These sites, their flow bands and their functions are discussed in the following sections.

For each function and process there are requirements for flow height, duration, frequency and seasonality. These have been identified for each zone based on the ecological and geomorphological requirements outlined in Chapter 6, and Appendices A, B and C.

11.3.2 FLOWS AND ENVIRONMENTAL WATER REQUIREMENT PROCESS OVERVIEW

Watercourses within the Light catchment are classified as semi-arid streams. These are characterised by low volumes of water with occasional large flows during periodic larger storm events that have high rainfall intensity and are generally of short duration.

The most important water dependent features in this subcatchment are the permanent pools and sedgelands maintained by groundwater, the remnant stands of short leaf honey myrtle and water quality in permanent pools that are maintained by low flows.

Flow bands considered important for maintaining riverine environments in each zone are described below. A more detailed description of environmental water requirements, including the recommended frequency, duration and seasonality of flows is provided in Appendix B.

Zone 7: Light River from junction with St Kitts Creek to Hansborough

The major environments in this zone include permanent pools with interconnecting cobble riffles, wide flooding sedgelands, and/or reedbeds dominated by the common reed (Plate 11.1). Fish surveys at the boundary of zones 7 and 8 found native fish populations whose flow needs must be met for populations to be maintained.

Plate 11.1 Light River at Ben Lomond Road crossing, Zone 7; a representative view showing pools, cobble riffles and sedges in a confined valley

Groundwater: In this zone, groundwater maintains the permanent pools, as well as the reedbed and sedgeland communities.

Baseflow/seasonal low flow: The water level of these flows inundate the cobble riffles to a sufficient depth to allow the development and recruitment of fish, frogs and macro-invertebrates. These flows are also very important in maintaining water quality in the pools of the zone by flushing through pollutants.

Mid flow: These flows allow fish spawning and hatching, as well as allowing the redistribution of fish to other sections of the river system. These flows are also important in transporting nutrients and organic matter to downstream reaches.

High–bankfull flow: These flows reach and maintain riparian sedges and short leaf honey myrtle, and allows their recruitment. These flows also have sufficient power to perform a number of important geomorphological functions such as removing sediments from riffle substrates and moving sediments through the system.

Overbank and extensive flood-out flow: These large flows are very important in preventing the filling in of pools by scouring out of sediments. These flows also 'reset' the watercourse habitat by shifting sediments, moving large woody debris, and turning over and moving the rocky substrate.

Zone 8: Light River from Hansborough to Marrabel

The major environments in this zone include large permanent pools with interconnecting areas of short leaf honey myrtle shrubland, reedbeds dominated by the common reed (Plate 11.2) or areas lacking in native riparian vegetation. Fish surveys at the boundary of zones 7 and 8 found native fish populations whose flow needs must be maintained.

Hansborough

Groundwater: At this site, groundwater maintains the permanent pools, as well as the reedbed and sedgeland communities. The maintenance of permanent pools in this zone is of particular importance, as it is likely that the fish develop and recruit in these pools after spawning during flow events.

Mid–high flow: These flows inundate shallow habitats suitable for the breeding and local movement of fish, frogs, and macro-invertebrates, as well as maintain water quality in pools to support these animals when the water ceases to flow. Riparian short leaf honey myrtle is also maintained by these flows. Geomorphological functions fulfilled by these flows include the transport of nutrients, sediment, and organic matter.

Overbank and extensive flood-out: The major functions of these flows are the maintenance of the channel form, as well as maintaining pools by removing sediments.

Hamilton

Groundwater: The groundwater at this site maintains the permanent pools for dependent biota such as fish, frogs, macro-invertebrates and several species of aquatic plants.

Seasonal baseflow–low flow: These flows provide a suitable habitat for the development, recruitment and local movement of fish. The flows also allow for the breeding of frogs and macro-invertebrates, as well as maintain water quality in pools that support these animals when the water ceases to flow. Riparian short leaf honey myrtle is also maintained by these flows.

Plate 11.2 Light River at Hamilton, Zone 8, showing remnant stands of short leaf honey myrtle (*Melaleuca brevifolia*), and fringing sedges

Mid flow: Fish spawning and hatching occurs at these flow levels, which also provide conditions for optimum fish development and recruitment if the duration is suitable. The flows also play an important role in the transport of sediment, nutrients and organic matter.

Bankfull flow: Large-scale fish spawning and hatching will occur at these flows, and fish can be distributed to other sections of the river system. These flows also maintain riparian sedgelands and fills floodplain flood runners, which creates good breeding habitats for macro-invertebrates and frogs.

Overbank–extensive flood-out flow: These large flows are important for geomorphological functions such as scouring sediments out of pools, removing sediments from riffles and resetting watercourse habitats by rearranging logs, branches, sediments and rocks.

Zone 9: Light River from Marrabel to Waterloo

This zone is generally a shallow channel that has poor native riparian vegetation, which consists mostly of sedge species. There are a number of small permanent pools and limited areas of reedbeds (Plate 11.3). No fish surveys were undertaken in this zone, so it is unknown if flows are required to maintain fish populations.

Plate 11.3 Light River at the Tothill Road crossing, Zone 9, a representative view of a shallow river with pools, common reed and sedgeland species

Groundwater: In this zone, groundwater maintains the permanent pools, as well as the reedbed and sedgeland communities.

Low flow: The main function of these flows is to maintain water quality in the permanent pools for aquatic animals and plants by flushing through pollutants (esp. salts).

High–overbank flow: The most important functions of these larger flows are geomorphological. They scour sediments from pools to prevent them filling in, transport sediments, nutrients and organic matter downstream, and maintain the channel form.

Zone 18: Freshwater Creek and surrounding tributaries

The watercourses in this zone have very little riparian vegetation, and are restricted to exotic annual grasses and limited areas of sparse sedges (Plate 11.4). The in-stream habitats are restricted to a few permanent pools that exist along only a few of these eastern tributaries.

Groundwater: The main function for groundwater in this system is to maintain the few permanent pools for the associated animal and plant life.

Low flow: These flows move water through the permanent pools and maintain water quality by flushing pollutants.

High flow: These flows are important for geomorphological functions such as scouring sediments out of pools, transporting sediment downstream and maintaining the channel form.

Plate 11.4 Tributary of the Light River off of Newlands Road, Zone 18, showing an incised channel with little native vegetation

Zone 19: Julia Creek

The major environments of Julia Creek are permanent pools with good water quality, which are mostly located in the southern reaches of the watercourse and are interspersed with dense reedbeds dominated by the common reed (Plate 11.5). Native fish have been captured within this zone, and has the most healthy macro-invertebrate populations found within the Light catchment.

Groundwater: In this zone, groundwater maintains permanent pools and reedbed communities.

Low flow: These flows allow the development and recruitment of fish, as well as promote local movement between populations. These flows also increase the available habitat for frogs and macro-invertebrates, and maintain water quality in permanent pools.

Mid–high flow: The most important function of these flows are to allow significant fish spawning and hatching, as well as allowing the redistribution of fish through the system. If the flow duration is long enough, it will allow for a very successful fish development and recruitment event. These flows will also maintain the riparian vegetation.

Overbank flow: The main functions of these flows are to maintain the floodplain lignum where it exists, and to reset the watercourse habitat by rearranging logs, branches, sediments and rocks.

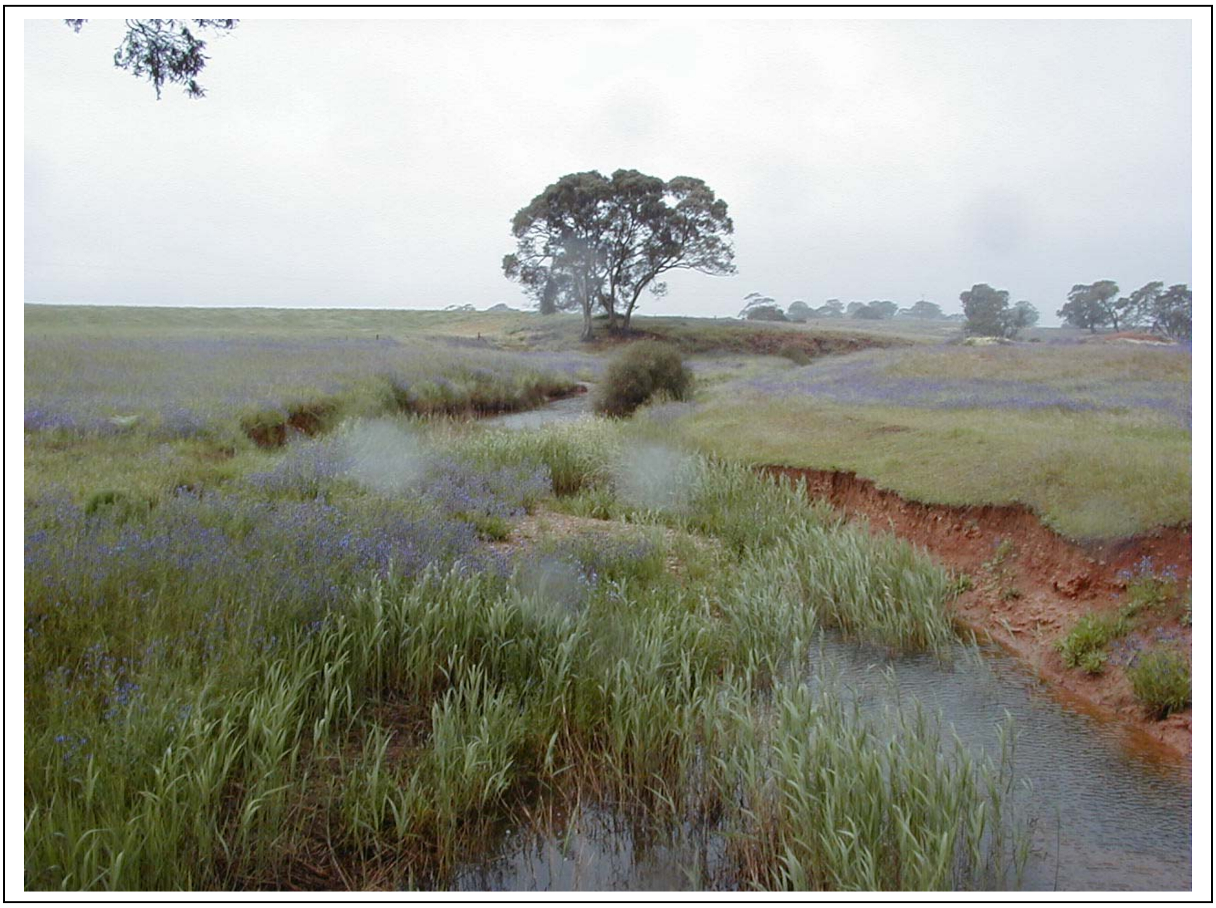


Plate 11.5 Julia Creek, Zone 19, a representative view showing pools and stands of common reed

Zone 20: Tothill Creek

Tothill Creek has very little riparian or in-stream vegetation but a few areas have good diverse sedgelands and others have eucalypt woodlands in good condition. There are permanent pools throughout the zone (Plate 11.6). Plants and animals are restricted in their distribution along Tothill Creek due to very high salinity levels.

Groundwater: In this zone, groundwater maintains the permanent pools as well as the reedbed communities.

Seasonal baseflow–low flow: These flows are important to maintain water quality by flushing pollutants through the system, particularly salts, which will build up in standing pools.

Mid–high flow: These flows maintain riparian vegetation such as lignum and sedges, and also transport sediments, nutrients and organic matter through the system.

Bankfull flow: The main functions of these large flows are to scour sediments from the permanent pools in the system, and to maintain the channel form.

Plate 11.6 Tothill Creek at the Braewood Road crossing, Zone 20, showing a pool, poor bank stability and newly germinated common reed

11.4 Watercourse management issues: priorities and strategies

11.4.1 SIGNIFICANT WATERCOURSE MANAGEMENT ISSUES

Ensuring environmental water requirements are being met will not result in a healthy river system unless the ecosystems dependent on these water requirements are maintained and protected. The project team assessed the current condition of the major watercourses within the Upper Light subcatchment and, in consultation with landholders, identified and located significant watercourse management issues.

Following is a brief description of the key watercourse management issues identified for the Upper Light subcatchment (see Map 11.1 for locations).

Remnant vegetation

Significant stands of remnant short leaf honey myrtle shrubs occur along the middle reaches of the Upper Light subcatchment between Hamilton and the junction of the Light River and St Kitts Creek. These stands of remnant vegetation occur along 5.9 km (3%) of the surveyed watercourses in this subcatchment.

These areas contain vegetation similar to that expected to be in the area prior to European settlement and that is important as seed sources for recolonisation and revegetation. These shrubland areas also add another layer of complexity to the riverine habitat and support animal species that have limited access to that habitat throughout the rest of the catchment.

The protection of remnant vegetation was voted as being the second most important issue by landholders of the subcatchment.

Good native watercourse vegetation

Areas of native vegetation that are in good condition but that have been modified by degrading processes such as stock grazing and clearance were located along 12 km (6.2%) of the surveyed watercourses of the Upper Light subcatchment.

Areas of sedgeland in good condition are found in the middle reaches of Tothill Creek, and also along the Light River and a tributary (both a short distance north of the Light River's junction with St Kitts Creek). Eucalypt woodlands in good condition but lacking understorey vegetation were found along the upper reaches of Tothill Creek and sparse shrublands of short leaf honey myrtle exist just east of Hansborough.

These areas in good condition have a higher habitat value, especially for birds and macro-invertebrates, than more degraded areas of the watercourse. However, their value is diminished because of their limited extent. Simply rehabilitating these isolated patches of vegetation may have limited benefit without addressing lack of native vegetation issues upstream and downstream of these sites.

Woody weeds

Riparian weeds were considered a significant management issue along 20 km (10.3%) of the surveyed watercourses in this subcatchment. The major weed species observed was wild rose, which was present along most of the length of the Light River north of Hamilton. Dense infestations of gorse (*Ulex europaeus*) were found in the upper most reaches of the Light River above Waterloo.

Lack of native watercourse vegetation

The most widespread management issue affecting ecosystem health along the upper Light River and its tributaries is poor riparian native vegetation, which affects 119.7 km (61.5%) of the surveyed watercourses in the Upper Light subcatchment. The shallow profile of the upper sections of the Light River makes fencing to encourage natural regeneration and/or revegetation difficult due to the high risk of flooding of surrounding cropland and resulting damage to fences.

Poor bank stability

Poor bank stability is a significant management issue along 81.1 km (4.2%) of the surveyed watercourses in the Upper Light subcatchment. Areas with poor stability were considered a significant management issue along a tributary in the uppermost reaches of the Light River, a section of the Light River between Hamilton and Hansborough, and along significant stretches of Tothill Creek. High salinity levels in Tothill Creek are limiting the growth of riparian vegetation which would ordinarily help stabilise the banks.

Information gathered from landholders also suggests that the smaller tributaries (3rd order and below) are major contributors to sediment to the system due to high erosion rates. Surveying these watercourses was beyond the scope of this project.

Exotic trees

The removal of exotic trees was a low priority for the landholders in the Upper Light subcatchment, and was identified as a significant management issue along 2.8 km (1.4%) of the surveyed watercourses. Pine (*Pinus* spp.) trees were identified in the uppermost reaches of the Light River, olive (*Olea* spp.) trees were found at Hamilton, and tree tobacco (*Nicotiana glauca*) was found along one of the eastern tributaries of the Light River south of Hansborough.

Structural works causing or threatened by erosion

Road culverts that are causing, or are threatened by, erosion were also identified as issues within the Upper Light subcatchment. Three such structures were found, two on a tributary of the Light River just south of Waterloo and one in the lower reaches of Tothill Creek. If these structures fail then there is the potential for significant erosion to occur with the possible formation of an erosion head.

Erosion heads

A number of erosion heads were found within the Upper Light subcatchment, most in the south-eastern tributaries of the Light River. The majority of these erosion heads were found to be stable due to vegetation establishment or the presence of rockbars preventing upstream migration. Only one erosion head was found to be actively eroding, and was located in the most southerly of the eastern hill tributaries.

No significant watercourse management issue

Areas with no significant watercourse management issues were found along 3.7 km (1.9%) of the surveyed watercourses. Typically these areas were dry grassy channels that flow irregularly and will not change if management practices are kept as they are.

11.4.2 WATERCOURSE MANAGEMENT ISSUES NOT PRIORITISED

The community was also concerned about other issues. These are not specifically addressed as they were not within the scope of the project but they are briefly discussed here.

Reeds in watercourse

The presence of significant stretches of watercourse dominated by the common reed was a concern for the landholders in the Upper Light subcatchment. Reedbeds are a natural feature of the environment but can dominate systems that have been disturbed by practices such as burning and grazing. The common reed will also grow very well in areas that have elevated levels of nutrients and fine sediments that may occur due to a lack of riparian vegetation that in a balanced system would filter runoff from the surrounding land. Catchment clearing often contributes to greatly increased sediment and nutrient loads in watercourses.

11.4.3 WATERCOURSE MANAGEMENT PRIORITIES

Table 11.2 lists the significant watercourse management priorities for the Upper Light subcatchment and outlines strategies for management. High, medium and low priorities have been set largely in terms of how much improvement in watercourse health is possible relative to the input of money and effort required. A low priority issue is not insignificant but simply one that may not require immediate attention or may require a large input of money and time to address. A more detailed discussion of the principles and guidelines used can be found in Section 7.8.

Community priorities for management are also listed and are based on votes placed by landholders at a meeting held at Marrabel on Thursday, 1 March 2001. Management of many of these issues will largely be the responsibility of landholders, regional organisations and the local community, and these priorities give an indication of community views and interests in undertaking river rehabilitation works.

11.5 Summary

The watercourses within the Upper Light subcatchment flow through a number of different environments. These include eucalypt woodlands in the upper reaches of Tothill Creek, remnant short leaf honey myrtle shrublands scattered between Hamilton and St Kitts Creek, and diverse sedgelands in the middle reaches of Tothill Creek and in the lower reaches of the Upper Light River.

Common reed exists at varying densities within the in-stream sections of the watercourses throughout this subcatchment. These reedbeds are supported by a high watertable and, in some areas, by permanent flow.

Permanent pools support macro-invertebrate and fish populations throughout the subcatchment, and pools on Julia Creek were found to support the highest diversity of macro-invertebrates within the whole of the Light River catchment. Other sites in this subcatchment were classified as being ‘mildly impaired’ in terms of macro-invertebrate populations.

Exotic fish numbers heavily outnumber those of native fish within this subcatchment. The site at Hansborough contained the only population of mountain galaxias found within the catchment, and is likely an important refuge area for this species.

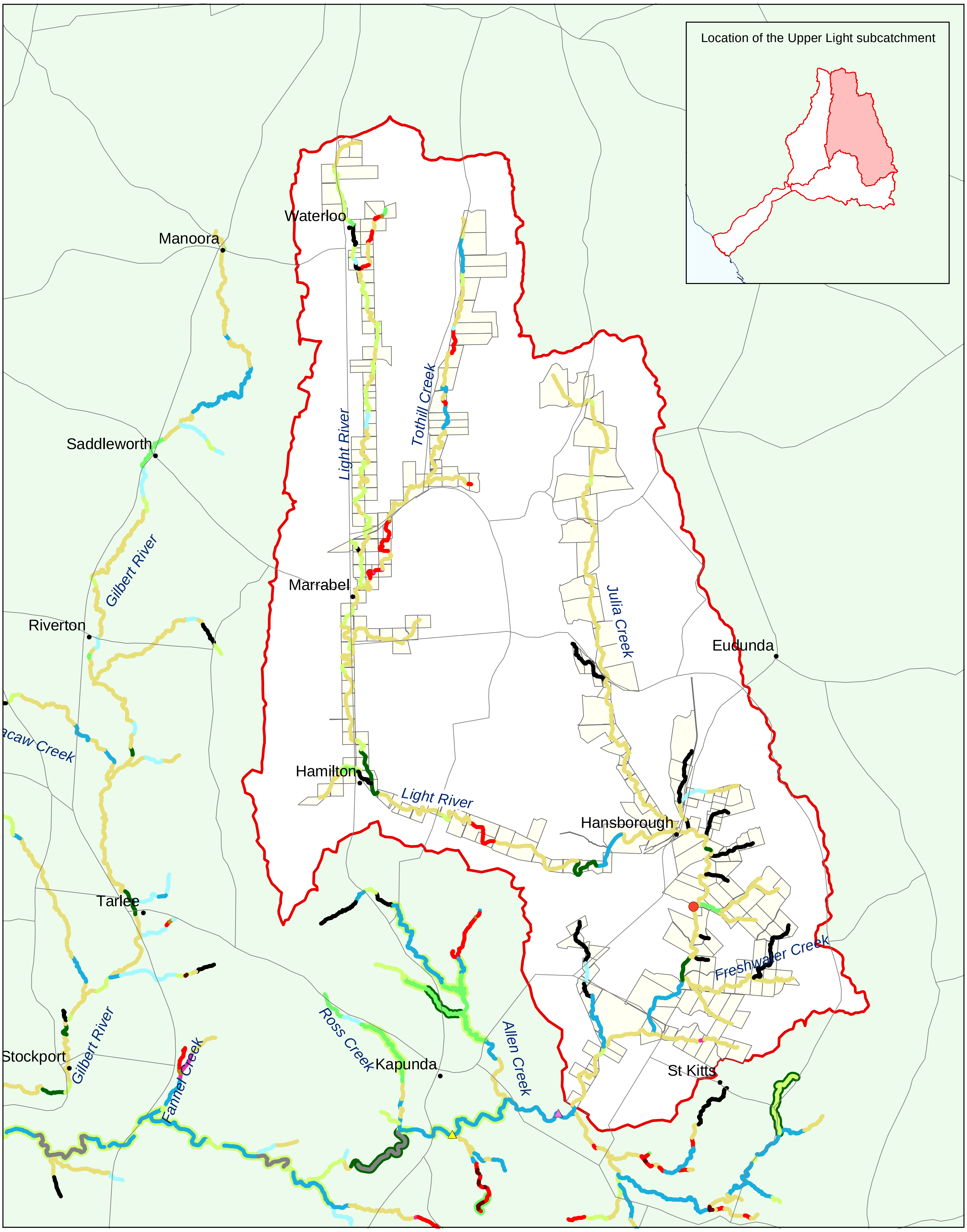
The areas of permanent pools and intermittent baseflow should be maintained in order to support the diverse animal and plant life that are dependent on these features.

Clearance and cultivation to the edge of watercourses is the key impact on riverine ecosystems within this subcatchment. Management of this impact is very important and is reflected in the highest priority issues: the protection and maintenance of remnant habitats and environments in good condition, revegetation of areas lacking native vegetation and management of riparian weeds.

Table 11.2 Management priorities, recommendations and strategies for the Mid Light subcatchment

Management issue (length)	Management strategies	Sub-catchment health priority	Community priority
Protect remnant vegetation (5.9 km)	• Manage stock to avoid damage to vegetation and allow natural regeneration • Remove and control weeds and limit the opportunity for weeds to invade • Monitor the site regularly	High	High
Improve/maintain areas of good native vegetation (12 km)	• Revegetate and/or encourage natural regeneration • Manage stock to avoid damage to vegetation and allow natural regeneration • Remove or control weeds and limit the opportunity for weeds to invade • Monitor the site regularly	High	Medium
Remove and control riparian weeds (species observed include wild rose and artichoke) (20 km)	• Remove by hand, spraying, burning or mechanical techniques (technique chosen will depend on the site and the density of the infestation; care is needed to prevent disturbance to watercourse bed and banks) • Control by: - regular spot spraying or removal by hand (use herbicides recommended for use near a waterway) - shading out weeds by retaining canopy cover and avoiding disturbance to the natural vegetation - excluding stock to prevent disturbance to ground and riparian vegetation • Allow natural regeneration or revegetate with locally native species to re-establish habitat, prevent erosion and allow riparian shading	High	High
Lack of native vegetation (119.7 km)	• In areas where flooding is not a major issue, revegetate with a full range of locally native plants including groundcovers, grasses, shrubs and trees • In areas prone to flooding issues, leave a vegetated buffer strip between cultivated areas and the watercourse — at the very least, a good continuous grass cover • Manage stock to avoid damage to vegetation and to encourage natural regeneration	High	Medium

Management issue (length)	Management strategies	Sub-catchment health priority	Community priority
Poor bank stability (8.1 km)	• Restrict stock access and revegetate for long term stabilisation; choose areas where vegetation has most chance of establishing • Choose native species useful for erosion control (e.g. grow at the toe of the bank, produce a dense root mat and can handle flooding) • Assess need for engineering works (e.g. rock riprap, gabions, battering) where erosion threatens a high value asset or is severe; seek professional advice • If bank erosion due to bed deepening (erosion head), control bed deepening processes before attempting to stabilise bank erosion	Medium	Medium
Structural works causing or threatened by erosion (3 sites)	• Monitor site to determine if erosion is active • Ensure structural works, such as culverts, fords and bridges are located on a straight and stable part of the watercourse, are correctly aligned, have secure footings and are designed to handle the flow capacity of the watercourse • Assess the need for erosion control works (e.g. rock chutes, drop structures) together with revegetation where erosion threatens a high value asset or is severe; seek professional advice	Low	Low
Remove and control exotic tree (2.8 km)	• Remove by cutting down and/or poisoning with a suitable herbicide (technique depends on the species and its location) • Do not remove all trees in a heavily infested area at the one time • Replace exotic vegetation with suitable native species	Low	Low
Erosion head (1 site)	• Monitor site to determine rate of erosion • Revegetate for long term stabilisation; choose areas where vegetation has most chance of establishing • Assess the need for erosion control works (e.g. rock chutes, drop structures) together with revegetation where erosion threatens a high value asset or is severe; seek professional advice	Low	High



Map 11.1: Significant watercourse management issues in the Upper Light subcatchment

- Towns
- Major roads
- Cadastral boundary
- Upper Light subcatchment boundary

Gauging Stations

- Mingays Waterhole gauging station
- Old Kapunda gauging station

Locality

- Ben Lomond Road crossing

Primary Issue

- Important riverine habitat
- Remnant vegetation
- Good native watercourse vegetation
- Poor native watercourse vegetation
- Exotic trees
- Woody weeds
- Structural works causing/threatened by erosion
- Poor bank stability
- Erosion head(s)
- Gully erosion/gully heads
- No significant issues
- Unsurveyed

Secondary Issue

- Remnant vegetation
- Exotic trees
- Woody weeds
- Poor bank stability

N

0 2.5 5 7.5 10 Km

Datum GDA94 - Map Production_MGA Zone 54

GDA

Natural Heritage Trust

The Department of Water, Land and Biodiversity Conservation

EPA South Australia

Government of South Australia

CHAPTER 12 RECOMMENDATIONS FOR THE LIGHT CATCHMENT

12.1 Introduction

The aims of the watercourse management recommendations in this chapter are to ensure that the flow regime of watercourses in the Light catchment meets the needs of the environment and to improve habitat conditions to enhance aquatic and riparian biodiversity.

The significant changes watercourses have undergone make it unrealistic to seek to restore them to pre-European condition. It is more realistic to aim for rehabilitation that returns, as far as possible, the vegetation, physical structure, hydrology and water quality of watercourses to a more ‘natural’ state that meets both environmental and human needs.

This goal also corresponds to views held by the community. Broadly the community felt that management of watercourses should aim to enhance the natural qualities and characteristics of the river system, and also allow for legitimate human activities to take place.

This chapter discusses the conclusions on the health of the Light River and its tributaries based on the studies in this project, and provides recommendations and actions for managing the river to improve and/or maintain its health. Subcatchment watercourse management issues and recommendations are outlined in Chapters 8 to 11.

Within the Light catchment there are a number of key stakeholder organisations and groups with watercourse, water resource or land management responsibilities or interests that directly or indirectly affect the river system. Where possible recommendations and actions include the key partners that the project team recommends become involved.

These include:

- Individual landholders
- Department for Environment and Heritage (DEH)
- Department of Water Land and Biodiversity Conservation (DWLBC)
- Primary Industries and Resources South Australia (PIRSA)
- Soil conservation boards
- Animal and plant control boards (APCB)
- Local government
- Northern and Yorke Agricultural Districts Interim Natural Resource Management Committee (NYAD INRM Committee)
- SA Water
- Greening Australia.

Natural resource management arrangements in South Australia are currently undergoing reform with the passing of the NRM Act. This will bring together three acts – the *Animal and Plant control (Agricultural Protection and Other Purposes) Act 1986, Soil Conservation and Land Care Act 1989,* and *Water Resources Act 1997.* The Act enables the formation of regional NRM Boards which will take over the responsibilities of existing animal and plant control boards, soil conservation boards, catchment water management boards and interim INRM groups, and will therefore take on the responsibilities of the relevant groups for the associated recommendations outlined in this chapter. The Light catchment is within the Northern and Yorke Agricultural District Integrated Natural Resource Management Committee administrative region.

12.2 Light catchment summary

This project, through watercourse assessment, community consultation, identification of environmental water requirements and management issues, will provide landholders and stakeholders with a significant amount of information on the condition of the Light River system and necessary management actions. The project has already had a positive effect on watercourse management in the region. A number of funding and works programs have been initiated within the catchment as a result of increased awareness and information provided by the project. Feedback from community meetings has also indicated an increase in awareness of watercourse condition and management issues within the catchment.

Since European settlement the catchment has undergone significant changes, and the state of the watercourses is presently degraded throughout much of the catchment, with few areas in good condition remaining.

The overall geomorphological condition of the Light catchment is rated fair to good (S Brizga, pers comm 2001). However, this condition varies throughout the catchment for different geomorphological areas and features. The estuary is in excellent condition but some of the gully areas in the eastern hill tributaries are in very poor condition. Other areas in poor geomorphological condition due to incision are generally found in the footslopes, for example the lower reaches of St Kitts Creek, and the upstream reaches of Allen and Tothill creeks.

Reedbeds can be both a symptom and a cause of increased sedimentation rates. Catchment clearing during settlement of the region has increased sediment and nutrient input into the watercourses of the region, creating a favourable habitat for reedbeds to grow. However, the presence of the reedbeds themselves can cause increased sedimentation rates by slowing flows and trapping sediments. This increased sedimentation and the excessive growth of reedbeds can have significant geomorphological implications.

There are significant stretches of reedbeds within the study area: along the Gilbert River and the downstream reaches of Julia Creek and along the Light River in the Mid Light subcatchment, extending through to the lower reaches of the river to The Rockies. Sedimentation rates in these areas are considered to be natural, and consequently these areas are considered to be in fair geomorphological condition. The condition will probably improve over time as the riverbed rises making it unsuitable for reed growth. If this occurs, it will become more suitable to sedgeland species and a new channel may evolve. The time period for this change can range from tens to hundreds of years.

Most of the remaining watercourses within the catchment, including areas that are lacking native vegetation and are not eroding, are in good geomorphological condition, as the lack of native vegetation does not have a significant impact on geomorphology (S Brizga, pers comm 2001).

Very little is known about the hydrology and hydrogeology — surface flows and groundwater — of the Light catchment apart from information on surface flows sourced from landholders and data from two gauging stations on the Light River near Kapunda. Information on hydrogeology was sourced from Water Search Pty Ltd, and from local landholder knowledge.

This information suggest that the flow regime of the Light River and its tributaries is intermittent, with the river flowing to the sea in most years for a short period and drying to pools with some areas of baseflow in drier months. Landholder observations indicate that flows have been reducing in the lower reaches of the Light River over several decades. However, there is insufficient data to confirm the reasons for this. It is believed to be largely climatic; there are only limited extractions from the groundwater aquifer and it is disconnected from the aquifer that the Virginia irrigators use. Further research into the aquifer and its interaction with flows in the catchment is necessary.

The combination of frequency and duration of flows in relation to the inundation of specific habitats (e.g. pools, riffles, benches and floodplains) is important in determining ecological responses. The key finding from the assessment of flow data from the composite records of the Kapunda and Mingays Waterhole gauging stations are that significant flow events are of a relatively short duration and may only just be meeting ecological requirements.

Permanent pools are of major importance to the ecology of the Light catchment; reductions in the current flow regime, and a decrease in the frequency of flushing, may further increase salinity levels in these pools. For this reason, water resource development should be controlled to minimise impacts.

In most of the catchment native riparian vegetation is missing or has been reduced to a narrow strip without understorey. Only pockets of remnant vegetation and important riverine habitat remain. The extent of reedbeds is believed to have significantly increased due to the loss of shading riparian vegetation and increased sedimentation.

The most ecologically valuable areas within the catchment were found along the Light River extending from the St Kitts Creek junction through to the estuary, which was found to be in excellent condition. These areas typically had more native riparian vegetation with a higher diversity than most other areas within the catchment. The Light River between the junction with St Kitts Creek and The Rockies also had numerous permanent waterholes and significant stretches of permanent flow, further increasing its ecological value.

The majority of other watercourses in the Light catchment have no or low densities of native riparian vegetation with little in-stream structural diversity. In ecological terms, most of these areas are in fair to poor conditions.

Weeds including African boxthorn (*Lycium ferocissimum*), wild artichoke (*Cynara cardunculus*), gorse (*Ulex europaeus*) and wild rose (*Rosa* spp.) are a problem along many watercourses throughout the catchment. Exotic trees were present in only a few small patches and do not represent a significant management issue at this stage.

The Light catchment is described as being in poor to fair condition for fish populations (Hicks and Sheldon 1999). Ten species were found within the catchment, seven of which were native. The estuary was the most diverse site, and had the healthiest populations of native fish, including salt water dependent species. If the estuary is excluded, exotic fish numbers account for 97.2% of all fish surveyed in the system.

The common jollytail was the most abundant and widespread native fish in the catchment above the estuary. It accounted for 1.1% of fish numbers above the estuary while the exotic eastern gambusia accounted for 96.9% of all fish numbers in the same area.

At present there is insufficient data on fish to pinpoint the exact cause of low abundance and diversity of native fish in the Light catchment. It is probably due to a number of factors including elevated salinity, loss of habitat and interaction with exotic species. Irregular migration flows connecting the estuary to upstream reaches (such as The Rockies), and barriers to migration (such as the Hamley Bridge weir) decrease the diversity of migration obligate species such as congolli. Further studies are required to determine the influence of flow regime and other environmental factors on fish in the catchment.

From the limited information available on fish and flows, it seems that flows are currently sustaining the small numbers of native fish throughout system. Fish populations appear to be in poor condition, which is likely to be due to loss of habitat and competition from the presence of high numbers of exotic fish. Also, the current flow regime does not appear to allow fish to have good breeding conditions regularly, however higher flow events will allow fish populations to recover in the years that they occur. Due to this, depending on location and timing, even small extractions have the potential to cause local extinctions.

In the Light River and its tributaries, 155 species of macro-invertebrates were recorded — lower than that recorded for comparable catchments such as the Broughton, Wakefield and Gawler. Venus et al. (2000) have suggested that this may be due to unsuitable flows, high salinity levels and lack of suitable habitat such as tall riparian vegetation.

It is possible that due to high salinity levels, which may be a natural feature, the Light catchment may have never contained a diverse macro-invertebrate population, and the lower number of families found may be a natural feature of the catchment.

The Light catchment provides habitat for a variety of frog species that have been monitored as a part of the annual EPA Frog Census. Most identified species are common and widespread across South Australia with the possible exception of Bibron's toadlet, the distribution of which is not well known.

Only small numbers of frogs have been recorded for the area during the Frog Census. This may suggest poor conditions for frogs or there may be seasonal variation in the frog populations that has not been detected from the September census (Walker, pers comm 2001). Additional surveys during other months would be valuable in answering these questions.

12.3 Management recommendations

The majority of watercourses in the Light catchment are in moderate to poor condition. Various locations within the catchment will degrade, or continue to degrade further, unless action is taken to address the management issues in those areas. Significant watercourse management issues and strategies have been discussed in detail in Chapter 7, and management priorities (ecological and community) and strategies have been discussed for each subcatchment in Chapters 8–11.

This section outlines recommendations for regional strategies for the management of watercourses within the Light catchment (Table 12.1). These are discussed in order from regional to local priorities, and suggest actions and key partners required to address these recommendations.

As stated in Section 12.1, natural resource management arrangements in South Australia are currently undergoing reform with the preparation of the NRM Bill. Once the Bill is passed, a Regional NRM Board will be formed covering the Northern and Yorke Agricultural Districts that will take over the responsibilities of existing animal and plant control boards, soil conservation boards, and the interim INRM Committee. The recommendations outlined below that relate to these groups will then become the responsibility of the newly formed NRM Board.

Investment strategies developed by the NYAD INRM Committee that relate to the recommendations outlined below are shown in parentheses next to the relevant management actions. Appendix F shows investment strategies for the NYAD INRM committee.

Table 12.1 Recommendations for watercourse management for the Light catchment and suggested partners

Regional recommendations	Partners*
1. Integrate stakeholder approaches to watercourse management in the Light catchment	All stakeholders
2. Develop management plans to control the impact of development on the health of the river system	NYAD INRM Committee, DEH (EPA), DWLBC, local government, Planning SA
3. Implement the watercourse management priorities and strategies identified in this management plan	NYAD INRM Committee, local government, soil conservation boards, general community, PIRSA, DWLBC, DEH
Targetted recommendations	**Partners***
4. Protect ecosystems of high ecological value	NYAD INRM Committee, local government, general community, DWLBC, DEH
5. Develop an exotic tree and weed control strategy targeting watercourses within the catchment	NYAD INRM Committee, animal and plant control boards, PIRSA, local government, DEH
6. Develop an integrated revegetation strategy that incorporates the plans of regional stakeholders	NYAD INRM Committee, PIRSA, Greening Australia, DEH
7. Develop guidelines to help stakeholders and landholders conduct watercourse management works	NYAD INRM Committee, local government, PIRSA, DWLBC, Planning SA, DEH
8. Develop management guidelines to assist stakeholders to assess and minimise the impacts of activities that impact on riverine environments	NYAD INRM Committee, PIRSA, DWLBC, DEH, Transport SA, local government
9. Develop a risk assessment strategy to identify potential point source and diffuse pollution impacts within the catchment	NYAD INRM Committee, EPA
10. Conduct further monitoring to adequately assess the resources and health of the Light River system	NYAD INRM Committee, DEH, DWLBC, PIRSA, EPA, SARDI, general community
11. Develop an eradication program for exotic fish	NYAD INRM Committee, PIRSA, SARDI, DWLBC

* DEH: Department for Environment and Heritage; EPA: Environmental Protection Authority; DWLBC: Department of Water Land and Biodiversity Conservation; PIRSA: Primary Industries and Resources South Australia; NYAD INRM Committee: Northern and Yorke Agricultural Districts Integrated Natural Resource Management committee; SARDI: South Australian Research and Development Institute.

Recommendation 1: Integrate stakeholder approaches to watercourse management in the Light catchment

An overall integrated approach is important to address the catchment scale issues threatening watercourse health. This approach must still consider subcatchment scale goals to the broader management goals for the entire catchment.

In the past a number of different organisations have had responsibilities that affect river management in the Light catchment, and the roles and responsibilities for river management have often been unclear and poorly understood. This has made it difficult to achieve a coordinated and integrated approach to water resource and watercourse management.

Landholders have indicated that a significant barrier to improved watercourse management is a lack of catchment management planning, and a lack of coordination and communication between organisations and individuals involved.

The NYAD INRM Committee (and future NRM Boards) has been established to address this issue with integrated NRM plans and well funded investment strategies.

It is important to include the community in watercourse management — keeping them informed of activities, involving them in decision making processes affecting catchment and subcatchment management, and forming partnerships between them and stakeholder groups in on-ground activities.

The formation of a steering group committee made up of stakeholders in watercourse management in the region will allow discussion on the activities and plans of the various groups, and will promote integration of activities and plans.

Action	Partners
Form a steering group committee from members of local stakeholders in watercourse management to integrate and coordinate actions for the Light catchment	NYAD INRM Committee, local government, soil conservation boards, animal and pest plant control boards, PIRSA

Recommendation 2: Develop management plans to control the impact of development on the health of the river system

Due to the limited flows in this river system, sites of high ecological value will occur in areas of permanent pools and lower lying wetland areas, such as around the entrances of tributaries rather than along greater lengths of the river system. Therefore, local impacts on the stream such as pollution events or water extraction could have significant implications for aspects of river ecology. This applies particularly to fish populations in the system; some areas may have relatively distinct populations due to the infrequency of flows suitable to allow migration, movement and reintroduction of fish.

Significant rainfall runoff flow events provide the greatest proportion of the flow volume in the catchment, and also stimulate the most significant ecological responses. The short duration of these flow events in the catchment is the greatest limiting factor for aquatic ecosystems. Surface flows within this range are of low salinity and have the potential to be targeted for development.

Also, recent investigations suggest that there may be an increased risk to geomorphological and ecological functions if flow statistics deviate from natural by more than 20–30% (Brizga 2000). As a general principle, the greater the deviations from the natural flow regime, the greater the risk of significant change.

Modelled flow data suggests that the current extraction rate is approximately 8%, however due to the short duration of ecologically significant high flow events it is essential to control developments that will impact on the water quality and quantity within the Light catchment.

Action	Partners
Control water resource development including damming and extraction from pools and groundwater Pay attention to areas in which water resource development is likely, such as the development of the wine industry in areas of Stockwell and St Kitts Creek	NYAD INRM Committee, Local government, DWLBC (6.1-v, vi, xiii, xiv, xv, xvi, xviii)*
Control agricultural and industrial developments that may pollute sensitive areas of the system (also see Recommendation 4)	NYAD INRM Committee, local government, EPA (6.2-v, xii, xvi, xvii, xviii; 7.2-xvii, xviii; 8.3-xxii)*

* Actions relate to NYAD INRM Committee investment strategies (Appendix F) as noted (NYAD INRM Committee 2003)

Recommendation 3: Implement the watercourse management priorities and strategies identified within the management plan

Catchment wide priorities and strategies for watercourse management are discussed in Chapter 7, and are discussed on a subcatchment scale in Chapters 8-11. The process of consultation has increased the awareness of watercourse management and management issues among the community and stakeholders. This should be followed up with the use of support programs to help implement on-ground works that are based on the priorities and strategies outlined in this plan.

To support the uptake of funds, technical advisers should be made available and known to landholders, and support should also be given to labour programs to help implement works. A possible avenue of this support is through corporate and industrial sponsors or partnerships.

Monitoring of these sites after the works have been completed is important to identify the success of the works, improvements that can be made either to the site or to the techniques used, and any threats of the works.

Action	Partners
Develop support programs to help implement management priorities: • funding to support on-ground works • a network of technical advisors • labour programs • corporate and industrial sponsorship and partnerships	NYAD INRM Committee, local government, PIRSA, animal and plant control boards, soil conservation boards
Implement priority watercourse management options as identified in Chapter 7, and on a subcatchment basis in Chapters 8-11	All stakeholders (6.1-ii, 6.2-iii)*
Monitor on-ground works to evaluate success, identify improvements and threats	All stakeholders (6.1-i; 6.2-ii; 6.3-i; 7.2-i, ii, iii; 8.1-i; 8.2-i, ii; 8.3-i, ii, iii, iv; 9.1-i, iii)*

* Actions relate to NYAD INRM Committee investment strategies (Appendix F) as noted (NYAD INRM Committee 2003)

Recommendation 4: Protect ecosystems of high ecological value

A number of sites have been found to have a high degree of ecological health or diversity. Without these sites the Light catchment's diversity and uniqueness would be significantly reduced. These sites are:

- the estuarine area;
- extensive riparian river red gum section between the estuarine area and The Rockies;
- Light River at The Rockies;
- areas of important riparian habitat and remnant vegetation between Hamley Bridge and Kapunda;
- areas of remnant small leaf honey myrtle between Hamilton and Hansborough;
- areas of remnant short leaf honey myrtle and baseflow in the lower Gilbert.

Threats to these areas need to be managed to ensure their ecological values is maintained. Threats include unrestricted livestock access, weeds and exotic trees, sediment input and changes to the flow regime. It is therefore important to integrate the watercourse management and environmental water requirement recommendations to effectively maintain these areas.

For more information on these areas see Map 7.1 for a catchment overview and Chapters 8–11 for subcatchment overviews.

Action	Partners
Protect ecosystems of high ecological value (identified above) by integrating watercourse management and environmental water requirement issues	NYAD INRM Committee, landholders, local government, DWLBC, DEH (heritage agreements) (6.1-ii; 6.2-ii)*

* Actions relate to NYAD INRM Committee investment strategies (Appendix F) as noted (NYAD INRM Committee 2003)

Recommendation 5: Develop an exotic tree and weed control strategy targeting watercourses within the catchment

Weeds within the riparian zone are a problem along significant areas of the Light catchment, and their removal and control is considered a high priority to the community. If left, infestations will spread and could threaten ecologically important areas of the catchment. Weed removal and control is recommended through these areas.

Small patches of exotic trees are found throughout the Light catchment. In these areas removal is recommended in a staged process coupled with revegetation to maintain bank stability and provide habitat.

Many sprays have adverse effects on the ecological systems associated with watercourses. The National Registration Authority approves chemicals for specific uses through the *Agricultural and Veterinary Chemicals Act 1994* (Cwlth).

There is a strong need for the development of guidelines for the management and control of weeds and exotic trees along watercourses. The current lack of any guidelines are a major barrier to appropriate practices being used for the control of pest plants (M Zwarts, Lower North Animal and Plant Control Board, pers comm 2001).

The animal and plant control boards act to control proclaimed weeds but there is no program in place that requires or acts to control weeds that may not be a significant threat to agricultural production but may be a serious threat to ecosystem health. It is important then to develop a strategy for controlling non-proclaimed ecological weeds throughout the Light catchment. This may involve sourcing funding, or gaining support from the Animal and Plant Control Commission.

A more detailed discussion on weeds and exotic trees as an issue can be found in Sections 7.4.3 and 7.4.4 respectively, and the locations of these species in the catchment is discussed in Section 5.5.1, as well as in the subcatchment Chapters 8–11.

Action	Partners
Develop strategies and promote methods of controlling weeds and exotic trees along watercourses	NYAD INRM Committee, Animal and plant control boards, Animal and Plant Control Commission, local government, DEH (9.1-v, viii, xiii, xiv, xvii, xviii, xx, xxi, xxiv, xxv, xxvi, xxvii)*

Action	Partners
Develop a strategy for the control of non-proclaimed ecological weeds such as wild rose along watercourses	NYAD INRM Committee, Animal and plant control boards, Animal and Plant Control Commission (9.1-viii, xiii, xiv, xvii, xviii, xx, xxi, xxiv, xxv, xxvi, xxvii, xxix)*

* Actions relate to NYAD INRM Committee investment strategies (Appendix F) as noted (NYAD INRM Committee 2003)

Recommendation 6: Develop an integrated revegetation strategy that incorporates the plans of regional stakeholders

A majority of the watercourses within the Light catchment have been cleared of riparian vegetation. This has resulted in many problems including loss of habitat, increased erosion, increased susceptibility to invasion of exotic plants and animals, increased growth of reeds due to lack of shading and increased input of sediment. Revegetation is recommended for areas lacking native vegetation.

Revegetation can also be an effective strategy for rehabilitating areas of poor bank stability and increasing the value of areas with good native overstorey that lack significant native understorey.

All stakeholders in revegetation need to be involved in an integrated approach to revegetation in the area if the greatest benefit is to be achieved for the effort put in and to ensure that priority areas are revegetated.

Action	Partners
Prioritise watercourse revegetation works based on the findings of this report. e.g. revegetate to control erosion, minimise sediment input, restore/improve ecological integrity	NYAD INRM Committee, PIRSA, Greening Australia, DEH (8.1-iii, iv)*

* Actions relate to NYAD INRM Committee investment strategies (Appendix F) as noted (NYAD INRM Committee 2003)

Recommendation 7: Develop guidelines to help stakeholders and landholders conduct watercourse management works

The initial community meetings held within the Light catchment revealed that a barrier for the community in better managing watercourses was a lack of knowledge on appropriate techniques. In light of this, a manual for watercourse management should be developed that discusses best and appropriate management practices for the watercourses within the region.

The manual would ideally include information on stock management, weed and exotic tree management, revegetation, bed and bank erosion, and property planning.

Action	Partners
Develop a watercourse management manual	NYAD INRM Committee, local government, PIRSA, DWLBC, Planning SA, DEH (8.1-xv)*

* Actions relate to NYAD INRM Committee investment strategies (Appendix F) as noted (NYAD INRM Committee 2003)

Recommendation 8: Develop management guidelines to assist stakeholders to assess and minimise the impacts of activities that may impact on the riverine environment

A number of different activities can have very significant detrimental effects on the riverine environment. Policies and guidelines need to be developed to better carry out riverine affecting activities, so as to minimise their impacts.

These policies and guidelines will ideally include information on activities that have direct impacts upon watercourse environments as well as those that have secondary impacts. Direct impact activities include dam construction (reduce flows), channel works such as excavation (can increase erosion), in-stream construction such as weirs (impede fish migration), vegetation removal including reedbeds (reduce ecological value and can cause erosion), and road ford construction (if done poorly, can cause erosion).

Secondary practices that will impact watercourses are mostly related to poor land management. Land management practices that will minimise impacts upon watercourses are the use of stubble retention and minimum tillage to minimise the volume and rate of surface runoff. This coupled with the restoration of vegetation buffer strips along watercourses will slow runoff and trap sediments and nutrients.

Action	Partners
Develop guidelines for best management practices for watercourse works (e.g. dam construction, watercourse excavation)	NYAD INRM Committee, local government, DEH, DWLBC, Transport SA
Develop guidelines for best land management practices to minimise impacts upon watercourses	NYAD INRM Committee, PIRSA, soil conservation boards, DEH (7.2-xv, xvi)*

* Actions relate to NYAD INRM Committee investment strategies (Appendix F) as noted (NYAD INRM Committee 2003)

Recommendation 9: Develop a strategy to identify potential point source and diffuse pollution impacts within the catchment

There are a number of potential sources of point source pollutants within the catchment, such as stormwater and wastewater from townships. As well as this, there is potentially significant input of diffuse source pollutants, such as sediments, pesticides and nutrients. All of these have the potential to significantly impact upon the physical and/or ecological features and processes of the watercourses within the catchment.

Action	Partners
Develop a risk assessment tool to determine the location of potential impacts of water quality on aquatic ecosystems in the catchment	NYAD INRM Committee, EPA (6.2-i)*

* Actions relate to NYAD INRM Committee investment strategies (Appendix F) as noted (NYAD INRM Committee 2003)

Recommendation 10: Further monitoring is required to adequately assess the resources and health of the Light River system

The project faced considerable information gaps in the production of this river management plan. To better manage the river system, it is important to increase certain aspects of our knowledge of the functioning of the system and this recommendation has several key monitoring actions. A table of key knowledge gaps that restrict our ability to effectively manage the system due to the lack of information can be found in Appendix E.

In order to determine whether environmental water requirements are being met and if flows are changing over time, it is important to monitor river flows. There is effectively only one gauging station at present, located at Mingays Waterhole, which only provides limited data on flows for the entire catchment. Two additional permanent gauging stations are required to monitor flow contributions from the Gilbert River and to quantify flows reaching the estuary. Three short-term stations are required to determine flow contributions from St Kitts Creek, the upper Light River (including flow from Tothill and Julia creeks) and the Light River upstream of Redbanks. Three water level loggers are recommended to determine flow height, duration and frequency in ecologically important areas. The results of this study indicate that these be located at Peters Road crossing, a site 3 km upstream of Hamley Bridge, and at Hamilton in the area of permanent pools and remnant short leaf honey myrtle. Finally a data level logger below Redbanks is recommended to assist in identifying and quantifying surface water to groundwater interaction and connectivity to the coast.

Very little is known about the groundwater system in the Light catchment and how it interacts with the watercourses in the area. At present there is little groundwater development, as salinity levels in most aquifers are too high for irrigation crops (M Cobb pers comm). However, the importation of water from outside the catchment area for irrigation purposes may increase groundwater levels and lead to potential salinisation problems.

Monitoring of the groundwater system should continue to determine what changes are occurring as management actions are put into place. This will determine their effectiveness and guide adaptation of these management recommendations so that they are more suitable in the future. One possible method of achieving this is through the development of an index of stream condition suitable for the characteristics of watercourses within the Mid North of South Australia.

The Monitoring River Health Initiative sampled macro-invertebrates at sites in the Light catchment and provided valuable information on the condition of the river in those areas. Macro-invertebrate survey programs should continue to be supported through the EPA and associated stakeholders.

Fish are an important component of inland water ecosystems and, although two separate surveys were conducted, there are still knowledge gaps of the fish distribution within the catchment. Very little is also known about the natural history of the fish populations that are known to exist within the catchment, particularly in terms of frequency of migrations to the estuary. The breeding biology of landlocked fish populations, particularly common jollytail, which usually migrates to the estuary to breed, is another unknown that needs to be understood to help make management decisions on water resource development that may affect this species.

There is very little known about the water quality of the system in all areas other than the Mingays Waterhole gauging station for which there are several years of data. The current minimal level of development does not necessitate development of an extensive water quality monitoring program. However, community monitoring programs such as Waterwatch would be very valuable in providing some level of water quality monitoring, while also playing an important role in community education.

Action	Partners
Install or upgrade additional and current gauging stations in the catchment to determine flow regimes including long-term and short-term gauging stations, as well as water level loggers Long-term gauging stations (rated weir and data logger) To measure continuous high resolution water level, flow, EC (salinity) and temperature data. **Lower Light River** A gauging station at a site between Port Wakefield Road and 5 km downstream would provide information on the flow connectivity between the Light River and the estuary. **Gilbert River** A gauging station at a site situated close to the junction of the Gilbert and Light rivers would provide information on the flow contributions of the Gilbert River to the Light River. Short-term gauging stations (rated weir and data logger) Minimum of 5 years recording subject to review. To measure continuous lower resolution water level, flow, EC (salinity) and temperature data. **St Kitts Creek** A gauging station at a site situated close to the junction of St Kitts Creek and the Light River would provide information on the flow contributions of St Kitts Creek to the Light River. **Upper Light River** A gauging station at a site situated downstream of the junction of the Light River and Julia Creek would provide information on the flow contributions of the Light River system above, and including, Julia Creek. **Light River upstream of Redbanks** A gauging station at a site situated at the downstream end of the permanent pools will help identify and quantify surface/groundwater interactions of the Light River on the coastal plains. Water level loggers Minimum of 5 years recording subject to review to measure the frequency and duration of the height component of flow; also recommend recording EC and temperature **Light River downstream of the Peters Road crossing** A water level logger would determine the flow characteristics at this ecologically important site which contains low-lying flooding areas, pools, riffles, and reedbeds and is potentially an important fish breeding area. **Light River at Hamilton** A water level logger would determine the flow characteristics at this ecologically important site which contains areas of remnant short leaf honey myrtle associated with pools, rockbars and reedbeds. This area is also the uppermost surveyed area in which a population of the native fish, the common jollytail (*Galaxias maculatus*) was observed. **Light River 3 km upstream of Hamley Bridge** A water level logger would determine the flow characteristics at this ecologically important site which contains low-lying flooding areas, pools, riffles and reedbeds, and is potentially a good fish breeding area.	NYAD INRM Committee, DWLBC (6.1-i)*

Action	Partners
Light River downstream of Redbanks A water level logger would assist in identifying and quantifying surface water to groundwater interaction and connectivity to the coast.	
Survey the groundwater systems within the catchment to determine interactions with watercourses, and monitor any long term trends in groundwater level and salinity	NYAD INRM Committee, DWLBC (6.3-i)*
Continue to support aquatic macro-invertebrate surveys to monitor watercourse health through the EPA and associated stakeholders	NYAD INRM Committee (8.1-i)*
Conduct research and additional surveys on the ecology and distribution of fish of the Light catchment	NYAD INRM Committee, DLWBC, SARDI (8.1-vi)*
Develop a program to review the health of the river system at 5–10 year intervals e.g. index of stream condition	DEH
Develop a Waterwatch program for the Light catchment	DEH (6.2-ii, xiv, xv)*

* Actions relate to NYAD INRM Committee investment strategies (Appendix F) as noted (NYAD INRM Committee 2003)

Recommendation 11: Develop a control and eradication program for exotic fish

Exotic fish, which were recorded throughout the catchment, can have serious detrimental effects on the aquatic environment by damaging aquatic habitat and out-competing native fauna.

Action	Partners
Develop a control and eradication program for exotic fish	NYAD INRM Committee, PIRSA, SARDI, DWLBC (9.1-iii, vii, xvi, xix, xxi, xxii, xxv, xxvii)*

* Actions relate to NYAD INRM Committee investment strategies (Appendix F) as noted (NYAD INRM Committee 2003)

12.4 Concluding remarks

This plan makes recommendations for watercourse management and outlines the environmental water requirements necessary to maintain or improve watercourse habitats and their ecosystem processes. The watercourse management priorities and options will form the basis of planning for on-ground action. They can be used by the community and key stakeholder organisations for both practical and strategic planning, and to set priorities for individuals or groups seeking funding for on-ground works.

An understanding was needed of the complexity of the river system, its condition, ecological processes and management issues for the development of this plan. In relation to baseline information, the data collected and analysed provides a ‘snapshot’ of the current condition of the river system. The field surveys and data analyses were completed within the scope of a one-year timeframe and the project budget.

The watercourse management priorities and options were developed based on the data collected and in consultation with local landholders and in this sense reflect both ecological and community priorities. The environmental water requirements have been identified and quantified through a process of field surveys and a scientific panel habitat assessment methodology. Further research and analysis are required to bolster our understanding of the Light River system. In particular, we need to understand better the long-term trends of the system.

The implementation of the recommendations for watercourse management and environmental water requirements will require flexible and adaptive management based on the monitoring of outcomes. In particular it is important to consider that there are a number of interacting elements that determine river condition. These include physical character, water quantity and quality, condition of the riparian zone and floodplain, and the diversity and population of plants and animals. Improved management of the Light River system therefore requires an integrated approach that combines flow, land and watercourse management.

Glossary

Adaptive management

A learning by doing approach often used in situations where there is little knowledge and/or complexity and there is a need to implement some management changes sooner rather than later; uses the best available information for initial management, implements the changes, monitors the outcomes and regularly evaluates and reviews management

Aerial video

Video footage taken using a video camera mounted on a small aircraft; used to observe and record the condition of major watercourses

Ambient water quality

The overall quality of water when all the effects that may impact upon the water quality are taken into consideration

Annual exceedence probability

The probability of exceeding a given flow rate within a period of one year; AEPs quoted have been derived from Log Pearson Type 3 distribution frequency analysis (annual series)

Aquatic macrophytes

Any non-microscopic plant that requires the presence of water to grow and reproduce

Aquifer

An underground layer of soil, rock or gravel able to hold and transmit water

AusRivAS

A rapid prediction system used to assess the biological health of Australian rivers. Australian River Assessment System.

Bankfull

The flow at which water just fills the primary flow channel without overtopping the banks

Bar

A temporary deposit of sediment within a stream channel that may be exposed during low water periods (Figure 2.1)

Baseflow

Stream flow that is not directly affected by rainfall but may be maintained by groundwater discharge

Bed

The horizontal part of a channel between the toes of the high banks

Bench

Bank attached feature aligned with the geometry of the channel formed by lateral accumulation of sands and gravels; usually lining both banks (Figure 2.1)

Biodiversity

The variety of life forms: the different plants, animals and micro-organisms, the genes they contain and the ecosystems they form; usually considered at three levels: genetic, species and ecosystem diversity

Biota

All of the organisms at a particular locality

Council of Australian Governments

A council that sets national policy directions for Australia; consists of the Prime Minister, state premiers, territory chief ministers and the President of the Australian Local Government Association

Detritus

Dead organic material (e.g. leaf litter) that usually accumulates on the bed of waterbodies

Electrical conductivity

1 EC unit = 1 micro-Siemen per centimetre (µS/cm) measured at 25°C; commonly used to indicate the salinity of water

Ecological processes

All processes whether biological, physical or chemical that maintain the ecosystem

Ecological values

The natural ecological processes occurring within ecosystems and the biodiversity of these systems

Ecosystem

A biological system involving interaction between living organisms and their immediate physical, chemical and biological environment

Endemic

A plant or animal restricted to a certain locality or region

Environmental water provisions

That part of environmental water requirements that can be met; what can be provided at a particular time after consideration of existing users' rights, and social and economic impacts

Environmental water requirements

Descriptions of the water regimes needed to sustain the ecological values of aquatic ecosystems at a low level of risk; developed by applying scientific methods and techniques, or local knowledge based on many years of observation

Ephemeral

Temporary or intermittent, for example a creek that dries up during summer and flows in winter

Faecal coliform

A minute micro-organism occurring in the intestines of warm blooded animals; used as an indicator of faecal contamination in water

Flood runners

A generally straight channel that occurs on the floodplain and only carries water during floods

Floodplain

Land adjacent to streams that is regularly flooded; often includes seasonal and perennial wetlands (Figure 2.1)

Flow regime

The character of the timing and amount of flow in a stream

Flow weighted water quality sampling

Sampling based on measurement during flow events rather than measurement at specific times

Geomorphology

Study of landform and landscape development and function

Habitat

The natural place, and its physical and biological properties, where an animal or plant, or communities of plants and animals live

Hydraulic jump

Abrupt turbulent rise in the water surface caused by an obstruction or change in slope of the streambed

Hyporheic zone

Zone beneath the stream bed within which a complex of microscopic animals occur

Incised channel

A channel that has eroded its bed to the point where high banks are formed

Indigenous plant species

Plant species native to an area, i.e. that have not been introduced from another area

Lateral bar

A sediment deposit that develops adjacent to the stream bank

Levee

An artificial or natural linear ridge on a floodplain designed to hold back floodwater (Figure 2.1)

Life history

The history of changes undergone by an organism from inception or conception to death

Longitudinal stream profiles

Plot of the elevation of the channel bed, banks and water level versus horizontal distance

Macro-invertebrates

Animals without backbones typically of a size visible to the naked eye; aquatic macro-invertebrates are an important part of aquatic ecosystems

Macrophyte

A non-microscopic plant

Median (or 50th percentile)

In an ordered distribution from highest to lowest, the value that has an equal number of events occurring above and below it; an indicator of the central tendency of the data

Monitoring River Health Initiative

A subprogram of the National River Health Program that provides a means of assessing the ecological condition of rivers and streams by using macro-invertebrates

Overstorey

Woody plants > 5 m tall, usually single stemmed

Percentile

The percentage of observations in a distribution that occur lower than or equal to a given value

Permanent pools

Pools of water in watercourses that are continually fed by groundwater discharge throughout the year

Point bar

A sediment deposit that develops on the inside of a bend

Pool

A deep body of still or slow moving water held back in a stream by a downstream control such as a bedrock or gravel bar (Figure 2.1)

Prescribed water resources

Water resources declared by regulation that can only be accessed by those in possession of a licence to take water issued by the Minister for Environment and Conservation; allocated according to a water allocation plan

Recruitment

Movement into an adult population usually by juveniles through breeding events but also through migration

Reed

A plant of the taxa: Typha, Phragmites, Juncus ignens and Eragrostis australasica

Riffle

Shallow, often stony areas, in streams that have rapid turbulent flow; these highly oxygenated areas are important habitat for macro-invertebrates (Figure 2.1)

Riparian

Pertaining to or situated on the banks of a watercourse (Figure 2.2)

River health

Capacity of the river ecosystem to sustain a normal and diverse suite of organisms and ecological processes

Run

Sections of streams that are channel like with an approximately constant width and depth (Figure 2.1)

Rush

Aquatic or semi-aquatic plants of the Juncaceae family; mostly tall and leafless with branching flower heads

Seasonal flows

River flows that occur on a seasonal basis, usually over the winter–spring period, although there may be some flow or standing water at other times

Sedges

Aquatic and semi-aquatic plants of the family Cyperaceae; mostly perennial grasses or rush-like herbs; common types include club-rush, bog-rush and sword-sedge

Sedimentation

The long-term filling of a stream channel, lake or estuary with sediment

State Water Plan

Policy document that sets the strategic direction for water resource management in the State and policies for achieving the objects of the Water Resources Act 1997; its contents are defined by the Act

Stream order

Used to indicate the size and flow of watercourses; under the system adopted in this report (the Strahler system) unbranched watercourses originating at a source are termed first order; when two watercourses of the same order join, a stream of that order +1 is formed

Terrace

A flat land surface above the general level of a stream's floodplain; usually the remains of an old floodplain or bed

Tributary

A river or creek that flows into a larger river

Understorey

Woody plants < 5 m tall, frequently with many stems rising at or near the base

Vegetation associations

A large climax community named after the dominant types of plant species

Water allocation plans

Plans developed by a catchment board or water resources planning committee that describe how water from a prescribed water resource will be allocated to licensed water users; must be developed through the consultation process specified in the Water Resources Act 1997

Water dependent ecosystems

Those parts of the environment in which the species composition and natural ecological processes are determined by the permanent or temporary presence of flowing or standing water; e.g. the in-stream areas of rivers, riparian vegetation, springs, wetlands, floodplains and estuaries

Sources: ARMCANZ and ANZECC (1996); Tootill (1984); Boulton (1999), Kapitske et al (1998)

Abbreviations

AEP	Annual Exceedence Probability
ANZECC	Australian and New Zealand Environment and Conservation Council
ARI	Average Recurrence Interval
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AusRivAS	Australian River Assessment System
COAG	Council of Australian Governments
Cumec	Cubic metres per second
DEH	Department for Environment and Heritage
DWLBC	Department of Water, Land and Biodiversity Conservation (formerly Department for Water Resources)
DWR	Department for Water Resources
EC	Electrical Conductivity
EPA	Environment Protection Authority (formerly Environment Protection Agency)
EWR	Environmental Water Requirement
GIS	Geographic Information System
GPS	Global Positioning System
IBI	Index of Biotic Integrity
IGA	Intergovernmental Agreement
INRM	Integrated Natural Resource Management
LWRRDC	Land and Water Resources Research and Development Corporation
MNRMPP	Mid North Rivers Management Planning Project
MRHI	Monitoring River Health Initiative
NYAD INRM	Northern and Yorke Agricultural Districts Integrated Natural Resource Management committee
NLWRA	National Land and Water Resources Audit
PIRSA	Primary Industries and Resources South Australia
STEDS	Septic Tank Effluent Disposal Schemes

References

Allen, GR. 1989. *Freshwater fishes of Australia.* Tropical Fish Hobbyist Publications, Neptune City.

ANZECC and ARMCANZ. 2000. *Australian and New Zealand guidelines for fresh and marine water quality*. National Water Quality Management Strategy Paper No 4. Australian and New Zealand Environment and Conservation Council, and Agriculture and Resource Management Council of Australia and New Zealand.

ARMCANZ and ANZECC. 1996. *National principles for the provision of water for ecosystems*. Occasional paper SWR No. 3, Sustainable Land and Water Resource Management Committee, Canberra.

Arthington, AH. 1998. *Comparative evaluation of environmental flow assessment techniques: Review of holistic methodologies.* Occasional Paper 26/98. Land and Water Resources Research and Development Corporation, Canberra.

Bell, I and Priestley, T. 1998. *Management of stock access to the riparian zone.* Department of Primary Industries, Water and Environment, Tasmania.

Boulton, A. 1999. Research interests. <www.ecoman.une.edu.au/aboulton/researchinterests.html>

Boulton, AJ and Brock, MA. 1999. *Australian freshwater ecology: processes and management*. Gleneagles Publications, Glen Osmond SA.

Brierley, GJ, Fryirs, K and Cohen, T. 1996. A geomorphic approach to catchment characterisation. *In* GJ Brierley, K Fryirs and T Cohen (eds), *Geomorphology and river ecology in south eastern Australia: An approach to catchment characterisation*. Graduate School of the Environment Working Paper 9603. Macquarie University, Sydney.

Brizga, SO. 2000. Burnett Basin WAMP: Proposed Environmental Flow Performance Measures. Department of Natural Resources, Brisbane.

Brizga, SO. 2001. *Light river system geomorphology and environmental water requirements.* Unpublished report to the Department for Environment, Heritage and Aboriginal Affairs, Adelaide.

Brown, W and Kraehenbuehl, D. 2000. *Riparian rehabilitation and revegetation in the Light catchment.* Unpublished report to the Department for Environment, Heritage and Aboriginal Affairs. PIRSA, Adelaide.

Canfield Jr, DE and Hoyer, MV. 1988. Influence of nutrient enrichment and light availability on the abundance of aquatic macrophytes in Florida streams. *Canadian Journal of Fisheries and Aquatic Sciences*, 45, 1467–72.

Carr, G, Lord, R and Seymour, S. 1999. Rehabilitation of disturbed stream frontages using natural vegetation templates — A case study on the Yarra River, Victoria. *In* I Rutherford and R Bartley (eds), *The challenge of rehabilitating Australia's streams: Proceedings of the Second Australian Stream Management Conference*, 8–11 February 1999. Cooperative Research Centre for Catchment Hydrology, Adelaide.

Carter, J. 1995. *Watercourse processes: A guide for watercourse managers in the Mount Lofty Ranges.* Water Resources Group, Department of Environment and Natural Resources, Adelaide.

Davies, PM and Bunn, S. 1999. Restoring fundamental ecological processes in small, forested upland streams: The importance of riparian vegetation. *In* I Rutherford and R Bartley (eds), *The challenge of rehabilitating Australia's streams: Proceedings of the Second Australian Stream Management Conference*, Adelaide, 8–11 February 1999. Cooperative Research Centre for Catchment Hydrology, Adelaide.

Department of Environment and Natural Resources. 1997a. *Torrens 1997 — An action plan for better water course management*. Riparian Zone Management Project, DENR, Adelaide.

Department of Environment and Natural Resources. 1997b. *A watercourse management action plan for the Onkaparinga River catchment*. Riparian Zone Management Project, DENR, Adelaide.

Department for Water Resources and State Water Plan Steering Committee. 2000a. *State Water Plan 2000. South Australia, Volume 1: Policies for a sustainable future*. Department for Water Resources, Adelaide.

Department for Water Resources and State Water Plan Steering Committee. 2000b. *State Water Plan 2000. South Australia, Volume 2:* . Department for Water Resources, Adelaide.

Department of Land and Water Conservation. 1992 *Estuary management manual*, New South Wales Government, Sydney.

Environment Protection Agency. 1998. Water monitoring report: Ambient water quality monitoring of South Australia's rivers and streams: Report No. 1. Environment Protection Authority, South Australia.

Evans, TD. 1994. Report on groundwater investigation in the Tothill Creek catchment for the Tothill Landcare Group. Department of Primary Industries South Australia, Adelaide.

Fletcher, A. 1986. *Effects of introduced fish in Australia*. *In* P DeDecker and WD Williams (eds), *Limnology in Australia*, pp 231–238. CSIRO, Melbourne.

Gooderham, J and Jerie, K. 1999. An introduction to stream ecosystems. In ID Rutherford, K Jerie and NA Marsh (eds) *A rehabilitation manual for Australian streams; Volume 1.* Land and Water Resources Research and Development Corporation, Canberra, and Co-operative Research Centre for Catchment Hydrology, Melbourne.

Hammer, M. 2001. *Field data for additional sites in the Light River catchment.* Unpublished report to the Department for Environment, Heritage and Aboriginal Affairs, Adelaide.

Harris, JH. 1995. The use of fish in ecological assessments. *Australian Journal of Ecology*, 20, 65-80.

Hatton, T and Evans, R. 1998. *Dependence of ecosystems on groundwater and its significance to Australia*. Occasional Paper No. 12/98. Land and Water Resources Research and Resources Development Council, Canberra.

Hicks, D and Sheldon, F. 1999. *Biotic survey of the Light River*. Unpublished report to the Department for Environment, Heritage and Aboriginal Affairs, Adelaide.

Kapitzke, IR, Pearson, RG, Smithers, SG, Crees, MR, Sands, LB, Skull, SD and Johnston, AJ. 1998. *Stream stabilisation for rehabilitation in North-East Queensland*, Land and Water Resources Research and Development Corporation, Canberra.

Karr, JR and Dudley, DR. 1981. Ecological perspectives on water quality goals. *Environmental Management*, 5, 55–68.

Koehn, JD and O'Connor, WG. 1990. *Biological information for management of native freshwater fish in Victoria*. Department of Conservation and Environment, Melbourne.

Lake, JS. 1978. Australian freshwater fishes: An illustrated field guide. Nelson, Melbourne.

Leopold, LB and Wolman, MG. 1957. *River channel patterns — braided meandering and straight.* Professional Paper 282B. US Geological Survey, Washington DC.

Lloyd, LN. 2001. *Report on the environmental water requirements and ecology of the Light River, SA*. Unpublished report to the Department for Environment and Heritage, Adelaide.

Lower North Soil Conservation Board. 2001. *Lower North Soil Conservation Board district plan*. Department of Primary Industries South Australia, Adelaide.

LWRRDC. 2000. *A rehabilitation manual for Australian streams*. Land and Water Resources Research and Development Corporation, Canberra.

McDowell, RM (ed). 1980. Freshwater fishes of south-eastern Australia. Reed, Sydney.

McDowell, RM (ed). 1996. *Freshwater fishes of south-eastern Australia* (2nd ed). Reed, Sydney.

McEvoy, P and Madden, C. 1999. *Determination of environmental flow requirements of the macroinvertebrate fauna of the Gawler River*. Unpublished report to the Department for Environment, Heritage and Aboriginal Affairs, Adelaide.

Merrick, JR and Schmida, G. 1984. *Australian freshwater fishes: Biology and management*. Griffin Press, Netley SA.

Murdoch, B. 2001. *Light River environmental water requirements: hydrology.* Department of Water, Land and Biodiversity Conservation.

Murray, R, Latchford, JA and McComb, AJ. 1995. Water regimes and marsh distribution. In AJ McComb et al. (eds), Samphire marshes of the Peel-Harvey estuarine system, Western Australia. Murdoch University, Perth.

Myers, R. 1999. The ABC of riparian plants: The importance of native, regional aquatic plants in stream rehabilitation. *In* I Rutherford and R Bartley (eds), *The challenge of rehabilitating Australia's streams: Proceedings of the Second Australian Stream Management Conference,* 8–11 February 1999. Cooperative Research Centre for Catchment Hydrology, Adelaide.

National Land and Water Resources Audit. 2000. Australian Water Resources Assessment 2000, National Land and Water Resources Audit. Natural Heritage Trust, Canberra.

Northern and Yorke Agricultural District INRM Committee Inc. 2003. Integrated Natural Resource Management Plan for the Northern and Yorke Agricultural District. Northern and Yorke Agricultural District INRM Committee Inc.

Pen, LJ. 1999. Managing our rivers: A guide to the nature and management of the streams of southwest Western Australia. Water and Rivers Commission, Perth.

Pollard, DA. 1971. The biology of a landlocked form of the normally catadromous salmoniform fish *Galaxias maculatus* (Jenys). I. Lifecycle and origin. *Australian Journal of Marine and Freshwater Research*, 22(1), 91-123.

Rose, TH and McComb, AJ. 1995. The ecological significance of saltmarshes to the Peel-Harvey estuarine system. In AJ McComb et al. (eds) *Samphire marshes of the Peel-Harvey estuarine system*, *Western Australia*. Murdoch University, Perth.

Rutherford, I, Jerie, K and Marsh, N. 1999. *A rehabilitation manual for Australian stream*s. Land and Water Resources Research and Development Corporation, Canberra and Cooperative Research Centre for Catchment Hydrology, Melbourne.

Soil Conservation Council. 2001. The Lower North Soil Conservation Board District Plan 2001. PIRSA, Adelaide.

Strahler, AN. 1964. Quantitative geomorphology of drainage basins and channel networks. In VT Chow (ed), *Handbook of applied hydrology,* pp 4–39. McGraw-Hill, New York.

Thoms, M. 1998. *Environmental flows.* Paper presented at CRCFE-AWWA Catchment Management Course. CRC for Freshwater Ecology and Australian Wastewater Association, Canberra.

Tootill, E. 1984. *Penguin dictionary of biology*. Penguin Books, London.

Venus, T, McEvoy, P, and Madden, C. 2000. *Determination of environmental water requirements of the macroinvertebrates in the Light River catchment*. Unpublished report to the Department for Environment, Heritage and Aboriginal Affairs, Adelaide.

Young, WJ (ed). 2001. *Rivers as ecological systems: The Murray-Darling Basin*. Murray–Darling Basin Commission, Canberra.

Zaret, TM. 1980. *Predation and freshwater communities*. Yale University Press, New Haven USA.

Acknowledgements

The Mid North Rivers Management Planning Project team – Glen Scholz, Jason VanLaarhoven, Laura Phipps, and Diane Favier – thanks the following people for their contribution to the project. Their assistance, advice and enthusiasm have been greatly appreciated.

The members of the Scientific Panel: Dr Sandra Brizga, Lance Lloyd, Chris Madden, Paul McEvoy, Michael Hammer, Bruce Murdoch, Steven Walker, and Peter Goonan.

The members of the Project Reference Group: Peter Gill (soil conservation boards); Phyllis Robinson (local government); Ben Coventry (animal and plant control boards); Jon Cameron-Hill (Clare Valley Water Resources Planning Committee); Mary-Anne Young (Primary Industries and Resources, SA); and Laurie Poppleton (Department of Water, Land and Biodiversity Conservation).

Saideh Kent (Community Landcare); Dave Clarke, Andrew Love and Nabil Gerges (Department of Water, Land and Biodiversity Conservation); Michael Cobb (Water Search Pty Ltd); Anne Brown (Greening Australia); Lee Heard (Planning SA); Lynette Reichstein (Light Regional Council); Scott Gillett (Primary Industries and Resources, SA); David Laws (Lower North Soil Conservation Board); and Sarah Heaslip (Broughton and Wakefield Waterwatch).

The individuals and landholders who provided information, established monitoring sites and/or allowed access for field sampling: Marcus Possingham; Hugh Tily; Ian Nairn; Jo and Chris Abell; Andrew Scholz; Roger Finch; G. Schmael and M. Williams amongst many others.

APPENDIX A – GEOMORPHOLOGY

This appendix provides an overview of links between geomorphology and flows in the Light catchment based on work of Brizga (2000).

Table A.1 outlines key linkages between geomorphology and flow. It shows the important functions of key flow bands with relation to geomorphology and hydraulic habitat maintenance, along with relevant hydrological criteria and reasons for significance.

The optimum duration and frequency of relevant flows have not been identified. This is because these parameters cannot be identified without reference to natural duration and frequency, or some other benchmark level. There is no single optimum duration and frequency for any particular process (e.g. erosion or sediment transport) that would be applicable for all types of watercourses.

Tables A.2 and A.3 outline key flow related geomorphological functions relevant for each geomorphic zone in the Light catchment.

Table A.1 Links between geomorphology and flows in the Light catchment

Function	Key flow bands	Relevant hydrological criteria	Significance
Maintenance of wetted habitat (low flow habitats such as riffles, rock bars and macrophyte beds) — these habitats are important for maintaining connectivity between pools, and sustaining aquatic biota	Low to medium flows determine the wetted habitat conditions that prevail for the majority of the time. However, high flows are likely to be important for channel and substrate maintenance.	Change in the magnitude–duration of low and medium flows. This can be quantified in a number of different ways, including change in daily exceedance duration for flows of specific depths or wetted perimeters, or change in flow magnitudes for specific daily exceedance duration (e.g. 90%, 80%, 50% of days in a nominated period).	Related to the extent and hydraulic character (e.g. depth, velocity) of wetted habitat
		Change in the duration of no flow	Related to the length of time for which wetted habitat occurs
		Change in the number and length of spells of low and no flow	Related to the length of time for which wetted habitat occurs
Maintenance of wetted habitat (pools) — pools provide habitat for aquatic biota and are important refuge areas when flows cease	The whole water balance is important, not just flow. Flows of all magnitudes contribute to pool filling. Flow sequencing is important (e.g. the length of zero flow spells may affect the likelihood of pool dry-outs, notwithstanding interactions between pool levels and groundwater).	Change in flow volumes	Affects pool water balances — reduced flow volumes may mean increased likelihood of dry-outs
		Change in the number and length of spells of no flow	Affects pool water balances — an increase in the number and/or length of no flow spells may mean that pools are more likely to dry out
Channel maintenance — this function is important for maintaining the physical structure of the river and stream channels, and habitats within them	High flows are important, including bankfull discharge and the 1:1.5 to 1:2 AEP flow (this flow is commonly the bankfull discharge in alluvial rivers, and in rivers with larger channels there is often a bench corresponding to this level). Flows larger than bankfull may also be important if they are confined on top of the channel or in the near-channel area.	Change in the frequency of bankfull discharge, as well as the 1:1.5 or 1:2 AEP flood if bankfull discharge is significantly larger, and larger flows where they are confined on top of the channel or in the near-channel area	If the frequency of channel-maintaining flows is reduced, increased vegetation encroachment into the channel and channel contraction may occur

Function	Key flow bands	Relevant hydrological criteria	Significance
Maintenance of riffle substrate — some biota associated with riffles live on clear rocks, others in the interstitial voids. Fine sediment and organic material may accumulate on riffles during low flow periods. Unless this fine sediment is periodically removed, a loss of habitat will occur.	High flows remove fine sediments from riffle surfaces and interstices. For this to occur, flow velocity/tractive force on the riffle surface needs to be sufficiently high to entrain the substrate.	Change in the frequency of floods exceeding sediment entrainment thresholds for the channel substrate	Affects the frequency of substrate entrainment. A reduction in the frequency of floods exceeding sediment entrainment thresholds means a reduction in the frequency of removal of fines from the riffle surface and therefore likely increased silting of the riffles
Scouring of pools — pools are subject to progressive infill with organic matter and sediment during low to medium flow periods. Flushing and scouring of this material by high flows is likely to be significant for pool maintenance, at least in some areas	Large floods may potentially scour out pools, depending on local hydraulic conditions.	Change in the frequency of large floods (e.g. 1: 20 year AEP)	A reduction in the frequency of large floods may mean a reduction in the frequency of pool scouring.
Bank erosion — this is natural process. Natural bank erosion processes are integral natural process in the development of meandering alluvial rivers. Bank undercuts and vertical cliffs provide habitats for some biota (e.g. bird nests in vertical faces). Bank erosion process may cause management problems in settled areas, if conflicts with other land uses arise. Also, if the riparian zone has been reduced to a line of trees, undermining of remnant trees by natural bank erosion processes can lead to riparian zone degradation.	Medium and high flows are likely to be important. Key processes include wetting of the bank and removal of sediment from the toe of the bank.	Change in the frequency and duration of medium and high flows	Reduced frequency of medium and high flows may mean reduced bank erosion rates due to reduced removal of sediment from toe of bank. However, if channel contraction occurs, the increase in hydraulic loadings resulting from the confinement of flows may counterbalance this, or even lead to increased rates of bank erosion.
		Flood recession rates	Increased flood recession rates (e.g. sudden fall in water levels due to pumping on flood recession) may lead to increased risk of bank erosion

Function	Key flow bands	Relevant hydrological criteria	Significance
Gully head erosion, stream incision — these processes are generally considered to be undesirable from a watercourse management viewpoint, because of damage/loss of infrastructure, loss of riparian vegetation, in-stream habitat alteration, and downstream sediment inputs	High and possibly medium flows are likely to be the most important. Studies elsewhere have shown that erosion head retreat generally occurs in floods.	Change in frequency and duration of medium and high flows	A reduction in the frequency and/or duration of medium or high flows may mean a reduction in the rate of gully retreat.
Tributary incision — this process is generally considered to be undesirable from a waterway management viewpoint, because of damage/loss of infrastructure, loss of riparian vegetation, in-stream habitat alteration, and downstream sediment inputs	Synchronicity of flows between the main stream and its tributaries	Change in flow regime seasonality Change in the frequency of a range of floods (e.g. 1:1.5, 1:5 and 1:20 AEP) in the main stream	Desynchronisation of flood events between a main stream and its tributaries may result in tributary incision due to lowered base level.
Sediment transport — the transport of sediment from catchment source areas to the sea is an important function of river systems in relation to natural geochemical cycles. Sediment loads in the Light catchment appear to have been elevated as a result of historical and present catchment and in-stream erosion processes.	Flows which exceed sediment entrainment and transport thresholds. Actual key flow magnitudes will depend on sediment sizes (e.g. medium to high flows for sand, high flows for gravel). In terms of total volumes of sediment transported, large floods are of key significance because they generally transport the largest volumes of sediment	Change in the frequency and duration of competent flows (i.e. flows exceeding sediment entrainment thresholds). In the absence of information regarding competent flows, a range of medium and high flows should be examined.	Reductions in the frequency and duration of competent flows indicate likely reductions in sediment transport
Sediment delivery to the estuary — the Light catchment is natural source of sediment to the Light River estuary.	High flows generally transport the greatest proportion of the total sediment load.	Change in the frequency and duration of high flows.	A reduction in flood frequency and duration means a reduction in the overall sediment transport capacity, and therefore potentially reduced sediment delivery to the estuary.

Function	Key flow bands	Relevant hydrological criteria	Significance
Avulsion — this is part of the natural floodplain development process in alluvial rivers with wide floodplains. In settled areas, avulsions can cause significant disruption to human activities (e.g. land tenure, land use, communications infrastructure).	Overbank flows, especially major floods are important (the key factor is the erosiveness of flows over the floodplain surface and in overflow channels). Channel maintenance flows are also relevant.	Change in the frequency of large overbank floods (e.g. 1:20 AEP and catastrophic* floods). Change in the frequency and/or duration of channel maintenance flows.	Reduced frequency of large floods may reduce rates of development of avulsions. Reduced channel maintenance flows may lead to loss of channel capacity, therefore increased overbank flows and increased likelihood of avulsion.

* Catastrophic floods are associated with major erosion/sedimentation events. Annual exceedance probabilities (AEPs) for these types of floods in specific parts of the Light River system have not been identified.

Table A.2 Key flow-related geomorphological functions, by zone (refer to Map 5.4)

(a) Light River

Key function	Zone 1 Light River (estuary)	Zone 2 Light River	Zone 3 Light River	Zone 4 Light River	Zone 5 Light River	Zone 6 Light River	Zone 7 Light River	Zone 8 Light River	Zone 9 Light River
Maintenance of wetted habitat (low flow control habitats such as riffles, rock bars and macrophyte beds)		✓	✓	✓	✓	✓	✓	✓	✓
Maintenance of wetted habitat (pools)		✓	✓	✓	✓	✓	✓	✓	✓
Scouring of pools		✓	✓	✓	✓	✓	✓	✓	✓
Removal of fines (riffles, rock bars)		✓	✓	✓	✓	✓	✓	✓	
Sediment delivery to the estuary	✓								
Sediment transport		✓	✓	✓	✓	✓	✓	✓	✓
Channel maintenance	✓	✓	✓	✓	✓	✓	✓	✓	✓
Avulsion		✓[3]				✓			
Bank erosion[1]		✓	✓						
Tributary incision[2]		✓	✓	✓	✓	✓	✓	✓	✓

[1] Bank erosion is identified as a key function in zones where it is important for maintenance of the natural channel morphology

[2] Tributary incision is a process that is generally considered to be undesirable from a waterway management viewpoint (reasons include damage/loss of infrastructure, loss of riparian vegetation, in-stream habitat alteration and downstream sediment inputs)

[3] There is no evidence to suggest that any avulsion is currently in progress in Zone 2; however, palaeochannel traces indicate that avulsions have occurred prehistorically

Table A.3 Key flow-related geomorphological functions, by zone (refer to Map 5.4)

(b) Tributaries

Key function	Zone 10	Zone 11	Zone 12	Zone 13	Zone 14	Zone 15	Zone 16	Zone 17	Zone 18	Zone 19	Zone 20
	Gilbert River	Gilbert River	Macaw Creek	Ross Creek	Allen Creek	St Kitts Creek	Stockwell Creek	St Kitts Creek tributary	Eastern hill tributaries	Julia Creek	Tothill Creek
Maintenance of wetted habitat (low flow control habitats such as riffles, rock bars and macrophyte beds)	✓				✓	✓				✓	✓
Maintenance of wetted habitat (pools)	✓	✓	✓	✓					✓	✓	✓
Scouring of pools	✓	✓	✓	✓	✓	✓			✓	✓	✓
Removal of fines (riffles)	✓				✓	✓			✓	✓	✓
Sediment delivery to the estuary											
Sediment transport	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Channel maintenance	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Gully head erosion, stream incision [1]					✓	✓	✓	✓	✓	✓	✓
Tributary incision[2]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

[1] Gully head erosion and stream incision are functions that are driven by flow; generally these processes are considered to be undesirable from a watercourse management viewpoint (reasons include damage/loss of infrastructure, loss of riparian vegetation, in-stream habitat alteration and downstream sediment inputs)

[2] Tributary incision is a process that is generally considered to be undesirable from a waterway management viewpoint (reasons include damage/loss of infrastructure, loss of riparian vegetation, in-stream habitat alteration and downstream sediment inputs)

APPENDIX B – EWR SITE SPECIFIC TABLES

The following tables (B.1–B.21) outline the recommended environmental water requirements for each geomorphic zone in the Light catchment (Map 5.4). Information in these tables is based upon current knowledge of geomorphological and ecological responses to flows (Brizga 2000; Lloyd 2001) and surveys conducted at representative sites for each geomorphic zone in the Light catchment. A simplified discussion of key flow bands for each zone can be found in the subcatchment Chapters 8–11.

These tables can be used as a basis to:

- set up hypotheses to test assumptions regarding the environmental water requirements of biota and geomorphological processes;
- assess the ecological impacts of changes in flow regime due to water resource development;
- monitor the ecological and geomorphological responses to various flow regimes.

Each table below presents the EWR's for a given geomorphic zone as surveyed at a specific representative site within that zone. The tables present key flow bands, a description of that flow band and key ecological and geomorphological functions followed by frequency, duration and seasonality. The tables do not provide a complete description of all flows but rather flow bands that have been identified as critical for an understanding of environmental water requirements. These indicators can be used for assessing the ecological implications of flow regime change resulting from proposed water resource development.

The key functions (indicated in bold type) have been determined as the functions that have the most critical ecological and geomorphological flow requirements within that particular flow band, and have been listed in order of ecological importance. For example, for the low flow band in Zone 1 it is assumed that if the flow requirements allocated for the survival of fish communities are met then the requirements of all macrobiota dependent on rivers will generally be accommodated (Cambray et al. 1989 in Hicks and Sheldon 1999). For the catastrophic flows in Zone 1 the key functions are geomorphological, the structural maintenance of the river channel.

The following text symbols in the frequency columns represent the key functions for that flow band based on flow requirements of flora and fauna shown in Appendix C and geomorphological flow requirements in Appendix A.

Fi — Fish

V — Vegetation

M — Macro-invertebrate

G — Geomorphological

The following terms in the frequency and duration columns represent a range of flow regimes that influence biotic population responses over the short and long term:

Optimum — flow regimes that ensure the population growth of a species.

Minimum — flow regimes that enable short-term survival but if applied over longer time periods will result in species decline, possibly leading to extinction within the system.

Sustaining — flow regimes that will maintain a population.

While an attempt has been made to simplify the tables by indicating the key functions linked to a particular flow band, often a particular function may be significant within a number of different flows. For example, sediment transport is mainly driven by the larger flows but other flows will also have an influence. Similarly the functions of different flow bands will change depending on the form of the channel. A flow that is bankfull in a zone with a shallow channel and wide floodplain may be a mid flow in a narrow, deeply incised channel. The assumptions in the tables below are related to the specific site described and do not necessarily apply to the whole geomorphic zone represented.

The lack of flow gauging for most of the catchment means that most of the specified frequencies and durations have not been verified against recorded flow data to see if they actually occur under natural conditions. Relating the recorded flow data to the water requirement tables has only been possible for two sites, zone 6 site 3, and zone 7 site 4. This information has been extrapolated from the Kapunda and Mingays Waterhole gauging stations and should not be considered definitive.

Cross-sections have been conducted for zones 2, 6, 7, 8 and 10 (Figures B.1–B.5, Map 5.4). For the tables relating to these sites, additional information is presented on flow heights and estimated flow volumes.

The specifications within these tables will allow hypothesis testing and require further modification as new knowledge becomes available through research and monitoring.

Table B.1 Zone 1: Light River, estuary; Site: downstream of estuarine area weir

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Tidal flow	Inundates tidal channels, flows vary with tidal movement	• **Flow transports sediments and nutrients in tidal zone** • **Maintain samphire and mangrove plants** • Provide food/habitat resources for fish and macro-invertebrates	Not defined	Not defined	Not defined
Low flow	Approx 1/4 bankfull in main channel upstream of tidal estuary, connecting flows: mixing of freshwater and saltwater in main channel	• **Fish migration between river and estuary** • Fish development and recruitment • Transport nutrients to the estuary	**Fi** / 1:1–1:5 Sustain. 1:3	1–2 months Sustain. 1 month	Late winter & spring
Mid flow	2/3 bankfull in main channel upstream of tidal estuary, higher connecting flows: mixing of saltwater and freshwater in main channel	• **Fish spawning and hatching** • **Large-scale fish development and recruitment (if there are sufficient overbank flows)** • Transport of sediment and nutrients to estuary • Fish migration between river and estuary	**Fi** / 1:1–1:3 Sustain. 1:2	2–10 days Sustain. 4 days	Late winter & spring
Bankfull–overbank	Freshwater flow in tidal channels and flooding of samphire flats and mangroves	• **Large-scale fish spawning and hatching** • **Transport of sediment, nutrients and organic matter to estuary** • Channel maintenance • Fish migration between river and estuary	**Fi** / 1:3–1:10 Sustain. 1:5	2–4 days Needs to be followed up by mid–high flow requirements (2–4 weeks) providing optimum conditions for development and recruitment.	Late winter & spring
Overbank–extensive flood-out	Inundation of tidal channels and extensive flooding of samphire flats	• **Transport of sediment and nutrients to estuary and tidal flats** • Channel maintenance • Fish migration between river and estuary	**G** / Natural — estimated >1:5	Natural — estimated hours–days	n.a.

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.2 Zone 2: Light River, estuary to downstream of Redbanks; Site: Gordon Road crossing (see cross-section Figure B.1)

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Groundwater	Permanent shallow pools in lower reaches of zone	• **Maintain pools for aquatic flora and fauna habitats**	**Fi** / Permanent	Permanent	Permanent
Low flow 1.58 m at survey site **3.9** cumec	Approximately 1/5–1/3 bankfull at cross-section Covers stream bed May have a groundwater component	• **Fish migration** • **Create temporary pools for fish migration** • **Fish development and recruitment** • **Maintain sedgeland communities (in-stream)** • **Maintain water quality (e.g. nutrients, salinity, dissolved oxygen)** • **Provide aquatic habitat for frogs, macro-invertebrates and fish** • **Breeding and recruitment of macro-invertebrates and frogs** • **Habitat connection for local movement of aquatic flora and fauna** • **Transport nutrients**	**Fi** / 1:1-1:5 Sustain. 1:3	1–2 months Sustain. 1 month	Late winter & spring
Mid–high flow 5.3 m at survey site **42** cumecs	Approximately 1/3 to 2/3 bankfull Inundates river red gum trunks and lignum	• **Fish spawning and hatching** • Maintenance and recruitment of riparian vegetation • Transport of sediment • Transport nutrients • Fish migration	**Fi** / 1:1–1:5 Sustain. 1:3	2–10 days Sustain. 4 days	Late winter & spring
Bankfull 6.55 m at survey site **63** cumecs	Fills channel, completely covers lower river red gum in channel Point of 1992 flood level	• **Maintenance and recruitment of riparian vegetation (lignum)** • **Transport of sediment** • **Transport nutrients** • **Scouring of pools** • **Channel maintenance**	**V** / 1:2–1:8 Sustain. 1:7	>1 day	Spring–summer
Overbank & extensive flood-out	Overbank flow that inundates floodplain	• **Maintenance and recruitment of floodplain vegetation (river red gum)** • **Habitat resetting** • **Inundate floodplain habitat for macro-invertebrates and frogs** • Transport of sediment and nutrients to estuary • Scouring of pools • Channel maintenance	**V** / 1:10–1:50	Approx. 1 week. Duration requirements may be fulfilled by water ponding in depressions.	Spring–summer

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.3 Zone 3: Light River downstream of Redbanks to downstream of The Rockies; Site: Redbanks bridge

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Low flow	1/5–1/3 bankfull in deep channel May have a groundwater component	• **Fish migration** • **Fish development and recruitment** • **Maintain sedgeland communities (in-stream)** • **Maintain water quality (e.g. nutrients, salinity, dissolved oxygen)** • **Provide aquatic habitat for frogs, macro-invertebrates and fish** • **Create temporary pools for fish migration** • **Habitat connection for local movement of aquatic flora and fauna** • **Breeding and recruitment of macro-invertebrates and frogs** • **Transport nutrients**	**Fi** / 1:1–1:5 Sustain. 1:3	1–2 months Sustain. 1 month	Late winter & spring
Mid flow	Approx 1/3–2/3 bankfull Waters river red gums and inundates lower growing lignum	• **Fish spawning and hatching** • Fish migration • Maintenance and recruitment of riparian vegetation • Transport of sediment • Transport nutrients	**Fi** / 1:1–1:5 Sustain. 1:3	2–10 days Sustain. 4 days	Late winter & Spring
High flow–bankfull	Fills channel inundates red gum	• **Maintenance and recruitment of riparian vegetation (lignum)** • **Flooding lignum to provide habitat for fish, macro-invertebrates and frogs** • **Habitat resetting** • **Channel maintenance** • **Scouring of pools** • **Transport of sediment** • **Transport nutrients**	**V** / 1:2–1:8 Sustain. 1:7	<1–2 weeks. Duration requirements may be fulfilled by ponded water in depressions.	Spring–summer
Overbank & extensive flood-out	Overbank flow that inundates floodplain and old terrace	• **Maintenance and recruitment of floodplain vegetation (river red gum).** • **Major structural channel change and habitat resetting.** • **Inundate floodplain habitat for macro-invertebrates and frogs.** • Transport of sediment and nutrients to estuary. • Scouring of pools	**V** / 1:10–1:50	Approximately 1 week. Duration requirements may be fulfilled by ponded water in depressions.	Spring–summer

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.4 Zone 4: Light River downstream of The Rockies to the Gilbert River; Site: The Rockies

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Groundwater	Permanent pools filled, riverbed damp or wet	• **Maintain pools for aquatic flora and fauna habitats** • **Maintain reedbed communities**	Permanent	Permanent	All year
Low flow	Flow over riverbed connecting pools and inundating riffles May have a seasonal baseflow component	• **Fish migration** • **Fish development and recruitment** • **Breeding and recruitment of macro-invertebrates and frogs** • **Create and maintain riffle habitats** • **Maintain water quality (e.g. nutrients, salinity, dissolved oxygen)** • **Habitat connection for local movement of aquatic flora and fauna** • **Inundate shallow habitat for frogs, macro-invertebrates and fish** • Transport nutrients	**Fi** / 1:1 to 1:5 Sustain. 1:3	1–2 months Sustain. 1 month	Late winter & spring
Mid flow	Approximately 50% reed height inundating shallow benches	• **Fish spawning and hatching** • **Maintenance and recruitment of riparian vegetation (lignum)** • **Inundate shallow habitat for frogs, macro-invertebrates and fish** • **Sediment transport** • **Transport nutrients** • **Large scale fish redistribution** • **Removal of sediments from riffle substrate** • **Large scale fish development and recruitment** • Habitat connection for local movement of flora and fauna • Maintain water quality (e.g. nutrients, salinity, dissolved oxygen) • Fish migration	**Fi** / 1:1 to 1:5 Sustain. 1:3	2–10 days Sustain. 4 days	Late winter & spring

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
High flow to Bankfull	Completely inundates reeds and covers benches	• **Large-scale fish spawning and hatching** • **Maintenance and recruitment of riparian vegetation (lignum)** • **Removal of sediments from riffle substrate** • Transport of sediment, nutrients and organic matter to estuary • **Channel maintenance** • **Scouring of pools**	**Fi** / 1:3–1:10 Sustain. 1:5	2–4 days with follow up flows at mid flow level for 2–4 weeks will provide optimum conditions for successful development and recruitment.	Late winter & spring
Overbank & extensive flood-out	Inundates floodplain within old terrace	• **Maintenance and recruitment of floodplain vegetation (river red gum)** • **Inundate floodplain habitat for macro-invertebrates, frogs and fish** • **Habitat resetting** • **Transport of sediment, nutrients and organic matter to estuary** • Channel maintenance • Scouring of pools	**V** / 1:10 to 1:50	Approximately 1 week. Duration requirements may be fulfilled by ponded water in depressions.	Spring–summer

***This zone is an important refuge for fish and invertebrates when lower Light River dries in summer.**
AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.5 Zone 5: Light River, junction of Gilbert River to below Peters Road crossing; Site: Hamley Bridge

Flow Band	Flow Band Description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Groundwater	Below bench level (permanent pools)	• **Maintain pools for aquatic flora & fauna habitats** • **Maintain reedbed communities**	**Fi**/ Permanent	Permanent	Permanent fluctuations
Baseflow	1/10 bankfull Connecting pools	• **Create and maintain riffle habitats** • **Maintain sedgeland communities** • **Inundate shallow habitat for frogs, macro-invertebrates and fish** • **Maintain water quality e.g. nutrients, salinity, dissolved oxygen** • Habitat connection for local movement of aquatic flora & fauna	**M**/ 2:1–1:1	1–3 months (full ecological functioning). Sustain. 1 month	Autumn–spring
Low flow	1/4 bankfull Inundating bench and inundating *M. brevifolia* and lignum	• **Fish migration** • **Fish development and recruitment** • **Transport nutrients** • **Habitat connection for local movement of aquatic flora & fauna** • Maintain water quality e.g. nutrients, salinity, dissolved oxygen	**F**/ 1:1–1:5 Sustain. 1:3	1–2 months Sustain. 1 month	Late winter–spring
Mid flow–bankfull flow	Bankfull level Inundates benches and some deep flood runners Below riparian lignum and river red gum level	• **Fish spawning and hatching** • **Large scale fish redistribution** • **Large scale fish development and recruitment** • **Maintenance and recruitment of riparian vegetation** • **Sediment transport** • **Removal of sediments from riffle substrate** • **Channel maintenance** • Transport of nutrients • Scouring of pools	**Fi** / 1:1–1:5 Sustain. 1:3	2–10 days Sustain. 4 days	Late winter–spring
Overbank	Over bankfull Flood runners completely inundated Lignum inundated	• **Large scale fish spawning and hatching** • **Maintenance and recruitment of floodplain vegetation** • **Habitat resetting** • **Scouring of pools** • Channel maintenance • Sediment transport • Transport of nutrients and organic matter	**Fi**/ 1:3–1:10 Sustain. 1:5	2–4 days, with follow up flows at mid to bankfull flow level for 2–4 weeks will provide optimum conditions for successful development and recruitment.	Late winter–spring

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.6 Zone 6: Light River, downstream Peters Road crossing to St Kitts Creek junction; Site: Downstream of Peters Road crossing (see cross-section Figure B.2)

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Groundwater	Fills permanent pools	• **Maintain pools for aquatic flora and fauna** • **Maintain reedbed communities**	Permanent	Permanent	Permanent with fluctuations all year round
Baseflow **0.1** cumec in winter. (exceeded in 50% of Augusts)	Shallow flow over runs and riffles	• **Maintain riffles and create habitats** • Maintain water quality e.g. nutrients, salinity, dissolved oxygen	**M** / 1:1 Seasonal increase in flow level. Actual flow frequency **1:1.02**	2 weeks–3 months (3 months for full ecological functioning). Sustain. 1 month Actual flow frequency **1 month = 1:1.3**	Autumn–spring
Low flow 2.76 m at survey site **1.17** cumec	Inundates in-stream bench and connects pools	• **Fish migration** • **Fish development and recruitment** • **Breeding and recruitment of macro-invertebrates and frogs** • **Inundate shallow habitat for frogs, macro-invertebrates and fish** • **Habitat connection for local flora and fauna** • **Maintain water quality e.g. nutrients, salinity, dissolved oxygen**	**Fi** / 1:1–1:5 Sustain. 1:3 Optimum 1:1 Actual flow frequency **1:1.1**	1–2 months Sustain. 1 month Actual flow frequency **7 days = 1:1.9** **14 days = 1:6.5**	Late winter–spring
Bankfull 4.28 m at survey site **9.1** cumec	Inundating *Juncus* spp. and lignum Watering *Melaleuca brevifolia*	• **Galaxias fish spawning and hatching** • **Fish spawning and hatching** • **Large scale fish development and recruitment** • **Maintenance and recruitment of riparian vegetation** • **Transport nutrients** • Sediment transport	**Fi** / 1:1–1:5 Sustain. 1:3 Actual flow frequency **1:1.5**	1–2 days followed by an event of 1 day up to 2–3 weeks later Actual flow frequency **1:2.9** (for 2 events at 1 day duration)	Late winter–spring

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Overbank 5.63 m at survey site **26** cumec	Overbank flow inundating inner floodplain to toe of terrace	• **Large scale galaxias spawning and hatching** • **Large scale fish redistribution** • **Large scale frog breeding and recruitment** • **Maintenance and recruitment of floodplain vegetation** • **Channel maintenance** • **Removal of sediments from riffle substrate** • **Sediment transport** • Transport nutrients	**Fi** / 1:3–1:10 Sustain. 1:5 Actual flow frequency **1:2.1**	1–2 days, followed by an event of 1 day up to 2–3 weeks later Actual flow frequency **1:6.5** (for 2 events at 1 day duration) A follow up flow at a significant level for 2–4 weeks will provide optimum conditions for successful development and recruitment. Actual flow frequency This pattern has not occurred during the recording period.	Late winter–spring
Large to catastrophic flood 9.5–11.3 m at survey site >26 cumec to 350 cumec	Large scale flood event above toe of terrace	• **Scouring of pools** • **Habitat resetting** • Channel maintenance • Sediment transport	**G** / Natural estimated >1:5 Actual flow frequency **>1:2.1–1:20**	Natural estimated hours–days	n.a.

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.7 Zone 7: Light River, St Kitts Creek junction to Julia Creek Junction; Site: Ben Lomond Road crossing (see cross-section Figure B.3)

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Groundwater	Riverbed and sediments damp and permanent pools filled	• **Maintain pools for aquatic flora & fauna habitats** • **Maintain reedbed communities** • **Maintain sedgeland communities**	Permanent	Permanent	Permanent
Baseflow–seasonal low flow 0.54 m at survey site **0.1** cumecs winter (exceeded in 50% of Augusts)	Inundates riffles up to level of *Juncus* spp.	• **Fish development and recruitment** • **Inundate shallow habitat for frogs, macro-invertebrates and fish** • **Habitat connection for local movement of aquatic flora & fauna** • **Create and maintain riffle habitats** • **Maintain water quality (e.g. nutrients, salinity, dissolved oxygen)**	**Fi**/ 1:1–1:5 Sustain. 1:3 Actual flow frequency is **1:1.02**	2–4 weeks Actual flow frequency is **4 weeks = 1:1.3**	Late winter–spring
Mid flow 1.16 m at survey site. **3** cumec	Inundates benches, bars and *Juncus* spp.	• **Fish spawning and hatching** • **Large scale fish redistribution** • **Transport nutrients and organic matter** • Habitat connection for local movement of aquatic flora & fauna • Maintain water quality (e.g. nutrients, salinity, dissolved oxygen) • Sediment transport	**Fi**/ 1:1–1:5 yrs Sustain. 1:3 Actual flow frequency 3 cumec **1:1.2**	2–10 days Sustain. 4 days Actual flow frequency **4 days = 1:2:2** **9 days = 1:8.7**	Late winter–spring

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
High flow 1.8 m at survey site **10** cumecs **Bankfull** **16** cumecs	Inundates *Juncus and M. brevifolia*, floods up to lignum zone *Due to the narrow profile this site is not suitable for large scale fish spawning and hatching.*	• **Maintenance and recruitment of riparian vegetation** • **Transport nutrients and organic matter** • **Sediment transport** • **Removal of sediments from riffle substrate** • **Channel maintenance**	**V**/ 1:2–1:10 Actual flow frequency 10 cumecs **1:1.6** 16 cumecs **1:1.8**	Hours–days Actual flow frequency for (yearly) 10 Cumecs **1 day = 1:1.4** **2 days = 1:1.5** **3 days = 1:3.7**	Spring–summer
Overbank 2.4 m at survey site **>16** cumecs **Catastrophic** **350** cumec 25 Dec 1999	Floods riparian zone over grasses up to base of river red gum *Due to the lack of riparian vegetation this site is not suitable for large scale fish spawning and hatching.*	• **Scouring of pools** • **Channel maintenance** • **Habitat resetting** • Sediment transport • Transport nutrients	**G**/ Natural estimated >1:5 Actual flow frequency **> 1:1.8–1:20**	Natural estimated Hours–days	n.a.

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.8 Zone 8a: Light River, Julia Creek junction to Tothill Creek junction; Site: Hansborough Road crossing (see cross-section Figure B.4)

Flow	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Groundwater	Riverbed and sediments damp and permanent pools filled	• **Fish development and recruitment** • **Maintain pools for aquatic flora & fauna habitats** • **Maintain reedbed communities** • **Maintain sedgeland communities**	Permanent	Permanent	Permanent
Mid–high flow	Inundates *Juncus spp.* Floods up to base of *Melaleuca brevifolia*, *Maireana aphylla* and lignum	• **Fish spawning and hatching** • **Inundate shallow habitat for frogs, macro-invertebrates and fish** • **Maintenance and recruitment of riparian vegetation (*M. brevifolia*)** • **Habitat connection for local movement of aquatic flora & fauna** • **Maintain water quality (e.g. nutrients, salinity, dissolved oxygen)** • **Transport nutrients** • **Sediment transport** • Channel maintenance • Possible scouring of pools	**Fi** / 1:1–1:5 Sustain. 1:3	2–10 days Sustain. 4 days	Late winter–spring
Overbank–extensive flood-out	Breaks banks Inundates *M. brevifolia*, *Maireana aphylla* and lignum	• **Maintenance and recruitment of riparian vegetation (lignum)** • **Channel maintenance** • **Scouring of pools** • Sediment transport • Transport nutrients • Possible habitat resetting	**V** / 1:2–1:8 Sustain. 1:7	<1–2 weeks Duration requirements may be fulfilled by ponded water in depressions	Spring–summer

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.9 Zone 8b: Light River, Julia Creek junction to Tothill Creek junction; Site: Hamilton Road

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Groundwater	Riverbed and sediments damp and permanent pools filled	• **Maintain pools for aquatic flora and fauna habitats** • **Maintain reedbed communities**	Permanent	Permanent	Permanent
Low flow 0.23 m at cross-section **0.08** cumecs	Flow across the stream bed covering base of *Phragmites* spp. and up to level of lower *Melaleuca brevifolia.*	• **Fish development and recruitment** • **Maintenance and recruitment of riparian vegetation (*Melaleuca brevifolia*)** • **Inundate shallow habitat for frogs, macro-invertebrates and fish** • **Spawning and hatching of macro-invertebrates and frogs** • **Maintain water quality (e.g. nutrients, salinity, dissolved oxygen)** • **Habitat connection for local movement of aquatic flora and fauna**	**Fi**/ 1:1–1:5 Sustain. 1:3	2–4 weeks	Late winter–spring
Midflow 1 m at cross-section **2.3** cumecs	Up to base of higher *M. brevifolia*	• **Fish spawning and hatching** • **Large scale fish development and recruitment** • **Maintenance and recruitment of riparian vegetation (*M. brevifolia*)** • **Transport nutrients** • **Removal of fine sediments from riffle substrates** • **Sediment transport**	**Fi**/ 1:1–1:5 yrs Sustain. 1:3	2–10 days Sustain. 4 days	Late winter–spring

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Bankfull flow 1.5 m at cross-section **4.1** cumecs	Extends over terrace and wets higher *Juncus* spp. And *M. brevifolia* Fills flood runner	• **Large scale fish spawning and hatching** • **Large scale fish redistribution** • **Inundate flood runner habitat for macro-invertebrates and frogs** • **Maintenance and recruitment of riparian vegetation (*M. brevifolia*)** • **Maintain riparian sedgeland communities** • **Channel maintenance** • **Scouring of pools** • Transport sediment • Transport nutrients	**Fi**/ 1:1–1:10 yrs Sustain. 1:5	2–4 days	Late winter–spring
Overbank to extensive flood-out 2 m at cross-section **11.4** cumecs 3.5 m at cross-section **87** cumecs	Extends over riparian zone grasses to edge of pasture zone Large flood into cropped area	• **Scouring of pools** • **Channel maintenance** • **Habitat resetting** • **Removal of sediments from riffle substrates**	**G** / Natural estimated >1:5	Natural estimated Hours–days	n.a.

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.10 Zone 9: Light River, upstream of Tothill Creek junction; Site: Tothill Road crossing

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Groundwater	Riverbed and sediments damp and permanent pools filled	• **Maintain pools for aquatic flora and fauna habitats** • **Maintain reedbed communities** • **Maintain lower in-stream sedgeland communities**	Permanent	Permanent	Permanent
Low flow	Covers bed of the low flow channel up to the base of lower *Juncus* spp.	• **Maintain water quality (e.g. nutrients, salinity, dissolved oxygen)** • **Maintain higher in-stream sedgeland communities** • Inundate shallow habitat for frogs and macro-invertebrates • Spawning and hatching of macro-invertebrates and frogs	**M** / 1:1	1–4 weeks Sustain. 1–2 weeks	Late winter–early summer
High flow–overbank	Covers in-stream benches, and wets base of higher *Juncus* spp.	• **Scouring of pools** • **Transport nutrients** • **Sediment transport** • **Channel maintenance**	**G** / Natural estimated >1:5	Natural estimated Hours–days	n.a.

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.11 Zone 10: Gilbert River, Light River junction to Saddleworth; Site: Tarlee (see cross-section Figure B.5)

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Groundwater	Riverbed and sediments damp and permanent pools filled	• **Maintain pools for aquatic flora and fauna habitats** • **Maintain reedbed communities**	Permanent	Permanent	Permanent
Seasonal baseflow–low flow 0.6 m at survey site **0.06** cumecs	Confined to low flow channel up to base of *Melaleuca brevifolia*	• **Maintain water quality (e.g. nutrients, salinity, dissolved oxygen)** • **Maintenance and recruitment of riparian vegetation (*M. brevifolia*)**	**M** / 1:1	1–4 weeks Sustain. = 1–2 weeks	Late winter–early summer
Bankfull flow 1.05 m at survey site **0.24** cumecs	½–¾ reed height. Inundates bench & extends up to *Juncus* line	• **Spawning and hatching of macro-invertebrates and frogs** • **Inundate shallow habitat for frogs, macro-invertebrates and fish** • **Maintain riparian sedgeland communities** • **Maintain reedbed communities** • Transport nutrients • Sediment transport • Channel maintenance • Possible scouring of pools	**M** / 1:1	2 wks–3 mths (full ecological functioning). Sustain. 1 month	Late winter–spring
Overbank Flow 1.9 m at survey site **13.2** cumecs	Floods past *Juncus* spp line and into cleared floodplain	• **Scouring of pools** • **Sediment transport** • **Transport nutrients** • **Large scale fish redistribution** • **Channel maintenance**	**G** / Natural estimated >1:5	Natural estimated Hours–days	n.a.

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.12 Zone 11: Gilbert River, upstream of Saddleworth; Site: Steelton Road bridge

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Groundwater	Riverbed and sediments damp and permanent pools filled	• **Maintain reedbed communities** • **Maintain sedgeland communities**	Permanent	Permanent	Permanent
Mid to high flow	½–¾ sedge height	• **Possible transport of nutrients** • Sediment transport	**G**/ Natural estimated 1:2–1:10	Natural estimated Hours–days	n.a.
Overbank – extensive flood-out	Inundates sedges, floods over banks	• Channel maintenance • Transport nutrients • Sediment transport	**G** / Natural estimated >1:5	Natural estimated Hours–days	n.a.

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.13 Zone 12: Macaw Creek, tributary of the Gilbert River; Site: Junction Macaw Creek and Messiter–Cole Road.

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Groundwater	Localised sediments damp and permanent pools filled	• **Maintain pools for aquatic flora and fauna habitats** • **Maintain reedbed communities**	Permanent	Permanent	Permanent
Low flow	¼ bankfull	• **Maintain water quality (e.g. nutrients, salinity, dissolved oxygen)** • **Inundate shallow habitat for frogs and macro-invertebrates**	**M** / 1:1	n.a.	n.a.
Bankfull flow	Bankfull	• **Channel maintenance** • **Transport of nutrients and organic matter** • **Sediment transport** • Scouring of pools	**G** / Natural estimated >1:5	Natural estimated Hours–days	n.a.
Overbank	Over bankfull	• **Maintenance and recruitment of floodplain vegetation (*Eucalyptus camaldulensis*)** • **Scouring of pools** • **Channel maintenance** • Transport of sediment nutrients	**V**/ 1:10–1:50	Approximately 1 week. Duration requirements may be fulfilled by ponded water in depressions.	Spring–summer

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.14 Zone 13:Ross Creek, Tributary of the Light River; Site: permanent pool below Kapunda, Hawkers Creek Road

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Groundwater 1.5 m deep pool	1/5 bankfull level	• **Maintain pools for aquatic flora & fauna habitats** • **Maintain reedbed communities** • **Maintain sedgeland communities**	Permanent flow	Permanent	All year round.
Low flow	¼ bankfull level	• **Breeding and recruitment of macro-invertebrates and frogs** • **Inundate shallow habitat for frogs and macro-invertebrates** • **Habitat connection for local movement of aquatic flora & fauna** • **Maintain water quality e.g. nutrients, salinity, dissolved oxygen** • **Transport nutrients**	**M** / 1:2–1:1	1–3 months 3 months for full ecological activity. Sustain. 1mth	Late winter–spring
High flow	¾ bankfull	• **Scouring of pools** • **Channel maintenance** • **Habitat resetting** • **Sediment transport** • Transport nutrients	**G** / Natural estimated >1:5	Natural estimated Hours–days	n.a.

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.15 Zone 14:Allen Creek tributary of the Light River; Site: Above weir Kapunda–Truro Road bridge

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Groundwater 0.5–1 m	Pools in sections: shallow water supporting water plants	• **Maintain pools for aquatic flora & fauna habitats** • **Maintain reedbed communities** • **Maintain sedgeland communities**	Permanent flow	Permanent	All year round
Low flow	1/3 bankfull level	• **Breeding and recruitment of macro-invertebrates and frogs** • **Inundate shallow habitat for frogs and macro-invertebrates** • **Habitat connection for local movement of aquatic flora & fauna** • **Maintain water quality e.g. nutrients, salinity, dissolved oxygen** • **Transport nutrients**	**M** / 1:2–1:1	1–3 months 3 months for full ecological activity. Sustain. 1mth	Late winter–spring
Overbank	Bankfull to edge of terrace Covers reeds completely	• **Maintenance and recruitment of floodplain vegetation (river red gum** • **Channel maintenance** • **Scouring of pools** • **Sediment transport** • **Habitat resetting** • Transport nutrients	**V** / 1:10–1:50	Approximately 1 week. Duration requirements may be fulfilled by ponded water in depressions	Late winter–summer

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.16 Zone 15: site11: St Kitts Creek, tributary of the Light River; Site: Bagot Well Road

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Low flow	1/5–¼ bankfull (shallow channel)	• **Inundate shallow habitat for frogs, macro-invertebrates** • **Maintain sedgeland communities** • **Maintain water quality e.g. nutrients, salinity, dissolved oxygen** • **Transport nutrients**	**M** / 1:2–1:1	1–3 months 3 months for full ecological activity. Sustain. 1 month	Late winter–spring
High–overbank flow	On bank river red gum line	• **Maintenance and recruitment of floodplain vegetation (river red gum)** • **Channel maintenance** • **Sediment transport** • Transport nutrients	**V** / 1:10–1:50	Approximately 1 week. Duration requirements may be fulfilled by ponded water in depressions	Late winter–summer

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.17 Zone 16: Stockwell Creek, tributary of St Kitts Creek; Site: Research Road

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Low flow	½ bankfull	• **Maintain sedgeland communities** • Transport nutrients and organic matter	**V**/ 1:1	n.a.	Inundated winter–late summer
Overbank	Top of channel to floodplain	• **Maintenance and recruitment of floodplain vegetation (river red gum)** • **Leaching of salts through soil profile** • **Breeding and recruitment of macro-invertebrates and frogs** • **Sediment transport** • **Transport nutrients** • **Channel maintenance**	**V**/ 1:10–1:50	Approximately 1 week. Duration requirements may be fulfilled by ponded water in depressions	Late winter–summer

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.18 Zone 17: Northern tributary of St Kitts Creek; Site: Upstream Watunga Road crossing

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Low flow	¼ bankfull of uneroded reach	• **Maintain sedgeland communities** • Transport nutrients and organic matter	**V**/ 1:1	n.a.	Inundated winter–late summer.
Bankfull to overbank	Extends to cropped riparian zone Completely inundates sedges	• **Maintenance and recruitment of riparian vegetation (river red gum)** • **Transport nutrients and organic matter** • **Sediment transport** • **Channel maintenance**	**V**/ 1:10–1:50	Approximately 1 week. Duration requirements may be fulfilled by ponded water in depressions	Spring–summer

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.19 Zone 18 – Eastern Hill tributaries; Site: Newlands Road

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Groundwater	Permanent pools filled	• **Maintain pools for aquatic flora and fauna habitats**	Permanent	Permanent	Permanent
Low flow	1/5–1/3 bankfull	• **Maintain water quality (e.g. nutrients, salinity, dissolved oxygen)**	**M** / 1:1	n.a.	n.a.
High flow	½–¾ bankfull	• **Scouring of pools** • **Transport nutrients and organic matter** • **Sediment transport** • **Removal of sediments from riffle substrate** • **Channel maintenance**	**G** / >1:5	n.a.	n.a.

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.20 Zone 19: Julia Creek, tributary of the Light River; Site: Marrabel Road crossing

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Groundwater	Riverbed and sediments damp and permanent pools filled	• **Maintain pools for aquatic flora & fauna** • **Maintain reedbed communities**	Permanent	Permanent	Permanent
Low flow	1/5 bankfull ½ reed height	• **Fish development and recruitment** • **Habitat connection for local movement of aquatic flora and fauna** • **Maintain water quality (nutrients, salinity, dissolved oxygen)** • **Inundate shallow habitat for frogs, macro-invertebrates and fish** • **Spawning and hatching of macro-invertebrates and fish**	**Fi** / 1:1–1:5 Sustain. 1:3	2–4 weeks	Late winter–spring
Moderate to high flow	¾ to whole reed height Flow in channel up to base of lignum and Juncus. (approx. 2 m deep at survey site)	• **Fish spawning and hatching** • **Large scale fish development and recruitment** • **Large scale fish redistribution** • **Maintain riparian sedgeland communities** • **Maintenance and recruitment of riparian vegetation** • **Transport nutrients matter** • **Sediment transport** • **Channel maintenance** • Scouring of pools	**Fi** / 1:1–1:5 yrs Sustain. 1:3	2–10 days Sustain. 4 days	Late winter–spring.
Overbank	Over top of bank, covers base of floodplain lignum	• **Maintenance and recruitment of floodplain vegetation (lignum)** • **Habitat resetting** • Transport nutrients • Sediment transport • Scouring of pools • Channel maintenance	**V**/ 1:2–1:8 Sustain. 1:7	<1–2 weeks Duration requirements may be fulfilled by ponded water in depressions	Spring–summer

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

Table B.21 Zone 20: Tothill Creek tributary of the Light River; Site: Braewood road crossing

Flow band	Flow band description	Key functions within the flow band	Frequency (AEP)	Duration (AEP estimated)	Seasonality
Groundwater	Riverbed and sediments damp and permanent pools filled	• **Maintain pools for aquatic flora and fauna** • **Maintain reedbed communities**	Permanent	Permanent	Permanent
Seasonal baseflow–low flow	1/5 bankfull level *Bolboschoenus* covered ½ by water level. Extends to start of riparian grass.	• **Maintain water quality (nutrients, salinity, dissolved oxygen)** • **Habitat connection for local movement of aquatic flora & fauna**	**M** / 1:1	n.a.	n.a.
Mid–high flow	¾ bankfull Extending up to base of lignum	• **Maintenance and recruitment of riparian vegetation (lignum)** • **Maintain riparian sedgeland communities** • **Transport nutrients and organic matter** • **Sediment transport**	**V**/1:2–1:8 Sustain. 1:7	<1–2 weeks. Duration requirements may be fulfilled by ponded water in depressions	Spring–summer
Bankfull	Up to edge of channel to cropping level. Covers reeds and lignum completely.	• **Scouring of pools** • **Sediment transport** • **Transport nutrients and organic matter** • **Channel maintenance**	**G** / Natural estimated >1:5	Natural estimated Hours–days	n.a.

AEP: Annual exceedance probability derived from Log Pearson Type 3 Distribution frequency Analysis. (Annual Series)
AEP (estimated): Estimated annual exceedance probability using tabulated information.
Note: important functions for particular flow bands are bolded, in order of ecological importance. The most important function for a particular flow band is bolded and highlighted. For functions in multiple flow bands, the most critical flow band for that function is bolded.

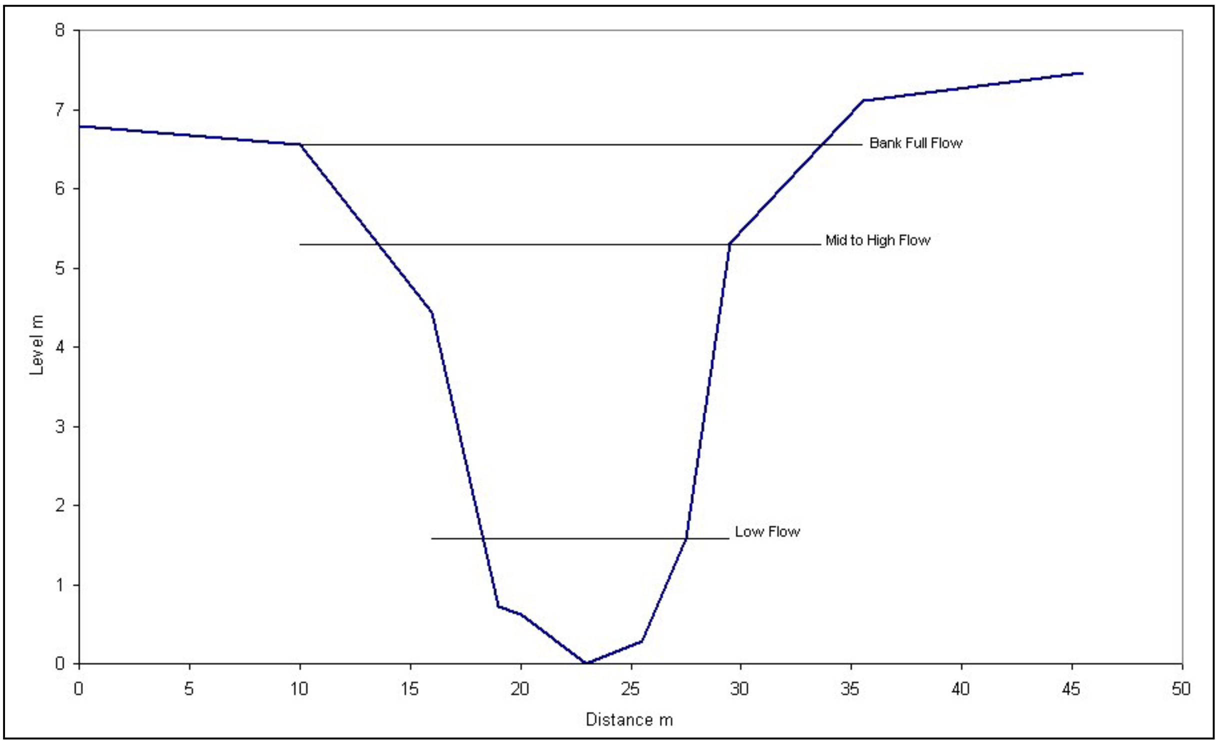


Figure B. 1 Light River Zone 2 at Gordon Road crossing

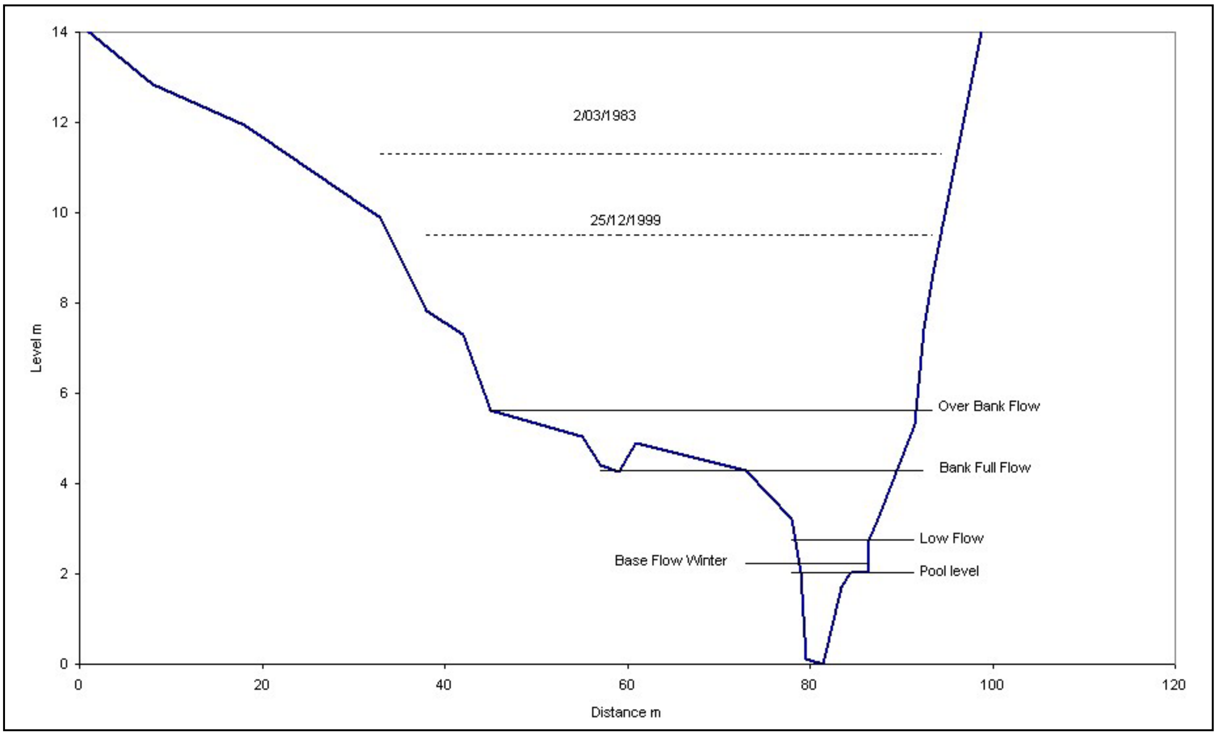


Figure B. 2 Light River Zone 6 downstream of Peters Road crossing

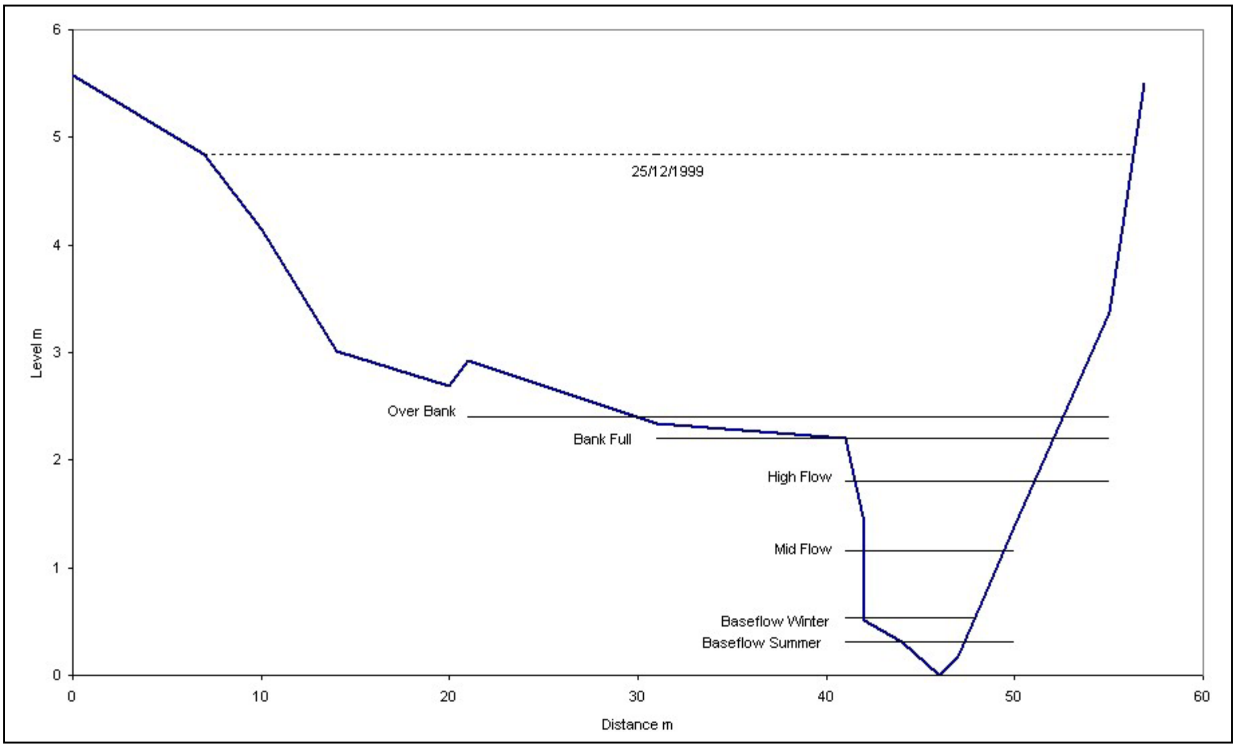


Figure B. 3 Light River Zone 7 at Ben Lomond Road crossing

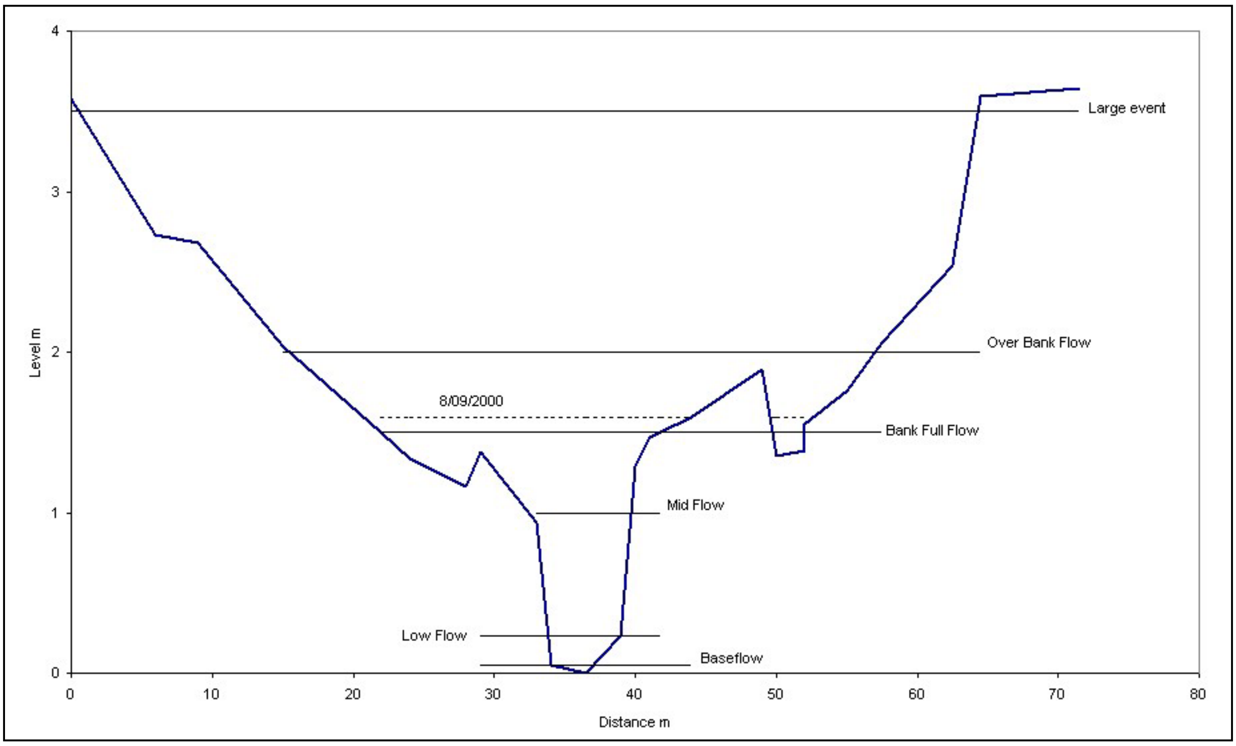


Figure B. 4 Light River Zone 8 at Hamilton

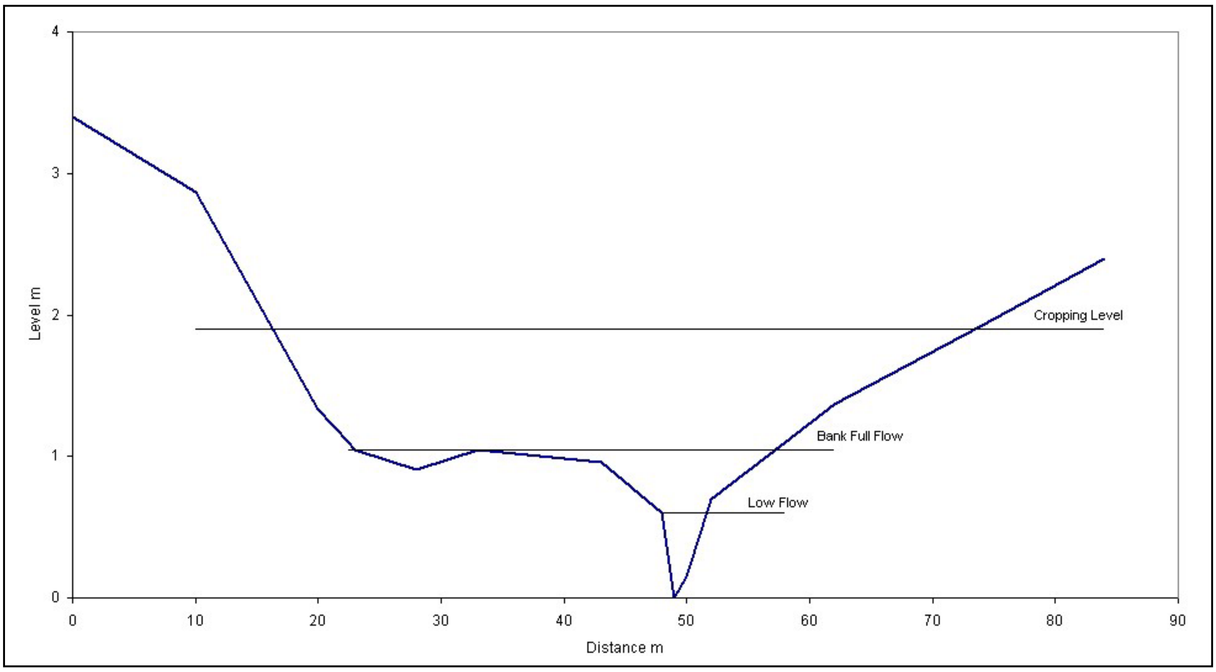


Figure B. 5 Gilbert River Zone 10 at Tarlee

APPENDIX C – ENVIRONMENTAL WATER REQUIREMENTS FOR FLORA AND FAUNA

The tables in this appendix present detailed lifecycle and flow requirements information for flora and fauna of the Light River system (adapted from Lloyd 2001).

Tables C.1 and C.2 summarise the flow requirements of the flora and fauna of the Light River. These tables have been used as a basis for the assessment of environmental water requirements for each geomorphic zone within the Light River system. These flow recommendations provide an initial basis to protect the natural values of watercourses within the catchment but should be considered as preliminary due to the limited knowledge of the ecology and flow relationships within the Light catchment.

Table C.3 presents lifecycle information for native fish species known or likely to inhabit the Light River and its tributaries.

The flow requirements are based on the life history of the flora and fauna inhabiting the aquatic environment of the Light catchment. While the biology of species in the Light catchment may not be well known locally, information on the same species in other locations is often available. In determining the key flow bands, timing and duration of flow required, life history characteristics such as life span and breeding season are aligned with habitats inundated at various flows and when these flows should occur to maximise an ecological response from target species. The flow requirements of flora and fauna are not necessarily always met under natural conditions. The Light River and its tributaries may be naturally suboptimal for many of the species it currently supports.

Table C.1 Flow bands and ecological requirements of vegetation communities (Lloyd 2001)

Vegetation community/ habitat	Key flow bands + location/lateral extent/depth	Purposes of flow bands	Average life span of species	Event frequency (range, sustaining requirement)	Event duration & seasonality (range, sustaining requirement)	Criteria for determining impacts
Reed beds (emergent macrophytes)	*Groundwater–baseflow* — to maintain a permanent wetted channel/permanent soil moisture	• Maintenance of reedbeds e.g. *Phragmites, Typha*, *Bolboschoenus*, *Schoenoplectus*	5–10 years	Permanent	All year	• Increasing salinity • Duration of dry periods • Species diversity of reeds • *Phragmites* invasions
	Low flows — inundation of stream channel and bars	• Germination and recruitment of reedbed plant species • Establishment and growth of reedbed plant species	5–10 years	1:1 years	Range 9–12 months per year, optimum requirement: all year	• Senescence of stands • Decreasing size of stands • Lack of recruitment
Sedgelands (sedgeland plants located in wetter parts of stream profile)	*Low flows* — Inundation of bars and low banks with shallow water	• Maintenance and establishment of sedgeland plants e.g. *Juncus, Eleocharis* and *Cyperus* • Increase habitat, stimulate growth of vegetation and associated fauna	1–5 years	1:1 to 1:2 yrs 1:1 yr sustaining	Range 2–8 months 3 months for sustaining flows; NB: Sediment needs to be damp – in one or several small events	• Lack of establishment of vegetation on bars and benches • Senescence of stands • Lack of recruitment
Submerged aquatic macrophytes	*Groundwater table* – to maintain a permanent surface water	• Maintenance of submerged aquatic vegetation e.g. *Chara, Potamageton*, *Nitella*	0.5–1 year	1:1 yrs permanent	All year (can dry out some years)	• Lack of establishment of vegetation in stream bed
	Baseflow–low flows — Inundation of bars and low banks with shallow water	• Increase habitat and stimulate growth of vegetation and associated fauna	0.5–1 year	Flows required 1:2 at least provided some aquatic habitat exist in intervening period	Range 9–12 months per year, at least 6–9 months per year	• Lack of establishment of vegetation on submerged bars and benches • Senescence and lack of recruitment • Species diversity decreasing

Vegetation community/ habitat	Key flow bands + location/lateral extent/depth	Purposes of flow bands	Average life span of species	Event frequency (range, sustaining requirement)	Event duration & seasonality (range, sustaining requirement)	Criteria for determining impacts
Riparian shrublands	*Groundwater/baseflow* — Maintain a permanent wetted channel/ permanent soil moisture	• Maintenance of *Melaleuca brevifolia*	>30–50+ yrs	Permanent; may dry out for periods in some years	Permanent; may dry out for periods in some years	• Condition of plant • Duration of dry periods
	Mid–high flow — Inundation of benches and riparian zone to increase wetted habitat	• Maintenance and establishment of riparian shrub species e.g. lignum, *Melaleuca** • Increase in habitat and stimulate growth of vegetation	15–50 yrs	1:2 –1:8 lignum. 1:3 to 1:10 yrs for recruitment / maintenance 1:7 — sustaining requirement Shorter flows (1–2 days) every 1–2 years will water these plants	< 1–2 weeks. Duration requirements maybe fulfilled by ponded water in depressions. Spring–Summer	• Condition of plant • Duration of dry periods • Lack of recruitment
Riparian woodlands/ forests	*Mid–high flows* — Inundation of root zone of large trees	• Growth and health of *Eucalyptus camaldulensis*.	>100 yrs	1:10 to 1:20 yrs for recruitment Shorter flows (1–2 days) every 1–2 years are required for germination and maintaining health	< 1–2 weeks Spring–summer	• Duration of wet event • Senescence of mature trees and high levels of disease
	Overbank flows — Inundation of benches and floodplains with floodplain depressions being filled and soils wetted up	• Recruitment, maintenance and establishment of *Eucalyptus camaldulensis*.	>100 yrs	Recruitment 1:10 – 1:50 yrs Watering flows every 2–3 years are required to ensure survival of trees if rainfall or groundwater sources are not available.	Recruit. ~1 week. Duration fulfilled by ponded water in depressions. June–Nov Sustaining for recruitment. Survival flows are required for ~1 day+	• Duration of wet event • Establishment of seedlings

**Melaleuca brevifolia* (short leaf honey myrtle) is a wet, open heath species normally occurring in swales and edges of lagoons and streams in moderately saline areas of 400–800 EC. This species is likely to require permanent access to water but it is unknown whether it requires flooding.

Table C.2 Flow bands and ecological requirements of aquatic animal communities (Lloyd 2001)

Biota	Key flow bands + location/lateral extent/depth	Purposes of flow bands	Average life span of species (see Section 4)	Event frequency (range, sustaining requirement)	Event duration & seasonality (range, sustaining requirement)	Criteria for determining impacts/benefits
Fish habitat	*Groundwater–baseflow* Pools inundated and channel bed wet	• Maintenance of minimum water level and quality • Inundation of areas of habitat and food resource	1–5 yrs	Frequent events annually. At least one event per year	Occurs for most of the year — low flow or dry in late summer	• Salinity increases • Species diversity • Habitat availability
Fish breeding	*Mid flow–overbank flow* Inundation of bars, benches, riparian zones, flood runners & floodplains to increase habitat	• High to overbank flows act as cue for breeding • Follow-up mid flows allow hatching and recruitment (see below)	Most 2–5 years. 1 year only for smelt & hardyheads	1:1–1:5 yrs; Sustaining flows at least 1:3 years Optimum 1:1 years	2–4 days for cue for breeding 4–7 days required for spawning and hatching	• Species diversity • Habitat availability • Extent & duration of inundation • Larvae present
Fish development and recruitment	*Low flow–mid flow* Inundation of bars, benches, and riparian zones to increase habitat	• Provide habitat/shelter for fish larvae to develop to juveniles	Most 2–5 years. 1 year only for smelt & hardyheads	1:1–1:5 yrs; Sustaining flows at least 1:3 years Optimum 1:1 years	2–4 weeks for development from larvae to juveniles	• Habitat availability • Extent & duration of inundation • Larvae present
Fish redistribution (local and large scale movement within freshwater reaches)	*Mid flow–high flow* Inundation of reedbeds, bars, benches and flood runners A sustaining of 20–30 cm water depth is generally required for fish movement	• Local movement / pool connection events • Long duration flows for large scale redistribution and recolonisation of habitats	1–5 years	1:1–1:5; sustaining flows are required at least 1:2 or 1:3 Species decline will occur if longer return periods occur	Local movement: 2 days – 2 weeks Large scale: 1–3 weeks; 1 week for sustaining populations	• Species diversity • Habitat availability • Duration of flows
Fish migration to the sea	*Mid flow–high flow*	• Migration to sea		1:2 years	1–2 months	• Duration of inundation • Extent of inundation

Biota	Key flow bands + location/lateral extent/depth	Purposes of flow bands	Average life span of species (see Section 4)	Event frequency (range, sustaining requirement)	Event duration & seasonality (range, sustaining requirement)	Criteria for determining impacts/benefits
Macro-invertebrate habitat	*Groundwater–baseflow* Pools inundated, channel bed wetted and flow over riffles	• Maintenance of diverse aquatic habitats • Maintain aquatic habitats as refugia during dry periods	Months to a few years	Permanent	Permanent	• Extent and diversity of habitats available
Macro-invertebrate Riffle habitat	*Low flow* Inundation of riffle zones	• Create riffle habitats for riffle dwelling species	Months to a few years	Annual	>2 weeks – 3 months Sustaining: 4 weeks	• Extent and diversity of habitats available
Macro-invertebrate large recruitment events	*Mid flow–overbank flow* Flows through reed bed, benches to overbank to inundate dry habitat	• Breeding events • Inundation of bars, benches, flood runners and floodplains to create new habitat for recruitment • Cleaning riffles to maintain habitat diversity	Months to a few years	Annual to 1:2 yr Sustaining = 2:3	1–3 weeks Sustaining = 1 week	• Species diversity • Habitat availability • Duration of inundation • Extent of inundation • Larvae present
Macro-invertebrate population loss events	*No flow and high–overbank flows*	• Population loss event • Prevention of dominance by single species • Habitat forming flows	Months to a few years	1:3 max. (dry) 1:1 to 1:2 is OK (high flow)	1–2 months (no flow) hours–days (high flow)	• Duration of dry event. • Velocity of high flow event
Frog habitat	*Groundwater–baseflow* Pools inundated and channel bed wet	• Maintenance of minimum water level and quality • Inundation of areas of habitat & food resource	1–5 years	Permanent (can withstand short periods of drying up)	Occurs for most of the year – low flow or dry in late summer	• Salinity increases • Species diversity • Habitat availability
Large scale frog breeding	*Low flow – high flow* Inundation of reedbeds, bars, benches and flood runners A sustaining of 20–30 cm water depth is generally required for frog breeding.	• Increase in habitat area • Increase in food resources	1–5 years	1:1 – 1:5; sustaining flows are required at least 1:3	4–6 weeks	• Species diversity • Habitat availability • Duration of flows

Table C.3 Ecological requirements of key fish species actually or likely to inhabit the Light River system (these requirements are based on current knowledge but can only be considered as approximate until further research is conducted on these species in the Light and elsewhere) (Derived from Koehn and O'Connor 1990; Lloyd 1987; Merrick and Schmida 1984; McDowall 1980)

Fish species		Life span	Spawning season	Incubation duration*	Migration	Other
Common name	**Scientific name**					
Blue spot goby	*Pseudogobius olorum*	2–3 years	Oct–Jan	4 days	Local only	Need hollow in or burrow under rock or wood as a substrate for laying eggs
Mountain galaxias	*Galaxias olidus*	2–4 years	July–Oct	5–7 days	Upstream, if at all	Leaf litter required
Congolli	*Pseudaphritis urvilli*	>5 years	Sept–Dec	Unknown (likely to be short: 3 or so days)	Upstream & downstream with increasing flows from Jun–Oct Needs further investigation	Susceptible to impacts from the presence of water flow barriers
Smallmouthed hardyhead (silverside)	*Atherinosoma microstoma*	1 year	Sept–Feb	4–7 days	Local only	Breeding probably occurs in estuary or lower reaches of rivers
Big-headed gudgeon	*Philypnodon grandiceps*	4–7 years	Oct–Feb	4–6 days	Local only	Hard surfaces required as a substrate for laying eggs
Australian smelt	*Retropinna semoni*	1 year	Sept–Nov	9–10 days	Local only	Aquatic macrophytes required as a substrate for laying eggs
Common jollytail	*Galaxias maculatus*	2–3 years	Aug–Nov	Normally take 10–16 days between flow events or tides (in estuary	It seems that the Light population is landlocked and therefore spring breeding movements are upstream into flooded creek margins	Riparian macrophytes (intertidal in estuary) or required as a substrates for laying eggs

* Time that eggs take to develop into larvae (eggs require inundation at least for this period)

APPENDIX D – LEGISLATIVE RIGHTS AND RESPONSIBILITIES

Landholders and land and water managers have certain legal rights and responsibilities for managing watercourses and water resources. It is important that these rights and responsibilities are understood. While the *Water Resources Act 1997* deals specifically with management of water resource and watercourses, other legislation dealing with environment protection, soil conservation, planning, native vegetation and pest plants and animals are also applicable.

Landowners — general duty of care

Under the *Water Resources Act 1997*, landowners or occupiers have an obligation to maintain a watercourse or lake in good condition. Landowners or occupiers also have a duty to take reasonable steps to prevent damage to the bed and banks of a watercourse or lake and to the ecosystems that depend on the watercourse or lake.

Section 25 of the *Environment Protection Act 1993* requires that a person must not undertake an activity that pollutes or might pollute the environment unless all reasonable steps are taken to prevent or minimise any environmental harm that might occur. Similarly, section 8 of the *Soil Conservation and Land Care Act 1989* imposes a duty on landholders to 'take all reasonable steps to prevent degradation of the land'.

Native vegetation

Under the *Native Vegetation Act 1991* it is generally an offence to clear native vegetation without the permission of Native Vegetation Council. There are certain prescribed circumstances, e.g. maintaining firebreaks, where clearance is permitted under the Act. The Act also allows for provision of incentives and assistance to landholders to help preserve and conserve native vegetation, to limit the clearance of vegetation and to encourage revegetation.

State Government agencies

The Department of Water, Land and Biodiversity Conservation administers a number of Acts related to management of water resources including the *Water Resources Act 1997* and the *Water Conservation Act 1936.* The department's main responsibility is the sustainable use and management of the State's water resources, particularly in prescribed areas.

The Department for Environment and Heritage is concerned with the conservation, protection and enhancement of the State's environmental resources and natural and built heritage. The department is responsible for a number of acts relevant to watercourse management including the *Environment Protection Act 1993*, the *Native Vegetation Act 1991* and sections of the *Water Resources Act 1997.*

Primary Industries and Resources, South Australia (PIRSA) is the key agency for industry development, natural resource management and policy advice and support to ensure sustainable economic development for South Australia. Legislation applicable to watercourse management which is administered by PIRSA includes the *Soil Conservation and Land Care Act 1989* and the *Animal and Plant Control (Agricultural Protection and Other Purposes) Act 1986.*

Local government

Local councils commonly have to deal with watercourse management issues, including: developments that may impact on the water resource or watercourses such as dams or weirs; management of watercourse vegetation, drainage, environmental flows; and pressures for intensification of landuse, tourism development and recreation impacts.

Councils have responsibility for drainage under the *Local Government Act 1999* and other matters such as provision of water services, protection of the council's area from natural and other hazards and managing, developing, protecting, restoring, enhancing and conserving the environment in an ecologically sustainable manner, and to improve amenity. The council may also have responsibility for areas declared as water conservation reserves under the *Water Conservation Act 1936*. The *Public and Environmental Health Act 1987* can be used by councils to prosecute polluters of watercourses.

For all watercourses and lakes in a council area, councils are able to take necessary action under the *Water Resources Act 1997* if a landowner or occupier:

- fails to comply with a notice requiring that they maintain a watercourse or a lake in good condition (Section 14) or,
- fails to comply with a notice requiring that they take reasonable steps to prevent damage to the bed and banks of a watercourse or lake and the ecosystems that depend on the watercourse or lake (Section 17).

To deal with many water resource or watercourse management issues, councils can prepare a local water management plan under *the Water Resources Act 1997*. A local water management plan is a statutory document that allows the council to manage water resources and watercourses as outlined under the *Water Resources Act 1997*. Its key functions include:

- controlling by the use of permits, water affecting activities listed under section 9 of the *Water Resources Act 1997;*
- addressing council's responsibilities as manager of land and watercourses on land owned by council;
- integrating council's powers under other legislation it administers e.g. *Local Government Act 1999*, the *Development Act 1993* and the *Public and Environmental Health Act 1987*.

In addition the opportunity exists for councils to amend their development plans through the local water management planning process to ensure both plans are consistent and to optimise use of the plans. This will allow councils to influence development to ensure that it does not have an adverse effect on surface water resources in the council area. In all cases information about the water resource and watercourses in the council area is crucial to planning and decision making.

It is important to note that the local water management plan can not limit the volume of surface water taken from a watercourse nor can it control the taking of groundwater or water taken for stock and domestic purposes. To control the taking of water, the resource would need to be prescribed under the *Water Resources Act 1997* and a water allocation plan prepared for that resource.

NYAD INRM Committee

The Commonwealth and South Australian governments are signatories to the Intergovernmental Agreement (IGA) on a National Action Plan for Salinity and Water Quality. Both parties have committed to an action plan, to motivate and enable regional communities to use coordinated and targeted action to address salinity, deteriorating water quality and the conservation of biological diversity.

An integrated natural resource management (INRM) plan will be developed for the Northern and York Agricultural district, covering the range of natural resource management issues in the region. The INRM plan will provide leadership and direction for statutory bodies involved in natural resource management. The river management plans for the Light, Wakefield and Broughton catchments will provide baseline information on the riverine issues and priorities in the Mid-North Region.

Soil conservation boards

The *Soil Conservation and Land Care Act 1989* allows for the establishment of soil conservation boards whose task is to help increase people's awareness of land conservation and to provide advice and assistance for landholders.

Soil conservation boards must develop and implement a district plan that identifies land classes and land use, outlines land capability and preferred uses, identifies land management and degradation issues and describes measures for rehabilitation and prevention of further degradation. Opportunities exist under the district plans for implementing land management measures that prevent degradation of watercourses. For example, activities that slow surface runoff and prevent water and soil erosion of the land will also prevent sedimentation and erosion along watercourses. More specific measures include maintaining a band of vegetation along watercourses to reduce erosion and soil loss and trap sediment and associated nutrients washed off surrounding land. Maintaining or planting of these watercourse buffer strips with indigenous species can also address native vegetation decline.

Animal and plant control boards

The *Animal and Plant Control (Agricultural Protection and Other Purposes) Act 1986* was proclaimed for the specific purpose of controlling animal and plants for

- the protection of agriculture;
- the protection of the environment;
- the safety of the public.

Animal and plant control boards must ensure that the provisions of the Act are carried out and enforced within the area of the board. The boards also develop and implement coordinated programs for the destruction and control of feral animals and noxious plants that are proclaimed under the Act. Landholders have a responsibility under the Act to control or destroy animals and plants proclaimed under the Act for their area.

APPENDIX E – KNOWLEDGE GAPS

The plan has been developed using the best information available at the time and is based on a 'snapshot' assessment of the current condition of the Light River system. River systems are dynamic and consequently the recommendations of this plan will need to be revised and adapted in the future, based on information collected over longer time scales through recommended research and monitoring activities.

Where possible knowledge gaps and monitoring specific to each subcatchment is discussed in Chapters 8–11. The following represents a summary of key knowledge gaps and research and monitoring recommendations identified by this project. Further investigations into areas lacking information is essential to improve the information base for sound watercourse management.

Knowledge gaps: targets for future research

Topic	Knowledge gaps
Hydrology	• Lack of knowledge of flows throughout the catchment
Hydrogeology	• Lack of knowledge of groundwater level and salinities throughout the catchment
Water quality	• Lack of data on water quality for point and diffuse pollution issues: beyond the scope of this project
Geomorphology	• Extent of incision to watercourses since European settlement
Water requirements of freshwater aquatic plants and animals	• Lack of detailed studies of water requirements particularly in the ephemeral or intermittent streams found in South Australia • Specific responses of plants and animals to different flow events in the Light catchment
Hyporheic environments	• Lack of knowledge of their role as a refuge in dry periods, the presence and location of hyporheic zones, animals and their lifecycle and water requirements
Fish ecology of the Light catchment	• Migration habits, lifecycle water requirements and the impacts of exotic fish species, migration barriers and other threats
Tea tree (*Melaleuca brevifolia*) scrub	• Extent of tea tree scrub along watercourses prior to European settlement
Reedbeds	• Extent of reedbeds prior to European settlement and historical changes to extent throughout catchment, future trends in extent • Causes of excessive growth of reedbeds dominated by common reed *(Phragmites australis)* and bulrush (*Typha* sp.); the long term implications for river health and management requirements
Groundwater dependent ecosystems	• The role of pools and baseflow in maintaining the ecology of the river during dry periods • Effects of water extraction on the ecology of permanent pools.

Topic	Knowledge gaps
Sediment transport processes within watercourses	• Sediment sources in the Light catchment • Location and rates of erosion, deposition and their responses to various flows in the Light catchment
Salinity	• Lack of stream salinity data in the Light River system • Location and extent of dryland salinity within the Light catchment • Salinity levels of the groundwater systems within the Light catchment
Groundwater–surface water interactions	• Lack of knowledge of groundwater–surface water interactions in the Light catchment • Cause of decreased baseflows in the lower Light as reported by landholders in the region • Location of groundwater recharge and discharge zones that influence baseflows in the Light River and its tributaries • Effects of water extraction from wells and bores on pools, baseflow and groundwater • Effects of practices aimed at reducing groundwater recharge (to combat dryland salinity) on permanent pools and baseflows
Ecological and geomorphological effects of changes to the flow regime	• How changes to baseflow, low and medium flows due to development will affect water level, velocities, durations and frequencies of flows • How do these changes affect the stream ecology and morphology?
Light River estuary	• Flow behaviour in the Light River estuary (specifically low flows, flood flow patterns and sediment delivery)
Impact of inputs of River Murray water	• Lack of knowledge into the impact of piping River Murray water into the Light River system on water quality and ecology (especially fish)

APPENDIX F – NYAD INRM COMMITTEE RECOMMENDED MANAGEMENT ACTIONS

The following tables show the recommended management actions outlined in the Integrated Natural Resource Management Plan developed by the Northern and Yorke Agricultural District Integrated Natural Resource Management (NYAD INRM) Committee (2003). Overlap between the management actions below and those of this project are shown in Chapter 12.

NYAD INRM Plan Section 6.1 – Achieving Sustainable Water Supplies and Use

Resource Condition Targets:

6.1A Water regimes restored to a level sufficient to sustain significant dependent ecosystems throughout the region by 2015

Management Targets:

6.1.1 Sustainable limits for surface & ground water determined by 12 /05

6.1.2 Dependent ecosystems & their water requirements identified by 6/04

6.1.3 Water use within sustainable limits throughout the region by 6/07

Recommended Management Actions and Link to Current Investment Program:

	Management Actions (from Plan)
	Benchmarks & Monitoring
i	Establish regional water quantity data base for surface and groundwaters, quantifying water resources and levels of use and dependent ecosystems and their water requirements, and monitoring programs
	On-Ground Actions
ii	Implement relevant recommendations from the Mid North rivers project reports to develop improved water regimes to support dependent ecosystems
iii	Develop and implement programs for the re-use of effluent and stormwater
iv	Incorporate best practice water conservation principles to new development and to the upgrading and construction of infrastructure
	Planning & Investigations
v	Maintain support for programs to develop more efficient water use options for irrigation & industry

vi	Review the impact of irrigation, stock and domestic use on water resources in the region
vii	Develop a river management plan for catchments at risk (such as the Willochra catchment)
viii	Complete regional inventory of water dependent ecosystems and their water requirements (both surface & ground)
ix	Investigate impacts associated with water importation
x	Investigate potential biodiversity/ revegetation offsets for water use in the region
xi	Develop regional action plan for provision of water to dependent ecosystems
xii	Ensure flood management planning takes into consideration natural resource issues
xiii	Review potential economic instruments to promote more efficient use of water resources
	Capacity Building
xiv	Develop and promote regional guidelines for improved water use efficiency
xv	Implement cooperative partnerships with industry to ensure that water use for production and industry purposes complies with sustainability objectives
xvi	Expand community education programs re environmental flow requirements and on methods to reduce the level of use/ wastage of water resources
xvii	Develop and implement water conservation opportunities, focusing on improved community skills and commitment
	Legislation and its Implementation
xviii	Ensure that there are adequate controls across the region to regulate water use and water affecting activities, to safeguard dependent ecosystems and provide long-term security for water users

NYAD INRM Plan Section 6.2 - Achieving Water Quality Improvement

Resource Condition Targets:

6.2A Maintenance or a progressive reduction below critical levels in average & peak nutrient loads (N&P),turbidity levels & other contaminants including pesticides, heavy metals & hydrocarbons in streams throughout the region, with clear targets determined by 12/04

6.2B Progressive improvement in river health as measured by key biological indicators, with targets determined by 12/04

Management Targets:

6.2.1 Identify thresholds for N, P, turbidity and other relevant / potential contaminants by 12/04.

6.2.2 Continue erosion control works at known critical or strategic areas & develop clear targets for erosion control by 6/07

6.2.3 Implement program to fence / protect priority remnant riparian vegetation and fence & revegetate strategic riparian areas based upon Mid North Rivers project & regional Biodiversity Plan by 6/07

Recommended Management Actions and Link to Current Investment Program:

	Management Actions (from Plan)
	Benchmarks & Monitoring
i	Develop and apply the Risk Assessment Framework for Water Resource Management to develop priorities for investment in on-ground actions, investigations, extension and compliance programs
ii	Strategically invest in regional monitoring and assessment programs for water quality (and catchment characteristic attributes affecting water quality) to establish subcatchment level benchmarks and targets and develop on-ground works monitoring and evaluation systems
iii	Implement management plan for riparian zone protection and restoration in accordance with recommendations from Mid North Rivers Management Planning Project
iv	Develop and invest in strategic programs to improve domestic waste water systems management
v	Develop and invest in programs to reduce contamination of stormwater run-off
vi	Continue erosion control works at known critical or strategic areas: Develop clear regional targets for erosion control through Risk Assessment Framework
vii	Implement program to fence / protect priority remnant riparian vegetation and fence and revegetate strategic riparian areas: Develop clear regional targets for erosion control through Risk Assessment Framework
	Investigations
viii	Complete riparian zone surveys and management planning for the major catchments in the region
ix	Develop regional plan for riparian zone protection & revegetation, including actual and potential erosion sites based on Risk Assessment Framework and biodiversity plan

x	Investigate key relationships between land use/management practices and water quality parameters to support the development of codes of practice and guidelines for sustainable land management and industry development
xi	Investigate impact of modified state of catchment on long-term survival of biota, including waterbirds and native fish
xii	Investigate impact of point source and diffuse contamination from urban and industrial areas upon watercourses and marine waters
	Capacity Building
xiii	Clarify roles and responsibilities between all authorities managing water resources in the region
xiv	Ensure that regional extension programs provide the community with adequate information & skills development to adopt best practice in water quality management, taking into account biodiversity and other objectives
xv	Ensure an adequate level of community involvement in monitoring programs related to water quality
	Legislation and its Implementation
xvi	Ensure adequate resources for compliance activities addressing point and diffuse pollution issues
xvii	Identify land use planning and development control mechanisms that could contribute to water quality improvement
xviii	Implement Environment Protection (Water Quality) Policy or equivalent legislative program

NYAD INRM Plan Section 6.3 - Managing Groundwater Driven Salinity

Resource Condition Targets:

6.3A Halt the rise in saline groundwater levels in local & intermediate groundwater systems & the increase in salinity levels in surface water bodies by 2020

6.3B Achieve improved economic productivity in 50% of primary production lands affected by salinity by 2010

6.3C Demonstrate progressive improvement in condition of significant biodiversity areas by 2015

Management Targets:

6.3.1 Establish regional benchmarks & monitoring programs for salinity in surface & groundwaters & associated impacts on production, natural biodiversity & infrastructure by 6/04

6.3.2 Establish clear targets for on-ground works in priority salinity areas by 12/04

6.3.3 Implement priority actions arising from salinity mgmt plans to address RCTs by 12/07

Recommended Management Actions and Link to Current Investment Program:

	Management Actions (from Plan)
	Benchmarks & Monitoring
i	Establish regional benchmarks and monitoring programs for salinity in surface and groundwater and associated impacts on production, natural biodiversity and infrastructure
	On-Ground Actions
ii	Implement actions arising from salinity management plans to reduce and eventually halt the rise of saline groundwater and the increase in surface water salinity and, where appropriate, to implement living with salt options for increased productivity
iii	Fence remnant native vegetation in priority sub-catchments and initiate ongoing management programs for those areas
	Investigations
iv	Complete salinity management plans for areas affected by and at risk from secondary dryland salinity
v	Complete investigation of effects of salinity on public infrastructure in identified salinity areas
vi	Develop and promote innovative and productive solutions for treatment of salinity-affected and at risk areas, including “living with salt” in areas likely to be affected on a long-term basis

vii	Encourage actions to improve water use efficiency in irrigation practices
viii	Develop a risk assessment process for assessing potential impacts of proposed developments and other actions in terms of implications for salinity management.
	Capacity Building
ix	Develop & implement integrated program involving NAP Salt Action Teams to raise community, industry and land manager awareness re salinity, to foster appropriate skills and to provide appropriate support for salinity management.

NYAD INRM Plan Section 7.1 - Managing Soil Structure, Fertility, Organic Matter and Acidity

Resource Condition Targets:

7.1A Soils supporting primary production reflecting optimum capability by 2015

7.1B Soils managed to support diverse soil biodiversity & natural ecosystems by 2015.

Management Targets:

7.1.1 Progressive increase in the number of properties incorporating best practice mgmt to sustain & enhance soil health & to limit the onset of acidification with clear targets set by 12/04

Recommended Management Actions and Link to Current Investment Program:

	Management Actions (from Plan)
	Benchmarks & Monitoring
i	Establish representative monitoring programs at the property and regional levels
	On-Ground Actions
ii	Implement a range of programs to maintain and improve soil health
iii	Develop and promote regional program for the monitoring, prevention and treatment of soil acidity
iv	Develop programs to encourage innovation in pasture, cropping and other primary production management practices for improved soil health and sustainability
	Investigations
v	Conduct research to further define areas in the NYAD at risk of soil acidity and appropriate preventative measures
vi	Conduct research to determine link between acid soils and other land management issues such as salinity and water quality
vii	Establish additional trials to demonstrate stubble, crop and pasture management in key areas
viii	Support investigation into innovative land management techniques
ix	Investigate, develop and promote non-acidifying fertilisers
x	Develop techniques to overcome mice, white snails, herbicide resistant rye grass etc which do not rely on burning residues or increasing cultivation of soil

	Capacity Building
xi	Maintain existing programs, including property management planning, to encourage best practice management to sustain and enhance soil health
xii	Expand the capacity of local and broader communities to value and address soil structure / organic matter and other soil and land management issues
xiii	Ensure that regional support programs are in place to assist land managers in review options for treatment of soil acidity and in applying appropriate prevention and treatment methods
xiv	Promote innovative approaches to improved soil health and sustainable production systems through partnerships between landholders, industry and Government

NYAD INRM Plan Section 7.2 - Managing Wind and Water Erosion of Soils

Resource Condition Targets:

7.2A Reduce incidence of sheet, rill & gully erosion events by 30% by 2015

7.2B Reduce area of sand hills with potential drift problems by 50% by 2015

Management Targets:

7.2.1 Adequate surface cover maintained over 80% of susceptible land for 10 months of the year

7.2.2 Adoption of reduced / no tillage & stubble retention on 80% of cropping land at risk of erosion by 2010

7.2.3 Grazing managed to maintain adequate levels of surface cover on 75% of land at risk by 2010

7.2.4 Perennial vegetation established on 80% of very high risk erosion areas by 2015

Recommended Management Actions and Link to Current Investment Program:

	Management Actions (from Plan)
	Benchmarks & Monitoring
i	Map area of bare/drifting sandhills in region by 12/05 and monitor change in area of bare sandhills
ii	Record incidences of sheet, rill and gully erosion events in region
iii	Maintain monitoring of surface cover and soil condition on selected transects in region
iv	Adoption of reduced / no tillage and stubble retention on 80% cropping land at risk of erosion
v	Grazing managed to maintain adequate levels of surface cover on 75% of land at risk
vi	Interrow horticultural practices to maintain adequate levels of surface cover adopted on 80% of land at risk
vii	Runoff control structures present on 30% of Class IIIe land
viii	Perennial vegetation established on 80% of very high risk erosion areas
ix	200 km of watercourses fenced off

	Investigations
x	Obtain more relevant data to assess impact of land management practices on rate of soil loss for region's soils and rainfall events
xi	Obtain more quantitative data on effect of range of tillage practices on soil erodibility
xii	Develop new design systems for contour banks to accommodate larger machinery
xiii	Develop techniques to overcome mice, white snails, resistant rye grass which do not rely on burning residues or increasing cultivation
xiv	Assess machinery developments / modifications which will increase land managers ability to adopt stubble retention and reduced / no tillage systems
xv	Assist land managers to manage land to land capability, retain stubble, reduce tillage, manage grazing, plant perennial cover, install contour bank systems, plant wind breaks etc by provision of information and advice through demonstrations, trials, field days, workshops
xvi	Provide technical training in soil conservation / land management to providers of information and services
xvii	Implement development controls to ensure that changes in land use development applications demonstrate how land is to be managed in a manner that will not cause erosion
xviii	Implement legislation that will enable severe or potential problems to be rapidly addressed through controlling land managers' actions

NYAD INRM Plan Section 8.1- Managing Natural Ecosystems

Resource Condition Targets:

8.1A No further fragmentation of native vegetation by 6/05

8.1B 50% of areas of remnant native vegetation exceeding 10ha, within large remnant & threatened habitat areas protected under covenant by 2015

8.1C Progressive improvement in the **condition** of areas of biodiversity significance, with clear targets established by 12/04

8.1D Progressive increase in the **area** of biodiversity significance through habitat restoration and reconstruction programs, with clear targets by 12/04

Management Targets:

8.1.1 Mechanisms in place to ensure no further fragmentation of native vegetation by 6/05

8.1.2 Increase area subject to protective covenant by 20% by 6/05

8.1.3 Increase areas of biodiversity significance being actively managed (eg weeds, pest animals, fire control) by 3000ha by 6/08

8.1.4 Restore / reconstruct 5000ha of natural habitat in significant biodiversity areas by 6/09

Recommended Management Actions and Link to Current Investment Program:

	Management Actions (from Plan)
	Benchmarks & Monitoring
i	Establish regional benchmarks & monitoring programs for selected biodiversity indicators
	On-Ground Actions
ii	Expand programs for the conservation & management of native vegetation remnants outside of the protected areas network. Increase area subject to protective covenant by 20%
iii	Regeneration and revegetation programs undertaken to link, expand and buffer remnant native vegetation: five year target of 5,000 ha revegetated in accordance with biodiversity objectives
iv	Continue native vegetation re-establishment in known strategic areas and linkages for biodiversity purposes: also link with salinity, water quality and other objectives: establish clear revegetation targets
v	Expand programs for management of weeds and problem animals in priority biodiversity areas in accordance with regional biodiversity plan
	Investigations & Planning
vi	Undertake comprehensive biological survey of the NYAD region
vii	Review condition and management status of areas of native vegetation (including wetlands, salt lakes and watercourses) outside of the Protected Areas Network
viii	Review effectiveness of current programs for the management of biodiversity in the protected areas network

ix	Conduct further research into the ecological management of grasslands and grassy woodland ecosystems, including the role of grazing
x	Complete floristic mapping in the NYAD region
xi	Develop guidelines and targets for the reconstruction of natural habitats in the region
xii	Develop and implement fire management plans or statements for significant biodiversity areas
xiii	Investigate options for the management of land adjacent and close to reserves and large remnants for conservation / revegetation purposes
xiv	Undertake research into the significance and condition of other habitats such as moss rocks, ridgelines, cliff-faces etc.
	Capacity Building
xv	Expand programs to provide community and land managers with information, skills and support in the protection, management and reconstruction of natural habitats
xvi	Produce regional codes of practice for recreational activities impacting on biodiversity
	Legislation and its Implementation
xvii	Ensure appropriate consultation mechanisms between Native Vegetation Council and planning authorities
xviii	Introduce amendments to Native Vegetation regulations to tighten clearance exemptions, provide scope for protection of revegetated areas, and to provide protection for dead native vegetation known to be of habitat value

NYAD INRM Plan Section 8.2 - Protecting and Managing Threatened Species & Ecological Communities

Resource Condition Targets:

8.2A Enhanced habitat for top 20% of priority threatened species & communities by 2010 & for all threatened species & communities by 2020

8.2B Progressive decrease in number of threatened species & communities due to recovery & long-term sustainability

Management Targets:

8.2.1 Recovery or management plans in place for all identified threatened species & communities in the region by 6/06

8.2.2 Recovery plans for top 20% of priority threatened species & communities initiated by 6/08

Recommended Management Actions and Link to Current Investment Program:

	Management Actions (from Plan)
	Benchmarks & Monitoring
i	Establish a comprehensive information base on threatened species status and requirements, including identification of species most at risk of extinction
ii	Establish a consistent monitoring and reporting framework on the performance of recovery programs, incorporating suitable indicator species/ populations for measuring outcomes
	On-Ground Actions
iii	Implement existing recovery plans and threat abatement plans (ongoing), and link with broader actions as outlined in Section 8.1
	Investigations
iv	Prepare and/or Recovery Plans for all priority threatened species and ecological communities that do not have a current plan
	Capacity Building
v	Provide increased information and support to land managers and community groups re actions to assist recovery of threatened species

NYAD INRM Plan Section 8.3 - Managing Coastal, Estuarine and Marine Systems

Resource Condition Targets:

8.3A Progressive improvement in the quality of marine & estuarine waters that are subject to diffuse and point-sourced land-based discharges, with clear targets established by 12/05

8.3B Progressive improvement in the condition of natural biodiversity in coastal, estuarine & marine systems through management of water quality, introduced pests & land use & mgmt: clear targets by 12/05

Management Targets:

8.3.1 Key discharge sources identified and management programs initiated with clear targets by 12/05

8.3.2 Marine, coastal & estuarine areas of particular biodiversity significance identified & mgmt programs initiated with clear targets by 12/05

8.3.3 Comprehensive planning basis in place for coastal, estuarine & marine biodiversity by 12/05

Recommended Management Actions and Link to Current Investment Program:

	Management Actions (from Plan)
	Benchmarks & Monitoring
i	Establish marine and estuarine water quality monitoring program on a regional basis
ii	Establish register or database of pollution incidents, sources and their impact on the marine environment
iii	Establish representative monitoring program for terrestrial coastal and marine biodiversity focusing on areas subject to water contamination and other threatening processes
iv	Ensure that programs are in place to monitor the condition of fisheries stocks and ensure effective control programs are in place to achieve sustainability
	On-Ground Actions
v	Support and invest in programs to protect and rehabilitate marine, coastal and estuarine areas of particular biodiversity significance
vi	Support and invest in programs to reduce contamination of marine and estuarine waters
vii	Support and invest in relevant on-ground actions derived from the Our Seas and Coasts strategy
viii	Ensure that coastal stormwater management is included in environmental criteria for engineering design and works
ix	Ensure that program is in place to protect natural coast protection features eg dunes, reefs
	Investigations & Planning
x	Develop, through the SA Marine Protected Areas program and /or Marine Planning Program, a comprehensive Risk Assessment program for marine, coastal and estuarine biodiversity, identifying areas / communities at risk, threatening processes & management strategies

xi	Complete survey of habitat requirements of sea and shore-birds in the region
xii	Identify critical fish spawning and nursery areas with the objective of providing some protection by integration of these areas into fish management plans
xiii	Ensure Investigation into factors contributing to decline in fish stocks and marine mammals
xiv	Develop & implement a strategy to deal with marine pest incursions and to restrict the opportunity for new introductions
xv	Review potential impacts and management options associated with predicted sea level rises
xvi	Develop a regional management plan for saltmarsh, mangrove and coastal dunes, wetlands and clifftop communities
	Capacity Building
xvii	Maintain existing partnerships between State agencies, Local Government and community groups (eg through the Coastcare Program) to develop and apply skills in managing coastal and marine biodiversity.
xviii	Develop targeted program to encourage landholders and visitors to protect coastal and marine environments
xix	Establish partnerships to promote educational & research programs focusing on biodiversity conservation in marine, coastal & estuarine areas
	Legislation and its Implementation
xx	Review current legislation relating to the development and management of coastal and marine areas to identify mechanisms to support improved biodiversity conservation
xxi	Implement Environment Protection (Water Quality) Policy
xxii	Ensure that relevant planning authorities have adequate support and advice in dealing with developments that may impact upon coastal, estuarine and marine biodiversity

NYAD INRM Plan Section 9.1- Managing Pest Plants, Problem Animals and Diseases

Resource Condition Targets:

9.1A Progressive improvement in the condition, integrity and viability of natural biodiversity and primary production systems, achieved through a progressive decrease in the impact of pest plants, problem animals & diseases: clear targets by 12/04

9.1B Pest plants (including environmental weeds), pest animals & diseases not impacting significantly upon primary production, significant biodiversity areas & sites for priority species & ecological communities by 2020.

Management Targets:

1.1 Halt & reverse spread of environmental weeds in large remnant and threatened habitat areas halted and reversed by 6/07

9.1.2 Maintain integrated programs for the management of pest plants, problem animals & diseases: establish clear mgmt targets by 12/04

9.1.3 Establish system for preventing introduction of new pests & diseases & for early detection and priority treatment of any introductions that do occur: by 6/05

Recommended Management Actions and Link to Current Investment Program:

	Management Actions (from Plan)
	Benchmarks & Monitoring
i	Establish mapping systems to link with pest databases and incorporate into ongoing monitoring of environmental and agricultural weeds
ii	Map distribution & abundance of ranked agricultural weeds
iii	Ensure adequate benchmarks and monitoring programs in place for problem animals and diseases of natural biodiversity (including pests & diseases of marine systems)
iv	Ensure that there are adequate regional benchmarks, monitoring programs and data systems for pests and diseases of primary production
	On-Ground Actions
v	Establish a program for early detection of new weed species and new outbreaks of existing weed species and a contingency strategy for dealing with them
vi	Establish system for early detection and reporting of new pests and diseases or new outbreaks of existing pests and diseases in terrestrial and marine areas
vii	Support the implementation of local policies for control of animals that threaten natural biodiversity (eg foxes, rabbits, feral goats, uncontrolled cats, deer)
viii	Develop and maintain integrated weed control programs, linking with biodiversity, primary production, fire prevention & other objectives
ix	Maintain integrated programs for the control of problem animals, linking with biodiversity, production & other relevant objectives
	Investigations
x	Ensure that contingency plans are in place for pests and diseases that have a significant probability of entering the region

xi	Develop contingency plans for the management of potential new pests and diseases (eg Phytophthora)
xii	Ensure bio-security strategy in place for preventing the introduction of new pests and diseases
xiii	Ensure strategy in place for preventing the introduction of new weed species and for the eradication of sleeper weeds
xiv	Conduct regional review of strategies, programs and resources for the control of environmental weeds, with reference to the State Weeds Strategy of 1998
xv	Conduct regional review of strategies, programs and resources for the control of agricultural weeds
xvi	Conduct regional review of strategies, programs & resources for the control of pest animals and diseases
xvii	Support ongoing Weed Risk Assessment (WRA) program for priority environmental and agricultural weeds
xviii	Support ongoing research into improved, targeted methods for control of the region's priority weeds
xix	Support ongoing research into improved targeted methods for control of priority pest animals and diseases in both terrestrial and aquatic systems
xx	Investigate options for increasing awareness amongst land managers and the community regarding weed species & their management
xxi	Ensure that co-ordinated programs are in place to provide land managers and community groups with relevant information and support for management of environmental pests
xxii	Ensure that programs are in place to raise community awareness and skills regarding pest animals, relevant diseases and their control
xxiii	Develop an induction program/ communication strategy for land owners regarding problem animal and disease control
xxiv	Foster co-ordinated targeted programs between land holders across districts and regions for control of weeds & weed spread
xxv	Develop targeted program for all land holders, lifestyle block owners and other key groups re responsibilities, methods and sources of support for pest plant and animal management
xxvi	Develop specific packages to encourage and support community involvement in the early detection of new pest introductions (including the marine environment)
xxvii	Develop regional capacity building strategy for increasing community and landholder awareness and capabilities of pests & diseases & their management
	Legislation and its Implementation
xxviii	Review legislative options relating to the management of pest plants and animals
xxix	Review scheduling arrangements under APC legislation as they apply to environmental weeds
xxx	Review the effectiveness of current legislation in the prevention of weed introductions and management of existing weed problems
xxxi	Review legislative responsibilities and processes relating to the control of problem animals and pests, including vertebrate pests subject to the APC legislation and uncontrolled cats
xxxii	Ensure that mechanisms are in place to provide for input of advice to planning authorities re pest management implications of development applications
xxxiii	Ensure that legal mechanisms are in place to identify notices on land relating to plant and animal control
xxxiv	Review progress in implementation of State Weeds Strategy and ensure that strategic actions that have not yet been addressed are initiated

NYAD INRM Plan Section 10.1- Safeguarding Indigenous Cultural Values

Resource Condition Targets:

10.1A Areas, sites, items and other Indigenous cultural values safeguarded in NRM by 6/05

Management Targets:

10.1.1 Processes in place to ensure that Indigenous cultural values & assets are subject to appropriate risk assessment & protection by 12/04

Recommended Management Actions and Link to Current Investment Program:

	Recommended Management Actions (from Plan)
	Benchmarks & Monitoring
i	Support local indigenous communities to research and inventory, historic sites and stories that relate to the history of the region and where appropriate, make this information available to visitors through interpretive material.
	On-Ground Actions
ii	Develop conservation plans to facilitate appropriate management of Aboriginal cultural heritage sites
iii	In co-operation with indigenous organisations and groups, identify opportunities to restore and protect historical and culturally significant sites.
	Investigations
iv	Research and inventory, historic sites and stories that relate to the history of the region and where appropriate, make this information available to visitors through interpretive material.
	Capacity Building
v	Implement program to ensure that land managers, community groups and land management authorities have an adequate awareness re Indigenous cultural values and a commitment to ensuring that those values are taken into account
vi	Develop appropriate partnerships with indigenous groups to facilitate a process to identify significant areas
vii	Encourage and support cultural heritage surveys, which include archaeological and anthropological studies within the region
viii	Develop and implement protocols for consultation with Indigenous communities regarding natural resource management actions in the region
ix	Implement Cross Cultural Awareness Programs to inform the community of the significance of holistic land values to Indigenous people, and extend interpretive programs where appropriate to include cultural experiences for visitors
x	Develop appropriate inclusive communication strategy
xi	Ensure that Indigenous communities have an input to relevant NRM actions to safeguard cultural values

NYAD INRM Plan Section 10.2 - Safeguarding Landscape Values

Resource Condition Targets:

10.2A Landscapes valued by the regional community safeguarded in NRM: clear targets by 6/05

Management Targets:

10.2.1 Develop a landscape mgmt strategy reflecting regional community objectives & establish processes to implement that strategy by 6/05

Recommended Management Actions and Link to Current Investment Program:

	Management Actions (from Plan)
	Benchmarks & Monitoring
i	Establish regional landscape objectives for NRM
	Investigations
ii	Review community priorities for landscape protection and enhancement and develop regional guidelines / code of practice
	Capacity Building
iii	Develop and use regional landscape guidelines / code of practice as basis for improving community input to sustaining landscapes
	Legislation and its Implementation
iv	Investigate opportunities for incorporation of landscape assessment in development plans and other relevant statutory processes

NYAD INRM Plan Section 10.3 - Safeguarding Significant Geological Assets

Resource Condition Targets:

10.3A Significant geological assets safeguarded in NRM by 6/05

Management Action Targets:

10.3.1 Develop an inventory of significant geological assets & establish processes to protect those assets by 6/05

Recommended Management Actions and Link to Current Investment Program:

	Management Actions (from Plan)
	Benchmarks & Monitoring
i	Develop a comprehensive database of the significant geological assets in the region
	On-Ground Actions
ii	Information and appropriate protective measures to maintain and promote the region's significant geological assets
	Investigations
iii	Encourage research into the region's significant geological assets
	Capacity Building
iv	Support community awareness and interest through public availability of appropriate information regarding the region's significant geological assets
	Legislation and its Implementation
v	Ensure appropriate legislation in place and enacted to protect significant geological assets