Australian Government

GOVERNMENT OF WESTERN AUSTRALIA

SWAN RIVER TRUST

Swan Canning Water Quality Improvement Plan

DECEMBER 2009

Caring for the Swan Canning Riverpark

Swan River Trust

Level 1, 20 Terrace Road
East Perth WA 6004
PO Box 6740
East Perth WA 6892

Phone: (08) 9278 0900
Fax: (08) 9325 7149
Email: info@swanrivertrust.wa.gov.au
Website: www.swanrivertrust.wa.gov.au

Swan River Trust after hours contact number:
0419 192 845

ISBN: 1 921094 16 8 (print)
ISBN: 1 921094 17 6 (online)

Minister's foreword

The Swan and Canning rivers are highly valued by the Western Australian community. They are a key feature of Perth's recreation, social and cultural landscape, regarded as an intergenerational treasure to be passed on to our children and grandchildren.

However, the Swan and Canning rivers and their tributaries are under enormous pressure from the surrounding catchment. The impacts of human activities, climate and land use change are causing stress on the rivers.

The Swan River Trust has developed a number of programs to address these impacts, including the Healthy Rivers Program. The Swan Canning Water Quality Improvement Plan also complements the Healthy Rivers Action Plan, focusing on reducing the nutrients entering the rivers from the Swan Canning Catchment. It recognises the valuable role of community in maintaining good water quality throughout the Swan Canning Catchment.

The Plan has been developed as part of the Coastal Catchments Initiative. This Federal program identified a number of nutrient 'hot spots' across the country for improvement during the next seven years. Ten water quality improvement plans have been developed across Australia.

The Swan Canning Water Quality Improvement Plan involved close collaboration between a number of State agencies, Western Australian Local Government Association, Perth Region NRM and Geographe Catchment Council. The Plan links directly to a number of programs undertaken by the Swan River Trust and other State Government agencies.

An extensive public consultation process has enabled strong community and local government engagement.

I commend this Plan to you, to drive nutrient reduction in the Swan Canning river system during the next seven years, and I look to your continued involvement in implementing these actions.

Hon Donna Faragher JP MLC
MINISTER FOR ENVIRONMENT; YOUTH

Executive summary

The Australian Government's Coastal Catchment Initiative (CCI) aims to improve water quality in coastal catchments throughout Australia. In 2006 the CCI identified the Swan Canning river system as a coastal "hot spot" and provided funding to the Swan River Trust to develop the Swan Canning Water Quality Improvement Plan (SCWQIP).

The SCWQIP's focus is to reduce nitrogen and phosphorus input from catchments into the Swan Canning river system. Other programs of the Swan River Trust, State agencies and catchment councils address nutrient and non-nutrient contaminants throughout the Swan and Avon catchments.

The Swan and Canning rivers and their tributaries are under enormous pressure from high nutrient concentrations. These nutrients enter the waterways through human activities such as farming and fertiliser use in the catchment. High nitrogen and phosphorus loads lead to algal growth, low oxygen levels, fish kills and loss of biodiversity.

The impact of nutrients is compounded by changes in estuary hydrology resulting from climate change. Diminished winter rainfall has seen river flow decrease markedly during recent years, resulting in reduced flushing of nutrients from the river to the ocean. Marine water is moving further up the river system during summer and autumn resulting in increasingly saline conditions and prolonged stratification further upstream.

The SCWQIP provides a roadmap for reducing nutrient levels using scientific modelling and decision support tools. It will guide investment during the next seven years, identifying the most cost-effective management actions to address the sources of land-based nitrogen and phosphorus and improve estuarine and coastal water quality.

The Trust has guided the development of the SCWQIP, in partnership with the Australian Government, State agencies (Department of Water, Department of Planning, Department of Agriculture and Food WA, Department of Environment and Conservation), Water Corporation, Western Australian Local Government Association and Perth Region NRM. The SCWQIP provides a whole of government and community commitment to reducing nutrient levels in the Swan Canning Catchment.

Key findings

Annually 250 tonnes of nitrogen and 26 tonnes of phosphorus enter the system. Numerical modelling was used to quantify nutrient loads by source and use in the Swan Canning Catchment.

Based on predictive modelling the maximum acceptable load to the Swan and Canning rivers per year is 130 tonnes of total nitrogen (TN) and 14 tonnes of total phosphorus (TP).

To meet these objectives the SCWQIP aims to:

- reduce the nitrogen load by 120 tonnes per year (49%); and
- reduce the phosphorus load by 12 tonnes per year (46%).

Other key findings of the SCWQIP, based on predictive modelling, are as follows.

1. The Avon River contributes a large proportion of the nutrient load (69% TN and 43% TP). While management of the Avon Catchment is outside the scope of this SCWQIP, the magnitude of the nutrient contribution highlights that it is imperative to reduce this input to improve water quality in the Swan and Canning rivers.
2. Of the Swan Canning sub-catchments Ellen Brook contributes the most nutrients with 70 tonnes of nitrogen (28% TN) and 10 tonnes of phosphorus (39% TP) per year.
3. The main source of phosphorus in the Swan Canning Catchment is farming activities (33% TP), predominantly beef cattle grazing in the Ellen Book sub-catchment.
4. The main source of nitrogen is residential (29%) and recreational (14%) activity in urban sub-catchments, in particular fertiliser application on grassed areas and gardens. It is also the second highest source of phosphorus (22% and 12% TP).
5. Flow from coastal sub-catchments including Ellen Brook has been equivalent to the Avon River in recent years. Urban sub-catchments are the main source of nutrients in summer when agricultural catchments are not flowing.

6. Septic tanks contribute significant amounts of nitrogen (18% TN) and phosphorus (8% TP) to the Swan Canning river system. This percentage is even higher in some sub-catchments.
7. Increased urbanisation will increase nutrient loads by 18% TN and 25% TP, due to increased runoff.
8. The effects of climate change, modelled over a 10-year period on the highest CO_2 output, reduces nutrient load by 15% TN and 31% TP. Modelled on the lowest CO_2 output, the effects of climate change will reduce phosphorus load by 5% and the nitrogen load by 3%.

Sub-catchment assessment

The SCWQIP assessed 30 sub-catchments of the Swan Canning Catchment, and categorised them into three levels:

- unacceptable water quality;
- water quality to be maintained and improved; and
- good water quality to be protected.

This provides land managers with practical goals for nutrient reduction. The following figures demonstrate these categories, which reflect the total nitrogen and phosphorus coming from each sub-catchment. It is very important to protect the sub-catchments with good water quality as they help maintain the overall water quality of the system.

Management recommendations

The SCWQIP identifies 13 management recommendations to reduce nutrients in the Swan Canning river system. These can be applied on local, sub-catchment and catchment levels.

The SCWQIP uses a “treatment train” approach, where management actions are combined to achieve water quality goals. A treatment train combines actions along nutrient pathways from their source. Predictive modelling of a range of management scenarios in the Swan Canning Catchment indicates that while no single management action will achieve nutrient reduction targets, in combination they can be met.

Management measures (not prioritised) focus on:

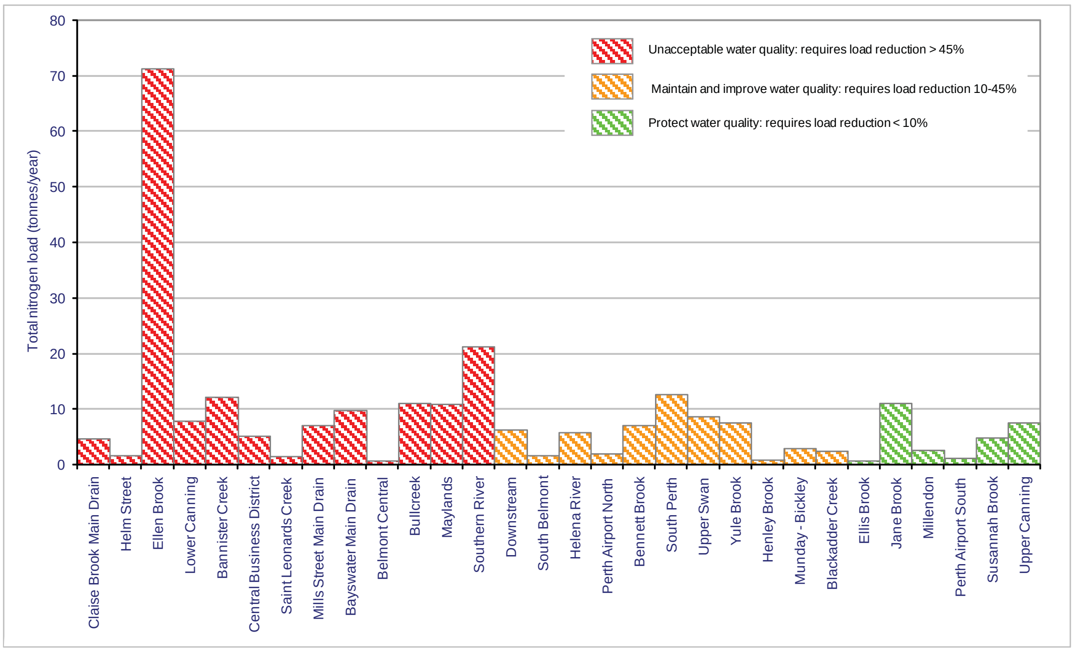
1. using water sensitive urban design (WSUD) in new developments;
2. fertiliser efficiency in the management of urban recreational areas;
3. using slow-release, low water-soluble phosphate fertilisers in rural areas;
4. education in fertiliser efficiency in urban and rural areas;
5. the use of soil amendments for soils with low phosphorus retention;
6. engineering modifications to intercept nutrients;
7. sub-catchment nutrient management, for example local water quality improvement plans;
8. nutrient point sources, primarily septic tanks;
9. no net increase in nutrient loads from sub-catchments from increased urbanisation or climate change;
10. optimising environmental flows; and
11. protecting and maintaining sub-catchments that currently have good water quality.

SCWQIP delivery

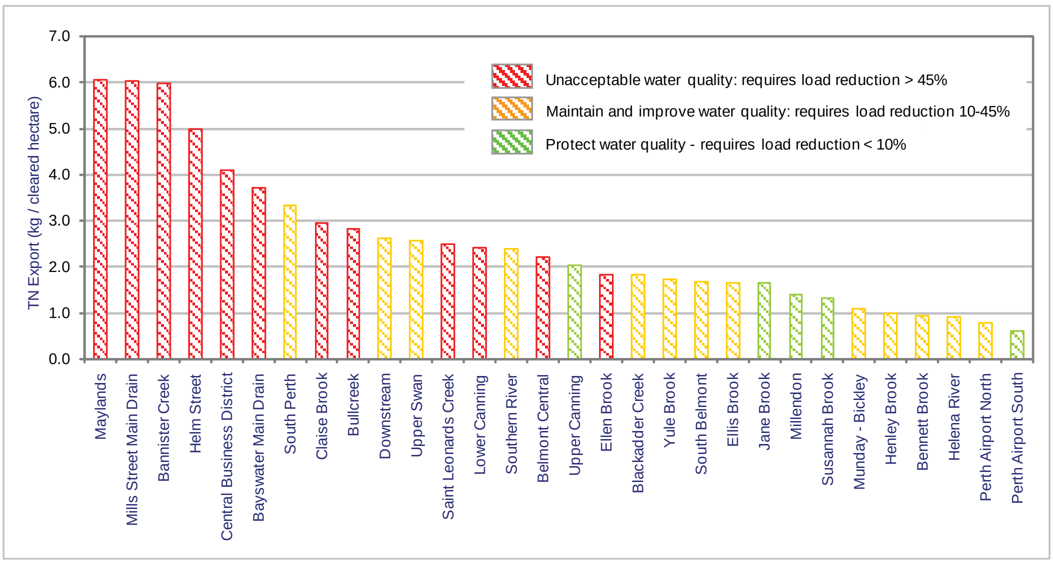
The following steps are recommended to implement the SCWQIP:

- develop costings for recommended nutrient reduction best management practices;
- engage the identified responsible organisations and partners for joint delivery of management actions;
- link to existing programs and strategies to achieve SCWQIP Trust and other partner outcomes; and
- identify other suitable vehicles and initiatives to deliver the SCWQIP through the key stakeholders.

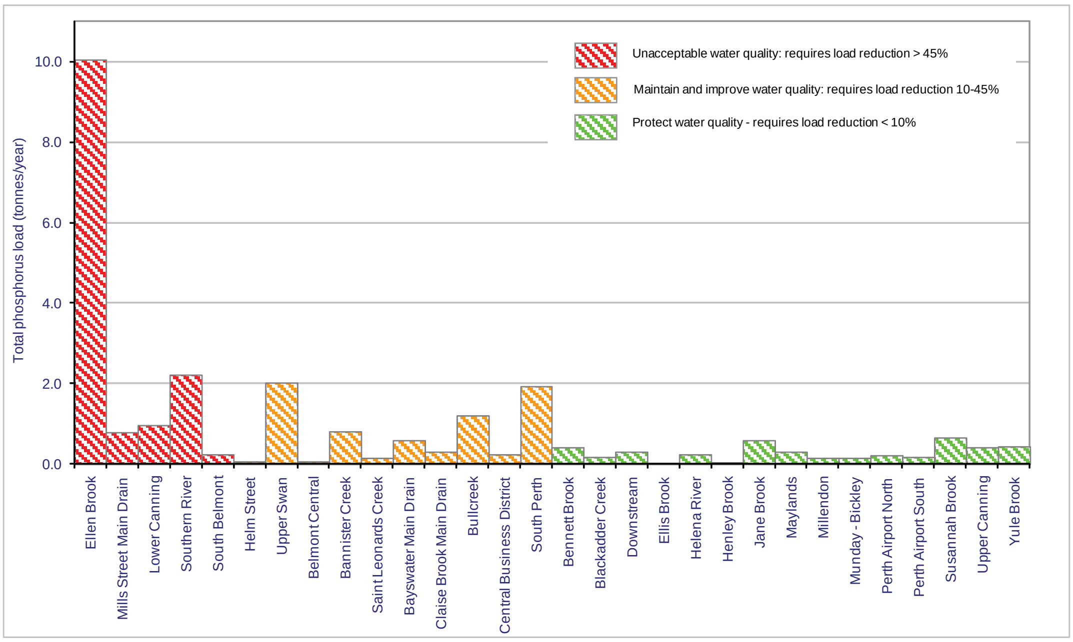
The SCWQIP provides a practical and scientifically-based set of initiatives that, if applied, can achieve nitrogen and phosphorus reduction in the Swan Canning river system during the next seven years.



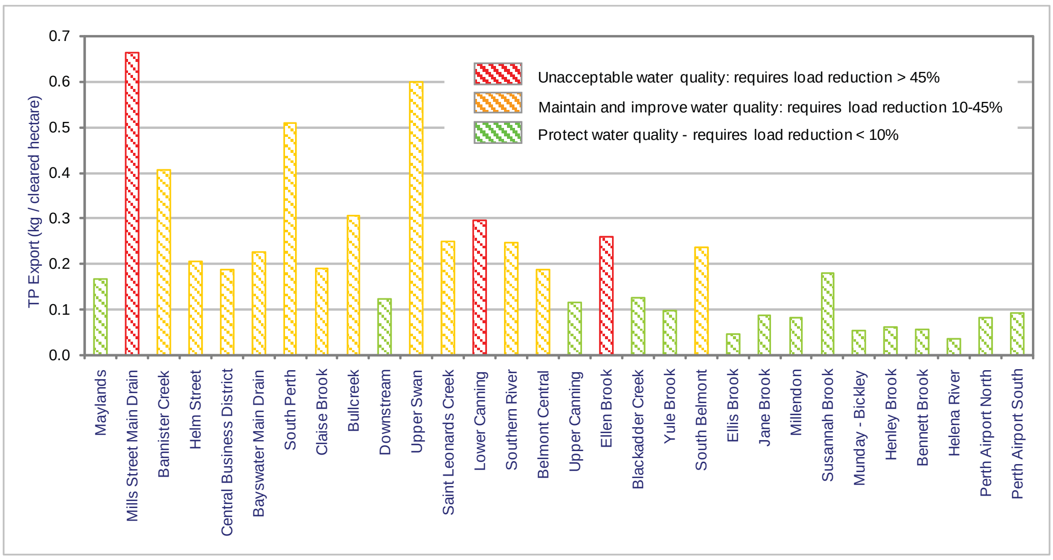
Total nitrogen loads and management priorities for sub-catchments in the Swan Canning Catchment



Total nitrogen export per hectare cleared for Swan Canning sub-catchments



Total phosphorus loads and management priorities for sub-catchments in the Swan Canning Catchment



Total phosphorus export per hectare cleared for Swan Canning sub-catchments

Table of contents

List of figures

List of tables

List of appendices

SWAN CANNING WATER QUALITY IMPROVEMENT PLAN

1. Introduction

The Swan Canning estuarine system has experienced excessive loads of nitrogen and phosphorus for more than 50 years. This is largely the result of expansion of land use activities contributing nutrients around the Swan and Canning rivers, with clearing for urban, farming and industrial activities.

The impact of nutrients is compounded by changes in estuary hydrology resulting from climate change. Diminished winter rainfall has seen river flow decrease markedly during recent years, resulting in reduced flushing of nutrients from the river to the ocean. Marine water is moving further up the river system during summer and autumn resulting in increasingly saline conditions and prolonged stratification further upstream.

In 2006 the Australian Government identified the Swan Canning river system as a coastal "hot spot", and provided funding to the Swan River Trust (Trust) to develop a Water Quality Improvement Plan (WQIP).

A coastal hotspot is defined by the Australian Government as an area that:

- encompasses one or more matters of national environmental significance as defined under the *Environment Protection and Biodiversity Conservation Act (1999)*;
- is under pressure as a result of population growth and development, disturbance of acid sulphate soils, and water quality decline; and
- is suffering ecosystem disturbance leading to habitat loss and biodiversity decline. (www.environment.gov.au)

Through the Swan Canning Water Quality Improvement Plan (SCWQIP) the Trust has provided recommendations to address nutrient management throughout the Swan Canning Catchment, including the Swan Canning river system. The SCWQIP provides a roadmap for reducing nutrient inputs into the river system and surrounding catchment using scientific models and decision support tools prepared under the Australian Government's Coastal Catchments Initiative (CCI). Other contaminants and environmental objectives are being addressed through a range of other programs including the Trust's Healthy Rivers Program.

What makes the SCWQIP different to other water quality plans?

There have already been a number of water quality management plans developed to address the nutrient excess in the Swan Canning river system.

The SCWQIP takes a different approach to the management of nutrient inputs.

1. **Using a combined multi-agency approach to nutrient reduction in the Swan Canning estuarine system**

State agency partners independently delivered aspects of the CCI projects, which leads to whole of government support for the projects of the SCWQIP. CCI project partners are the Swan River Trust, Department of Environment and Conservation, Department of Planning, Department of Water, Department of Agriculture and Food WA, Western Australian Local Government Association and Perth Region NRM (formerly Swan Catchment Council).

The SCWQIP links to existing State Government programs identified as part of the implementation planning.

2. **Setting practical goals for nutrient reduction**

Previous targets for nutrient reduction have been applied to the whole catchment. The use of the predictive model Stream Quality Affecting Rivers and Estuaries (SQUARE) has enabled differentiation into 30 sub-catchments of the Swan Canning system. This process has identified those sub-catchments with unacceptable water quality; those with water quality to be maintained and improved; and sub-catchments that have good water quality to be protected. The source of nutrients in each sub-catchment has been identified, providing land managers with practical goals for nutrient reduction. The development of the decision support tool – the Support System for Phosphorus and Nitrogen Decisions (SSPND) – for the Ellen Brook sub-catchment, provides local land managers with the ability to assess the effect of land use change and management interventions on pollutant loads.

It provides a tool for priority setting and investment planning to achieve the SCWQIP load targets.

3. **Recognising the impacts of increased water run-off from urban catchments**

Urban catchments have different flow characteristics to rural catchments, with flow occurring all year round, rather than just in the winter and spring in rural catchments. This affects the delivery of nutrients into the system. The SCWQIP has adopted long-term concentration targets for the impervious urban catchments of 0.5 mg/L TN and 0.05 mg/L TP. The modelling recognises that with urban expansion Swan Canning sub-catchments are rapidly changing from pervious landscapes of open paddocks to impervious surfaces of paved roads and buildings.

4. **Exploring alternative approaches**

The SCWQIP addresses nutrient reduction in the urban environment differently to the rural environment. To better integrate land use and water planning in the urban environment, the water sensitive urban design (WSUD) project has developed the *Better Urban Water Management* guidelines under *State Planning Policy 2.9 Water Resources*, modelling and assessment tools including the Model for Urban Stormwater Improvement Conceptualisation (MUSIC), and the New WAter Ways capacity building program to increase local government and industry participation in the principles and practices of WSUD.

In the rural environment, the SSPND model has been developed and tested in the Ellen Brook sub-catchment, providing a decision support tool for land managers.

Several rural best management practices, including drain fencing and revegetation, in-stream intervention, perennial pastures and the use of nutrient retentive material in and around drains, have been installed for testing throughout the Swan Coastal Plain. This and further research on the effectiveness of management practices will continue to inform future management and provide demonstration sites to observe the potential nutrient reductions that can be achieved.

The SCWQIP has investigated innovative approaches to achieve the nutrient reduction targets. The nutrient offset policy position paper explores the capacity to achieve no net nutrient export from the sub-catchments through offsetting.

5. **Modelling for climate change and urban growth**

Use of the SQUARE model to predict the effects of various management scenarios provides the ability to include the impact of climate change and urban growth in future management planning for the Swan Canning river system.

6. **Swan Coastal Plain linkages**

The Trust and Peel Harvey and GeoCatch Catchment Councils (Vasse-Wonnerup Wetlands/Geographe Bay) have collaborated, sharing knowledge and targeting nutrient reduction across the Swan Coastal Plain, broadening the knowledge base to enable more robust management strategies. The Peel Harvey Water Quality Improvement Plan (WQIP) was released in 2007, and has provided a solid basis to develop the Swan Canning and Vasse-Geographe WQIPs, and build projects and relationships for all three Western Australian WQIPs.

1.1 Setting the scene

1.1.1 Background

It has been estimated that globally, approximately 80% of marine pollution is generated from land-based activities. These activities include urban development, agriculture, manufacture, transport, energy production and day-to-day domestic activity (Natural Resource Management Ministerial Council, 2006).

In 1995, in response to the impacts of pollution, the international community agreed to the non-binding Global Programme of Action for the Protection of the Marine Environment from Land-based Activities. Participating governments were invited to develop National Programmes of Action for the Protection of the Marine Environment from Land-based Activities.

In Australia, the response to the land-based sources of marine pollution is endorsed by the Council of Australian Government’s Natural Resource Management Ministerial Council. The response recognises national issues of catchment degradation, coastal development, industrial development and habitat loss.

The response encompasses actions through a range of levels from Australian Government, State Government, local government, non-government organisations and industry.

A number of national actions to address land-based activities have been developed, ranging from national water quality management strategies and pollution inventories, to state of the environment reporting and the National Action Plan for Salinity and Water Quality (Natural Resource Management Ministerial Council, 2006).

1.1.2 The Coastal Catchments Initiative (CCI)

The CCI was an Australia-wide bilateral action to address the sources of land-based pollution to coastal water quality 'hotspots', aimed at improving water quality in coastal catchments (Figure 1). This is achieved through significantly reducing the discharge of land-based pollution from point and diffuse sources into these catchments. The CCI was implemented in partnership with Federal, State and local governments, and regional natural resource management organisations. The initiative was aligned with the frameworks for the Global Program of Action for the Protection of Marine Environment from Land-based Activities.

The CCI addressed a range of legislative and policy objectives relating to Australia's international obligations. It is a priority action in the *National Cooperative Approach to Integrated Coastal Zone Management* and provides information for the State of the Environment Reporting. Through a common planning framework the CCI links the *National Water Quality Management Strategy* and *National Principles for Provision of Water for Ecosystems*.

The initiative links ecological attributes and functions to targets for water quality and pollutant loads, supporting an integrated water cycle management approach.

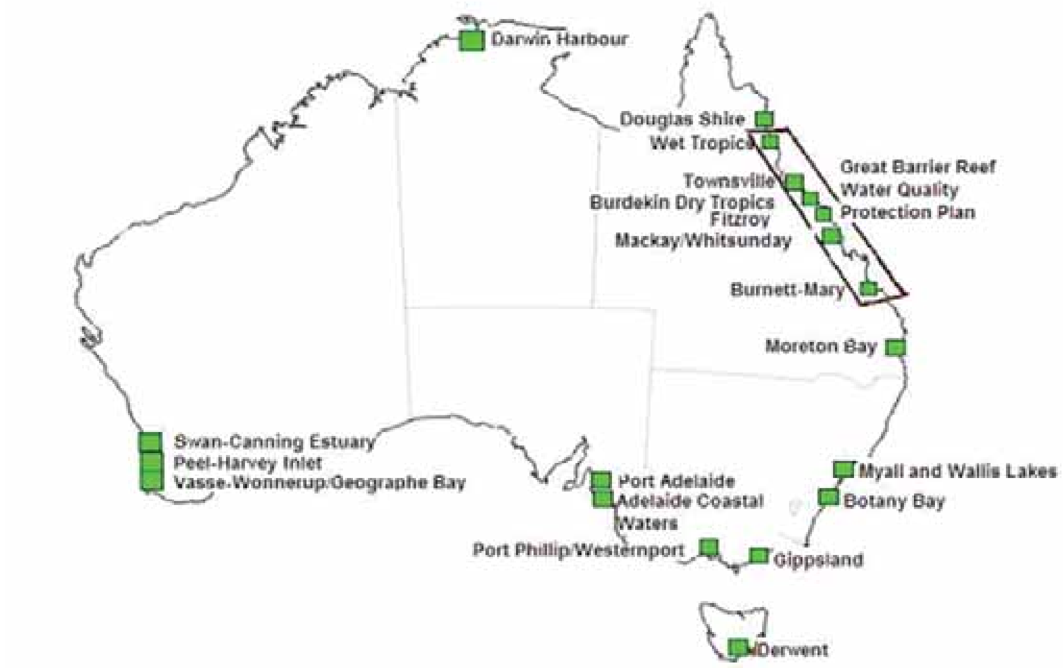


Figure 1 Current Coastal Catchments Initiative 'hotspots' (Department of the Environment, Water, Heritage and the Arts)

Figure 2 Coastal Catchments Initiative on the Swan Coastal Plain (Department of Environment and Conservation)

Through predictive modelling the CCI contributes to the assessment of likely impacts of development and allows Australian governments to determine and set appropriate environmental conditions. It addresses diffuse sources of pollution through agricultural diffuse source controls and institutionalising water sensitive urban design in State and local government planning and decision making (Natural Resource Management Ministerial Council, 2006).

1.1.3 The Coastal Catchments Initiative in Western Australia

The Swan Coastal Plain

In Western Australia three catchments were identified on the Swan Coastal Plain by the Australian Government as coastal "hotspots". These were the Swan Canning estuarine system, Vasse Wonnerup Wetlands/Geographe Bay and Peel Harvey system (Figure 2). A WQIP was developed for each of these catchments to address nutrient management issues, prepared in accordance with the "Framework for Marine and Estuarine Water Quality Protection". The WQIP for the Rivers and Estuary of the Peel Harvey system is being implemented throughout the region.

1.1.4 The Coastal Catchments Initiative in the Swan Canning river system

To reduce pollutants entering the coast from the Swan Canning Catchment, the Swan Canning CCI is aimed specifically at reducing nitrogen and phosphorus inputs to the Swan Canning river system. The Trust was responsible for coordinating the CCI for the Swan Canning river system, which was comprised of four component projects (Figure 3). These projects have contributed to the development of the WQIP for the Swan Canning river system.

The SCWQIP provides a roadmap for reducing nutrient levels into the river system using scientific models and decision support tools prepared under the CCI. The SCWQIP aims to guide investment to reduce nutrient input during the next seven years using a comprehensive decision-making framework. The framework is based on nutrient load targets and identifies the most cost-effective management measures to reduce nutrients in the Swan Canning river system. The SCWQIP has been prepared in accordance with the Framework for Marine and Estuarine Water Quality Protection which builds on key elements of the *National Water Quality Management Strategy (NWQMS)* and the *National Principles for the Provision of Water for Ecosystems*.

Recognising the nutrient contribution from Ellen Brook, a local WQIP was developed by the Trust to target the management of nitrogen and phosphorus in this sub-catchment.

The component projects of the CCI were delivered by various State agencies working in collaboration. The outcomes of each of the projects have been significant and provide a sound basis for developing a practical management approach to reduce nutrient inputs to the Swan Canning river system (Table 1).

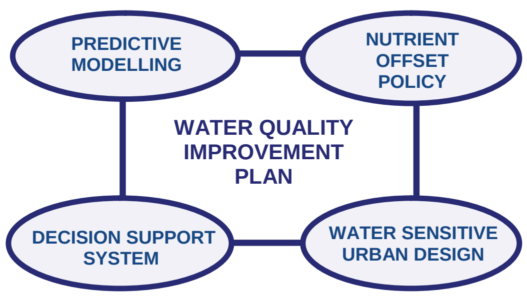


Figure 3 Swan Canning Coastal Catchments Initiative component projects

Table 1 Swan Canning Coastal Catchments Initiative projects and achievements

CCI project	Lead agencies	Achievements
Predictive modelling	Department of Water	Developed SQUARE to model nutrient loads and develop load reduction targets for 30 Swan Canning sub-catchments Modelled management scenarios including climate change and urban growth *Appendix 1*
Water sensitive urban design (WSUD)	Department of Planning Department of Water Western Australian Local Government Association	Developed a framework to integrate land use and water planning – *Better Urban Water Management* Calibrated MUSIC to model and pilot assessment of water quality in the urban development areas of the Swan Coastal Plain Established New WAter Ways as a capacity building program, targeting local government and industry involved in WSUD *Appendix 2*
Decision support system and rural best management practice	Department of Agriculture and Food WA Department of Water	Installed field trials in Ellen Brook to test the effectiveness of drain fencing, in-stream interception (nutrient retentive material in gabions), and the application of nutrient retentive material in and around drains Developed SSPND for assessing the effect of land use change and management interventions on nutrient loads in Ellen Brook *Appendix 3*
Nutrient Offset Policy	Swan River Trust	Developed a draft interim Nutrient Offset Policy based on voluntary contributions Scoped a framework for banking and trading nutrient offsets through a policy position paper *Appendix 4*
Swan Canning Water Quality Improvement Plan	Swan River Trust	Developed management measures to meet the concentration and nutrient reduction targets for 30 Swan Canning sub-catchments and the Swan Canning river system Developed a local WQIP for the Ellen Brook sub-catchment *Sections 2 and 3*

Department of **Agriculture and Food**
Department of **Planning**
Department of **Water**

SWAN RIVER TRUST

WALGA

Predictive modelling

The predictive modelling project was delivered by the Department of Water and supports the development and implementation of the Swan Canning and Vasse Geographe WQIPs.

The aims of the predictive modelling project were three-fold:

- model water quality and hydrology of sub-catchments of the Swan Canning river system;
- develop and implement water quality monitoring programs for catchments and receiving water bodies to improve the calibration of the predictive model; and
- deliver outputs of the predictive model in a user-friendly decision support system developed by the Department of Agriculture and Food for the Ellen Brook sub-catchment.

Previous targets for nutrient reduction have been applied to the whole catchment. The use of SQUARE in the predictive modelling has enabled differentiation of 30 sub-catchments of the Swan Canning river system into those with unacceptable water quality; those with water quality to be maintained and improved; and catchments that have good quality to be protected. This differentiation provides land managers with practical goals for nutrient reduction.

Use of the SQUARE model to predict the effects of various management scenarios provides the ability to include the impact of climate change and urban growth into the future management of the Swan Canning system.

SQUARE aims to answer the question: ***What do we put where in the catchment to meet a specific set of nutrient targets under a specific climate scenario?*** In Ellen Brook this model is coupled with an economic model (SSPND) that will estimate the cost of the different remediation strategies.

Water sensitive urban design (WSUD)

WSUD provides for holistic management of urban water resources. It addresses water quality, quantity and conservation, together with other social and environmental objectives, as part of urban planning and design. Its application is fundamental in reducing the impact of existing and new urban development. The application of WSUD aims to achieve the management of flood risk, while minimising water use, maximising water reuse, and reducing the water-borne transport of pollutants, particularly nutrients.

The aim of the WSUD project was to integrate WSUD into the planning process to achieve better water management outcomes in urban development settings and implement WSUD practices.

There were three key elements of the WSUD project, with a lead agency responsible for the coordination of each element.

- Develop a framework to better integrate land use and water planning – Department of Planning.
- Develop modelling and assessment tools for the management of water quality and quantity from urban development – Department of Water.
- Capacity building for Government and industry in water sensitive urban design - Western Australian Local Government Association.

In 2006 the WA State Government gazetted *State Planning Policy 2.9 Water Resources*, under Section 26 of the *Planning and Development Act 2005* which is the “highest” form of planning policy. This policy requires land use planning to contribute to the protection and wise management of water resources by ensuring local and regional land use planning strategies, structure plans, schemes, subdivisions, strata subdivision and development applications take into account total water cycle management and WSUD principles. This ensures development is consistent with best management and planning practices for the sustainable use of water resources.

Further guidance to implement *State Planning Policy 2.9 Water Resources* has been provided with the development of a framework to integrate land and water planning by incorporating a total water cycle approach to water resource issues and supporting WSUD for development. The framework entitled "*Better Urban Water Management*" (WAPC, 2008) outlines how water resources should be considered at each stage of the planning system and identifies the information and investigations required to support planning decisions. Water management strategies are required to be presented with planning proposals that contain information relevant to the site characteristics and water management issues for the area. This supports holistic planning decisions that are underpinned by consideration of the total water cycle.

All planning proposals, where significant water issues are present, are required to present a water management strategy as outlined in *Better Urban Water Management* in order to demonstrate compliance with the objectives of *State Planning Policy 2.9 Water Resources*.

In addition, a capacity building program known as New WAter Ways was established to build a greater level of understanding and support for WSUD, particularly targeting local government authorities and industry practitioners. New WAter Ways provides training and information sharing through expert speakers, workshops, on-site inspections, study tours, case studies, a comprehensive website, leadership from the early adopters and networking events. New WAter Ways is a strong partnership between Department of Water, Department of Planning, Western Australian Local Government Association, Urban Development Institute of Australia (Western Australian Division) and Perth Region NRM. Through this partnership, New WAter Ways acts as a bridging organisation to gather WSUD resources, local and national, and disseminate information as a knowledge broker.

WSUD development presents a challenge to many professionals and organisations, as it requires a departure from the more familiar conventional approach to provision of urban water services on which they have developed their expertise. Capacity development is required at all levels of Government and in all industry sectors (e.g. public service, builders and contractors) to facilitate the shift to water sensitive urban development. Capacity building is a key to implementation and the need is urgent. The lack of environmental planners, hydrologists and staff with a comprehensive knowledge of the components of integrated water cycle management and how to integrate them was seen as an issue requiring urgent management, particularly with the rapid growth Western Australia is experiencing.

To address the lack of modelling and assessment tools for water quality management in Western Australia, a tool known as MUSIC, developed through *eWater*, has been calibrated for various catchments in developing areas in the Shire of Busselton and City of Swan. Guidelines have been produced to demonstrate how MUSIC can be modified to enable SymHyd, the underlying hydrological model in MUSIC, to model hydrological conditions on the Swan Coastal Plain. It can also provide some parameters that should be modified in MUSIC to be more reflective of catchment conditions on the Swan Coastal Plain.

Agricultural decision support system and rural best management practice (Ellen Brook)

The Department of Agriculture and Food is managing two projects designed to gather information on how nutrients are used and managed; and what is happening in the Ellen Brook sub-catchment in relation to nutrient management practices.

Initially the project identified the most appropriate management practices for nutrient reduction in relation to a particular site or location in the sub-catchment. It then developed and promoted rural land use practices that maximise nutrient efficiency and reduction, estimating the degree of implementation required to protect the water quality of the receiving waters. This investigation enables “reasonable assurance” that land use practices can achieve nutrient reduction for the Ellen Brook sub-catchment.

The second project involved the creation of a computer-based decision support tool (SSPND) to guide development and implementation of catchment planning and management. SSPND estimates the effect of a land management change on water quality in rural catchments like Ellen Brook. Changes that result in water quality improvement can be costed, providing cost-benefit analysis for the land holder and the environment. SSPND plays a critical role in adaptive implementation of the SCWQIP and provides a tool for priority setting and investment planning to achieve agreed SCWQIP load targets.

Nutrient offset project

Through the nutrient offset project, the Trust explored alternative approaches to improve water quality in the Swan Canning river system.

The project recognised that even with the application of best practice planning tools, proposed changes in land use could result in increased nutrient and other contaminant inputs to the rivers.

If it is known or likely that there will be an increase in nutrient input to the Swan Canning river system, the nutrient offset project proposes that they be counter-balanced by a nutrient reduction elsewhere in the catchment.

Two outcomes of the nutrient offset project are:

1. an interim Nutrient Offset Policy based on voluntary contributions; and
2. a framework for banking and trading nutrient offsets.

This project identified the use of nutrient offsets in the Swan Canning Catchment as a feasible option to be further explored.

1.1.5 Existing programs reducing nitrogen and phosphorus inputs to the Swan Canning river system

An important feature of WQIPs is that they link to existing projects and programs in each catchment area.

There are a range of programs being delivered in the Swan Canning Catchment aimed at reducing nutrient and non-nutrient contaminant input into the Swan Canning river system (Table 2).

Table 2 Examples of existing programs, reports and strategies in the Swan Canning Catchment

Program	Coordinating organisation
River Protection Strategy	Swan River Trust
Healthy Rivers Program	Swan River Trust
Swan Region Strategy for Natural Resource Management 2004	Perth Region NRM
State of the Environment Report	Environmental Protection Authority
Southern River Integrated Land and Water Management Plan	Department of Water
Avon Upper Swan Nutrient Intervention and Salinity Amelioration Project	Ellen Brockman Integrated Catchment Group
Ellen Brook Sustainability Initiative	Water Corporation

The Trust has a long history of managing water quality in the Swan and Canning rivers. In 1994, recognising the deteriorating health of the Swan and Canning rivers, the State Government launched the Swan-Canning Cleanup Program (SCCP) – a five-year project to study major environmental problems, find out how to reverse any deterioration that had occurred, and develop a program to clean up the Swan Canning river system. The program involved State and local government, universities and research groups, business and community projects, with the Trust responsible for delivery.

Links between SCWQIP management actions and State Government programs

Swan Canning Water Quality Improvement Plan

Predictive Modelling

Water Sensitive Urban Design (WSUD)

Decision support system and rural best management practice

Nutrient Offset Project

Management actions

Urban planning at a strategic level
Application of water sensitive urban design practices

Continue to monitor water quality throughout the Swan Canning Catchment
Develop local water quality improvement plans and other sub-catchment nutrient management plans
Support structural nutrient intervention

Promote best rural fertiliser management practices
Expand urban education in efficient fertiliser management to reduce nutrient input
Apply best management practice for nutrient management
Apply nutrient fixing soil amendments to sandy soils

Reduce nutrient input from industry

Improve urban drainage design and stormwater management
Promote urban drainage initiatives

Achieve zero nutrient contribution from sewage

Implementation programs

Department of Planning - *Better Urban Water Management*

Swan River Trust - Healthy Rivers Action Plan

Department of Environment and Conservation - Fertiliser Action Plan

Perth Region NRM - Light Industry Audit Program

Department of Water - Urban Drainage Initiative

Water Corporation programs

This program identified nutrient enrichment as the dominant stress on the Swan Canning river system, with increasing threat from climate change, non-nutrient contaminants and population expansion. In response, the SCCP Action Plan was released by the Trust in 1999, and provided a number of actions to manage these threats.

Following a detailed evaluation of SCCP in 2005-2006, the Healthy Rivers Action Plan (HRAP) was developed, with the aim of securing the health of the rivers into the future. The HRAP presents targeted, integrated programs to improve water quality through coordinated actions, managing nutrients and non-nutrients in the Swan Canning river system, in both catchment and estuary.

The SCWQIP responds to components of catchment nutrient management in the HRAP. Local WQIPs developed through the HRAP address nutrient management on the sub-catchment scale.

1.1.6 Consultation in developing the SCWQIP

A collaborative effort from a wide range of committed stakeholders is required for the successful development and implementation of the SCWQIP.

A joint steering committee comprised of members of the Swan Canning and Vasse Geographe CCI steering committees have met quarterly since the project inception in July 2006. In February 2007 the steering committee developed a consultation strategy for public participation in the projects of the CCI (Appendix 5). This strategy provided an overarching framework for stakeholder engagement, to be adapted and implemented for each of the five component projects of the CCI.

The key stakeholders and appropriate communication tools were identified. These include State and local government, regional and subregional natural resource management groups, general public, landholders and project partners, and using tools such as websites, meetings, information updates and forums.

The implementation of the consultation strategy has been reviewed on a regular basis throughout the development of the CCI projects to ensure the target stakeholders continue to be informed and engaged.

The key message identified in the consultation strategy is “if we do not work together towards reducing nutrient input, our waterways will continue to deteriorate. There are no simple, quick fix solutions to water quality issues” (Appendix 5).

Coastal Catchments Initiative Joint Steering Committee representatives

Department of Agriculture and Food Western Australia

Department of Environment and Conservation

Department of the Environment, Water, Heritage and the Arts

Department of Planning

Department of Water

GeoCatch

Perth Region NRM

Swan River Trust

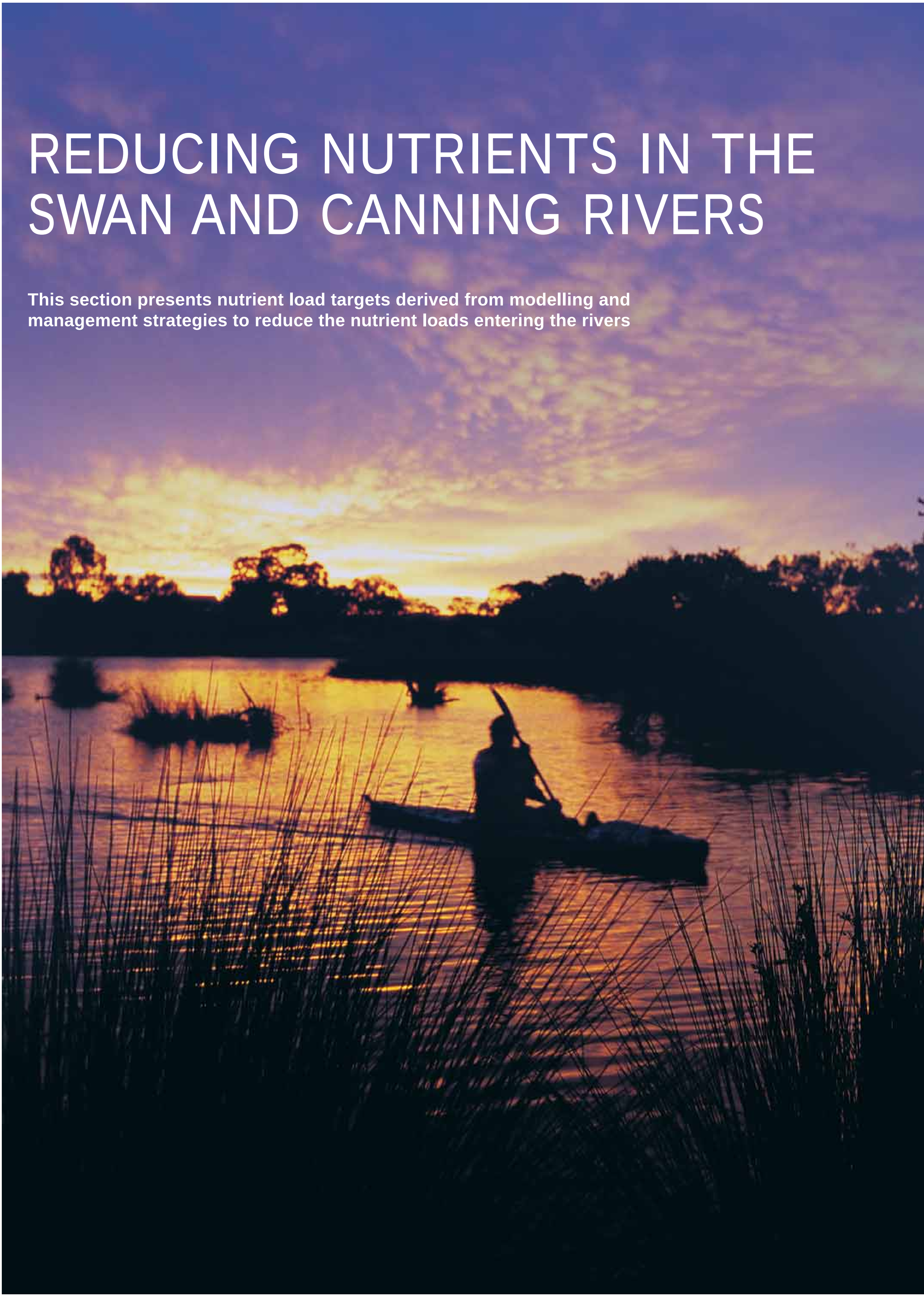
Water Corporation

Western Australian Local Government Association

Former Perth Region NRM Chair Colin Heinzman and Swan River Trust member and Coastal Catchments Initiative Swan Canning Steering Committee Chair Dr Jane Chambers at the second annual CCI stakeholder forum, June 2007

REDUCING NUTRIENTS IN THE SWAN AND CANNING RIVERS

This section presents nutrient load targets derived from modelling and management strategies to reduce the nutrient loads entering the rivers



2. Reducing nutrient loads in the Swan Canning river system

2.1 Water quality aims and objectives

The SCWQIP focus is to reduce nitrogen and phosphorus input from catchments into the Swan Canning river system.

Modelling shows the average current nutrient load in the Swan Canning is 250 tonnes of nitrogen and 26 tonnes of phosphorus per year.

Based on predictive modelling, the maximum acceptable load of total nitrogen to the Swan and Canning rivers is 130 tonnes per year.

The maximum acceptable load of total phosphorus is 14 tonnes per year.

The water quality objectives modelled for the SCWQIP to meet these loads are to:

- reduce the nitrogen load by 120 tonnes per year (49%); and
- reduce the phosphorus load by 12 tonnes per year (46%).

2.2 Nutrient sources: a summary

Key outcomes of predictive modelling relevant to nutrient load in the Swan Canning Catchment are as follows.

1. The Avon River contributes a large proportion of the average annual nutrient load (69% TN and 43% TP), reflecting the size of the Avon Catchment and episodic nature of the contributing Avon sub-catchments. While management of the Avon Catchment is outside the scope of the SCWQIP, the magnitude of the nutrient contribution highlights that it is imperative to reduce this input to improve water quality in the Swan and Canning rivers.
2. Of the Swan Canning coastal sub-catchments, Ellen Brook contributes the most nutrients with 70 tonnes of nitrogen (28% TN) and 10 tonnes of phosphorus (39% TP) per year (Figures 4 & 5).
3. The main source of phosphorus is farming activity (33% TP), predominantly the grazing of beef cattle. This activity is mostly located in the Ellen Brook sub-catchment.
4. Residential and recreational land use (including turfed areas) contribute the main source of nitrogen (29% and 14% TN), and second highest source of phosphorus (22% TP and 12% TP).
5. Flow from coastal sub-catchments including Ellen Brook has been equivalent to the Avon River in recent years. Urban sub-catchments are the main source of nutrients in summer when agricultural catchments are not flowing.
6. Septic tanks are considered a locally-based point source of nutrients, contributing significant amounts of nitrogen (18% TN) and phosphorus (8% TP) into the Swan Canning river system. However, in some sub-catchments, the proportional contribution of septic tanks is greater. For example, in the Mills Street Main Drain septic tanks contribute 50% TN and 62% TP to the rivers. Land use in this sub-catchment is predominantly industrial.
7. Increased urbanisation, if not implemented in accordance with water sensitive urban design principles, may increase nutrient loads by 18% TN and 25% TP, due to the increased runoff resulting from “traditional” urban development practices.
8. The effects of climate change, modelled on the highest CO_2 output, reduces the nutrient load by 15% TN and 31% TP but with more intense delivery of nutrients. Modelled on the lowest CO_2 output, the effects of climate change will reduce phosphorus load by 5% and the nitrogen load by 3%.

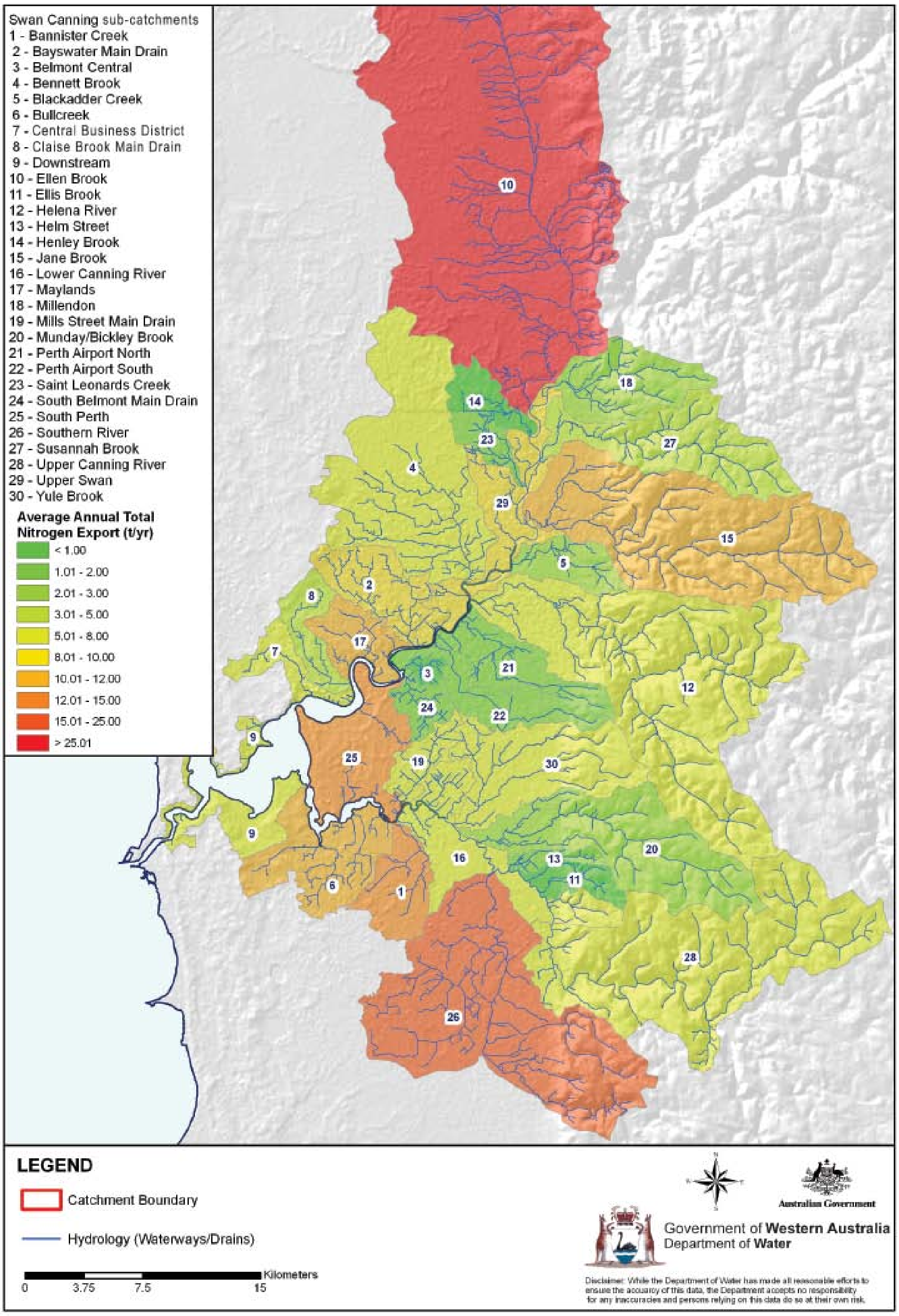


Figure 4 Average annual TN export (tonnes) from the Swan Canning sub-catchments

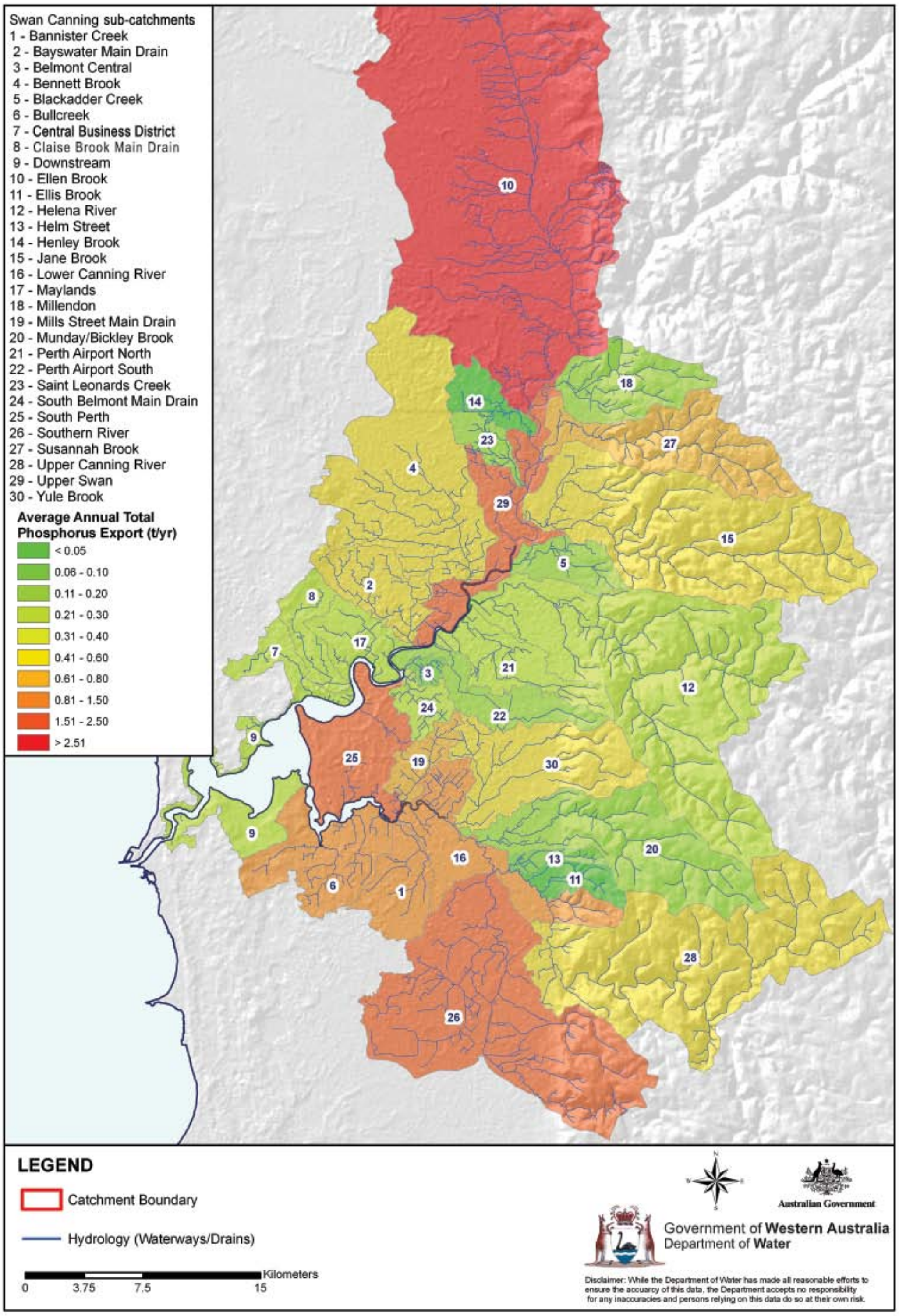


Figure 5 Average annual TP export (tonnes) from the Swan Canning sub-catchments

2.3 Management measures to reduce N and P loads

The SCWQIP combines a number of management measures throughout the Swan Canning Catchment to achieve the required nutrient reduction, targeting point and diffuse nutrient sources.

The management measures (not prioritised) focus on:

1. the use of water sensitive urban design in new developments;
2. fertiliser efficiency in the management of urban recreational areas;
3 implementing the Fertiliser Action Plan
4. the use of slow-release, low water-soluble phosphate fertilisers in urban and low phosphorus retention index (PRI) soil rural areas;
5. education in fertiliser efficiency in both urban and rural areas;
6. use of soil amendments for soils with low phosphorus retention;
7. engineering modifications to intercept nutrients;
8. sub-catchment nutrient management, for example local water quality improvement plans;
9. point sources of nutrients, primarily septic tanks;
10. no net increase in nutrient loads from the sub-catchments from increased urbanisation or climate change;
11. optimising environmental flows; and
12. protecting and maintaining sub-catchments that currently have good water quality.

Figure 6 presents the current state of the Swan and Canning rivers, with the associated pressures, targets and implementation actions from the SCWQIP to progress towards the desired state.

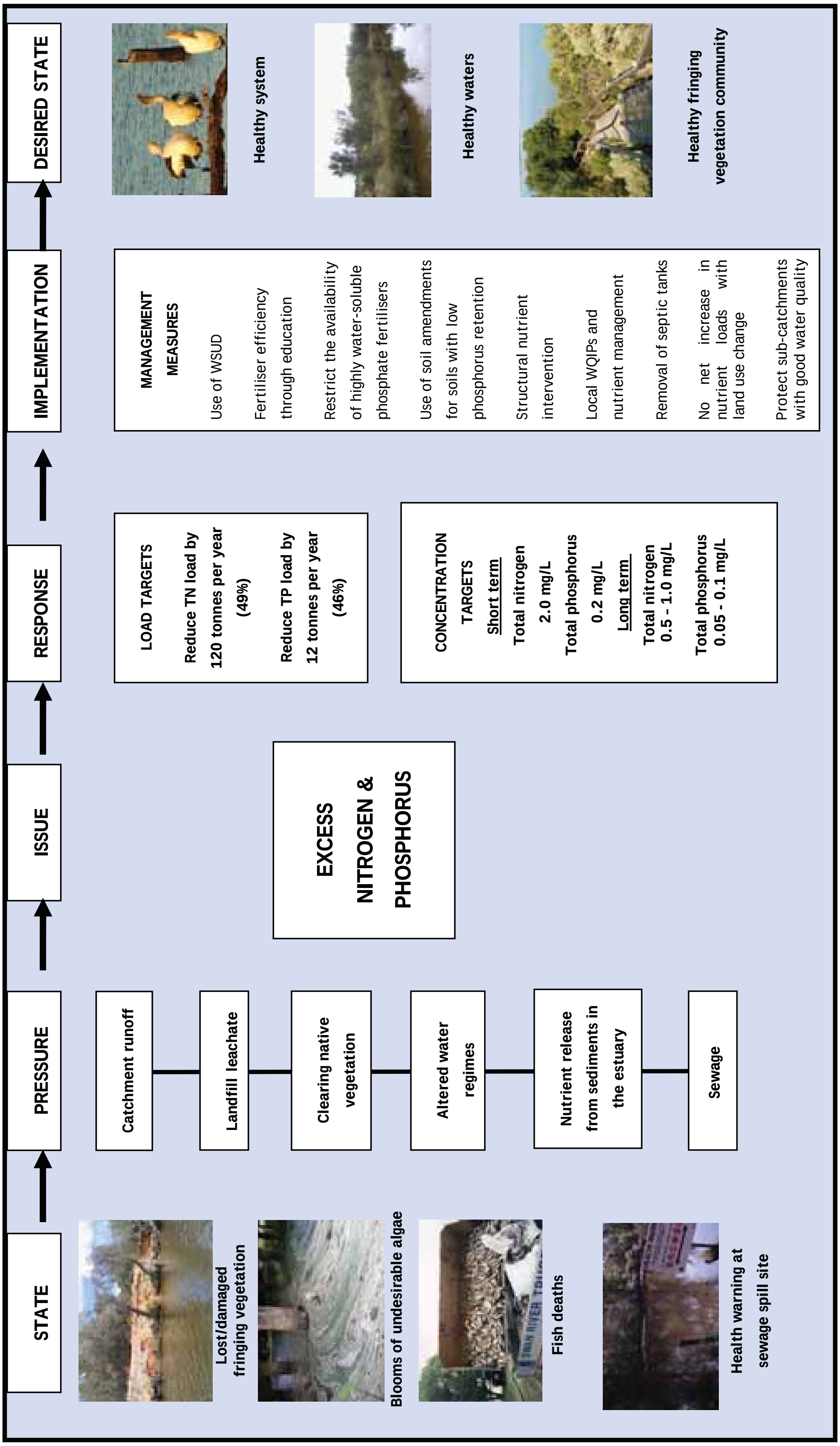


Figure 6 Summary of existing state, pressures, water quality issues and management in the Swan Canning Catchment

2.3.1 The treatment train approach

A treatment train is a suite of management practices designed to function together to achieve water quality goals and objectives effectively and efficiently (Australian Government 2002). These management practices include planning for better water quality, controlling pollutants at source, increasing operational efficiencies to improve water quality, intercepting pollutants with wetlands and filtration and treating water before it enters the system.

A treatment train combines these management actions along nutrient pathways from their source to reduce nitrogen and phosphorus export into the waterways (Figure 7).

The management actions addressing sources of nitrogen and phosphorus are delivered under different components of the treatment train. Combining actions can have a greater effect on reducing the nutrient load than a single treatment.

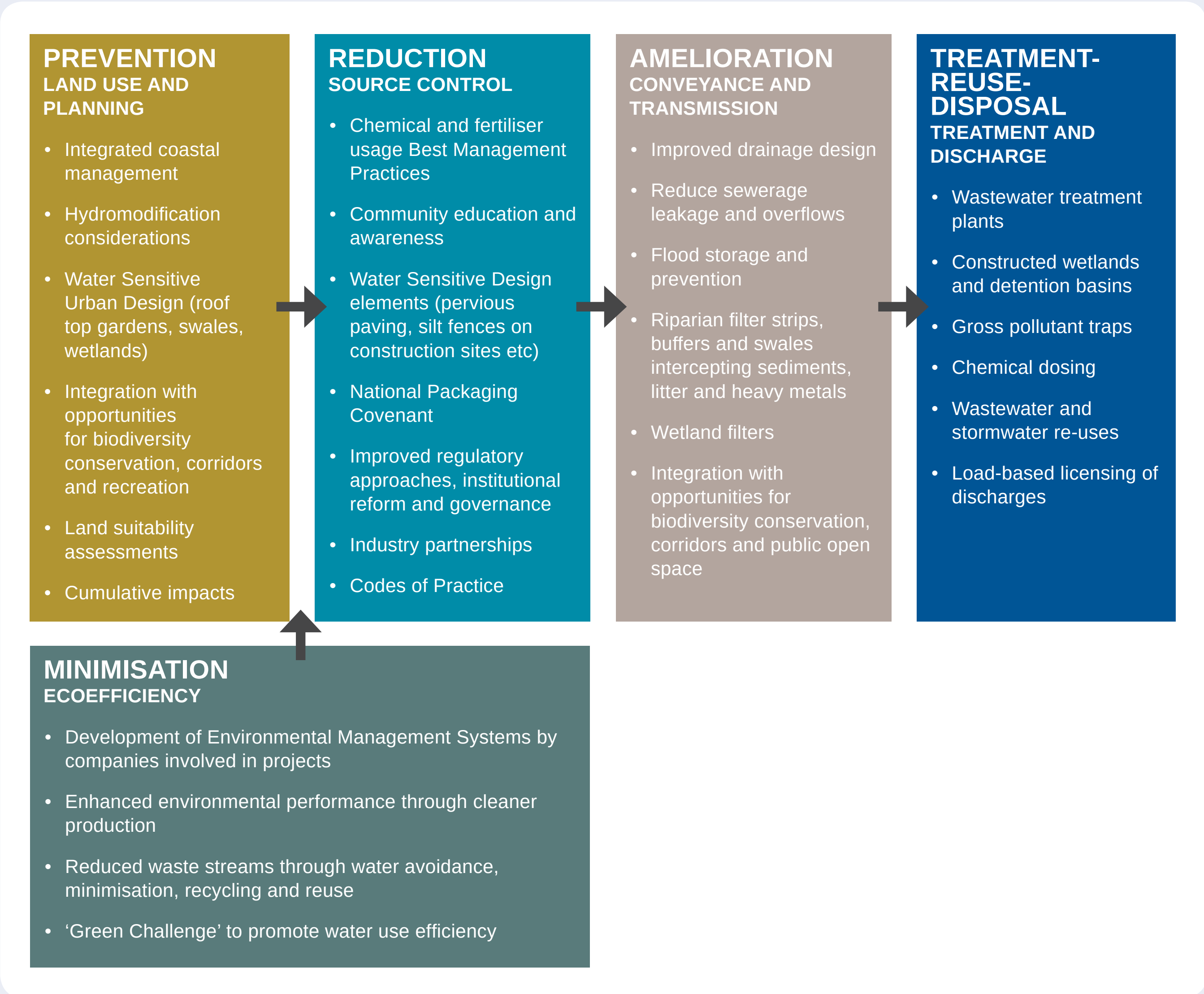


Figure 7 Treatment train for pollutant management (adapted from Australian Government framework)

A number of management scenarios were modelled against the load target for the Swan Canning river system. When modelled separately it was apparent that no single treatment could reduce either the nitrogen or phosphorus load to achieve the maximum acceptable load for the system (Figures 8 and 9). Further details of the modelling are in section 7.4.

A selection of management scenarios were then modelled in combination for the Bayswater Main Drain sub-catchment. The modelling indicates that by selecting the correct treatments and using them in combination, it is possible to achieve the load targets in the Bayswater Main Drain sub-catchment (Figures 10 and 11).

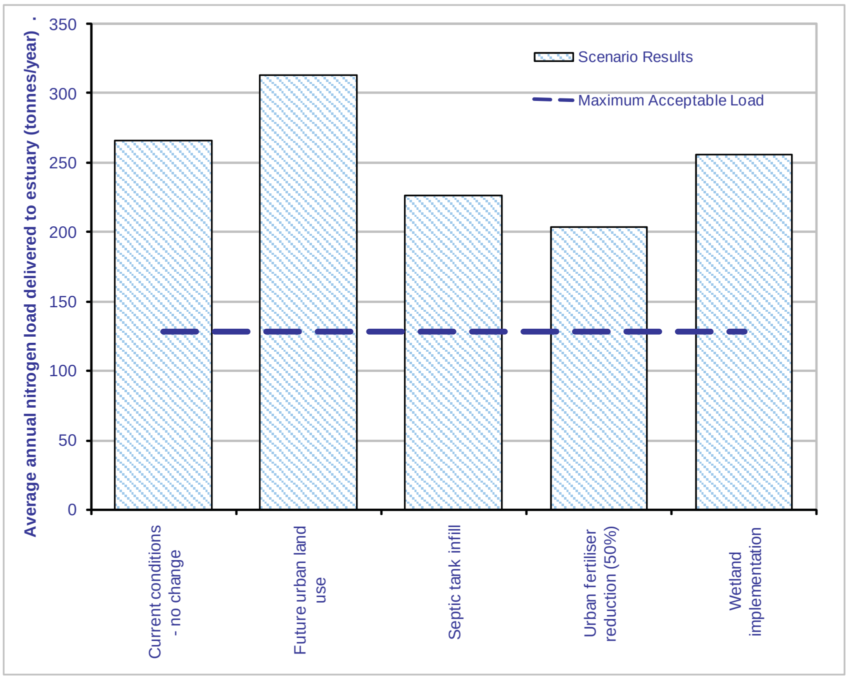


Figure 8 Individual management scenarios to reduce nitrogen in the Swan Canning river system

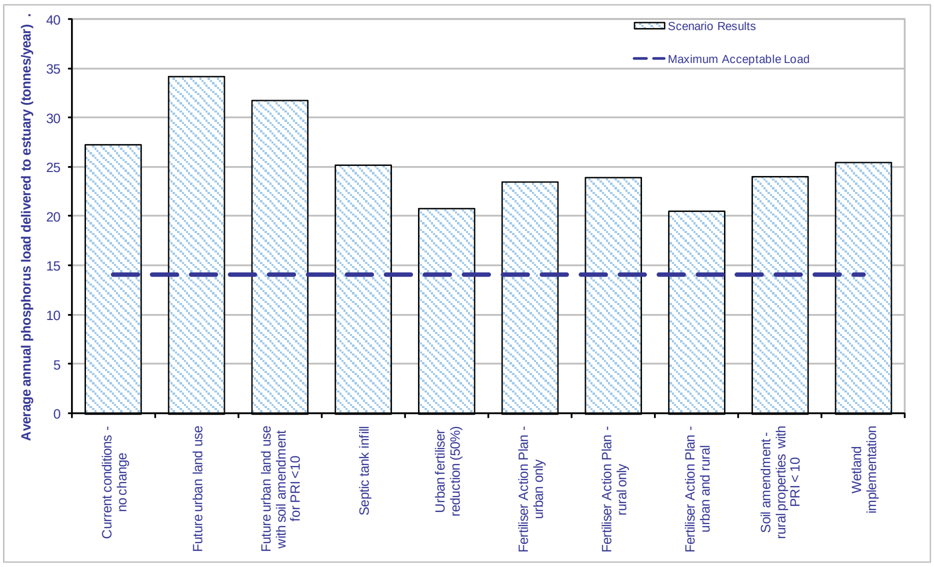


Figure 9 Individual management scenarios to reduce phosphorus in the Swan Canning river system

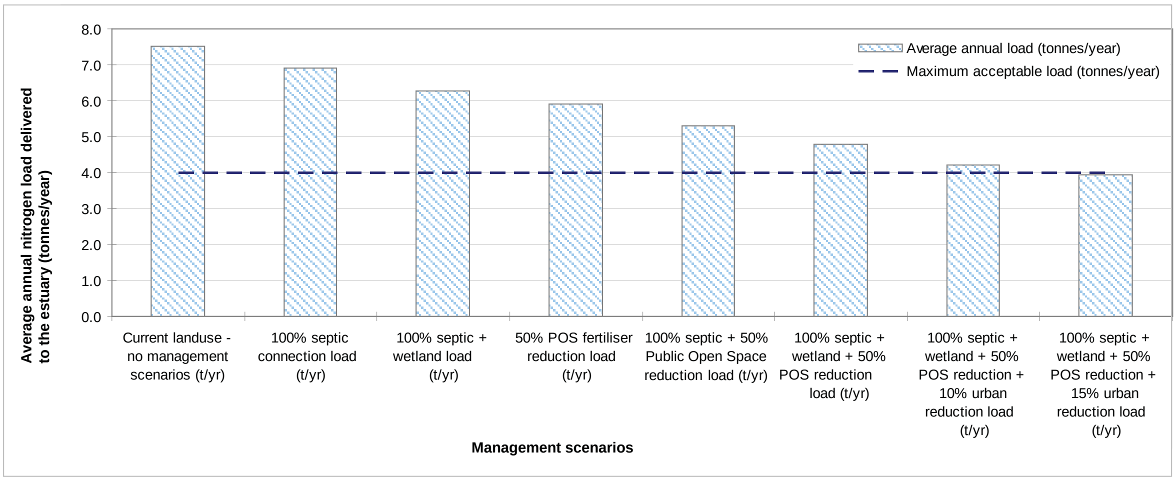


Figure 10 Nitrogen reduction scenarios in combination for Bayswater Main Drain sub-catchment

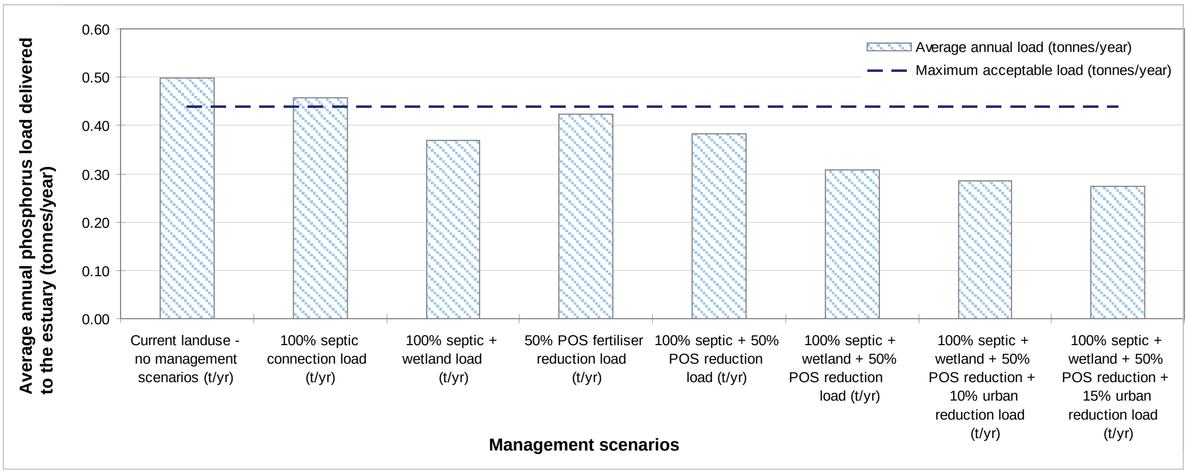


Figure 11 Phosphorus reduction scenarios in combination for Bayswater Main Drain sub-catchment

2.3.2 Management measures to reduce nutrients in the Swan Canning Catchment

Thirteen broad management measures are recommended for the Swan Canning Catchment, integrating components of the treatment train (Table 3).

The scale of delivery ranges from Swan Coastal Plain, Swan Canning Catchment, to sub-catchment level, depending on which outcome is being addressed.

Details of each of the management measures are presented in Table 3, with estimates of implementation costs and timelines detailed in Table 4 at the end of this section. The sources of tools recommended in the management measures are included in further information.

Table 3 Management action recommendations for the SCWQIP

Treatment train component	Management action	Responsible authority/partners
Prevention - land use and planning *Science supporting planning decisions*	**1. Urban planning at a strategic level**	
	1.1 Continue to support a holistic total water cycle approach to addressing water issues in the planning decision-making process via the Better Urban Water Management *framework*	Western Australian Planning Commission; Department of Planning; Department of Water; local government
	1.2 Integrate the use of predictive modelling and decision support tools at the planning phase of a land use change	Department of Water; Department of Agriculture and Food WA; local government; Western Australian Planning Commission; Department of Planning
	1.3 Continue to investigate the use of nutrient offsets	Swan River Trust
	2. Application of water sensitive urban design practices	
	2.1 Continue to ensure the objectives of State Planning Policy 2.9 Water Resources *are met, via the application of* Better Urban Water Management*, in planning decision-making including the assessment of subdivisions and developments*	Department of Planning; Western Australian Planning Commission; Department of Water; local government; Swan River Trust
	2.2 Promote local government participation in education programs for land use planners	Western Australian Local Government Association; local government; Department of Water
	3. Continue to monitor water quality throughout the Swan Canning Catchment	
	3.1 Expand and review water quality monitoring at gauged and ungauged sites	Department of Water; local government; Swan River Trust; Perth Region NRM; Wheatbelt NRM

Treatment train component	Management action	Responsible authority/partners
Minimisation *Efficiency in nutrient use*	**4. Promote best rural fertiliser management practices**	
	4.1 Encourage the use of slow release, low water-soluble phosphate fertilisers	Department of Environment and Conservation
	4.2 Implement the Fertiliser Action Plan	Swan River Trust; Department of Environment and Conservation; Department of Water
	5. Expand urban education in efficient fertiliser management to reduce nutrient input	
	5.1 Reduce urban fertiliser use through education programs, particularly targeting the use of highly water-soluble phosphate fertilisers	Local government; Department of Environment and Conservation; Swan River Trust; community; Department of Water
	5.2 Reduce the availability of highly water-soluble phosphate fertilisers for domestic use	Department of Environment and Conservation
	5.3 Implement the Fertiliser Action Plan	Department of Environment and Conservation; Department of Water; Swan River Trust
	5.4 Promote local government participation in New WAter Ways	Western Australian Local Government Association; Department of Water
	5.5 Continue to build the capacity of State and local government, industry and practitioners to implement Better Urban Water Management	Department of Planning; Department of Water
	5.6 Increase uptake of the Department of Water Stormwater Management Manual for Western Australia	Department of Water; Stormwater working group
	5.7 Seek funding for effectiveness measurement of the practices within the manual to improve water quality	
	6. Reduce nutrient input from industry	
	6.1 Regulate industry input through the application of the Unauthorised Discharge Regulations	Department of Environment and Conservation; local government; community
	6.2 Increase uptake and participation in industry education programs	Local government; Perth Region NRM; community
	6.3 Encourage companies involved in industrial projects to develop Environmental Management Systems	Local government; Perth Region NRM; community

Treatment train component	Management action	Responsible authority/partners
Reduction and source control *Keeping nutrients on the land*	**7. Develop local water quality improvement plans and other sub-catchment nutrient management plans**	
	7.1 Identify catchment characteristics and nutrient sources using predictive modelling and decision support tools	Swan River Trust; local government; State government stakeholders; community; Department of Water
	7.2 Confirm modelling results with onground investigations	
	7.3 Develop local water quality improvement plans and other sub-catchment nutrient management plans, based on source management and land use	
	8. Apply best management practice for nutrient management	
	8.1 Ensure new development meets water quality targets and incorporates best management structural and non-structural stormwater management measures	Urban: New WAter Ways - Western Australian Local Government Association; Department of Water
	8.2 Provide access to modelling tools to identify the most suitable best management practice option	Rural land managers; local government; Department of Agriculture and Food WA; community; Department of Water
	8.3 Customise Graphical User Interface for SQUARE to different stakeholder needs	Department of Water
	8.4 Educate urban land managers in best management practice options and support their use in urban areas	Western Australian Local Government Association; community; Department of Water
	8.5 Educate rural land managers in best management practices options and support their use in rural areas	Department of Agriculture and Food; community; Swan River Trust
	9. Apply nutrient fixing soil amendments to sandy soils	
	9.1 Explore the potential to apply appropriate soil amendments to existing rural and urban properties on soils with a low phosphorus retention ability	Department of Agriculture and Food; Department of Water
	9.2 Apply soil amendments with high phosphorus retention to new urban developments (lot and estate scale) in areas with sandy soils	Urban Development Institute of Australia; local government; Department of Water
	9.3 Dilute organic soil amendments. Incorporate nutrient retentive materials into existing organic soil amendments known to be applied in excess of nutrient requirements (such as manures or soil blends)	Urban Development Institute of Australia; local government

Treatment train component	Management action	Responsible authority/partners
Amelioration *Links to existing programs*	**10. Support structural nutrient intervention**	
	10.1 Promote the installation of constructed wetlands in suitable sites	Swan River Trust; Water Corporation; local government; CSIRO; universities; Department of Water; community
	10.2 Promote the conversion of drains to living streams	
	10.3 Support the application of nutrient retentive material in suitable sites	
	10.4 Identify opportunities to address nutrient export from sub-catchments using foreshore restoration	
	10.5 Support and educate local government and land managers in best management practice for nutrient reduction	Swan River Trust; Department of Environment and Conservation*; Department of Water; local government; community
	11. Improve urban drainage design and stormwater management	
	11.1 Maximise retrofitting of stormwater management systems to achieve improved water quality outcomes	Department of Water; local government
	11.2 Increase uptake of the practices contained in the Department of Water Stormwater Management Manual for Western Australia	Department of Water; Stormwater working group
Treatment-Reuse-Disposal *Managing the nutrients that cannot be kept on site*	**12. Achieve zero nutrient contribution from sewage**	
	12.1 Support the provision of deep sewerage throughout the Swan Canning Catchment	Water Corporation; Swan River Trust; Department of Water; Department of Planning
	12.2 Full connection of existing industrial, commercial and residential areas where a sewerage scheme is available	State government; local government
	12.3 Explore the use of incentives and nutrient offsets	Swan River Trust; Water Corporation
	13. Promote urban drainage initiatives	
	13.1 Encourage the use of gross pollutant traps and in-stream trapping systems	Department of Water; local government
	13.2 Explore the re-use of stormwater and waste water while maintaining flow for environmental requirements	

** when located on Department of Environment and Conservation-managed lands*

Prevention - land use and planning

Science supporting planning decisions

1. Urban planning at a strategic level

Actions

1.1 *Continue to support a holistic total water cycle approach to addressing water issues in the planning decision-making process via the* Better Urban Water Management *framework.*

1.2 *Integrate the use of predictive modelling and decision-support tools at the planning phase of a land use change.*

1.3 *Continue to investigate the use of nutrient offsets*

Scale of application
Swan Coastal Plain – urban

Modelling and measurement has shown in some years flow to the estuary from coastal sub-catchments is greater than the contribution of the entire Avon catchment. This has significant ramifications for the health of the estuary in our drying climate, and clearly supports the need to prevent additional nutrients entering the estuary from urban sources.

Although there is significant pressure to undertake urban and industrial development across the Swan Canning Catchment, consideration must be given to ensuring the location and form of new development is appropriate, and ensuring that new development does not increase the export of nutrients to the groundwater, waterways or estuary. Where a decision on change of land use is likely to result in an increase in nutrient export, consideration should be given to the use of offsets to reduce nutrients in other areas of the catchment.

Decisions on land use change should be supported by an appropriate level of information, including an estimation of the amount of nutrients that will be exported from the site post-development.

The predictive modelling and decision-support tools enable the effects of planning decisions on nutrient export to be modelled at the time of land use change. This provides planners with the ability to manage changes in nutrient export that may accompany the land use change. By using the predictive modelling and decision-support tools at the planning stage, nutrient intervention and management can be incorporated into the design. Modelling tools, such as SQUARE, MUSIC and SSPND should be made available to local government and the Western Australian Planning Commission (WAPC) to aid their assessment of proposals for land use change in the Swan Canning Catchment.

Recognising a lack of modelling and assessment tools for water quality management in Western Australia, a tool known as MUSIC, developed by *eWater* in the eastern states, has been calibrated for various catchments in developing areas in the City of Swan as a pilot project for the Swan Coastal Plain. In addition, the SSPND model has been developed by the Department of Agriculture and Food WA as an assessment tool targeting the Ellen Brook Catchment.

The WQIP requires “no net increase” in nutrient export as a result of a land use change in the sub-catchments of the Swan and Canning rivers. To achieve this may require a combination of nutrient management measures to be incorporated into the design phase, on site and downstream of the land use change. Examples of management measures include structural interventions and nutrient offsets.

A nutrient offset contributions scheme has been proposed for the Swan Canning to offset residual loads of nutrients from selected activities entering the Swan Canning Catchment and improve regional water quality outcomes (Appendix 4) (BDA 2008). The proposed scheme will focus on offsetting nitrogen and phosphorus loads separately.

The scheme is not a substitute for existing planning and other regulations protecting local environmental amenity and seeking best management practice to minimise residual loads.

Approval requires the following:

- the Government's environmental standards are met in the first instance; and
- offsets will not replace or diminish existing regulatory requirements to protect local environmental amenity.

In those cases where approved development with best management practice will still result in nutrient discharges, the use of environmental offset contributions will 'make good' the potential degradation of regional water quality and protect waterway health in the Swan Canning Catchment by funding nutrient removal projects elsewhere in the catchment (BDA, 2008).

2. *Application of water sensitive urban design practices*

Actions

2.1 *Continue to ensure the objectives of* State Planning Policy 2.9 Water Resources *are met, via the application of* Better Urban Water Management*, in planning decision-making including the assessment of subdivisions and developments.*

2.2 *Promote local government participation in education programs for land use planners.*

Scale of application
Swan Coastal Plain – urban

Water sensitive urban design has been identified as the most appropriate philosophy for the holistic management of urban water resources (Appendix 2). The application of water sensitive urban design aims to manage flood risk to development, while minimising water use, maximising water reuse, and reducing the water-borne transport of pollutants, particularly nutrients.

Water sensitive urban design can be applied throughout the urban areas of the Swan Coastal Plain.

Following the gazettal of *State Planning Policy 2.9 Water Resources* (2006) by the WA State Government, the Department of Planning has been working in partnership with the Western Australian Local Government Association and Department of Water to develop the *Better Urban Water Management* planning framework and *Planning Bulletin 92: Urban Water Management*.

These documents provide a framework to integrate land use and water planning through the application of water sensitive urban design via the planning and approvals process, consistent with the *State Planning Policy 2.9 Water Resources* (2006).

Better Urban Water Management (WAPC, 2008) provides guidance for planners, engineers and decision-makers regarding the consideration of water issues during the urban land use planning and development process. It recommends specific actions and investigations to support planning decision-making recommended at each of the key stages of planning.

As further support for the application of the *Better Urban Water Management* guidelines, the capacity building program New WAter Ways has been established to build a greater level of understanding of the effectiveness of water sensitive urban design. This program targets local government and industry practitioners through networking and training events.

3. *Continue to monitor water quality throughout the Swan Canning Catchment*

3.1 *Expand and review water quality monitoring at gauged and ungauged sites.*

Scale of application
Swan Coastal Plain – urban

The models need to reflect land use and activities. Updating water quality monitoring data is necessary to increase the accuracy of the models and maintain its relevance to current conditions. Continuing the water quality monitoring program throughout the Swan Canning Catchment, and expanding the program to include more monitoring sites, will provide a more robust data set. Using models enables better integration between land use planning and nutrient management.

Without an understanding of individual best management practices, modelling at a large scale will continue to be confounded.

Through water quality monitoring there is an opportunity to include coliform testing for human health indicators at the monitoring sites, in partnership with the Department of Health. This recognises the high value the community places on the recreational aspects of the Swan and Canning rivers, increasing the quality of recreation in the rivers.

Minimisation

Efficiency in nutrient use

4. *Promote best rural fertiliser management practices*

Actions

4.1 Encourage the use of slow release, low water-soluble phosphate fertilisers.

4.2 Implement the Fertiliser Action Plan.

Scale of application
Swan Canning - rural

On the Swan Coastal Plain the soils are mainly sandy with low fertility. Common practice is to apply highly water-soluble fertilisers, which leach rapidly through the sandy soils or are washed away through surface water flow, into the Swan and Canning river system.

The use of slow release low water-soluble phosphorus fertilisers reduces the rapid leaching of fertiliser. This increases the efficiency of the fertiliser application, as well as reducing the phosphorus input into the Swan Canning river system.

In 2006 the Western Australian Government announced the phasing-out of highly water-soluble phosphate fertilisers in environmentally sensitive areas by 2011.

A joint government and fertiliser industry working group was established to develop a Fertiliser Action Plan (FAP) that would achieve the announced phase-out.

In leading the implementation of the FAP, the Department of Environment and Conservation undertook consultation and is continuing to oversee its implementation with the involvement of the fertiliser industry and user groups.

The scenario modelling indicates that adoption of the FAP in rural areas will result in a reduction of 12.3% TP (Figure 12).

5. *Expand urban education in efficient fertiliser management to reduce nutrient input*

Actions

5.1 Reduce urban fertiliser use through education programs, particularly targeting the use of highly water-soluble phosphate fertilisers.

5.2 Reduce the availability of highly water-soluble phosphate fertilisers for domestic use.

5.3 Implement the Fertiliser Action Plan.

5.4 Promote local government participation in New WAter Ways.

5.5 Continue to build the capacity of State and local government, industry and practitioners to implement Better Urban Water Management.

5.6 Increase uptake of the Department of Water Stormwater Management Manual for Western Australia.

5.7 Fund effectiveness measurement of the practices within the manual to improve water quality.

Scale of application Swan Canning - urban

Predictive modelling indicates export of nitrogen from residential areas is the greatest contributor to nitrogen in the Swan Canning river system, contributing 29% TN.

Phosphorus export from residential areas is the second highest contributor at 22% TP.

Education programs targeting household fertiliser use (eg. Great Gardens Workshop Program) provide participants with practical and sustainable gardening techniques. These enable them to become water and fertiliser-wise gardeners, providing the knowledge to reduce the use of highly water-soluble phosphorus fertilisers. Participation rates in the Great Gardens Workshop Program is high, with more than 15,000 people attending workshops held in the Swan Canning Catchment since the program's inception in 2003. Independent research in 2007 demonstrated that behaviour change has resulted in 30-40% less irrigation, fertiliser application and nutrient loss when averaged across the gardens of all participants attending environmental education programs (Swan River Trust 2008a).

Product placement and availability in the retail sector can also have significant impact on household fertiliser use. By limiting the availability of highly water-soluble phosphorus fertilisers, the purchase of these products for household use reduces, which can have a flow-on effect on phosphorus export. This is the subject of a current study through the Swan River Trust, with results expected in 2009.

The Fertiliser Action Plan sets a target of phasing out bagged (retail) highly water-soluble phosphorus fertilisers in 12 months. Based on scenario modelling, adoption of the Fertiliser Action Plan in urban areas will result in a reduction of 13.9% TP. Adoption of the Fertiliser Action Plan in urban and rural areas will result in an overall reduction of 24.8% TP (Figure 12). Monitoring of this action will provide more accurate reduction figures.

Recreational areas, including public open space and turfed areas, contribute 14% TN and 12% TP to the Swan Canning Catchment. Through WALGA, the New WAter Ways local government education program targets fertiliser use efficiency in local government. This can lead to significant cost savings, particularly for local government managing large areas of turf. The Phosphorus Action Group conducts an annual survey of local government fertiliser use. Efficiencies can be tracked for local government during a number of years through this program. The Local Government Natural Resource Management Policy Manual (produced by the Swan River Trust and Eastern Metropolitan Regional Council) provides local government with policy recommendations for fertiliser management strategies.

The *Stormwater Management Manual* (Department of Water 2004-07) provides State and local government and other land managers with a toolbox of information to enable the integration of water sensitive urban design into land use planning and development, reducing nutrient export. It is important that funding is provided to measure the effectiveness of the BMPs in improving water quality.

6. Reduce nutrient input from industry

Actions

6.1 Regulate industry input through the application of Unauthorised Discharge Regulations.

6.2 Increase uptake and participation in industry education programs.

6.3 Encourage companies involved in industrial projects to develop Environmental Management Systems.

Scale of application Swan Coastal Plain - urban

The Unauthorised Discharge Regulations provide local government with the statutory backing to manage the discharge of pollutants, including nutrients from industrial activities. The use of these

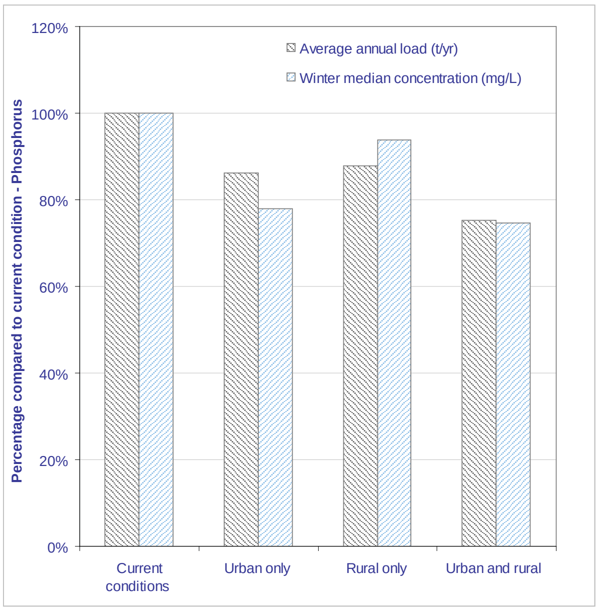


Figure 12 Management scenario – application of the Fertiliser Action Plan in urban and rural areas

regulations by local government can reduce the nutrient inputs to the Swan Canning Catchment.

Industry education programs have also had an effect on reducing nutrient inputs from industrial activities. The Perth Region NRM Light Industry Audit Program has been piloted by a number of local governments in the Swan Canning Catchment, resulting in a reduction in nutrient and non–nutrient contaminants.

Development of environmental management systems by industry, including site remediation management planning, will assist in regulating and reducing inputs to the catchment. Building codes of practice and information on best management practice for urban stormwater management are available through existing programs including the *Stormwater Management Manual for Western Australia* (Department of Water, 2004-07).

Reduction and source control

Keeping the nutrients on the land

7. Develop local water quality improvement plans and other sub-catchment nutrient management plans

Actions

7.1 Identify catchment characteristics and nutrient sources using predictive modelling and decision support tools.

7.2 Confirm modelling results with on-ground investigations.

7.3 Develop local water quality improvement plans and other sub-catchment nutrient management plans, based on source management and land use.

Scale: Swan Canning sub-catchments

Each of the 31 Swan Canning sub-catchments has unique characteristics and opportunities for nutrient management.

The predictive modelling project has identified the sources of nitrogen and phosphorus for 30 sub-catchments (Munday and Bickley Brook have been combined, see section 4.3). In addition, the current and environmental flow from each sub-catchment has been identified (Appendix 6), which provides an indication of the amount of nutrient load to be expected from the catchment and seasonal timing of delivery.

For effective nutrient management, the source and composition of nitrogen and phosphorus loads require specific management on a sub-catchment level.

There are opportunities for sub-catchment nutrient management plans such as local water quality improvement plans to reduce nutrient export to the system. Combined with management scenarios that model the effects of management changes, each sub-catchment has the opportunity to develop individual nutrient management plans, or local WQIPs, based on catchment characteristics and feasibilities.

Through the Healthy Rivers Program and the CCI, local WQIPs are being developed with the community, State and local government stakeholders for the priority sub-catchments in the Swan Canning Catchment. However, planning and continued support for on-ground activities that protect sub-catchments with good water quality is as important as managing priority sub-catchments. Developing local WQIPs may be considered for sub-catchments with good water quality where resources are available. This would identify and protect assets that are maintaining water quality and inform community and other stakeholders of best practice and actions to maintain catchment performance.

Details of developing local WQIPs are provided in Section 3.

8. *Apply best management practice for nutrient management*

Actions

8.1 Ensure new development meets water quality targets and incorporates best management structural and non-structural stormwater management measures.

8.2 Provide access to modelling tools to identify the suitable best management practice options.

8.3 Customise Graphical User Interface for SQUARE to different stakeholder needs.

8.4 Educate urban land managers in best management practice options and support their use in urban areas.

8.5 Educate rural land managers in best management practice options and support their use in rural areas.

Scale of application
Swan Coastal Plain – urban and rural

Urban: A number of best management practices have been trialled and modelled throughout the Swan Coastal Plain. All new development should aim to achieve appropriate water quality targets through the application of structural and non-structural best management practices for water quality. This includes treatment of all stormwater drainage flows and improved fertiliser management in public open space.

The use of modelling tools such as MUSIC aids the design of stormwater management systems to achieve agreed design objectives.

The New WAter Ways capacity building program through WALGA builds a greater level of understanding and support for water sensitive urban design, particularly targeting local government authorities and industry practitioners.

The SQUARE predictive modelling should be made available through a Graphical User Interface (GUI), customised for different stakeholder needs to increase its accessibility to land managers and decision makers.

Rural: A number of cost effective best management practices to reduce nutrient export in the Ellen Brook Catchment have been trialled by the Department of Agriculture and Food WA. The trials include streamlining and revegetation, soil amendment and replacing annual pastures with perennials.

Support is required to build the capacity of land managers in education and application of best management practices, including opportunities for training, field visits to demonstration sites and information dissemination through landcare and other groups, eg. Ellen Brockman Integrated Catchment Group.

9. *Apply nutrient fixing soil amendments to sandy soils*

Actions

9.1 Explore the potential to apply appropriate soil amendments to existing rural and urban properties on soils with a low phosphorus retention ability.

9.2 Apply soil amendments with high phosphorus retention to new urban developments (lot and estate scale) in areas with sandy soils.

9.3 Dilute organic soil amendments. Incorporate nutrient retentive materials into existing organic soil amendments known to be applied in excess of nutrient requirements (such as manures or soil blends).

Scale of application
Swan Canning Catchment

There are a number of soil amendments available and being trialled which have nutrient fixing abilities, enabling the nitrogen and phosphorus to be held in the soil structure.

Soil amendments, e.g. yellow sands, can be applied at the estate and lot scale to reduce nutrient loss from sandy soils. Support is required to build the capacity of land managers and developers in education and application of soil amendments, including opportunities for training, creation of demonstration sites and information dissemination.

Scenario modelling indicates that applying soil amendment to all future urban properties to increase the phosphorus retention index (PRI) of soils from less than 10 to a PRI of 10 will reduce the amount of phosphorus export from these areas by 8%. Based on predictive modelling throughout the Swan Canning Catchment, urbanisation with no soil amendment results in an increase of 25% TP, while urbanisation with a suitable soil amendment results in an increase of 17% TP (Figure 13).

The modelling suggests that sub-catchments respond differently to soil amendments, related to their soil types and the types of amendment. Depth of soil amendment to achieve a PRI of 10 was modelled at 30cm but varies with soil type. Soil types are discussed in further detail in section 5.1. Based on their soil types, some sub-catchments respond well to the use of amendments while in other sub-catchments they have no effect. For example, using amendments in future urban sites at Southern River, which naturally have soils of a higher PRI, will result in an increase in export of only 6% TP. Without soil amendment phosphorus export with urbanisation will increase by almost 70%. In contrast, the use of soil amendments in the Bennett Brook sub-catchment will have no effect on reducing phosphorus export (Figure 14).

Modelling indicates that soil amendments are effective in rural areas. For example, the use of streamlining on heavy soils can also reduce the export of particulate phosphorus. The application of soil amendment to rural properties to increase the PRI of soils from less than 10 to a PRI of 10 reduces phosphorus export by 12% TP (Figure 15).

Predictive modelling suggests soil amendments have minimal effect on nitrogen reduction.

Amelioration

Links to existing programs

10. Support structural nutrient intervention

Actions

10.1 Promote installation of constructed wetlands in suitable sites.

10.2 Promote the conversion of drains to living streams.

10.3 Support the application of nutrient retentive material in suitable sites.

10.4 Identify opportunities to address nutrient export from sub-catchments using foreshore restoration.

10.5 Support and educate local government and land managers in best management practice for nutrient reduction.

Scale of application
Swan Canning – local sites

Drainage nutrient intervention structures intercept the export of nutrients into the Swan Canning river system. A range of nutrient intervention structures have been tested throughout the Swan Canning Catchment, including wetlands designed to strip nutrients from runoff, in-stream intervention, use of nutrient retentive material, and development of living streams.

The *Stormwater Management Manual for Western Australia* presents a range of best management practice nutrient interventions for urban areas (Department of Water 2004-07).

Effective nutrient intervention is site dependent. An example of a constructed wetland is the Liege Street Wetland, developed by the Trust. This four hectare site delivers 45% TN and 27% TP reduction in a low flow situation. Other interventions are being trialled at Ellen Brook on minor and major tributaries, using sedimentation wetlands and nutrient filters. These target soluble phosphorus and ammonium nitrogen (GHD 2007).

Predictive modelling indicates the installation of a wetland (where feasible) delivers an average reduction of 7%TP and 4% TN coming from the sub-catchments, but varies greatly between sub-catchments (Figures 16 and 17).

The conversion of drains to living streams is an option in sites where the area available for remediation is restricted. Living streams can reduce nutrients through slowing flow, thus enabling instream vegetation to establish. They can be

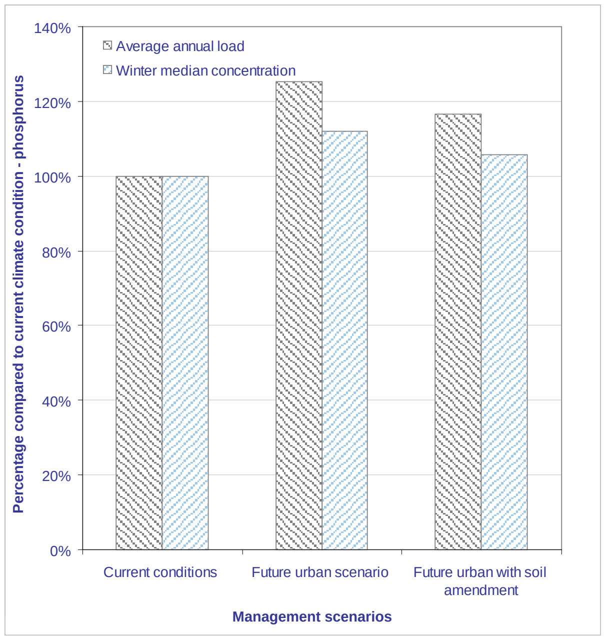


Figure 13 The effect of soil amendment on reducing phosphorus export from future urban land use in the Swan Canning Catchment

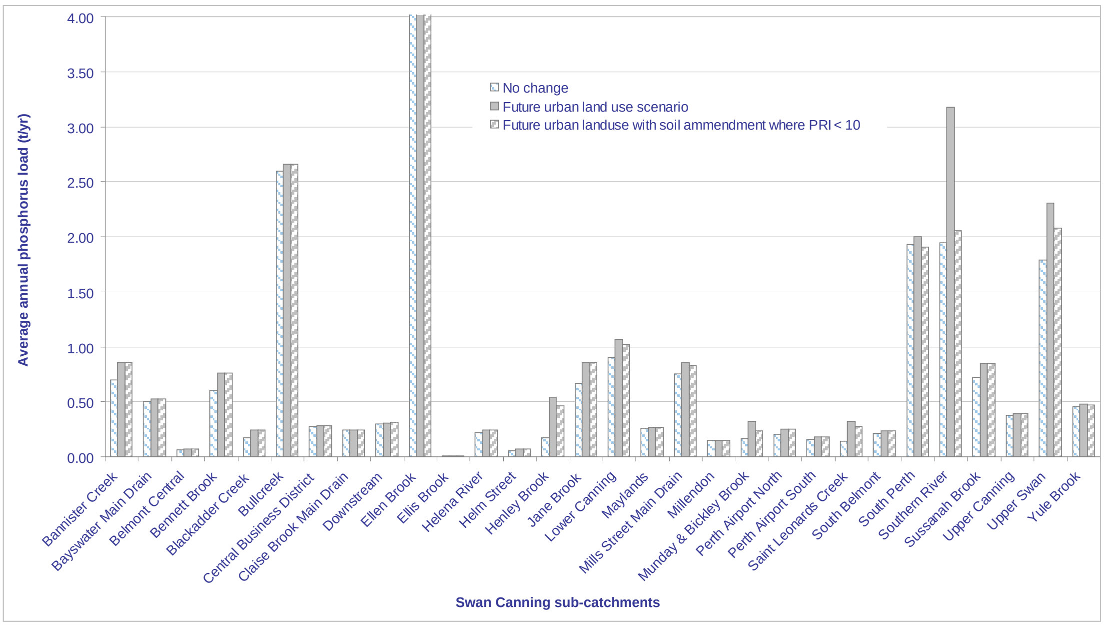


Figure 14 The effect of soil amendment on reducing phosphorus export from future urban land use by sub-catchment

designed to ensure flood flows are uninhibited while removing nutrients during periods of low flow.

Trials were conducted using nutrient retentive material including a zeolite/laterite nutrient curtain, installed perpendicular to the drain, which filters water in subsurface flow to the drain. This treatment has been modelled to be only effective in extremely low flow situations (Figure 18).

Foreshore restoration is another method of nutrient intervention. While the current foreshore restoration activities target vegetation and shoreline restoration, there is the opportunity to expand these activities to also target nutrient export from priority sites.

Support for local government and foreshore managers conducting best management practice foreshore restoration activities is important, as is the education of other managers. Linking to existing programs that demonstrate best practice foreshore restoration provides an opportunity to also address nutrient export, for example the Trust's Riverbank program.

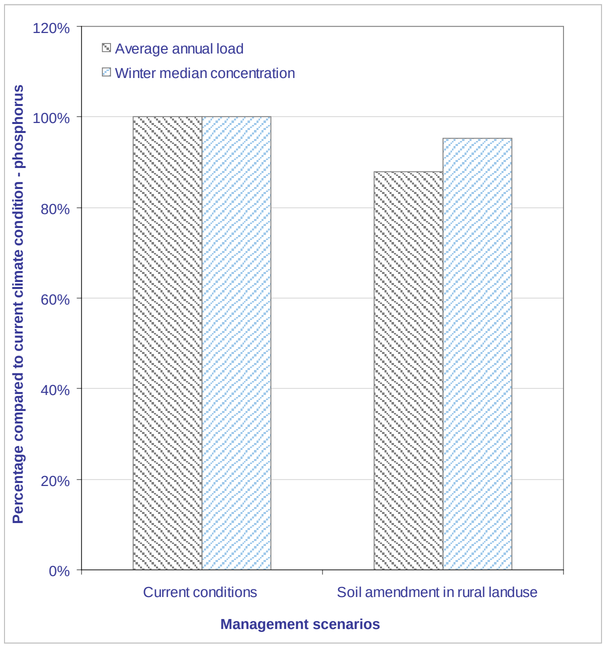


Figure 15 The effect of soil amendment on reducing phosphorus in rural areas

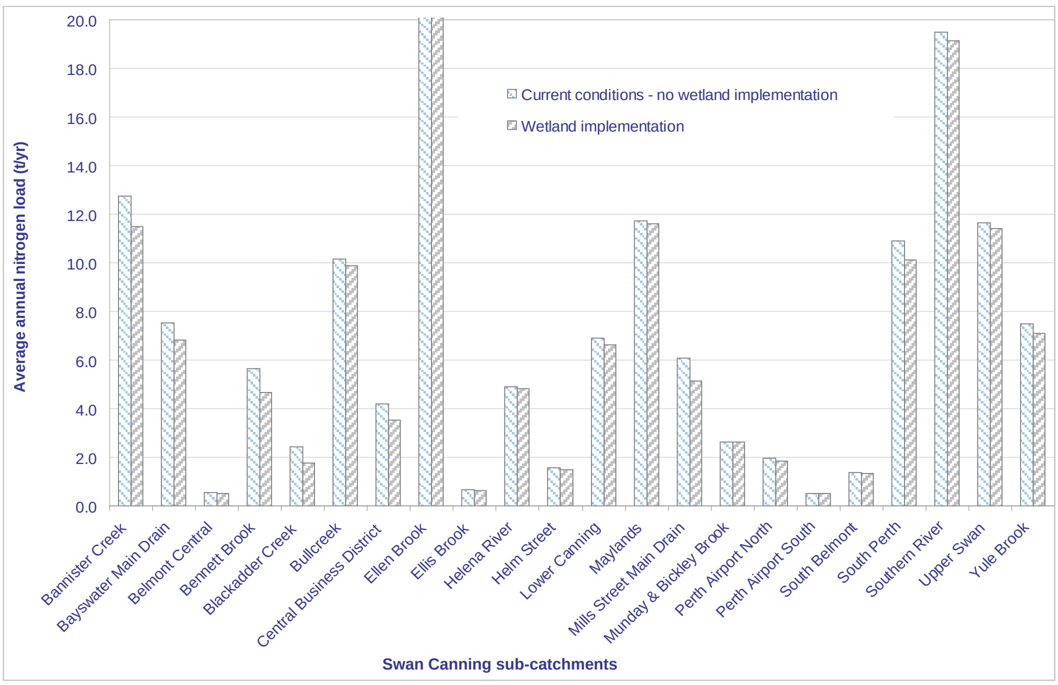


Figure 16 The effect of a constructed wetland on reducing nitrogen by sub-catchment (Current annual nitrogen load for Ellen Brook is 92.8 t/yr, with wetland implementation this would drop to 90.9 t/yr)

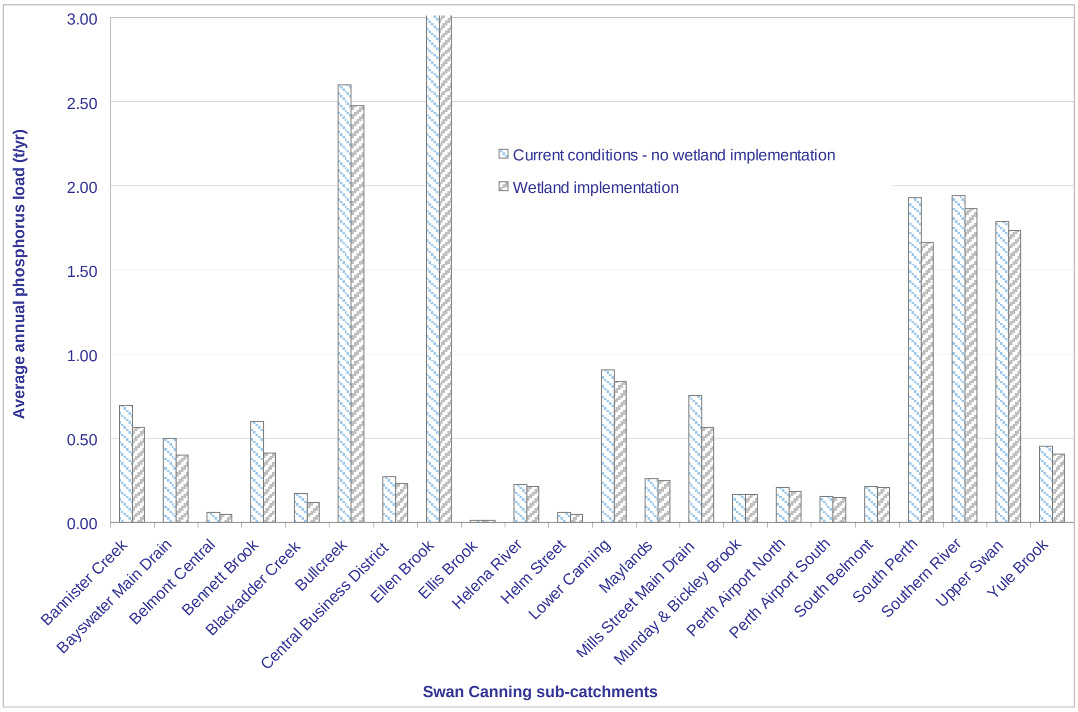


Figure 17 The effect of a constructed wetland on reducing phosphorus by sub-catchment (Current annual phosphorus load for Ellen Brook is 10.55 t/yr, with wetland implementation this would drop to 10.15 t/yr)

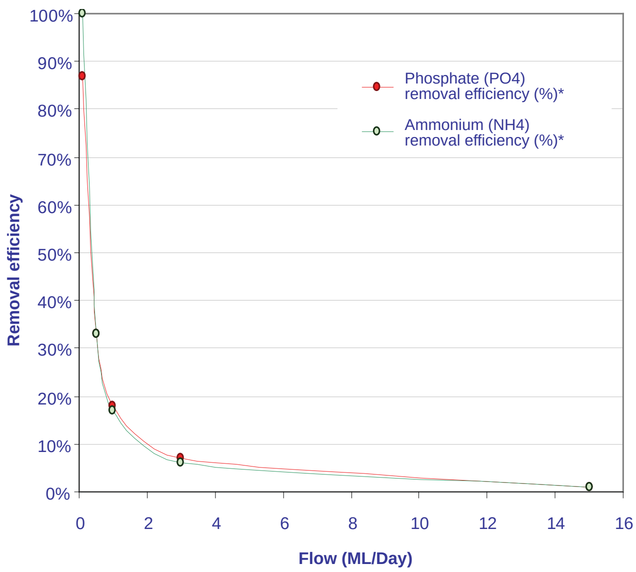


Figure 18 Nutrient removal by flow using the zeolite/laterite nutrient curtain

11. Improve urban drainage design and stormwater management

Actions

11.1 *Maximise retrofitting of stormwater management systems to achieve improved water quality outcomes.*

11.2 *Increase uptake of the practices contained in the Department of Water* Stormwater Management Manual for Western Australia.

Scale of application
Swan Coastal Plain - urban

There is a need to improve the water quality management performance of existing urban drainage systems so that stormwater from hard surfaces such as roofs, car parks and roads is treated prior to reaching waterways and water bodies. Although opportunities for large retrofitting projects, such as the Liege Street Wetlands and Bayswater Brook projects should be investigated, the opportunity exists to incorporate water quality treatment measures into existing drainage systems as part of scheduled maintenance works (where possible). Measures which should be considered include: rain gardens; tree pits and biofiltration systems; modified kerbing; porous paving; swales; bottomless soakwells; gross pollutant traps and trash racks; soil amendment and erosion; and sediment control.

It is recommended that the development of an overarching program framework and investment design strategies to manage stormwater on a regional basis would be more effective. For example, Melbourne Water manages the Stormwater Action Program for greater Melbourne which provides the framework for a coordinated approach to urban stormwater management.

Actions to improve the management of stormwater quality tend to focus on the use of structural (or permanent) practices. Improved water quality outcomes are also able to be achieved through the use of non-structural controls – policy and practices such as education programs, management and maintenance practices and programs, catchment management plans and activities, as well as town planning controls. These types of controls can influence the behaviours and practices of management and maintenance staff and the general community, which can result in reduced application of fertilisers and improved building site practices.

Additional information on stormwater management plans, retrofitting, structural and non-structural controls and monitoring is contained in the *Stormwater Management Manual for Western Australia* (Department of Water, 2004-07).

Treatment – Reuse – Disposal

Managing the nutrients we can not keep on site

12. Achieve zero nutrient contribution from sewage

Actions

12.1 *Support the provision of deep sewerage throughout the Swan Canning Catchment.*

12.2 *Full connection of existing industrial, commercial and residential areas where a sewerage scheme is available.*

12.3 *Explore use of incentives and nutrient offsets.*

Scale of application
Swan Canning – urban and rural

Nutrient contribution from sewage has been identified as a point source through predictive modelling, contributing 17.5% TN and 8% TP of the average nutrient load across the sub-catchments. Scenario testing has calculated that 100% infill of urban septic tanks, including caravan parks, houses, industrial and aerobic treatment units, will result in a 14.7% reduction in TN and 7.7% reduction in TP. However, the nutrient contribution from sewage is not consistent throughout the Swan Canning Catchment, therefore its management will be more effectively addressed on a sub-catchment scale.

Nutrient export from sewage is linked to areas of industrial land use. Sewerage is not provided to most existing industrial areas, and these can become a major nutrient point source. For example, Mills Street Main Drain sub-catchment is highly industrialised, with septics contributing 50% nitrogen and 62% phosphorus export. Total nutrient load reduction required from Mills Street Main Drain to meet the target load is 64% TN and 65% TP.

The target of zero nutrient contribution from sewage to the Swan Canning river system provides the opportunity to explore other alternatives to achieve the target, including:

- providing incentives to households to encourage residential sewerage connection; and
- developers and industry using nutrients offsets.

13. Promote urban drainage initiatives

Actions

13.1 Encourage the use of gross pollutant traps and in-stream trapping systems.

13.2 Explore the re-use of stormwater and waste water while maintaining flow for environmental requirements.

Scale of application
Swan Canning Catchment - urban

Gross pollutant traps, also referred to as litter and sediment management systems, are recommended for use at source to be most effective in pollutant management (Department of Water, 2004-07). These systems do not target nutrient management but can result in nutrient reduction by trapping nitrogen and phosphorus in sediments and slowing the rate of water movement. However, to be effective they require regular monitoring and maintenance which must be included in the cost analysis.

Stormwater and waste water retention and re-use can reduce the pollutant load entering the river system by capturing and holding the stormwater at source and preventing runoff from rainfall events (Department of Water, 2004-07). During infiltration and retention, water quality can improve by natural processes removing some of the nutrient load. The environmental flow requirements to support ecosystem health must also be considered with this option to ensure flow is maintained at adequate levels.

2.3.3 Use of market-based instruments

There is opportunity in the Swan Canning Catchment to use market-based approaches as management measures to achieve the SCWQIP water quality objectives.

The Perth Region NRM, through its Sustainable Production Program, is engaged in a National Pilot Project aimed at assisting small to medium enterprises (businesses with 200 employees or less) in adopting better environmental practices.

A recent review of incentives and incentive-based initiatives has found that they:

- are voluntary and market-based rather than regulatory approaches;
- typically provide positive motivation to improve performance, rather than threat as a consequence of poor performance (i.e. ‘rewards and carrots’, ‘pulling’ business towards improved performance, rather than ‘sticks’, ‘pushing’ business towards better performance);
- typically relate to financial benefits, directly through financial support or cost savings, or indirectly through potential enhanced company reputation, customer attraction and sales;

- may, if a broader definition is adopted, include 'in kind' and intangible general benefits, such as access to advice, support and information, as well as tangible reward (the incentive is receiving free services which may generate business benefits which would otherwise have to be paid for); and
- are distinguished from traditional 'command and control' regulatory approaches such as emissions standards and licensing (P Male, pers. comm. 2008).

While it can be argued that regulation provides an 'incentive' to improve performance (e.g. risk of a fine or other penalty) there is not so much an incentive to perform as a disincentive to poor performance.

Working with industry in the Swan Canning Catchment, Perth Region NRM has identified that this group responds well to:

- simple cost saving measures that can include water use efficiencies;
- environmental accreditation, eg Green Stamp for printers and cleaners, as a market based incentive; and
- use of Unauthorised Discharge Regulations for polluters (Clark, 2008).

Perth Region NRM is also working with WALGA, to progress the development and adoption of green procurement policies for the purchase of goods and services from 'green accredited' businesses. The adoption of nutrient reduction measures in this program needs to be investigated.

Further information

New WAter Ways
http://www.newwaterways.org.au

Better Urban Water Management
http://www.wapc.wa.gov.au/Publications/1725.aspx

Planning Bulletin 92 Urban Water Management
http://www.wapc.wa.gov.au/Publications/1724.aspx

Swan River Trust http://www.swanrivertrust.wa.gov.au

Table 4 Estimates of costs and timelines for SCWQIP management actions

MANAGEMENT ACTION	START/ FINISH	COST ESTIMATE (ANNUAL)	MILESTONE	LEAD ORGANISATION
1. Urban planning at a strategic level				
1.1 Continue to support a holistic total water cycle approach to addressing water issues in the planning decision-making process via the *Better Urban Water Management* framework	Ongoing	[2] Costs covered under existing budget-allocated State Government program	Total water cycle management implemented through an integrated urban stormwater quality program	Department of Planning, Department of Water
1.2 Integrate the use of predictive modelling and decision support tools at the planning phase of land use change	Ongoing	[2] $50,000 for modelling support officer	All land use change includes predictive modelling during planning	Department of Planning
1.3 Continue to investigate the use of nutrient offsets	Ongoing	[2] Costs covered under existing budget-allocated Swan River Trust program	Not defined	Swan River Trust
2. Application of water sensitive urban design practices				
2.1 Continue to ensure the objectives of *State Planning Policy 2.9 Water Resources* are met, via the application of *Better Urban Water Management*, in planning decision-making including the assessment of subdivisions and developments	Ongoing	[2] Costs covered under existing budget- allocated State Government program	Subdivisions and developments implement State Planning Policy 2.9 Water Resources	Department of Planning
2.2 Promote local government participation in education programs for land use planners	Ongoing	[2] $200,000 for program management and operating expenses –New WAter Ways	All local governments participating in education programs	Western Australian Local Government Association, Department of Water
3. Continue to monitor water quality throughout the Swan Canning Catchment				
3.1 Expand and review water quality monitoring at gauged and un-gauged sites	Ongoing	[2] $455,000 p.a. • quarterly catchment water quality monitoring within seven sub-catchment nutrient hotspots ($115,000) • fortnightly river outlet water quality monitoring – 30 outlets into the Swan and Canning rivers ($195,000) • fortnightly (during flow periods) water quality monitoring – Avon River and major tributaries ($145,000)	Annual water quality monitoring	Perth Region NRM, Swan River Trust, Wheatbelt NRM
4. Promote best rural fertiliser management practices				
4.1 Encourage the use of slow release, low water-soluble phosphate fertilisers	Ongoing	Not defined		Department of Environment and Conservation
4.2 Implement the Fertiliser Action Plan	Ongoing	[2] Costs covered under existing budget allocated to Fertiliser Action Plan	Not defined	Department of Environment and Conservation
5. Expand urban education in efficient fertiliser management to reduce nutrient input				
5.1 Reduce urban fertiliser use through education programs, particularly targeting the use of highly water-soluble phosphate fertilisers	Ongoing	[2] $20,000 education program delivery (Stormwater Management Manual)	Reduction in urban fertiliser use	Department of Water, Swan River Trust

MANAGEMENT ACTION	START/ FINISH	COST ESTIMATE (ANNUAL)	MILESTONE	LEAD ORGANISATION
5.2 Reduce the availability of highly water-soluble phosphate fertilisers for domestic use	2008-10	[2.] Costs covered under existing budget allocated to Fertiliser Action Plan	Highly water-soluble phosphate fertiliser no longer available to purchase	Department of Environment and Conservation
5.3 Implement the Fertiliser Action Plan	2008-13	Included in MA 4.2		
5.4 Promote local government participation in New WAter Ways	Ongoing	Included in MA 2.2		
5.5 Continue to build the capacity of State and local government, industry and practitioners to implement *Better Urban Water Management*	Ongoing	[2.] Costs covered under existing budget-allocated State Government program	Land managers, practitioners and consultants using the framework	Department of Planning
5.6 Increase uptake of Department of Water *Storm Water Management Manual for Western Australia*	Ongoing	[2.] Costs covered under existing budget allocated State Government program	Increased use of slow release, water soluble phosphate fertilisers	Department of Water
5.7 Seek funding for effectiveness measurement of practices within the manual to improve water quality	Ongoing	[2.] Costs covered under existing budget allocated State Government program	Some level of funding achieved; other opportunities explored	Department of Water
6. Reduce nutrient input from industry				
6.1 Regulate industry inputs through the application of the Unauthorised Discharge Regulations	Ongoing	[2.] $480 - $875 per premises for point source management	Industry inputs reduced	Department of Environment and Conservation
6.2 Increase the uptake and participation in industry education programs	Ongoing	[2.] $70,000 - $180 000 for program management	Increased participants in programs; participants applying learnings from programs	Perth Region NRM
6.3 Encourage companies involved in industrial projects to develop Environmental Management Systems	Ongoing	Included in MA 6.2		
7. Develop local water quality improvement plans and other sub-catchment nutrient management plans				
7.1 Identify catchment characteristics and nutrient sources using predictive modelling and decision support tools	Ongoing	[2.] $180,000 (approximately $6000 per sub-catchment)	Swan Canning sub-catchments modelled	Swan River Trust, Department of Water
7.2 Confirm modeling results with on ground investigations		Not defined - site specific	Not defined	Department of Water
7.3 Develop local water quality improvement plans and other sub-catchment nutrient management plans, based on source management and land use	Ongoing	[2.] $100,000 for program management – Healthy Rivers Action Plan	Local WQIPs developed for Swan Canning sub-catchments	Swan River Trust
8. Apply best management practice for nutrient management				
8.1 Ensure new development meets water quality targets and incorporates best management structural and non-structural stormwater management measures	Ongoing	Included in MA 2.2 through the local government development approval process		

MANAGEMENT ACTION	START/ FINISH	COST ESTIMATE (ANNUAL)	MILESTONE	LEAD ORGANISATION
8.2 Provide access to modelling tools to identify the most suitable best management practice option	Ongoing	2. $100,000 for program coordination through Department of Water	BMPs modelled for management activity	Department of Water
8.3 Customise Graphical User Interface (GUI) for SQUARE to different stakeholder needs	2010-11	Included in MA 8.2	GUI developed and used by stakeholders	Department of Water
8.4 Educate urban land managers in best management practice options and support their use in urban areas	Ongoing	Included in MA 2.2		
8.5 Educate rural land managers in best management practices options and support their use in rural areas	Ongoing	2. $100,000 for program coordination - Ellen Brook Catchment Management Plan Fencing and on-ground management costs	Rural land managers using best management practices	Swan River Trust, Department of Agriculture and Food
9. Apply nutrient fixing soil amendments to sandy soils				
9.1 Explore the potential to apply appropriate soil amendments to existing rural and urban properties on soils with a low phosphorus retention ability	2009-19	1. $34,000 per annum over 10 years to trial and promote soil amendments Grants scheme and/or industry support for landholders undertaking soils amendment once approved	Soil amendments applied to increase PRI	Department of Agriculture and Food, Department of Water
9.2 Apply soil amendments with high phosphorus retention to new urban developments (lot and estate scale) in areas with sandy soils	2009-29	Dependent on MA 9.1		
9.3 Dilute organic soil amendments. Incorporate nutrient retentive materials into existing organic soil amendments known to be applied in excess of nutrient requirements (such as manures or soil blends)	Ongoing	Not defined - site specific	Organic soil amendments diluted and include nutrient retentive material	
10. Support structural nutrient intervention				
10.1 Promote installation of constructed wetlands in suitable areas	Ongoing	2. Costs covered under existing budget allocated to Healthy Rivers Action Plan	Wetland installation considered at suitable sites	Swan River Trust
10.2 Promote the conversion of drains to living streams	Ongoing	2. Costs covered under existing budget-allocated State Government program	Drains converted to living streams where feasible	Department of Water
10.3 Support the application of nutrient retentive material in suitable sites	Ongoing	2. Costs covered under existing budget allocated to Healthy Rivers Action Plan	Sites assessed for response to nutrient retentive material and applied as appropriate	Swan River Trust
10.4 Identify opportunities to address nutrient export from sub-catchments using foreshore restoration	Ongoing	2. Costs covered under existing budget-allocated Healthy Rivers Program (Riverbank)	Nutrient reduction capability considered in foreshore restoration	Swan River Trust
10.5 Support and educate local government and land managers in best management practice for nutrient reduction	Ongoing	Included in MA 5.1		

MANAGEMENT ACTION	START/ FINISH	COST ESTIMATE (ANNUAL)	MILESTONE	LEAD ORGANISATION
11. Improve urban drainage design and stormwater management				
11.1 Maximise retrofitting of stormwater management systems to achieve improved water quality outcomes	Ongoing	[1] Construction: $500,000/ha of surface area (includes gross pollutant traps, engineering structures and landscaping) Maintenance: $3000/ha of surface area/yr (*Stormwater Management Manual for Western Australia*) Capital cost: $5000-$10,000/ha of catchment Maintenance: $8000/yr/ large GPT Removal of pollutants from pits in an enclosed drainage system: - $2.80/inlet - $147,000/10,000 pits twice yearly (385 pits/wk, 150 tonnes of waste) Removal of materials from open drains: $80-$180/m^3	Retrofitting stormwater management systems maximised	Department of Water, local government
11.2 Increase uptake of the practices contained in the Department of Water *Stormwater Management Manual for Western Australia*	Ongoing	Included in MA 5.6		
12. Achieve zero nutrient contribution from sewage				
12.1 Support the provision of deep sewerage throughout the Swan Canning Catchment	Ongoing	[2] Costs covered under existing budget-allocated State Government program	Deep sewerage provision supported	Swan River Trust, Department of Water, Department of Planning, Water Corporation
12.2 Full connection of existing industrial, commercial and residential areas where a sewerage scheme is available	Ongoing	Not defined	100% connection of properties to sewerage	State Government, local government
12.3 Explore the use of incentives and nutrient offsets	Ongoing	[2] Costs covered under existing budget-allocated State Government program	Feasibility of the use of nutrient offsets fully investigated	Swan River Trust, Water Corporation
13. Promote urban drainage initiatives				
13.1 Encourage the use of gross pollutant traps and in-stream trapping systems	Ongoing	Included in MA 5.6		
13.2 Explore the re-use of stormwater and waste water while maintaining flow for environmental requirements	Ongoing	Included in MA 11.2		

[1] capital cost
[2] operating cost

3. Reducing nutrient loads in the sub-catchments

Predictive modelling has calculated nutrient input into the Swan and Canning rivers for 30 Swan Canning sub-catchments (Appendix 1).

This provides an opportunity to establish management priorities at a catchment and sub-catchment level throughout the Swan Canning Catchment and to target management activities to achieve the most cost-effective result.

The five-step approach can be adopted at a sub-catchment level to guide management activities using the predictive modelling in the SCWQIP (Figure 19).

Each of the sub-catchments has its own characteristics. Investigating the feasibility of the management options for each catchment is important when conducting cost/benefit analysis for management options.

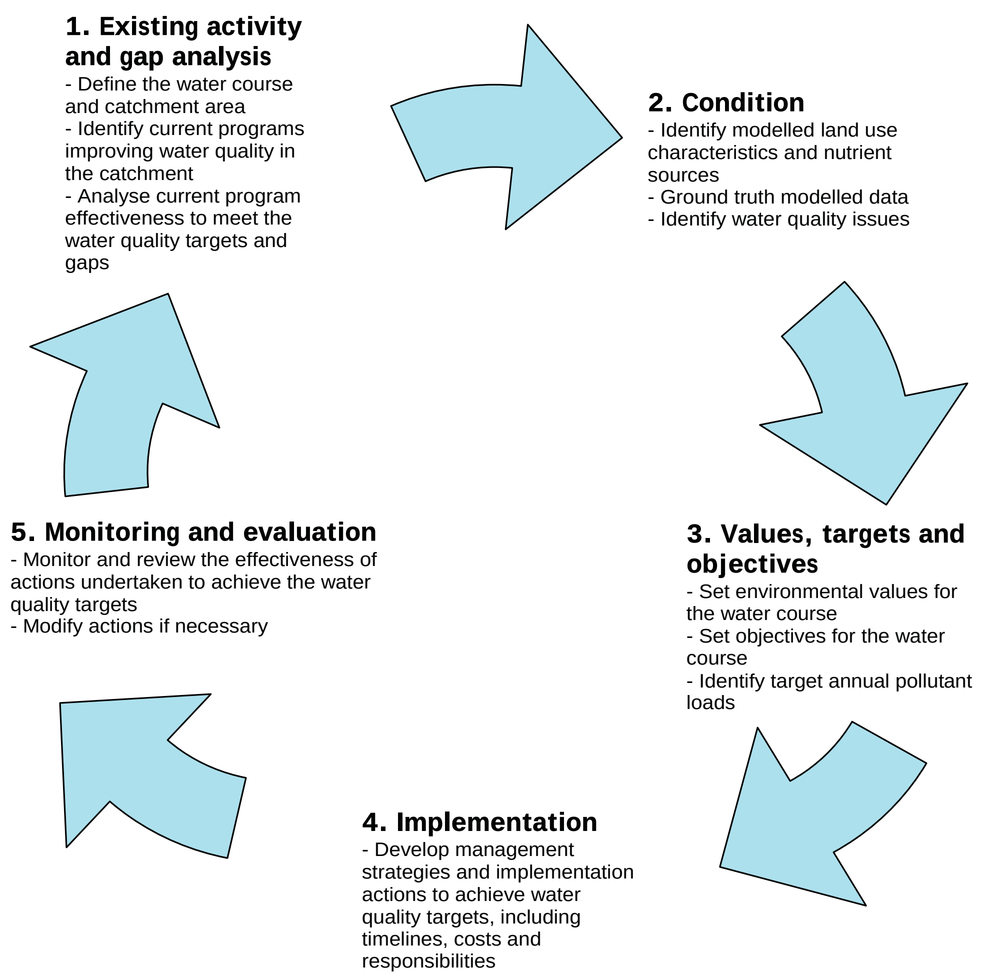


Figure 19 Five steps to developing a local water quality improvement plan

3.1 Sub-catchment management priorities

The SCWQIP has divided the 30 modelled sub-catchments into three management priorities, based on the modelled load reduction required for each catchment. The management priorities are as follows:

1. improve unacceptable water quality – greater than 45% load reduction required;
2. maintain and improve water quality – 10-45% load reduction required; and
3. protect water quality – less than 10% load reduction required (Figures 20 to 23).

3.1.1 Sub-catchments to improve water quality

The following sub-catchments require nutrient load reductions of greater than 45% to achieve the modelled water quality targets.

Nitrogen – *Claise Brook Main Drain, Ellen Brook, Helm Street, Lower Canning, Bannister Creek, Saint Leonards Creek, Central Business District, Mills Street Main Drain, Bayswater Main Drain, Bullcreek, Maylands, Southern River and Belmont Central.*

Phosphorus – *Ellen Brook, Mills Street Main Drain, Southern River, South Belmont and Lower Canning*.

Reducing the export of nutrients from these sub-catchments will have the greatest impact on improving water quality in the Swan and Canning rivers.

Ellen Brook Local Water Quality Improvement Plan

Ellen Brook is identified as the sub-catchment in the Swan Canning Catchment contributing the greatest amount of nutrients to the Swan Canning river system (28% TN and 39% TP). This reflects the size of the sub-catchment (34% of the total area of the Swan Canning Catchment) and nutrient export from the dominant land use (cattle for beef) combined with low PRI soils.

The Ellen Brook sub-catchment is a priority nutrient management area. The Ellen Brook Catchment Management Plan has been compiled by the Ellen Brockman Integrated Catchment Group and recommends a number of actions to manage nutrient export from this sub-catchment.

Through the CCI, the Trust has developed the Ellen Brook WQIP, using a number of the management actions from the Catchment Management Plan (Table 5).

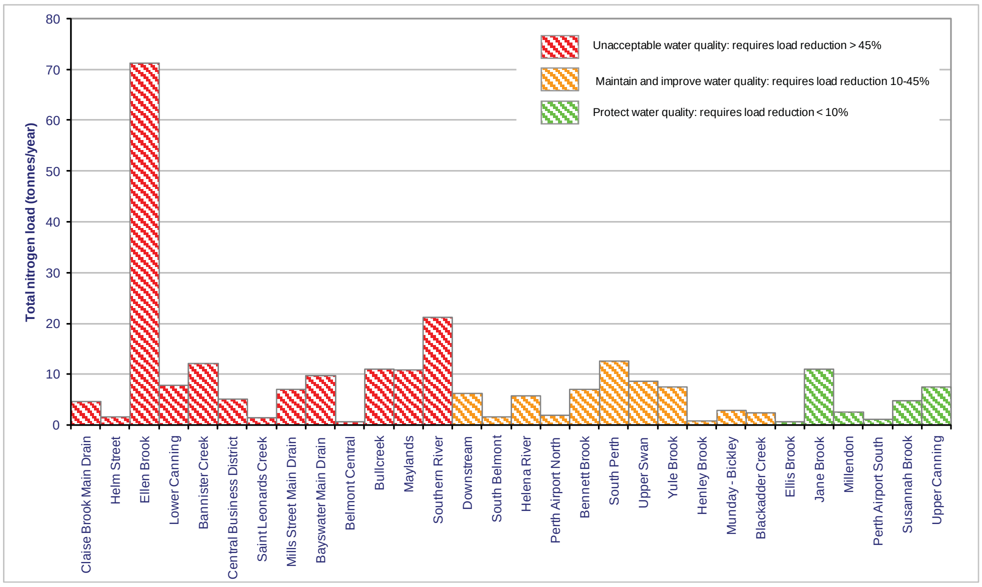


Figure 20 Total nitrogen loads and management priorities for Swan Canning sub-catchments

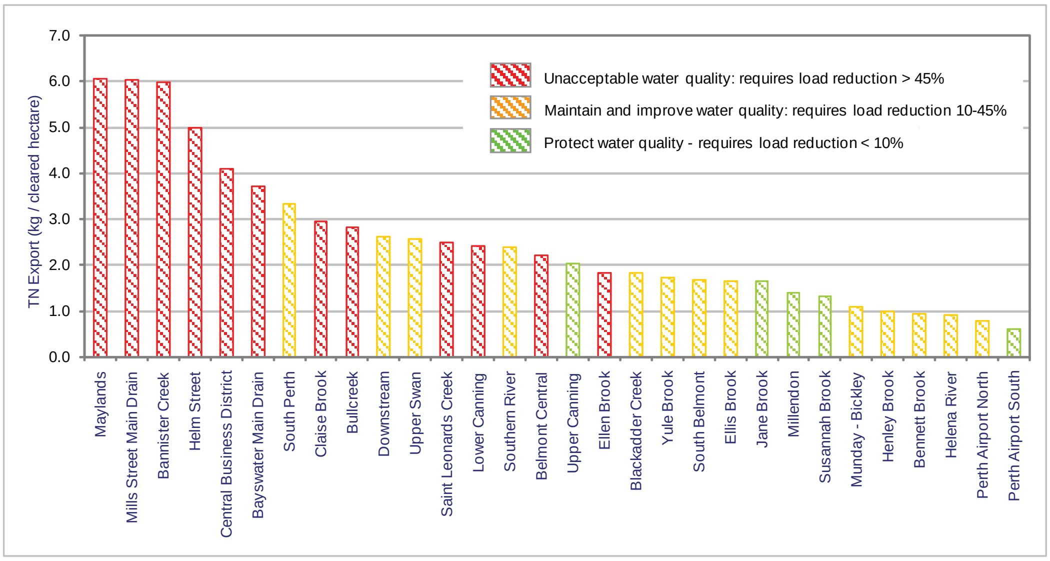


Figure 21 Total nitrogen export per hectare cleared for Swan Canning sub-catchments

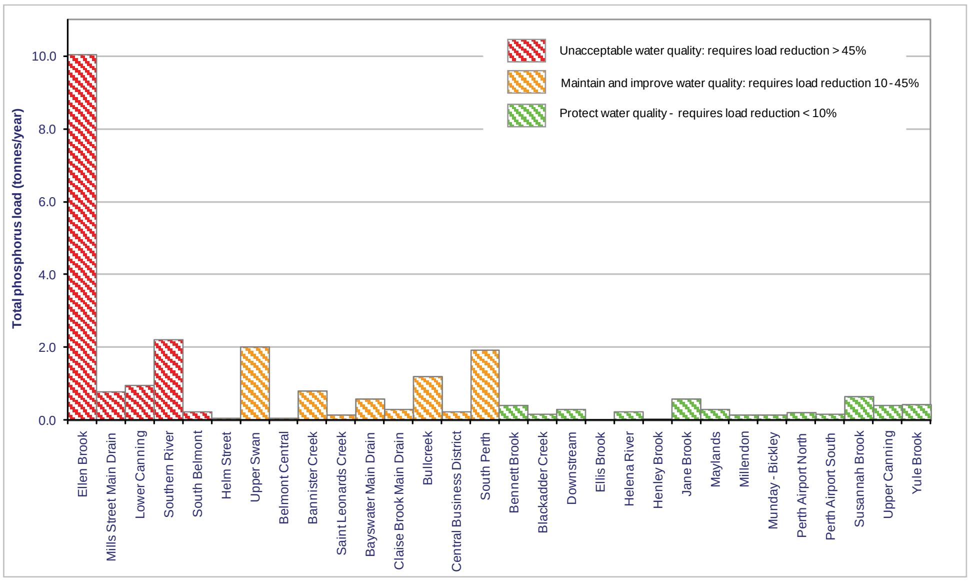


Figure 22 Total phosphorus loads and management priorities for Swan Canning sub-catchments

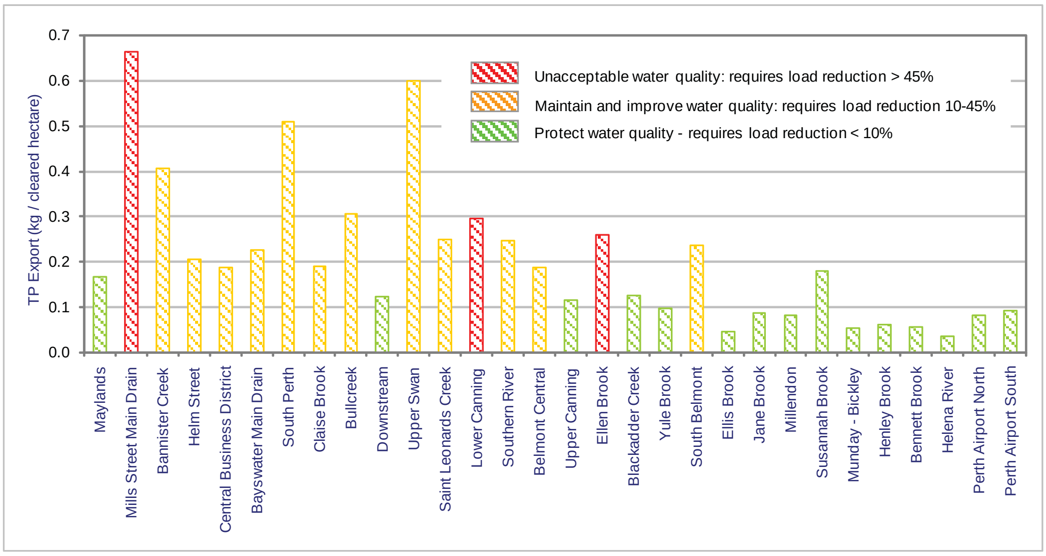


Figure 23 Total phosphorus export per hectare cleared for Swan Canning sub-catchments

Table 5 Ellen Brook action table for nutrient management

TREATMENT TRAIN	MANAGEMENT STRATEGIES	IMPLEMENTATION ACTIONS
1. Prevention Land use and planning	1.1 Policy development and review	• Councils should adopt Local Planning Policy 5.1.2 as developed by Eastern Metropolitan Regional Council and the Swan River Trust which requires developers to incorporate erosion and sediment control measures in local structure plans or outline development plans
		• Develop and implement a Fertiliser Reduction Policy for the Bassendean and Yanga soils (100% TP export risk) to use best management practices to reduce nutrient and other pollutant outputs which incorporates: (i) tissue analysis and soil sampling prior to broadacre fertilisation; and (ii) the use of low water-soluble fertiliser in domestic gardens
		• Explore the use of alternative policy mechanisms to protect Ellen Brook and optimise water quality
	1.2 Better Urban Water Management	• Ensure water sensitive urban design is incorporated into all relevant planning proposals, consistent with the requirements of *Better Urban Water Management*
	1.3 Subdivision conditions	• Incorporate fencing and revegetation of all tributaries as a condition of subdivision for all developments
		• New developments to be sewered where possible or adopt best practice wastewater treatment technologies, including Muchea and West Bullsbrook townsites
	1.4 Water quality monitoring	• Expand, review and continue water quality monitoring program
		• Prioritise sub-catchments with high discharge loads for remediation, as identified by predictive modelling and the Ellen Brook Sub-catchment Water Quality Analysis (EBSWQA)
2. Minimisation Efficiency in nutrient use	2.1 Reduce agricultural industry nutrient output through discharge regulation	• Assess all licensed agricultural industry for compliance, with zero nitrogen and phosphorus discharge
		• Develop strategies to prevent any further discharge of water of unacceptable quality from agricultural industry sites which discharge effluent water (saleyards, sewerage plants, feed lots)
	2.2 Reduce agricultural industry nutrient losses through fertiliser management	• Promote regular soil and groundwater testing by land managers to determine fertiliser application efficiencies for horticultural, viticultural, and market gardens through water and nutrient retention in the root zone of plants
		• Implement the Fertiliser Action Plan
	2.3 Reduce outputs through increasing community capacity	• Develop and implement fertiliser efficiency education and provide opportunities for landowners to examine alternative farming practices (including, but not exclusively, tree farming, alternative cropping and pastures, farming bush foods and maintenance of remnant vegetation)

TREATMENT TRAIN	MANAGEMENT STRATEGIES	IMPLEMENTATION ACTIONS
3. Reduction Source control	3.1 Reduce agricultural industry nutrient losses through best management practices	• Land managers on land units identified as having high discharge loads shall undertake actions including streamlining and revegetation, fertiliser management and alternative production regimes to reduce nutrient export
		• Landowners in the Bassendean and Yanga soil types to trial soil amendments *in-situ* to determine effectiveness in reducing nutrient run off and groundwater contamination
		• Implement soil amendment based on results from trials and land use change to perennial pastures
		• Replace annual pastures with perennial pastures on all erosion-prone and high-leaching soils
4. Amelioration Conveyance and transmission	4.1 Nutrient intervention and improved drainage	• Implement nutrient interventions: (i) where "off-paddock drains" enter Ellen Brook to prevent nutrient export; (ii) to major waterways where appropriate; and (iii) to treat ground water in drains where suitable
		• Seek funding to continue fencing and revegetation of Ellen Brook tributaries until all are protected from stock incursion
5. Treatment-Reuse-Disposal	5.1 Full connection to infill sewerage	• Ensure full connection of all properties to deep sewerage in the Muchea and West Bullsbrook townsites

Other local WQIPs

The Swan River Trust, through the Healthy Rivers Program, is working with the community and local government to develop and implement local WQIPs for priority catchments where catchment management or nutrient management plans do not already exist. Based on more than 10 years of monitoring data, those catchments contributing the greatest amount of nutrients or other contaminants to the Swan Canning river system are identified as priority catchments in Healthy Rivers Action Plan.

The status of local WQIPs for each of the priority catchments identified in the Healthy Rivers Action Plan are presented in Table 6.

Table 6 Local Water Quality Improvement Plans

Sub-catchment	Status of local WQIP
1. Ellen Brook	Local WQIP completed
2. Bayswater Brook	Local WQIP completed
3. Southern River	Local WQIP completed
4. Bickley Brook	Local WQIP completed
5. Canning Plain	Local WQIP completion expected in 2009
6. Bennett Brook	Local WQIP completion expected in 2009

By focusing investment in on-ground works in these areas, the Healthy Rivers Action Plan is aiming to reduce nutrient inputs from priority catchments by 2015. The vital support provided by the community and local government to protect the values of these sub-catchments is well recognised.

The Bayswater Brook Water Quality Improvement Plan is an example of a local WQIP developed specifically to manage the nutrient sources at a sub-catchment level (Appendix 6). This local WQIP identifies the primary nutrient source as residential and recreational activities. Management activities target fertiliser management and structural nutrient intervention.

In the Bayswater sub-catchment, a combination of nutrient management treatments has been modelled which achieves the maximum acceptable loads for the sub-catchment (Figures 10 and 11, Section 2.3). The following treatments were modelled, consistent with the Bayswater Brook local WQIP:

- reducing outputs from residential areas by 15%;
- reducing outputs from public open space by 50%;
- 100% infill of sewerage; and
- installation of a constructed wetland.

3.1.2 Sub-catchments to maintain and improve water quality

A number of sub-catchments have adequate water quality. However in these catchments a change in land use or external influences such as climate change may cause the sub-catchment to move into a higher management priority, requiring an improvement in water quality. Community commitment to the natural environment in many of these sub-catchments is high and contributes to the good water quality of the area.

Sub-catchments in this management category require nutrient reduction between 10-45% to meet their load reduction targets and include:

Nitrogen – *Downstream, South Belmont, Helena River, Perth Airport North, Bennett Brook, South Perth, Upper Swan, Yule Brook, Munday-Bickley Brook, Blackadder Creek and Henley River*.

Phosphorus – *Upper Swan, Helm Street, Bannister Creek, Saint Leonards Creek, Bayswater Main Drain, Belmont Central, Claise Brook Main Drain, Bullcreek, Central Business District and South Perth*.

A local WQIP is being developed for the Southern River sub-catchment. The modelled load reduction for this sub-catchment is 46% TN and 48% TP. This sub-catchment has been recognised as a priority for management as, through scenario modelling, urban expansion increases the nutrient loads by 31% TN and 64% TP. Predictive modelling suggests this sub-catchment will respond well to the use of soil amendments to reduce phosphorus.

3.1.3 Sub-catchments to protect water quality

Water quality in a number of sub-catchments is good, with less than 10% load reduction required.

Management action recommended for these catchments is to protect the current water quality. This category includes the following catchments.

Nitrogen – *Ellis Brook, Jane Brook, Millendon, Perth Airport South, Susannah Brook and Upper Canning*.

Phosphorus – *Bennett Brook, Blackadder Creek, Downstream, Ellis Brook, Helena River, Jane Brook, Maylands, Millendon, Munday-Bickley, Perth Airport North, Perth Airport South, Susannah Brook, Upper Canning and Yule Brook*.

Many of these catchments are not heavily urbanised and are located on the margins of the Swan Canning Catchment, often with part of the upper catchment located in the Western Darling Range soils. These soils have high nutrient retention capacity. The community and local government have provided a high level of support to the management of these sub-catchments, which has contributed to their good water quality. Ongoing support for on-ground community activities will be pursued through the SCWQIP.

A change in the existing land use can impact water quality and a robust monitoring program is vital to anticipate increased nutrient loads and protect water quality.

Lesmurdie Falls. Picture: John Goldsmith

4. Monitoring and evaluation

4.1 Monitoring water quality

The effectiveness of the SCWQIP implementation will be reflected through reduced nutrient loads from the 30 sub-catchments. This can be measured by:

- progress towards meeting nitrogen and phosphorus load reduction targets;
- progress towards meeting nitrogen and phosphorus concentration targets; and
- changes in nutrient sources in sub-catchments, including the removal of point sources.

Other measures of improved water quality can include reduced algal blooms and fish deaths throughout the Swan Canning river system, although this cannot always be directly attributed to nutrient levels.

A comprehensive monitoring program is required to measure change as a response to management actions.

1. Regional monitoring of the 30 sub-catchments that allows changes in TP and TN concentrations to be measured. Load reduction targets were established to meet stream concentrations of TN and TP specifically set for SCWQIP modelling. The reduction target is met when the stream concentration of TN or TP meets the target amount.
2. Project monitoring should be established so that effectiveness of individual management actions can be measured and evaluated against objectives.
3. Predictive model runs at very high resolution using a large number of sub-catchments for each reporting catchment. To utilise the power of the model and to make decisions at a sub-catchment scale some in-fill sampling is required within the smaller sub-catchments.

Regional Scale Monitoring

The Healthy Rivers Program measures nitrogen and phosphorus fortnightly at 16 sites in 15 priority catchments (Figure 24). This data is used to provide annual progress reporting and prepare catchment report cards. Progress reporting against targets is discussed in Section 6.2. A further 17 sites in 15 additional catchments were sampled during the SCWQIP process to provide calibration and validation to the model. It is recommended that these sites be continued as part of the overall monitoring and reporting for the SCWQIP implementation phase (Figures 25 and 26). A compliance scheme will be developed to track progress towards required load reductions.

The uptake of the management recommendations and actions of the SCWQIP will provide a management measure of SCWQIP implementation through the Swan Canning Catchment.

4.2 Development of WQIP load reduction targets

The aim for the sub-catchments throughout the Swan Canning river system is to meet the long and short-term targets for nitrogen and phosphorus (Table 7). The HRAP uses compliance testing, measuring the number of times nutrient concentrations at a monitored site exceed a target, using data from the previous three years. The SCWQIP delivers the nutrient reduction actions for the HRAP and is based on establishing load reduction targets for 30 catchments.

Table 7 HRAP interim targets for median TN and TP in Swan Canning Catchment tributaries (Swan River Trust 2008b)

Target	TN	TP
Short-term	2.0 mg/L	0.2 mg/L
Long-term	1.0 mg/L	0.1 mg/L

TN and TP concentrations in the Swan Canning river system's urban waterways are diluted by increased water yields from highly impervious catchments. Semi-rural catchments such as St Leonards Brook have an average annual water yield of 61mm, while urban catchments such as Bayswater Main Drain have an average annual water yield of approximately 304mm - five times more flow for similar rainfall.

HRAP interim targets were derived from comparison with data in natural rivers (pervious catchments) and are not directly applicable to the highly impervious urban catchments. Swan Canning Coastal Plain catchments were examined in terms of the following characteristics:

- percentage of impervious area;
- average annual water yield;
- summer flow percentage;
- average annual yields of TN and TP per area; and
- observed stream TN and TP concentrations.

HRAP interim concentration targets for impervious catchments were adjusted for the SCWQIP to account for their higher flow. This results in lower nutrient concentrations for comparable nutrient load than pervious catchments. Nutrient loads have been calculated for 30 Swan Canning sub-catchments. Munday and Bickley Brook comprise parts of the same sub-catchment and have been combined for predictive modelling (Table 13).

Sub-catchments are ordered by increasing average annual water yield. This is the flow from each catchment, presented as a percentage of impervious area, and is linked to catchment urbanisation.

Adjusted concentration targets

SCWQIP concentration targets were developed specifically to allow load reduction targets to be derived and provide a mechanism to calculate whether load reduction targets are being met. They do not replace the HRAP targets for public reporting.

Concentration targets for urban catchments were adjusted to reflect their greater water yields. The criteria for distinguishing between sub-catchments, based on their annual water yield, was determined by a panel of experts from the Trust and Department of Water.

Pervious sub-catchment (<100mm annual water yield) median TN and TP concentration targets are the same as HRAP interim targets (Table 7).

Impervious sub-catchment (>200mm annual water yield) targets are 0.5mg TN/L and 0.05mg TP/L. These catchments have an impervious area of more than 20% (Table 8).

Targets for sub-catchments with an annual water yield between 100mm and 200mm are 0.75mg TN/L and 0.075mg TP/L (Table 8).

Table 8 Targets for median TN and TP concentration in tributaries of the Swan-Canning river system

Annual water yield	TN concentration	TP concentration
< 100 mm	1.0 mg/L	0.1 mg/L
100 to < 200 mm	0.75 mg/L	0.075 mg/L
> = 200 mm	0.5 mg/L	0.05 mg/L

These targets were used to derive 49% N and 46% P reductions.

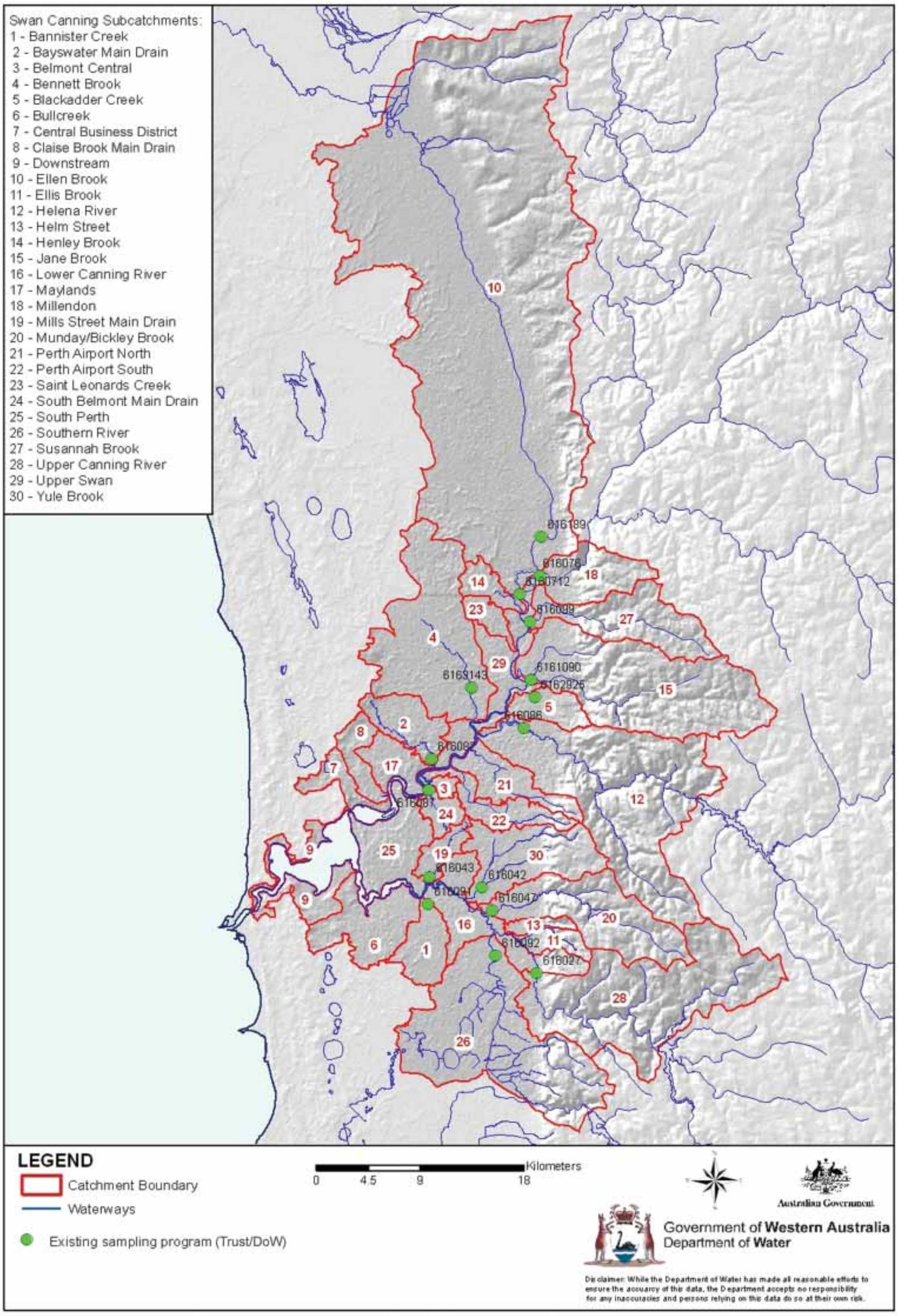


Figure 24 Existing water quality monitoring sites in the Swan-Canning coastal catchments

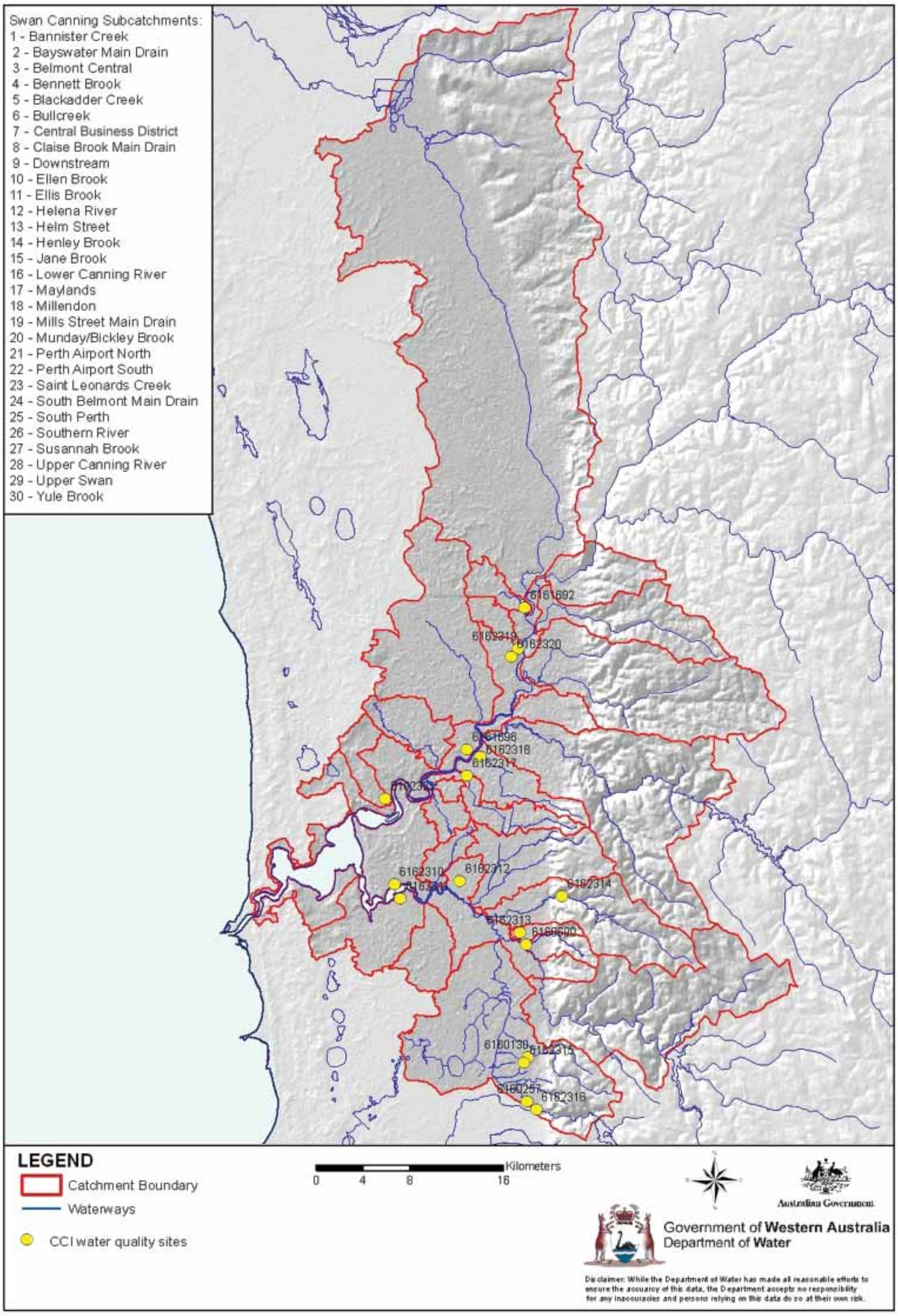


Figure 25 CCI water quality monitoring sites in the Swan-Canning coastal catchment

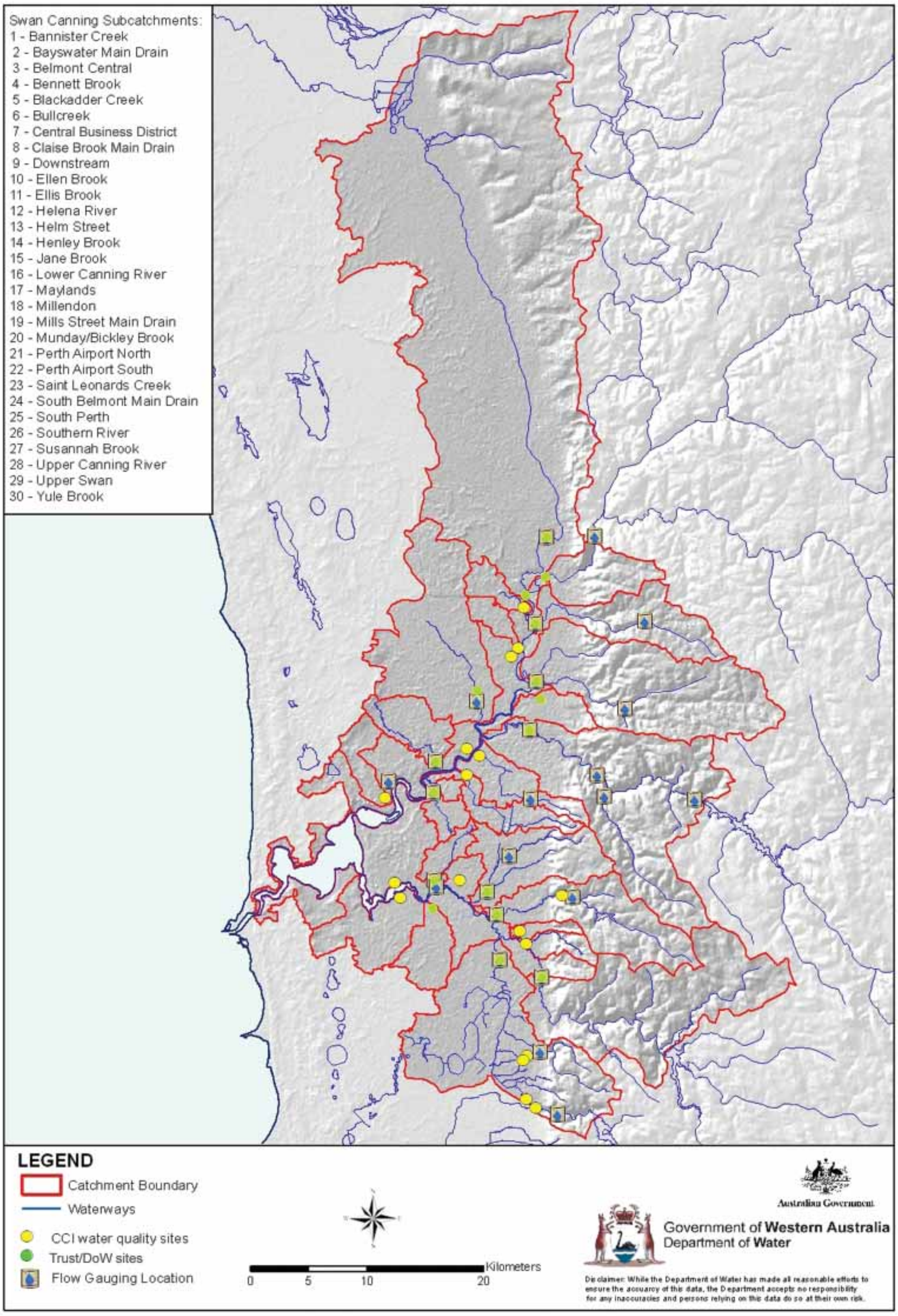


Figure 26 Recommended monitoring program water quality sites and flow gauging stations

4.4 Adaptive management

The SCWQIP uses an adaptive management approach.

Adaptive management refers to a continuous improvement model which responds to new information and adjusts management accordingly. This approach is particularly useful where there are knowledge gaps and uncertainties.

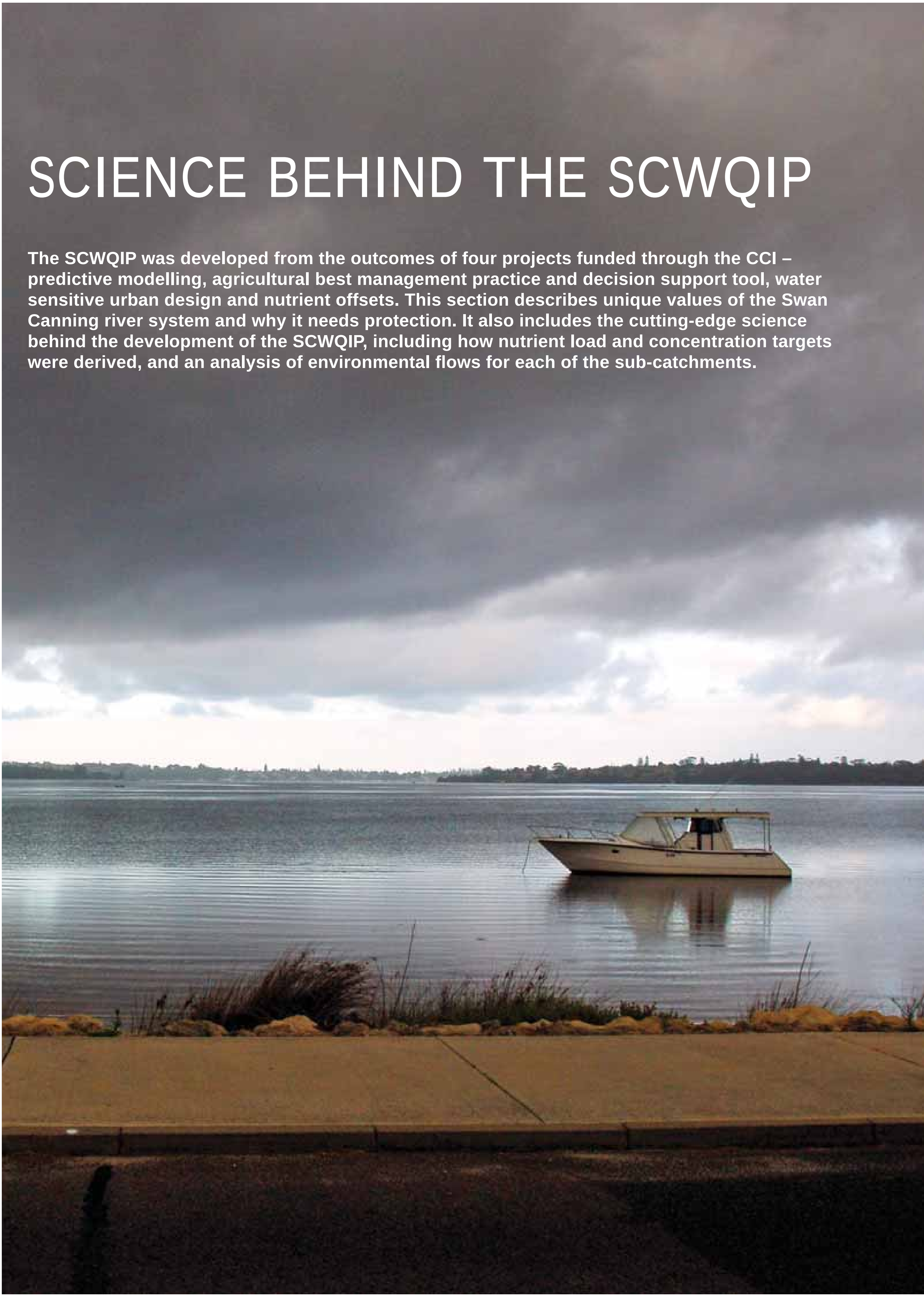
Monitoring and evaluating the effectiveness of management measures implemented through the SCWQIP is important to adaptive management.

Key inputs to the adaptive management process include:

- ground-truthing predictive modelling of the sub-catchments;
- updating water quality targets in accordance with the target review occurring through the development of the Swan River Trust River Protection Strategy;
- reviewing and expanding the current water quality monitoring program, compliant with the standards of the *National Water Quality Management Strategy*;
- measuring nitrogen and phosphorus speciation;
- updating the predictive modelling load targets as more data becomes available; and
- capturing changes in land use in the sub-catchments.

SCIENCE BEHIND THE SCWQIP

The SCWQIP was developed from the outcomes of four projects funded through the CCI – predictive modelling, agricultural best management practice and decision support tool, water sensitive urban design and nutrient offsets. This section describes unique values of the Swan Canning river system and why it needs protection. It also includes the cutting-edge science behind the development of the SCWQIP, including how nutrient load and concentration targets were derived, and an analysis of environmental flows for each of the sub-catchments.



5. Swan Canning Catchment characteristics, values and pressures

5.1 Swan Canning river system

The Swan Canning Catchment comprises 2090 square kilometres of total catchment area in the Swan Avon system of approximately 126,000 square kilometres. The Swan and Canning rivers flow through the metropolitan area of Perth, a city of more than 1.5 million people. The Swan River stretches 72 kilometres from Fremantle to Walyunga National Park where it meets the Avon River. The Canning River is 110 kilometres long and extends from Applecross through Armadale towards Wandering. The major tributaries are the Helena (Swan) and Southern River (Canning).

There are 31 major sub-catchments in the Swan Canning river system (Figure 27). The hydrology, including drainage patterns, of each of these sub-catchments is influenced by local climate and catchment characteristics, such as land formation and soil type.

The Swan Coastal Plain is the dominant land form around Perth. The soils of the Swan Coastal Plain are more than 100,000 years old. During this time much of the original sediment has been highly leached and the surface sediments now consist mainly of sand with poor nutrient-binding abilities (Figure 28). The coastal plain is quite flat and therefore its watercourses flow relatively slowly.

The lower reaches of the Swan and Canning rivers form an estuary. Open, slow-moving and shallow river conditions, together with long hot summers and soils with poor nutrient-binding properties, provide an ideal environment for plant growth (including seagrass) and make the river system naturally susceptible to algal blooms.

5.2 Land Use

5.2.1 Historic land use

Nyoongar History. In Nyoongar language the lower Swan River is called “Derbal Yaragan” which means “Turtle Estuary”. The Nyoongar people inhabited the area surrounding the Derbal Yaragan for approximately 25,000 years before the arrival of settlers from other countries in 1829. The Nyoongar people held a deep sense of respect and kinship towards the rivers and land. Their lives and culture were interdependent, based on ensuring their local environment and ecology remained healthy. The area was abundant in wildlife, fish and natural resources sustaining the local Aboriginal people. Sites along the rivers were used extensively by the Nyoongar people as places where they camped, hunted, gathered and traded with other tribes. The people had a stewardship and spiritual connection with the land and rivers and followed sustainable practices – not taking more than was required and being aware of the life patterns of the species they hunted so species remained in a healthy balance.

European Settlement. After European settlement in 1829 widespread clearing of vegetation for development and agriculture began. Wetlands and other valuable habitats were lost in this process, and nutrient runoff and fertilisers from farmlands began to affect the rivers. The construction of dams and weirs, urban development, riverbank clearing, and changes to the watercourses began to alter the state and health of the rivers in a relatively short period of time.

Recent History. In recent years Perth’s economic boom has resulted in a sharp population increase with greater development pressure on the catchment. More people are using the rivers for a greater variety of recreational pastimes, and fishing activities have

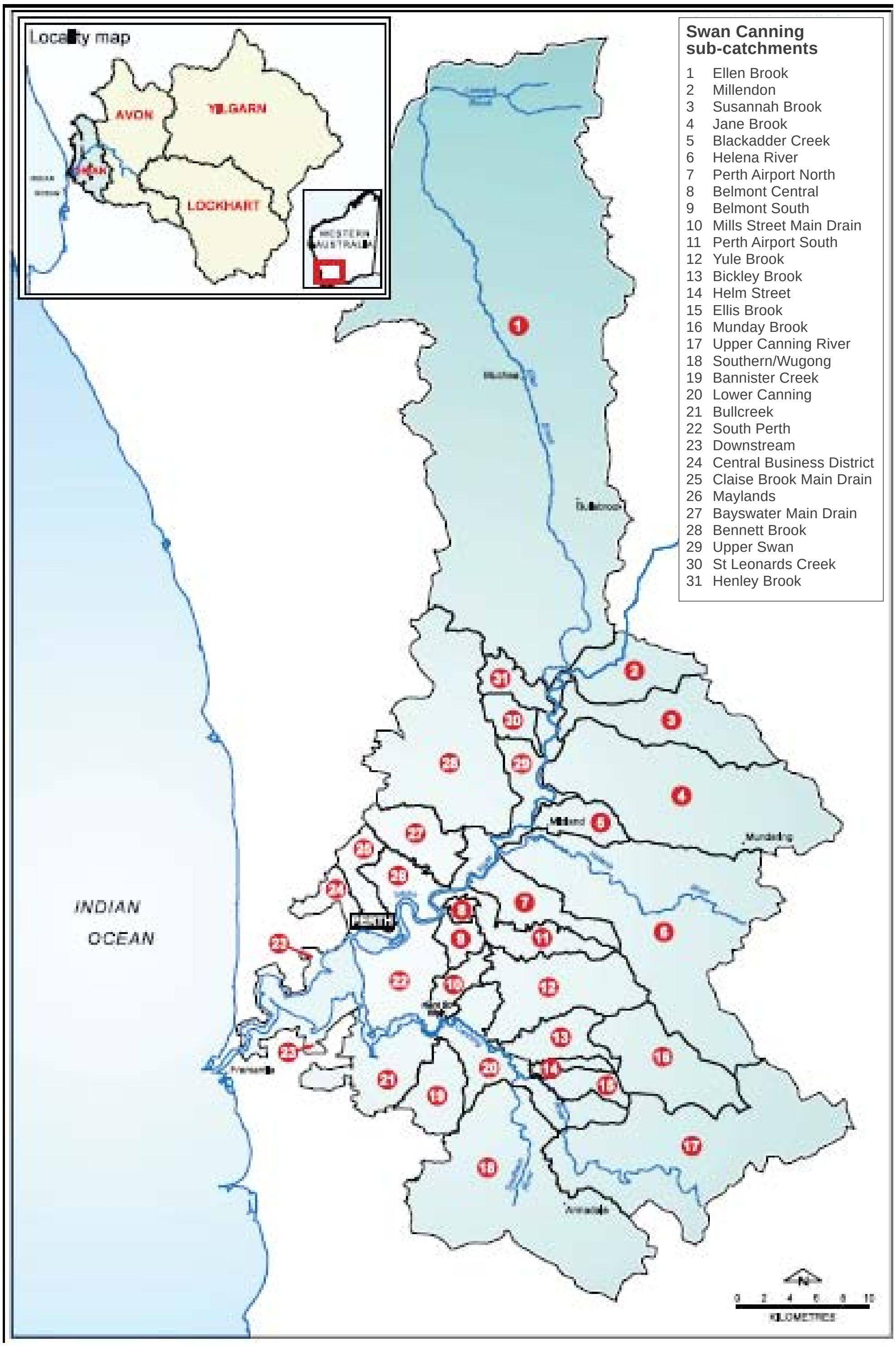


Figure 27 Swan Canning sub-catchments (Swan River Trust 2008b)

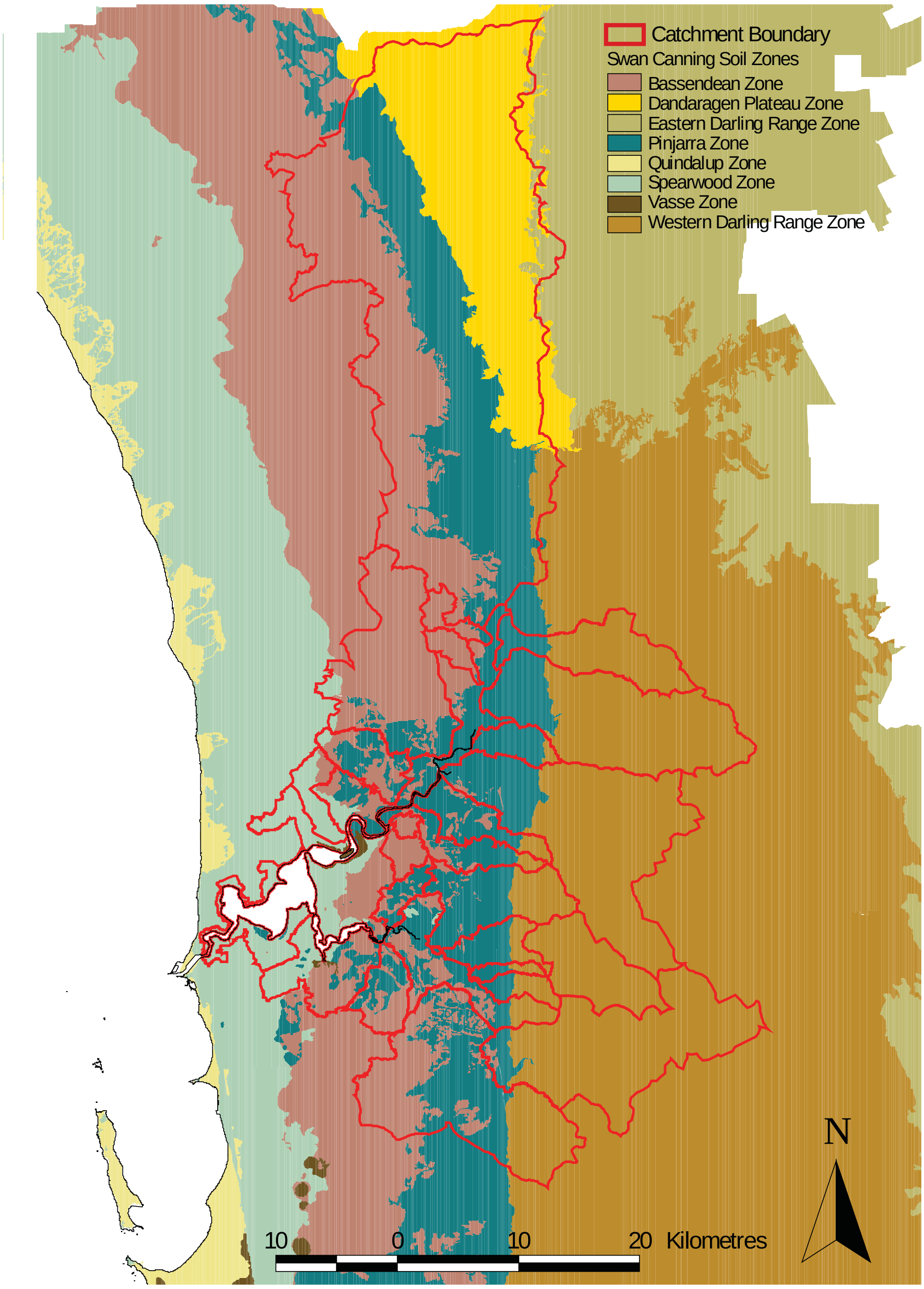


Figure 28 Soils in the Swan Canning sub-catchments

further exacerbated pressure on the rivers' health and ecology. The extent to which the catchment and rivers have been altered since 1829 means that careful management is now required (Sustainable Development Facilitation 2008).

5.2.2 Current land use

The single biggest land use in the Swan Canning Catchment is conservation and natural uses, comprising 44% of the total area, due to large areas of State forest and national parks. Other major land uses include farming (16%), industry/manufacturing (13%), and residential (10%) (Figure 29). Land use varies greatly between each of the 31 sub-catchments. In particular, land use in the peri-urban catchments is likely to be highly altered during the next 10 years with predicted urban expansion (Appendix 1).

Ellen Brook is the largest sub-catchment in the Swan Canning Catchment, comprising 34% (715 km^2) of the total catchment area. The dominant land use in Ellen Brook exporting high levels of nutrient is farming (cattle for beef). Activities in this sub-catchment have great influence on the Swan Canning river system and the management of nutrient export from Ellen Brook is identified separately in the SCWQIP.

5.2.3 Future land use

The population of Perth is growing rapidly, with the existing size of 1.5 million residents anticipated to increase to 2.5 million by 2026, doubling to 3 million in 50 years (Australian Bureau of Statistics, 2008). This is likely to have a significant effect on the condition of the Swan and Canning rivers, increasing pressures on the system. Land use will alter throughout the catchment, with residential land use likely to become dominant.

Climate change will also impact on the future land use in the Swan Canning river system. Climate change predictions suggest the Swan Canning river system will experience:

- continued increases in atmospheric and water temperatures;
- an acceleration in sea and estuary water level rise;
- decreases in winter rainfall and streamflow;
- decreases in groundwater levels and consequent flows to drains and streams; and
- increases in warm spells and heat wave frequency (Swan River Trust, 2007); and
- decreased flushing of the estuary due to decreased catchment flows (M.Robb, pers comm. 2009)

These will cause changes to the ecology, social and economic values in the Swan Canning river system, as well as reducing the influence of the Avon Catchment on the Swan River with reduced flow.

5.3 Environmental values of the Swan Canning river system and Ellen Brook

Protecting the environmental values of coastal water bodies is fundamental to their management. Environmental values include those which the local community and stakeholders want to protect and enjoy now and in the future (Australian Government, 2002).

The Swan and Canning rivers are highly valued by the community. They are considered "iconic" – an important community asset strongly valued as a key feature of Perth's recreational, social and

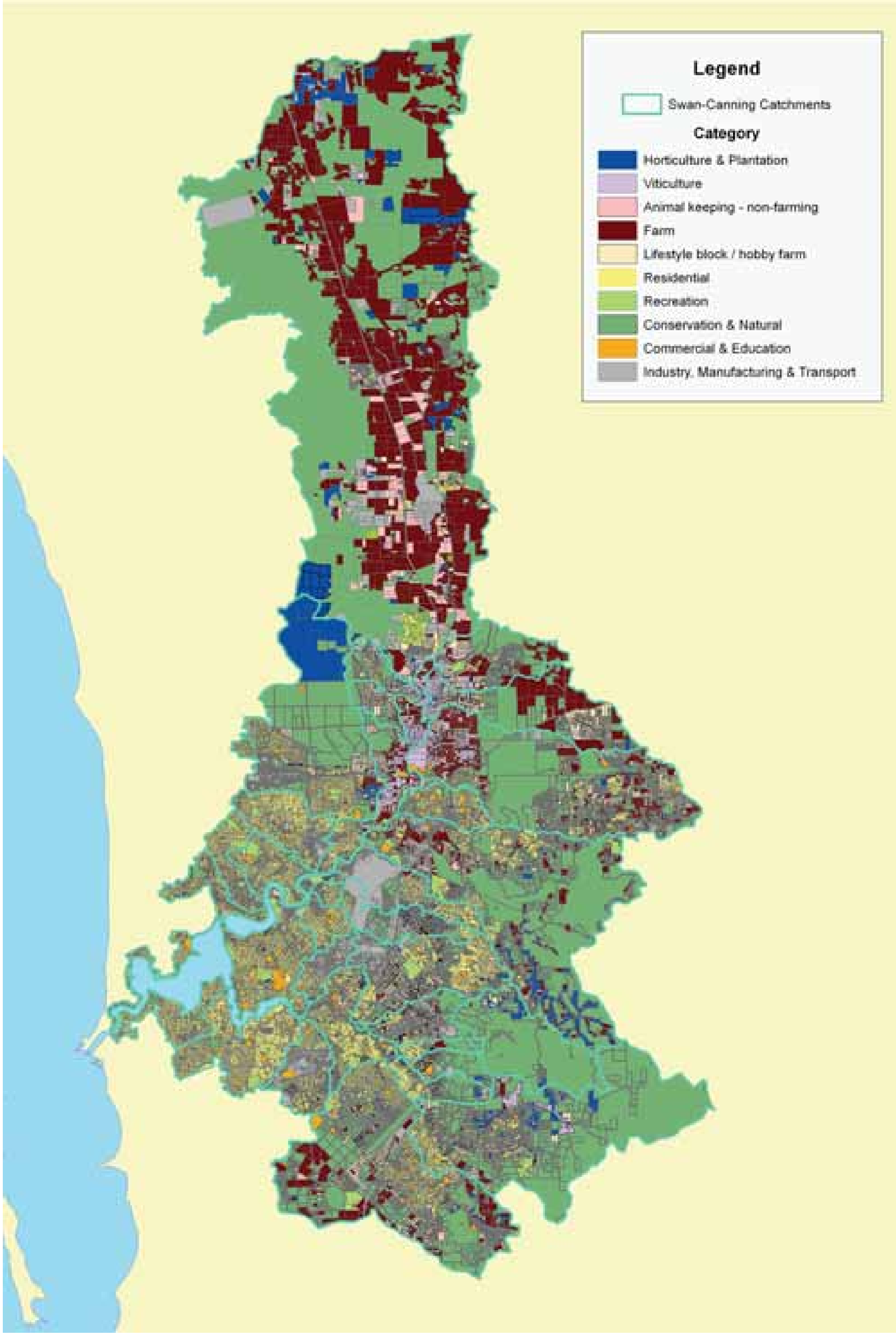


Figure 29 Land use in the Swan Canning Catchment

cultural landscape. The rivers are regarded as an intergenerational resource – a “treasure” that needs to be passed on to children and grandchildren (Swan River Trust, 2007).

Maintaining the recreational value of the Swan and Canning rivers is important to the community. They expect a standard of water quality suitable for year-round swimming, boating activities and fishing, and preferably with a significant improvement in water quality during the next 10 years (Swan River Trust, 2007).

Maintaining the recreational value includes maintaining the ecological values of the Swan and Canning rivers and their surrounds. These are also highly valued by the community for recreation, and include activities such as bird watching, fishing and passive recreation in the natural environment (Sustainable Development Facilitation, 2008). There is economic value in maintaining water quality for recreation, including ecotourism, commercial uses and real estate values.

In the rural area, the Swan Canning river system is also valued as irrigation for horticulture, industrial processing and stock drinking water. The Ellen Brook sub-catchment represents the major area of rural land use and typifies rural values in the Swan Canning Catchment. Ellen Brook is valued by the community for its rural values including stock water and irrigation. Much of the foreshore of Ellen Brook is in private ownership, and therefore less accessible to the public than the Swan and Canning rivers (Ellen Brook Management Plan, 2008).

Importantly, located in the Ellen Brook sub-catchment in the Ellen Brook Nature Reserve is one of the last wild populations of the western swamp tortoise (*Pseudemydura umbrina*). The western swamp tortoise is one of Australia’s most endangered reptiles (listed under the *Environment Protection and Biodiversity Conservation Act 1999*), with less than 200 remaining in the wild.

The Swan Canning river system and Ellen Brook have important indigenous cultural and spiritual values.

Table 9 summarises the environmental values of the Swan and Canning rivers, and Ellen Brook, consistent with the values in the *National Water Quality Management Strategy*.

Western swamp tortoise. Picture: Perth Zoo

Table 9 Environmental values of the Swan and Canning rivers and Ellen Brook

Environmental values of water	Swan and Canning rivers	Ellen Brook
Aquatic ecosystems	Maintenance of aquatic and riparian ecosystems Native fish breeding and spawning Waterbird habitat Biodiversity conservation Ecotourism Protection of Ramsar wetland located south of the Swan River at Forrestdale (and Thomsons lakes draining into the Peel Harvey Catchment)	Maintenance of aquatic and riparian ecosystems Native fish breeding and spawning Waterbird habitat Biodiversity conservation Western swamp tortoise habitat
Primary industry	Irrigation for orchards and other horticulture (Canning River) Stock drinking water Public water supply Commercial fishing for blue manna crabs	Stock drinking water Limited irrigation for orchards
Recreation and aesthetics	Swimming Recreational fishing – crabs, prawns, fish Boating – powerboats, waterskis, yachts, jet skis, kayaks, tour boats Visual amenity – foreshore recreational use including passive recreation, entertainment, commercial and retail activities, real estate value, tourism	Visual amenity
Industrial water	Processing uses e.g. cooling	
Cultural and spiritual – Indigenous	Traditional use – food source from aquatic fauna and surrounding vegetation Spiritual significance to the Nyoongar people	Traditional use – food source from aquatic fauna and surrounding vegetation Spiritual significance to the Nyoongar people
Cultural and spiritual – European	Historic significance – numerous heritage sites	Historic significance – heritage sites

Indigenous cultural and spiritual values

The Swan Region has a rich Aboriginal history deeply significant to the Nyoongar people (Swan Region Strategy, 2004). Areas of significance within Nyoongar culture include: land formations; rivers; wetlands; estuaries; freshwater pools; Aboriginal sites; biodiversity; air; water; communities; walk trails; and traditional knowledge.

The Swan Coastal Plain was traditionally an area with abundant water supplies and a variety of environmental zones providing rich resources. The area was valued by the local Nyoongar people. They hunted and gathered for many thousands of years on these resources. The Swan and Canning rivers and associated creek systems sustained traditional Nyoongar life in the area. The flow of lakes and wetlands running parallel to the coast and at the foot of the Darling Scarp were also of importance, along with many other features of the landscape. These features not only provided the economic resources on which the local Nyoongar people depended, but were also intricately linked to the Dreaming stories of ancestral beings.

Spiritual beings roamed the local and surrounding areas forming the basis of indigenous spiritual and cultural beliefs. Nyoongar people believe the *Wogarl* or Rainbow Serpent formed the river bed of the Swan River when it slid through the sand with its huge body. The Nyoongar name for the Swan River is Derbal Yaragan or Turtle Estuary. Point Walter is known as Djun'dal-up, meaning place of the long white hair.

The *Wogarl* represents a vital force of running water. The wetlands are considered of great significance to the Nyoongar people – water means life and needs to be protected (Swan Region Strategy, 2004).

In a pristine state Ellen Brook was used as a food source, with freshwater mussels and smaller fish for protein as well as bird life and eggs from the adjacent wetlands. Lake Chandala was well known to the Nyoongar people and used frequently (Ellen Brook Management Plan 2008).

6. Water quality and nutrient load targets

6.1 Health of the Swan Canning river system

The environmental condition of the Swan Canning river system varies from the Darling Scarp to the coast, and changes throughout the year. The river system has four distinctive seasonal changes in river flow, temperature and exchange with the ocean. These alter the way the rivers and estuary process nutrient input from the catchment and recycle nutrients in the system.

The Swan Canning estuarine system is considered eutrophic to hypereutrophic. Significant pressures face the Swan Canning river system including:

- excessive nutrients, organic matter and algal growth, leading to low oxygen levels, fish kills and loss of biodiversity;
- erosion of soils from catchments and banks of waterways, leading to loss of fringing vegetation, sedimentation and turbid waters, in turn contributing to eutrophication and contamination;
- alteration of water regimes – decreases and increases – resulting in a loss of biodiversity, ecosystem function, eutrophication, acidification and erosion; and
- loss/degradation of salt marsh and fringing vegetation (Swan River Trust 2008b).

The high level of nutrients is a priority environmental issue throughout the Swan Canning river system. Problems due to nutrient enrichment are exacerbated by erosion and sedimentation (as sediment particles carry nutrients), altered river flow and loss of fringing vegetation (which filters nutrients from water passing through it).

Climate change has the potential to influence the seasonal health of the system through a decrease in rainfall and winter flows, an increase in movement of marine water upstream, and an extension of the autumn period which is characterised by warm, still conditions. This can lead to less mixing, stronger stratification (layering) in the water column, low oxygen levels and increased nutrient release from sediments. These conditions favour algal blooms, and can stress aquatic organisms such as fish.

Population growth will result in increased development and recreational pressures on the rivers from activities such as fishing and boating.

The effects of climate change (reduced rainfall and river flow) and population increase will further increase the vulnerability of the river system to nutrient enrichment. As groundwater levels decrease, climate change may increase the risk of exposure of acid sulfate soils and resulting acidification, and heavy metal contamination.

Emerging environmental issues of non-nutrient contamination and acid drainage, and social issues such as fishing pressure, require further assessment.

The Swan Canning river system can be divided into a number of ecological management zones based on water quality, indicated by salinity, dissolved oxygen and nutrient levels (Figure 30).

The health of these zones is summarised below.

- **Ecosystem health:** water quality in the lower Swan/Canning Estuary is generally good; the Canning Estuary is generally fair; the middle Swan Estuary is generally poor; and the upper Swan Estuary and lower Canning River are seasonally very poor.
- **Recreation and aesthetics:** the waters of the lower Swan/Canning Estuary and Canning Estuary are generally of good quality; the middle Swan Estuary is generally of moderate quality; and the upper Swan Estuary and lower Canning River are of seasonally poor quality.

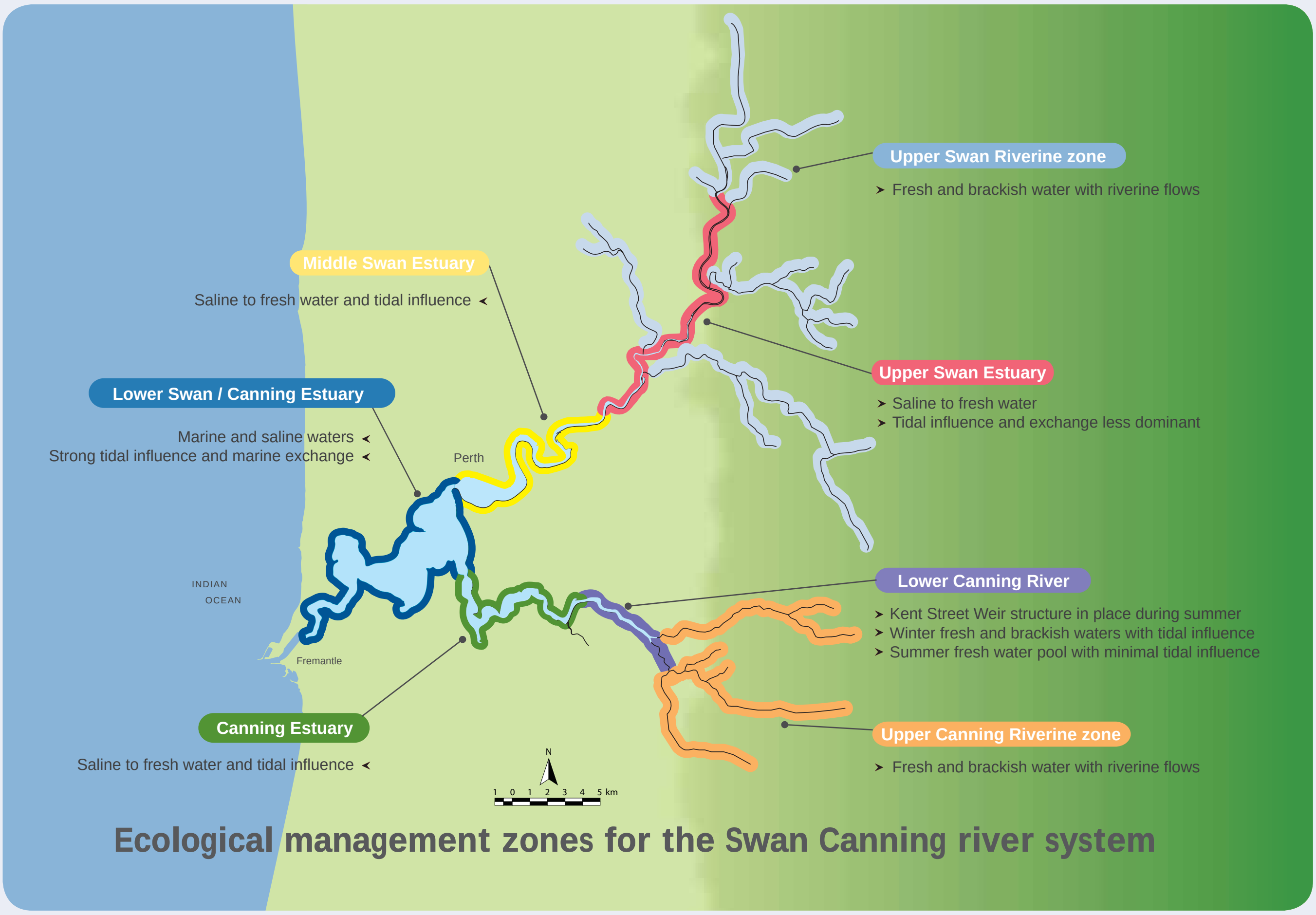


Figure 30 Ecological management zones for the Swan Canning river system

6.2 Public reporting

The Trust has an obligation to conduct annual reporting against a number of key performance indicators through the Healthy Rivers Program. Key effectiveness indicator 1 relates directly to water quality:

- the extent to which management water quality targets are achieved in the Swan Canning estuary and catchments.

The relevant effectiveness indicator is:

- total nitrogen (TN) and total phosphorus (TP) concentration in 15 tributaries of the Swan Canning Catchment compared to target levels.

In the Swan River Trust Annual Report 2008-09, compliance tables of the 15 monitored tributaries discharging into the Swan Canning river system is as follows in Tables 10 and 11.

A red cell indicates the tributary failed the short-term target in the previous year and was therefore assessed against the short-term target in the current year. Blue means the tributary had previously passed the short-term target but failed the long-term target and was therefore being assessed against the long-term target. A green cell means the tributary had passed both targets, and the data was used to make sure the tributary continued to meet the long-term target.

Table 10 Compliance of monitored tributaries discharging into the Swan Canning river system with short-term and long-term nitrogen targets

Tributary	2005	2006	2007	2008	2009
Ellen Brook					
Mills Street Main Drain					
Bannister Creek					
Bayswater Main Drain					
Southern River					
Bickley Brook					
Bennett Brook					
Yule Brook					
Blackadder Creek					
Canning River					
Helena River					
South Belmont Main Drain					
Avon River					
Susannah Brook					
Jane Brook					
Short-term target met (%)	100	100	100	93	93
Long-term target met (%)	53	53	53	53	53

Table 11 Compliance of monitored tributaries discharging into the Swan Canning river system with short-term and long-term phosphorus targets

Tributary	2005	2006	2007	2008	2009
Ellen Brook					
Mills Street Main Drain					
Southern River					
South Belmont Main Drain					
Bannister Creek					
Yule Brook					
Bayswater Main Drain					
Bickley Brook					
Blackadder Creek					
Jane Brook					
Avon River					
Bennett Brook					
Canning River					
Helena River					
Susannah Brook					
Short-term target met (%)	93	93	93	93	93
Long-term target met (%)	73	73	73	80	80

Annual reporting can be immediately applied as a monitoring tool for the SCWQIP.

Through the River Protection Strategy the use of nutrient report cards for public reporting is being reviewed. These will include measures of nitrogen and phosphorus against concentration targets and can be used for SCWQIP monitoring.

6.3 Modelled catchment condition

6.3.1 Average annual flows and loads

The 30 modelled sub-catchments and Avon River deliver nutrients to various points along the Swan and Canning rivers. The Avon River becomes the Swan River at its confluence with Wooroloo Brook in the Walyunga National Park. Using SQUARE, average annual flow and amount of nitrogen and phosphorus delivered to the various parts of the Swan Canning river system were calculated for the 30 sub-catchments (Table 12). Annual loads for the Avon River were calculated using LOESS (Table 13).

In an average year, a total of 826 tonnes of nitrogen is delivered to the Swan Canning river system –

Table 12 Average annual TN and TP loads to the Swan Canning estuary modelled from 1997-2006

Catchment	Area (km2)	Average annual discharge (ML)	Annual average TN load (T)	Annual average TP load (T)
Avon / Swan River:	123,891	253,934	575	20
Swan estuary:				
Bayswater Main Drain	27.2	8,267	9.8	0.60
Belmont Central	3.6	900	0.7	0.06
Bennett Brook	113.1	4,997	7.1	0.42
Blackadder Creek	17.1	2,993	2.5	0.17
Central Business District	13.7	2,413	5.2	0.24
Claise Brook	16.1	3,411	4.7	0.30
Downstream	26.2	5,852	6.3	0.30
Ellen Brook	716.4	26,752	71.4	10.04
Helena River	175.7	4,876	5.8	0.23
Henley Brook	12.6	681	0.8	0.05
Jane Brook	137.7	14,776	11.0	0.58
Maylands	18.7	3,726	10.9	0.30
Millendon	35.2	3,154	2.6	0.15
Perth Airport North	28.1	3,070	2.0	0.21
Perth Airport South	24.6	2,048	1.1	0.17
Saint Leonards Creek	9.8	594	1.4	0.14
South Belmont	10.5	2,427	1.7	0.24
South Perth*	27.0	9,487	8.5	1.3
Susannah Brook	54.7	6,207	4.8	0.65
Upper Swan	40.5	4,004	8.6	2.01
Subtotal	1,508	110,637	167	18.2
Canning River above Kent St weir:				
Ellis Brook	11.7	1,427	0.7	0.02
Helm Street	6.0	765	1.7	0.07
Lower Canning	44.3	6,560	7.9	0.97
Munday - Bickley	73.7	3,343	2.9	0.14
Southern River	149.5	16,037	21.3	2.21
Upper Canning	148.9	10,831	7.5	0.42
Yule Brook	55.7	7,574	7.5	0.43
Subtotal	490	46,537	49.5	4.3
Canning Estuary below Kent St weir:				
Bannister Creek	23.6	8,557	12.1	0.82
Bullcreek	42.5	14,444	11.1	1.20
Mills Street Main Drain	12.3	4,418	7.1	0.78
South Perth*	13.5	4,743	4.2	0.6
Subtotal	91.9	32,162	34.5	3.4
Subtotal (All catchments)	**2,090**	**189,336**	**251**	**26**
Total	**125,981**	**443,270**	**826**	**46**

*South Perth delivers approximately 2/3 of its flow and nutrient yield to the Swan Estuary and the remainder to the Canning Estuary

575 tonnes (70%) from the Avon and 251 tonnes (30%) from the Swan Canning sub-catchments. A total of 46 tonnes of phosphorus is delivered – 20 tonnes (43%) from the Avon and 26 tonnes (57%) from the sub-catchments. The flow volume for an average year is 443GL – 254GL (57%) from the Avon River and 189GL (43%) from the sub-catchments.

Historically it has been thought that most of the nitrogen from the Avon comes in large winter flow events and flows directly to the ocean with little impact on the estuary.

Some of the drains and smaller rural catchments of the Swan deliver large amounts of nutrients to the rivers and estuaries during summer and autumn when conditions are optimum for algal growth and neither Ellen Brook or the Avon River are flowing.

Table 13 Annual TN and TP loads from the Avon River, site 616011, from 1997-2006

Year	Annual Flow (ML)	Annual TN Load (Tonnes)	Annual TP Load (Tonnes)
1997	184,367	248	7.7
1998	196,248	257	8.0
1999	588,999	1,454	41.6
2000	576,296	2,403	95.6
2001	90,518	116	3.9
2002	87,750	84	2.5
2003	278,435	428	14.3
2004	118,509	139	4.0
2005	304,607	458	16.2
2006	113,614	161	5.5
Average	**253,934**	**575**	**20**

Table 14 Targets for median TN and TP concentration for each tributary

Catchment	Area (km2)	Impervious area (%)	Water Yield (mm)*	Summer Flow (%)	TN target conc (mg/L)	TP target conc (mg/L)
Bennett Brook	113.1	9	14	12	1.0	0.1
Helena River	175.7	5	35	2	1.0	0.1
Ellen Brook	716.4	1	38	0	1.0	0.1
Munday - Bickley	73.7	2	45	0	1.0	0.1
Henley Brook	12.6	9	54	5	1.0	0.1
Saint Leonards Creek	9.8	5	61	11	1.0	0.1
Upper Canning	148.9	3	73	7	1.0	0.1
Perth Airport South	24.6	17	82	3	1.0	0.1
Ellis Brook	11.7	2	85	1	1.0	0.1
Millendon	35.2	2	90	2	1.0	0.1
Upper Swan	40.5	27	100	12	0.75	0.075
Perth Airport North	28.1	16	101	3	0.75	0.075
Jane Brook	137.7	5	103	1	0.75	0.075
Southern River	149.5	8	106	3	0.75	0.075
Helm Street	6.0	7	113	6	0.75	0.075
Susannah Brook	54.7	3	116	0	0.75	0.075
Lower Canning	44.3	21	148	10	0.75	0.075
Blackadder Creek	17.1	21	171	3	0.75	0.075
Yule Brook	55.7	19	179	4	0.75	0.075
Maylands	18.7	24	208	17	0.5	0.05
Central Business District	13.7	28	211	17	0.5	0.05
Claise Brook	16.1	26	211	17	0.5	0.05
Downstream	26.2	25	229	18	0.5	0.05
South Belmont	10.5	28	231	17	0.5	0.05
Belmont Central	3.6	29	251	17	0.5	0.05
Mills Street Main Drain	12.3	37	278	10	0.5	0.05
Bayswater Main Drain	27.2	27	304	14	0.5	0.05
Bullcreek	42.5	25	347	11	0.5	0.05
Bannister Creek	23.6	26	361	11	0.5	0.05
South Perth	40.5	21	364	11	0.5	0.05

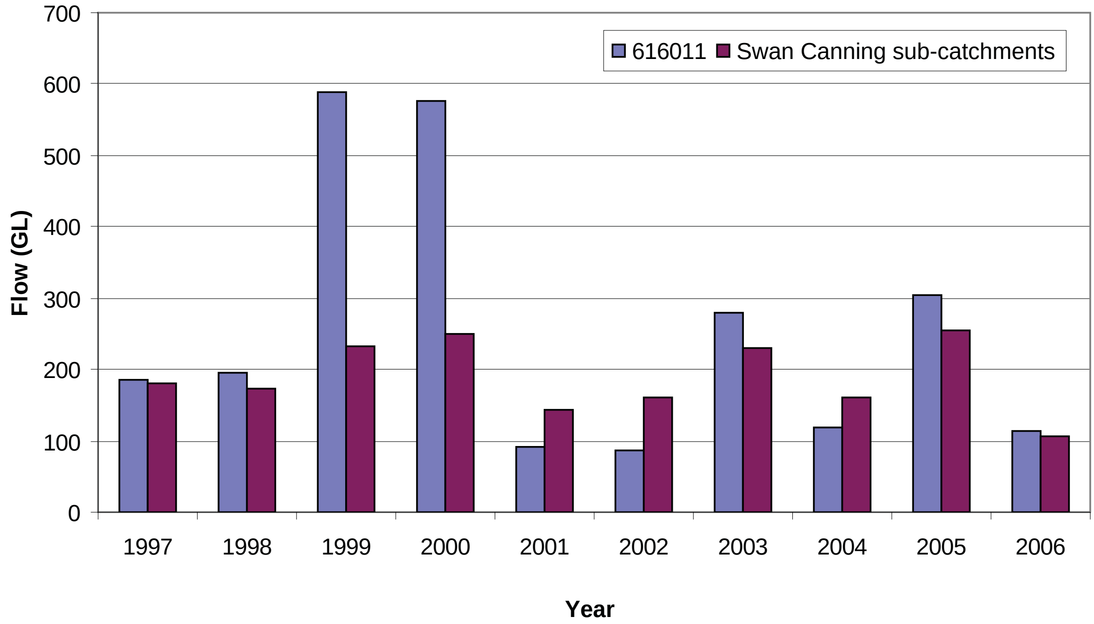


Figure 31 Annual flows (GL) from the Avon River, site 616011 and the sub-catchments

The seasonal delivery of nutrients is discussed further in Section 6.3.3. However, through modelling, the nutrient load for the Avon is found to be a significant contribution to the Swan Canning river system.

At the Kent Street weir much of the nutrient load is delivered in winter when the weir is open to the estuary. However there is sufficient nutrient delivered in spring, summer and autumn or built up in the sediments to drive algal blooms in the Kent Street weir pool. The main contributor to the Kent Street weir pool is the Southern River sub-catchment which contributes about half the nutrient load. Approximately 35 tonnes of nitrogen and 3.4 tonnes of phosphorus are delivered to the Canning Estuary below Kent Street weir each year by the Canning River.

6.3.2 Annual delivery of nutrients

The annual flows for the Avon River at site 616011 and the total for all the Swan Canning sub-catchments from 1997 to 2006 are presented in Figure 31. In years of higher rainfall the Avon tends to contribute annual flows which are greater than the flows from the sub-catchments, while in low rainfall years the Avon contributes significantly less annual flow than the sub-catchments.

The average annual flow from the Avon River was 392 GL from 1974 to 1996, whereas the average annual flow from 1997 to 2006 was 254 GL (35% less). This decrease in flow volume due to the drying climate in south-west Western Australia means the estuary will be less well flushed, more saline, and water quality will be dominated by the input from the Coastal Plain catchments. Urban drains, as well as having high nutrient loads, may also contain metals, detergents, petroleum hydrocarbons, polycyclic aromatic hydrocarbons, endocrine disrupting chemicals and other pollutants typical of the urban environment (Nice *et al* 2009).

The timing of rainfall is important. Even though the annual flow from the Avon River had about the same value for 1999 and 2000 (about 590GL) the timing of the rainfall was different. For example, in 1999 the flow from the Avon River followed its typical pattern of no flow in summer, flow commencing at the beginning of the winter rainy season, high flows in winter and dropping off towards the end of the year. In 2000 the flow was dominated by a cyclonic event in January and winter flows were similar to those of an average rainfall year such as 2003. This

SUMMER SURPRISE- The Swan River blue-green algal bloom, February 2000

Conditions that made the river green and potentially toxic.

The cause of the unusual and massive toxic blue-green algae bloom in the Swan and lower Canning rivers in February 2000 can be largely explained by two unseasonably large rain events that occurred in January 2000.

The rain that fell in early January gave much of the hinterland of the Swan Avon river system a good soaking. This resulted in the catchment being unable to absorb much more rain.

A week later, rain-laden clouds left over from Cyclone Steve came down from the north and deposited over 12 000 million tonnes, i.e 12 000 gigalitres(GL) of water on the Avon River Catchment, an area the size of Tasmania. This resulted in more than 270GL entering the estuary.

This was enough water to fill the Swan Canning rivers and estuary five and half times over. The soil was already saturated from the earlier January rain, so there was rapid and huge runoff particularly from the normally dry Lockhart sub-catchment and Yenyenning Lake system, about 200km south east of Perth, in the Avon catchment. It was the first time waterways in the Lockhart sub-catchment had flowed significantly in the summer for 40 years.

RiverSCIENCE 2, issue 2 September 2000

unusual summer flow from the Avon River in January 2000 caused a bloom of the toxic cyanobacteria (*Microcystis aeruginosa*) during which the the Swan river estuary was closed to recreation and fishing.

6.3.3 Seasonal delivery of nutrients

A regular cycle of algal growth occurs in the Swan Canning river system every year – usually from spring to autumn. The succession pattern of the blooms is affected by the timing of flows and nutrient input, sediment nutrient release and changes in salinity. Blooms of different species can occur concurrently. Figure 32 displays the general succession pattern for algal blooms in the Swan Canning river system.

The impervious urban catchments have significant flows in summer when the Avon River, Ellen Brook and several of the other rural catchments have no or small flow volumes (Table 14). As the conditions in summer and autumn are often favourable for algal blooms, decreasing the nutrient input from the urban impervious catchments in this period may significantly improve the health of the Swan Canning river system. Identifying and managing the sources of nutrients is an important component of this process.

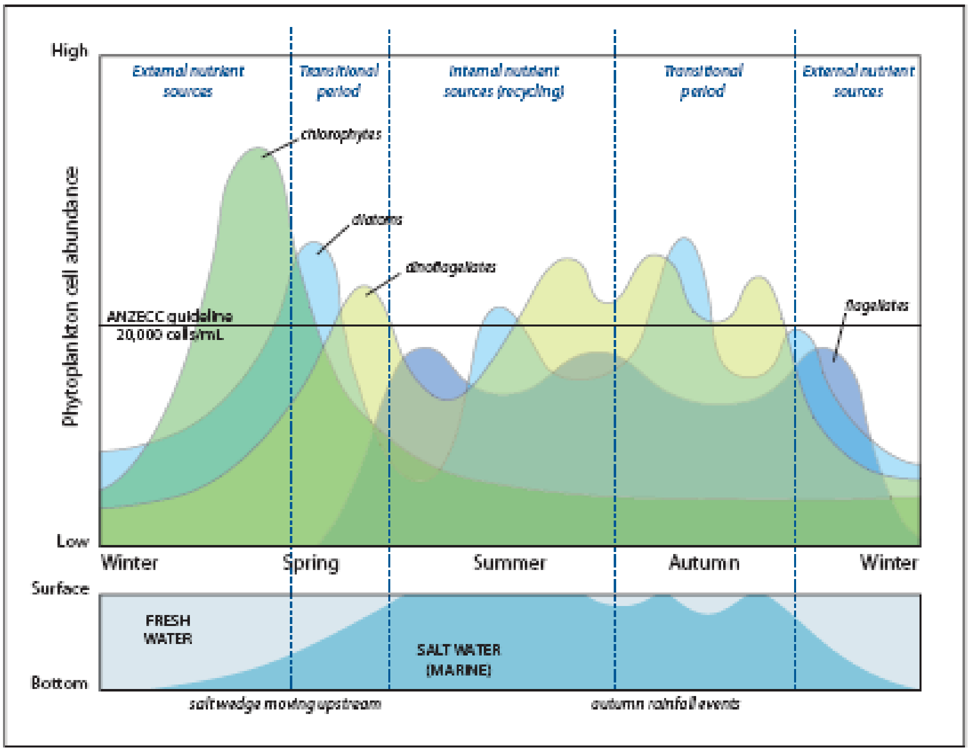


Figure 32 Phytoplankton in the Swan Canning river system. (Note the vertical scale is arbitrary. Peaks in abundance are many times higher than background numbers. River Science 3)

7. Nutrient sources

SQUARE modelling of the sub-catchments shows the input of nutrients to the Swan Canning river system is very diverse, geographically and by source. Nutrients come mainly from diffuse sources, which requires a holistic management approach.

7.1 Nutrient loads by sub-catchment

The average annual loads and average annual loads per unit area (yields) of TN and TP for the Avon River and sub-catchments are listed in Table 15. The TN and TP loads from the sub-catchments are displayed below and TN and TP loads per cleared catchment area are displayed in figures 33 and 34.

In some cases (e.g. Ellen Brook) high loads are the result of the large area of the sub-catchment. The figures show which sub-catchments contribute large nutrient inputs relative to their size.

Cleared area is used to normalise the catchment exports because it gives a better indication of the intensity of nutrient exports from developed land compared to normalisation by total catchment area alone.

The Swan Canning sub-catchment with the greatest modelled nutrient export is Ellen Brook, exporting an average annual load of 71 tonnes TN and 10 tonnes TP to the Swan River from 1997-2006. This is the sub-catchment of greatest area, being 34% of the total area of the Swan Canning Catchment.

The sub-catchments with the highest modelled yields per unit area are Mills Street Main Drain for TP (64 kg/km^2) and Maylands (582 kg/km^2) for TN. These sub-catchments have the most intensive land uses.

The yields of TN and TP for the Avon Catchment are much less than the Swan Canning sub-catchments, with a total average annual load of 5kg/km^2 TN and 0.2kg/km^2 TP.

Table 15 Average annual flow, TN and TP loads and yields modelled for the Avon River and Swan Canning sub-catchments

Catchment	Area (km^2)	Average annual discharge (ML)	Average annual TN load (T)	Average annual TN yield (kg/km^2)	Average annual TP load (T)	Average annual TP yield (kg/km^2)
Avon	123,891	253,934	575	5	20	0.16
Bannister Creek	23.6	8,557	12.1	513	0.82	35
Bayswater Main Drain	27.2	8,267	9.8	360	0.60	22
Belmont Central	3.6	900	0.7	198	0.06	17
Bennett Brook	113.1	4,997	7.1	63	0.42	3.7
Blackadder Creek	17.1	2,993	2.5	147	0.17	10
Bullcreek	42.5	14,444	11.1	261	1.20	28
Central Business District	13.7	2,413	5.2	380	0.24	18
Claise Brook	16.1	3,411	4.7	288	0.30	19
Downstream	26.2	5,852	6.3	241	0.30	11
Ellen Brook	716.4	26,752	71.4	100	10.04	14
Ellis Brook	11.7	1,427	0.7	60	0.02	1.7
Helena River	175.7	4,876	5.8	33	0.23	1.3
Helm Street	6.0	765	1.7	283	0.07	12
Henley Brook	12.6	681	0.8	64	0.05	4.0
Jane Brook	137.7	14,776	11.0	80	0.58	4.2
Lower Canning	44.3	6,560	7.9	178	0.97	22
Maylands	18.7	3,726	10.9	582	0.30	16
Mills Street Main Drain	12.3	4,418	7.1	579	0.78	64
Millendon	35.2	3,154	2.6	74	0.15	4.3
Munday - Bickley	73.7	3,343	2.9	39	0.14	1.9
Perth Airport North	28.1	3,070	2.0	71	0.21	7.5
Perth Airport South	24.6	2,048	1.1	45	0.17	6.9
Saint Leonards Creek	9.8	594	1.4	143	0.14	14
South Belmont	10.5	2,427	1.7	161	0.24	23
South Perth	40.5	14,230	12.7	314	1.94	48
Southern River	149.5	16,037	21.3	142	2.21	15
Susannah Brook	54.7	6,207	4.8	88	0.65	12
Upper Canning	148.9	10,831	7.5	50	0.42	2.8
Upper Swan	40.5	4,004	8.6	212	2.01	50
Yule Brook	55.7	7,574	7.5	135	0.43	7.7
All Swan Canning sub-catchments	2,090	189,336	251	120	26	12

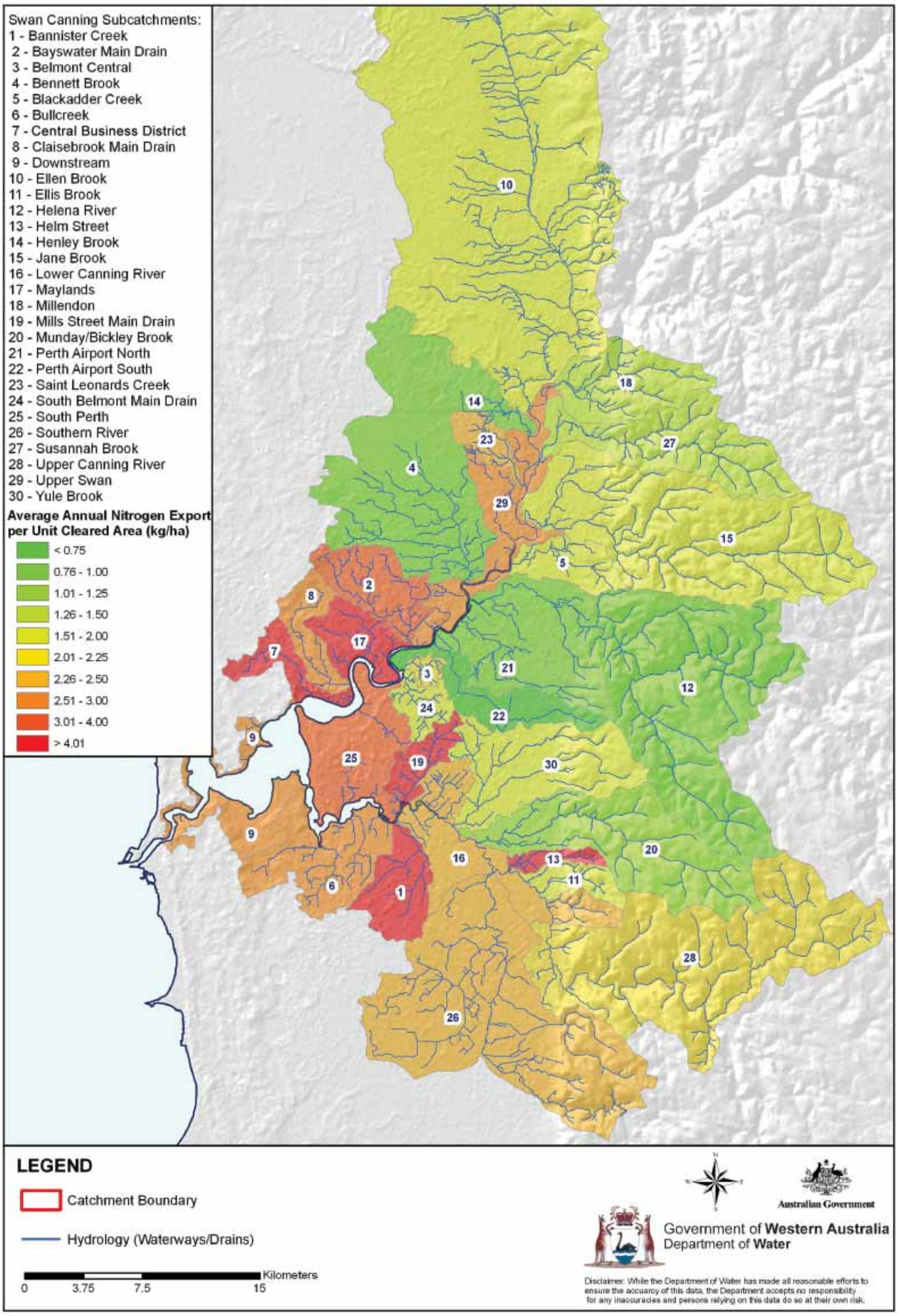


Figure 33 Average annual TN export per unit cleared catchment area (kg/ha) for the Swan Canning sub-catchments

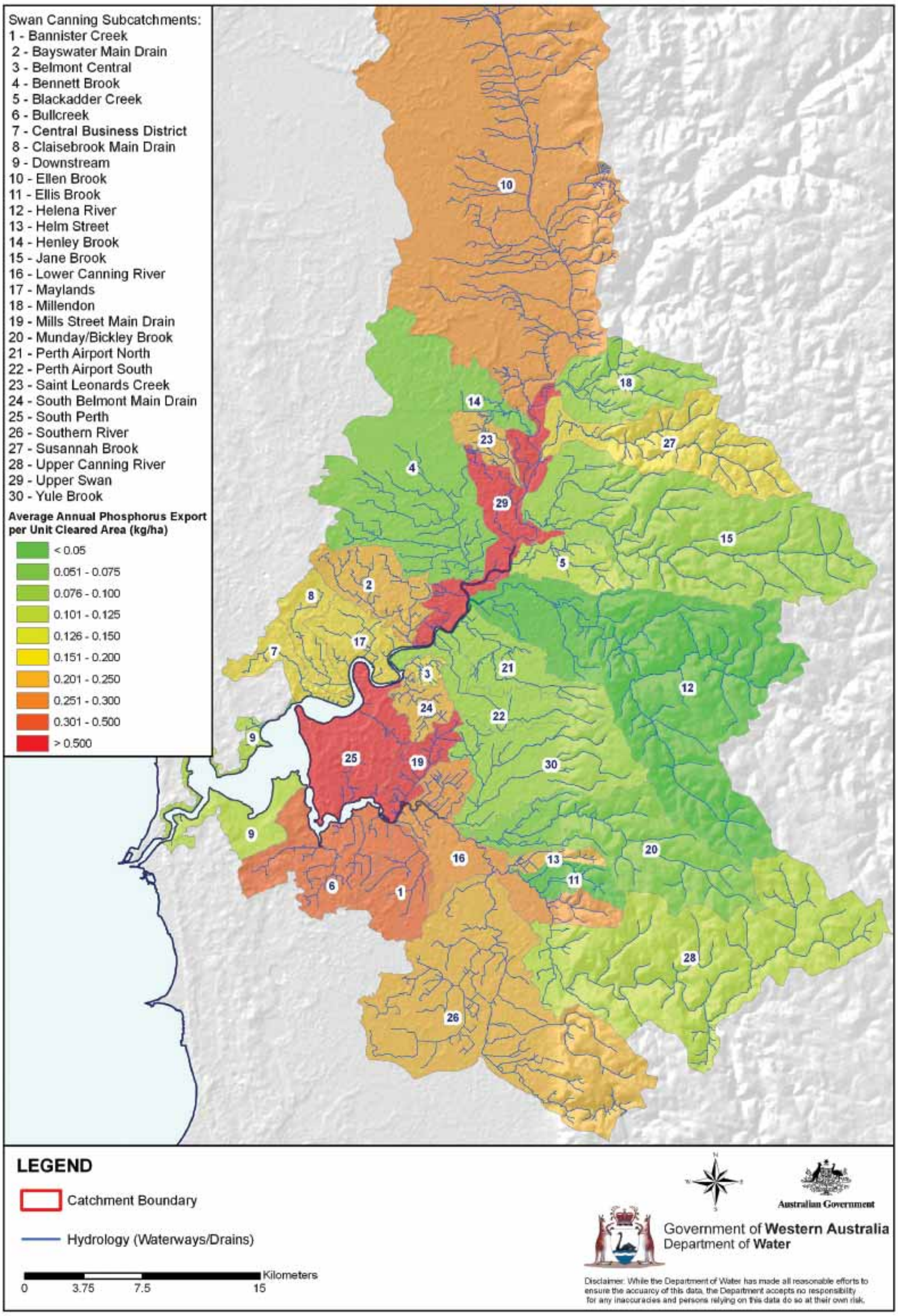


Figure 34 Average annual TP export per unit cleared catchment area (kg/ha) for the Swan Canning sub-catchments

7.2 Nutrient export by land use (source separation)

The modelled distribution of nutrient sources in the Swan Canning Catchment is closely linked to land use. Nutrient contribution varies greatly between land uses in the Swan Canning sub-catchments.

The SQUARE modelling groups land uses into 10 categories for reporting purposes, based on similarities. Table 16 and Figure 35 contain the areas of each land use and their TN and TP export for the Swan Canning Catchment. Appendix 1 presents tables and nutrient source separations for each sub-catchment.

While recognising the contribution of nutrients from the Avon, identifying nutrient sources in the Avon Catchment is not addressed in this plan but identified as a future research requirement.

Table 16 Land use areas and TN and TP exports modelled for the Swan Canning sub-catchments

Land Use	Area (km^2)	TN		TP	
		Export (tonnes)	Percent	Export (tonnes)	Percent
Residential	214	65.7	29%	5.59	22%
Horticulture & plantation	86	12.3	6%	1.81	7.0%
Recreation	50	32.1	14%	2.98	11.5%
Viticulture	23	0.9	0%	0.92	3.6%
Horses, kennels, catteries	37	14.5	6%	2.10	8.1%
Farm	339	58.6	17%	8.43	32.7%
Lifestyle block/ hobby farm	104	7.9	4%	0.29	1.1%
Offices, commercial & education	40	5.2	2%	0.70	2.7%
Conservation & natural	924	7.5	1%	0.00	0.0%
Industry, manufacturing & transport	273	3.1	1%	0.61	2.4%
Point sources		3.9	2%	0.29	1.1%
Septic		39.2	18%	2.10	8.1%
Total	**2,090**	**251**	100%	**26**	**100%**

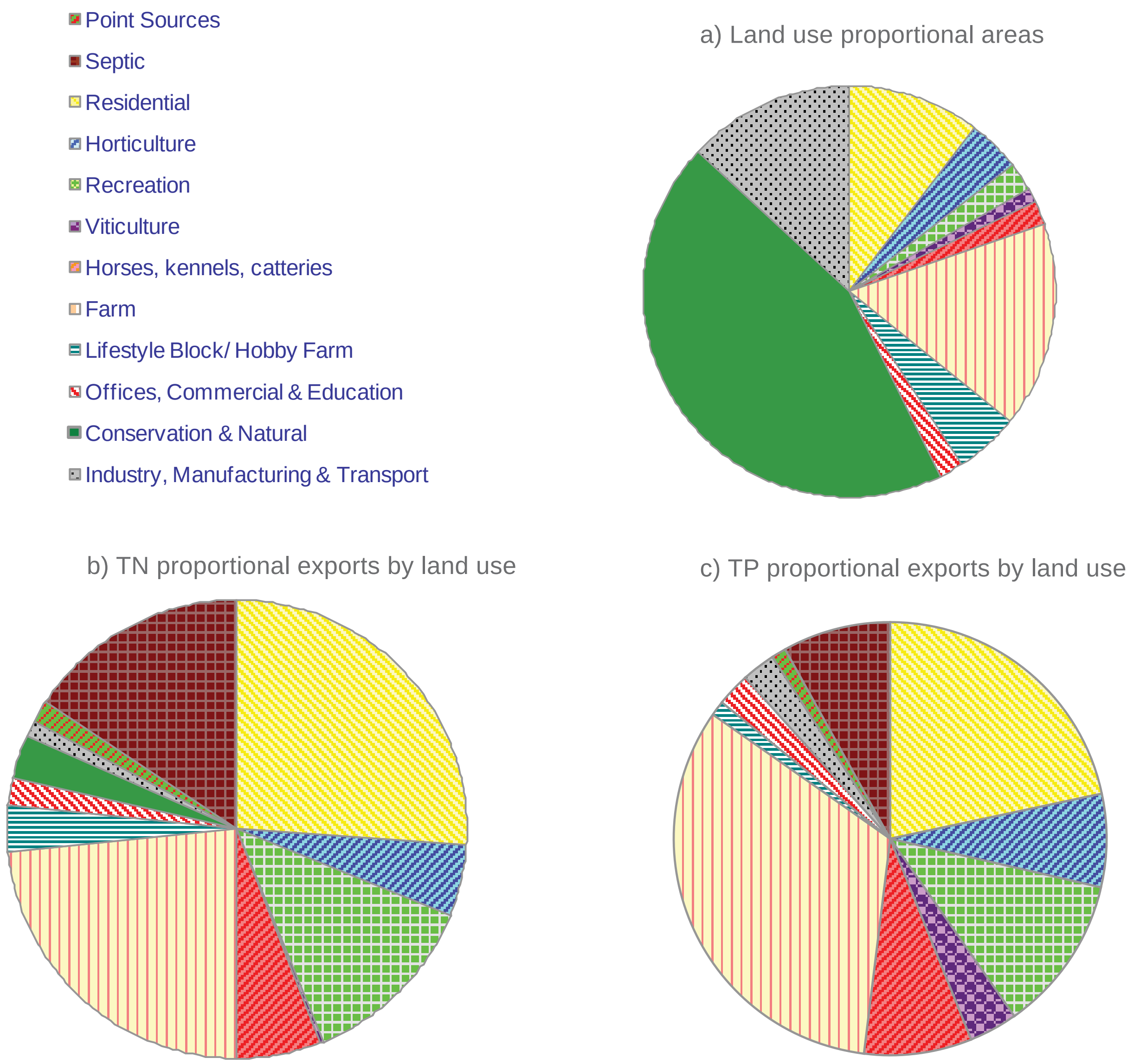


Figure 35 Nutrient source separation modelled for the Swan Canning sub-catchments

A description of each of the nutrient sources follows.

Farming

Farming is the greatest contributor to phosphorus input at 33% of the modelled load. The export rates of nitrogen are also high at 17% TN, which is related to the amount of area under farming. Farming activities include areas under commercial crops or pasture of area greater than 20234m^2 and predominantly occur in the Ellen Brook sub-catchment.

Residential

Residential sources have been modelled to be the largest contributors of nitrogen at 29%, but also contribute 22% TP. The size of the residential area in the Swan Canning Catchment is expanding rapidly and contribution of nutrients from this source is likely to increase.

The heavily urbanised catchments were found by the model to be those contributing the most nutrients from residential sources. Initial results from the urban nutrient survey (Kitsios & Kelsey, in preparation) identified the rate of fertilisation for these areas was independent of block size as there was a range of fertilisation rates at any one block size.

Recreational areas and turf

Modelling recreational areas and turf showed they contribute 14% nitrogen input and 12% phosphorus input. The recreational areas include a variety of grassed public open space facilities, caravan and camping sites. Turf includes those areas that are well watered and fertilised, for example grass tennis courts, bowling greens, golf courses, race courses and sports ovals.

The nutrient export from this land use is high in the urban areas of the Swan Canning Catchment.

Septic tanks

Septic tanks contribute 18% modelled nitrogen and 8% modelled phosphorus. Figure 36 identifies the location of septic tanks throughout the Swan Canning Catchment. This includes industrial areas and sites that have deep sewerage available but have not connected.

Horticulture/plantation

Horticultural land uses have high fertilisation rates but as their area is relatively small they have been modelled to only contribute 6% nitrogen input and 7% phosphorus input to the Swan Canning river system. Horticulture and plantations include orchards, floriculture and pine plantations and generally occur around the outer margins of the Swan Canning Catchment.

Horses, kennels, catteries

Horses contribute 6% nitrogen input and 8% modelled phosphorus input. The source of phosphorus occurs from the locally concentrated animal waste associated with this activity. This land use includes all intensive livestock industries (kennels, catteries and horse stables) but excludes farm livestock.

Lifestyle blocks/hobby farms

Lifestyle blocks and hobby farms contribute 4% modelled TN and 1% TP. These areas are often unsewered and include localised nutrient loads from tethered livestock. They are defined as large blocks greater than 4046m^2, typically cleared of native vegetation, with minor farming activities.

Point sources

The modelling estimates point sources contribute approximately 2% nitrogen input and 1% phosphorus input to the Swan Canning river system. However data on emissions from point sources of nutrient pollution are difficult to obtain and the only point sources included in the model were those in the National Pollutant Inventory database. Further investigation of nutrient exports from point sources on the Swan Coastal Plain is recommended, particularly for historic landfill and liquid waste disposal sites.

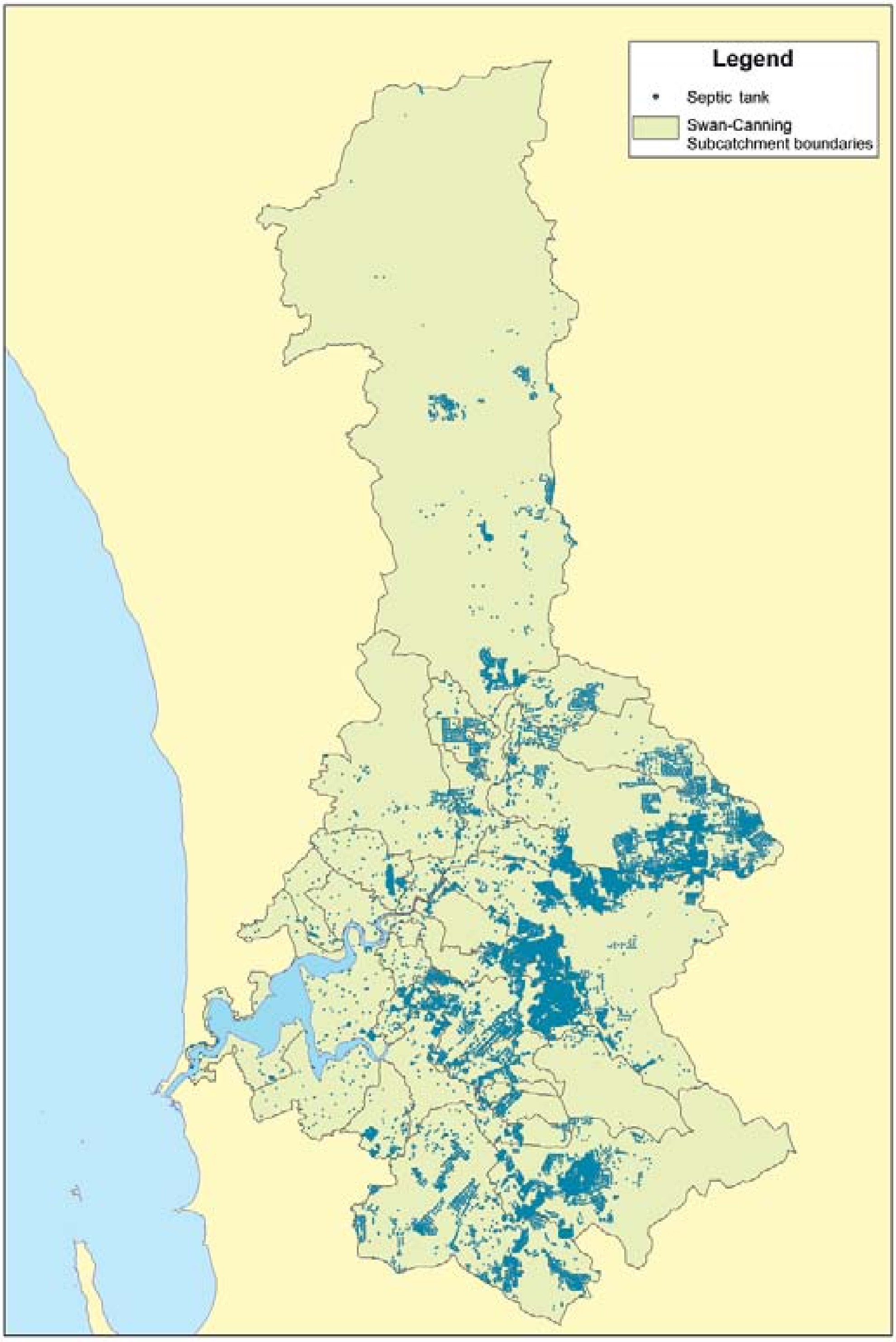


Figure 36 Septic tanks in the Swan Canning Catchment

Other nutrient sources

There are a number of other sources of nutrients contributing to loads in the Swan and Canning rivers. These are important on a sub-catchment level and the required management approach is local.

Modelling data confirms natural land uses constitute a large area of the coastal catchment (44%) but output from these areas is estimated to be small – less than 0.1% phosphorus and nitrogen.

7.3 Load reduction targets

Nutrient load measures the total weight of a particular nutrient delivered to or by a waterway during a given period, and is a function of nutrient concentration and flow.

Through the SQUARE modelling, load reduction targets for TN and TP have been set for each of the Swan Canning sub-catchments.

The load reduction target is equal to the current annual load minus the maximum acceptable load.

Streams meeting their concentration targets have a load reduction target of zero.

The TN and TP current loads, load reduction targets and maximum acceptable loads are presented in Tables 17 and 18 and Figures 37 - 40.

The load reduction targets will be used to guide management actions and the effect of various management actions are given in terms of loads. The necessary scale of catchment remediation will be determined by the load reduction targets.

The load targets have been derived using the climate sequence from 1997-2006. The loads, and load targets would be different if deduced for a different period (i.e. different climate sequence) because of the dependence of load on rainfall. This needs to be considered when modelling future management options, because of the drying climate in Western Australia. It must also be taken into consideration when assessing compliance to management targets.

Table 17 Modelled TN current loads, load reduction targets and maximum acceptable loads

Nitrogen						
Catchment	Current load (1997-2006) tonnes/year	Load reduction target tonnes/year	Maximum acceptable load tonnes/year	Current winter median conc mg/L	Target winter median conc mg/L	% reduction
Bannister Creek	12.1	8.2	3.9	1.51	0.50	68%
Bayswater Main Drain	9.8	5.8	4.0	1.22	0.50	59%
Belmont Central	0.7	0.4	0.3	0.92	0.50	58%
Bennett Brook	7.1	2.3	4.8	1.46	1.00	32%
Blackadder Creek	2.5	0.4	2.1	0.91	0.75	16%
Bullcreek	11.1	6.2	4.9	1.07	0.50	56%
Central Business District	5.2	3.5	1.7	1.60	0.50	67%
Claise Brook	4.7	3.4	1.3	1.70	0.50	72%
Downstream	6.3	2.8	3.5	1.20	0.50	44%
Ellen Brook	71.4	49.3	22.1	2.73	1.00	69%
Ellis Brook	0.7	0.0	0.7	0.46	1.00	0%
Helena River	5.8	2.2	3.6	1.20	1.00	38%
Helm Street	1.7	1.2	0.5	2.34	0.75	71%
Henley Brook	0.8	0.2	0.6	1.63	1.00	25%
Jane Brook	11.0	0.0	11.0	0.71	0.75	0%
Lower Canning	7.9	5.4	2.5	2.30	0.75	68%
Maylands	10.9	5.8	5.1	1.89	0.50	53%
Mills Street Main Drain	7.1	4.5	2.6	1.56	0.50	63%
Millendon	2.6	0.0	2.6	0.85	1.00	0%
Munday - Bickley	2.9	0.6	2.3	1.43	1.00	21%
Perth Airport North	2.0	0.7	1.3	1.01	0.75	35%
Perth Airport South	1.1	0.0	1.1	0.65	1.00	0%
Saint Leonards Creek	1.4	0.9	0.5	2.70	1.00	64%
South Belmont	1.7	0.7	1.0	0.83	0.50	41%
South Perth	12.7	3.9	8.8	0.82	0.50	31%
Southern River	21.3	9.9	11.4	1.32	0.75	46%
Susannah Brook	4.8	0.0	4.8	0.74	0.75	0%
Upper Canning	7.5	0.0	7.5	0.72	1.00	0%
Upper Swan	8.6	1.9	6.7	1.68	0.75	22%
Yule Brook	7.5	1.9	5.6	1.06	0.75	25%
TOTAL	251	122	129			49%

The current total nitrogen load from the 30 sub-catchments to the Swan Canning river system is 251 tonnes. There are 24 catchments that do not meet the median concentration targets for TN, although 49 tonnes of the required TN reduction is for the Ellen Brook sub-catchment. The catchments that meet the targets for TN are Ellis, Jane, Millendon, Perth Airport South, Susannah and Upper Canning. These catchments have only small areas of residential urban land use.

The current total phosphorus load from the 30 sub-catchments to the Swan Canning river system is 26 tonnes. Only 13 of the 30 sub-catchments exceed the median concentration targets for TP. The catchments which require phosphorus load reductions are generally those with low phosphorus-retaining soils and intensive land uses such as Ellen Brook, St Leonards Brook and Southern River catchments. Ellen Brook requires a phosphorus load reduction of 7.9 tonnes which is 79% of the total load reduction for all the sub-catchments. Southern River, which requires a 1.1 tonne TP load reduction, is responsible for about half of the nutrient input to Kent Street weir pool.

Table 18 Modelled TP current loads, load reduction targets and maximum acceptable loads

Phosphorus						
Catchment	Current load (1997-2006) tonnes/year	Load reduction target tonnes/year	Maximum acceptable load tonnes/year	Current winter median conc mg/L	Target winter median conc mg/L	% reduction
Bannister Creek	0.82	0.27	0.55	0.080	0.050	33%
Bayswater Main Drain	0.60	0.16	0.44	0.060	0.050	27%
Belmont Central	0.06	0.02	0.04	0.060	0.050	33%
Bennett Brook	0.42	0.00	0.42	0.050	0.100	0%
Blackadder Creek	0.17	0.00	0.17	0.040	0.075	0%
Bullcreek	1.20	0.19	1.01	0.060	0.050	16%
Central Business District	0.24	0.03	0.21	0.060	0.050	13%
Claise Brook	0.30	0.00	0.30	0.060	0.050	0%
Downstream	0.30	0.00	0.30	0.050	0.050	0%
Ellen Brook	10.04	7.91	2.13	0.460	0.100	79%
Ellis Brook	0.02	0.00	0.02	0.020	0.100	0%
Helena River	0.23	0.00	0.23	0.020	0.100	0%
Helm Street	0.07	0.03	0.04	0.110	0.075	43%
Henley Brook	0.05	0.00	0.05	0.120	0.100	0%
Jane Brook	0.58	0.00	0.58	0.020	0.075	0%
Lower Canning	0.97	0.57	0.40	1.900	0.075	59%
Maylands	0.30	0.00	0.30	0.040	0.050	0%
Mills Street Main Drain	0.78	0.50	0.28	0.140	0.050	64%
Millendon	0.15	0.00	0.15	0.020	0.100	0%
Munday - Bickley	0.14	0.00	0.14	0.040	0.100	0%
Perth Airport North	0.21	0.00	0.21	0.040	0.075	0%
Perth Airport South	0.17	0.00	0.17	0.030	0.100	0%
Saint Leonards Creek	0.14	0.04	0.10	0.110	0.100	29%
South Belmont	0.24	0.11	0.13	0.100	0.050	46%
South Perth	1.94	0.18	1.76	0.060	0.050	9%
Southern River	2.21	1.06	1.15	0.140	0.075	48%
Susannah Brook	0.65	0.00	0.65	0.020	0.075	0%
Upper Canning	0.42	0.00	0.42	0.030	0.100	0%
Upper Swan	2.01	0.00	2.01	0.070	0.075	0%
Yule Brook	0.43	0.00	0.43	0.070	0.075	0%
TOTAL	25.9	11.1	14.8			43%

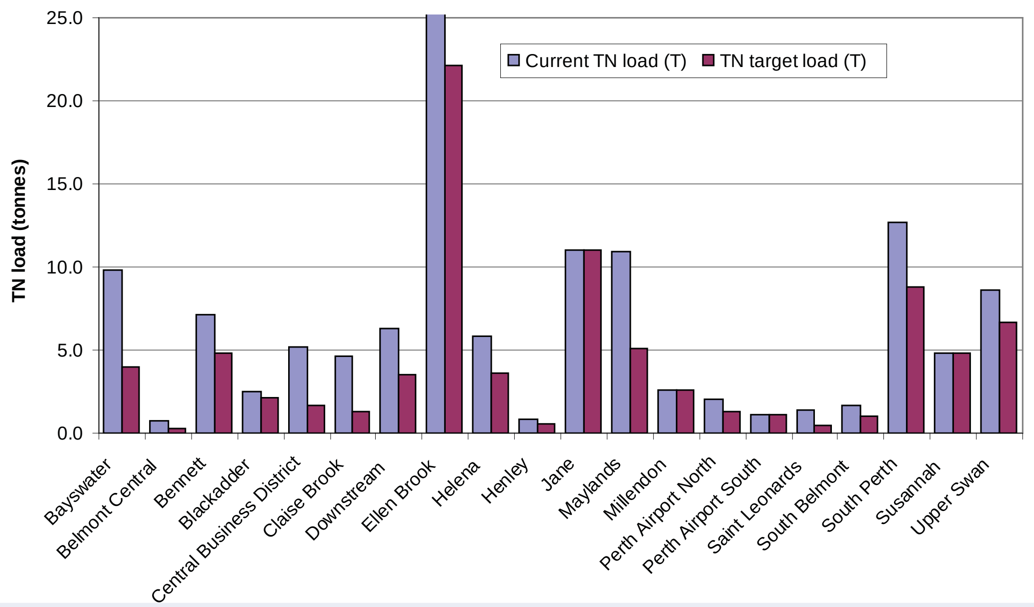


Figure 37 Current modelled TN loads (1997-2006) and maximum acceptable loads for the Swan sub-catchments (note Ellen Brook current TN load = 71.4 tonnes)

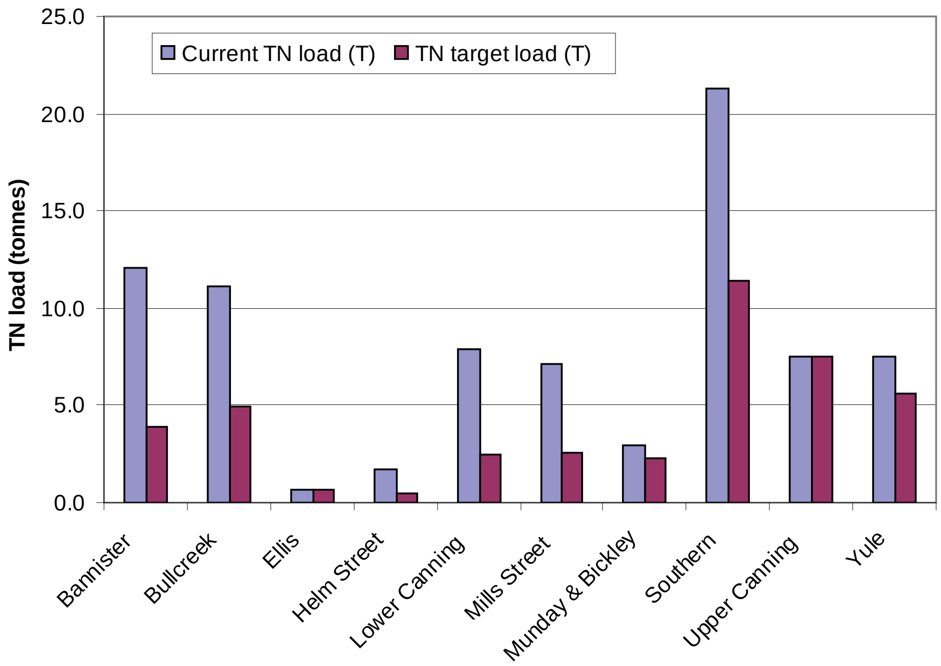


Figure 38 Current modelled TN loads (1997-2006) and maximum acceptable loads for the Canning sub-catchments

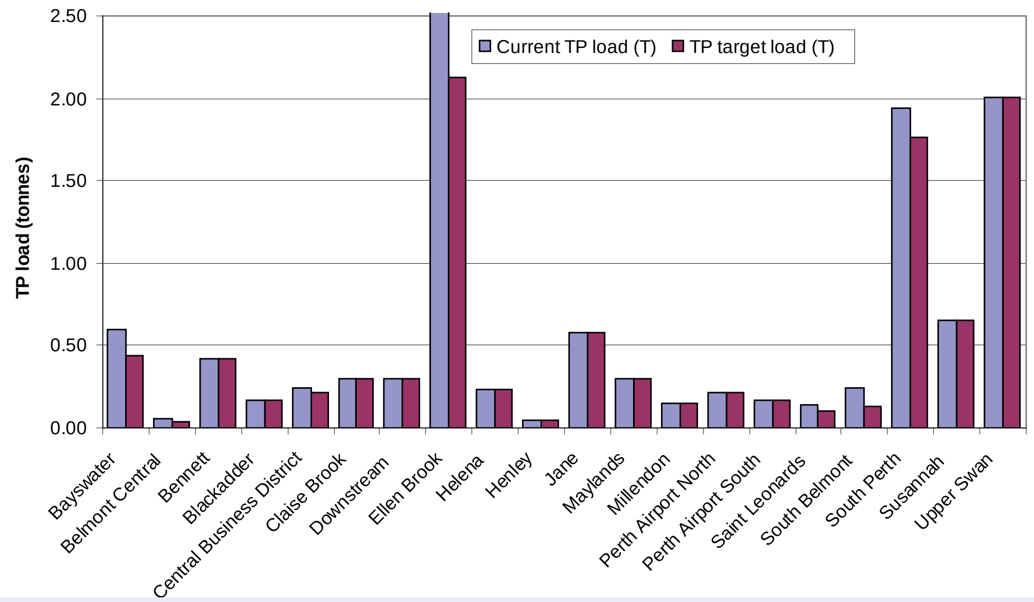


Figure 39 Current modelled TP loads (1997-2006) and maximum acceptable loads for the Swan sub-catchments (note Ellen Brook current TP load = 10 tonnes)

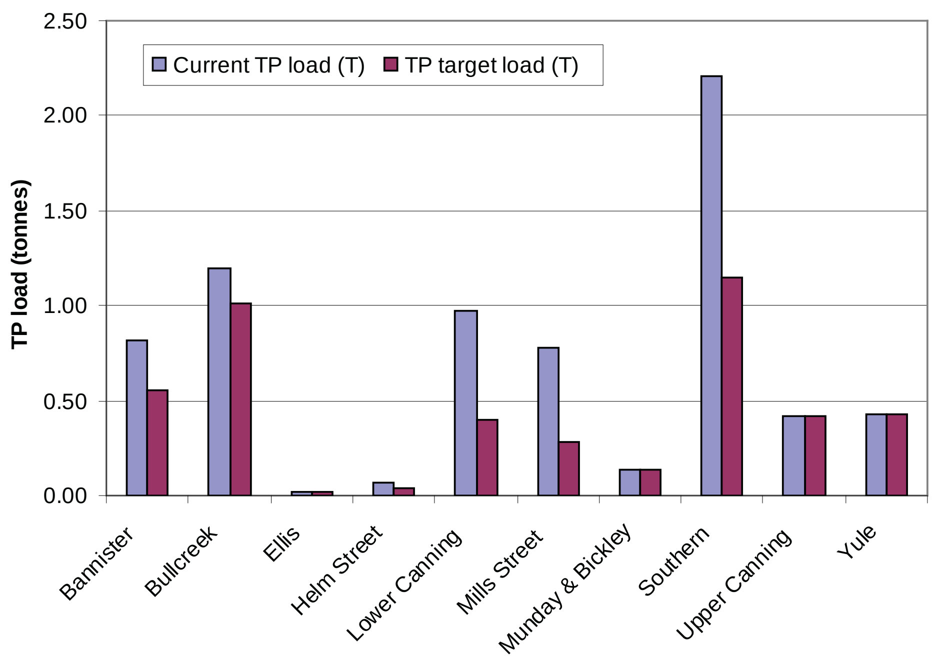


Figure 40 Current modelled TP loads (1997-2006) and maximum acceptable loads for the Canning sub-catchments

Urban development is progressing rapidly in many of the sub-catchments such as Southern River, St Leonards Brook and Ellen Brook. It is paramount for appropriate urban development to both minimise fertiliser input, and to process and retain applied nutrient on-site.

7.4 Scenario modelling

Eleven scenarios selected by members of the CCI Steering Committee were modelled separately through SQUARE to predict the impacts of various pressures and management measures on the Swan Canning Catchment and for each of the 30 modelled sub-catchments (Table 19, Figures 41 and 42)

Future urban land use

All potential land in the Metropolitan Region Scheme is developed. Future urban development was based on the Metropolitan Regional Planning Scheme (MRS, October, 2005). All areas in the MRS designated urban residential, which had a rural or peri-urban land use in the 2006 land use map, were changed to residential.

The future urban development was modelled with:

1. no best management practices (BMPs) included in the development; and
2. soil amendment applied to areas of low PRI soils. Developed areas which had a PRI of less than 10 were given a PRI of 10.

No other BMPs have been modelled, as the effectiveness of the urban BMPs on the Swan Coastal Plain have not been quantified. The scenario without soil amendment gives the estimated nutrient yields for urban development similar to existing Perth residential areas. This is thought to be the worst-case scenario.

Future urban land use with soil amendment for PRI < 10

All potential land in the Metropolitan Region Scheme is developed with soil amendments to increase the phosphorus retention index (PRI) of soils from < 10 to PRI 10.

Septic tank infill

100% infill of septic tanks including caravan parks, houses, industrial and aerobic treatment units.

Urban fertiliser reduction (50%)

A 50% reduction in fertiliser input from urban areas through community education programs, efficient fertiliser management by local government and turf managers.

Climate change B1 and A2

The B1 climate change scenario is the best case for reductions in carbon emissions. The A2 climate change scenario is the worst case for reductions in carbon emissions.

Fertiliser Action Plan – urban, rural and urban/rural

Application of the Fertiliser Action Plan, predominantly reducing the application of highly water-soluble phosphate fertilisers on low PRI soils.

Soil amendment – rural properties with PRI < 10

Appropriate soil amendment applied to rural properties with low PRI soils to increase the PRI of soils from < 10 to PRI 10.

Wetlands implementation

Wetlands for nutrient intervention constructed at the end of the sub-catchments. The impact of nutrient-stripping wetlands at the outlets of 22 sub-catchments was modelled. The location and sizes of the wetlands were specified by the Swan River Trust.

Table 19 Scenario modelling results for the Swan Canning Catchment

Scenario	Phosphorus load (tonnes/ year)	Change from current conditions	Nitrogen load (tonnes/year)	Change from current conditions
Current conditions - no change	**27.28**	-	**265.9**	-
Future urban landuse	34.16	25.2%	312.9	17.7%
Future urban landuse with soil amendment for PRI <10	31.82	16.6%	*	-
Septic tank infill	25.18	-7.7%	226.7	-14.7%
Urban fertiliser reduction (50%)	20.85	-23.6%	203.5	-23.5%
Climate change - B1 scenario	25.95	-4.9%	257.2	-
Climate change - A2 scenario	18.86	-30.9%	225.4	-0.2
Fertiliser action plan - urban only	23.50	-13.9%	*	-
Fertiliser action plan - rural only	23.94	-12.3%	*	-
Fertiliser action plan - urban and rural	20.51	-24.8%	*	-
Soil ammendment - rural properties with PRI < 10	24.01	-12.0%	*	-
Wetland implementation	25.48	-6.6%	256.0	-3.7%
Maximum acceptable load	**14.08**	**-48.4%**	**128.2**	**-51.8%**
*Scenario applies only to phosphorus				

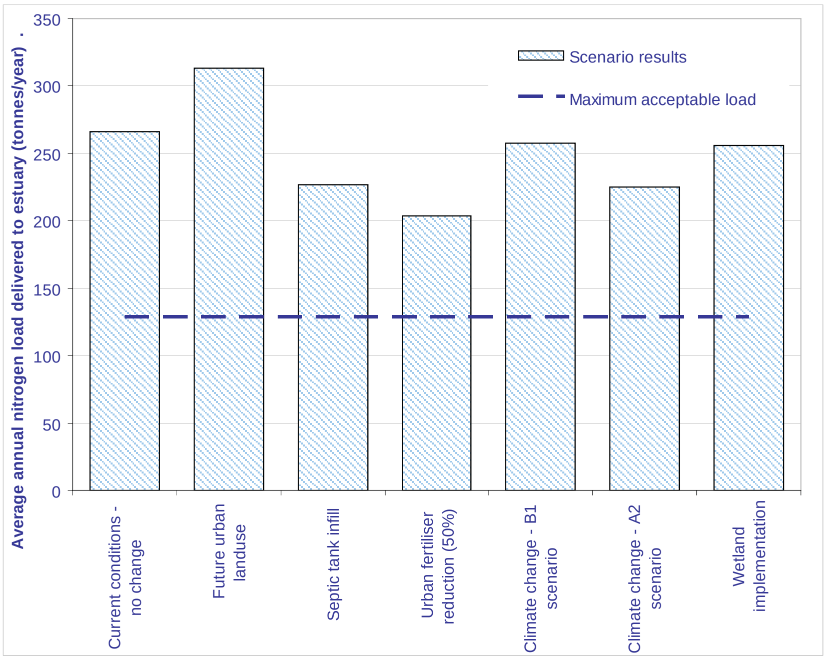


Figure 41 Scenario modelling for nitrogen management in the Swan Canning Catchment

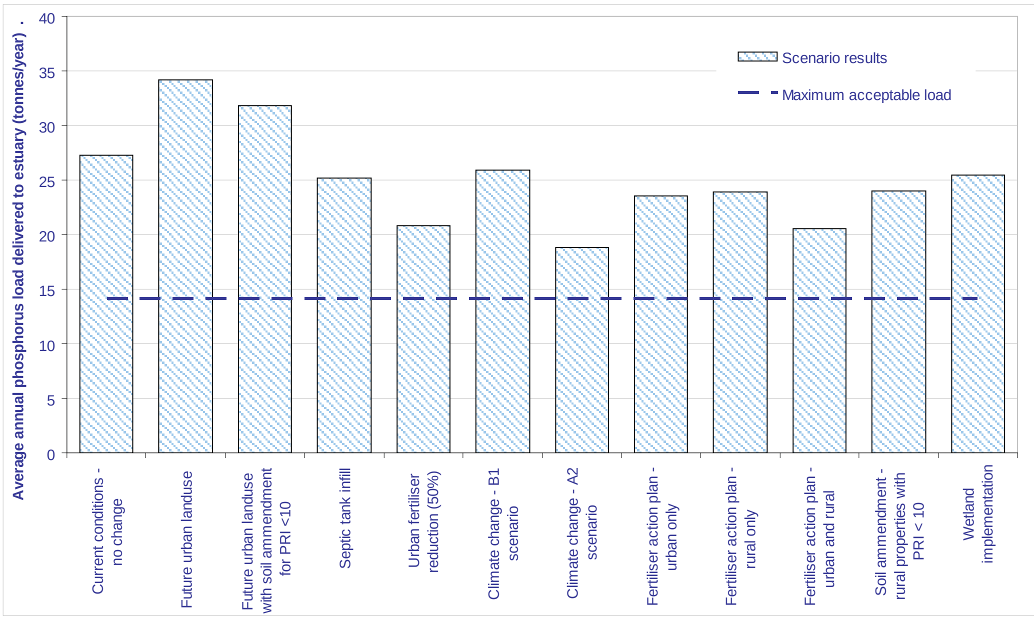


Figure 42 Scenario modelling for phosphorus management in the Swan Canning Catchment

8. Environmental flows

8.1 Introduction

Every catchment in the Swan Canning river system has an individual or "signature" flow regime with characteristic flow quantities and seasonal flow patterns. These flow characteristics influence aquatic flora and fauna and key physical processes such as sediment transport. Once the flow characteristics for a particular catchment have been identified, an environmental flow regime can be developed to meet the current needs of the aquatic ecosystems and anthropogenic consumptive uses.

The river flow objective for tidal reaches of the Swan and Canning rivers is to maintain current flow variability. Flows in the sub-catchments provide an important flushing mechanism for the Swan and Canning rivers.

The SCWQIP identifies environmental flow objectives to protect wetlands and flood plains by mimicking natural inundation and drying patterns, and to minimise the effects of dams and extraction on streams, wetlands and estuary water quality by mimicking natural frequency, duration and seasonal flow.

Ecological Water Requirements (EWR) are descriptions of water regimes that maintain or restore ecological processes and protect environmental values consistent with National Principles for Provision of Water to the Environment (Water and Rivers Commission, 2000; ANZECC and ARMCANZ 2000). EWRs define quantitative flows required to achieve environmental flow objectives. Water regime is a description of the variation of flow rate and volume (rivers, streams, drains) or water level (wetland, groundwater) over time, but may also include a description of water quality. When determining an EWR, the ecosystem is considered as a whole. EWRs are based on the premise that particular flow events perform specific ecological functions. For example, high flows following storm events have the energy to scour the river channel, create diverse riverbed habitats and flood riparian vegetation. Early winter flows relieve summer stress (such as high water temperatures and low levels of dissolved oxygen), provide cues for native fish breeding migrations, and provide habitat for organisms such as water birds, micro-crustaceans, aquatic insects, in-stream vegetation and larval stages of terrestrial insects.

Environmental Water Provisions (EWPs) are water regimes provided as a result of the water allocation decision-making process. They take into account ecological, social and economic impacts. In an ideal world EWPs maintain EWRs and environmental flow objectives, however this is not always possible and EWPs may compromise environmental flow objectives.

Undertaking EWR studies and the translation of EWRs into EWPs by the Water Resource Use Division of Department of Water is an intensive process. Within the Swan Canning river system, only the Canning River (between Canning Dam and the Kent Street weir) has a completed EWR study (Radin *et al* 2009). EWRs for the Canning River require maintenance of a continual flow of water in the lower Canning River in summer (summer baseflows) to maintain flow connectivity, pool depth and prevent oxygen concentrations becoming too low. Occasional additional flows to allow large fish passage in summer (fish pulse flows) are also a requirement. EWRs outside the summer period include over-bank flows to inundate riparian vegetation, and flows which provide additional habitat for fish spawning. These are met by rainfall and catchment runoff.

8.2 Monitoring of river flows

Flow data of the Swan Canning Catchment was based on 12 representative stations throughout the SCWQIP area primarily near the end of catchments (Figure 43)[1]. These Department of Water and Water Corporation gauging stations are operational with at least 10 years of flow measurements.

The greatest freshwater contribution to the estuary is from the Swan River (median ~100 megalitres per day (MLD), mean ~900 MLD) upstream of the Ellen Brook confluence. The median flow of the Swan River is approximately a factor of seven greater than the

[1] *The gauging stations at Wooroloo (616001) and Brockman River (616019) are not in the Swan Canning Catchment study area of the WQIP.*

Figure 43 Map of SCWQIP area (thick blue line), major waterways (thin blue lines) and gauging stations of the Department of Water (blue dots) and Water Corporation (red dots)

Canning River and 10-15 times greater than other substantial tributaries (Bayswater Main Drain, Mills Street Main Drain, Yule Brook, Southern River, Ellen Brook) (Table 20). However, the mean discharge is greater by a factor of 25-100 than all of these catchments, except for Ellen Brook, which yields roughly 10% of the annual flow of the Swan River because of its large catchment size.

Groundwater is a substantial component of the water balance of the surface water regime in many of the brooks and drains on the Swan Coastal Plain, particularly during summer, but also during winter. During summer, groundwater input often maintains perennial flow in brooks and drains, whereas in winter elevated base flows are maintained by high groundwater "leakage" input during seasonal maxima in superficial aquifer levels. The ratio of the annual mean to annual median flow at a gauging station provides a rough index of the relative groundwater contribution in a particular catchment. For example, groundwater influences the flow regime of the Bayswater Main Drain (median ~7 MLD, mean ~19 MLD, mean:median ~3) to a greater extent than Ellen Brook (median ~5 MLD, mean ~85 MLD, mean:median ~17). Stations in the main stem and tributaries of the Canning River have similar mean:median ratios to the Bayswater Main Drain, which indicates significant groundwater input into the surface hydrology. In fact, the Mills Street Main Drain has the lowest mean:median ratio of ~2, which suggests groundwater influences the surface hydrology to a greater extent than any of the other catchments. In contrast, Ellen Brook has a high mean:median ratio indicative of higher seasonal flow variability and less groundwater influence.

Table 20 Gauging station details and simple statistics of flow over record of measurement

Station number	Sub-catchment/ station drainage name	location	Start year	End year	Catchment area (km2)	Mean (MLD)	Median (MLD)	10th percentile (MLD)	25th percentile (MLD)	75th percentile (MLD)	90th percentile (MLD)
SWAN RIVER AND TRIBUTARIES											
Main Stem											
616076	Swan River	Great Northern Highway	1996	2006	~120000	803.1	100.7	1.2	5.8	861.9	2379.8
616011	Swan River	Walyunga	1971	2006	~120000	923.1	89.3	0.0	1.6	818.5	2431.6
Tributary											
616082	Bayswater Main Drain	Slade Street	1989	2005	28	18.6	7.0	0.4	0.9	28.5	52.3
616189	Ellen Brook	Railway Parade	1984	2006	581	86.9	4.6	0.0	0.0	66.0	227.4
616045	Mount Lawley Main Drain	Mount Lawley	1984	2006	2	1.3	0.6	0.3	0.4	1.0	2.1
616015	Perth Airport North	Poison Gully Creek	1991	2006	7	2.9	0.3	0.0	0.0	2.9	8.2
616084	Bennett Brook Main Drain	Benara Road	1993	2006	99	1.3	0.1	0.0	0.0	1.6	4.2
CANNING RIVER AND TRIBUTARIES											
Main stem											
616027	Canning River	Seaforth	1975	2006	877	36.0	14.5	2.6	5.5	43.0	87.8
Tributary											
616092	Southern River	Anaconda Drive	1997	2006	152	37.3	10.2	1.0	1.9	39.8	106.3
616042	Yule Brook	Brixton Street	1986	2006	69	28.3	9.4	0.8	2.0	33.3	72.4
616043	Mills Street Main Drain	Palm Place	1985	2006	12	10.9	5.7	1.2	2.6	12.0	25.5
616044	Nerrigen Brook	Abbey Road	1985	2006	25	10.4	5.0	0.2	1.1	13.7	26.0

Discharge data from five representative sub-catchments of the SCWQIP area have been selected to highlight flow regimes during the past 20-30 years, namely:

- main stem of the Swan River, which provides the largest freshwater input into the Swan Canning Estuary (Figure 44);
- middle Canning River Catchment where flow has been altered by large dams (Canning Dam, Wungong Dam) (Figure 45);
- agricultural sub-catchment of Ellen Brook (Figure 46);
- Yule Brook, a mixed sub-catchment covering scarp and coastal plain as well as rural and urban land use (Figure 47); and
- predominately urban (residential and industrial) Mills Street Main Drain (Figure 48).

For descriptions of the flow regimes of the other seven sub-catchments refer to the companion report to this chapter (Appendix 6).

Flow exceedance curves[2], box and whisker plots[3] and continuous flow charts[4] are used to illustrate graphically the interannual variability, monthly simple statistics and daily discharge extremes for each of the flow measurement records of the five selected stations, respectively. The box and whisker plots and the continuous flow charts are presented with log and linear scales for flow to highlight low and high flow conditions. The box and whisker plots and continuous flow charts demonstrate seasonal flow trends and the range of discharge on monthly and daily time scales, respectively. The flow exceedance curves characterise the interannual variability of flow conditions across the measurement record.

The general pattern across all five gauging stations is that flows are generally seasonal with maximum discharge during July and August and minimum flow (if any) from January to March.

These five gauging stations demonstrate there is a variety of freshwater flow regimes across the SCWQIP area that potentially provide a ‘rich’ hydrological setting for ecological diversity and management approaches. Some key patterns include the following:

- Ellen Brook generally has the longest period of no flows, often from December to May (Figure 46), though the small sub-catchments of Perth Airport North (December-April) and Bennett Brook (February-April) also have long summer periods of no flow (not shown).
- Though the Avon River at the Walyunga gauging station often has no flow from January to February (not shown), there is flow throughout the year at the Great Northern Highway gauging station (Figure 44). Hence, the main stem of the Swan River generally has continuous freshwater input into the river system.
- Most of the drains including Bayswater (not shown) and Mills Street (Figure 48), brooks such as Yule Brook (Figure 47), and rivers such Canning River (Figure 45) and Southern River (not shown) that drain substantial portions of the sandy Swan Coastal Plain have substantial flow (>100 m^3 day-1) throughout the year in large part because of groundwater input during dry periods.
- Interannual variability in flow tends to correlate between catchments with 2006 generally the driest (or nearly) year in terms of flow on record across all stations.

[2] *Flow exceedance curves provide the percentage of time over the duration of the measurement record that daily flows exceed a particular discharge. A flow exceedance curve is shown for each year based on daily discharge data.*

[3] *Box and whisker plots represent the median as the line within the box, the 75th and 25th percentile as the top and bottom of the box, and the 90th and 10th percentiles as the top and bottom ‘whiskers’. At least three data points are required to compute the 25th and 75th percentiles, and at least nine data points are required for the 10th and 90th percentiles. If insufficient data exists to construct a complete box and whisker plot, then only portions that can be estimated are shown.*

[4] *The daily continuous flow charts illustrate the maximum, median and minimum daily discharge for each day of the year over the record of measurements.*

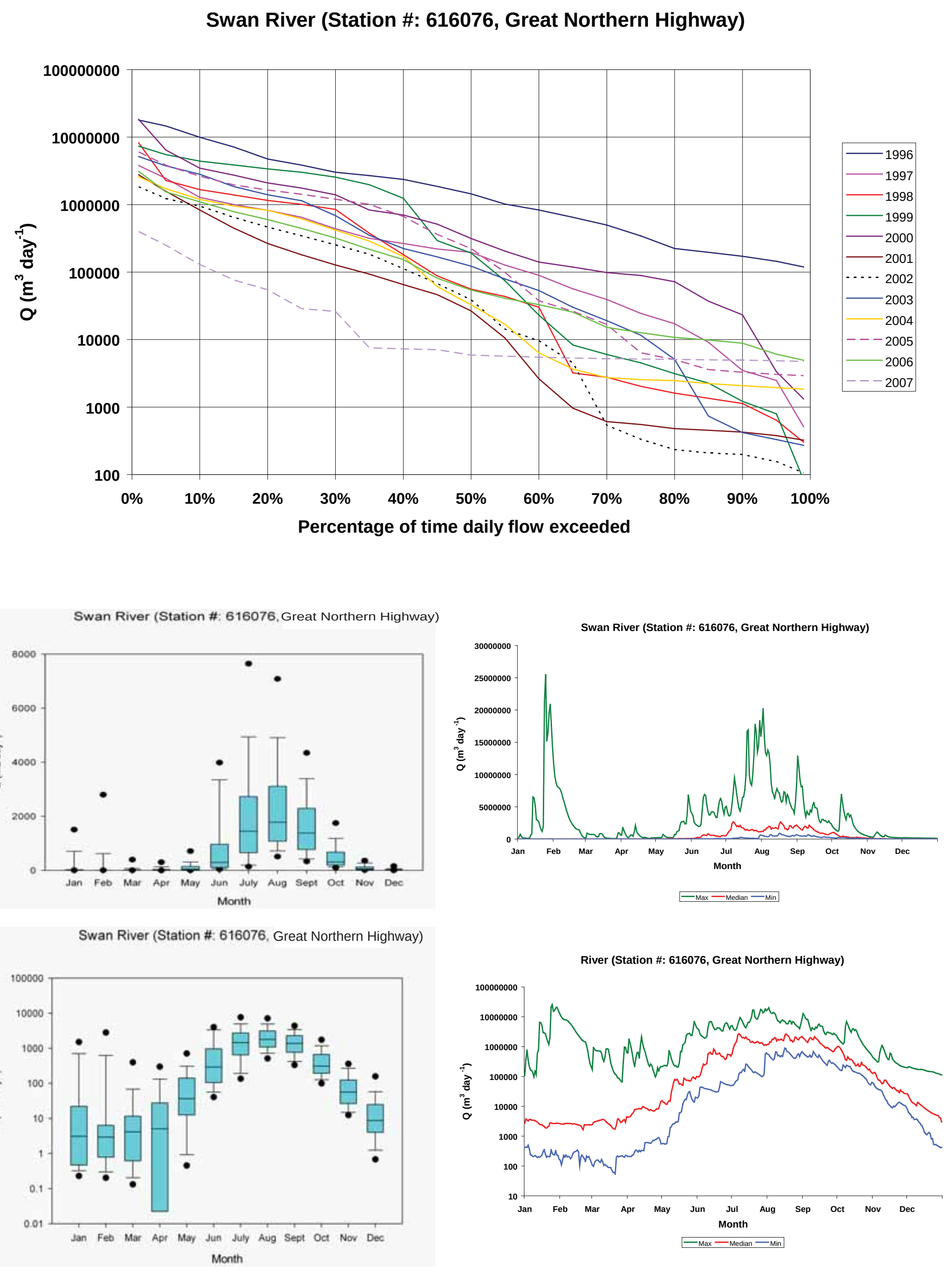


Figure 44 Flow exceedance curves for the Swan River at the Great Northern Highway gauging station (616076) for each year from January 1996 – December 2006 (upper plot). Monthly box plots (left plots) and daily flow charts with daily maximum (green), minimum (blue) and median (red) (right panels) with linear (middle panels) and log (bottom panels) y-axis scaling (Department of Water)

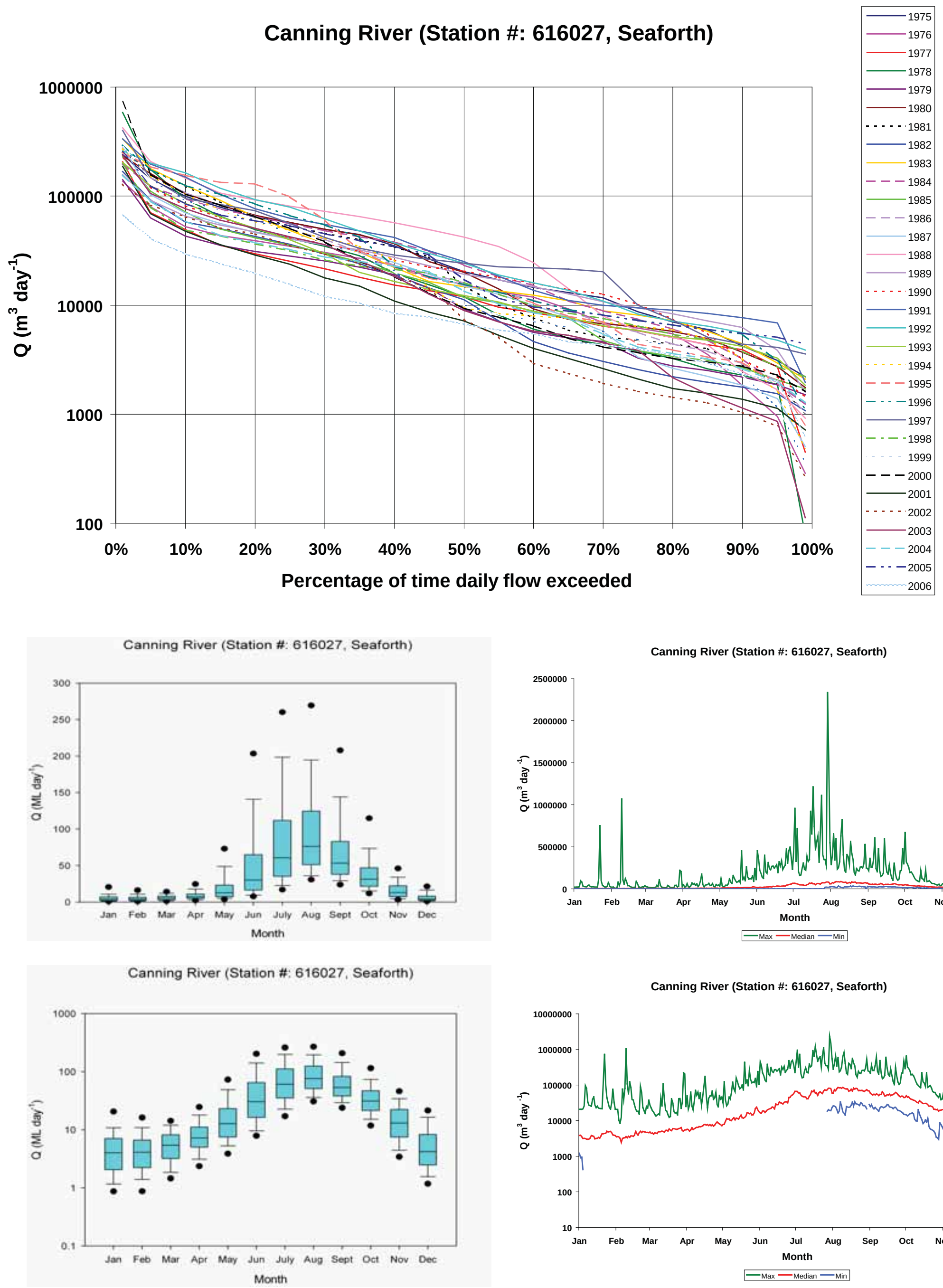


Figure 45 Flow exceedance curves for the Canning River at the Seaforth gauging station (616027) from January 1975 – December 2006 (Department of Water)

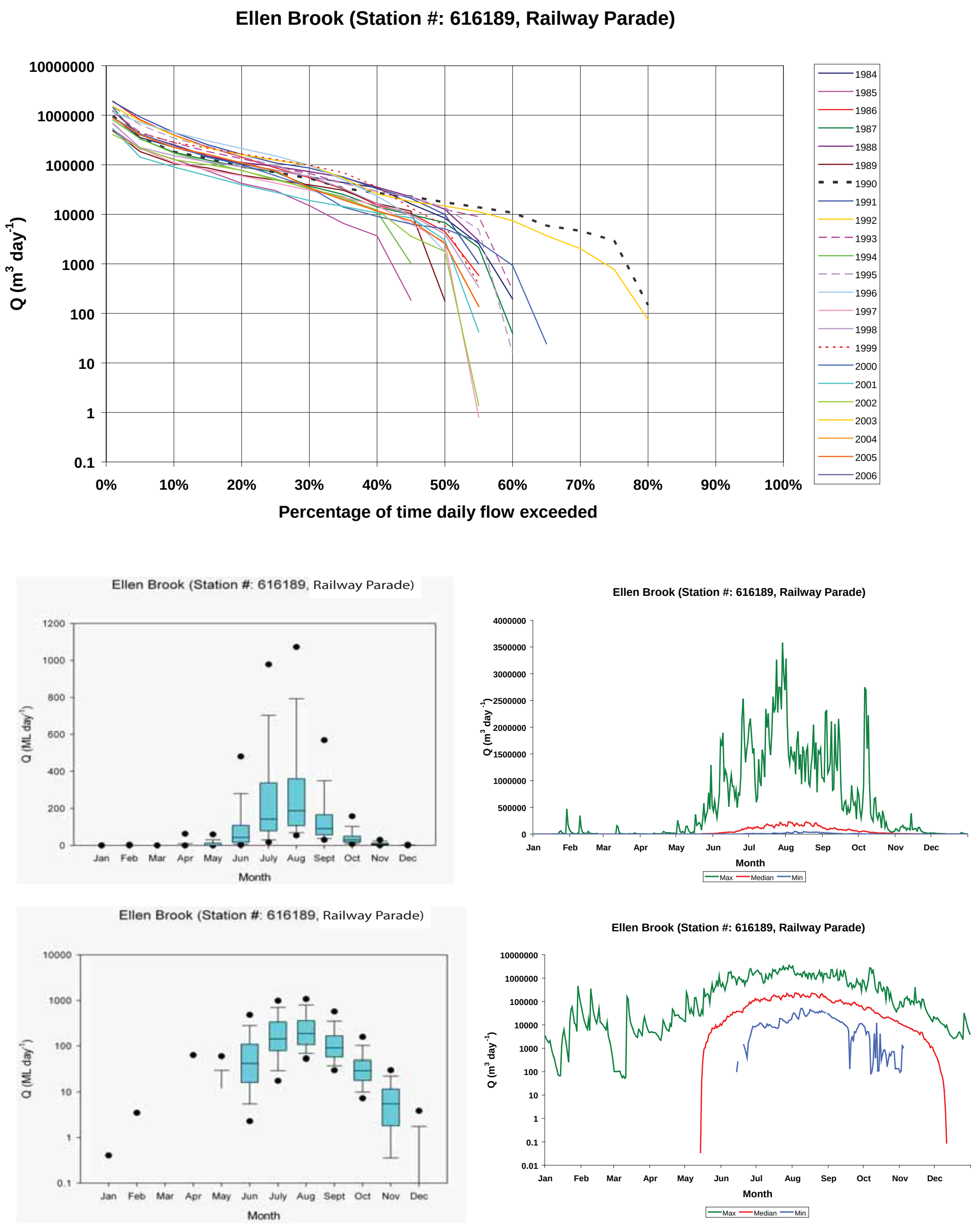


Figure 46 Flow exceedance curves for Ellen Brook at the Railway Parade gauging station (616089) from January 1984 – December 2006 (Department of Water)

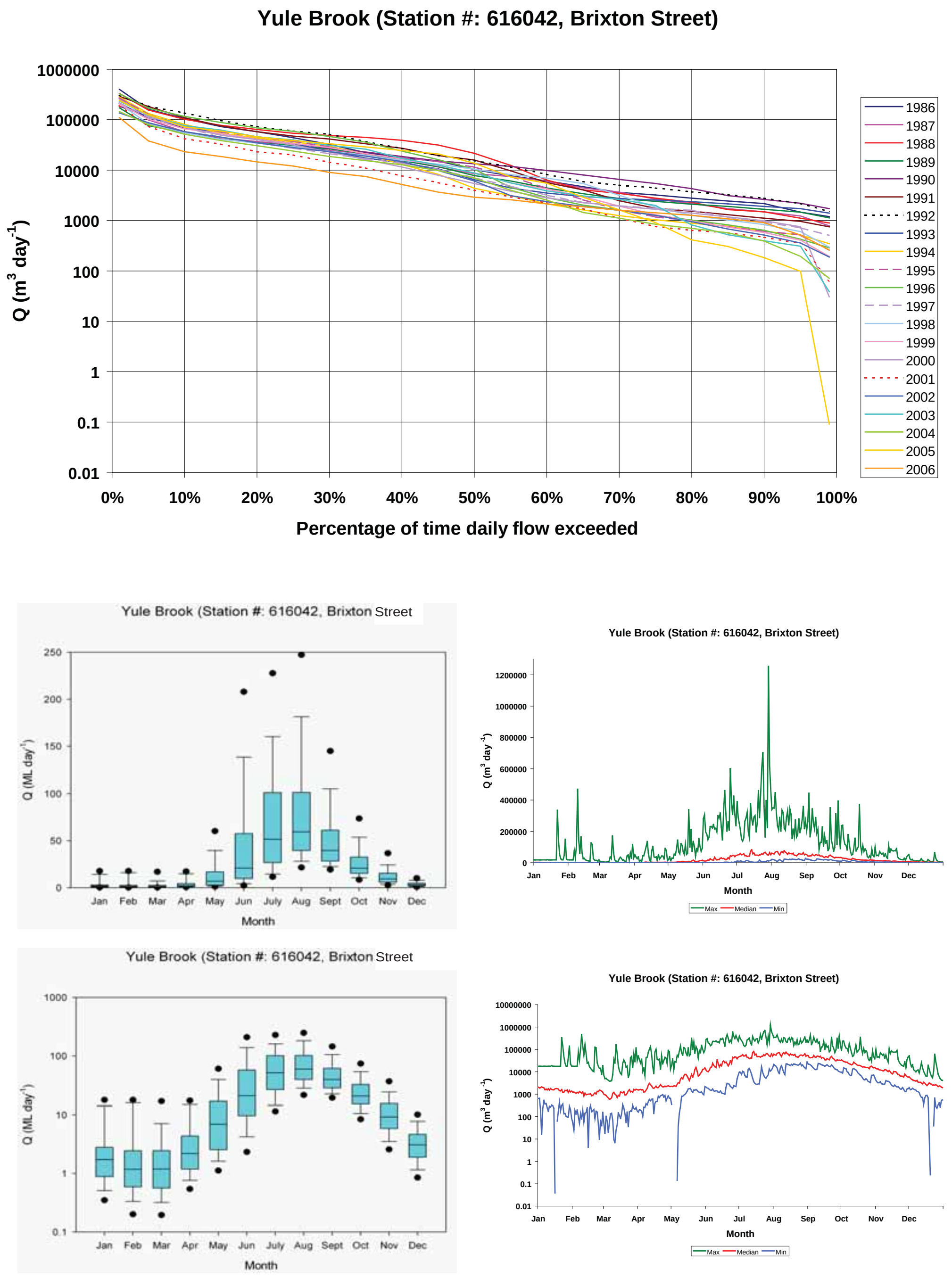


Figure 47 Flow exceedance curves for Yule Brook at the Brixton Street gauging station (616042) from January 1986 – December 2006 (Water Corporation)

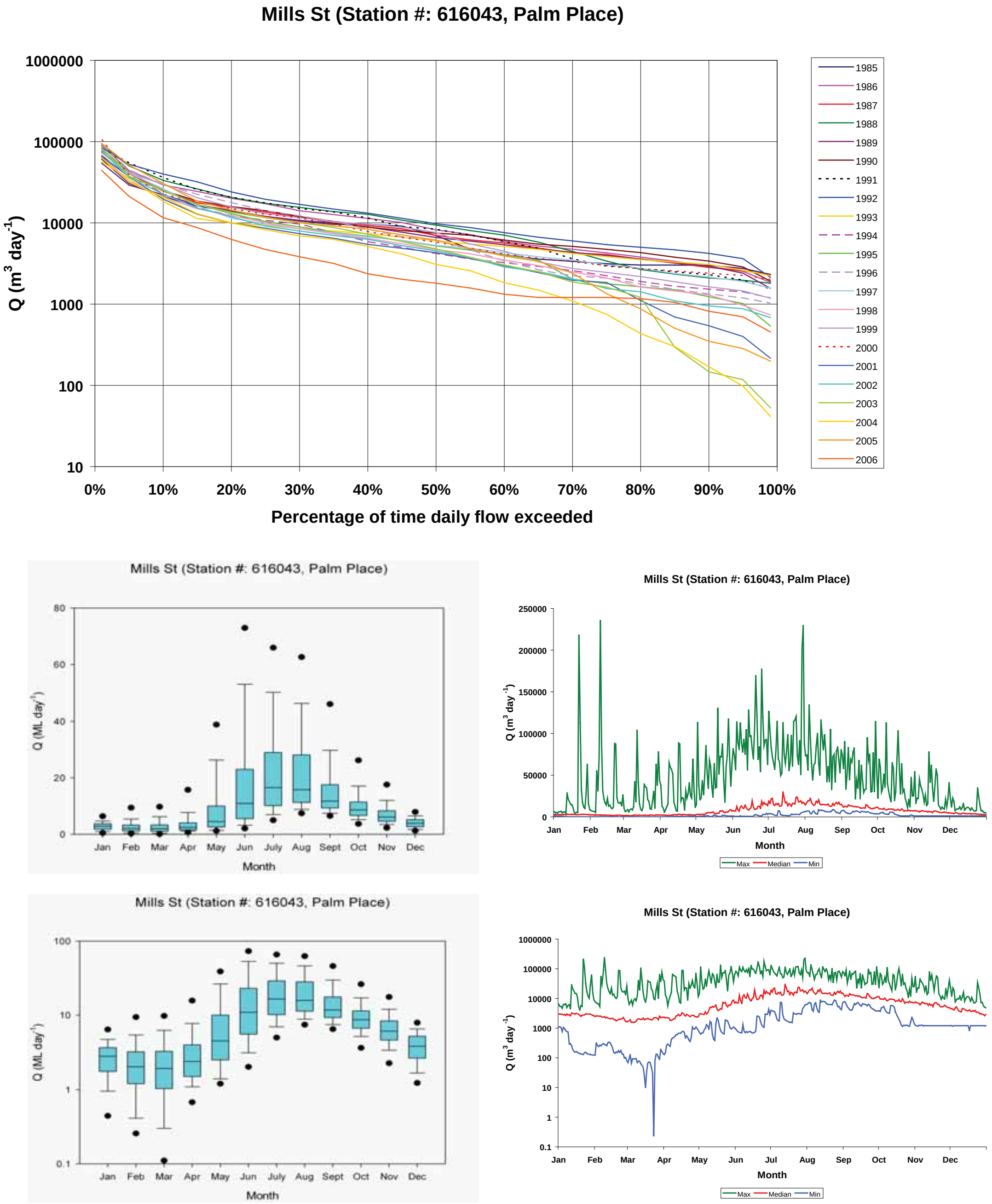


Figure 48 Flow exceedance curves for Mills Street Main Drain at the Palm Place gauging station (616043) from January 1985 – December 2006 (Water Corporation)

8.3 Environmental flow objectives

Environmental flow objectives for a range of environmental attributes have been identified as summarised in Table 21 below (GHD 2008).

Table 21 Flow objectives summary

Environmental attributes pertaining to	Environmental flow objectives
Hydrology, hydrodynamics and channel geomorphology	Scour pools with flow velocities of 20-30cm/sec to remove accumulated sediments and organic material Maintain shape of the active channel For tidal reaches maintain current flow (i.e. tidal range) to provide salt wedge movements and salinity variations in estuary
Aquatic and riparian vegetation	Maintain and/or restore wetland/riparian vegetation in winter-wet pastured floodplain regions and along the periphery of drains, brooks and rivers Inundation of wetland/riparian vegetation in winter-wet vegetation to restore and maintain these areas Seasonal inundation of emergent and mid-bank vegetation for survival, germination and recruitment Maintain submerged macrophytes during low flow periods for recolonisation
Fish assemblages	Provide native fish passage during impoundments during migration periods Maintain oxygen levels above 2.0 mg/L to avoid possible fish kills Inundate submerged, emergent, fringing and trailing vegetation at >0.1m in the existing channel and off-channel areas for spawning and recruitment of small-bodied freshwater fish species Maintain existing pools at a thalweg depth of 0.5-0.8m for cobbler nests and as refuge habitat for other fish species Maintain shallow backwater areas as nursery, predator avoidance, and habitat areas for juvenile fish as well areas to avoid high flows in the main channel Maintain overbank flows to inundate and connect floodplain wetlands and shallow-flooded off-river areas (tributaries/drains) for foraging and spawning habitat for native fish Prevent sediment aggregation in pools to maintain habitat for fish Maintain estuarine seasonal and interannual salinity variability
Macroinvertebrates	Maintain a minimum height of 5-10cm over gravel runs and riffles Maintain submerged macrophyte beds as habitat for macro-invertebrates Ensure marginal reeds/rushes are trailing and provide habitat for macro-invertebrates Seasonally inundate floodplain and backwater areas for habitat and avoidance of high flows Maintain connectivity of pools in summer Maintain seasonal and interannual variability of estuarine flows
Waterbirds	Maintain permanent pools as summer and drought refuges Maintain adequate flow to protect key habitat sites Maintain seasonal and interannual variability of estuarine flows of foraging areas
Riverine floodplains	During the wet season lower level terraces should be occasionally inundated through flood pulses
Water quality	Prevent significant stratification or anoxia in pools during summer (hydraulic retention time of less than two weeks) Flushing flows to reduce nutrient and pollutant concentrations in summer

8.4 Sustainable Diversion Limit methodology

Department of Water has adopted a sustainable diversion limit (SDL) approach in the relatively unmodified streams of south-west Western Australia. SDLs are deduced solely on discharge measurements and follow methodology developed by Department of Water (Sinclair Knight Merz, 2008). A SDL is a conservative limit on water extraction that cannot be exceeded unless more detailed investigations, such as EWRs, are completed. SDLs allow a first estimation of EWRs and EWPs. This method was developed for surface water resources with low use and modification so application to the Swan Canning coastal sub-catchments is problematic.

The SDL method specifies that:

- water may only be extracted from the stream during winter between 15 June and 15 October (winterfill period);
- a minimum flow threshold (MFT) is set during the winterfill period above which water may be extracted. The MFT is calculated as the maximum of either 0.3 times the mean daily flow or the 95th exceedance percentile of the annual median winterfill period daily flow;
- during the winterfill period a maximum extraction rate (MER) is set for pumped extractions to maintain flood peaks required for geomorphological and riparian flood plain processes. The MER is calculated as the 25th exceedance percentile of the difference between the daily flow and the MFT for those days during the winterfill period when the MFT is exceeded; and
- an SDL or total extraction volume is calculated on the basis of 80% annual reliability of supply. That is the 80th percentile of the annual discharge volume of the potential diverted flows derived from application of the MFT and MER rules, which generally equates to approximately 10% of the annual flow.

Inherent in this methodology are the following assumptions:

- the discharge record is greater than 10 years and is representative of the water regime the waterway's ecology has adapted to. Maintenance of this ecological system can be achieved by extracting the SDL volume derived by this hydrological method;
- all discharge from October 15 to June 15 is retained in the system. This ensures the maintenance of sufficient flow for perennial waterways outside winter for macroinvertebrates, fish, water quality and pool depths;
- during the winterfill period the MFT must be defined to maintain baseflow ecological processes above which extraction is allowed;
- during winter the MER must be defined to maintain ecological services depending on high flow rates such as fish passage (September to October), pool scouring, floodplain-waterway interactions and channel geomorphology processes; and
- the SDL during the winterfill period provides an expected diversion volume for consumption.

It should be noted that SDLs need to be updated to include the consequences of the drying climate. Their impacts on river and estuary health should also be reviewed regularly.

Application of SDL methodology to Swan Canning tributaries

The Swan Canning river system contains five major water supply dams in the Darling Scarp and many coastal plain streams have been modified to increase their drainage capacity. A large artificial drainage network has been established and many coastal plain wetlands have been drained or filled for urban and agricultural land uses. Swan Canning streams and drains are highly modified and an SDL approach based on maintaining existing modified flow regime is generally inappropriate. For highly-modified streams, altering the existing flow regime (for example to improve summer baseflows) can provide an improved riverine environment.

The SDL approach also has considerable restrictions on when water can be taken, i.e. only during winter. In reality water licence holders take water throughout the year and are more likely to take water during the summer period when rivers are most stressed.

Department of Water provides licences for surface and ground water extraction in Western Australia. Generally in Swan Canning sub-catchments no more water can be diverted from the “natural” tributaries (Bannister Creek, Bennett Brook, Blackadder Creek, Ellen Brook, Ellis Brook, Helm Street, Henley Brook, Jane Brook, Saint Leonards Creek, Susannah Brook and Yule Brook) or tributaries with dams in their headwaters (Helena River, Southern River, Upper Canning, Lower Canning and Munday/Bickley).

Consequently the SDL approach may only be feasible for artificial drains in the Swan Canning sub-catchments. It is likely maximum extraction rate criteria for urban drains would be larger as geomorphological processes and riparian floodplain management are not relevant issues in drains. Decisions to abstract water from drains would depend on their ecological values and whether water extraction drain would improve or worsen downstream water quality. Abstraction would need to be considered on a case-by-case basis.

The flow output from the SQUARE model was used to determine the SDLs for nine tributaries of the Swan Canning river system: Bayswater Main Drain, Belmont Central, Central Business District, Claise Brook, Maylands, Mills Street Main Drain, Perth Airport North, Perth Airport South and South Belmont. The reasons SDL calculations are inappropriate in the other 21 sub-catchments are as follows:

- There are four sub-catchments for which SDLs were not calculated because multiple small drains flow to the estuary: Bullcreek, Downstream, South Perth and Upper Swan. In some cases there was more than one drain in a SQUARE sub-catchment; and generally confidence in the modelling results is not sufficient to report at such small scales.
- The Millendon catchment encompasses the area draining to the Swan River between Walyunga (site 616011) and Great Northern Highway (site 616076). The main channel is the Swan River and determining SDLs for the Swan-Avon system was beyond the scope of this project.
- Water allocations in the 11 natural tributaries (Bannister Creek, Bennett Brook, Blackadder Creek, Ellen Brook, Ellis Brook, Helm Street, Henley Brook, Jane Brook, Saint Leonards Creek, Susannah Brook and Yule Brook) have been exceeded and no more water may be diverted from these streams.
- There are five regulated catchments (catchments which have dams in their head waters) for which SDL calculations are impossible because the rivers do not contain “natural” flows. The Helena catchment is downstream of the Mundaring Reservoir, which last overflowed in 1996; the Munday-Bickley catchment contains Victoria Reservoir; and Southern River catchment is downstream of the Wungong dam. The Upper Canning and Lower Canning catchments, which are downstream from the Canning dam (and Churchman Brook reservoir), have EWRs specified by Department of Water which mandate dam releases to these catchments (Radin *et al*., 2009). A summary of the results of the interim hydrological method is provided in Table 22.

Table 22 Sustainable Diversion Limits for the Swan Canning coastal sub-catchments

Catchment	Minimum flow threshold (ML/day)	Maximum extraction rate (ML/day)	Average annual flow ML/year (1997-2006) (ML/year)	SDL (80% reliability) (ML/year)	SDL (%)
Bayswater Main Drain	26.7	6.4	8165	383	5%
Belmont Central	2.5	0.4	875	33	4%
Central Business District	6.4	1.0	2160	64	3%
Claise Brook	10.2	1.5	3411	101	3%
Maylands	6.8	1.1	2296	77	3%
Mills Street Main Drain	11.9	2.6	4418	157	4%
Perth Airport North	6.6	5.7	2468	432	17%
Perth Airport South	4.1	4.5	1888	342	18%
South Belmont	6.8	1.2	2427	95	4%
TOTAL			28108	1685	6%

9. Research requirements

While the SCWQIP identifies a number of research requirements, two major research gaps can be highlighted.

1. **Field testing and costing recommended best management practices**. There is limited information available on the effectiveness of the recommended best management practices (BMPs) for urban and rural areas in the Swan Canning Catchment. Many of the BMPs have not been field tested and there is a heavy reliance on modelled data. Costs are difficult to ascertain as they tend to vary greatly between sites and field conditions. Research into field testing and monitoring the effectiveness of the BMPs in reducing nutrient loads will provide a strong basis for good cost-benefit analysis.
2. **Environmental flows.** Further research on the manner to provide high and low flows, maintain habitat inundation of wetlands and floodplains, mimic seasonal flows, and minimise the effects of dams in some tributaries is needed. During the next several years an expanded knowledge base and the refinement of decision-support systems will provide the tools to allow catchment stakeholders to meet environmental flow objectives. Investigations should include hydrological and hydrographic assessments to determine flows sufficient to maintain the life cycle of target species and support viable populations, to determine in-stream assimilation and bio-availability of nutrients, develop decision-support tools and assess capacity to deliver the various components of the flow regime. Representative "priority" catchments are recommended (GHD 2008) to focus these investigations on the basis of relative importance in regards to nutrient loading to the river system and similarity to other catchments in terms of hydrology, land use and habitat quality. These resource intensive investigations need to be undertaken within wider programs of water resource management.

Research priorities for urban stormwater are being determined by an expert panel of stakeholders, which will contribute to the research gaps identified in the SCWQIP.

Other research recommendations that are beyond the scope of the SCWQIP include:

- collaboratively managing the nutrient loads from the Avon River including strengthening links with Wheatbelt NRM (formerly Avon Catchment Council). Activity is already occurring in the Avon through Wheatbelt NRM and the Department of Water which must be supported in the SCWQIP. Ongoing collaboration between the Swan River Trust and Wheatbelt NRM is an important component of SCWQIP implementation;
- managing non-nutrient contaminants;
- studying the nutrient load from sedimentation; and
- studying the influence of groundwater on the Swan Canning river system.

10. Delivery of the SCWQIP

The SCWQIP identifies a number of important strategies and partnerships that will progress towards nutrient management in the Swan Canning Catchment, including the Fertiliser Action Plan, Urban Drainage Initiative and Ellen Brook Catchment Management Plan.

Implementation of the SCWQIP requires a combined, committed approach from natural resource management organisations, Australian Government, State agencies, local government, and community partners. The SCWQIP was developed through a committed multi-agency approach. The same level of commitment must be provided to implement the SCWQIP using a whole-of-government approach to develop and adopt cost-effective best management practice, with allocation of resources to committed partners.

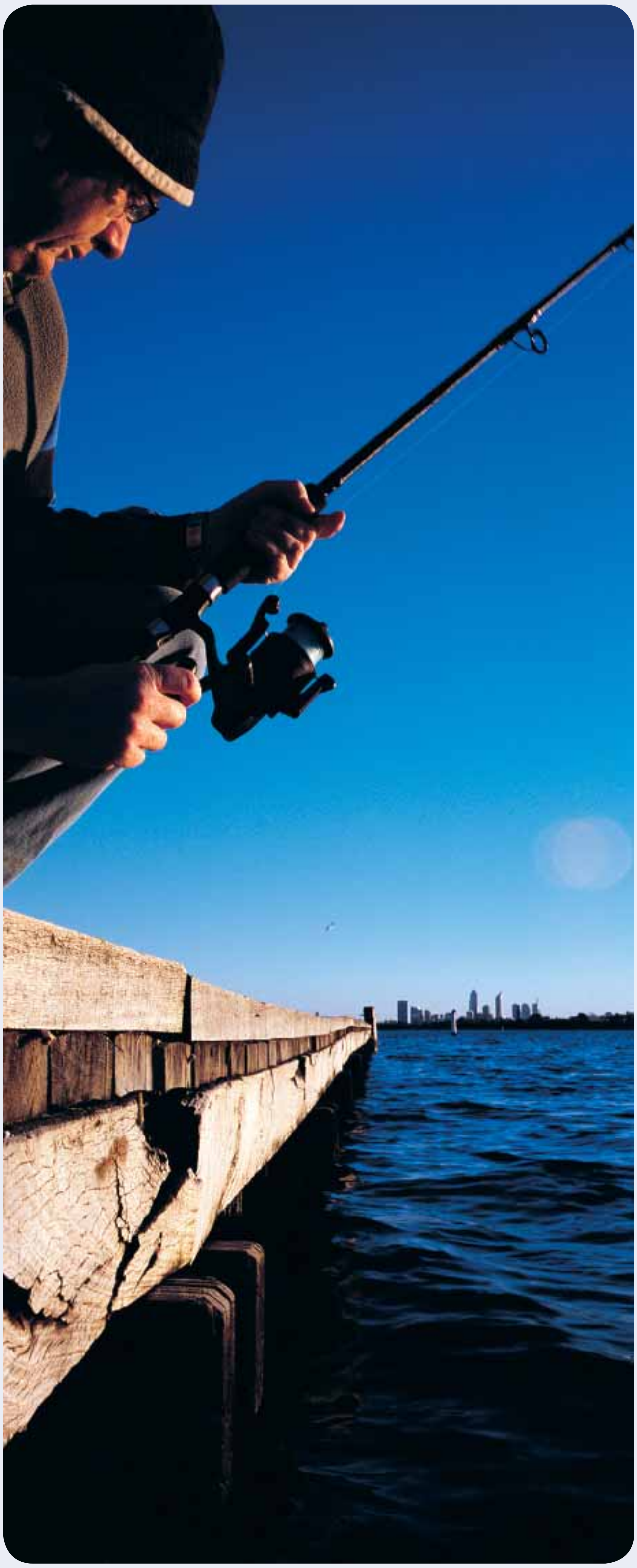
The following steps are recommended to implement the SCWQIP:

1. develop costings for recommended nutrient reduction best management practices;
2. engage the identified responsible organisations and partners for joint delivery of management actions;
3. link to existing Trust and other partner programs and strategies to achieve WQIP outcomes; and
4. through key stakeholders, identify other suitable vehicles and initiatives to deliver the WQIP.

The Swan Canning Joint Steering Committee (Section 1.1.6) guided the development of the SCWQIP. Its implementation should be guided by a similar steering committee comprised of responsible organisations identified in management actions.

Tools for implementation include:

- A reasonable assurance statement that nutrient load targets and river flow regimes will be achieved by implementing the SCWQIP is provided in Appendix 8.
- A review of statutory and legislative arrangements in the Swan Canning Catchment identifying legal instruments that can be used in implementing the SCWQIP is provided in Appendix 9.



Acronyms

BBMD	Bayswater Brook Main Drain
BMP	Best Management Practice
CCI	Coastal Catchments Initiative
DAFWA	Department of Agriculture and Food Western Australia
DEC	Department of Environment and Conservation
DOW	Department of Water
DoP	Department of Planning
EPA	Environmental Protection Authority
EWP	Environmental Water Provisions
EWR	Environmental Water Requirements
GL	Gigalitres
HRAP	Healthy Rivers Action Plan
MER	Maximum Extraction Rate
MFT	Minimum Flow Threshold
MLD	Megalitres per day
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
NWQMS	National Water Quality Management Strategy
POS	Public Open Space
PRI	Phosphorus Retention Index
SCCP	Swan-Canning Cleanup Program
SCWQIP	Swan Canning Water Quality Improvement Plan
SDL	Sustainable Diversion Limit
SQUARE	Stream Quality Affecting Rivers and Estuaries
SPP	State Planning Policy
SSPND	Support System for Phosphorus and Nitrogen Decisions
TN	Total Nitrogen
TP	Total Phosphorus
UDIA	Urban Development Institute of Australia
WALGA	Western Australian Local Government Association
WAPC	Western Australian Planning Commission
WQIP	Water Quality Improvement Plan
WSUD	Water Sensitive Urban Design

References

ANZECC and ARMCANZ (1996) *National Principles for the Provision of Water for Ecosystems.* Occasional Paper SWR No 3. S. o. W. R. Sustainable Landuse and Water Resource Management Committee, Canberra. http://www.environment.gov.au/water/publications/environmental/ecosystems/water-provision.html

ANZECC and ARMCANZ (2000) *National Water Quality Management Strategy*. Australian and New Zealand Environment and Conservation Council, Canberra.

Australian Government (2002) *The Framework for Marine and Estuarine Water Quality Protection: A Reference Document* Version 1. Australian Government, Department of the Environment and Heritage, Canberra, ACT.

BDA Group (2008) *A nutrient offset contributions scheme for the Swan-Canning catchment*. A Policy Position Paper prepared for the Swan River Trust, Perth, Western Australia.

Clark (2008). *Incentives for Small to Medium Enterprises to Improve their Environmental Performance.* Report for Perth Region NRM. March 2008.

Department of Water, 2004-2007, *Stormwater Management Manual for Western Australia.* Department of Water, Perth, Western Australia.

Department of Water (2007) *Environmental values, flow related issues and objectives for the Canning River, Western Australia.* From the Canning Dam to Kent St Weir. Department of Water, Perth, Western Australia.

Eastern Metropolitan Regional Council and Swan River Trust (2002) *Local Government Natural Resource Management Policy Manual.* Swan River Trust, Perth, Western Australia.

Ecotones & Associates (2008) *SSPND: The Support System for Phosphorus and Nitrogen Decisions – BMP Scenarios for the Ellen Brook Catchment.* Consultant report to Department of Agriculture and Food.

Ellen Brockman Integrated Catchment Group (2008). *Ellen Brook Action Plan*. Report prepared for Swan River Trust, Perth, Western Australia.

Fertiliser Industry Working Party (2007) *Fertiliser Action Plan Phasing-out the use of Highly Water Soluble Phosphorus Fertilisers in Environmentally Sensitive Areas of South West, Western Australia.* A report to the Western Australian Minister for the Environment.

Kitsios, A. and Kelsey, P. (in preparation) *Nutrient survey of urban areas in coastal catchments of Western Australia*. Department of Water, Perth, Western Australia.

GHD (2007) *Report for Selection of Drainage Improvement Sites and Nutrient Interventions in the Lower Ellen Brook Catchment Final Report*. Prepared for the Swan River Trust, Perth, Western Australia.

GHD (2008) *Report for Environmental Flow and Objectives Swan and Canning Rivers.* Report to the Swan River Trust.

Government of Western Australia (2006) *State Planning Policy 2.9 Water Resources.* Western Australian Planning Commission, Perth, Western Australia. http://www.wapc.wa.gov.au/Publications/1281.aspx

Natural Resource Management Ministerial Council (2006) *Australia's National Programme of Action for the Protection of the Marine Environment from Land-based Activities*. Natural Resource Management Ministerial Council, Canberra, ACT.

Natural Resource Management Ministerial Council (2006) *National Cooperative Approach to Integrated Coastal Zone Management Framework and Implementation Plan*. Australian Government, Department of the Environment and Heritage, Canberra, ACT. http://www.environment.gov.au/coasts/publications/framework/index.html

Nice, HE, Grassi, M, Foulsham, G, Morgan, B, Evans, SJ & Robb, M (2009) *A baseline study of contaminants in the Swan and Canning catchment drainage system*, Water Science Technical Series Report No. 3, Department of Water, Western Australia.

Radin, L, Pauli, N, La Spina, K, Braimbridge, M & Malseed, B (2009) Ecological Water Requirements for the lower Canning River, Department of Water, Perth, Western Australia.

Sinclair Knight Merz (2008) *Estimation of Sustainable Diversion Limits over Winterfill Periods in Catchments in South West West Australia*. Department of Water, WA.

Sustainable Development Facilitation (2008). *River Protection Strategy and Management Program for the Swan and Canning rivers*. Scoping Report. Report to Swan River Trust, Perth, Western Australia.

Swan Catchment Council (2004) *The Swan Region Strategy for Natural Resource Management.* Swan Catchment Council, Perth, Western Australia.

Swan River Trust (1999) *Swan-Canning Cleanup Program Action Plan.* Swan River Trust, Perth, Western Australia.

Swan River Trust (2000) *`Summer surprise' The Swan River blue-green algal bloom. RiverSCIENCE 2* Issue 2. Swan River Trust, Perth, Western Australia.

Swan River Trust (2005) *Algal blooms in the Swan-Canning estuary: Patterns, causes and history. RiverSCIENCE 3* Issue 3. Swan River Trust, Perth Western Australia.

Swan River Trust Technical Advisory Panel (2007) *Potential Impacts of Climate Change on the Swan and Canning Rivers: Technical Report.* Swan River Trust, Perth, Western Australia.

Swan River Trust (2008a) *Swan River Trust Annual Report 2007-08*. Swan River Trust, Perth, Western Australia.

Swan River Trust (2008b) Healthy Rivers Action Plan, Swan River Trust, Perth, Western Australia.

Swan River Trust (2009) *Swan River Trust Annual Report 2008-09*. Swan River Trust, Perth, Western Australia.

Water and Rivers Commission (2000) *Environmental water provisions policy for Western Australia*. Statewide Policy No. 5.

Western Australian Planning Commission (2005) *Planning and Development Act 2005*. Western Australian Planning Commission, Western Australia. http://www.wapc.wa.gov.au/Publications/742.aspx

Western Australian Planning Commission (2008) *Better Urban Water Management*, Western Australian Planning Commission, Perth, Western Australia. http://www.wapc.wa.gov.au/Publications/1725.aspx

Western Australian Planning Commission (2008) *Planning Bulletin 92 Urban Water Management*. Western Australian Planning Commission, Perth, Western Australia. http://www.wapc.wa.gov.au/Publications/1724.aspx

Websites:

Australian Bureau of Statistics (2008) http://www.abs.gov.au/ausstats/abs@.nsf/mf/3222.0

Australian Government (2008) *Threatened species and ecological communities*. www.deh.gov.au/biodiversity/threatened).

Department of Environment, Water, Heritage and Arts (2008) http://www.environment.gov.au/coasts/pollution/npa/casestudies.html

New WAter Ways http://www.newwaterways.org.au

Swan River Trust (2008) http://www.swanrivertrust.wa.gov.au/Publications/

Western Australian Consolidated Acts. *Swan and Canning Rivers Management Act 2006*. http://www.austlii.edu.au/au/legis/wa/consol_act/sacrma2006313/

Acknowledgements

The Swan River Trust would like to thank the following for their contribution to the development of the SCWQIP.

The project was co-funded by the Australian Government's Coastal Catchments Initiative (CCI) and the Swan River Trust. The Trust acknowledges the project teams of the four supporting projects, also co-funded through the CCI – Department of Water, Department of Planning, Western Australian Local Government Association and Department of Agriculture and Food WA.

These supporting projects are included in full in the appendices of this report. It should be noted that the information in these documents does not necessarily reflect the views of the Trust in its entirety.

Special thanks are due to Dr Jane Chambers, Chairperson of the Swan Canning CCI Steering Committee and Trust member, for her contribution and guidance in the development of the plan.

Compilation of the SCWQIP and CCI projects was coordinated by Marion Cahill.

Other individuals who have provided significant support throughout the development of the SCWQIP include:

Rob Summers
Chris Longley
Peta Kelsey
Shelley Shepherd
Trish Pedelty
Carissa Lloyd
Anthony Sutton
Tracey Perkins
Mark Batty
Felicity Bunny
Vaughn Cox

The Swan Canning CCI Steering Committee also provided support to the development of the SCWQIP, and was comprised of representatives of the following organisations:

Department of Water
Department of Environment and Conservation
Perth Region NRM
Department of Agriculture and Food WA
Department of Planning
Department of the Environment, Water, Heritage and the Arts
Swan River Trust
Western Australian Local Government Association
Water Corporation

Notes

Printed on Cyclus 100% recycled paper