

South West Yarragadee Water Supply Development: Sustainability Evaluation/Environmental Review & Management Programme

Volume 2

SOCIO-ECONOMIC AND ENVIRONMENTAL
REVIEWS

HYDROGEOLOGY AND MODELLING

ENVIRONMENTAL MANAGEMENT PROGRAM

Prepared for
Water Corporation
by Strategen

February 2006



**South West Yarragadee
Water Supply Development:
Sustainability
Evaluation/Environmental
Review & Management
Programme**

Volume 2

SOCIO-ECONOMIC AND ENVIRONMENTAL
REVIEW

HYDROGEOLOGY AND MODELLING

ENVIRONMENTAL MANAGEMENT
PROGRAM

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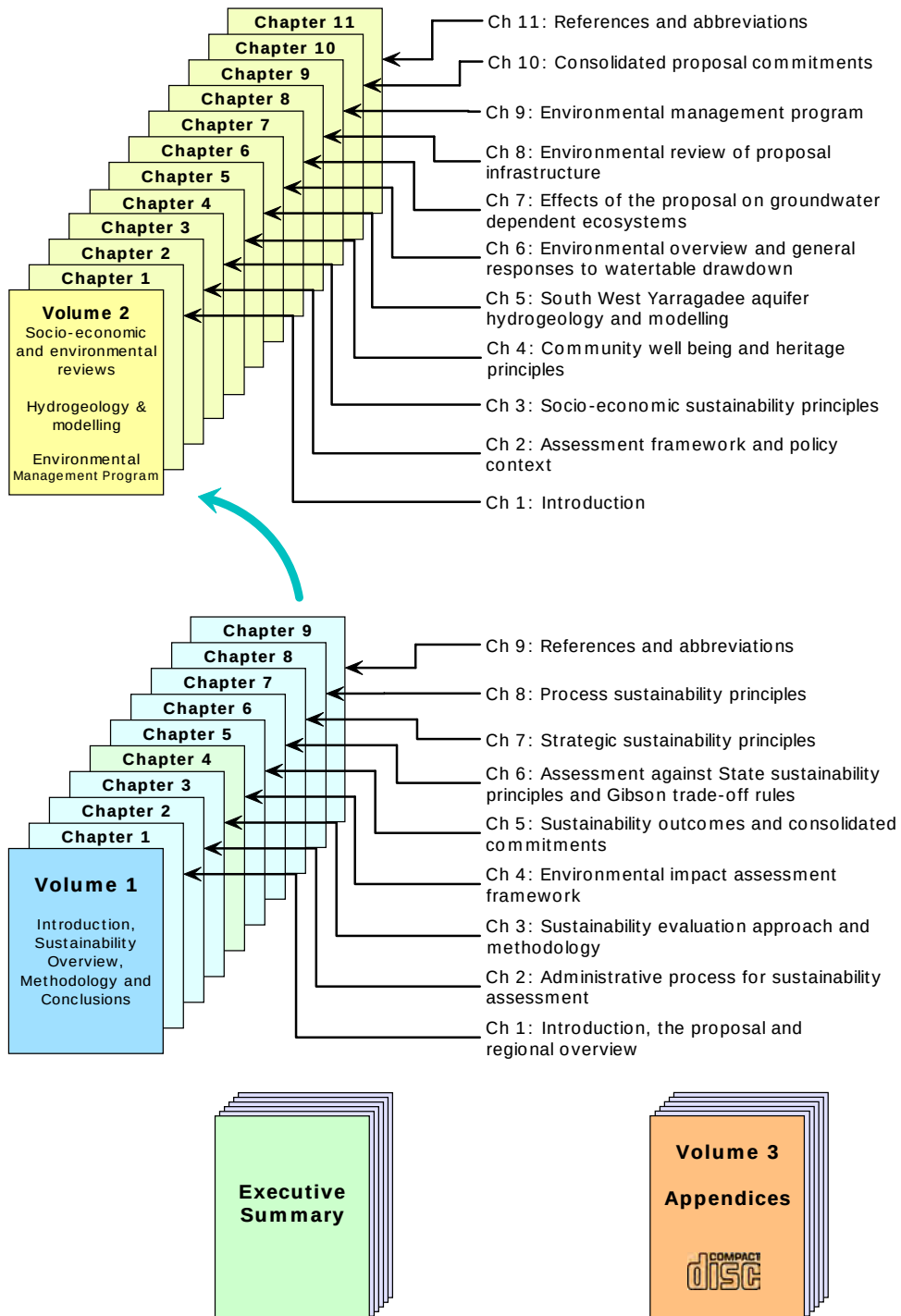
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Client: Water Corporation

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Sustainability Evaluation/ERMP Document Structure

This Sustainability Evaluation/ERMP is presented in three volumes as shown diagrammatically below. The Executive Summary is presented in a separate stand-alone document.



VOLUME 2

Socio-economic and environmental review

Environmental Management program

Chapters:

- 1. Introduction**
- 2. Assessment framework and policy context**
- 3. Socio-economic sustainability principles**
- 4. Community well being and heritage principle**
- 5. South West Yarragadee aquifer hydrogeology and modelling**
- 6. Environmental overview and general responses to watertable drawdown**
- 7. Effects of the proposal on groundwater dependent ecosystems**
- 8. Environmental review of proposal infrastructure**
- 9. Environmental management program**
- 10. Consolidated proposal commitments**
- 11. References and abbreviations**

Key Findings:

The process of evaluating and modifying the proposal against the environmental, strategic, process, socio-economic, and social principles and objectives developed to achieve a sustainable outcome has resulted in a proposal that is considered to meet all the objectives and to satisfy all the principles.

The Yarragadee aquifer is a major groundwater resource within the Southern Perth Basin in the South West of Western Australia. The basin contains about 1.2 million gigalitres of water in storage, of which about 1 million gigalitres is stored within the Yarragadee aquifer. The basin is recharged at a rate of about 374 gigalitres per year through infiltration of rainfall over the region, of which about 151 gigalitres per year is recharged to the Yarragadee aquifer.

Current groundwater use from the Southern Perth Basin is about 72 gigalitres per year, of which about half is taken from the Yarragadee aquifer. Estimates of future regional growth in groundwater use suggest that total use in the region will be about 175 gigalitres per year by 2033.

A numerical computer model of the groundwater systems of the Southern Perth Basin has been developed to allow the drawdown effects of a range of future scenarios of future climate (recharge) and groundwater abstractions to be simulated and examined. The model has been peer reviewed and found to be suitable for considering regional scale responses. However, the model has limitations that result in a degree of over-prediction of watertable drawdown when considered at the local scale. Interpretation of the results is required to consider local scale impacts.

The model has been used to simulate the potential effects of the Water Corporation proposal to abstract 45 gigalitres per year from the Yarragadee aquifer together with future regional growth, and under various possible future rates of recharge. The interpreted modelling results have provided indications of the extent of drawdowns that may be experienced in identified risk areas, and allowed for evaluation of the environmental and socio-economic implications and management requirements.

As a result of groundwater abstraction by the proposal, there will be gradual drawdown impacts on the groundwater dependent ecosystems in several small areas (Poison Gully, Milyeannup Brook, St John Brook, and minimal drawdowns on the Swan Coastal Plain and the eastern Scott Coastal Plain). There will also be construction and infrastructure footprint impacts, which will be managed to minimise impacts and ensure that all species and communities of conservation significance are avoided. The impacts are considered insignificant as they either affect a very restricted area, or are unlikely to be measurable. The impacts do not represent any loss of rare vegetation types, and the types affected are well represented in the region. Impacts on faunal habitat will be limited to small areas. No rare or priority fauna will be significantly affected. The drawdown-generated vegetation changes are expected to be gradual, with down-slope migration of drier environment vegetation types partially replacing more groundwater dependent vegetation types along the lower slopes.

The fundamental approach of the Water Corporation to managing the cumulative drawdown impacts in these areas is to take full responsibility for offsetting and management in those areas where the Water Corporation is the major contributor to the drawdown effect. In those areas where the Water Corporation is a minor contributor to drawdowns, involvement will be limited to monitoring, reporting, and only offsetting the impacts of the Water Corporation proposal.

The Water Corporation is committed to an adaptive management approach based on sound baseline information, pre-agreed management objectives, stakeholder engagement, extensive monitoring and a decision-making process to be followed if unexpected impacts occur. A hierarchy of contingency measures has been developed, ordered by response to impacts of increasing severity as follows:

1. Site-specific contingencies including supplementation of flows in the Blackwood River, St John Brook and Milyeannup Brook if unacceptable flow reductions are recorded in any of these systems.
2. Adjustment of the abstraction regime by altering the proportion of water abstracted from the different units of the Yarragadee Formation. If major adjustment of abstraction is required, additional wells will be drilled at identified contingency well sites.
3. Contingencies developed in consultation with the Monitoring Review Group and the regulatory agencies as required.
4. Temporary reduction in abstraction rates while further investigations into the unexpected occurrence are undertaken.
5. Permanent reduction in abstraction rates.
6. Cease abstraction and investigate alternative sources.

VOLUME 2: SOCIO-ECONOMIC AND ENVIRONMENTAL REVIEW ENVIRONMENTAL MANAGEMENT PROGRAM

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Chapter 1 Introduction

The Sustainability Evaluation and Environmental Review and Management Programme (ERMP) is presented in three volumes with a separate Executive Summary. Volume 1 describes the proposal, the sustainability evaluation process, the assessment of the proposal outcomes against a range of sustainability principles and rules, consolidated commitments and overall sustainability conclusions. Volume 1 also includes the discussion of the strategic and process principles that are relevant as both context for the proposal, (e.g. Government policy and climate change) and in relation to the proposal itself (e.g. extension of the IWSS into the South West and inclusion of climate change in the modelling).

Volume 2 (this volume) contains a description of the aquifer hydrogeology and modelling, the evaluation against the full range of sustainability factors established through the project scoping process, together with the environmental management program.

Volume 3 (Compact Disc) contains the Appendices.

Figure 1.1 Structure and contents of the Sustainability Evaluation & ERMP document

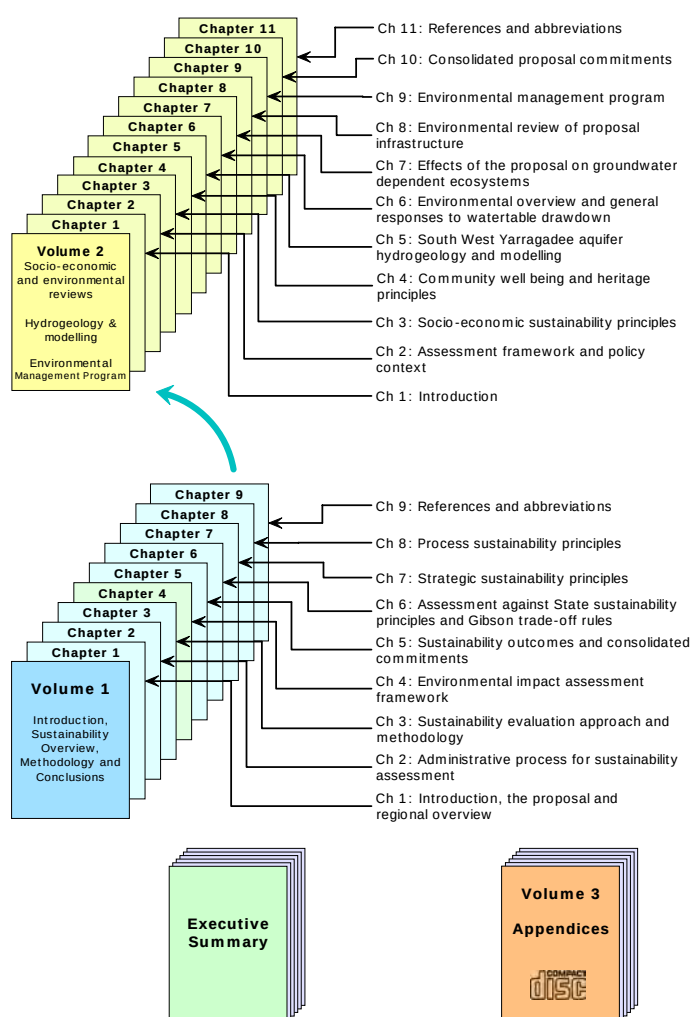
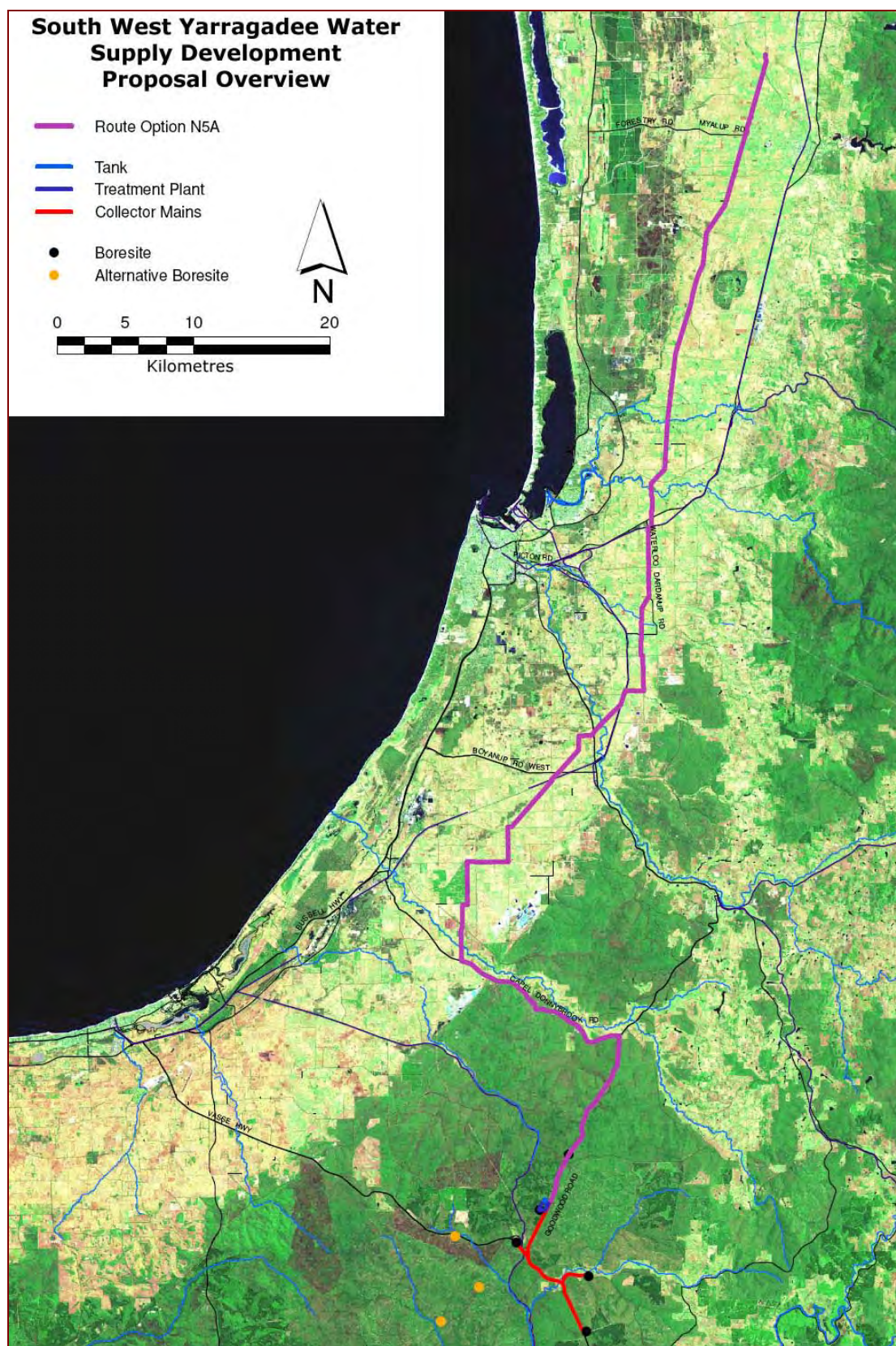


Figure 1.1 shows the structure of the Sustainability Evaluation and ERMP document with the Executive Summary presented as a separate document.

Figure 1.2 Locality plan showing wellfield and nominal pipeline route

1 SOUTH WEST YARRAGADEE WATER SUPPLY DEVELOPMENT PROPOSAL

The proposal involves an extension of the IWSS (Integrated Water Supply Scheme) into the South West of Western Australia based on the development on the Yarragadee aquifer in the Southern Perth Basin. In summary, the components of the development are proposed to be (Figure 1.2):

1. Abstraction of 45 GL/yr from the South West Yarragadee aquifer.
2. Installation of a wellfield near Jarrahwood.
3. A filtration-based treatment plant and storage tank to be located to near the wellfield on Goodwood Rd.
4. A transfer main to take water from the treatment plant to the existing Stirling Trunk Main at Harvey.

A detailed description of the proposal is provided in Volume 1 Chapter 1 Section 2.4 of this evaluation.

2 CONSIDERATION OF ALTERNATIVES

2.1 ALTERNATIVES TO THIS PROPOSAL

The consideration of alternatives to this proposal is addressed in detail in Volume 1 Chapter 1 Sections 1.4.6 and 1.4.7 and Volume 1 Chapter 4 Section 2.1. It is also discussed under the socio-economic principle for *Long-term economic health* in Chapter 3 Section 2.1.4 of this volume, and under the socio-economic principle *Public water supply* in Chapter 3 Section 4.1.

In summary, the Water Corporation approach to meet future growth in demand is to ensure water supply security through diversity, adopting a multi-faceted strategy for supply and demand management.

Implementation of the Water Corporation *Security Through Diversity* strategy (Appendix 8) has led to the development of an integrated resource plan based on viable supply and demand options (Water Corporation 2005a at Appendix 7). The plan draws viable supply and demand options together in an integrated program for their development that takes account of:

- the costs and benefits of each option
- the timeframes involved
- the practicalities associated with implementing each option within specific timeframes
- supply security requirements
- flexibility to deal with deviations from the planning assumptions and other uncertainties.

If the South West Yarragadee Water Supply Development is not approved, then a second 45 GL/yr desalination plant will need to be constructed. Desalination is the only alternative water supply source capable of supplying the required amount of water within an appropriate timeframe to meet the immediate needs of growing demand at the level of security required by the community.

2.2 ALTERNATIVE OPTIONS FOR DEVELOPMENT OF THE PROPOSAL

Within South West Yarragadee Water Supply Development, alternative means of developing the source were considered. The alternatives include options for:

- wellfield configuration, including both the location and the depth of the wells
- pipeline and infrastructure routes
- staging of the supply development
- mitigation and enhancement options
- end use of the supply.

The assessment of alternatives or variations has led to the proposal described in this Sustainability Evaluation/ERMP, which is expected to provide the optimal environmental, social and economic outcome.

3 APPLICATION OF THE PRECAUTIONARY PRINCIPLE

The *Precautionary* principle is one of the sustainability process principles applied in this Sustainability Evaluation/ERMP. Mitigation, risk management and adaptive management of the proposal if it is implemented, were considered to be related to this principle and will be applied in the development and implementation of the proposal.

The following is the definition of the *Precautionary* principle used in this Sustainability Evaluation/ERMP as stated in the *Environmental Protection Act 1986* (EP Act):

“Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

In the application of the precautionary principle, decisions should be guided by:

careful evaluation to avoid, where practicable, serious or irreversible damage to the environment; and

an assessment of the risk-weighted consequences of the options.”

The *Precautionary* principle is relevant to the proposed groundwater abstraction from the Yarragadee aquifer, as the two conditions of threat and scientific uncertainty exist. The *Precautionary approach* factor will address how the Water Corporation has, and will, apply the *Precautionary* principle within this project. Volume 1 Chapter 8 Section 1 describes how the *Precautionary* principle has been applied in the proposal development, and how it will be incorporated into the implementation of the proposal through the adaptive management process.

3.1 SCIENTIFIC UNCERTAINTY

Scientific uncertainty, or incomplete knowledge, is a reality for most decisions about natural resources. Recognising this, it is important not to use “lack of full scientific certainty” as a reason to prevent a project, with substantial benefits to the State, from proceeding. It is equally important that “lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation”. The *Precautionary* principle provides the tools to move forward with a project in a low risk way, with inbuilt mechanisms to change some aspects of the project to avoid, minimise, or mitigate any unacceptable impacts if they occur.

1. Scientific uncertainty could exist regarding:
2. The spatial and temporal extent and rate of watertable drawdown that may occur from the proposed pumping.
3. The susceptibility of the groundwater dependent ecosystems to changes in the watertable regime.
4. The effects of climate on valuable groundwater dependent ecosystems. The predictions of a drying climate suggest that there will be changes to ecological systems in any event. The scientific uncertainty relates to the extent and timing of future climate change, and how ecological systems will respond.

5. The setting of a “benchmark ecological condition” and the evaluation of any consequential impacts of the proposal can be highly problematic. Notwithstanding this, proposals for assessment of future impact within the context of the uncertainty of climate change are described in Volume 1 Chapter 7 Section 2.1.6.

Scientific uncertainty has been addressed in the development of the proposal, to this stage, through scientific studies on the characteristics of the groundwater system, and the presence and response of groundwater dependent ecosystems, particularly in areas of interest. An extensive range of studies has been carried out to improve the level of scientific certainty associated with the proposal. These include drilling and geophysical investigations into hydrogeology: vegetation, flora and fauna surveys: environmental water requirement studies: and economic and social studies into the need for, and implications of, the proposed development. The reports associated with the studies have all been included in the Appendices.

3.2 ADAPTIVE MANAGEMENT

The Environmental Protection Authority (EPA) has indicated, in its position statement about the environmental protection of the Cape Range Province, that adaptive management may be appropriate if the impacts are reversible as follows (EPA 1999).

“This provides a means of considering environmental impacts where a high value element of the environment would be affected by development, and there is lack of knowledge, or insufficient knowledge, or uncertainty about potential impacts and management of impacts and cumulative effects. Where the impacts of a development are reversible, the EPA may advise that the development may be environmentally acceptable if an adaptive environmental management approach, using the Precautionary Principle, is adopted. An example is abstraction of water from wells where if detrimental impacts are detected, abstraction from the well can be stopped.”

The State Sustainability Strategy has “precaution” as one of its process principles:

“Sustainability requires caution, avoiding poorly understood risks of serious or irreversible damage to environmental, economic or social capital, designing for surprise and management for adaptation.”

The adaptive management approach for the implementation of the proposal includes:

1. Design and implementation of a monitoring program: Hydrogeological studies have identified the areas that may be affected by groundwater pumping. In these areas baseline information on the vegetation and flora has been collated, and a monitoring program to identify any changes to the current situation will be finalised in conjunction with the proposed South West Yarragadee Monitoring Review Group.
2. Definition of management criteria and associated management responses: Ecosystems are dynamic. There are natural climate cycles and weather patterns that affect groundwater levels, soil moisture, and vegetation condition. Criteria for acceptable variation in the monitored parameters need to be set, and must recognise the stochastic variability of the system.

The process for setting criteria, and for the ongoing review of criteria and management objectives will be:

- based on technical advice, the Water Corporation will devise draft criteria and management responses

- the draft criteria and management responses will be reviewed and refined in consultation with the proposed South West Yarragadee Monitoring Review Group (Volume 1 Chapter 8 Section 3.2.3) and the Department of Environment (DoE).
3. Development of a contingency plan: If monitoring indicates that pumping is having an unacceptable impact, the rate and location of the pumping can be altered. Monitoring will continue to establish whether or not the environmental limits are met.
 4. Ongoing research into climate change, ecological system dependencies on groundwater and climate, and feedback on monitoring data.

4 WATER CORPORATION ENVIRONMENTAL MANAGEMENT SYSTEM

The Water Corporation has a corporate Environmental Management System (EMS) that provides a structured framework to assist it to proactively manage environmental aspects of its operations. The EMS provides greater assurance that the Water Corporation will achieve the environmental commitments that may accompany approval of a new development.

Chapter 2 Assessment framework and policy context

1 SUSTAINABILITY

1.1 STATE SUSTAINABILITY STRATEGY

The Western Australian *State Sustainability Strategy* was released in September 2003. The strategy discusses the concept of sustainability and how it can be integrated into our government and decision-making. The strategy defines sustainability as “meeting the needs of current and future generations through integration of environmental protection, social advancement and economic prosperity”.

A key aspect of the sustainability evaluation framework proposed by the *State Sustainability Strategy* is a shift away from the approach that tends to be taken within “impact assessments” where the focus is on the negative aspects of impacts and on justifying and minimising them. Sustainability assessment is intended to focus on the positive aspects and the means of creating net economic, social and environmental benefits.

1.2 EPA PRELIMINARY POSITION STATEMENT NO. 6

This statement aims to add to the discussion and understanding of sustainability for Western Australia. It generally discusses environmental issues, the major sectors that need to address sustainability issues, and how these considerations may be integrated into our decision making, education and planning.

The statement includes a “Provisional check list of questions to be asked when proposals are being considered”. The questions relate to the impact the proposal may have on non-renewable and natural resources, energy use, waste production, social impacts, risk management, and use of industry best practice.

2 GROUNDWATER

The Department of Water (DoW), as the State water resource management agency, is responsible for ensuring the sustainable use of the groundwater resource, with a requirement to consider the needs of the environment in its water allocation decision making.

The formal State and Federal policy framework for considering environmental water has advanced over the last decade, beginning with the *National Strategy for Ecologically Sustainable Development* (DEH 1992) and the Intergovernmental Agreement on the Environment in 1992, the Council of Australian Governments water reform agreements in 1994, the *National Principles for the Provision of Water for Ecosystems* (ARMCANZ/ANZECC 1996), and most recently the Water and Rivers Commission *Environmental Water Provisions Policy for Western Australia* (Water and Rivers Commission 2000). Elements of these considerations were included in the 2000 reform of the *Rights in Water and Irrigation Act 1914* (RWI Act) as the principal legislation for managing the taking of natural waters.

The Water and Rivers Commission manages groundwater resources in terms of quantity, through licensing abstractions under the RWI Act. The Act requires all groundwater users in declared areas to have a licence to construct a well¹ and/or abstract groundwater. Licences specify an allocation of water, which limits the amount of water the licensee may take, and is usually specified as an annual volume. Licences usually include other conditions pertaining to the taking and use of the water.

¹ A well is defined under the *Rights in Water and Irrigation Act 1914* as meaning “an opening in the ground made or used to obtain access to underground water.” This definition includes structures commonly known as “bores”.

3 VEGETATION AND FLORA

3.1 NATIONAL STRATEGIES FOR CONSERVATION OF AUSTRALIA'S BIODIVERSITY AND ECOLOGICALLY SUSTAINABLE DEVELOPMENT

The State and Federal Governments have endorsed the *National Strategy for Conservation of Australia's Biodiversity* and the *National Strategy for Ecologically Sustainable Development* that protects biodiversity. The strategies address the conservation of Australia's biological diversity.

The principles adopted by the strategies that are relevant to the South West Yarragadee Water Supply Project are described below:

1. Biological diversity is best preserved in-situ.
2. Although all levels of government have clear responsibility, the cooperation of conservation groups, resource users, Indigenous peoples, and the community in general is critical to the conservation of biological diversity.
3. It is vital to anticipate, prevent and attack at source the causes of significant reduction or loss of biological diversity.
4. Processes for and decisions about the allocation of Australia's resources should be efficient, equitable and transparent.
5. Lack of full knowledge should not be an excuse for postponing action to conserve biological diversity.
6. Central to the conservation of Australia's biological diversity is the establishment of a comprehensive and adequate system of ecologically viable protected areas integrated into sympathetic management of all areas, including agricultural and other resource production systems.
7. The close, traditional association of Australia's Indigenous peoples with components of biological diversity should be recognised, as should the desirability of sharing equitably benefits arising from the innovative use of traditional knowledge of biological diversity.

3.2 EPA POSITION STATEMENT NO. 2

The EPA regards biological diversity as a key environmental factor in the EPA Guidance for the assessment of environmental factors (EPA 2000). The EPA will focus on the principles and the related objectives and actions of the *National Strategy for Conservation of Australia's Biological Diversity*. The EPA, in assessing a clearing proposal outside the agricultural region, will include the following elements in its consideration of biological diversity:

1. A comparison of development scenarios or options to evaluate protection of biodiversity at the species and ecosystem levels, and demonstration that all reasonable steps have been taken to avoid disturbing native vegetation.
2. No known species of plant or animal is caused to become extinct as a consequence of the development and the risks to threatened species are considered to be acceptable.
3. No association or community of indigenous plants or animals ceases to exist as a result of the project.

4. There would be an expectation that a proposal would demonstrate that the vegetation removal would not compromise any vegetation type by taking it below the “threshold level” of 30% of the pre-clearing extent of the vegetation type.
5. Where a proposal would result in a reduction below the 30% level, the EPA would expect alternative mechanisms to be put forward to address the protection of biodiversity.
6. There is comprehensive, adequate and secure representation of scarce or endangered habitats within the project area and/or in areas that are biologically comparable to the project area, protected in secure reserves.
7. If the project is large (and what is meant by large will vary depending on where in the State) the project area itself should include a comprehensive and adequate network of conservation areas and linking corridors whose integrity and biodiversity is secure and protected.
8. The on-site and off-site impacts of the project are identified and the proponent demonstrates that these impacts can be managed.

Biodiversity has two key aspects:

- its functional value at the ecosystem level
- its intrinsic value at the individual species, species assemblages and genetic levels.

3.3 EPA POSITION STATEMENT NO. 3

EPA Position Statement No. 3 (Terrestrial Biological Surveys as an Element of Biodiversity Protection) discusses the principles that the EPA would apply when assessing proposals, which may impact on biodiversity values in Western Australia. The outcomes sought by this Position Statement are intended to:

- promote and encourage all proponents and their consultants to focus their attention on the significance of biodiversity and therefore the need to develop and implement best practice in terrestrial biological surveys
- enable greater certainty for proponents in the environmental impact assessment process by defining the principles the EPA will use when assessing proposals, which may impact on biodiversity values.

3.4 FOREST MANAGEMENT PLAN 2004–2013

The Western Australian Forest Management Plan 2004–2013 (Conservation Commission 2004) has been prepared in accordance with the *Conservation and Land Management Act 1984* (CALM Act) for land vested in the Conservation Commission within the Swan, South West and Warren regions of the State. The plan provides objectives for biological diversity, productive capacity, and ecosystem health and vitality that are considered relevant to this assessment. These include:

- conserve biodiversity and seek to conserve self-sustaining populations of native species and communities
- establish formal and informal reserves to conserve biodiversity
- conserve biodiversity through a diverse representation and distribution of forest structures and understorey seral stages
- promote integrated management across all land categories

- prevent any species moving to a higher category of threat or, in particular, declining to irretrievably low levels as a result of management actions
- protect, and assist the recovery of, threatened and priority species of flora and fauna and ecological communities
- develop an improved understanding of the biodiversity of forest regions and the response of forest ecosystems to natural and human induced disturbance, with a view to improving forest management practices
- regenerate or rehabilitate disturbed forest so as to maintain the productive capacity, flora composition and structural attributes of that forest in the long term
- minimise, as far as is reasonable and practicable, the impact on the health and vitality of forest ecosystems of pathogens and their associated diseases
- protect those areas currently free from *Phytophthora cinnamomi*
- control weeds and pests in forest ecosystems.

3.5 SIGNIFICANCE OF VEGETATION

Vegetation is considered significant by the EPA (Guidance for the Assessment of Environmental Factors Draft February 2003) for a range of reasons including:

- scarcity
- unusual species
- novel combinations of species
- a role as a refuge
- a role as a key habitat for threatened species, or large populations representing a significant proportion of the local to regional total population of a species
- being representative of the range of a unit (particularly: a good local and/or regional example of a unit in “prime” habitat; at the extremes of range; recently discovered range extensions; or isolated outliers of the main range)
- a restricted distribution.

Threatened Ecological Communities (TECs) as listed by the Department of Conservation and Land Management and under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) are of high significance.

3.6 SIGNIFICANT FLORA

The preservation and conservation of flora is covered primarily by the following three Western Australian, and one Federal statutes:

- *Wildlife Conservation Act 1950*
- *Conservation and Land Management Act 1984*
- *Environmental Protection Act 1986*
- *Environment Protection and Biodiversity Conservation Act 1999* (Federal)

Under the *Wildlife Conservation Act 1950* (Wildlife Act), the Minister for the Environment may declare species of protected flora to be Rare Flora if they are considered to be in danger of extinction, rare or otherwise in need of special protection. Such species are referred to as Threatened Flora, and receive special management attention. There are also three categories of Priority Flora defined to cover poorly known species. The categories are arranged to give an indication of the priority for undertaking further surveys based on the number of known sites, and the degree of threat to those populations. A fourth category of Priority Flora is included for those species that have been adequately surveyed and are considered to be rare, but are not currently threatened. Special consideration should be given to the management of these species. CALM lists flora species on Priority lists as set out in Table 2.1.

Table 2.1 CALM flora priorities

Priority	Definition
Priority 1 taxa	Taxa which are known from one or a few (generally less than five) populations which are under threat, either due to small population size, or being on lands under immediate threat
Priority 2 taxa	Taxa which are known from one or a few (generally less than five) populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered)
Priority 3 taxa	Poorly Known Taxa- taxa which are known from several populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered)
Priority 4 taxa	Taxa which are considered to have been adequately surveyed and which, whilst being rare (in Australia), are not currently threatened by any identifiable factors

3.7 CLEARING OF VEGETATION

All clearing of vegetation within Western Australia is regulated by the Environmental Protection (Clearing of Native Vegetation) Regulations 2004.

4 FAUNA

The determination of fauna of conservation significance is assessed under the following Acts:

- Federal *Environment Protection and Biodiversity Conservation Act 1999*; and the
- State *Wildlife Conservation Act 1950*.

These use levels of significance recommended by the International Union for the Conservation of Nature and Natural Resources (IUCN) and reviewed by Mace and Stuart (1994), although the Wildlife Act also has a category of “Other Specially Protected Fauna” that has no equivalent IUCN level. These IUCN categories of significance are shown Table 2.2.

Table 2.2 Fauna significance categories

Significance category	Definition
Extinct	Taxa not definitely located in the wild during the past 50 years.
Extinct in the Wild	Taxa known to survive only in captivity
Critically Endangered	Taxa facing an extremely high risk of extinction in the wild in the immediate future
Near Threatened	Taxa that risk becoming Vulnerable in the wild
Conservation Dependent	Taxa whose survival depends upon ongoing conservation measures. Without these measures, a conservation dependent taxon would be classed as Vulnerable or more severely threatened
Data deficient (Insufficiently known)	Taxa suspected of being Rare, Vulnerable or Endangered, but whose true status cannot be determined without more information
Least Concern	Taxa that are not Threatened

In Western Australia, CALM has produced a supplementary list of Priority Fauna, for species that are not considered Threatened under the IUCN categories, but for which CALM feels there is cause for concern. Levels of Priority are described in Table 2.3.

Table 2.3 CALM supplementary list of Priority Fauna

Priority	Definition
Priority 1	Taxa with few, poorly known populations on threatened lands
Priority 2	Taxa with few, poorly known populations on conservation lands
Priority 3	Taxa with several, poorly known populations, some on conservation lands
Priority 4	Taxa in need of monitoring

In addition to the assessment of fauna under the CALM Priority list and the IUCN categories, some fauna are recognised under international treaties such as the China Australia Migratory Bird Agreement and the Japan Australia Migratory Bird Agreement. Species listed under these agreements are mostly migrants that spend part of the year in each country, although some of the species are non-migrants that occur in both countries.

The Federal Department of the Environment and Heritage has also supported the publication of reports on the conservation status of reptiles (Cogger et al. 1993), birds (Garnett & Crowley 2000), monotremes and marsupials (Maxwell et al. 1996), rodents (Lee 1995) and bats (Duncan et al. 1999). The Threatened Species and Communities Section of Department of the Environment and Heritage has produced a list of Threatened Australian Fauna (Department of the Environment and Heritage 1999), although this list is effectively a precursor to the list produced under the EPBC Act. These publications also use the IUCN categories, although those used by Cogger et al. (1993) differ in some respects as this report pre-dates Mace and Stuart’s (1994) review.

Fauna species included under Federal conservation acts and/or agreements, are of national significance, while those listed as Priority Species, can be considered of regional significance, and possibly of national significance. Species that are not listed under any of the above categories can still be considered of Regional Conservation Significance if they are at the limit of their distribution, or are common, but within a very restricted range.

The IUCN Red List of Threatened Species provides taxonomic, conservation status and distribution information on threatened taxa that have been globally evaluated using the IUCN Red List Categories and Criteria. This system is designed to determine the relative risk of extinction. The main purpose of the IUCN Red List is to catalogue and highlight those taxa that are facing a higher risk of global extinction (i.e. those listed as Critically Endangered, Endangered and Vulnerable). The goals of the IUCN Red List Program are to:

- identify and document those species most in need of conservation attention if global extinction rates are to be reduced
- provide a global index of the state of degeneration of biodiversity.

5 WETLANDS

5.1 WETLANDS CONSERVATION POLICY FOR WESTERN AUSTRALIA

The Wetlands Conservation Policy for Western Australia (Government of Western Australia 1997) is a policy to identify, maintain and manage the State's wetland resource, including the full range of wetland values, for the long-term benefit of the people of Western Australia. The principal objectives of the Government with respect to the conservation of the State's wetland resource are to:

- *prevent the further loss or degradation of wetlands and wetland types, and promote wetland conservation, creation and restoration*
- *include viable representatives of all major wetland types and key wildlife habitats and associated flora and fauna within a Statewide network of appropriately located and managed conservation reserves which ensure the continued survival of species, ecosystems and ecological functions*
- *maintain, in viable wild populations, the species and genetic diversity of wetland-dependent flora and fauna*
- *maintain the abundance of waterbird populations, particularly migratory species*
- *greatly increase community awareness and appreciation of the many values of wetlands, and the importance of sound management of the wetlands and their catchments in the maintenance of those values.* (Government of Western Australia 1997).

5.2 EPA POSITION STATEMENT NO. 4: ENVIRONMENTAL PROTECTION OF WETLANDS

The EPA states "wetlands are widely recognised as important wildlife habitats and as being among the most biologically productive and biologically diverse habitats on the planet".

The EPA has released Position Statement No. 4 (June 2001) to define the important environmental values and functions of wetlands and establish principles for their environmental protection, for the management of wetlands on the Swan Coastal Plain.

The goals of the EPA with regard to wetland management are:

- to protect the environmental values and functions of wetlands in Western Australia
- to protect, sustain and, where possible, restore the biological diversity of wetland habitats in Western Australia
- to protect the environmental quality of the wetland ecosystems of Western Australia through sound management in accordance with the concept of "wise use", as described in the Ramsar Convention, and ecologically sustainable development principles, regardless of land use or activity
- to have as an aspirational goal no net loss of wetland values and functions.

The principles adopted by the EPA for environmental protection of wetlands are:

1. *Ecologically sustainable development*: "using, conserving and enhancing the community's resources so that ecological processes, on which life depends are maintained and the total quality of life, now and in the future, can be increased" (DEH 1992, p 6).

2. *“Wise Use” concept*: defined at the Ramsar Convention as, “the wise use of wetlands is their sustainable utilisation for the benefit of mankind in a way compatible with the maintenance of the natural properties of the ecosystem”. Sustainable utilisation is defined as “Human use of a wetland so that it may yield the greatest continuous benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations”.
3. *Ecosystem management approach*: in assessing proposals, the EPA will use an ecosystem management approach that explicitly recognises the environmental benefits provided by wetlands and wetland processes. Ecosystem management is defined as “the integration of ecological, economic, and social principles to manage biological and physical systems in a manner that safeguards the ecological sustainability, natural diversity, and productivity of the landscape”.
4. *Inter-generational equity*: long-term impacts must be considered so that the wetland values are there for future generations.
5. *Precautionary principle*: As listed in section 4A of the EP Act.

5.3 ENVIRONMENTAL WATER PROVISIONS

The need to improve the approach to water resource allocation and management, and to incorporate the needs of the environment in particular, has been recognised in the *National Principles for the Provision of Water for Ecosystems* (ANZECC/ARMCANZ 1996). The purpose of these principles is to provide policy direction on how the issue of water for the environment should be dealt with in the context of general water allocation decisions. The overriding goal of the principles is to provide water for the environment to sustain, and where necessary restore, ecological processes and biodiversity of water dependent ecosystems.

In Western Australia, the Statewide Policy on Environmental Water Provisions (Water and Rivers Commission 2000) protects ground and surface water dependent ecosystem values through the establishment of ecological water requirements. The policy describes the DoW approach in determining the allocation of water resources to ensure the protection of associated environmental values.

The policy was guided by State water and environmental legislation, the *National Strategy on Ecologically Sustainable Development* and the *National Principles for the Provision of Water for Ecosystems* (ANZECC/ARMCANZ 2000). It considered the environmental water allocation for both surface water and groundwater dependent systems.

Ecological water requirements are determined on the basis of the best scientific information available. A conservative approach is taken to the estimation of ecological water requirements in allocation planning and licensing processes where scientific knowledge of ecosystem requirements is limited. Social water requirements are elements of the existing or historic water flow regime that are required to sustain key social values such as recreation and Aboriginal heritage and culture.

5.4 RAMSAR WETLANDS

Under the EPBC Act, a Ramsar wetland is either:

- an Australian wetland on the List of Wetlands of International Importance kept under the Ramsar Convention; or
- a wetland declared to be a Ramsar wetland by the Commonwealth Environment Minister.

Ramsar wetlands are recognised as a matter of national environmental significance under the EPBC Act assessment and approval provisions. Actions that will have, or are likely to have, a significant impact on the ecological character of a Ramsar wetland require approval from the Commonwealth Environment Minister.

6 ENVIRONMENTAL OFFSETS

6.1 EPA PRELIMINARY VERSION 2 POSITION STATEMENT NO. 9

Environmental offsets aim to ensure that significant and unavoidable adverse environmental impacts are counterbalanced by a positive environmental gain, with a goal of achieving a net environmental benefit. Environmental offsets should only be considered where on-site impact mitigation has been reasonably considered or demonstrated, and where residual adverse impacts are considered significant – but not significant enough to make a project unacceptable.

An offset is an environmentally beneficial activity undertaken to counterbalance an adverse environmental impact, aspiring to achieve no net environmental loss or a net environmental benefit outcome. There are two types of offsets discussed by the EPA.

Direct offsets are environmentally beneficial activities that counterbalance the adverse environmental impact. Examples of direct offsets include: restoration or rehabilitation of ecosystems, management and control of threatening processes (feral animal or weeds), re-establishment of a strategically important ecosystem in cleared areas, and pollutant sequestration.

Contributing offsets are environmentally beneficial activities that do not contribute towards the “no net loss” goal, but instead complement and enhance the direct offset activity. Some examples are: land acquisition for conservation, fencing, buffering, removal of threats, environmental trusts or banking, education and research.

When considering the potential impacts of a proposal, environmental offsets are only one of the approaches that can be taken to mitigate impacts. Mitigation approaches include (in order of preference):

1. Avoidance – avoiding the adverse environmental impact all together
2. Minimisation – limiting the degree or magnitude of the adverse impact
3. Rectification – repairing, rehabilitating or restoring the impacted site as soon as possible
4. Reduction – gradually eliminating the adverse impact over time by preservation and maintenance operations during the life of the action that created the impact
5. Offsets – undertaking activities that counterbalance an adverse, residual environmental impact.

Some of the key principles for considering environmental offsets are:

1. Environmental offsets should only be considered after all other reasonable attempts to mitigate adverse impacts have been exhausted.
2. An environmental offset package should address both direct offsets and contributing offsets.
3. The offset should ideally be “like for like or better”. The offset should be applied to the same type of ecosystem that has been affected. In this context, an ecosystem may be vegetation, habitat, species, landscape, hydrology, or physical area. Ideally, the offset should be applied close to the area of impact. “Like for like or better” is a principle that aims to achieve an improved environmental outcome by enhancing either the quality or quantity aspects of the offset activity beyond “like for like”.
4. Positive environmental offset ratios should apply where risk of failure is apparent.

5. Environmental offsets must entail a robust and consistent assessment process.
6. Environmental offsets must meet all statutory requirements.
7. Environmental offsets must be clearly defined, transparent and enforceable.
8. Environmental offsets must ensure a long-lasting benefit.

The EPA position statement notes that there is a presumption against the EPA recommending approval for proposals likely to cause significant adverse impacts on “critical assets”. The EPA does not consider it appropriate to validate or endorse the use of environmental offsets where projects are predicted to have significant adverse impacts on critical assets. However, the EPA notes that in special circumstances, significant adverse impacts on critical assets may be approved by State Government Ministers to provide an essential community service such as water. Appropriate mitigation and offsets would be conditions of any such approval.

7 CULTURAL HERITAGE

Human interference with Aboriginal sites is an offence under the *Aboriginal Heritage Act 1972* (AH Act), unless authorised as outlined in section 17 of the Act. An application to disturb a site may be made to the Aboriginal Culture Material Committee (ACMC) under section 18 of the Act. The ACMC will not consider such an application unless appropriate Aboriginal people have been consulted.

The Minister for Indigenous Affairs is responsible for the administration of the AH Act. The Minister's responsibility is to ensure that all places in Western Australia that are of traditional or current sacred, ritual or ceremonial significance to Aboriginal people should be recorded and their importance evaluated on behalf of the community.

The Minister considers both recommendations from the ACMC, and the general interests of the community, when making a decision on disturbance of a site. The Minister may also impose conditions on an approval.

The Registrar of Aboriginal Sites is responsible for maintaining the Register of Aboriginal Sites. The Department of Indigenous Affairs has a database of all recorded sites.

Other relevant legislation and policy includes:

- *Australian Heritage Commission Act 1975* (Federal) establishes and regulates powers of the Australian Heritage Commission, whose function includes identification, protection and conservation of the National Estate
- *Heritage of Western Australia Act 1990* regulates the Heritage Council of Western Australia and conservation of places significant to the cultural heritage of Western Australia
- *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (Federal) regulates the preservation and protection of places, areas and objects of particular aboriginal significance
- *Native Title Act 1993* (Federal) recognises and protects native title, and establishes a mechanism for determining claims of native title, and compensation.

Chapter 3 Socio-economic sustainability principles

The socio-economic principles associated with the South West Yarragadee Water Supply Development proposal are addressed in this Chapter.

1 INTRODUCTION

Four inter-related principles relate to the socio-economic considerations for the proposal:

Table 3.1 Socio-economic sustainability principles and factors

Principle	Objective	Key factors
Socio-economic		
1. Long-term economic health	The proposal will assist current and future economic growth, and generate government revenue, business development and investment opportunities within IWSS and South West Region	Economic growth Economic efficiency Economic diversity Business development
2. Public water supply for existing and future generations	The Water Corporation in conjunction with other water supply authorities will supply water of appropriate quality to meet existing and future public demand in the IWSS and South West Region.	Water use efficiency Quality of supply Existing and future needs South West town supplies Drinking water source protection
3. Regional needs	The proposal will be developed such that reasonable regional needs for water, including social, recreational and projected future development needs are not compromised by the proposal.	Regional needs for private water supplies Current key water users
4. Community well being and heritage	The proposal will maintain or improve the quality of life for the Western Australian community	Lifestyle, amenity and recreational use and access Direct and indirect job generation Sense of place Indigenous communities Development footprint

The first three principles are discussed in this chapter as they are principally economically based, albeit with substantial social implications. The *Community well being and heritage* principle is essentially a social issue and is discussed separately in Chapter 4.

1.1 BACKGROUND INFORMATION – WATER USE

Projections for the South West region indicate a base-case increase in groundwater use over the next 25 years of 101 GL/yr (Economics Consulting Services 2003). The increase is dominated by irrigation in agricultural enterprises and urban water use applications. Agricultural irrigation is the dominant water use industry at present. Pasture production for dairy cattle, and horticulture are the largest individual industry sectors.

Growth in agricultural demand will depend on the fortunes of the different rural sectors. When the forecasts of future use were made in 2003 – 04, the outlook for the viticulture, dairy and export vegetable sectors was far more promising than in mid-2005. Vegetable export markets in South East Asia have weakened for Australian producers following the entry of low-cost Chinese products. The world viticulture sector is undergoing rationalisation following an expansionary period that has seen large new plantings in all wine producing countries. Dairy product prices have also softened. The net effect is that the forecast irrigation increase developed by Economics Consulting Services (2005 at Appendix 4) appears to be at the optimistic end of the scale.

Urban water use will increase in line with the population. Mining and industry use will depend on a small number of large consumers. No increase is expected in mining use across the region as a whole, but an allowance was included for a large industrial application.

Since the report from Economics Consulting Services (2003), the possibility of using the South West Yarragadee aquifer as a source for augmenting town water supplies in the Bridgetown area has arisen. This has resulted in the 2030 regional groundwater use estimate being increased to 103 GL/yr.

The difficulty of forecasting where water will be needed, and its source, has resulted in the adoption of a conservative approach based on optimistic assumptions on the agricultural outlook, and on town water supply growth.

1.2 WATER ALLOCATION POLICY

The allocation of rights to use groundwater in Western Australia is made by the State Government, through a licensing regime, in areas where there are competing demands for water use, and water availability is limited. The allocation framework complies with commitments made by the State Government under the 1994 COAG framework. Key issues that relate to government allocation decisions in the South West of the State include:

- the retention of adequate water for the environment
- equity in allocation to promote the most efficient and beneficial water use
- maximising national income and welfare with allocation to “highest and best” use of water
- mechanisms for the initial allocation of rights and subsequent interchange.

The State Government also takes into account a range of other policy commitments, including principles set out in a State Water Strategy and policies on regional development. The key issue in terms of the application by the Water Corporation for a licence to abstract water from the Yarragadee aquifer is that “*reasonable regional needs*” are to be met before water is exported from a *region*.

This requirement to meet “*reasonable regional needs*” potentially conflicts with the COAG commitments, as the reservation of water for local use may inhibit allocation to the “*highest and best use*” as required under the COAG agreement. The extent of this conflict depends on the interpretation of the terms “*reasonable*” and “*region*”. A major consideration in this is alignment with Government regional development strategies, which have strong social objectives incorporated in them.

1.3 ECONOMIC IMPACT OF THE PROPOSAL

Economics Consulting Services (2005 at Appendix 4) reached the following conclusions about the potential impact of the proposal on economic opportunities for regional development:

1. Developing the wellfield and treatment plant and constructing a pipeline into the region provides water supply infrastructure of potential use to a wide range of regional consumers within a reasonable distance of the pipeline.
2. The future water consumers that would appear to be potentially disadvantaged by the supply of water to the extended IWSS are primarily those undertaking irrigated agriculture on the Scott Coastal Plain. If the proposal does not proceed, the availability of water on the Scott Coastal Plain will not increase by the same amount as the IWSS abstraction, because the abstraction for the IWSS is about 30 km from the Scott Coastal Plain. Environmental constraints may only permit several additional GL/yr to be allocated to uses on the plain if the proposal does not proceed. Unless the Water Corporation wellfield is developed, the maximum economic benefit from the resource cannot be achieved for the State, irrespective of where the water is used.
3. If more water is needed in the future by intensive agricultural users in the Cowaramup–Margaret River region, those users may be able to meet the costs of a pipeline to the area from the Blackwood Plateau if locally available water becomes limiting. This abstraction should be managed to minimise competition with the proposed Water Corporation wellfield abstractions.
4. The current outlook for the dairy, viticulture and vegetable sectors is unclear. These sectors have enjoyed robust growth in the past but now face difficult market conditions. Industry rationalisation is occurring. This uncertainty is a significant issue in any consideration of reserving water for future expansion of these sectors.
5. The decision on use of the South West Yarragadee aquifer to supply water to the IWSS is a comparison between a reasonably certain demand and high value use in an integrated supply system with an uncertain and low value use in local agriculture.
6. The key to ensuring that reasonable regional needs are met within the constraints of the national water policy is to ensure that the IWSS becomes a scheme that caters equitably for all its consumers. Government ownership of the supply authorities, and Government control of the tariffs charged for public water supplies will ensure that this outcome is achieved.
7. The transfer pipeline will bring a substantial source into the system, and transport water across the region. This will facilitate local access to good quality water, rather than inhibit it.
8. Extension of the IWSS into the South West Region will provide an opportunity for economically valuable uses in the region that may not otherwise be available. The job creation potential offered by these uses will far outweigh the agricultural job potential that might result. The key to realising this benefit is to ensure the IWSS becomes a scheme that caters equitably for demand centres in the region when compared with the other demand centres forming the IWSS. The economics of provision of public water supplies will ensure this outcome is achieved.
9. Use of an extra 45 GL/a in the IWSS could create a net public benefit of close to \$4.5 billion/yr compared with a maximum of \$1 billion/yr if used locally in high value viticulture enterprises and much less if used in lower value agriculture such as dairy and horticulture.

These conclusions form a major consideration in the discussion on economic aspects of the proposal in the forthcoming sections.

2 SOCIO-ECONOMIC PRINCIPLE – LONG-TERM ECONOMIC HEALTH

The sustainability objective for *Long-term economic health* is:

The proposal will assist current and future economic growth, generating government revenue, business development and investment opportunities within IWSS and South West regions.

The population of Western Australia is continuing to increase, with the South West Region one of the fastest growing areas. This growth and reduced streamflow into surface water storages, have combined to increase the demand for new water sources across the region.

The South West Yarragadee Water Supply Development project will provide an additional 45 GL/yr of high quality water to the Integrated Water Supply System (IWSS). This will provide any future users in the region who have the capacity to meet connection charges an opportunity to connect to the potable water supply.

The sustainability factors associated with this socio-economic principle are:

- *Economic efficiency*
- *Economic growth*
- *Economic diversity*
- *Business and industry development.*

The *Economic efficiency* factor is discussed below. The *Economic growth*, *Economic diversity* and *Business development* factors are highly interrelated and are dealt with jointly in Section 2.2 of this Chapter.

2.1 ECONOMIC EFFICIENCY

Economic efficiency requires that water be made available at the lowest possible cost, whether this is achieved by reduced demand, or new source development. The State has committed to efficient water supply under the COAG agreements and the *State Water Strategy*.

Sustainability objective

The objective for the *Economic efficiency* factor is:

The proposal will provide the most cost-effective water supply source for the State.

There are four aspects to economic efficiency:

- maximising economic output
- equity considerations
- comparative public benefit of alternative uses of the water
- economic cost of the proposed source in comparison to alternative sources.

2.1.1 Maximising economic output

There are two aspects to maximising the value of economic output from the use of water. The first is the maximisation of availability of water, and the second is the allocation of that available water to uses that maximise the value of output. A discussion on how availability can be maximised is beyond the scope of this report, except to note that the main factors that affect this are:

- “competition” with environmental and social *in situ* uses of water
- spatial distribution of groundwater draw points (spreading draw locations yields more water than concentrating them, and provides access to water that may otherwise not be accessed)
- vertical distribution of draw points (spreading abstraction between different aquifers provides access to water that may otherwise not be accessed).

Maximising the value of output is important in considering the potential losses and gains associated with transfer of water from the region. If the water to be transferred is from a source that cannot be developed for local use, then there is no loss to the region in transferring the water. However, there is a loss to the State if it is not transferred for use elsewhere. The benefits are foregone.

In terms of allocation, policies that reserve water for prescribed uses by industry, or by location, have the potential to inhibit the objective of maximum economic output. Reservation requires a reliable prediction of future demand, which has historically proven to be a difficult prediction to make. It is a high-risk approach given the vagaries of industry sector forecasting, and the benefits that may or may not develop. Refusing access to water for a previously unanticipated, but high value *bona fide* proposed new use, because water is reserved for a possible future alternative use, is difficult to justify.

The community places highest value on water for human consumption (drinking) followed by water for sanitation and health, and then by water for essential food production. The value obtained from water use in other industry sectors (concerned with productive enterprise activities rather than human survival) is a function of the value of the output of that sector and the water needed to produce that output. Low water use sectors with high value outputs, such as the services sectors concerned with business, will be high value users.

Urban water sales through a public water supply system generally provide the highest value from the use of water, as this is where the valuable service sector businesses operate. Regional water supply schemes that deliver water to large rural centres that also have industrial and service sectors will also have substantial output ratios. Agricultural enterprises using local water sources can provide moderately high output levels depending on the level of water use and value added in processing. However, the values are generally far lower than enterprises associated with integrated public water supply systems. These conclusions are confirmed by examination of the historical capacity or willingness to pay of the various use sectors.

The IWSS currently services around 78% of the State’s population including Perth, Mandurah, Pinjarra, Harvey and Waroona, towns and properties along the Goldfields pipeline to Kalgoorlie–Boulder, and a major agricultural area system. The additional water will facilitate the expansion of economic capacity of these users, as well as new consumers who access the new infrastructure. The pipeline and wellfield effectively expand the size and reach of the IWSS. Both local town water supply authorities have an increased potential to access the new infrastructure. The connection of these local schemes would see an integrated system covering more than 80% of the State’s population.

2.1.2 Equity considerations

There are conflicts between efficiency and equity goals. *Efficiency* is focused on maximising the output while *equity* is concerned with how the benefits will be shared.

The key aspect to considerations of equity relate to fairness in Government regulation and process in water allocation. Concepts of sharing and compensation emerge as key issues. An Australian Research Centre for Water in Society (ARCWIS 2003) survey of social attitudes found that respondents in the South West ranked environmental needs highly, along with a preference for water allocation that provided local development and employment opportunities. However, while protection of the environment was ranked as highly important, South West residents put local household use and food production for local people ahead of specific environmental concerns. A survey of Perth residents generally supported the importance of environmental allocation, and the right of local people to use of local water before others outside their region. However, ARCWIS acknowledged that cost information was not provided to those surveyed, and people can make different choices when they know the costs.

The ranking of preferred water uses by local respondents does not agree with the best economic use of the water. Supply into a public water supply system for use by anyone with access to that system maximises economic output.

2.1.3 Comparative public benefit of use of the water

An examination of the economic impacts of the proposal shows that increasing the capacity of the IWSS by 45 GL/yr provides the potential for an expansion in the State economy of up to \$4.5 billion/yr in the longer term. This is based on an economic output of metropolitan use of water of \$100/kL/yr (Economic Consulting Services 2005).

The analysis of the value of economic output if 45 GL/yr were used for a range of agricultural applications in the South West is set out in Table 3.2.

Table 3.2 Agricultural Sector Industry Values

Use	Output (\$ per ML)	Industry Value for 45 GL (\$million)
Wine production	26 000	1 170
Milk powder plant and associated dairy farms	4 450	200
Viticulture – wine grapes	4 000	180
Dairy farm	470 – 2050	20 – 92
Potatoes	670	30

The most valuable regional output (in terms of these industry sectors) would be achieved if a 45 GL/yr allocation were used to irrigate wine grapes with associated local wine production. The cost of infrastructure to deliver 45 GL/yr of untreated water for viticulture production to the Cowaramup area could be more than \$100 million. The resulting wine would be valued at \$1.2 billion/yr if it could be sold at an average price of \$10 per litre. Such production is beyond any forecast for the region and raises a number of issues. However, it is a comparative indication of the most valuable local use in agriculture that could be developed. This is substantially less than the \$4.5 billion per year resulting from use in the IWSS.

If an additional 45 GL/yr is not made available to the IWSS, then the likelihood of severe water restrictions for customers of that scheme increases substantially. A study by Economics Consulting Services (2002) indicated that Level 6 restrictions² would cost the community a net \$385 million/yr. Losses would occur from reduced sales in nurseries, turf, reticulation and other garden industry sectors. Associated job losses would be around 3 800 with some compensatory gains occurring in the sectors supplying groundwater services, brick paving and other dry landscaping. Level 7³ restrictions would involve community costs for adjustment of more than \$500 million/yr and nearly 7 000 job losses. The total cost would not be lost to the economy overall because of savings in water consumer costs, which would be reinvested elsewhere, but it would be a real cost to the sectors that are affected. This is best thought of as an adjustment cost with a significant social component.

In comparison with the economic benefits of proceeding with the proposal, the cost for development of the scheme is relatively low. The annualised costs of construction and operation of the scheme are estimated at \$70 million/yr.

Taking these benefits and costs into account, net public benefit of investment in providing 45 GL/yr to the IWSS would be about \$4.5 billion/yr.

2.1.4 Economic cost of alternative water sources

To ensure cost effectiveness, it is important to consider the comparative costs of other water supply source options. Assuming that 45 GL/yr is available from the South West Yarragadee source for the IWSS, the choice is not whether to develop the source, but whether to develop it now, given the alternative sources available to meet IWSS demands.

The South West Yarragadee water development is the most cost effective approach to meet the forecast need of 45 GL/yr within a practically achievable timeframe. Purchase of water allocations from the South West Irrigation District would provide some of the required water at a marginally lower unit cost. Subject to negotiation of appropriate arrangements, 17.1 GL/yr is understood to be available. However, this would not meet the extent of anticipated demand in the short to medium term. Purchase of additional water from the irrigation systems may be possible in the longer term.

A second desalination plant is an option as an alternative water source, but this would be at substantial additional financial cost. An additional desalination plant has a net present value cost at least \$125 million more than the Yarragadee option. This cost is effectively the cost to the Water Corporation if the South West Yarragadee water development does not proceed and future sources have to be brought forward in time to compensate.

More detailed information on alternative short and long term sources is provided in Volume 1 Chapter 1 Sections 1.4.6 and 1.4.7.

² Level 6 restrictions effectively mean only hand watering of lawns and gardens is permitted (total sprinkler ban).

³ Level 7 restrictions effectively prohibits watering of lawns and gardens except with a watering can.

2.1.5 Potential impacts

An evaluation of the range of water sources that might provide the level of water sought demonstrated that the proposal represents the most cost-effective option able to meet the demand timetable. There are other options, but they are more expensive, cannot be implemented in time, or create wider social issues that need to be addressed. Use of the water in the IWSS will result in economically efficient outcomes for the State compared to use of the water by other sectors. Extension of the IWSS into the region will improve the employment opportunities in high economic value industries in the region.

2.1.6 Outcome

The proposal will provide cost-effective water supplies to those communities serviced by the IWSS.

2.2 ECONOMIC GROWTH AND DIVERSITY AND BUSINESS DEVELOPMENT

The Yarragadee aquifer development proposal includes consideration of ways to sustain and enhance economic growth and business diversity of the region and for the customers of the IWSS.

Objectives

The objectives for the factors of *Economic growth*, *Economic diversity* and *Business and industry development* are:

The proposal will facilitate economic growth in the IWSS and South West regions.

The proposal will enhance economic diversity in the IWSS and the South West

The proposal will provide opportunities for increased business activity

These objectives are interrelated and the three factors are discussed together in this section.

2.2.1 Potential impacts

Communities with a diversity of economic enterprises tend to be more stable and less subject to economic cycles. They offer a wider range of employment opportunities, which leads to a more diverse business culture and richer society. Diversity maintains population levels and reduces outward migration. It may even attract inward migration.

Water is vital to many businesses, and vital to all of them if the essential supplies needed for drinking and sanitation purposes are included. While it is a vital input, the cost of water is not a major factor in many businesses. However, the development of businesses such as irrigated broad acre agriculture, where water is a large proportion of the overall production cost, will be inhibited when supply costs are anything but very low.

Water from the Yarragadee Formation is potentially available to consumers in the region who can directly access the aquifer, or those who can connect to a scheme water supply such as the IWSS. Approximately 36 GL/yr is currently drawn from the Yarragadee aquifer to service town supplies and self-supplied enterprises, including agriculture. Development of the proposed wellfield and allocation of 45 GL/yr to the Water Corporation does not preclude future use by the local water boards and other private users. The transfer pipeline brings a substantial source into the system and transports it across the region. This will facilitate local access to a public supply of good quality water, rather than inhibit it.

Although mining in the region uses groundwater, forecasts suggest no increase in demand from this source. Mining activities are expected to come and go, but maintain current levels overall. Forecasts by the South West Development Commission indicate a potential demand from new industries coming to the Bunbury and Kemerton areas. These may be close enough to the South West Yarragadee source to justify, in their own right, a piped supply from that source. However, the pipeline, as proposed, will pass close to these areas and can provide a source of high quality water if required. On balance, the pipeline infrastructure is likely to assist with the development of new industries in the region.

The only future water consumers that may be potentially disadvantaged by the granting of the Water Corporation application are local farmers able to independently access the Yarragadee Formation at a low enough cost to allow irrigation. Availability of groundwater from the Yarragadee aquifer for growth in local agricultural use may be marginally reduced. Licensed groundwater allocations in the region that can be identified as agricultural, total 50.3 GL/yr. Most, but not all, of this is from shallow aquifers other than the Yarragadee Formation. Use is understood to be about 64% of the allocated volumes.

The dominant agricultural uses of water in the region can be summarised as:

- dairy farming in the Scott Coastal Plain, Capel–Ludlow and Quindalup–Vasse areas
- potato farming in the Capel–Ludlow area, Vasse and Scott Coastal Plain
- vegetable farming in the Capel–Ludlow area and Scott Coastal Plain
- viticulture between Cowaramup and Broadwater–Jindong.

The primary area of potential future competition for water between the Water Corporation proposal and agricultural use is the Scott Coastal Plain. Large-scale dairy enterprises have recently become established in this area as a result of the availability of reasonably priced land with access to groundwater for pasture irrigation. Licensed allocations in this area total 8.2 GL/yr. The Water Corporation proposal is not expected to significantly affect availability to other private users in any other areas.

Rejection of the Water Corporation proposal to abstract 45 GL/yr for the IWSS will not increase availability to the Scott Coastal Plain by that same amount. Because the Water Corporation abstraction is about 60 km from the Scott Coastal Plain, rejection of the proposal is only likely to allow several additional GL/yr to be made available for agriculture if the same constraints on drawdown effects on groundwater dependent ecosystems are applied.

Forecasts of future water use for agriculture in the region indicated a demand for an additional 50 – 70 GL/yr by 2030 (Economics Consulting Services 2003). The main increase is expected to come from dairy pastures, vegetables, fruit and viticulture. Since these studies were completed, the outlook for the dairy, viticulture and vegetable sectors has become less promising. Each is facing greater competition in world markets and soft prices. This is a significant issue in any considerations of reserving water for future expansion of these sectors.

2.2.2 Employment

Examination of employment numbers in the South West shows the dominance of the service sector: most jobs are in education, health, financial, property, recreation and cultural services. The relatively low water usage of the service sector is in contrast to the large water consumption in irrigation based agricultural use. A dairy farm employing three people uses about 900 ML/yr of water (the equivalent domestic household water consumption of 7 500 people). For each irrigated hectare in agriculture, more than over 20 people could be supplied with water in an industry sector where water is used only for domestic purposes, including the home and garden of the employees. If employment creation is the goal, water allocation should focus on those industry sectors where water use is low.

Water supplied into a public water supply system will offer substantial economic opportunities in terms of the potential value of output and employment creation. In regions where there are limited public water supply demands, agriculture may provide the most reliable employment opportunities. Agriculture enterprises find local favour because they are a safe form of job creation; they preserve the rural landscape and culture of the region. However, agricultural use of water is at an employment cost to the rest of the community if water availability is a limiting factor.

From a regional perspective, the transfer of water out of the region is effectively a transfer of potential future employment opportunities. While the transfer may result in a net increase in the number of jobs from a State perspective, it will be at the cost of regional job opportunities (albeit of a lower number than the State gain). This is of concern in the region.

The geographic distribution of the water sources and extraction points is a factor that will increase the ratio of potential State jobs gained, to potential regional jobs lost, because of the proposed transfer. The Water Corporation proposal is to take water from the centre of the Blackwood Plateau in an area to which private agricultural users have no access. As discussed in previous sections, prohibiting the taking of water from the proposed wellfield area in the centre of the plateau will significantly reduce the potential water availability in the region, and will result in a loss of economic output.

2.2.3 Proponent sustainability commitments

The Water Corporation has a responsibility to supply water to all customers on terms agreed by the Government. The Water Corporation commits to making water available from the new infrastructure to any consumer prepared to enter into the standard access arrangements that apply to water users in the State. New customers in the region will be eligible to apply for access to the proposed pipeline on the standard terms.

The Water Corporation commits to:

1. The water from the proposal will be available to any consumer prepared to enter the standard access arrangements (user pays cost of connection or as otherwise supported by the Government) and the uniform tariff pricing policy that applies to other IWSS water users in the State.

2. If the groundwater abstraction is reduced by the Water Corporation in accordance with the adaptive management program, or the Water and Rivers Commission reduces the licence allocation in the future, the Water Corporation commits to develop alternative sources to satisfy any shortfall in IWSS supply to IWSS consumers including those in the south west.

2.2.4 Outcome

The proposal will contribute to the maximisation of economic output for the State. It will enhance economic diversity and provide opportunities for economic growth through increased business activity in the South West Region and areas served by the IWSS.

The proposal will facilitate economic growth in the IWSS and South West Region through the provision of expanded water supply infrastructure. The development of new water supply infrastructure enhances water access for those consumers willing to connect to the new services. Businesses that rely on reticulated water supplies will benefit from the infrastructure.

Water users in the urban areas serviced by the two regional water boards (Bunbury and Busselton) will have the opportunity to access additional supply infrastructure, thus ensuring future water supplies in the areas serviced by the boards. Government ownership of all three water supply utilities will ensure that all agencies will share in local water supplies.

Future large industrial customers will benefit in that most, including the Kemerton Industrial Park and light industrial estates around Bunbury, are expected to locate in areas close to the new pipeline. Availability of water will facilitate the establishment of such activities with most industrial processes seeking a reticulated and potable water supply.

Reticulated water supplies are needed by most secondary and tertiary economic activities. These activities will expand the region employment base and business diversity. They will add to the agricultural and mining base.

3 SOCIO-ECONOMIC PRINCIPLE – REGIONAL NEEDS

Sustainability objective

The proposal will be developed such that reasonable regional needs for water, including social, recreational and projected future development needs are not compromised by the proposal.

There are two inter-related factors associated with the *Regional needs* principle, with objectives as listed:

Regional needs for private water supplies

The proposal will be developed such that reasonable regional needs for water; including social, recreational and projected future development needs are not compromised by the proposal.

Impact on current key water users

Water Corporation will seek to understand and articulate the impact of the proposal on current key water users, to ensure that existing water users are recognised and protected from unreasonable impact.

In developing an approach to these two factors, it is important to consider the overall aspect of “Reasonable regional needs” as identified in the *State Water Strategy* (Government of Western Australia 2003).

3.1 REASONABLE REGIONAL NEEDS

The *State Water Strategy* indicates that the South West Yarragadee source should be developed “for the benefit of communities in the South West and those serviced by the Integrated Water Supply Scheme”. While the source is being investigated at this time to meet strong growth in the existing IWSS, once connected, these new assets would also be available to deliver water to high value uses in the South West.

The approach is in keeping with the historical development of the Water Corporation inter-regional water systems. The Goldfields pipeline enabled connection to many rural towns and industries across the agricultural region. The most recent extension of the IWSS, which linked the Stirling Dam into the scheme, resulted in the communities of Harvey, Binningup, Myalup and Waroona being connected.

The South West Yarragadee proposal will extend the existing IWSS from Harvey to the proposed treatment plant near Jarrahood. A transfer main along the Swan Coastal Plain will pass near the growing regional centres of Bunbury, and Capel, and the Kemerton Industrial Park. Water supplied through an integrated system provides the greatest opportunity for economic benefits to both the region and the State. An enhanced water supply will support expansion of the population and a higher overall level of economic activity in the South West.

The *State Water Strategy* sets a requirement that transfer of water from the region should only be undertaken when it can be ensured that “... all reasonable regional needs including social, recreational and projected future development will be satisfied before transfers can take place” (Government of Western Australia 2003).

3.1.1 Considerations in the definition of reasonable regional needs

A position statement on the issue of “reasonable regional needs” (Strategen 2005b at Appendix 9) was developed following consultation with the Community Reference Group. The statement discusses the issues associated with meeting reasonable regional needs. These issues are:

- existing water use and entitlements, and demand projections and scenarios
- maintaining regional development opportunity and balancing of State interests with regional interests
- understanding potential risks and identifying a management regime.

Water use, entitlements and demand projections

Existing water use and entitlements, and regional groundwater demand projections used in this Sustainability Evaluation/ERMP in considering regional needs are based on studies by Economics Consulting Services (2003), modified by more recent information.

The total groundwater use within the South West Region was 72 GL/yr in 2003, which represents about 62% of the licensed allocations (Table 3.3). Half of the groundwater being used is being drawn from the Yarragadee Formation for use in mining, industry, town water supply (independent of statutory water services providers) and irrigation (Scott Coastal Plain and Swan Coastal Plain).

The Leederville aquifer is widely used on the Swan Coastal Plain for town water supply, industrial use and horticulture. The Lesueur Sandstone aquifer is used in the Augusta area for town water supply (Augusta) and, more recently, for dairy farm operations at Forest Grove.

Economics Consulting Services (2003) has estimated the major categories of use within the three proclaimed groundwater areas in the region (Table 3.3 and Figure 3.1). Use has been estimated based on metering of the larger users (approximately half of the current use is metered) and surveys of a limited number of un-metered licensees.

Figure 3.1 Proclaimed groundwater areas



Table 3.3 Licensed groundwater allocations and use (May 2003)

Category of use	Licensed allocations (GL/yr)	Current use (GL/yr)	Current use (% of allocation)	Current use (% of total use)
Town/Industry/Urban	45.1	30.4	67%	42%
Agriculture	50.3	32.1	64%	45%
Mining	18.7	8.9	48%	12%
Other Uses	2.2	0.5	23%	1%
Total	116.3	71.9	61.8	100

In considering regional needs, the groundwater demand projections to be used in the Sustainability Evaluation/ERMP have been based on the studies by Economics Consulting Services (2003), modified by more recent information.

Economics Consulting Services (2003) estimated that growth in demand for groundwater from the Southern Perth Basin would be about 101 GL/yr by 2030. This was adopted in the Water Study Report (Strategen 2004 at Appendix 10) which outlines investigations undertaken during 2002 – 2003. This estimate excludes the components of regional demand expected to be met from surface water and from other groundwater sources outside the Southern Perth Basin. Table 3.4 shows the estimated future demands by sector, with an adjustment made to account for more recent information.

Table 3.4 Current groundwater use and forecast demands

Category of user	Current use GL/yr (2003)	Projection of future use GL/yr (2030) (ECS estimates) [#]	Projection of future use GL/yr (2030) (Updated estimates) ^{##}
Town/Industry/Urban	30	65	67
Agriculture	32	98	98
Mining	9	9	9
Other Uses	1	1	1
Total	72	173	175

Notes: The projections are total use, assuming continuation of current (2003) use.

#: "ECS estimates" refer to estimates made by Economics Research Services (2003). Estimates include current use continuing.

##: "Updated estimates" are the Economics Research Services (2003) estimates, updated to include Bridgetown, Hester, Boyup Brook, Greenbushes, Balingup, Mullalyup and Kirup water supplies. Estimates include current use continuing at 72 GL/yr.

Balancing State interests with regional interests

An important consideration in assessing the merits of the Water Corporation proposal is the need to maintain regional development opportunities in the South West. In identifying the Yarragadee Formation as a major supply option, the *State Water Strategy* discussed the issue of inter-regional transfer of water and noted that:

"The transfer of water from one area to another has long been a part of the history of water supply in this vast State. The most well known and visible example is the Goldfields Pipeline that transfers water more than 550 kilometres from Mundaring Weir in the Darling Range outside Perth to Kalgoorlie Boulder in the Goldfields, supplying water to towns and communities along the way."

There are many examples of inter-regional transfers in Western Australia, including the Pilbara in the North West, a scheme extending deep into the Great Southern from the Harris Dam outside Collie, while the most recent is water transferred to Perth from the Stirling Dam on the Harvey River through a 105-kilometre water pipeline.

Water is a State resource. Western Australia has low, intermittent and unreliable rainfall making it critically important that the State's water resources can be accessed and transferred beyond regional boundaries. This ensures a more reliable and equitable access to water for all. Importantly, in undertaking this process all reasonable regional needs including social, recreational and projected future development will be satisfied before transfers can take place. To achieve this requires consultation to ensure that needs are understood and reasonably addressed."

A major consideration in the determination of State and regional benefit is management of the resource to maximise the amount of water that can be made available for use. The Water Corporation proposal has been deliberately located in the State forest area of the Blackwood Plateau to minimise impact on water availability to other users, and to maximise overall water availability from the resource.

The limited access to State forest, and its remoteness from farming areas where water is required for regional use, is likely to limit abstraction from this resource for uses other than public water supply.

Understanding and managing risks

The provision of water to the IWSS can present a risk to potential future regional needs if a decision is made based on currently available information that may be imperfect or incomplete. However, risks can be addressed if they are understood and managed through an adaptive process that includes contingencies developed to deal with them, if they materialise.

The principal risks are:

- the proposed abstraction causing impacts beyond those expected
- unforeseen regional needs or growth in regional needs occurring at a rate faster than currently anticipated.

Responses to these risks, if they did materialise, may include use of currently unallocated surface water in the region, and temporary use of unused public water supply allocations, or both.

Discussions at the *Reasonable Regional Water Needs Forum* in Busselton (June 2005) indicated that there are alternative sources available, as a contingency measure, to meet regional demands. These options are not universally available to private users, being dependent on the proximity of the user to the alternative source, and their financial ability to access it. Nonetheless, an important outcome was recognition that the region is not entirely dependent on the Yarragadee Formation as its only future water supply source.

Application of reasonable regional needs principles

The “reasonable regional needs” position statement (Strategen 2005b) notes that the following basic principles should be applied to considerations of how reasonable regional needs should be addressed. These principles are:

- water is a State resource available for the maximum benefit of all Western Australians
- Western Australians need reliable access to water
- water must be permitted to be transferred between regions
- current use and users should be protected
- consultation should be undertaken to ensure regional needs are understood and reasonably addressed
- decision making on water allocation should consider the values and priorities of the regional community
- it is unreasonable to transfer water and leave a region deficient in water for any use that is of similar or higher social and economic value
- risks, and the mechanisms to manage those risks, must be clearly stated and understood
- known benefits should not be foregone to preserve uncertain future benefits
- to maximise the benefits, water should be used efficiently.

In considering the issues and competing interests in application of the above principles, the proposal provides considerable opportunity for additional water to be made available from the groundwater resources of the Southern Perth Basin.

The water available is expected to exceed current and near-future demand by a significant margin. The Yarragadee aquifer system will be significantly under-utilised in the short to medium term, at the regional scale. Therefore, based on current demand projections, any competition between the various demands is not expected to occur for several decades. This provides an opportunity to develop the resource and learn more about its behaviour under higher levels of abstraction than it is now experiencing. The information gained will be invaluable in making future management decisions about limits on use.

3.1.2 Preferred approach to addressing reasonable regional needs

Figure 3.2 is a diagrammatic representation of the preferred approach to addressing reasonable regional needs, developed in consideration of the above principles and information on the South West Yarragadee resource. Under this preferred approach the following sequence of events is envisaged:

1. 45 GL/yr will be transferred to the IWSS servicing the areas north of Harvey in the first instance, commencing in 2009.
2. As regional public water supply demands grow, regional use of water from the IWSS is also expected to meet those needs.

3. By 2033, it is expected that a substantial proportion of the 45 GL/yr provided to the extended IWSS from the Yarragadee aquifer will be used locally to meet some of public water supply, or high value needs, of the South West, and only the remaining portion would be transferred out of the region.

Figure 3.2 Preferred approach to address regional needs from the Southern Perth Basin



Note: Diagrammatic only, not to scale.

If there is future competition for groundwater between the extended IWSS and other regional demands, then this competition should be addressed on the specific merits and impacts of the competing uses, under the circumstances that apply at the time and in accordance with the reasonable regional needs principles outlined above. This approach will ensure that the opportunities for regional development will be maximised, particularly in terms of job creation, and in a manner that is beneficial to both the State and the South West Region.

As detailed in Volume 1 Chapter 8 Section 3.2.6, the Water Corporation has committed to the preparation of a South West Public Water Supply Future Plan, if the South West Yarragadee Water Supply Development project is approved.

3.2 REGIONAL NEEDS FOR PRIVATE WATER SUPPLIES

Sustainability objective

The proposal will be developed such that reasonable regional needs for water; including social, recreational and projected future development needs are not compromised by the proposal.

3.2.1 Potential impacts, mitigation and enhancements

Perceived impacts

One of the major concerns of all five South West communities is the perception that *“if the water gets removed from the South West there will not be enough water for growth in the South West and future opportunities for growth will be lost”*. This is a concern about water availability and access, particularly in terms of water needed for future growth and development opportunity.

All South West communities researched were concerned about whether existing water users would be affected by the proposal, with concerns centring on drawdown effects for those currently using groundwater and future water availability for agricultural sectors. They were also uniformly concerned about futures foregone, in other words whether there would be enough water from the Yarragadee aquifer for the future needs and growth in the region.

Augusta

The Augusta community was concerned about agricultural viability if the proposal restricted water for farmers in East Augusta and on the Scott Coastal Plain – futures foregone in the Augusta area. Futures foregone were related to the health of the Blackwood River, as the health of the community is considered reliant on the health of the river. One of the main questions was:

- *Will we be able to build an eco-tourism industry to bring us economic prosperity?*

Bunbury

Community concerns in Bunbury were also about futures foregone; whether there would be enough water for residential, industrial and agricultural uses in the future, and potential impacts on bore access. There was also interest in the proposal's impact on regional viability. One of the main questions was:

- *Will smaller towns be affected to the extent that their impact has a flow-on effect to Bunbury?*

Busselton

The Busselton community's concerns were related to futures foregone, agricultural viability and infrastructure issues. One of the main questions was:

- *Will this put our over-stretched infrastructure under even more pressure?*

Margaret River

The Margaret River community was concerned about futures foregone and agricultural viability. The questions were:

- *Will our agricultural base be impacted to the point where its viability will be threatened?*
- *Will farmers still be able to earn a living on the land if water is restricted?*
- *Could this proposal ultimately impact on the preservation of rural land for agricultural purposes? If so, what would that mean to our community viability and identity?*

Nannup

The community concerns were slightly different in Nannup. Agricultural viability and security of water were areas of concern and futures foregone reflected the following:

- *Will we have enough water for growth for agriculture, residential development and tourism in the future?*
- *We have a small rate base so need to maximise the opportunities we have.*
- *This is about survival, and knowing we have sufficient water available to support intensive dairy, intensive agriculture, potential industry, and housing development.*
- *Want to be sure that our community won't have big problems.*

The Scott Coastal Plain farmers contacted during the Sustainability Evaluation process are not in favour of this proposal proceeding. They perceive that adverse social impacts may potentially be experienced if this proposal adds to existing constraints on water availability and restricts expansion of agricultural practices on the plain. One result of the decreased water availability for future growth may be changes in land use (plantation timber farming rather than irrigated agriculture) or farm management practices (increased water use efficiency).

If land use changes occur, there may be a small economic flow-on effect to the Shire of Nannup. However, in comparison to the much larger impacts of the Regional Forest Agreement on the Shire, and its ability to manage those impacts, the scale of potential impact of the Water Corporation proposal is expected to be small, and will not affect any existing uses.

A summary of the potential positive and negative benefits of the proposal for South West communities are summarised in Table 3.5.

Table 3.5 Net benefit summary of water availability and futures foregone for selected communities of the South West

Community	Expected positive effect	Expected neutral effect	Expected negative effect	Net outcome
Augusta	South West Public Water Supply Study will enable water quality issues to be addressed.	Proposal does not affect water availability now or into the future. Water quality issues would continue to exist, with or without the proposal. Significant impacts on the Blackwood River are not anticipated. Contingencies are planned if significant impacts were to occur.		Positive – Neutral Unlikely to experience an impact positive or negative from this proposal but water quality of supply to be addressed.

Community	Expected positive effect	Expected neutral effect	Expected negative effect	Net outcome
Bunbury	Better water supply to industrial areas through extension of the IWSS would allow growth. Regional communities which Bunbury relies on would benefit through improved access. Removes potential limitations to growth in town water supply through restriction on Aqwest to access sources outside the Bunbury water area.			Positive
Busselton	Potential benefit of access to an extended IWSS to meet future growth and development. Removes potential limitations to growth in town water supply through restriction on Busselton Water Board to access sources outside the Busselton water area.			Positive
Margaret River	Potential benefit of access to an extended IWSS to meet future growth and development.	Water availability for farmers is an issue because of diminishing surface water sources and controls on dams. This proposal will not have an effect on water availability for farmers.		Positive – Neutral
Nannup	Good information on land use practices and water management and modelling expertise is available for benefit of Scott Coastal Plain farmers. Mitigation offered by the proposal also mitigates existing and future agricultural use of Yarragadee aquifer.	No impacts on Blackwood River social values, or tourism and recreation, or directly on the Nannup Shire.	Perceived incremental constraints to water availability for Scott Coastal Plain farmers. Potential indirect flow-on effect to Nannup Shire from potential changes to land use on Scott Coastal Plain. Extent of impact expected to be small.	Positive with small Negative

Futures foregone – water availability

Early in the evaluation process, the issues of futures foregone, and maintaining sufficient water in the South West to satisfy reasonable regional needs, were raised by the South West communities. The responses to these concerns are:

- the proposal does not significantly reduce availability of water from the Yarragadee aquifer that is required to satisfy reasonable regional needs
- the proposed *Reasonable regional needs* policy principles (Section 3.1 of this Chapter) protect these needs
- extension of the IWSS to the region will enhance public water supply to towns in the South West

- the proposed South West Public Water Supply Future Planning Study will ensure South West public water supply is planned, and demand met
- public water supply will be enhanced for some South West towns from the South West Yarragadee aquifer or other sources.

In addition, the Water Corporation is committed to assisting Scott Coastal Plain farmers to improve water availability to that area. The key means of achieving this is through commitments to undertaking the proposed Sustainability Initiative (Volume 1 Chapter 7 Section 4.1.1).

Impact of this assessment on regional needs

The environmental impact assessment of the proposal in this Sustainability Evaluation/ERMP includes abstraction of water from the Yarragadee aquifer to meet reasonable regional needs into the foreseeable future. The conclusion of this evaluation is that the environmental outcomes of this mitigated proposal are acceptable. However, if the environmental outcomes of the proposal are considered environmentally unacceptable by the EPA, it is highly likely that abstraction of groundwater from the Yarragadee aquifer to meet reasonable regional needs will also be unacceptable.

There are three basic reasons why this may be the case:

1. The additional potential impact of the proposal on the coastal plains is relatively small when compared with those related to existing use and future reasonable regional needs (such as irrigated agriculture).
2. The Water Corporation has made substantial commitments to mitigate (including offsetting) the small, but potentially cumulative, environmental impacts of the proposal (including those related to satisfying reasonable regional needs). It is unlikely that those managing lower value uses, such as the proposed irrigated agriculture, could afford to fund the required levels of mitigation and offsetting. In effect, it could be argued that the Water Corporation proposal would also enhance the sustainability of abstraction to satisfy reasonable regional needs.
3. The proposed adaptive management approach, driven by the Water Corporation, will ensure that appropriate investigation and monitoring of impacts and investigations and management responses to those impacts are developed through an open, transparent stakeholder engagement process. This process avoids “regulatory grid lock” as it accepts that there are uncertainties in forecasts of impacts, but provides for implementation of the proposal with appropriate caution.

3.2.2 Monitoring, adaptive management and accountability

The Water Corporation proposes to monitor the trends in water usage from the Yarragadee aquifer as well as potential future reasonable regional needs for water from this aquifer. The proposed Monitoring Review Group (Volume 1 Chapter 8 Section 3.2.3) will be involved in the development of the monitoring program and the assessment of monitoring results.

The monitoring results will be published in an annual Sustainability Report for the project if implemented (Volume 1 Chapter 8 Section 3.2.4).

The Water Corporation is committed to the continued collection of information within an adaptive management process, and recognition of the principles of reasonable regional needs in the supply of water from the Yarragadee aquifer.

3.2.3 Proponent sustainability commitments

The Water Corporation commits to supporting the application of reasonable regional needs principles through the following:

1. The water from the proposal will be available to any consumer prepared to enter the standard access arrangements (user pays cost of connection or as otherwise supported by the Government) and the uniform tariff pricing policy that applies to other IWSS water users in the State.
2. If the groundwater abstraction is reduced by the Water Corporation in accordance with the adaptive management program, or the Water and Rivers Commission reduces the licence allocation in the future, the Water Corporation commits to develop alternative sources to satisfy any shortfall in IWSS supply to IWSS consumers including those in the south west.
3. Undertake a South West Public Water Supply Future Planning Study to provide a plan for meeting the future public water supply needs in the South West. This plan would be undertaken in conjunction with Aqwest and Busselton Water Board and involve extensive consultation and market surveys of community satisfaction with the water planning and management. The plan would investigate and address the following:
 - 3.1. future public water supply demand
 - 3.2. potential sources for public water supply
 - 3.3. source development program for public supply
 - 3.4. assessment of quality and security of existing public water supplies
 - 3.5. program for upgrading existing quality and security of public water supplies where required
 - 3.6. program for new connections to the extended IWSS or other sources.

The Water Corporation will undertake the proposed Sustainability Initiative (Volume 1 Chapter 7 Section 4.1.1) with the express intention of providing information to support maximising the availability of water for use in the region.

3.2.4 Outcome

The formulation of the proposal has resulted in gathering of information that has enabled more reliable assessment of environmental risks, and reduced uncertainty in forecasting impacts of the proposal. The proposed adaptive management approach, and commitment to the Sustainability Initiative, will provide further knowledge of the Yarragadee aquifer resource. This increased knowledge will allow greater certainty in the sustainable management of this resource.

The proposal is not anticipated to significantly constrain water availability from the Yarragadee aquifer to meet reasonable regional needs.

The proposal has the potential to enhance overall water availability from the aquifer through:

- mitigation and offsetting of cumulative impacts
- application of an adaptive management approach that provides for increased knowledge and certainty while proceeding cautiously
- location of the proposal wellfield away from existing and proposed agricultural areas

- application of contingency actions, including development of other water sources, in case of unforeseen impacts
- research into acid sulphate soils and associated management issues
- provision of an information base to support water management and maximisation of water availability.

Based on current information, it is not anticipated that competition between the proposal and regional needs will occur in the near future, and may be several decades away. However, it is apparent that expansion of water use in localised areas of the Scott and Swan Coastal Plains may be limited by environmental constraints, even in the absence of the IWSS abstraction.

3.3 IMPACT ON CURRENT KEY WATER USERS

Sustainability objective

Water Corporation will seek to understand and articulate the impact of the proposal on current key water users, to ensure that existing water users are recognised and protected from unreasonable impact.

3.3.1 Potential impacts, mitigation, enhancements and monitoring

The three potential areas of impact of the proposal on current key users are:

- water availability
- drawdown interference
- seawater intrusion.

Water availability

Water from the Yarragadee Formation is potentially available to consumers in the region who are able to either directly access the aquifer, or connect to a scheme water supply such as the IWSS. Approximately 36 GL/yr is currently drawn from this aquifer to service many of the town supplies, as well as self-supplied enterprises, including agriculture. Development of the proposed wellfield and allocation of 45 GL/yr to the Water Corporation does not preclude future use by the local water boards or other private users. The Government could not deny local public water supply demands while transferring water out of the region for public water supply. The proposed pipeline will facilitate local access for centres seeking a public water supply of good quality water, rather than inhibit it.

The proposal will not result in any reduction in water availability to existing users in the region, in terms of existing water allocations and levels of use. The issue of impacts on potential growth in regional water use has been discussed in the preceding sections.

Drawdown interference

The proposed Water Corporation abstraction will generate drawdowns that will propagate across the region, and there is potential for some level of drawdown interference with existing private wells, particularly in the Yarragadee Formation. The Water Corporation wellfield has been located as far from existing users as practically possible, as the primary means of minimising drawdown interference with those users, and causing reductions in well yield. The extent of this drawdown interference is minor. The proposed approach to deal with drawdown interference is discussed in detail in Chapter 5 Section 4.11.

Seawater intrusion

The cumulative effect of Water Corporation abstractions, together with other regional groundwater abstractions, has potential to cause an inland movement of the interface between the fresh groundwater in the regional aquifers, and seawater from the oceans into which the aquifers discharge. The expected extent of the intrusion is relatively small, but may affect some existing wells in the Bunbury area. The main wells at risk for seawater intrusion are those of Aqwest, which are located at the end of the Yarragadee aquifer flow system, and which have experienced minor impacts from seawater intrusion in the past. This issue is discussed in detail in Chapter 5 Section 4.12.

No impacts of seawater intrusion are expected in other areas, as the seawater interface is located many kilometres offshore, and any inland movement is not expected to affect existing wells.

This phenomenon does not occur suddenly. Appropriate monitoring of movement of the interface can provide early warning of the potential impact. The effects of seawater intrusion can be managed simply by relocation and management of the affected wells. Other engineering techniques, such as barrier injection wells, are available if more sophisticated solutions are eventually required. It is expected that the impacts of the Water Corporation proposal will take many years to manifest. This will allow sufficient time to monitor and plan a management response if this is required.

3.3.2 Proponent sustainability commitments

The Water Corporation commits to:

1. If existing Aqwest (formerly Bunbury Water Board) or Busselton Water Board public water supply wells are affected by saltwater intrusion (to the extent that they no longer meet the water quality criteria for potable use) caused by the Water Corporation groundwater abstraction from the Yarragadee aquifer, the Water Corporation will provide alternative means for accessing an equivalent amount of potable water at an equivalent cost, through either:
 - provision of funding to install new wells into the Yarragadee aquifer further inland
 - direct supply of water to the relevant company by the Water Corporation.

4 SOCIO-ECONOMIC PRINCIPLE – PUBLIC WATER SUPPLY

There are several inter-related factors associated with the *Public water supply* principle, which have overlapping objectives as listed below:

Existing and future needs for public water supply

This is an amalgamation of two factors associated with the principle of *Public water supply*. The combined objectives of the *Existing and future needs* and *South West town supplies* factors are:

The proposal will contribute to meeting the existing and forecast demand for public water supply in the IWSS and the South West under a range of possible future climate scenarios.

Water will be available to meet reasonable regional public water supply needs.

This proposal will increase supply security for South West towns.

Equitable access to water

The Water Corporation will ensure fair and equitable access to water for domestic use for all Water Corporation customers.

Water use efficiency

The Water Corporation will encourage the efficient use of water.

Quality of supply

To supply high quality water to customers.

Drinking water source protection

The Water Corporation will work with the Water and Rivers Commission, Conservation Commission and CALM to protect recharge areas.

Public water supply for existing and future generations

The Water Corporation in conjunction with other water supply authorities will supply water of appropriate quality to meet existing and future public demand in the IWSS and South West Region.

Each of these sustainability factors is discussed in turn in the following sections in the context of the Water Corporation preferred approach to addressing reasonable regional needs outlined in Section 3.1.2 of this Chapter.

4.1 EXISTING AND FUTURE NEEDS FOR PUBLIC WATER SUPPLY

Sustainability objectives

The proposal will contribute to meeting the existing and forecast demand for public water supply in the IWSS and the South West under a range of possible future climate scenarios.

Water will be available to meet reasonable regional public water supply needs.

This proposal will increase supply security for South West towns.

This section discusses the amalgamated factors of *Existing and future needs for South West towns and South West town supplies*. The section also presents and addresses the results of the social impact assessment (Synnott Mulholland Management Services 2005) which examined concerns about water availability and access, particularly in terms of water needed for future growth and development opportunities.

4.1.1 Existing and future environment

Existing and future South West towns water demand

The Water Corporation supplies water to most South West towns, with the exception of Busselton and Bunbury, which are supplied by separate independent statutory water boards. Harvey, Waroona, Binningup, Myalup and Hamel are already connected to and supplied from the IWSS. The Great Southern Towns Water Supply Scheme involves the supply of water from the Harris Dam, near Collie, to Collie and 31 other towns throughout the southern wheatbelt area.

Other towns are currently supplied by individual local dams or groundwater systems. In June 2005, Manjimup, Boyup Brook, Hester, Greenbushes, Balingup and Bridgetown were all reliant on surface water sources: all were on severe water restrictions due to low rainfall and resultant decreased streamflow into dams.

A new \$70 million interconnected water supply scheme is planned to supply Bridgetown, Hester, Boyup Brook, Greenbushes, Balingup, Mullalyup and Kirup, to provide long-term supply reliability equivalent to, or greater than, that planned for the IWSS. Additional water will be supplied from either a new dam on either Gregory or Nannup Brook, or from wells drawing from the South West Yarragadee aquifer. In the short term, the Water Corporation attempted to avoid restrictions by pumping water into local water supply dams from nearby creeks and streams during the 2005 winter.

The current use, allocations, and future reservations of water for public water supplies for South West towns are summarised in Table 3.6 below. In addition to the licensed allocations, reserve allocations for future growth in public water supply demand are recognised by the Water and Rivers Commission.

Table 3.6 Town water supply allocations (July 2005)⁴

Water service provider	Current licensed allocations (GL/yr)	Allocations under application (GL/yr)	Reserve allocations (GL/yr)	Total allocations (GL/yr)	Current use (GL/yr)
Bunbury	11.3	1.9	0	13.2	6.8
Busselton	18.0	0	2.0	20.0	4.0
Water Corporation	10.5	0	4.4	14.9	6.7
Total	39.8	1.9	6.4	47.9	17.5

Economics Consulting Services (2003) estimated that growth in demand for groundwater from the Southern Perth Basin for town, industry, and urban use would be about 65 GL/yr by 2030. With the recently emerging potential to supply Bridgetown, Hester, Boyup Brook, Greenbushes, Balingup, Mullalyup and Kirup water supplies, the 2030 demand for this sector is estimated to be about 67 GL/yr.

Water supplies of communities potentially affected by the proposal

The social impact assessment conducted by Synnott Mulholland Management Services (2005) presented information on the views of South West communities on existing and future water usage.

Augusta

Population growth in the Augusta region has been approximately 3.8% (CSIRO 2004). Sixty-six percent of the population of the Augusta region lives in the town (approximately 1000 people) with the remaining one-third in rural areas (ABS 2002). The Augusta community is focused on the future economic viability of the town – making businesses more viable and creating more jobs. The community sees eco-tourism as an area of opportunity. Continued vitality of the Blackwood River is seen as essential for eco-tourism opportunities to be developed.

The town water supply comes from two sources: Leeuwin Spring, near the Lighthouse at Cape Leeuwin, and groundwater extracted from a deep bore into the Leederville aquifer at Fisher Road. The town reticulation is partitioned so that water from the two sources does not mix. Sufficient water is available: however, water from Leeuwin Springs is considered “hard”. This hardness does not exceed the NH&MRC (National Health and Medical Research Council and Agriculture and Resources Management Council of Australia and New Zealand) Drinking Water Guidelines (NH&MRC/ARMCANZ 1996) but does cause dissatisfaction with Water Corporation customers as it affects appliances and plumbing fittings. Interim measures to reduce hardness have been put in place.

Future water availability for the Augusta town supply is unlikely to become an issue as the Fisher Road wellfield could be extended to provide additional water within planning already being undertaken by the Water Corporation.

⁴ Data provided by Department of Environment.

Bunbury

The City of Bunbury has a population of 30 000, within the Greater Bunbury urban area population of 50 000. The City of Bunbury expects the Greater Bunbury population to rise to more than 130 000 by 2030 (City of Bunbury 2005). This growth rate (almost 4%) is significantly higher than the medium scenario population projection rate of 1.7% used by the Department for Planning and Infrastructure, and may be optimistic.

Bunbury has a diverse economy with significant employment sectors including retail, manufacturing, construction, health and community services, property and business. The wealth of the region is driven traditionally by mining, agriculture and forestry, and the port activity generated by these sectors. Knowledge industries are on the rise in Bunbury and have the potential to be an important economic driver in the future. The tourism industry is also growing as Bunbury is increasingly recognised as a short-break destination. In recent years, visitor numbers in Bunbury have risen by 11%/yr (City of Bunbury 2005).

City of Bunbury water comes from the Yarragadee aquifer and is supplied by Aqwest under its licensed allocation. Outer communities are supplied by the Water Corporation from the Yarragadee and Leederville aquifers. Availability and quality of city water supplies are not limiting factors, but the lack of a water supply at the Kemerton Industrial Estate is an inhibiting factor to future expansion of the industrial estate. The boundary of the Aqwest water area is set under the *Water Boards Act 1904* and limits its supply activity to that area.

While Bunbury can currently access sufficient water supplies through its wellfield, as the city grows and draws more water, there may be a need to import water from outside the Aqwest water area.

Busselton

In 2001, Busselton had a population of 22 060 people. The town of Busselton is one of the fastest growing Western Australia country towns (of those that are not considered to be regional centres), and the Shire is the sixth fastest growing rural Shire in Australia (Shire of Busselton 2005). The town provides services to people from the Augusta–Margaret River Shire. Population swells to approximately 60 000 during peak holiday times.

The makeup of the Shire population reflects a broadening of the area's economy and increasing employment opportunities, with a corresponding reduction in the significance of the area's "retirement" function.

Busselton water supply is drawn from the Yarragadee aquifer and supplied by the Busselton Water Board under its licensed allocation. The Busselton Water Board allocation was recently increased to 18 GL/yr and a 2.0 GL/yr "reserve" is acknowledged by the Water and Rivers Commission as being available to the Board. Current use is about 4.0 GL/yr. The availability and quality of water are not considered limiting factors for the town.

As with Aqwest, the Busselton Water Board operations are limited to a water area under the *Water Boards Act 1904*.

Margaret River

The population of Margaret River is approximately 6 300, with 60% in the town and 40% in rural areas (CSIRO 2004). The town recorded greater growth than the Shire population with an average annual growth rate of 6.9%. The Shire aim is to spread development through hamlet or node development so it is not all focused on the Margaret River township. The intention is to avoid strip development and preserve a distinct agricultural break between towns (J McAll, Shire of Augusta–Margaret River, pers. int. 2005). The Shire wishes to preserve its agricultural character.

The Shire of Augusta–Margaret River has no significant underlying aquifers, and relies entirely on surface water. Over the years, farmers have captured the surface water by damming streams on their properties, but are now facing increased controls from both the Shire and the Water and Rivers Commission, prohibiting landholders from building dams without approval. These constraints place a limitation on the growth of water dependent industries.

A preliminary proposal to build a pipeline to provide a reticulated irrigation supply from the Lesueur Sandstone aquifer, east of the town, has been proposed as an option.

Current town water supply to Margaret River, Prevelly, Gnarabup and Cowaramup is from the Ten Mile Brook Dam. Witchcliffe and Gracetown are not connected to a reticulated water supply scheme.

Nannup

The population of Nannup Shire was 1211 in 2001 (ABS 2002), but is now closer to 1400, with 600 in town and 800 in rural areas (B. Dunnet, pers comm. 2005). Following the trend elsewhere in the South West, the age profile shows a reducing trend for the age groups of 20-24 and 25-29. Recent times have seen an influx of retirees to the area, and the sale of many rural subdivisions to house them, with more subdivisions planned (S. Collie, pers. int. 2005).

Eighty-five percent of the Shire is under forest: however the rich soils, high rainfall and a favourable climate provide ideal conditions for a wide range of agricultural activities, including dairying, beef cattle, horticulture, aquaculture, agroforestry, viticulture and hobby farming.

There are few secondary industries within the Shire, and the lack of employment opportunities is affecting the Shire's population growth. Tourism plays a large part in the life of the community. In its marketing material the Shire of Nannup is described the as "The Garden Village" (Shire of Nannup 2005).

Nannup town water supply comes from Tanjannerup Dam, which has sufficient capacity to support further expansion of the town and has good water quality. People living in the semi-rural subdivisions in the area supplement their water supply with bores and rainwater tanks.

There is strong community appreciation of the importance of the rural sector, and its role in keeping the local economy moving. In particular there is community concern for the future growth of Scott Coastal Plain agriculture. Access to water, and, security of access (including allocation licence conditions and terms), are the main issues for Scott Coastal Plain farmers. The community feels that investment in the area would be affected if the security of allocation licences was threatened. The South West Yarragadee Water Supply Development is seen as another threat in an already difficult situation.

Farmers on the Scott Coastal Plain source their water from both groundwater and surface water, and orchardists to the north and east of Nannup use only surface water. Many of the farmers would like to increase their groundwater allocations in order to expand their businesses. The delays in obtaining a decision on allocations, and the requirement to demonstrate the extent of environmental impact of the additional allocations, are felt to restrict water availability and therefore economic growth.

The South West Yarragadee proposal is seen as further restricting water availability in this area.

Existing and future IWSS water demand

The existing and future IWSS water demands are discussed in detail in Volume 1 Chapter 1 Section 1.4.1.

4.1.2 Potential impacts, mitigation, enhancements and monitoring for South West communities

As a result of the internal sustainability evaluation process carried out by the Water Corporation, the proposal to abstract water from the South West Yarragadee Formation for the IWSS has developed into a plan to extend the IWSS into the South West Region. The proposal will contribute directly to achievement of the *Public water supply* sustainability objective of meeting existing and forecast demand for public water in the IWSS through extension of the IWSS into the region. This will provide major water transfer infrastructure in the South West Region that will offer an opportunity for development of a public water supply system in the region. In the short term, water will be transferred from the South West to meet IWSS demands north of Harvey. Water will remain available for growth in public water supply demand in the South West in all the centres that are currently serviced by public supplies. There will also be sufficient water available in the South West for the development of local town water supplies, for those centres that do not currently have public supplies (e.g. Witchcliffe).

The proposed South West Public Water Supply Future Planning Study (Volume 1 Chapter 8 Section 3.2.6) will develop a plan to meet future public water supply needs in the South West, and for how they will be delivered. The plan will provide certainty to the South West, and will help to resolve the concerns of futures foregone, benefit and equity, and accommodating reasonable regional needs.

4.1.3 Proponent sustainability commitments

See commitment to undertaking the South West Public Water Supply Future Planning study in Volume 1 Chapter 8 Section 3.2.6 and the commitments in Chapter 3 Section 3.2.3.

4.1.4 Outcome

The proposal will:

- provide a major increase in the supply capability and reliability of the IWSS
- provide major infrastructure to support the development of high-value economic development in the region through the provision of an integrated public water supply system
- result in a comprehensive plan to provide for the future development of regional public water supplies.

4.2 WATER USE EFFICIENCY

Sustainability objective

The Water Corporation will encourage the efficient use of water.

4.2.1 Background

Water use efficiency essentially means using less water to achieve the same outcomes. Achievement of efficient water use requires a balanced package of elements if substantial long-term gains are to be achieved. The Perth's Water Future study (Water Authority 1995a) set the basic parameters for the WaterWise program, currently being pursued by the Water Corporation with the objective of achieving a substantial reduction in per capita water use.

A major plank of the *State Water Strategy* is water conservation and efficiency. The Government has set a target of reducing per capita water use from the current unrestricted level of 180 kL/person/yr to 155 kL/person/yr by 2012.

The Water Corporation has committed to achievement of that strategic objective. The target is to be included as a condition of Water Corporation water allocation licences. It is expected that this would apply to the licence being sought for the South West Yarragadee Water Supply Development.

4.2.2 Potential impacts and mitigation and enhancements

Demand management program for the IWSS

The Water Corporation is undertaking an extensive demand management program to support achievement of the 155 kL/yr per capita water use target for the IWSS. These program initiatives include:

- the Government WaterWise Rebate Scheme, launched as part of the *State Water Strategy* in 2003
- various WaterWise programs including guidance for plumbers, garden centres, display villages and garden irrigators
- water efficiency advertising and community awareness campaigns
- support for, and leadership in, establishing a new, nationally endorsed, mandatory water conservation labelling system for appliances
- WaterWise Schools Program
- working with industry sectors such as the landscaping, nursery, drilling, and turf-growing industry associations to develop water conservation approaches that will benefit those industry sectors
- supporting research into water use efficiency measures
- water recycling initiatives that will recycle approximately 20% of wastewater suitable for use in industrial processes for use in industries that currently use public water supplies
- managed aquifer recharge using treated wastewater.

The current water restrictions have resulted in per capita water use reducing to about 150 – 155 kL/yr, demonstrating the achievability of this target. However, the target is set for water use under a situation where restrictions are lifted. The intention of the WaterWise Program is to provide the means of achieving this target.

4.2.3 Proponent sustainability commitment

No commitment required as the Water Corporation has committed to undertaking a demand management program to support achievement of the 155 kL/yr per capita water use target for the IWSS, under the *State Water Strategy*.

4.2.4 Outcome

Increasing efficiency in water use in the IWSS through progressive implementation of a demand management program.

4.3 QUALITY OF SUPPLY AND DRINKING WATER SOURCE PROTECTION

Sustainability objectives

To supply high-quality water to customers.

The Water Corporation will work with the Water and Rivers Commission, Conservation Commission and CALM to protect recharge areas.

4.3.1 Background

Through its Customer Charter (Water Corporation 2005b) the Water Corporation has committed to provide the community with water that is safe to drink, and complies with directions on drinking water quality made by the Minister for Health. These directions are based on the NH&MRC/ARMCANZ drinking water guidelines (NH&MRC/ARMCANZ 1996), which are based on regular reviews of public health issues within Australia.

4.3.2 Potential, impacts and mitigation and enhancement

Influencing activities

Water in the South West Yarragadee aquifer is of a quality highly suited for public drinking water supplies. The water is well within NH&MRC/ARMCANZ (1996) guidelines for all constituents, with the exception of iron, for which the water will need to be treated. The resource is one of the highest quality groundwater sources in Western Australia. Table 3.7 shows the comparison of groundwater abstracted from the Crouch Road test well with the guideline values.

Table 3.7 Comparison of South West Yarragadee aquifer water quality with drinking water guidelines

Parameter (mg/L unless otherwise stated)	Well samples (Crouch Road test well)	ANZECC guideline value ⁵
Total dissolved solids	190	1000
Electrical conductivity (mS/m)	33 – 41	
pH	5.29 – 6.16	6.5 – 8.5
Calcium	0.75 – 1.2	
Potassium	13 – 14	
Magnesium	5.5 – 6.0	
Sodium	43 – 48	300
Silicon	27	
Sulphate	7.5 – 8.5	400
Nitrate + Nitrite	<0.05 – <0.08	11.3
Chloride	80	400
Total alkalinity as CaCO ₃	14 – 15	
Hardness as CaCO ₃	25 – 27	500
Turbidity (NTU)	0.3 – 6.0	5
Iron	0.161 – 0.24	0.3
Phosphorous	<0.002 – 0.005	
Arsenic	<0.002	0.007
Manganese	0.020 – 0.050	0.1
Aluminium	0.012 – 0.018	0.2
Zinc	0.04 – 0.08	5
Lead	<0.002	0.01

Iron is a common natural occurring constituent of groundwater. Its occurrence throughout the Perth Basin is highly variable and it is difficult to predict the likely concentrations in water from future production wells. It is of aesthetic concern because it causes staining in laundry and when used on gardens. A level of 0.3 mg/L is considered an adequate level to avoid laundry staining. Removal of iron is a simple process consisting of aeration and filtration. Aeration (exposure to air) of water containing iron converts the iron in its soluble form to iron oxide (insoluble form) through a simple oxidation process. The insoluble iron oxide is then easily removed by filtration, leaving the water iron free. In the production wells proposed to be drilled, iron values may exceed the guideline values.

The Yarragadee aquifer occurs at depth and is confined over most of its area by overlying formations, including several relatively impermeable formations. This means it is well-protected against contamination from activities on the land surface. Most of the recharge zone is within State forest, where the potential for contamination from the surface activities is also low. The resultant high level of protection is an important positive aspect of the use of this major groundwater resource.

⁵ Several parameters do not have guideline values because there are no specific health or aesthetic consequences associated with the presence of the substance in drinking water.

Impact and management

The South West Yarragadee aquifer is an ideal source for high quality public drinking water supplies because of its naturally high water quality, and the high level of natural protection against potential contamination. The proposal to develop the South West Yarragadee aquifer includes a filtration plant to be located north of the source works to remove naturally occurring iron (Volume 1 Chapter 1 Section 2). The water will also be chlorinated to remove any pathogens that may enter the water after pumping from the aquifer, and fluoridated in accordance with Government policy.

Management of catchments to achieve water quality protection is administered under the *Country Areas Water Supply Act 1947*, which provides for by-laws to be made to control potentially polluting activities within declared public water supply catchment areas. The legislation is administered by the Water and Rivers Commission. Much of the catchment is vested with the Conservation Commission and managed by the Department of Conservation and Land Management (CALM).

Declaration of the catchment under the *Country Areas Water Supply Act 1947* will not affect ownership of any land within the catchment. However, the by-laws may restrict some potentially polluting activities from being undertaken. Development of the by-laws and catchment water quality protection plan would be undertaken in close consultation with all landholders within the proposed catchment area to be declared.

Water from the Yarragadee aquifer is a strategically important resource with the capability to contribute to both regional and State needs for high quality public water supplies.

4.3.3 Proponent sustainability commitments

The Water Corporation commits to working with the relevant agencies to arrange declaration of a public water supply catchment area over the relevant portions of the Yarragadee aquifer recharge zones.

4.3.4 Outcome

The outcome of use of the Yarragadee aquifer as proposed, will be a high-quality public water supply suitable for use with minimal treatment. The administration of catchment protection under the *Country Areas Water Supply Act 1947* will assist in ensuring the quality of water is maintained for the future.

Chapter 4 Community well being and heritage principle

1 INTRODUCTION

Water is a pervasive resource that plays an important role in a range of community values and activities, and makes a major contribution to community well being. Water is used for a wide variety of economic and non-economic uses. It is used for lifestyle and recreational purposes, and it provides cultural and heritage values to communities. Water makes a major contribution to the quality of life of those communities with reliable access to good quality water.

The abstraction of groundwater to enhance some of these uses or values may have a detrimental effect on others. Resolution of the conflicting interests in water is one of the major challenges for water resource managers. A consideration of the impacts of the Water Corporation proposal on the social values of water, in terms of community well being and heritage, is important.

1.1 RELEVANT PRINCIPLES, FACTORS AND OBJECTIVES

Sustainability principle and associated factors

The project sustainability objective for the principle of *Community well being and heritage* is:

The proposal will maintain or improve the quality of life for the Western Australian community.

The sustainability factors and associated objectives related to this principle are:

Lifestyle amenity and recreational use and access

Water Corporation will determine, through community consultation, whether community members anticipate changes to lifestyle, amenity, or recreational use and access as a result of the proposal, to ensure that negative impacts do not occur from this project and to explore potential positive outcomes.

Sense of place

Water Corporation will determine through community consultation, whether community members with strong attachments to places and heritage values anticipate changes to those places and values as a result of the proposal, to ensure that negative impacts do not occur from this project and to explore potential positive outcomes.

Indigenous communities

Water Corporation will undertake to protect and avoid disturbance of Aboriginal heritage sites.

The Corporation will explore potential positive outcomes for and with the Indigenous communities.

Development footprint

The construction and maintenance of infrastructure will cause minimal permanent disturbance to the community.

Another related factor and associated objective, addressed in Chapter 3 Section 4.1 is:

Existing and future needs for public water supply

The proposal will contribute to meeting the existing and forecast demand for public water supply in the IWSS and the South West under a range of possible future climate scenarios.

1.1.1 Other relevant principles and factors

The key process principles relevant to this topic and the conduct of social impact assessment were *Stakeholder engagement* and *Accountability* which state:

The Water Corporation will seek the views of stakeholders and take them into account in the development, construction and operation of the proposal.

The Water Corporation will report publicly on its sustainability performance and provide public access to information on the proposal.

The *Stakeholder engagement* and *Accountability* principles, and associated factors, are addressed in Volume 1 Chapter 8 Sections 2 and 3.

1.2 SOCIAL IMPACT STUDIES**1.2.1 Earlier studies**

A survey of social values (ARCWIS 2003), an issues scoping study (Water and Rivers Commission 2003) and an economic value study (Economic Consultancy Services 2003) were undertaken in 2002 and 2003. The social value survey was part of the community involvement and social analysis process. It focused on the values and views of residents of the South West and Perth on the proposal to export water to the IWSS, and explored circumstances in which attitudes to the proposal may change. The issues scoping paper was prepared by the Water and Rivers Commission. It described hydrological, ecological, social, allocation planning, and communication issues that arose from consultation with a broad range of stakeholders through public and individual meetings, and from ongoing liaison with groups and individuals with an interest in the development (Water and Rivers Commission 2003).

1.2.2 Recent social impact study

Synnott Mulholland Management Services (2005) conducted a three-phase social impact assessment which employed the following methodology:

1. Community scoping and profiling, and identification of social variables of interest.
2. Scoping of impacts and projection of estimated effects.
3. Recommendations for mitigation, remediation and enhancement, and monitoring.

Phase one: Community scoping and profiling

The assessment process integrated data from different methods and sources, both primary and secondary, to enhance validity. These included:

- telephone and community surveys
- focus groups
- more than 85 interviews with interest groups, business and community groups, local residents and other stakeholders
- presentation and discussion of findings at Community Reference Group meetings to gather additional feedback
- reports from earlier studies related to this project
- literature reviews, Australian Bureau of Statistics data, demographic and economic reports
- planning reports generated by the communities themselves.

Multiple data sources have brought diverse viewpoints into the process, and have helped to validate viewpoints through triangulation. For example, community findings from the scoping phase were discussed at the Community Reference Group to test accuracy of conclusions drawn, and community interviews which dealt with the same topics from different perspectives allowed issues to be fully understood.

The community interviews followed a discussion guide and covered:

- their community – aspirations, current issues, current priorities, issues in relation to water in general and the Yarragadee proposal specifically
- community views about the proposal and what is driving those views
- risks and benefits of the proposal
- acceptability of the risk, and what might change their view of acceptability
- notion of reasonable regional needs
- how to safeguard community interests
- community views about how changes could be managed to optimise desired outcomes.

Additional information sources included community surveys undertaken by the Water and Rivers Commission and the Water Corporation, and community submissions made during the public comment period related to the Scoping Report (October – November 2004).

Phase one identified three social variables to be further investigated:

1. Sense of place and social values.
2. Futures foregone.
3. Benefit and equity in terms of accessing water.

Phase two: Social impact assessment

Phase two involved further studies to fully understand the three social variables identified in Phase 1:

- sense of place and social values
- futures foregone
- benefit and equity in relation to water access.

At this time, work was also progressing in the environmental and economic impact assessment studies, and aquifer modelling. Those results were critical inputs, helping to clarify:

- areas of likely drawdown and extent of drawdown under a worst case scenario
- extent of drawdown under a worst case scenario
- extent of likely environmental impact under a worst case scenario
- areas that appear unlikely to be affected.

In addition, the project team was developing a conceptual approach to reasonable regional needs, and the extension of the IWSS infrastructure further into the South West. These were relevant to the assessment of issues of futures foregone, and benefit and equity in relation to water access.

Phase two involved more stakeholder contact to obtain specific information on social impacts as well as a review of academic and research literature covering past studies of the tourism industry in the South West, studies from the Regional Forest Agreement process, heritage and cultural studies, regional planning studies, maps, government policies and management plans, and data from the Australian Heritage Database and the Heritage Council of Western Australia.

This phase also involved a more detailed study of Nannup. In the Phase one research, some community members identified Nannup as the community most vulnerable to impact through this proposal. Its proximity to the Blackwood River – a resource of perceived high social value – provided a second rationale for examining any potential impact on Nannup. A third rationale is the potential for social impact on the Scott Coastal Plain, which is a major agricultural community within the Nannup Shire. This detailed study drew on Australian Bureau of Statistics census data for the years 1991, 1996 and 2001, supplemented by interviews with several community development leaders in Nannup. Secondary data sources included: regional planning documents (e.g. Warren–Blackwood Regional Planning Strategy; Warren–Blackwood Rural Strategy), social impact studies conducted for the Regional Forest Agreement and literature on resource-dependent communities.

The views of Perth residents were also explored at this stage through focus group discussions. These group discussions were deliberately held late in the process, to take advantage of information from the extensive environmental research studies and aquifer modeling.

Phase three: Recommendations for monitoring and mitigation of social impacts

The third phase focused on developing mitigation and management options for the social impacts related to the proposal. Preliminary ideas about monitoring and mitigation, and the community's expectations in relation to these, came from the community interviews in Phase one. Analysis of social impacts determined which factors required a monitoring or mitigation solution to achieve a net benefit outcome. Where mitigation was being considered, the community's views were considered, alongside lessons learned from other communities who have faced change.

2 LIFESTYLE, AMENITY AND RECREATIONAL USE AND ACCESS

Sustainability objective

The sustainability objective for the factor of *Lifestyle, amenity and recreational use and access* is:

The Water Corporation will determine, through community consultation, whether community members anticipate changes to lifestyle, amenity, or recreational use or access as a result of the proposal, to ensure that negative impacts do not occur from this project and to explore potential positive outcomes.

2.1 EXISTING ENVIRONMENT

The dominant social values of the Blackwood Plateau and its surrounds are:

- Aboriginal sites of cultural significance (dealt with under *Indigenous communities* factor, Section 4)
- historic features and cultural sites of early settlement (dealt with under *Sense of place* factor, Section 3)
- tourism and recreation values
- areas of high scenic quality.

Collectively these contribute to the *Sense of place* factor, and the latter two particularly relate to the *Lifestyle, amenity, and recreational use and access* factor.

2.1.1 Tourism and recreation

In Australia, the tourism industry sector is valued at over \$70 billion/yr, a third of which is from nature, eco- and adventure tourism (Department of Industry, Tourism and Resources 2003; Wegner et al. 2005). A significant portion of the tourism industry in Australia revolves around wildlife, natural areas and their associated attractions (Hughes & Carlsen 2004). This is also true of the South West Region.

A 2004 study by Tourism Western Australia and the University of Western Australia found that tourists most likely to visit the South West Region were either looking to “relax and take it easy” or seeking outdoor adventure activities (cited in Tourism WA 2004). Both of these types of visitor rely heavily upon the pristine natural environment of the South West, including its coastal areas and inland forests and rivers.

Within Western Australia, the South West Region is second only to the Perth region in terms of visitor numbers. In 2003/04, a total of 2 150 100 visitors stayed overnight in the South West (cited in Tourism WA 2004). Most (92%) were domestic visitors (inter- and intra-state). The South West is most often visited in January, followed closely by April, July and October. These times primarily correspond with school holidays, and show the popularity of the region for families throughout the year. The peak time for international visitors is from October to December (36%). The annual value of tourism to the South West is estimated at \$588 million (SWDC 2004).

Tourism in the Lower Blackwood–Augusta area

The town of Augusta is at the mouth of the Blackwood River. The Scott National Park abuts the Hardy Inlet near Molloy Island. The Scott River, a tributary of the Blackwood River, passes through the national park.

There are a number of popular tourism and recreation activities that take place on and around the Blackwood River and Hardy Inlet. These activities include water skiing, eco-cruises and fishing. Water skiing is limited to an area of approximately 1 km² near Molloy Island. The ski destination has become increasingly popular with people from outside the locality, as recent low rainfalls in the Perth region have meant less water in the dams nearby.

Two companies based in the Augusta area operate sightseeing tours on the Blackwood River. Both (Augusta Eco Cruises and Miss Flinder's Eco Tour) promote themselves as eco-cruises. The Miss Flinder's Eco Tour operates from September to May and typically attracts about 4000 people over the tour season.

Fishing has been a popular activity on the river for many years. Today only one commercial operator remains, operating in the Hardy Inlet. Two fishing tour operators work in the Hardy Inlet and Blackwood River. They provide mainly catch-and-release fishing trips for tourists (Department of Fisheries 2004).

Other river-based activities include yachting, with regular meets held each Sunday by the local Augusta Yacht Club. A commercial houseboat operator maintains two houseboats on the Blackwood River, available for hire all year. In addition, CALM manages a number of picnic and camping facilities on its lands along this section of the Blackwood. Popular activities include canoeing, fishing, mountain-bike riding and swimming.

Tourism in the Lower Blackwood–Nannup area

Much of the land on either side of the river in the Nannup area is either State forest or National Park managed by CALM. The proposed Blackwood River National Park – covering 15 600 ha – was one of the parks to result from the implementation of the Regional Forest Agreement (RFA).

Both active and passive forms of recreation are popular on this section of the Blackwood. These include canoeing, dinghy racing, bushwalking, swimming, bird watching, wild flower viewing, and fishing.

Two canoe operators are based on the river and both are open all year. Increased river flows due to winter rains make July the most popular time for canoeing. One operator is based at River Road, and the other is located at Poison Swamp Road, just upstream of the confluence of the Blackwood River with Poison Gully, to take advantage of the summer groundwater discharge to the river from further upstream.

The Power Dinghy Racing Club organises two events around Nannup each year – the Blackwood Classic 250 in October, and the Nannup Cup in June.

Another popular activity along the river is fishing for marron during the 16-day marron season in late January. The bulk of the marron is caught downstream from Nannup. Fishing is seen by many as an activity in which the whole family can participate. This recreational activity is important given the increasing number of families visiting the area.

Many of the accommodation providers in the area also rely on the river. Some accommodation is very close to the river (e.g. Blackwood River Holiday Cottages, Jalbarragup Homestead) offering visitors the opportunity to experience the river. The CALM- managed Sues Bridge camping and picnic area is on the banks of the Blackwood River (Sues Road off Brockman Highway). It is a large site with camping areas dotted through the forest. Activities include swimming, fishing and canoeing.

Beyond the Blackwood (Lake Jasper)

Lake Jasper is one of a number of other waterways in the surrounding area that attract tourists. Within D'Entrecasteaux National Park, Lake Jasper attracts a number of different types of tourists, but primarily 4WD enthusiasts and those seeking to view pristine waterways. The lake is Western Australia's largest permanent freshwater lake, which is a reason it attracts some nature enthusiasts.

Much of the D'Entrecasteaux National Park is managed for its wilderness values, so few facilities are provided. There is a CALM operated campground at Lake Jasper with a shaded camping area, barbecues, picnic tables, water and toilets.

Tourism in Margaret River

The Margaret River area promotes itself as a premier tour destination based on ecologically sustainable tourism. Recreational activities include windsurfing, whale watching, sailing, caving, scuba diving, fishing, bushwalking, golfing, and gourmet pursuits.

The Augusta–Margaret River region receives approximately 551 500 visitors annually (2002 – 03 figures), 75% of whom visit for holidays and leisure. Fifty-eight percent engage in outdoor or nature based activities including going to the beach, visiting. National and State parks, bushwalking, rainforest walks, visiting botanic and public gardens, going whale and dolphin watching, and visiting farms (Tourism WA 2004).

Social tourism attracts 86% of tourists (Tourism WA 2004), and viticulture-based tourism is expected to continue to drive strong economic growth in Margaret River (CSIRO 2004).

2.2 POTENTIAL IMPACTS AND MITIGATION OR ENHANCEMENT

In summary, all communities included in the scoping phase of the social impact assessment study were concerned about potential changes to their enjoyment of the area because of the proposal. Their concerns related to potential changes to the environment that would change:

- the way they use the area
- the look of the area
- its intrinsic value
- the attractiveness of the area both as a place to live and as a place to visit.

Community concerns were focused strongly on the Blackwood River in terms of its iconic nature, as expressed by the social variable of *Sense of place*. They were concerned about the extent of environmental impacts, and whether those impacts will affect environmental amenity and hence sense of place. If this was so, their concern was whether these impacts could be managed.

The following questions sum up the key concerns:

- *Will the Blackwood River change?*
- *If so, will that change mean that people won't visit the area?*
- *Will this impact on tourism numbers affect our viability as a community, given that we rely strongly on tourism?*

The Yarragadee Formation is located several tens of kilometres to the east of the town of Margaret River, geologically isolated from the townsite, and consequently no direct impact on this community is expected as a consequence of the proposal. The caves in the Augusta–Margaret River Shire are also geologically isolated from the Yarragadee Formation, and therefore are not subject to any direct impact from this proposal.

The risk of impact of the proposal on flow in the Blackwood River is expected to be insignificant notwithstanding a minor reduction in summer flow (Chapter 7 Section 1.3). The change in summer minimum flows of up to 9%, based on a reduction in groundwater baseflow, could be experienced in the driest of years. Given that there is usually a surface water component to summer flows, in most years the reduction in flow because of this proposal would be less than 9%.

Small areas in Poison Gully and Milyeannup Brook (tributaries of the Blackwood River) will most likely be affected, but this is anticipated to be of only local significance (Chapter 7 Section 2). The area is not frequently visited by residents or tourists and has an intrinsic “existence value” rather than any specific core value.

These potential changes in streamflow are minor, and are not expected to affect the social values of enjoyment or amenity of the river. The changes will not have an affect on recreational use of the Blackwood River, aquatic life in the Blackwood River, or quality of the river itself. Lifestyle, amenity and recreational use are unlikely to be adversely affected by this proposal.

Through the South West Yarragadee Monitoring Review Group (Volume 1 Chapter 8 Section 3.2.6), stakeholders will be engaged in the implementation of monitoring programs, and the development of contingency actions, through an adaptive management practice if unexpected adverse impacts occur.

2.3 MONITORING, ADAPTIVE MANAGEMENT AND ACCOUNTABILITY

Community stakeholders have identified a number of aspects that they believe need to be monitored, despite the expectation of minimal impact. The South West communities have voiced a desire to have local involvement in the monitoring process, and in the assessment of monitoring results. The Water Corporation proposes to establish a South West Yarragadee Monitoring Review Group composed of people from the South West to participate in the assessment of monitoring programs.

Many of the social values of the region relate directly to the value of environmental features, so the proposed environmental monitoring will also assist in dealing with these social values. The Water Corporation will monitor key characteristics of the Blackwood River. These will include flow rate, water quality, riparian vegetation, and flora and aquatic fauna, and will allow any unanticipated adverse impacts to be identified and appropriate management responses implemented. Control areas that will not be affected by the proposal (e.g. areas outside the geological fault lines that contain the Yarragadee Formation) will also be monitored.

Monitoring will not only include ecological, physical, and chemical parameters, but also the social outcomes of the proposed abstraction in relation to:

1. *Lifestyle, amenity and recreational use*, and *Sense of place*, through changes to environmental and ecological values in the Blackwood and at key recreation spots (St John Brook, Barrabup Pool, Workmans Pool, and Hardy Inlet) which might signal a change to recreational amenity of those areas – in particular changes to swimming, fishing, canoeing and dinghy racing activities.
2. *Existing and future needs*, or *Futures foregone*, where changes to community characteristics might signal the need for revisions in water planning. In particular these may be: population increases or decreases, demographic changes, significant shifts in the economic base of a community and the relative contributions of different sectors, changes in income levels, or changes in employment patterns. This monitoring would be undertaken through review of national census results as they are published.
3. Equitable access to water, or benefit and equity through:
 - market surveys of the level of community satisfaction with water planning and management
 - market surveys of levels of community satisfaction with adequacy of the water supply.

The changes that may be observed through the proposed monitoring could result from a variety of causes, particularly changes in community activities and demographics, which are outcomes totally unrelated to the proposal. Consequently, the Water Corporation does not commit to taking any specific actions to address the changes that may occur, unless those changes can be unequivocally attributed to the proposal.

Where changes can be attributed to the proposal, processes will be developed to deal with the issues arising, including processes to identify and work with stakeholders, and to develop strategies to address their concerns and expectations. These processes will be developed in consultation with the affected community.

2.4 PROPONENT SUSTAINABILITY COMMITMENTS

Commitments related to *Lifestyle, amenity and recreational use and access* are described under the *Accountability* sustainability principle in Volume 1 Chapter 8 Section 3.2.7. The Water Corporation also commits to undertake market surveys as part of the South West Public Water Supply Future Planning study to determine if community satisfaction levels with water planning and management, and with adequacy of the water supply.

2.5 OUTCOME

No changes to amenity, lifestyle and recreational use in the area will occur. A benefit will come from increased community involvement in monitoring and reporting of results leading to better safeguards of community amenity.

3 SENSE OF PLACE

Sustainability objective

The sustainability objective for the factor of *Sense of place* is:

The Water Corporation will determine, through community consultation, whether community members with strong attachments to places and heritage values anticipate changes to those places and values as a result of the proposal, to ensure that negative impacts do not occur from this project and to explore potential positive outcomes.

3.1 BACKGROUND

3.1.1 What is sense of place?

Sense of place is an intensely personal response to the environment, both social and natural, which the individual experiences in daily life, and at a broader level it can be the individual's perception of a whole region, state or nation. Individuals might have more than one “sense of place”.

Sense of place comprises:

- place attachment and the natural environment
- cultural landscapes
- heritage
- aesthetics and property values.

Adverse impacts on the *Sense of place* may be defined as any modification in landforms, water bodies, or vegetation, or any introduction of structures, which negatively interrupt the visual character of the landscape (U.S. Department of Interior, undated).

Higher priority is given to protecting those areas with the most important scenic or aesthetic values. The scenic quality of a landscape is evaluated by examining seven factors (U.S. Department of Interior, undated):

- land form
- vegetation
- water
- colour
- adjacent scenery
- scarcity
- cultural modifications.

Sense of place is tangible but personal in that each person with an attachment to a physical location may have a different rationale for that attachment.

The development of the proposal included identification of significant places, and identification and consideration of adverse impacts on these places, recognising that these impacts will represent a social impact and therefore mitigation will be necessary.

3.2 EXISTING ENVIRONMENT

3.2.1 Augusta

Many of the tourist accommodation facilities in Augusta and its vicinity identify views of the Blackwood River in their promotional literature. There are a number of popular tourism and recreation activities that take place on and around the Blackwood River and Hardy Inlet. A high percentage (93%) of respondents to a Human Services Survey conducted in Augusta in November 2003 said that their preferred recreation or leisure activity was available in Augusta.

Eco-tourism is seen by the community as a major future contributor to the town's economy, with a focus on river-based activities for tourism and recreation. These activities include water skiing, eco-cruises, whale-watching, fishing, yachting, and bush activities including bushwalking, camping and picnicking.

Water enjoyment and environmental amenity are seen as important by the Augusta community with water-based recreation activities enjoyed by residents and tourists alike.

3.2.2 Bunbury

Bunbury is a large commercial centre with a strongly diversified industrial and mining base, and a good capability for self-determination. It has a low sensitivity to change, and to any impacts from this proposal, because of its size, its diverse and strong economic base, its population growth, and its regional importance. Bunbury does take a regional view and can appreciate the benefits of interdependency between the towns in the South West, and the value to Bunbury if all communities are prospering.

Appreciation of environmental amenity is important in Bunbury. It is a city bounded by water on several sides and people enjoy this location.

3.2.3 Busselton

Busselton is a robust and growing community. It is presently focused on managing an influx of people, and the consequent development, within the profile of a quiet seaside town. It has low sensitivity to change due to its size, proximity to Bunbury, rapidly increasing population, high occupancy rates, and growing economic base.

Busselton describes itself as a typical Australian coastal community affected by the "sea change" phenomenon. Sea change communities typically have high-value natural environments and, having become popular havens from metropolitan areas, are experiencing rapid growth and social change (The Embers Trust 2005, p.5).

The Shire sees itself as facing the challenges of balancing growth with maintaining environmental features. Factors that illustrate this challenge are:

Geographe Bay and the Leeuwin–Naturaliste Ridge both provide high quality scenic views that attract strong demand for residential land

- the local natural environment is recognised as a global bio-diversity hotspot
- there is a situation of high population growth and a strong tourism industry
- the economy’s major industry sector is agriculture (The Embers Trust 2005).

As with Bunbury, appreciation of the environment is strong in Busselton, largely because of its coastal location. The community is also home to the Vasse–Wonnerup Wetlands, which are listed on the Ramsar List of Wetlands of International Importance. The community would like to develop the wetlands as an educational and study resource, and planning is underway to develop an “eco-tourism experience” at the western end of the wetlands (The Embers Trust 2005).

3.2.4 Margaret River

The township of Margaret River is situated next to the Margaret River and was originally developed for farming and dairying. The area has grown to be Western Australia’s main wine region since the first grapevines were planted in 1967. Margaret River is a popular tourist destination for its fine wines and wineries, cave formations, forests, national parks, restaurants, art galleries, rugged coastal scenery, and world class surf beaches (CSIRO 2004). Agriculture in the Shire includes the major industries of viticulture and wine production, dairy and beef cattle, sheep, fishing, and horticulture.

Environmental amenity is strong in this community because of its location among State forests, proximity to the Margaret and Blackwood Rivers, and tourist attractions such as the Mammoth and Jewel Caves. Environmental concerns relate to sustainability of the Yarragadee aquifer (given climate change conditions), and impacts on the Margaret and Blackwood Rivers. The community believes that environmental amenity is a major reason for people visiting the area.

Community views are mixed when considering development versus retention of the assets of the community for the locals. Water is already a sensitive issue in Margaret River, with environmental concerns very high in the community psyche. There is a strong appreciation in the community for the importance of the rural sector, and viticulture in particular (Synnott Mulholland Management Services 2005).

3.2.5 Nannup

The Shire of Nannup is small, but strong, and committed to action. It is a cooperative community, where new arrivals are integrated quickly, and people work together to build the community (from community interviews).

Environmental amenity is important in this community and is based on social values of the Blackwood River. Some Nannup residents refer to the Blackwood River as Nannup’s “coastline”. The coastline is not only valued by local residents, but is also a key drawcard for tourists to the area, in part due to its aesthetic value.

Heritage values in the area include two heritage features within the Blackwood River area (Augusta–Nannup) which are listed on the State Register of Heritage Places. They are Jalbarragup Bridge and Brockmans Bridge, both in the Shire of Nannup.

Several other features are listed on the Australian Heritage Council Register of the National Estate. These are Alexandra Bridge (Brockman Hwy east of Karridale), Donnybrook Sunklands areas (Blackwood River and Hardy Inlet), Scott National Park, and Black Point (D’Entrecasteaux National Park). Both Augusta and Nannup have numerous places listed in their respective municipal heritage inventories, but none are listed on the State Register of Heritage Places.

3.3 POTENTIAL IMPACTS AND MITIGATION OR ENHANCEMENT

In summary, all South West communities were concerned about potential changes to their enjoyment of the region as a result of the proposal.

1. Community concerns in Augusta related to potential environmental impact on the Blackwood River and Hardy Inlet; more specifically, to reductions in flow, increase in salinity and decrease in water level. Such changes may affect people’s traditional use of the water and therefore may potentially adversely affect amenity and tourism.
2. The Bunbury community was concerned, generally about environmental impacts of the proposal.
3. Community concerns in Busselton related to both environmental impacts and amenity values and, in particular, impact of the proposal on the attractiveness of Busselton as a “sea change” destination, which is the basis for the continued growth of the town.
4. In Margaret River, the community concerns related to general environmental impacts.
5. Community concern in Nannup related to potential changes to the Blackwood River.

The overall concerns were similar to those identified under the factor of *Lifestyle, amenity and recreational use and access*. Concerns related to potential changes to the environment that could adversely affect:

- the look of the area
- its intrinsic value
- the attractiveness of the area both as a place to live and as a place to visit.

The extent of social impact on *Sense of place* is dependent on the extent of risks to valued environmental features. For this proposal, the Blackwood River emerges as the main area where impacts on *Sense of place* would be most significant.

There would be considerable community concern if the Blackwood River were adversely affected by the proposal.

The impact of the proposal on the quality and volume of streamflow in the Blackwood River is anticipated to be low (Chapter 7 Section 1.3). Given that people who use, visit or live alongside the Blackwood River are unlikely to experience changes in their current relationship with the area as result of the proposal, *Sense of place* is unlikely to be adversely affected.

Some farmers on the Scott Coastal Plain are concerned that the proposal will cause, or accelerate, a change in land use from farming to blue gum plantations. Blue gum plantations are already a feature on the Scott Coastal Plain, and are likely to increase in number in the future, whether the proposal is implemented or not.

Farmers have expressed the view that if the water available from the Yarragadee aquifer for irrigated agriculture is reduced, and therefore affects future farm development, they may lease some land for blue gum plantations to achieve better financial returns. They see that such a change would affect their *Sense of place*. However, there may be environmental constraints that restrict availability and usage of water on the Scott Coastal Plain for agriculture, whether or not the proposal proceeds. The impact of more blue gum plantations on *Sense of place* will not be substantially attributable to this proposal.

Despite the expectation of minimal impact on *Sense of place*, community members have voiced a desire to have local involvement in the monitoring process, and the assessment of monitoring results.

3.4 PROPONENT SUSTAINABILITY COMMITMENTS

Commitments relevant to the *Sense of place* factor are described under the *Precautionary* principle and the *Accountability* principle in Volume 1 Chapter 8 Sections 1.3 and 3.2.7 respectively.

3.5 OUTCOME

No changes to *Sense of place* will occur, which is a neutral outcome.

4 INDIGENOUS COMMUNITIES

Sustainability objective

The sustainability objective for the *Indigenous communities* factor is:

Water Corporation will undertake to protect and avoid disturbance of Aboriginal heritage sites. The Corporation will explore potential positive outcomes for and with the indigenous communities.

4.1 EXISTING ENVIRONMENT

The Blackwood River retains significant heritage and cultural value for the Aboriginal community. There are numerous sites near the Blackwood River on the Department of Indigenous Affairs (DIA) Register of Aboriginal Sites. This includes sites such as the Hardy Inlet (archaeological deposit, camp), Blackwood River Ochre Deposit, Sues Bridge (meeting place, camp, hunting place), Blackwood Riverbank (mythological), and Barrabup Pool (mythological), as well as the Blackwood River itself.

The value of the region was highlighted in the South West Yarragadee–Blackwood Groundwater Aboriginal Cultural Values Survey, which was commissioned by Water and Rivers Commission (Goode 2003 at Appendix 23). At the time of the study, the Blackwood River was undergoing assessment by the DIA based on its mythological significance in relation to the Waugal. Those consulted in the study considered the river and its associated aquifer to be of the “same spiritual energy”, meaning the aquifer is also associated with the Waugal. As a result, those consulted thought the river and its tributaries should be considered for registration as a site under the AH Act. To date only the Blackwood River has been added to the register.

The Blackwood River also held importance as a source of food, including fish, marron, and duck, for the Aboriginal peoples (Appendix 23). The river was also identified as a territorial boundary between the Pibbelmen and Wardandi language groups (Appendix 23).

The proposed St John Brook and Jarrahwood Conservation Parks are significant for members of the Bibbulmun Tribal Group, as St John Brook was a traditional travel route along the Blackwood River. People of this group employed a mobile lifestyle, moving along river systems in search of alternative food sources. River pools were particularly significant as sources for food and as camping locations. Three pools (Barrabup, Workmans and Cambray) were identified by Goode (Appendix 23) as sites of mythological significance, in association with Waugal beliefs. Within the proposed Jarrahwood Conservation Park is the Nannup Scarred Trees site, registered under the AH Act. The area around Barrabup Pool is currently being considered for registration under the AH Act. The project area is within three registered native title claim areas: WAD6279/98 South West Boojarah, WAD6274/98 Gnaala Karla Booja and WAD6006/03 Single Noongar Claim (Area 1) (National Native Tribunal 2005).

The proposed pipeline route crosses the Capel, Ferguson, Preston, Collie and Brunswick Rivers. These are all registered as Aboriginal heritage sites or proposed to be registered (Capel River). The pipeline may need to be installed under or over the rivers without disturbance depending on the outcome of the Aboriginal heritage surveys to be carried out by the Water Corporation.

As part of the RFA process, Aboriginal heritage places in the South West were examined (Synnott Mulholland Management Services 2005). They were evaluated using the criteria employed to determine inclusion in the National Estate. Some features were already listed, while others were not, but had sufficient attributes to be listed. Both the Blackwood River and the Scott River engravings – Dunnet’s Farm were identified as candidates for listing. Neither is currently listed in the National Estate and both were considered to have significant values. The Blackwood River (in its entirety, including its banks and immediate surrounds) was identified as having high social and cultural value because of its use for hunting, fishing, marroning and camping.

Another site listed on the Aboriginal heritage sites register, and on the Register of the National Estate is Lake Jasper. It has been on the Register of the National Estate since 1978 (Class: Indigenous; Status: Registered). It is an Aboriginal archaeological site of significance. Lake Jasper contains Australia’s only underwater prehistoric site of human habitation (Western Australian Forest Alliance 2005).

Approval under Section 18 of the AH Act will be required prior to construction of the pipeline to ensure that heritage issues are not compromised by the proposal, particularly in relation to siting of the wellfield and pipeline.

4.2 POTENTIAL IMPACTS AND MITIGATION OR ENHANCEMENT

Some heritage sites may be affected by the proposal. The implications of these effects need to be discussed with Indigenous communities, and will be the subject of a separate extensive consultation process that will be reported separately.

The Water Corporation will discuss opportunities for employment of Aboriginal people on aspects of the project with Indigenous representative groups.

4.3 MONITORING, ADAPTIVE MANAGEMENT AND ACCOUNTABILITY

Monitoring, management and reporting of impacts on heritage sites will be undertaken within the requirements of the AH Act.

4.4 PROPONENT SUSTAINABILITY COMMITMENTS

The proponent commits to:

1. Conduct a detailed Aboriginal heritage survey of the proposed infrastructure footprint before construction of proposal infrastructure in consultation with the local Indigenous community and in accordance with the requirements of the DIA.
2. Seek approval for any disturbance of identified heritage sites under s18 of the AH Act.

The Water Corporation is committed to discussing opportunities to employ Aboriginal people on aspects of the project within the provisions of the Water Corporation Involvement and Indigenous Employment Opportunities Policy.

4.5 OUTCOME

The Water Corporation objective is to protect and avoid disturbance of Aboriginal heritage sites, and to explore potential positive outcomes for, and with, the Indigenous communities. The Water Corporation has undertaken the preliminary infrastructure design to minimise any disturbance to Aboriginal heritage sites, which includes avoiding all sites on the current Department of Indigenous Affairs register, except in the case of linear features such as listed rivers. Further consultation will establish the protocols for future field surveys to identify any sites not currently on the register.

Where possible, opportunities will be provided for Aboriginal people to be employed on aspects of the project.

5 DEVELOPMENT FOOTPRINT

Sustainability objective

The sustainability objective to be met by the proposal for the *Development footprint* factor is:

The construction and maintenance of infrastructure will cause minimal permanent disturbance to the community.

5.1 BACKGROUND

The focus in discussions with communities has primarily been on the abstraction of water from the Yarragadee aquifer. However, the social impacts of construction and operation of the pipeline and treatment plant have the potential to be significant. Community expectations raised during Phase one of the social impact study (Volume 1 Chapter 8 Section 2.1.4) are for some short-term economic benefit resulting from employment opportunities during construction.

Comprehensive consultation with potentially impacted landowners has not yet taken place, as the final pipeline alignment is yet to be determined, notwithstanding that a notional route has been indicated (Volume 1 Chapter 1 Section 2.1).

The intention is to commence an intensive engagement process following submission of the proposal to the EPA, Sustainability Panel, Water and Rivers Commission and the DoW.

5.1.1 Location of wellfield

Groundwater modelling was used to help define an optimum location for the wellfield on the Blackwood Plateau, south of Busselton and north-north-west of Nannup. This location is anticipated to have lower impact on other users and the environment than at other locations further to the west.

The wellfield is proposed to be located in State forest. Water will be pumped through underground pipes to a treatment plant and storage tank on an elevated site on the Whicher Scarp, to the north of the source works, and then by an underground trunk main to the Stirling Trunk Main. The water will be gravity fed from the storage tank to and through the pipeline, eliminating the need for pumping stations along the route.

5.1.2 Pipeline routes

The pipelines from the wellfield to the treatment plant will travel primarily along gazetted roads through State forest, subject to CALM and the Conservation Commission requirements.

Properties in the southern part of the pipeline route (south of Dardanup and Burekup) are primarily used for dairying and other agricultural production. Properties along the northern part of the pipeline route are mostly smaller irrigated lots. The Water Corporation intention is to lay the pipeline along roads or boundaries, where possible, rather than traversing properties.

The proposed corridor avoids remnant bush and heritage sites wherever possible. Some linear heritage sites, such as the registered rivers, will be impacted, no matter what route is chosen. These situations will be subject to heritage consultation and approvals process.

5.2 POTENTIAL IMPACTS AND MITIGATION OR ENHANCEMENT

There will be three main infrastructure elements:

- wellfield
- treatment plant and storage tank
- pipelines.

5.2.1 Wellfield

The closest towns to the proposed wellfield location are Jarrahwod, Busselton and Nannup. Construction of the wellfield is likely to take 18 months and directly employ 20 – 30 specialised personnel. This is highly specialised work, which will be managed by a large contractor with specialist drilling crews. While such services are unlikely to be sourced locally, the Water Corporation has a “buy local” policy and will seek local contractors to undertake other appropriate tasks such as earthworks, supplies and haulage.

The specialist drilling teams will be required to live locally during construction of the wellfield, and will need to use accommodation in nearby towns. Companies undertaking previous drilling contracts (for the investigation drilling program) took accommodation in Nannup. Construction crews from outside the region may choose to stay in Nannup or Busselton during the construction period, providing a boost to the local economy during construction.

5.2.2 Treatment plant and storage tank

The treatment plant and storage tank are proposed to be on the Whicher Scarp, in State forest to the north of the source works near Jarrahwod. The closest towns are Capel and Nannup. Construction of the treatment plant is likely to take 18 months.

The treatment plant and storage tank construction workforce is likely to include up to 100 people. Less specialisation is needed for this work than for wellfield construction and laying of pipelines. Various civil works and engineering support services, such as concreting, fencing, earthworks, fabrication and surveying, will be required. All of these skills are available in the regional centres of Busselton and Bunbury, and some may be sourced from other nearby smaller towns. Local suppliers will have the opportunity to sub-contract to the experienced lead contractor.

Access to the proposed site would be via the established main road systems. Some additional traffic on roads around Jarrahwod can be expected during normal working hours.

A workforce of up to 100 people will have significant impacts on a community the size of Nannup (town population of 600), by swelling the local population for a considerable time. Capel, with a population of 1600, is the next nearest town, and would also notice the impact of an additional 100 people in the community for 12 months or so.

If sufficient accommodation is not locally available, these crews would be likely to use accommodation in larger centres such as Busselton, Dunsborough or Bunbury.

5.2.3 Pipeline

The construction of the pipeline will have a more direct impact on the local community than either the treatment plant or the wellfield, due mainly to the nature of the excavations required to bury the pipe, and land issues related to large linear infrastructure.

The pipeline laying process involves:

- surveying and geotechnical investigations
- indigenous heritage surveys
- advance site work including fencing of the trench site
- digging the trench and storage of the earth
- laying the pipe
- backfilling of the trench and restoration of vegetation.

Disturbance and compensation for landowners

The pipeline route passes through two distinct areas of farmland on the Swan Coastal Plain. The northern section of the route, from Dardanup to Harvey, is within an irrigation area, where the land usage is closely aligned to the availability of irrigation water. Flood irrigation on the smaller properties in this area is common. The pipeline route will be chosen to avoid disturbing the gradient across each property, and will follow property boundaries or roads wherever possible.

The southern section, from Dardanup to the foot of the Whicher Scarp east of Capel, is an area predominantly used as pasture for dairy and beef production. The properties are much larger than in the northern section, hence the impact of a pipeline crossing them will be different. There may be disruption and fragmentation of grazing pasture for a short period of time (of the order of days) during the construction of the pipe trench and during pipe laying. Disturbance, including any access tracks required, will be restricted to a narrow strip of pasture. Recovery of full productivity of affected land may take some time (up to one year).

Construction will take place during the summer months (November to April) over two summers.

Landowners will be compensated for loss of land value, as well as lost income from loss of production, as part of the easement process. Easements consisting of a strip of land either side of the pipeline will be acquired to protect the pipeline from disturbance. The easements will not impede agricultural practices or vehicular movement, but will be areas where excavations and erection of structures and fences are restricted. Some permanent assets (e.g. air valves) will need to be placed within property boundaries. Access to these will be required, and there may be some restriction on surface movements. Permanent assets will be placed wherever possible, adjacent to property boundaries or road reserves. Where they cannot be placed so as to minimise impacts, the easement process will provide compensation.

Impacts will be mitigated where possible through individual negotiation with each landholder. Work will be scheduled to minimise disturbance. On-site work on individual properties may last an average of one to two weeks, depending on the size of the property.

Other potential impacts may arise during construction from dust and noise emissions, increased on-site traffic, access disturbance, and a workforce of up to 20 people on each pipe-laying team. Traffic on to properties will be for the delivery of pipes and equipment, haulage of soil for storage, and excavation equipment. The project will require 7 – 10 work teams along the entire length of the pipeline.

The Water Corporation will seek to manage these issues through a Construction Management Plan and in cooperation with landholders.

Construction workforce

The laying of the pipes is a specialist skill and will be provided by contractors. Local contractors will have the opportunity to sub-contract for haulage of pipes, removal of excess soil, and excavation. The regional centres of Busselton and Bunbury have local contractors with the capacity to undertake this work.

Construction will move progressively along the pipeline route, and construction workers may choose to change their accommodation for each six month construction period, or may choose to move progressively along the route. The fact that the pipeline corridor is closely aligned to the towns of Harvey, Dardanup, Boyanup, Capel and Nannup would facilitate the latter approach. Alternatively, contractors may choose to base themselves in Busselton or Bunbury to take full advantage of existing haulage routes and suppliers.

Summary

The construction phase will last for 18 months. The potentially significant impacts likely to be experienced during this period are summarised below:

1. There will be impacts on individual landholders whose land is on the pipeline route. These may include disturbance to summer cropping, restricted access, dust, noise, increased traffic on site, and the effects of a work team of up to 20 people on their properties. Access will be negotiated with each landholder before commencement of construction.
2. There will be impacts on local communities due to the influx of construction workers for extended periods of time. Positive impacts include the economic flow-on benefits to the community through accommodation, meals and other services. Negative impacts could occur in smaller communities, such as Nannup and Capel, from the presence of construction personnel over an extended period during construction of the treatment plant and storage tank.
3. Positive impacts on local communities will manifest through employment opportunities available to tradesmen, and new business for suppliers of relevant services. These opportunities will be available for construction of all components of the proposed development.

There will be minimal social impacts from the operation of the infrastructure. These will be addressed through good management practice and communication with the local community by the Water Corporation.

5.3 PROPONENT SUSTAINABILITY COMMITMENTS

The proponent commits to:

1. Develop and implement a landowner engagement program to finalise the pipeline alignment, management of pipeline construction and ongoing maintenance procedures.

2. Act within the provisions of the *Land Administration Act 1997* for the pipeline easement interest, but wherever possible, agree on compensation for the interest in land, for loss or for compensation through negotiation.

5.4 OUTCOME

The Water Corporation will engage in a program of direct dialogue with those affected by the proposal, including landholders on the proposed pipeline route. Construction impacts will be largely minimised through the Water Corporation standard procedures, which include discussion with landholders to plan construction activities to minimise disruption.

The outcome will be positive overall, but may be negative in the short term for farmers whose properties are along the pipeline route. Water Corporation will determine a final alignment in consultation with landowners, and will manage construction of the pipeline to minimise impact on those properties affected. The impact will occur during one cropping season only, and it is anticipated that impacts will be confined to that season. There will be no ongoing impacts during operation, thereby achieving the objective of minimal permanent disturbance to the community.

The potential benefits of employment and economic activity will be enhanced through the Water Corporation “buy local” policy. The potential impacts on smaller communities from the influx of construction workers will be managed through discussion with the potentially affected shires.

Chapter 5 South West Yarragadee aquifer hydrogeology and modelling

1 HYDROGEOLOGICAL ENVIRONMENT

The proposal involves the construction and operation of a wellfield to draw water from aquifers⁶ within the South West Yarragadee Formation within the Southern Perth Basin. The Southern Perth Basin refers to the southern part of a deep sedimentary basin (the Perth Basin) that lies between the Darling Range and the Leeuwin-Naturaliste Ridge.

The Perth Basin extends from just south of Geraldton to the Southern Ocean. The Southern Perth Basin is the portion between Geographe Bay and the Southern Ocean. In this part of the basin, it comprises two main geological units: the Bunbury Trough and the Vasse Shelf. These are separated by the Busselton Fault, a north – south aligned near-vertical fault through the sediments of the basin. The Dunsborough Fault on the western edge separates it from the granitic rocks of the Leeuwin–Naturalist Ridge. On the eastern edge, the Darling Fault separates it from the similarly granitic rocks of the Darling Plateau. The location of the Southern Perth Basin and its geological structure is shown in Figure 5.1.

Figure 5.1 Structural geology



1.1 HYDROGEOLOGICAL INVESTIGATIONS

1.1.1 Previous investigations

Groundwater in the region has been developed for over a century, with the first production wells into the Yarragadee Formation drilled for the Bunbury water supply around 1898.

⁶ An aquifer is a layer of rock or rocks that can store and transmit water in reasonable quantities.

Systematic investigation commenced in the late 1960s. This work built on information from oil exploration programs, and followed drilling of town water supply wells for Capel, Eaton and Busselton in the early 1960s.

Exploratory drilling by the Geological Survey of Western Australia commenced in 1967, with drilling of the “Quindalup Line” of deep exploration wells between Busselton and Dunsborough. The drilling program continued through to 1992 with a series of deep wells on several transects across the basin (Picton, Boyanup, Cowaramup and Karridale Lines). This was complemented by several shallow groundwater investigation programs over the Swan and Scott Coastal Plains.

This investigation work provided a good regional-level understanding of the hydrogeology of the Yarragadee and Leederville Formations, and a detailed understanding of the coastal plains. This work indicated the presence of a strategically important major water resource. Long range water plans, such as the 1995 *Perth’s Water Future* study (Water Authority of Western Australia 1995a, 1995b), identified the potential for the Yarragadee source to become part of a future extended integrated water supply system.

1.1.2 Water Corporation investigations

The Water Corporation proposal to develop the groundwater resources of the Yarragadee Formation in the central Blackwood Plateau generated a need to undertake more detailed work in this area to quantify the extent of the resource. An extensive investigation program was undertaken during 2002 – 2005 to meet this need.

This investigation is one of the largest groundwater investigations carried out in Western Australia, consisting of a suite of geophysical surveys, exploratory drilling at 48 sites, test pumping, as well as measurement and estimation of groundwater recharge and discharge, stream flow, groundwater flow and response to pumping.

Specific objectives of the investigation (Baddock 2005a) were to:

- determine the distribution of the Bunbury Basalt within the Bunbury Trough below the Blackwood Plateau (aeromagnetic survey)
- define the outcrop area of Yarragadee Formation (radiometric survey, remote sensing)
- aid identification of major faults within the basin (gravity survey)
- assess the lithology of the Leederville and upper Yarragadee Formations to aid downward leakage estimates (drill logs)
- determine groundwater flow directions within upper Yarragadee aquifer (piezometers)
- refine deeper regional flow direction within the Yarragadee aquifer (piezometers)
- extend the Carbon-14 dating of groundwater in the Leederville and Yarragadee aquifers
- verify the suitability of groundwater quality from the Yarragadee Formation for potable use
- carry out test pumping of the Yarragadee aquifer to determine aquifer characteristics
- quantify runoff from the Blackwood Plateau (hydrologic modelling)
- quantify groundwater discharge into the Blackwood River downstream from Nannup
- assess the contribution of tributaries flowing into the Blackwood River

- quantify recharge by measurements of chloride or other tracers from cores
- model recharge fluxes
- collate time-series water-level data for use in model calibration
- prepare a detailed hydrogeological report presenting data and analysis of existing and investigation findings.

The aerial geophysical surveys were carried out between December 2002 and January 2003, followed by the investigation drilling between January and June 2003. The test pumping of observation bores commenced, and an additional investigation site was completed, in October. The test pumping was carried out from October to November 2003.

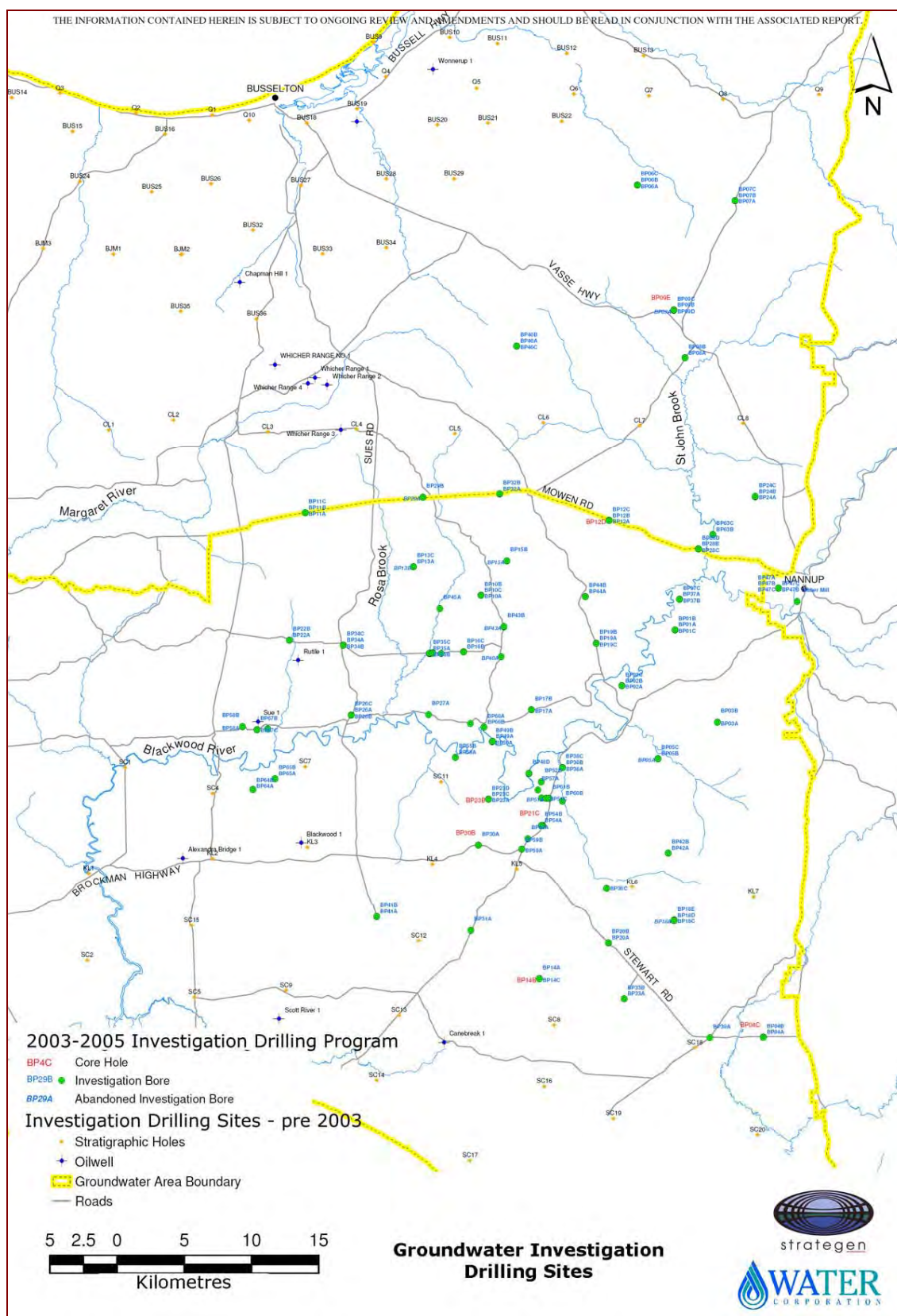
Sites have been drilled to a range of depths, up to about 1600 m below the surface, with up to three wells being drilled at each site in the various programs between 1996 and 2004 (Figure 5.2). Pump testing was carried out at a number of sites to establish the hydraulic characteristics of various formations.

The drilling and testing program was supplemented by other investigations including a variety of geophysical⁷ investigations and hydrologic studies. The hydrologic studies were primarily aimed at understanding the relationship between the surface and groundwater resources of the study area, and determining the recharge characteristics of the groundwater resources.

The Blackwood River, Rosa Book, St John Brook, Reedia Wetlands and Lake Jasper areas were foci of this work to understand their interactions with groundwater.

The results from the investigations have been consolidated into a report on the conceptual hydrogeology of the region (Baddock 2005a) and interpreted into a 3-dimensional computer model of the regional groundwater system (Chapter 5 Section 3). This section provides a summary of the results of the hydrogeological investigations.

⁷ Geophysics is the science of mapping variations in the physical properties of the rocks and soil at and beneath the surface of the earth.

Figure 5.2 Groundwater investigation drilling sites

1.2 REGIONAL HYDROGEOLOGY

The Southern Perth Basin (Bunbury Trough) is a sedimentary basin containing layers of rock, generally called formations. These layers have been formed over geological timescales with the younger formations overlaying the older ones. The layers consist of a wide variety of rock types, including sands, gravels, sandstones, clays, shales, silts, siltstones, basalts and coal seams. These materials have different abilities to store and transmit water. Some formations can consist of a mix of the various rock types, and some such as the Bunbury Basalt may comprise one dominant rock type.

The Yarragadee Formation occurs within the Bunbury Trough (Figure 5.1) and is predominantly sand (Figure 5.3), with some gravel and with layers of interbedded shales and siltstones. Some of the sandy layers are clayey, particularly in the younger (shallower) layers of the formation. Sandy and gravelly layers have a greater capability to transmit and store water than clayey layers, or shales and siltstones.

The basin extends to depths of more than 12 000 m in parts, with the upper 1000 to 2000 m containing fresh water. The main formations in general order of age (depth) are set out in Table 5.1, together with a summarised explanation of their water bearing properties.

Figure 5.3 Sample of coarse sands from Yarragadee Formation



Table 5.1 Main geological formations of the upper Southern Perth Basin

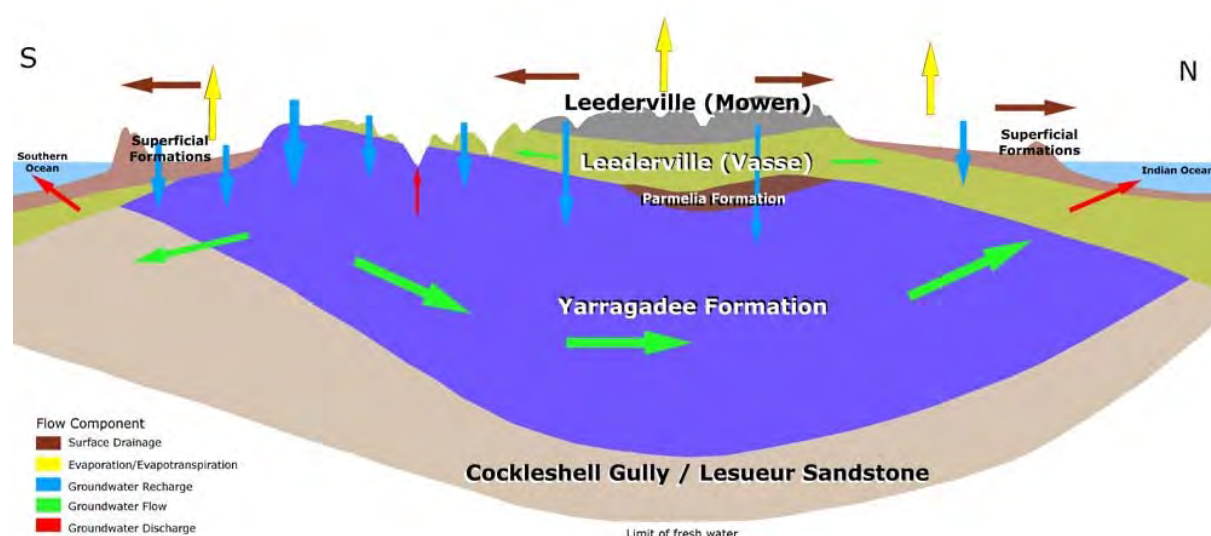
Formation	Location	Depth and thickness	Rock types and water bearing properties
Superficial formations	Coastal plains and small amounts in river valleys/floodplains	Surface formation. Often less than 10 m thick, but extends to 200 m thick under coastal sand dunes.	A variety of sands and gravels, with some clays, silts, limestone and peat. Contains shallow watertables (<3 m), and is a moderate aquifer.
Leederville Formation comprises Mowen aquitard and Vasse Member	Extensive within Bunbury Trough and Vasse Shelf	Occurs at surface over Blackwood Plateau and below superficial formations on coastal plains. Typically 150 m thick.	The Mowen aquitard ⁸ comprises the Mowen Member and Quindalup Member dominated by clay and silty clay and is a poor aquifer. The Vasse Member is stratified with highly permeable sand beds and forms a good aquifer. The ability to transmit water vertically varies considerably depending on the presence of clayey layers.

⁸ An aquitard is a layer of rock or rocks that does not allow water to transmit through them easily. Formations that do not allow any flow are called aquicludes.

Formation	Location	Depth and thickness	Rock types and water bearing properties
Bunbury Basalt	Bunbury Trough	Occurs in eroded valleys in the top of the Yarragadee Formation. Outcrops at the surface at several locations. Variable thickness to more than 100 m.	Comprises massive rock or weathered clay and has little or no water bearing properties. Acts as a barrier to water flow.
Parmelia Formation	Bunbury Trough	Eastern portion of Bunbury Trough beneath Blackwood Plateau and overlain by either Bunbury Basalt or Leederville Formation. Typically 80 m thick.	Mainly clay, similar to the Mowen Member but with a lower proportion of silt and sand. It is a poor aquifer and acts as a barrier to water flow.
Yarragadee Formation	Extensive within Bunbury Trough	Overlain variably by younger formations. Outcrops at the surface near the Blackwood River. Very thick formation varying from 1000 to 2000 m.	Stratified layers comprising four units. Unit 1 (shallowest unit) is a good aquifer. Unit 2 is a moderate aquifer. The sandier Unit 3 is the highest yielding aquifer zone. Unit 4 (the deepest) is a moderate aquifer.
Cockleshell Gully Formation	Extensive within Bunbury Trough. Small occurrence on Vasse Shelf.	60 to 1300 m thick. No outcrops and is generally overlain by the Yarragadee Formation.	The upper part of the formation contains good aquifers and is considered part of the Yarragadee Formation flow system, where they are in contact.
Lesueur Sandstone	Central Vasse Shelf and within Bunbury Trough	Occurs at depths of 400 m or more under the Cockleshell Gully Formation in the Bunbury Trough and may extend to depths of more than 4000 m. Outcrops on the Vasse Shelf or is overlain by the Leederville Formation.	The upper part of the formation contains good aquifers and is considered part of the Yarragadee Formation flow system where they are in contact.

Groundwater flows in the Yarragadee Formation are dominated by flows in Unit 3 (the most transmissive zone). The majority of recharge that percolates down to the aquifer zone eventually discharges to the oceans to the north and south (Figure 5.4).

Figure 5.4 Diagrammatic north–south cross section of the Southern Perth Basin (Bunbury Trough) showing groundwater flows



1.3 GROUNDWATER RECHARGE

Several studies of recharge were undertaken to estimate the amount of water that enters the groundwater system, as one of the factors to be taken into account in modelling their performance.

The rate of groundwater recharge is controlled by climate, land use, vegetation type and density, soil hydraulic properties, geology and topography.

Recharge to the groundwater system arises principally from rainfall infiltration. Most of the rain that falls in the region returns to the atmosphere through various forms of evaporation and transpiration (collectively evapotranspiration). Any precipitation that exceeds both the soil moisture deficit and evapotranspiration will either become surface runoff, or percolate downward to the watertable (gross recharge). The downward flow of water is dependent on the properties of the soil profile, and it may or may not reach the watertable. For example, the existence of a very low conductivity horizon may induce a lateral flow that may discharge into rivers or constructed drainage systems.

Water may be lost from the watertable when transpired by vegetation that has a capability to take water from the watertable (phreatophytes). Water, once it reaches the watertable, may also later emerge as surface water where streambeds intersect the watertable. The remaining water can be considered net recharge and generally discharges as regional groundwater outflow, or by abstractions from wells).

The primary method used in the Water Corporation study to calculate potential gross recharge was through a water balance simulation, based on physical processes, and using available data on vegetation type and density, soil properties, and daily records of rainfall and evaporation. To avoid bias in computational methods, two alternative recharge models were used for comparison, both of which have been successfully applied to Western Australia conditions. These were the WEC-C model (Croton and Barry 2001) and the WAVES model (Zhang and Dawes 1998). A description of the methodology is given by Baddock (2005a).

Two other methods of estimating recharge were also applied as checks to ensure that there were no gross errors in recharge estimates synthesised from the physical processes. These were:

- application of a chloride balance to soil and water samples from investigation drilling (Rockwater 2004c at Appendix 15)
- calculation of a water balance on gauged catchments within the region (Sun & Cornish 2004).

The results of these calculations are presented in Table 5.2 for comparison with the recharge value adopted from calibration of a 3-dimensional numerical computer model of the Southern Perth Basin (SWAMS v2.0) developed to simulate the performance of the system under various future abstraction scenarios. Development of the model is discussed in detail in Chapter 5 Section 3.

Table 5.2 Comparison of annual net recharge estimations

Model	WEC-C	WAVES	Water balance	Chloride balance	SWAMS v2.0
Net recharge (GL/yr):	330	360	341	302 – 342	374

The comparative recharge estimates are of a similar order and give a high level of confidence that the SWAMS v2.0 modelling adequately represents recharge at the regional scale. The SWAMS v2.0 modelling results imply that net recharge is about 6.5% of annual rainfall.

1.4 RECHARGE TO THE YARRAGADEE FORMATION

Recharge to the Yarragadee Formation occurs at rates that vary spatially according to the thickness and water transmitting properties of the overlying formations.

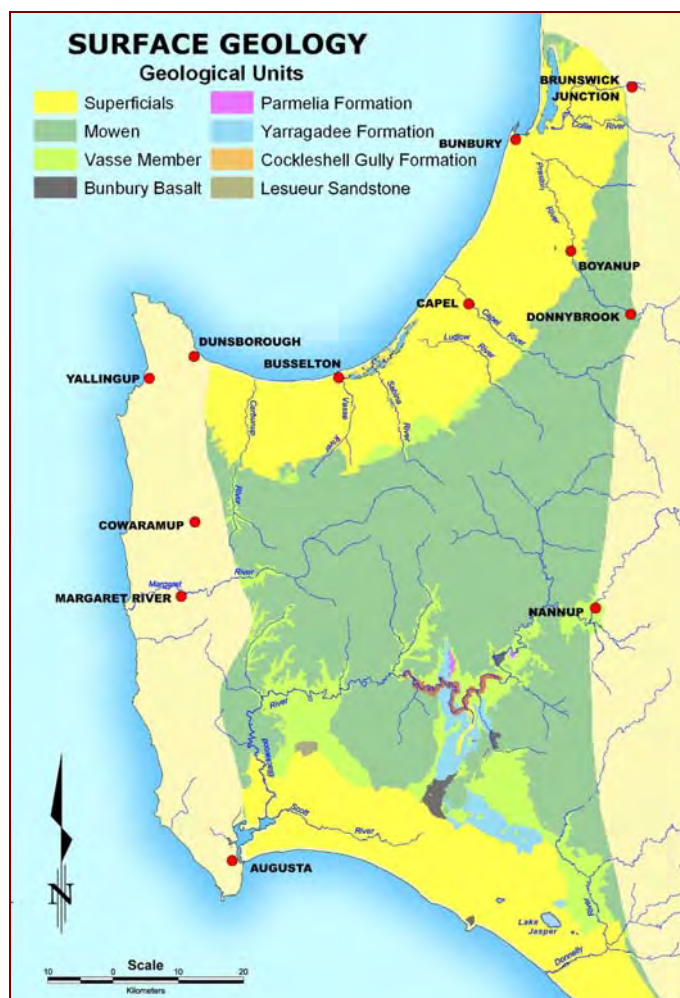
The Yarragadee Formation is recharged by direct infiltration of rainfall in areas where it directly outcrops at the surface, and by leakage from overlying formations in other areas. The Mowen Member is the predominant geological unit at the surface over the Blackwood Plateau, particularly in higher parts of the landscape (Figure 5.5). In southern parts of the plateau, the Mowen Member has been removed by erosion so that the Vasse Member and upper Yarragadee Formation outcrop at the surface. Recharge rates through the Mowen Member tend to be considerably lower than through the Vasse Member and Yarragadee Formation, because of the presence of substantial clay layers restricting vertical flow.

The Yarragadee Formation outcrops at the surface near the Blackwood River (Figure 5.5). In the more elevated part of this outcrop area, to the south of the river, rainfall directly infiltrates into the Yarragadee Formation at much higher rates per unit area than in areas where it is overlain by other formations.

The Vasse Member of the Leederville Formation is also recharged directly by rainfall where it outcrops at the surface. Although the rate of recharge is less than for the outcropping Yarragadee Formation, the Vasse Member outcrops over a larger area and contributes a significant quantity of water to the regional groundwater system.

Recharge to the Yarragadee Formation is inhibited where aquitards or aquicludes⁹ directly overlie the formation. The Mowen Member is an aquitard, but does allow some downward leakage into the underlying aquifers, albeit at a low rate. The leakage volume is significant because of the extensive area of outcrop of the Mowen Member.

Figure 5.5 Surface geology



⁹ An aquitard is a layer of rock having low permeability that stores groundwater but delays its flow. Formations that are sufficiently impervious so as to not allow any flow through them are called aquicludes.

Recharge to the Yarragadee Formation was estimated from modelling to average 151 GL/yr during the period 1990 – 2003. This value would increase with pumping from the Yarragadee Formation by inducing flow from overlying and underlying formations as a result of lowered pressures in the lower formation.

The Bunbury Basalt is a major aquiclude through which there is virtually no vertical movement of water. It directly overlies the Yarragadee Formation over a substantial area (Figure 5.6).

Aquitards and aquicludes have a two-fold effect on groundwater movement. Firstly, they inhibit downward leakage of water to the Yarragadee Formation. Secondly, they inhibit the transmission of water-level drawdown, or pressure reduction, to the surface formations.

Water flows into and out of the Yarragadee Formation in the southern part of the Blackwood Plateau where it interacts with the Blackwood River and superficial formations of the Scott Coastal Plain. This is shown diagrammatically in Figure 5.7. As discussed above, significant recharge rates occur through the exposed areas of the Yarragadee Formation, with lower rates where it is overlain by other formations. Water discharges directly into the Blackwood River where the river bed cuts into the Yarragadee Formation.

Figure 5.6 Extent of Bunbury Basalt overlying Yarragadee Formation

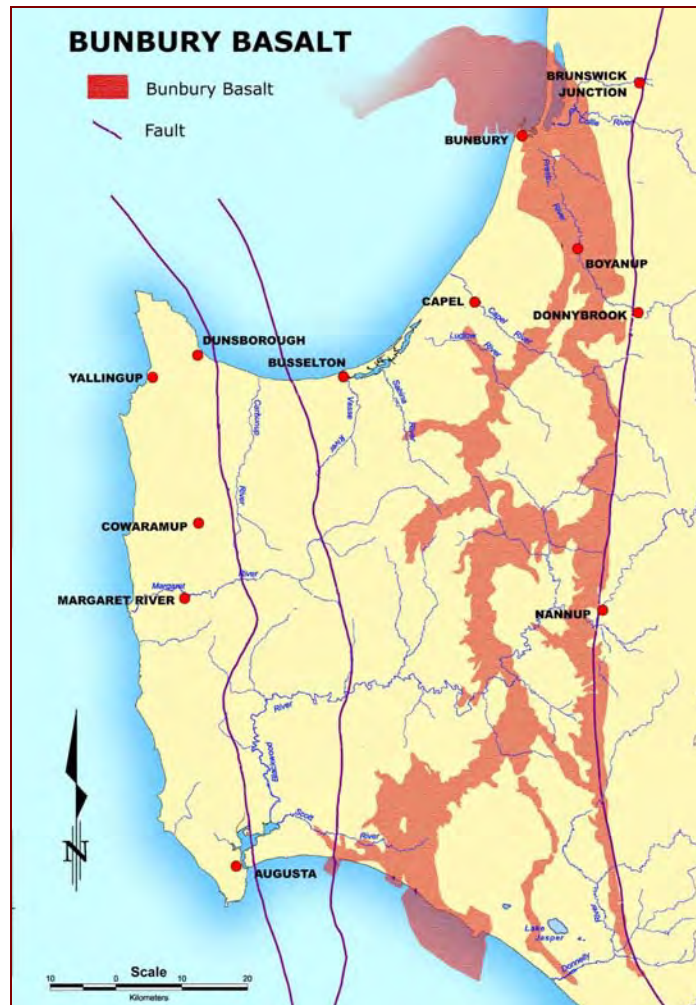
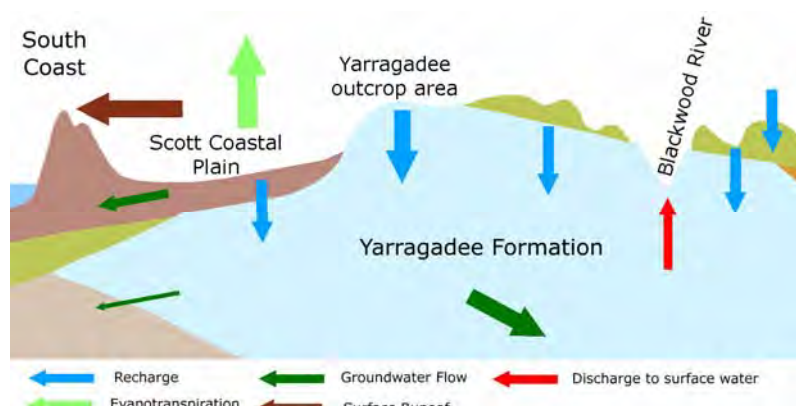


Figure 5.7 Yarragadee Formation interactions



These groundwater parameters have been applied in the 3-dimensional (SWAMS v20) computer model of the groundwater system. The model has been used to test how the system might behave under a range of future scenarios, taking into account different levels of abstraction, and changes in recharge resulting from climate change (Section 3).

1.5 DISCHARGE FROM THE YARRAGADEE FORMATION

Most of the water flowing through the Yarragadee Formation discharges as subsurface flow into the ocean (Indian Ocean at Geographe Bay and the Southern Ocean off the south coast). This discharge is thought to occur directly from the Yarragadee Formation where it intersects the sea floor, and through upward discharge into overlying formations and then to the ocean (for example, via the Leederville Formation and the superficial formations).

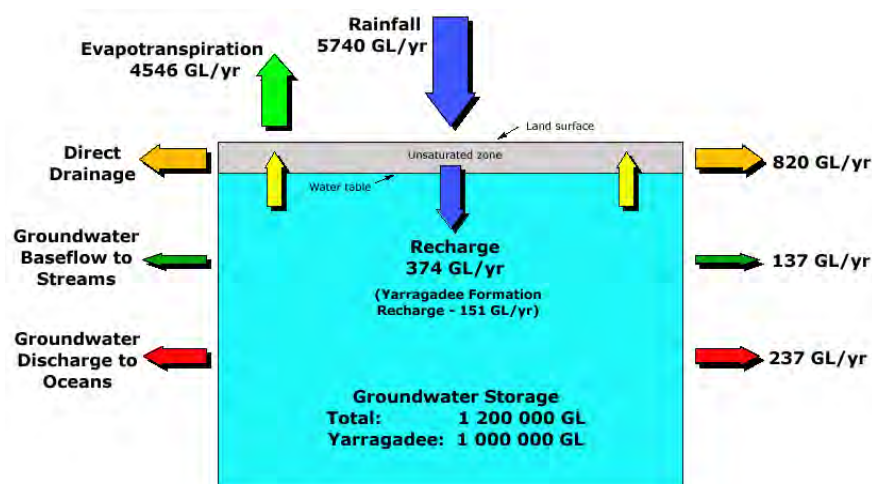
The most transmissive part of the Yarragadee aquifer is exposed to the ocean near Bunbury, where there is a significant amount of groundwater discharge. Groundwater discharge rates are much lower through the overlying Leederville Formation elsewhere beneath Geographe Bay. There is a similar exposure of the Yarragadee Formation to the ocean near Black Point, off the southern coast, although in this area the aquifer is believed to comprise the less permeable Cockleshell Gully Formation, which restricts the rate of discharge.

There is also a discharge from the Yarragadee Formation into the Blackwood River downstream of Darradup where it outcrops into the river bed. This is discussed in detail in Section 4.3.

1.6 GROUNDWATER FLOW AND WATER BALANCE

An estimate of the components of the natural average annual water balance of the Southern Perth Basin has been developed on the basis of investigations and analysis completed to date (Figure 5.8). The quantities will vary from year to year depending on the actual rainfall each year.

Figure 5.8 Natural water balance in the Southern Perth Basin



One of the outstanding features of the Southern Perth Basin is the volume of fresh water held in storage within the various formations. Approximately 1 200 000 GL¹⁰ is held in storage within the formations down to depths of about 2000 m. This equates to about 3200 times the annual recharge and provides considerable buffering capacity to even out the effects on storage of any annual variations in rainfall.

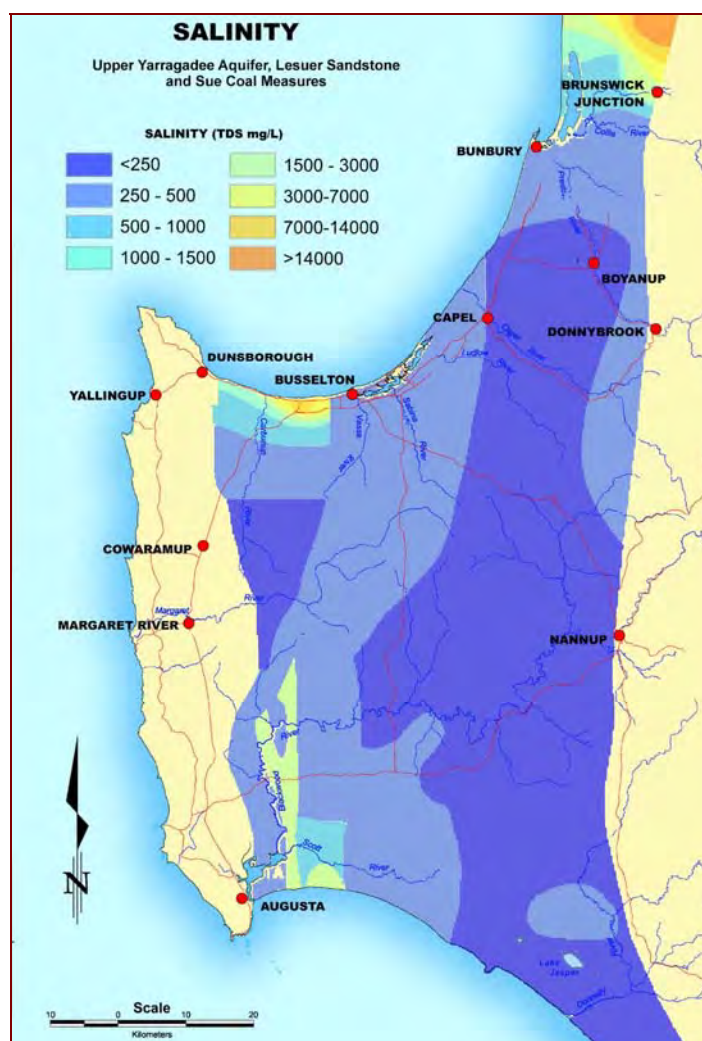
1.7 GROUNDWATER QUALITY

Groundwater in the upper Southern Perth Basin is generally fresh, but with brackish water occurring in some areas, particularly in the superficial formations and the Leederville Formation on the Swan Coastal Plain. The Yarragadee Formation groundwater is fresh to very fresh water, generally containing less than 500 mg/L Total Dissolved Salts (TDS). The average salinity of groundwater within Yarragadee Units 1 to 3 is 360 mg/L. In Unit 4 it averages 440 mg/L. Treatment is required to remove naturally occurring dissolved iron to enable the water to be used in domestic water supplies. Iron is a not health-related water quality parameter. Rather, it is regarded as having unwanted aesthetic effects such as staining of laundry.

Salinity at the top of the Yarragadee Formation, Lesueur Sandstone and Sue Coal Measures varies significantly (Figure 5.9).

There is a seawater interface along the coast at Bunbury, extending several hundred metres inland as a wedge of saltwater underlying the fresh groundwater. This is discussed further in Section 2.4.

Figure 5.9 Salinities in upper aquifers



¹⁰ The values of groundwater storage and recharge estimates have been re-evaluated since the publication of earlier information by Strategen (2005c at Appendix 33). The previously published material was a preliminary estimate based on the reconnaissance level investigation work undertaken prior to completion of the current investigations.

2 GROUNDWATER MANAGEMENT ISSUES

The key management issues associated with the abstraction of groundwater by the South West Yarragadee Water Supply Development project are:

- future groundwater abstractions for the IWSS and local regional needs for groundwater
- drawdown impacts on groundwater dependent ecosystems
- drawdown effects on other users (interference effects)
- seawater intrusion
- potential acid sulphate soils
- effect of climate change on recharge and implications for groundwater availability.

2.1 GROUNDWATER ABSTRACTION

Management of abstraction is a key issue, as demands on the resource grow both from the Water Corporation proposal, and from economic development that is dependent on groundwater resources.

2.1.1 Current groundwater usage

The total estimated current abstraction of groundwater from the various aquifers of the Southern Perth Basin is about 72 GL/yr (Economics Consulting Services 2003 at Appendix 24).

The Leederville aquifer is widely used on the Swan Coastal Plain for town water supply, industrial use and horticulture (Figure 5.11). However, most large-scale use of groundwater in the region is from the Yarragadee aquifer (Figure 5.12). This use includes mining, industrial, town water supply, and irrigation on the coastal plains. The Lesueur Sandstone is used for Augusta town water supply, and more recently for dairy farm operations at Forest Grove to the north-east of Augusta. The licensed groundwater allocations and estimated use within the three proclaimed Groundwater Areas (see Figure 5.10 for location of these areas) are distributed between the major use categories as shown in Table 5.3 (Appendix 24). Use has been estimated based on metering of the larger users (approximately half of the current use is metered) and surveys of a limited number of un-metered licensees.

Table 5.3 Licensed groundwater allocations and use (May 2003)

Use category	Licensed allocations (GL/yr)	Current use (GL/yr)	Current use (% of allocation)	Current use (% of total use)
Town/Industry/Urban	45.1	30.4	67%	42%
Agriculture	50.3	32.1	64%	45%
Mining	18.7	8.9	48%	12%
Other	2.2	0.5	23%	1%
Total	116.3	71.9	61.8	100

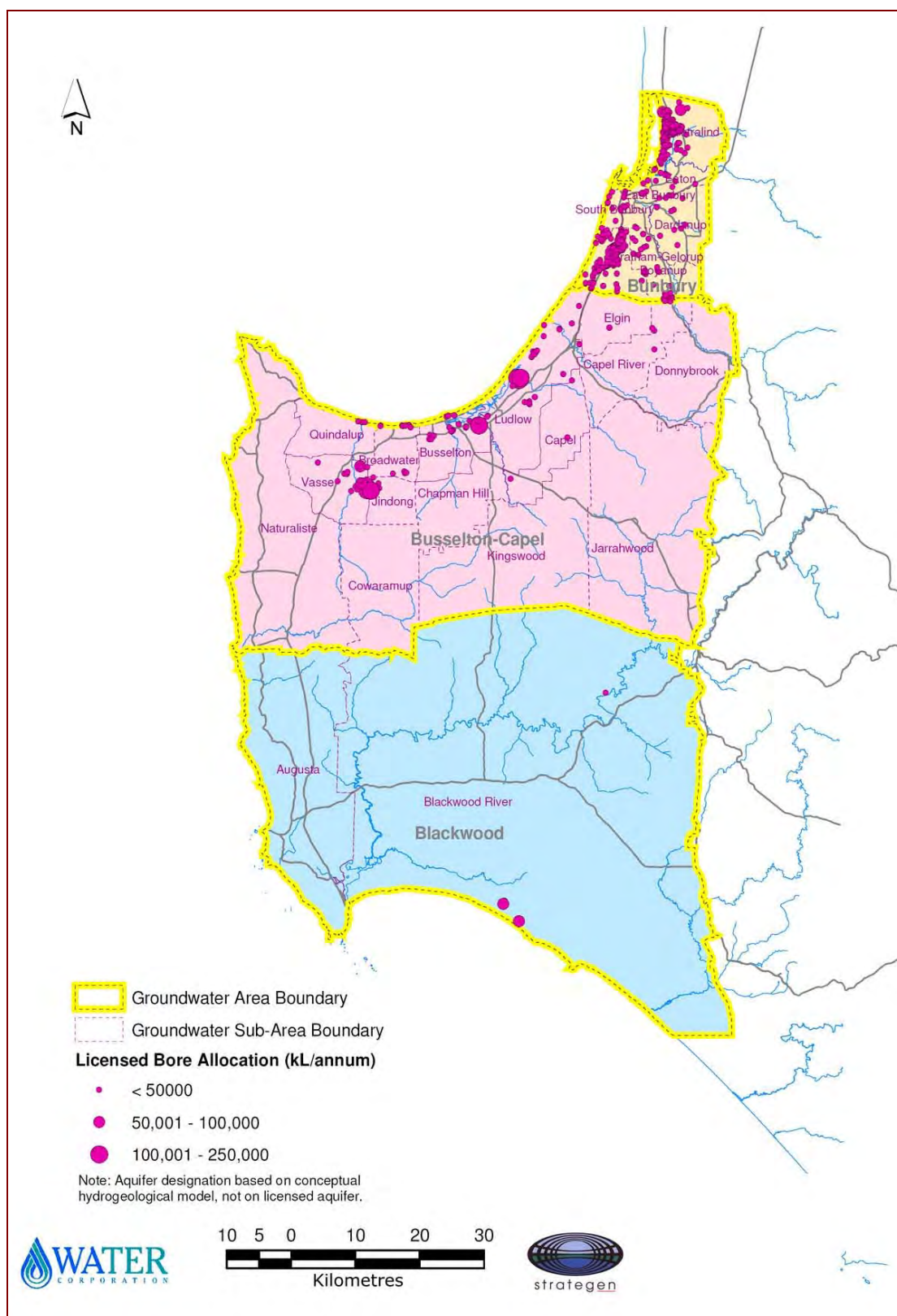
Figure 5.10 Licensed groundwater allocations – superficial formations

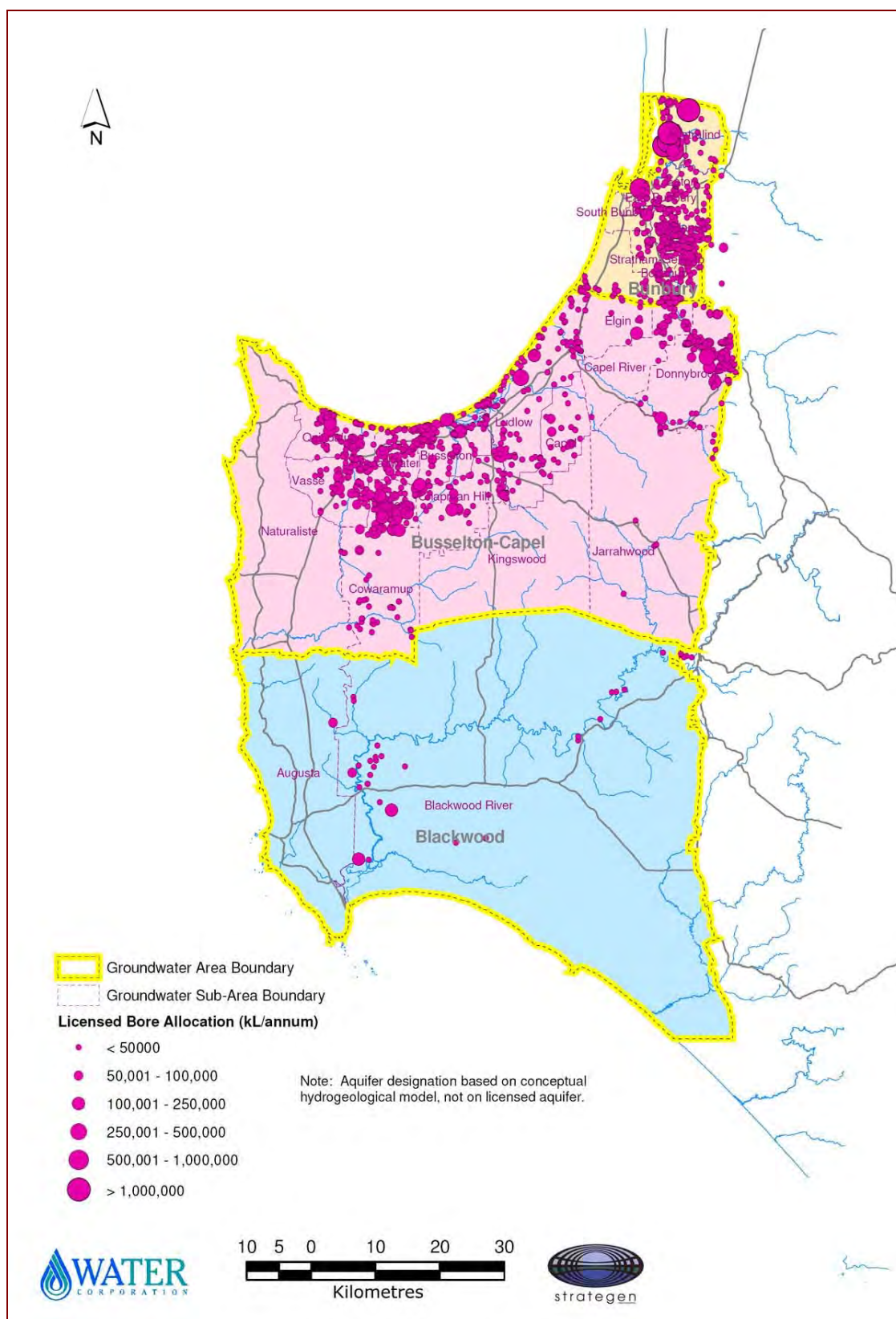
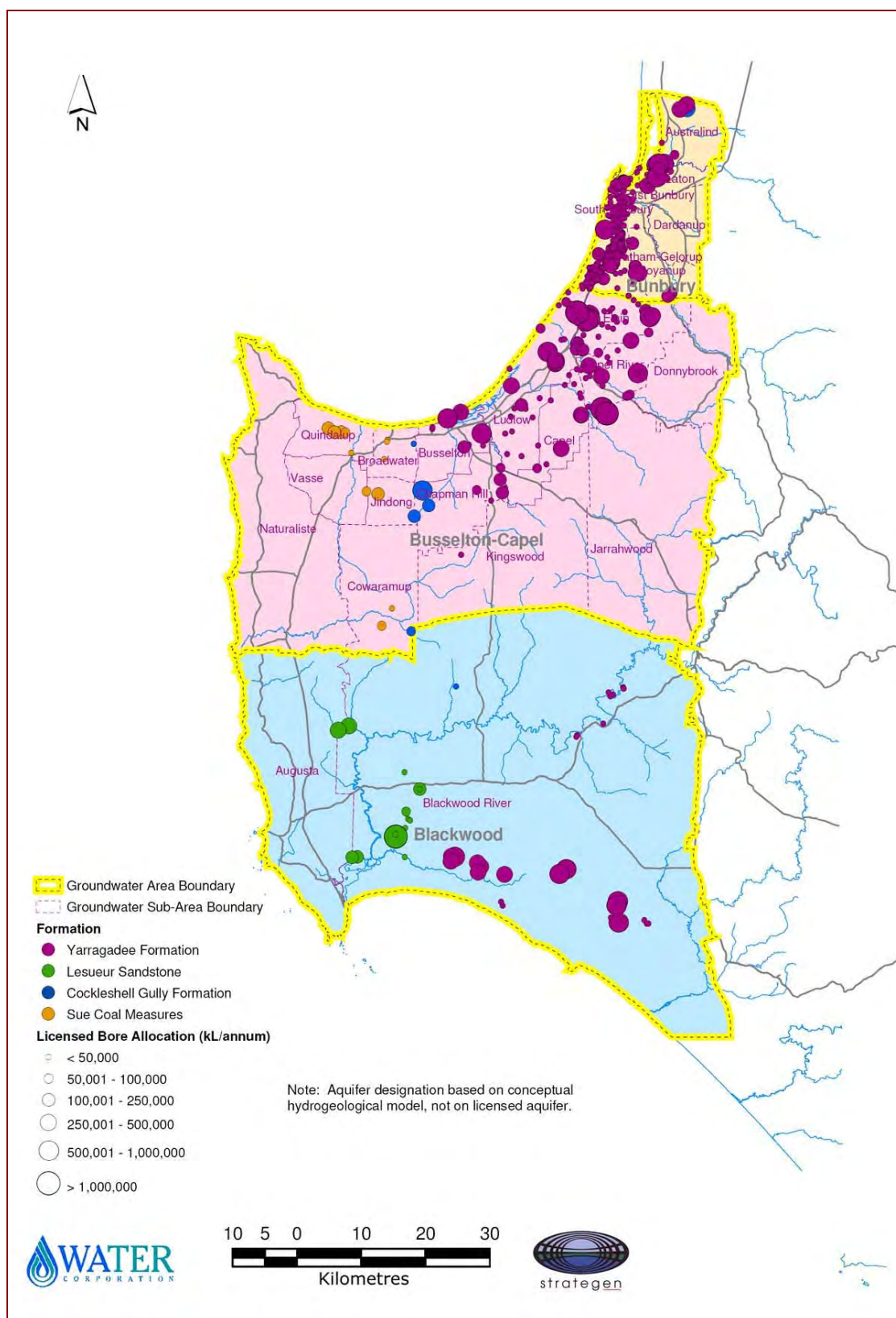
Figure 5.11 Licensed groundwater allocations – Leederville aquifer

Figure 5.12 Licensed groundwater allocations – Yarragadee aquifer



In addition to the licensed allocations, “reserve allocations” for future growth in public water supply demands are acknowledged by the DoW as being available to provide for future growth in demand above that catered for by the current licences (Table 5.4).

Table 5.4 Town water supply allocations (July 2005)¹¹

Water service provider	Current licensed allocations (GL/yr)	Allocations under application (GL/yr)	Reserve allocations (GL/yr)	Total allocations (GL/yr)	Current use (GL/yr)
Bunbury	11.3	1.9	0	13.2	6.8
Busselton	18.0	0	2.0	20.0	4.0
Water Corporation	10.5	0	4.4	14.9	6.7
Total	39.8	1.9	6.4	48.1	17.5

Licensed groundwater allocations are distributed over the major aquifer systems throughout the South West Region as shown in Figure 5.10 through Figure 5.12.

2.1.2 Projected future local water demand

Economics Consulting Services was engaged by the Department of Environment (DoE) in 2003 to undertake an economic assessment of the value of the water resources of the region. Part of the assessment was to forecast future local groundwater demands to 2030. This section summarises the assessment.

Two approaches were used by Economics Consulting Services to estimate future water demand in the South West Region:

- extrapolation of work completed for the National Land and Water Resources Audit
- specific studies of the horticulture, viticulture and irrigated dairy sectors.

National Water Resources Audit based estimates

Regional economic growth estimates produced for the National Land and Water Resources Audit were the basis for estimates of growth in water demands to 2020 – 21. This produced a range of estimates (from minimum to maximum scenarios) for each of 19 regions covering Western Australia. Water demands were proposed for four broad categories: livestock requirements, irrigation, mining and power generation and urban and industrial use. The regions of interest to this study include Preston, Vasse, and Blackwood.

Best estimates of water use (surface and groundwater) for the three regions and water use sectors were determined (Table 5.5 and Table 5.6). These tables reflect estimates of the projected water use for each region as estimated for the National Water Resources Audit, corrected in terms of their overlay on the study area. These figures represent combined surface and groundwater use.

¹¹ Data provided by Department of Environment

Table 5.5 National Land and Water Resources Audit – best estimates of future water use

Region	2000 (GL/yr)	2006 – 08 (GL/yr)	2010 – 11 (GL/yr)	2015 – 16 (GL/yr)	2020 – 21 (GL/yr)	2030 (GL/yr)
Preston	46.2	49.6	52.5	56.1	61.3	
Vasse	42.8	52.6	60.9	70.5	82.1	
Blackwood	6.1	7.4	8.2	9.4	10.7	
Total	95	110	121	136	155	203

The long-term outlook by use sector suggests agriculture will account for about 50% of the total. However, the growth rate in local urban use is expected to be significantly higher than in either the agricultural or the mining sectors (Table 5.6).

Table 5.6 Water use in the study area by major water use sector

Sector	2000 (GL/yr)	2030 (GL/yr)	Increase (GL/yr) after 30 years	Annual change (%/yr)
Agriculture	55	105	50	2.2
Mining	14	26	12	2.0
Urban	26	72	46	3.4
Total	95	203	108	2.6

Industry sector based estimates

Economics Consulting Services (2003 at Appendix 24) reported on its analysis of three agricultural industry studies commissioned by the DoE. Contact was made with key water users in the region to compile an alternative and more detailed estimate of possible future demands to those proposed by the National Land and Water Resources Audit (Table 5.7).

Table 5.7 Forecast water use by sector

Water use sector		Estimated increase in demand to 2030 (GL/yr)
Agriculture	Dairy	30.0
	Viticulture	17.0
	Horticulture	23.0
Urban town water supply	Bunbury/Busselton	12.2
	Water Corporation	6.7
Other urban		9.6
Industrial	General	8.3
	Kemerton	0 – 15.0 ¹²
Mining		0.0
Other uses (assuming 100% growth)		0.6
Total		107.5 – 122.5

¹² The modelled base case scenario assumes Kemerton will not be supplied from groundwater south of Bunbury.

Future demand scenarios

Based on analysis of the DoW groundwater licensing data base, and assumptions on the extent to which surface and groundwater will be used to meet future increases in demand, current groundwater use and forecast groundwater demand can be estimated (Table 5.8).

Table 5.8 Current groundwater water use and forecast demands

Groundwater use sector	Groundwater use 2003 (GL/yr (from Table 5.3)	National audit projection 2030 (GL/yr)	Industry base case future projection 2030 (GL/yr)	Industry expansion future projection 2030 (GL/yr)
Town/Industry/Urban	30	74	65	80
Agriculture	32	80	98	98
Mining	9	21	9	9
Other uses	1		1	1
Total	72	175	173	188

The assumptions on the proportion of groundwater expected to meet future demands are:

- 95% of the growth in demand for town water supplies, industry and urban use to come from groundwater
- 100% of future growth in demand for mining and “other uses” to come from groundwater
- 95% of the growth in demand in agriculture from to come from groundwater sources based on 100% in dairy and horticulture and 80% of viticulture.

For modelling future growth in demand, the industry base case projection was selected as representing the most likely scenario. Total use was similar to the National Audit projection total; however, the low mining growth was felt to be more realistic than the 130% increase suggested by the National Audit. The selected projection also reflected a significantly higher increase in agricultural demand, which would contribute to a more conservative consideration of the competing interests in use of the water. The town/industry/urban component was based on a more contemporary and location specific analysis of this growth sector than was undertaken by the Audit.

Since these growth estimates were made, the need to supplement water supplies for Bridgetown, Hester, Boyup Brook, Greenbushes, Balingup, Mullalyup and Kirup has arisen as a consequence of recent low rainfalls. The Yarragadee Formation is being considered for development as a source to meet the needs of these locations and the projected town/industry/urban demand of 65 GL/yr (Table 5.8) has consequently been increased by 2.0 GL/yr to cater for the potential growth of these centres.

The future use projections are based on assumptions that growth in use will occur through a combination of take-up of unused portions of existing allocations as well as through new allocations. It is not possible to predict precisely when the currently unused portion of existing allocations will be taken up. It is also expected that allocations will exceed usage, to some extent, until allocations reach the sustainable limits of the resource. Under these circumstances, it is expected that growth in use would then be largely through take-up of the unused portion of the existing allocations. This is expected to happen in a progressive manner on an area-by-area basis, rather than in an overall sense. For example, groundwater allocations from the Leederville Formation in the Jindong Area have reached the extent of the DoW assessment of sustainable yield. Growth in groundwater use from the Leederville Formation can now be permitted only through use of unused portions of existing allocations, or through accessing groundwater in alternative formations, such as the Yarragadee Formation, or through water trading.

2.2 GROUNDWATER DEPENDENT ECOSYSTEMS

There are a number of water dependent ecosystems¹³ distributed over the Southern Perth Basin that rely, to varying degrees, on the presence of groundwater close to the land surface for their sustenance. These ecosystems fall into several categories including:

- ecosystems dependent on surface flows being maintained by groundwater discharge
- wetlands where the topography is lower than the watertable
- wetland or vegetation that is reliant on the proximity to a watertable to provide either a permanent or temporary source of water.

Groundwater abstractions that affect the watertable will potentially affect these ecosystems.

2.2.1 Preliminary groundwater modelling

A preliminary numerical computer model of the Southern Perth Basin was constructed in 2003, based on information available at that time. This model was used to identify areas where future groundwater pumping might affect the watertable under a range of possible pumping scenarios (including pumping to meet current and future regional demands as well as 45 GL/yr for the IWSS). The model results suggested that for all growth scenarios modelled, interim environmental criteria might not be met in several areas, with or without pumping 45 GL/yr for the IWSS. These areas were:

- Blackwood River and tributaries, including the Poison Gully wetlands
- St John Brook
- areas of the Swan and Scott Coastal Plains
- Reedia Wetlands.

These areas of potential risk were subjected to closer investigation to understand the local hydrogeology and potential for changes that may affect the groundwater dependent ecosystems (GDEs). The results of this work are discussed in Section 4. The expected environmental impacts of the groundwater abstraction by South West Yarragadee Water Supply Development proposal are described in Chapter 7.

¹³ Water dependent ecosystems are defined by the Department of Environment as being: “Those parts of the environment, the species composition and natural ecological processes of which are determined by the permanent or temporary presence of flowing or standing water and water within groundwater aquifers.” (Water and Rivers Commission 2000)

2.2.2 Interim ecological requirements

URS Australia (2004a at Appendix 25) reported on interim ecological water requirements¹⁴ (EWRs) of GDEs with potential to be affected by abstraction from the Yarragadee aquifer. The interim EWRs were based on existing data and knowledge, previous specific and regional studies and datasets held and managed by the Department of Conservation and Land Management (CALM). A summary of the interim EWRs is presented in Table 5.9.

EWRs can be very specific for different components of the environment and for different species, but those with the most demanding requirements can act as bio-indicators for the whole species assemblage of a particular ecosystem. In assessing EWRs, URS Australia (2004a at Appendix 25) assumed that there should be no loss of (or change to) existing values. This conceptually provides a conservative approach as it is essentially based on no risk to those values.

URS Australia (2004a at Appendix 25) noted that because of the absence of specific and detailed data on the range of ecological values in the four areas identified for further study, ecological modelling to predict changes in ecosystems in response was difficult. URS also noted that, “As ecological values change with time, there is a need to incorporate temporal shifts in values in any modelling.” It is important to note that there is a range of causes of impacts to ecological values that need to be considered – not just declines in groundwater level resulting from abstraction. There are a number of existing disturbances in the potential risk areas, including logging, “dieback” infection, fire regimes, feral pigs, invasive plants, eutrophication from agricultural runoff, acidification, drainage, mining, and vehicular access to sensitive areas. Climate change has considerable potential to have a significant effect on all water dependent ecosystems.

The approach taken in this evaluation has been based on a detailed evaluation of the groundwater dependent ecosystems, and identification of the potential risks for those ecosystems as a consequence of both the proposal and future regional groundwater use, rather than determination of an arbitrary environmental water requirement for each ecosystem or component.

¹⁴ Ecological Water Requirements (EWRs) are defined by the Water and Rivers Commission as “the water regimes needed to maintain the ecological values of water-dependent ecosystems at a low level of risk.” (Water and Rivers Commission 2000).

Table 5.9 Summarised interim EWR criteria for high conservation value and high ranking potential GDEs

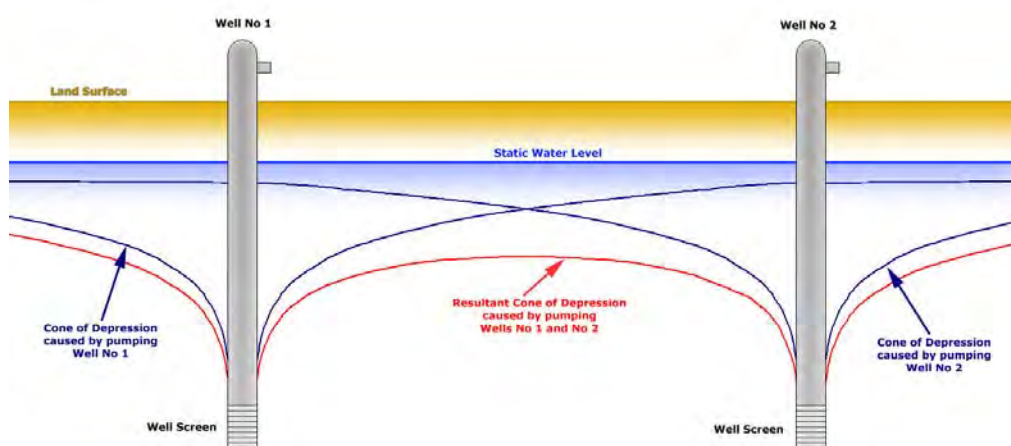
Groundwater dependent feature	Occurrence	Management objectives	Interim EWR criteria	
			Maximum permissible absolute change in groundwater attribute	Maximum permissible rate of change in groundwater attribute
Wetlands (sumplands and damplands)	Bunbury–Capel coastal and inland wetlands, and Scott Coastal Plain wetlands	Minimise potential for changes in water availability and quality (e.g. salinity and shifts in seawater wedge in coastal wetlands, and nutrient enrichment on inland Swan Coastal Plain)	Less than 0.25 m	Less than 0.1 m/yr
Wetlands that could potentially be modified by changes in bio-geochemistry	Bunbury–Capel coastal, Blackwood Valley and Scott Coastal Plain wetlands	Minimise potential for changes in water quality, anaerobic conditions maintained, to avoid acidification plume developing	Levels should be maintained within historical range. (Less than 0.25 m?)	Within historical range. (Less than 0.1 m/yr?)
Vegetation (sumpland and dampland communities)	Bunbury–Capel coastal, Blackwood Valley and Scott Coastal Plain wetlands	Minimise potential for rapid and extreme changes in water availability and quality	Less than 0.25 m below current summer minimum level. Some vegetation on coastal plains are threatened ecological communities (TECs) and subject to seasonal fluctuations	Less than 0.1 m/yr, as many communities (including TECs) dependent on seasonal fluctuations for survival
Vegetation (riparian and phreatophytic communities)	Blackwood Valley – main stem discharge area and tributaries	Minimise potential for rapid changes in water availability for vegetation during extreme fluctuations in flows to avoid reduction in seed set and recruitment for species within communities	Less than 0.5 m below current summer minimum level; potential very high for vegetation on flood plains and levees on Blackwood River	Not Applicable
Flora (species, subspecies and varieties in riparian and phreatophytic communities)	Blackwood Valley – main stem discharge area	Minimise potential for rapid changes in extreme fluctuations in flows to avoid reduction in seed set and recruitment	Less than 0.5 m below current summer minimum level; potential very high for flora on flood plains and levees on Blackwood River	Not Applicable
Flora (species, subspecies and varieties in sumplands and damplands)	Blackwood Valley and Scott Coastal Plain wetlands	Minimise potential for rapid and extreme changes in water availability and quality	Less than 0.25 m below current summer minimum level	Less than 0.1 m/yr
Fauna (species in rivers and associated floodplains)	Blackwood Valley – main stem discharge area and tributaries	Maintenance of floodplain habitats and diversity of fauna and refugia	Less than 0.5 m below current summer minimum level on floodplain. Maintain the condition of habitats on flood plains and levees on Blackwood River	Not Applicable
Fauna (species in sumplands and damplands)	Blackwood Valley and Scott Coastal Plain wetlands	Minimise potential for rapid and extreme changes in water availability and quality	Less than 0.25 m below current summer minimum level; – some of fauna may be rare or endangered and dependent on both seasonal water and habitats in these areas	Less than 0.1 m/yr
Biological values dependent on water flows	Blackwood Valley – main stem discharge area and tributaries	Maintain seasonal elevated flows in Blackwood main stem and existing range of channels and pools in tributaries	For perennial streams, a minimum of 20 cm maintained over riffle zones during Sept – Oct; at other times, it can reduce to 5 cm In main Blackwood River, absolute minimum river flow of 4.6 GL/yr (0.15 m ³ /s) during Sept – Oct and minimum annual flow of 54 GL/yr	Not Applicable
Biological values dependent on water quality	Blackwood Valley – main stem discharge area and tributaries	Maintain water quality	Blackwood main stem: At Hut pool, a shift in long-term median (monthly) salinity to current 80th percentile. 10% increase in monthly salinity within Yarragadee discharge area Tributaries: a shift in median (monthly) salinity to current 95 th percentile for salinity in perennial systems	Not Applicable

Note: Table reproduced from Strategen (2004) at Appendix 10

2.3 DRAWDOWN INTERFERENCE EFFECTS

Pumping groundwater lowers water levels or water pressures around the pumped well (drawdown). The extent of drawdown depends on the amount of water being pumped, the hydrogeologic setting in which the well is constructed, and the characteristics of construction of the well itself. The drawdown below the static water level¹⁵ is greatest close to the well and decreases with distance from the well. The area surrounding the pumping well that experiences the drawdown effect is called the “cone of depression”. Drawdown interference effects can be experienced when the cones of depression of two or more wells intersect. The drawdown within the resulting cone of depression generally reflects the combined effect of the interfering wells, as shown diagrammatically in Figure 5.13.

Figure 5.13 Resultant cone of depression from two wells experiencing interference drawdown effects



Interference drawdown becomes significant when it causes drawdowns in the affected well (or wells) to the extent that the pump intake in the well needs to be lowered, or, in more extreme cases, for the well to be deepened (when drawdown extends below the well screen). Interference effects are usually managed by maintaining an adequate distance between wells with potential to interfere with each other. The required distance is a function of a range of factors, which include the efficiency of affected wells, in terms of the drawdown they need to generate their design yield. Poorly constructed (inefficient) wells are more susceptible to interference effects than efficient wells. Well efficiency also tends to deteriorate with age.

In considering groundwater well licence applications under the *Rights in Water and Irrigation Act 1914* (RWI Act), the Water and Rivers Commission endeavours to minimise interference effects between licensed wells, particularly where the wells are of different ownership.

¹⁵ “Static water level” refers to the groundwater level that would occur if there were no drawdown effects from pumping.

In setting out the information requirements to support the licence application for the South West Yarragadee Water Supply Development project, the Water and Rivers Commission advised the Water Corporation that:

“The Corporation should demonstrate that the taking of the volume of water requested in the application, would not result in unacceptable adverse impacts on other groundwater users within the Blackwood, Busselton–Capel and Bunbury Groundwater Areas.”

See Appendix 2

This requirement is understood to stem from Schedule 1, Section 7(2)(e) of the RWI Act requiring the Commission to consider whether the proposed taking and use of water would, in the opinion of the Commission, have a detrimental effect on another person. The assessment factor relevant to this issue has been expressed by the Commission as:

“Detrimental impacts on other bore users do not occur or agreed process in place to provide reasonable compensation (monetary or other).”

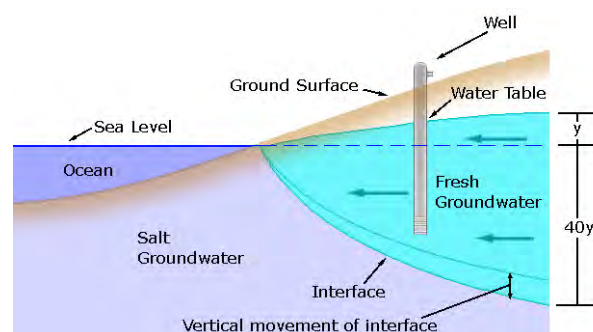
See Appendix 2

The primary reason for siting the proposed Water Corporation wellfield on the Blackwood Plateau was to maximise separation from all other existing groundwater users in the region, as a means of minimising any potential interference effects with existing wells. The existing groundwater abstractions are mainly on the coastal plains, largely because of the lack of private land over the central plateau area (Figure 5.10 through Figure 5.12). The extent to which the Water Corporation wellfield will cause interference effects on existing users has been examined and is discussed in Section 4.11.

2.4 SEAWATER INTRUSION

Seawater intrusion into coastal freshwater aquifers can take place if groundwater abstraction is not adequately managed. Fresh groundwater discharging into the ocean does so through an interface with the seawater. The position of the interface depends on the relative densities of the fresh and salt water and the amount of freshwater flow towards the ocean. Seawater is approximately 2.5% more dense than freshwater. The lighter freshwater therefore tends to float on top of the salty groundwater. Hydrostatic equilibrium requires the freshwater column floating on the seawater to be about 1.025 times as high as the saltwater column. That is, one unit of freshwater would exist above sea level for every 40 units of freshwater below sea level (Figure 5.14). The elevation of the watertable is related to the amount of groundwater flow discharging through the aquifer towards the ocean. In simple terms, the higher the amount of water discharging towards the ocean, the higher (steeper) the elevation of the watertable, and consequently the deeper the seawater interface.

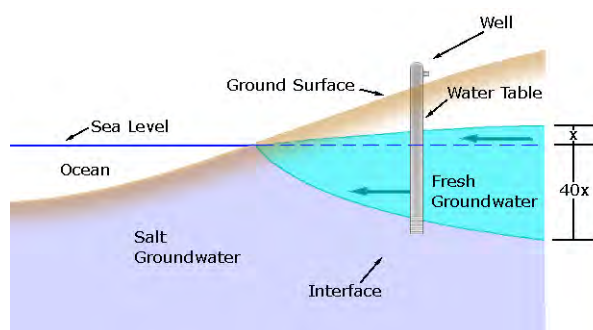
Figure 5.14 Diagrammatic representation of a typical saltwater interface



If abstraction reduces groundwater outflows to the ocean, then the watertable lowers and the position of the saltwater interface moves upward to a position to maintain the 1:40 relationship. In effect, the toe and face of the wedge move inland in proportion to the reduction in flow. Response of the interface to any change in flow will not be instantaneous, because the freshwater in storage that would be displaced through interface movement will take some time to physically leave the system.

Saltwater intrusion becomes a problem if the interface moves far enough inland to intersect the screened zones of pumping wells, which then experience a decline in water quality through pumping saltier water (Figure 5.15)

Figure 5.15 Saltwater interface affecting pumping well



The simplest form of management to avoid this effect is to ensure that sufficient groundwater flow is maintained towards the ocean to keep the interface at an adequate distance from pumping well screens. Wells in zones near a saltwater interface also need to be designed to ensure the intake zone is far enough above the interface to minimise the opportunity for the interface to affect the well.

Concerns with saltwater intrusion in Aqwest wells were raised in the late 1970s and early 1980s when growth in abstraction of the town supply appeared to be causing inland movement of the interface and some wells to produce saltier

water. Recommendations were subsequently made to modify the wellfield layout and design, by moving wells further inland, and spreading abstraction over a greater range of aquifer intervals (Boyd 1979, Water Authority of Western Australia 1994). Aqwest consequently decommissioned several production wells located close to the ocean and interface, which have since been used as strategic monitoring wells.

Reductions in groundwater outflow resulting from the combined abstractions of all users have the potential to affect existing wells in coastal locations. Examination of predicted changes in water level provides the primary means of evaluating the potential for existing wells to be affected. The extent to which the proposed Water Corporation wellfield will cause saltwater intrusion effects has been examined and is discussed in Section 4.12.

2.5 POTENTIAL ACID SULPHATE SOILS

Acid sulphate soils are naturally occurring soils that contain iron sulphide minerals, predominantly as the mineral pyrite. These iron sulphides are generally found in a layer of permanently waterlogged soil or sediment. Acid sulphate soils are most likely to be found in coastal regions, in low-lying areas containing estuarine sediments, peaty sediments underlying wetlands, and in mineral sands deposits along former shorelines. It is important to note, however, that in the natural environment, pyrite and other sulphides are continually being created, as well as being oxidised.

Acid sulphate soils are benign when undisturbed, and when the pyrite layers remain below the watertable. However, exposure of pyrite to the air (oxidation¹⁶) by lowering of the watertable (through drainage, drawdown effects from groundwater abstraction, or low rainfall) or excavation of soil can generate sulphuric acid, iron precipitates, and concentrations of dissolved heavy metals, such as aluminium, iron and arsenic. Drainage water in contact with the oxidising soil usually becomes acidic and can leach metals from the soil. The discharge of acidic water into waterways and wetlands can contaminate surface water with sulphates, arsenic and other metals. This contamination can affect fish and cause loss of aquatic biodiversity, and can contaminate groundwater

Wetlands underlain by pyritic sediments may become acidic if water levels are lowered substantially by groundwater pumping, or by an extensive period of low rainfall, and increases in acidity can greatly reduce the biodiversity of aquatic ecosystems in these waterbodies (Appleyard and Angeloni 2003). The extent to which the proposed Water Corporation wellfield may cause acid sulphate effects has been examined and is discussed in Section 4.14.

2.6 CLIMATE CHANGE IMPACTS

Climate change refers to the anticipated changes in the world's climate as a consequence of global warming of the atmosphere resulting from increased greenhouse gas emissions. The groundwater systems of the Southern Perth Basin are recharged mainly by direct infiltration of rainfall over the area of the basin. Changes in rainfall in the region have implications for groundwater availability and groundwater dependent ecosystems. The current research into climate change indicates that the likely scenario for the south-west of the State is for a drier climate than the average experienced during the last century (CSIRO 2001). The extent to which rainfalls will decrease is uncertain. The research suggests prognoses for the south-west ranging from 5% increases to 20% declines in annual rainfall by 2030, with the balance of scientific opinion falling on the side of an overall decline.

The extent to which groundwater availability will be affected will depend on:

1. The biological response to reduced rainfall will result in the make-up of vegetation types shifting to those associated with drier climate regimes. Biological responses have already been observed in areas of the State as a consequence of the lower rainfall period experienced since the mid-1970s. The Tick Flat area on the northern part of the Gnangara Mound is an example. In this area, vegetation with predominantly wetland characteristics has gradually changed to vegetation characteristic of upland areas, and with lower dependencies on groundwater, since the 1970s (Mattiske 2003). The only influence on vegetation type in this area that could have caused this change is the drier climate experienced in the region over recent decades.
2. Because the values of water dependent ecosystems in the region will change in response to a modified climate regime, the basis of determining acceptability of drawdown impacts on those systems will need to be re-evaluated against the potentially changing benchmark. This is a major policy issue and is discussed in detail in Volume 1 Chapter 7 Section 2.1.6.

In the base case model of the South West Yarragadee aquifer system, recharge rates about 9% lower than the estimated historical recharge for the region have been used. To examine the potential impacts of extreme climate change, the effect of further progressive 5% and 10% reductions in annual recharge to groundwater over the next 30 years were also examined. The results are discussed in Section 4.13.

¹⁶ Oxidation generally means the addition of oxygen or the removing of hydrogen to a substance in a chemical reaction.

3 GROUNDWATER MODELLING APPROACH

Groundwater systems are complex natural systems with substantial variability in their physical characteristics, both vertically and laterally. While the fundamental theory of groundwater hydraulics¹⁷ is relatively simple, application of the theory to aquifer systems with complex 3-dimensional geometry, interactions with surface water, and changing inputs (e.g. climate and recharge) and outputs (e.g. abstractions and drainage) requires significant computing capability. Computer-based groundwater flow modelling techniques have been developed to allow these complex systems to be simulated and various management possibilities to be tested. Essentially, these techniques allow estimates of how water levels and pressures in aquifers will vary over time, in response to any range of recharge and abstraction scenarios that are considered likely.

The consequences of the water level and pressure responses can then be analysed to understand the environmental, social and economic implications.

As pumping changes, the entire water balance changes in response and adjusts to a new equilibrium. Pumping affects all the components of the water balance to varying degrees, with the exception of rainfall.

The dynamics of these changes require computer-modelling techniques to estimate how the system might respond to effects such as pumping and climate change. Computer modelling of groundwater systems has been undertaken extensively by specialists in both the Government and private sectors since the early 1970s, and has developed into a very mature science. The development of a computer model of the Southern Perth Basin to predict the regional-scale effects of possible future groundwater development and climate change is discussed in the following sections.

3.1 METHODOLOGY

3.1.1 What is a groundwater model?

A groundwater model is a representation of the essential features of a natural hydrogeological system that uses the laws of science and mathematics. Most groundwater models are constructed within computers to allow the solving of the large set of complex mathematical equations that quantify the physical processes of the aquifer system(s) being modelled. A groundwater model provides a predictive scientific tool to indicate the potential impacts on the system of a specified range of hydrological, pumping and other stresses.

The key components of a groundwater model are a conceptual model and a mathematical model. The conceptual model is a descriptive representation of our hydrogeological understanding of how water flows into, through and out of a groundwater system. This is usually presented in the form of diagrams and maps of the physical characteristics of the geological formation geometry and flow systems and flow directions. The conceptual model of the system being studied for the South West Yarragadee Water Supply Development proposal is described in detail by Baddock (2005a) and summarised in Chapter 5 Section 1.

¹⁷ Groundwater hydraulics is the theory of groundwater movement.

The mathematical model is the assembly of numerical data sets that reflect the conceptual model, and the computer-coded package of equations that enable calculation of changes in water level or pressures in the various geological strata. MODFLOW was selected as the appropriate modelling software for this Sustainability Evaluation/ERMP. MODFLOW is a public domain, international industry-standard, groundwater modelling software package developed by the United States Geological Survey. MODFLOW version 2000 was applied to construct a three-dimensional mathematical model of the aquifers under study, using all the available hydrogeological, hydrological, pumping, and climate data developed from the extensive investigation programs.

There are three stages in the development and use of a mathematical groundwater model, and these are discussed in the following sections:

- construction
- calibration
- application.

This discussion is a summary of the description of the modelling work reported in detail by Sun (2005).

3.1.2 Model construction

The area to be modelled is overlain by a rectangular grid. Each cell in the grid is represented by a point at the centroid of that cell, to which specific hydraulic characteristics are assigned to represent the spatial variability in the system being modelled. The grid can be applied to a number of layers if the hydraulic characteristics of the geology change with depth (as they do in the study area). Each individual cell within each layer is assigned values for properties such as the ability to store water, the ability to transmit water (horizontally and vertically), the vertical thickness of the formation at that point, and water level or pressure. In areas where more detailed modelling is required, such as areas with special environmental features, a closer spaced grid can be used.

Recharge rates can be assigned to each surface cell, and those rates can be varied over time. Pumping wells are located in the cells representing their location (actual or proposed), including specifying which layer the well draws water from, and how that draw might vary over time.

The investigation team established the framework of the groundwater flow model of the South West Aquifer Modelling System based on previous modelling work by Cymod (2004). The current version of the model (SWAMS v2.0) is an extensive modification of that earlier model (SWAMS v1.2.1), with the modifications in part being in response to a review by an independent expert Peer Review Panel (DoE 2004a). Major modifications included boundary condition locations, fault locations and hydraulic characteristics, new model layers and parameter domains based on newly collected data and more detailed hydrogeological interpretation. The SWAMS v2.0 modelling system consists of a significantly improved and comprehensive database containing abstraction, monitoring and environmental data, a MODFLOW 2000 saturated flow model, pre and post processors and a Geographical Information System (GIS) database.

The model domain adopted for SWAMS v2.0 is approximately 190 km long and 70 km wide, covering an area of approximately 8500 km² (Figure 5.16).

A grid of 363 rows and 193 columns was used to represent the area of interest (approx. 70 000 cells). The grid is variable with cells ranging in size from 250 m x 250 m for more environmentally significant areas, to 1000 m x 1000 m in less significant areas. Vertically, the model has eight layers, which represent the major aquifers and aquitards in the Southern Perth Basin. The model comprises approximately 500 000 individual cells. The grid extends under the ocean, both to the north and south, so that offshore groundwater discharges can be taken into account. The grid is closer spaced through the areas of concern, such as the Blackwood River, the eastern Scott Coastal Plain, and the northern Swan Coastal Plain. The Bunbury Trough is subject to a finer mesh than the Vasse Shelf.

The vertical layering of the formations within the model is shown diagrammatically in Figure 5.17. Figure 5.18 shows part of a typical cross section of the study area and the vertical structure of cells to represent the various strata within the eight layers.

A model can simulate interaction with surface drainages, in terms of water draining from the watertable when levels are high enough. In areas such as the coastal plains and along the Blackwood River, where evapotranspiration losses may vary in response to changes in the watertable, the model incorporates a process to calculate these responses.

The system under study is hydrogeologically very complex. There are aquitards on the Blackwood Plateau, outcrop areas for the Yarragadee aquifer, perched watertables, and significant occurrences of basalt with irregular shapes and thickness. These make the water table geometry highly variable. In some places (e.g. on the Blackwood Plateau) the slope of the watertable surface can be steep. Calibrating a model for such a system presented a significant challenge.

Figure 5.16 Model domain of the South West Aquifer Modelling System

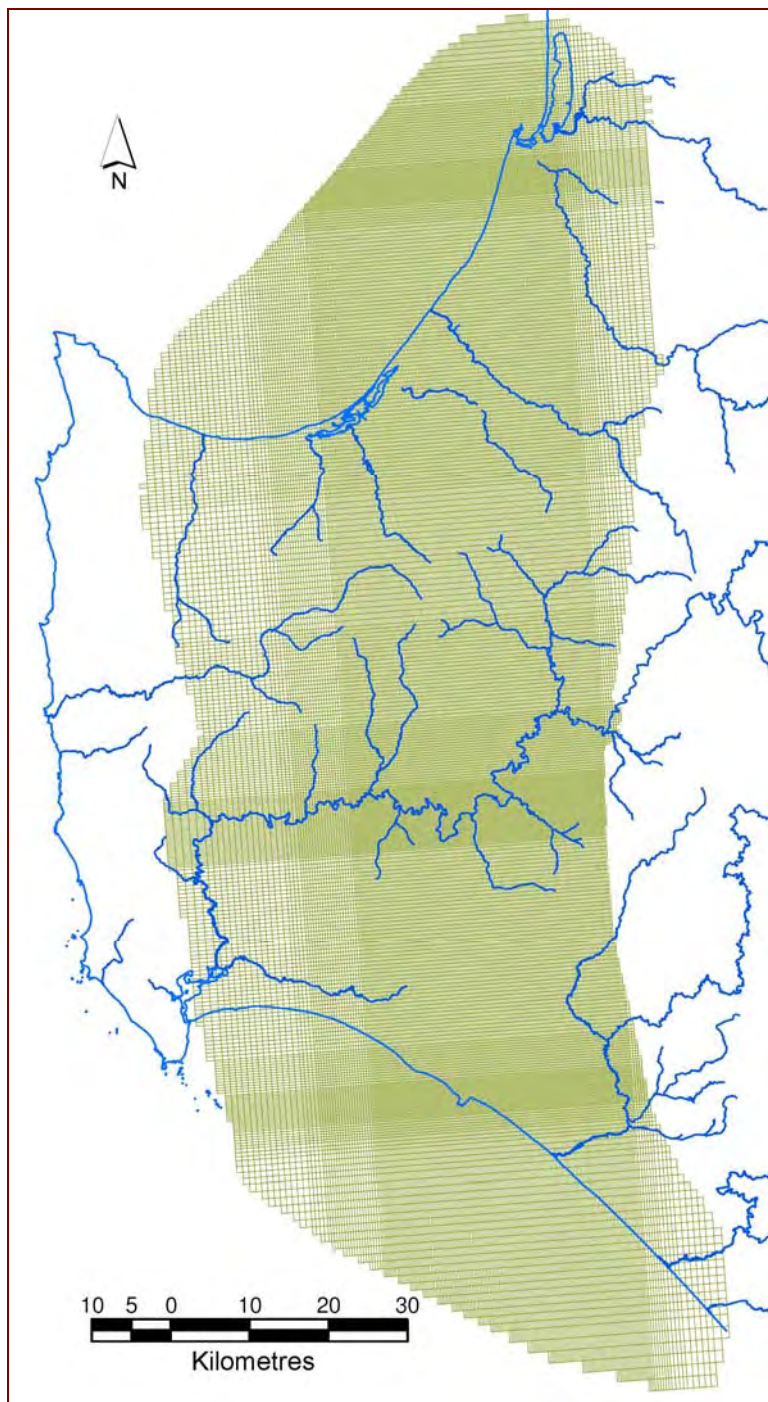
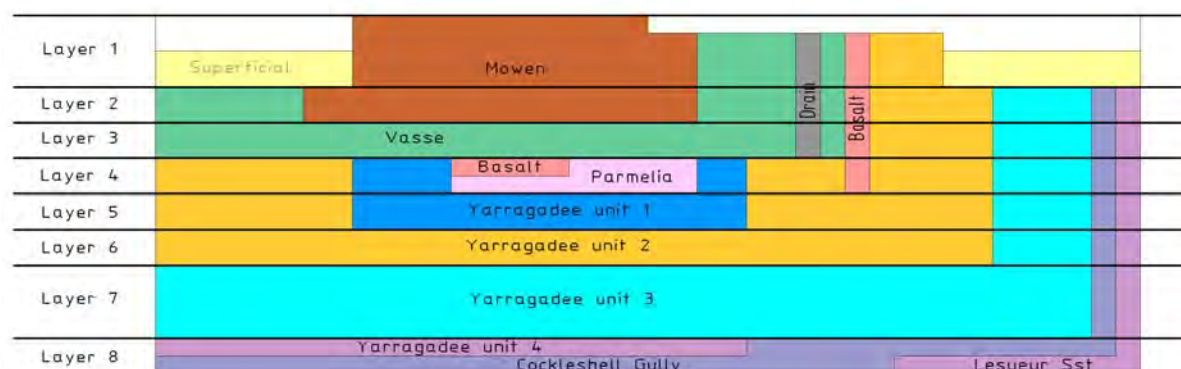


Figure 5.17: SWAMS model vertical layering

Boundary conditions

No-flow boundary conditions were assigned to the eastern and western model boundaries of all layers, to represent the Darling and Dunsborough Faults, which are impervious to groundwater flow.

For the superficial aquifer, the northern and southern boundaries were assigned to be the ocean, which was modelled as a constant-head boundary at sea level (Australian Height Datum) at the shoreline. For layers one to three, the superficial and Leederville aquifers are presumed to extend offshore and discharge upwards into the ocean across the continental shelf. Constant-head boundaries at sea level were assigned to these layers over the submerged areas.

For layers four through eight, constant heads were assigned, at the continental shelf in the south, and in the Bunbury Trough in the north. In the offshore areas of the model the boundary condition accounted for the density of seawater (a head of 2.5 m above sea level was added to each 100 m depth below sea level to account for seawater being 2.5% more dense than fresh water).

The lower boundary of the model (the base), set as a no-flow boundary, was adopted as the depth at which the salinity of groundwater exceeds 1000 mg/L TDS.

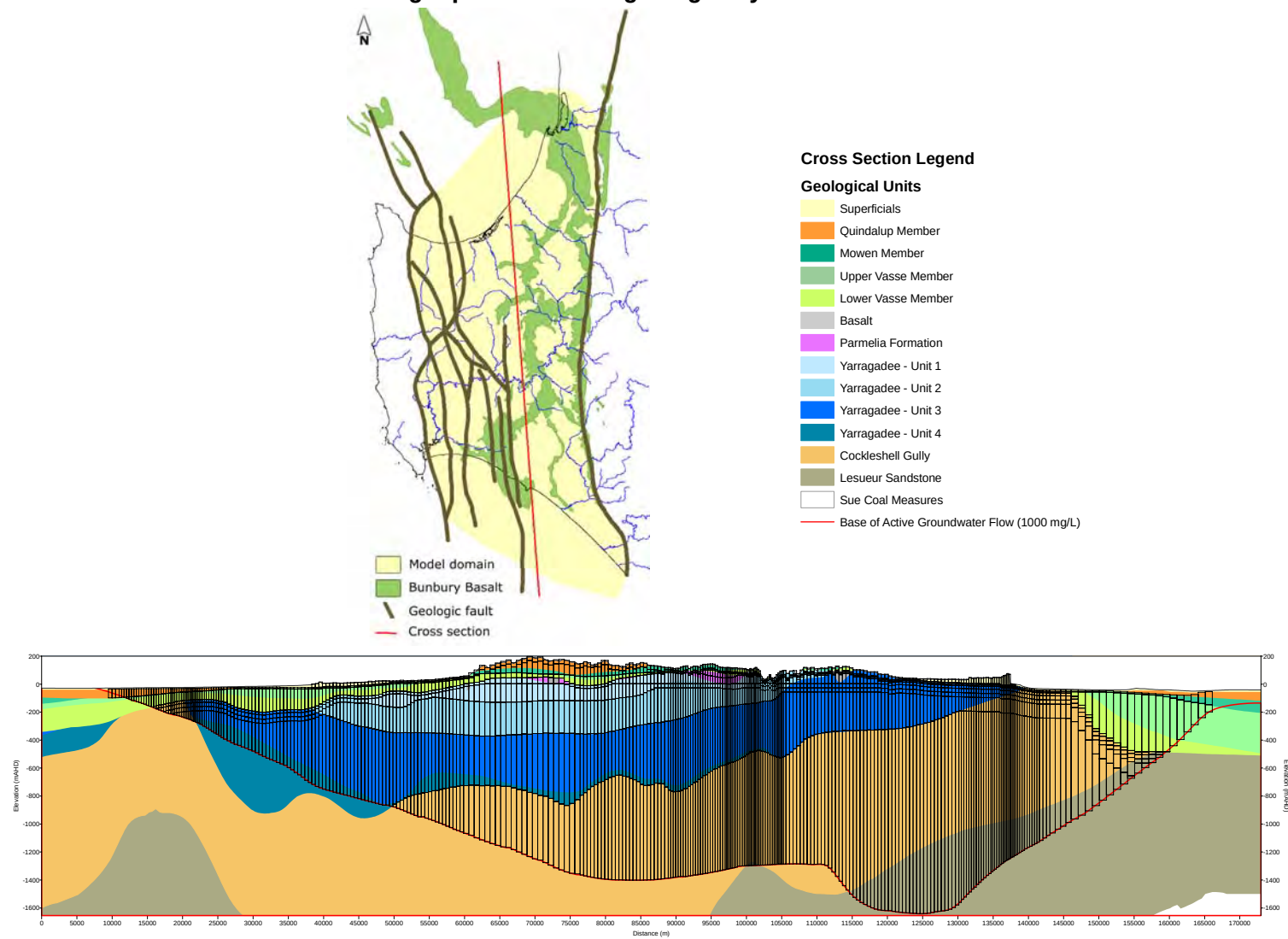
The model accounted for areas where the watertable intersects with riverbeds (with consequent discharge from the aquifer) as specified by topographic and watertable mapping.

Model parameters

A range of horizontal and vertical conductivity values for each of the geological formations was pre-estimated by the investigation team, based on pump test information (where available), examination of core samples, and experienced opinion. The spatial distribution of aquifer parameters was developed from data obtained from several investigation wells, and from correlation with pumping tests. These estimates, based on the work of Sun (2005), represented best estimates of upper and lower bounds for properties that could be assigned during model calibration (Table 5.10).

Table 5.10 Estimated ranges for aquifer parameters

Formation	Horizontal permeability (m/d)	Vertical permeability (m/d)
Quindalup Member	0.1 – 0.5	$10^{-6} - 10^{-3}$
Vasse Member	0.1 – 5	$10^{-4} - 10^{-2}$
Parmelia Formation (3B)	0.005 – 0.05	$10^{-6} - 10^{-5}$
Bunbury Basalt	$10^{-7} - 10^{-6}$	$10^{-7} - 10^{-6}$
Yarragadee Layer 1	5 – 15	$10^{-3} - 10^{-1}$
Yarragadee Layer 2	1 – 10	$10^{-3} - 10^{-1}$
Yarragadee Layer 3	5 – 30	$10^{-2} - 1$
Yarragadee Layer 4	2 – 5	$10^{-3} - 10^{-1}$
Cockleshell Gully Formation	0.5 – 4	$10^{-4} - 10^{-2}$
Lesueur Sandstone	0.2 – 5	$10^{-3} - 10^{-1}$

Figure 5.18 North-south cross section showing representation of geologic layers in model cells

Recharge and evapotranspiration

The initial recharge mapping over the area of the model was developed from a range of hydrogeological studies and from chloride data in shallow groundwater aquifers.

The model calibration then adjusted these estimates to fit with observed head data (Sun 2005).

Annual recharge rates were scaled temporally to estimate monthly recharge, based on a relationship with runoff rather than rainfall, to enable better representation of the inter-annual variations in annual recharge. A review of previous modelling results (SWAMS v1.2.1) indicated that seasonal recharge variation is generally under-represented when using rainfall as the temporal scaler for recharge distribution in the landscape. The spatial distribution of recharge values adopted is shown in (Figure 5.19).

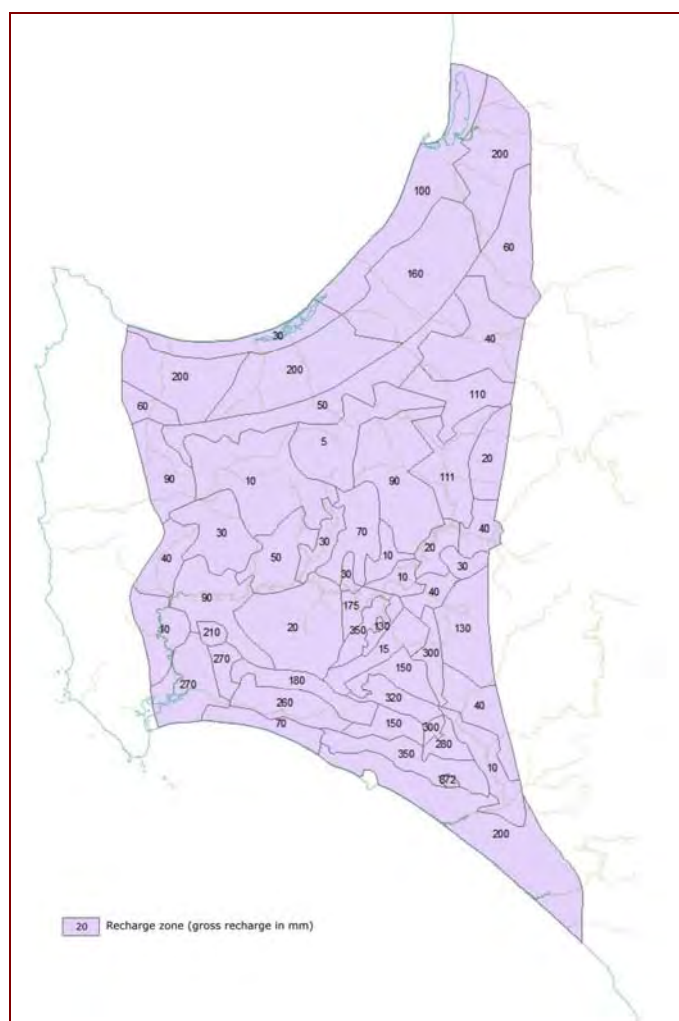
The recharge values adopted are a mix of gross and net recharge, depending on the hydrogeology of the area being considered. In areas with a very shallow watertable, as over much of the coastal plain areas, the net recharge varies according to the depth to watertable, through two mechanisms:

- evapotranspiration losses from the watertable vary with the depth to watertable
- recharge will be rejected, and will discharge as surface runoff, when the watertable is near the surface and the aquifer system is essentially “full”.

On the Swan Coastal Plain, and part of the Scott Coastal Plain, where the watertable is shallow, recharge is specified as gross recharge. The EVT module of MODFLOW 2000 is used to account for water loss due to evapotranspiration to calculate net recharge. The EVT module calculates evapotranspiration as a declining function based on depth to watertable below the ground surface to a depth below which evapotranspiration is assumed zero (the extinction depth). Extinction depths of 2 m and 5 m were used for agricultural land, and a mix of agriculture and forests, respectively.

The maximum evapotranspiration rate (E_m) is specified as a fraction of the measured monthly pan evaporation as measured at Bunbury. E_m varies spatially but is held constant for each location during a model run.

Figure 5.19 Recharge zone distribution



The seasonal variation in evapotranspiration is accounted for in the model by scaling E_m with the measured average daily pan evaporation, for each month, as measured at Bunbury. The calculated evapotranspiration is assumed to vary linearly from a maximum at the surface, to zero at the extinction depth at any location. Maximum evapotranspiration rates and extinction depths were modified as required during calibration.

Evapotranspiration is not modelled for the Blackwood Plateau and part of the Scott Coastal Plain. This is a conservative approach adopted in the previous version of the model, and retained in the current version. Net recharge is used for these areas, which effectively removes recharge that can be potentially induced by future abstraction and lowered water levels.

The distribution of the zones for evapotranspiration, and the evapotranspiration factors adopted for each zone, are shown in (Figure 5.20).

Faults

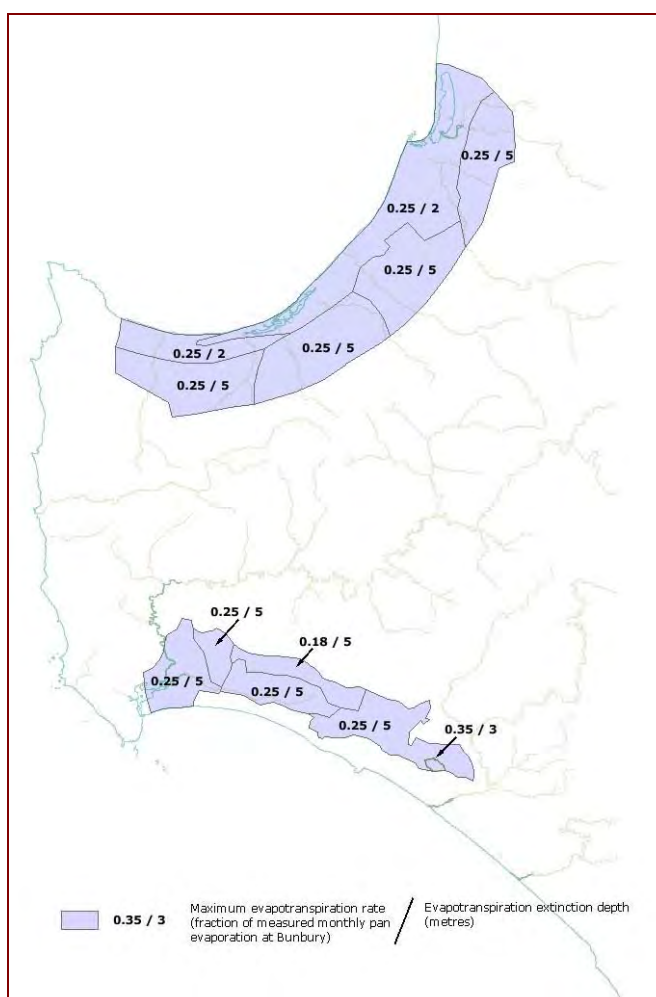
Based on a review of piezometric heads, geology, and carbon-14 data, a number of major faults were identified as being hydrogeologically significant and included in the model. These faults include the Darling, Dunsborough, Darradup and Busselton Faults (Figure 5.18).

The Darling Fault forms the eastern boundary of the model domain and is impermeable to groundwater flow. The Dunsborough Fault forms part of the western boundary of the model and is also impermeable.

The other faults that lie within the model domain were modelled as horizontal flow barriers for the lowest four layers of the model, using the horizontal flow barrier (HFB) module in MODFLOW. The modelling of a fault using HFB required two parameters: a directional parameter related to the rectangular geometry of the grid, and a conductance (with units of m^{-1}) across the fault. For most faults, the conceptual

hydrogeological model implied them to be relatively impermeable flow barriers. The conductance of the faults as applied in the model was determined through calibration.

Figure 5.20 Evapotranspiration zone distribution



Abstraction

Groundwater abstraction throughout the model domain is subject to licensing under the RWI Act and all licences specify an annual limit on abstraction by the licensee. Wells for domestic and stock water are exempt from this licensing requirement. Metering is required for licensed abstractions in excess of 0.5 GL/yr. Agricultural abstractions of less than 0.5 GL/yr were estimated from an audit of the types and areas of crops grown in the modelled area, with watering rates as advised by the Department of Agriculture (AgWA).

Historical groundwater abstraction over the model domain was estimated from examination of metering data where available, coupled with audit information on licensed sites collected by DoE officers. For licences with allocations less than 0.2 GL/yr, it was assumed that 80% of the annual licensed allocation has been abstracted.

The abstractions were quantified both spatially and temporally, on a monthly basis over the model calibration period. The data was defined in terms of unique draw-points, where each draw-point is a single well. Where no information was available for a licence having multiple draw-points, each draw-point was assigned an equal portion of the annual allocation.

Unlicensed stock and domestic abstractions are mainly from the superficial aquifer, and are likely to be relatively small in volume. These abstractions were considered to be negligible in the model area and were not included¹⁸. Two-thirds of total abstraction is through 184 large wells, with the remaining one-third through 2982 wells. Total abstraction increased from 36 GL/yr in 1990 to 62 GL/yr in 2003.

Table 5.11 summarises the estimated abstraction from 1990 to 2003, by aquifer, used in the SWAMS model.

The DoW licensing database does not provide information on the monthly pattern of abstraction for individual licensed wells. Most un-metered water is used for irrigation and domestic purposes. Irrigation abstraction has a strong seasonal pattern, with maximum volumes in January and February, and typically no abstraction in May, June and July. Domestic use has a similar pattern but a weaker seasonal component, as the in-house use component tends to be independent of climate or season.

From a DoE investigation of water use patterns in the study area, specific seasonal water use patterns were developed for the following water use sectors (Figure 5.21):

- Swan and Scott Coastal Plain agriculture
- mining
- golf course irrigation
- park and recreation area irrigation
- town water supply.

For these sectors, the annual abstraction for licensed wells was scaled on a monthly basis to account for seasonal water trends for different areas and industries.

¹⁸ The consequence of exclusion of unlicensed stock and domestic abstractions is considered unlikely to affect the modelling results within the accuracy range of the model. The consequence of this exclusion, if any, will be a more conservative model. That is, one that will tend to over-predict the effects of future abstraction.

Table 5.11 Estimated historical abstraction by aquifer 1990 – 2003

Year	Superficial (GL)	Leederville (GL)	Yarragadee (GL)	Total (GL)
1990	2.6	11.0	22.0	35.6
1991	3.2	12.6	21.7	37.4
1992	3.5	12.3	21.9	37.8
1993	3.5	13.2	22.1	38.8
1994	3.7	14.4	22.4	40.5
1995	4.0	15.4	24.4	43.8
1996	4.5	15.1	25.1	44.7
1997	4.8	15.0	29.7	49.5
1998	5.4	15.5	32.1	53.0
1999	5.7	16.1	31.2	53.0
2000	6.1	17.2	30.2	53.5
2001	6.7	17.5	30.2	54.4
2002	6.9	16.7	32.9	56.5
2003	7.1	18.0	36.9	62.0

The return of groundwater to the superficial aquifer from irrigation has not been accounted for in the model. Irrigation return flows determined from research on the Gngangara Mound are of the order of 25% of the water abstracted for irrigation (pers. comm. DoE, August 2005). Because this flow component is not taken into account in either the calibration or the scenario modelling, the effect would be to over-predict drawdowns for scenarios with abstractions higher than those experienced during the calibration period. That is, the calibrated model will be conservative.

3.1.3 Model calibration

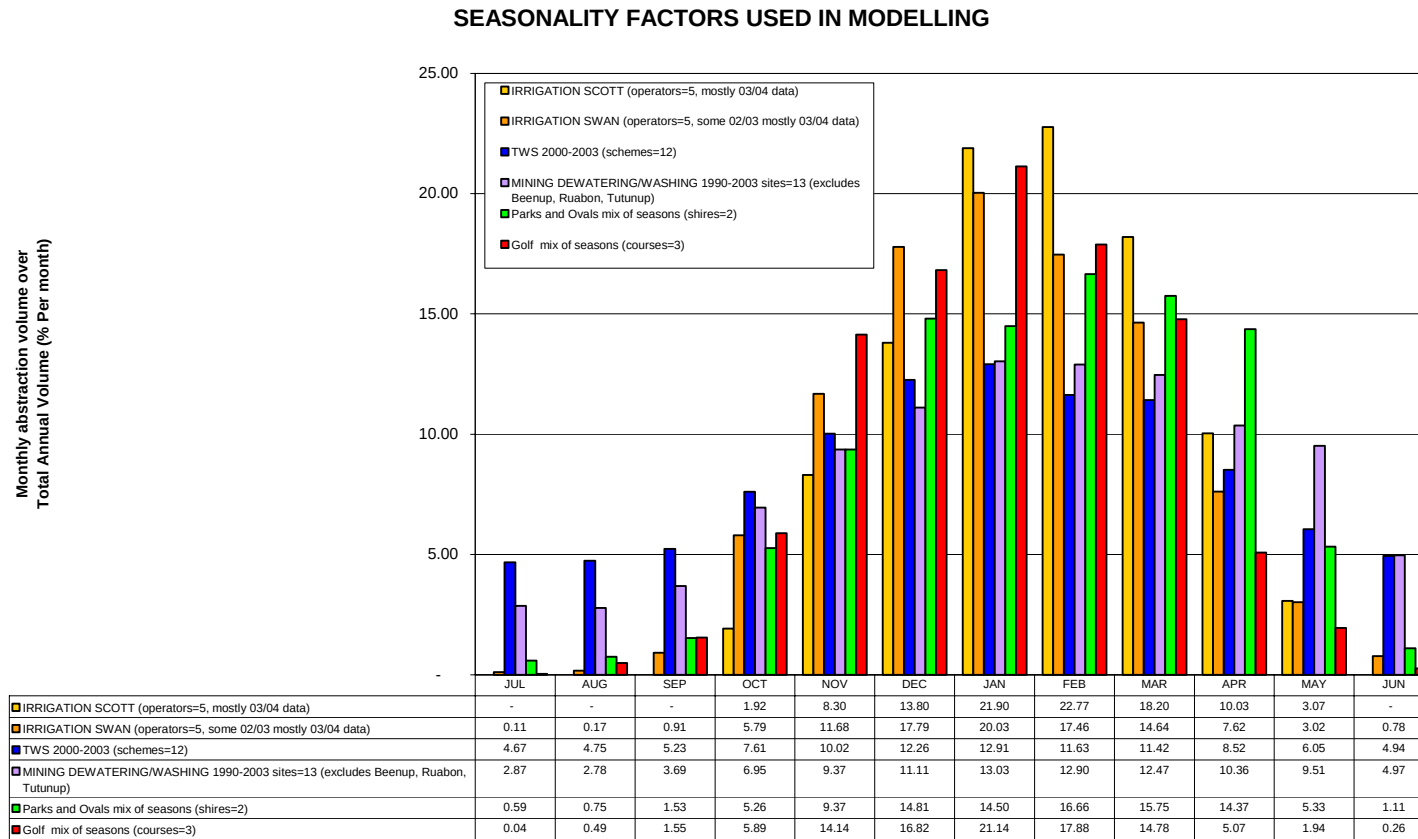
Model calibration is a process in which the model is iteratively adjusted until it closely simulates the measured historical performance of the system being modelled. The model is run over a period during which the actual behaviour of the system has been observed, and the model is examined in terms of how well it simulates that actual behaviour at the points where water levels and pressures have been measured. Where simulated behaviour does not match the observed behaviour, careful adjustments are progressively made to model parameters until an acceptably close match between simulated and observed responses is achieved. The closeness of the match is mathematically analysed so that the accuracy of the overall calibration can be quantitatively assessed.

Because the extensive grid developed in construction of the model does not have measured data to characterise every cell through all layers, assumptions were made on the distribution of measured aquifer information from known points, to all the cells in the model domain.

Two types of calibration can be undertaken:

- steady state (or quasi steady state) where input variables and boundary conditions are held constant with time
- transient, where predicted hydrographs are compared to measured hydrographs over a selected period, and input variables change with time.

Figure 5.21 Seasonal scaling factors used for private abstraction



Steady-state calibration is undertaken to characterise the model in terms of demonstrating that under constant conditions, the modelled water levels are stable, and have values close to those expected under natural (non-pumped) conditions. Key parameters are varied until an appropriate stability is achieved. Transient calibration is then undertaken using values from the steady-state calibration as the starting values, and running the model over a period during which historical performance of the model has been observed, and adjusting and fine-tuning model parameters to mimic observed behaviour as closely as possible.

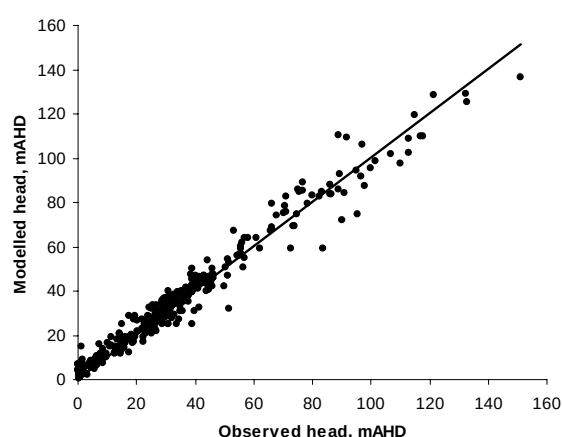
In the case of the SWAMS model, there was sufficient data to consider that most of the model area was close to steady state prior to 1990. After 1990 there was sufficient data to undertake a transient calibration in most areas of the model, though, in some areas, the only change in transient conditions was rainfall. The SWAMS v2.0 model was consequently calibrated in steady state and under transient conditions.

The transient model was calibrated from 1990 to 2003 using historical groundwater data using observed and simulated head data for 328 calibration wells (Figure 5.22). These included all investigation wells on the Blackwood Plateau and all other wells with observation periods greater than 50 months.

Given the complexity of the hydrogeology, the calibration error is believed to be what can be reasonably achieved under existing hydrogeological interpretation and boundary conditions.

Annual water balance estimation by the model shows that average gross recharge to the aquifer system during 1990 – 2003 was 651.5 GL/yr, with a net recharge of 373.6 GL/yr. Average abstraction during the calibration period was modelled at 45.4 GL/yr starting from 35 GL in 1990, increasing to 62 GL¹⁹ in 2003.

Figure 5.22 Comparison of calibrated and observed head in the study region



The modelled major drain flows compared to the measured flows is shown in Table 5.12.

Table 5.12 Comparison of modelled and observed annual drainages

Drain discharge	Blackwood: between Nannup and Hut Pool	Blackwood: from Yarragadee outcrop area	Donnelly River	Scott River	Swan Coastal Plain
Modelled drain discharge (GL/yr)	59.5	9.7	22.2	1.5	26.8
Observed drain discharge (GL/yr)	24.0	10.0	6.0	0.03	44.5*

* Estimated, less reliable data

¹⁹ The modelled abstraction for 2003 does not match the total estimated abstraction from the groundwater system presented in Table 5.3 of this report (page 5-12) as the model domain does not cover the full extent of the three groundwater management areas for which data is presented in Table 5.3.

While this comparison gives a general guide as to the modelled results for drain discharge, there are several problems that can potentially distort the comparison:

1. The observed annual groundwater discharge is based on an assumption that observed summer groundwater derived baseflows are constant throughout the year. This could substantially underestimate the total groundwater discharge if winter groundwater discharges are at higher rates.
2. In the areas where evapotranspiration is simulated, such as over the Coastal Plains, it can cause significant variation to modelled drain discharges. On the Blackwood Plateau, where the evapotranspiration function is not used, local discharge from the aquifers can only take place through the model drains, while in reality some of the discharge would be through evapotranspiration. For example, the Donnelly River system (above the stream gauging site) discharges an average of 6 GL/yr, while the modelled discharge is at 22.2 GL/yr. Although the modelled drain conductance and recharge in this area were reduced to unrealistically low levels, it was not possible to reduce the modelled discharge to levels closer to those observed. Analysis of groundwater levels in the area suggests that heads not far from the river are generally 10 m above the level of the streambed. Given that evapotranspiration does not appear to be sufficient to account for the discrepancy in flows, this suggests that connectivity between the riverbed and the underlying aquifers is extremely low, and that little groundwater can discharge into the Donnelly River, or that the observed flows are underestimates for the reason given in the previous paragraph.
3. The total groundwater discharge to the Blackwood River is over-estimated by the model when compared with observed flows. A salt balance model applied to the Blackwood River gave an estimated total discharge of 43 GL/yr between Nannup and Hut Pool (Mauger 2003). This provides some evidence that the assumption of constant baseflow at the summer rate is flawed, and the observed discharges are actually higher than estimated. The salt balance model includes some evaporation from the water surface and riparian zones, and is a closer match to that modelled. This also suggests that evapotranspiration may play a significant role in groundwater discharge to the Blackwood River. A significant amount of groundwater can discharge via evapotranspiration in various landscapes (Meinzer & Stearns 1927; Rasmussen & Andreasen 1959; Tschinkel 1963; Arnold et al. 1993; Sun & Cornish 2004) and the model may be significantly under-representing this process.

Modelled discharge from the Yarragadee outcrop in the middle of the Blackwood River was predicted to be 9.7 GL/yr, which compares closely to the observed average discharge of 10 GL/yr from the same area. Discharge to the river from the Yarragadee Formation would not be expected to be subject to the same seasonal fluctuations as would discharges from shallower formations. The annual observed value is expected to be reasonably accurate. The groundwater heads levels also matched particularly well in this area. This indicates that the Yarragadee outcrop area is modelled realistically, and provides confidence in the modelling of a key area of interest.

The observed dry summer flow in the Scott River is very low and was well represented by the model. However, there are some difficulties in representing winter flows because the model is not capable of modelling the reduced drainage that occurs under lowered watertable situations. The closeness of observed and modelled drainage on the Swan Coastal Plain is difficult to assess, as numerous drainages are not monitored, and because irrigation return flows complicate discharge estimations.

Based on the available evidence, the current model is considered a reasonable and valid representation of the Southern Perth Basin aquifer system at the regional scale.

There are areas where improvements to calibration of the model can be made. However, significant improvements cannot be made without either further extensive hydrogeological investigation and mapping, or calibration against longer periods of observed performance, preferably under different stress regimes than experienced during the 1990 – 2003 calibration period. Increased abstraction levels, or climate patterns different to those recently experienced, would provide good data for refining the calibration.

Calibrated model parameters

The following parameters were adjusted as part of the model calibrations:

- horizontal hydraulic conductivity K_h ,
- vertical hydraulic conductivity K_v ,
- recharge
- drain conductance.

No adjustment of boundary conditions, specific yield, and specific storage were made during calibration. A summary of the calibrated aquifer parameters is given in Table 5.13. The ranges of the calibrated aquifer parameters are consistent with those recommended in the conceptual hydrogeological model (Table 5.10). The spatial distributions of K_h , K_v , specific yield and specific storage for all layers are as presented by Sun (2005).

Table 5.13 Calibrated aquifer parameters

Parameter	Calibration	Comments
Superficial aquifer (Layer 1)		
Horizontal hydraulic conductivity (m/d)	0.001 – 30	
Specific yield	0.1 – 0.2	
Drain conductance	10	
Specific storage (m^{-1})	0.005	
Vertical hydraulic conductivity (m/d)	1×10^{-5} – 0.5	Includes Bunbury Basalt
Leederville aquifer (Layer 2 – 4)		
Horizontal hydraulic conductivity (m/d)	0.0001 – 23	
Specific yield	0.05 – 0.2	Not including basalt
Drain conductance	20 – 30	
Specific storage (m^{-1})	1×10^{-7} – 1×10^{-5}	
Vertical hydraulic conductivity (m/d)	1×10^{-5} – 0.2	Includes Bunbury Basalt and Parmelia Formation
Yarragadee aquifer (Layer 5–8)		
Horizontal hydraulic conductivity (m/d)	0.1 – 30	
Specific yield	0.05 – 0.2	
Specific storage (m^{-1})	5×10^{-7} – 5×10^{-6}	
Vertical hydraulic conductivity (m/d)	10^{-5} – 0.07	

Sensitivity analysis

As part of the calibration process, a sensitivity analysis was carried out to understand which parameters are the most and least likely to affect the model results, and the extent to which they may affect results. This comparative process is important to determine which parameters may need more investigation to increase confidence in the capability of the model.

In addition to sensitivity testing of the hydraulic parameters of the model, the sensitivity of recharge was tested, as recommended by the peer review of the previous model version (DoE 2004a). This was done by running the model twice using two recharge inputs (one slightly less than the other) and obtaining the differences in head responses for all observation wells caused by the differences in recharge. A number of sensitivity parameters (Table 5.14) were used in the sensitivity analysis.

Table 5.14 Layer sensitivity parameters and input data tested

Parameter	Layers
Horizontal hydraulic conductivity, K_h	1 – 8
Vertical hydraulic conductivity, K_v	1 – 8
Specific yield	1
Recharge	Aquifer based test

Table 5.15 Scaled composite sensitivity for tested parameters and recharge

Parameter/layer	Superficial aquifer	Leederville aquifer	Yarragadee aquifer
K_h / 1	0.79	0.73	0.48
K_h / 2	0.17	1.22	0.22
K_h / 3	0.71	2.50	0.60
K_h / 4	0.24	0.28	0.34
K_h / 5	0.19	0.88	1.14
K_h / 6	0.14	0.23	0.80
K_h / 7	0.49	1.09	3.23
K_h / 8	0.10	0.28	1.18
K_v / 1	0.43	2.26	1.03
K_v / 2	0.49	2.29	0.86
K_v / 3	0.45	2.72	1.37
K_v / 4	0.12	1.08	0.87
K_v / 5	0.10	0.78	0.75
K_v / 6	0.15	0.33	0.70
K_v / 7	0.08	0.18	0.42
K_v / 8	0.06	0.07	0.71
Specific Yield / 1	0.67	0.85	0.31
Recharge	5.96	6.00	7.35

The most sensitive parameters for each aquifer are highlighted in

Table 5.15. In general, the sensitivity test results are consistent with the conceptual understanding of the modelling system.

In summary, this analysis indicated that recharge was the most sensitive variable of all parameters tested. Of the hydraulic parameters, vertical hydraulic conductivity of layer three within the Leederville aquifer (Figure 5.17) is the single most sensitive parameter. In the superficial aquifer, the sensitivity analysis indicated that the horizontal hydraulic conductivity in layer one and the vertical hydraulic conductivity in layer two were the most important for horizontal and vertical conductivity respectively. The horizontal hydraulic conductivity in layers three and seven were also important, suggesting the Leederville and Yarragadee flows both have a significant effect on superficial aquifer heads. The results indicated that the connections between horizontal flow processes in the aquifers are important, while (vertically) the top few layers were the most important for the superficial aquifer.

In the Leederville aquifer, heads were most strongly influenced by the properties of layer three, and the vertical hydraulic conductivity of the top two layers. This indicates that vertical flow processes are important for the Leederville aquifer. The spatial mapping of vertical leakage in layers two and three of the model was difficult in calibration, because of the hydrogeological complexity of the aquifer. Calibrated heads were also sensitive to the horizontal hydraulic conductivity of layer two and layer seven of the Yarragadee aquifer.

Heads in the Yarragadee aquifer are most sensitive to horizontal hydraulic conductivity in layer seven. They are also strongly influenced by the vertical hydraulic conductivity of the Leederville aquifer, reinforcing the importance of vertical leakage through the Leederville for simulating heads in the Yarragadee aquifer. The Yarragadee aquifer is also sensitive to horizontal hydraulic conductivity in layers five and eight and to vertical hydraulic conductivity in layer one, reflecting the significance of recharge in the Yarragadee outcrop area.

Water balance

Using the calibrated transient model, an average annual water balance from 1990 to 2003 was estimated for the study area (Table 5.16).

Table 5.16 Water balance from the model calibration during 1990 – 2003 (GL/yr)

Region	Gross recharge	Evapo-transpiration	Net recharge	Flow to the ocean	Average abstraction	Storage depletion	Drainage
Blackwood Plateau	234.4	not modelled	234.4*	not connected			72.3
Swan Coastal	208.7	166.4	42.3	89.4			26.8
Scott Coastal	208.4	111.5	96.9	147.7			33.1
Total	651.5	277.9	373.6	237.1	45.4	41.1	132.2

*Direct recharge from the Yarragadee outcrop in the middle and south of the Blackwood Plateau is 58 GL/yr, of which 44 GL/yr leaks to lower layers and 14 GL/yr discharges as drainage.

The annual gross recharge varied from 24% – 170% of the average recharge during the calibration period, with the maximum and minimum recharge occurring in 1996 and 2001 respectively. The average rainfall

for the calibration period was 93% of the long-term average rainfall to 2004 and represents a lower recharge regime than the long-term historical average.

A water balance was also calculated for the Yarragadee aquifer (the downward flux to layer 4 and below) (Table 5.17). The average annual influx (gross recharge) to the Yarragadee aquifer for the calibration period is 151.1 GL/yr, of which 44 GL/yr enters through the outcrop area and 107.1 GL/yr through the overlying sediments in the remaining areas.

Table 5.17 Water balance for the Yarragadee aquifer during 1990 – 2003 (GL/year)

Total influx to Yarragadee	Influx through outcrop Yarragadee	Influx other than the outcrop Yarragadee	Upward flux from Yarragadee
151.1	44	107.1	13.3

Model validation

Validation of a calibrated model normally requires an independent set of groundwater level data in addition to the calibration data set. This is often not possible because the data sequence is often not long enough, or adequate, to provide for both calibration and validation. However, there is substantial carbon-14 data collected from the region (Rockwater 2004c at Appendix 15) which can be used to assess the relative age (and consequently flow rates) and water pathways in the calibrated model. Comparison of the carbon-14 data and the simulated travel times and flow patterns can provide an independent verification of the simulated groundwater flow.

The simulated flow paths and carbon-14 age data for both the Leederville and Yarragadee aquifers produced spatial patterns of flow and relative groundwater ages that were similar to observed data, which supports the model representation of flows in the relevant aquifers (this is discussed in detail by Sun 2005).

A large-scale pumping test was undertaken by the Water Corporation during late 2003 near Rosa Brook to test and obtain aquifer parameters for the Yarragadee Unit 3 in that area. The test involved a 14 day constant rate pumping test at 9936 m³/day with comprehensive monitoring of drawdowns in the various aquifers at varying distances from the pumping well. The constant rate test was preceded by a short step-drawdown test to establish well efficiency and thus to allow for a more accurate analysis of the constant rate test. The pumping test results were analysed and modelled to provide an estimation of horizontal conductivity for Yarragadee Unit 3 for the local area (Table 5.18). Estimates of horizontal conductivity were derived from an analytical estimation, two estimations from regional modelling, and two estimations from local models derived from regional modelling.

Table 5.18 Estimations of horizontal conductivity of Yarragadee Unit 3 at Rosa Brook

Estimations	Analytical estimation	SWAMS v1.2.1 calibration	SWAMS v2.0 calibration	SWAMS v1.2.1 Local model estimation	SWAMS v2.0 Local model estimation
Horizontal conductivity (m/d)	6	10	9	10	9

The conductivities derived from the various methods are fundamentally consistent with each other, particularly after the limitations of modelling in undertaking local-scale evaluation of aquifer parameters

are taken into account. This analysis provided partial, but significant, evidence that the parameters used in regional modelling are consistent with those derived from a pumping test, providing further support to the validity of the model in representing the natural aquifer system.

3.1.4 Model limitations

SWAMS v2.0 is considered to be a valid regional-scale representation of the aquifer systems of the Southern Perth Basin within the limitations of a regional-scale model. The model is capable of providing a reasonable representation of drawdown and water flow for current and future abstractions at the regional scale. The model does have limitations in its application. These are due to the incomplete representation of some hydraulic processes resulting in the over-prediction of drawdown at the watertable; the need to average hydrogeological properties over large areas; and some hydrogeological uncertainties. Examination of results at the local scale need to be interpreted with consideration of local hydraulic properties and processes to provide a more realistic view of expected impacts. Ultimately, the expected groundwater responses can only be tested through monitoring actual performance, and associated risks managed through an adaptive management approach.

Some of the specific limitations of the model are discussed below.

MODFLOW is a simplified representation that focuses on groundwater flow processes, but has limitations in simulating surface hydrological processes. This is an issue in terms of simulating flooding effects on the coastal plains. As a result, the predicted watertable drawdowns in these areas due to abstraction are likely to be exaggerated by the model compared to what actually occurs or may occur on the coastal plains. Observed and predicted watertable drawdowns for the dry period of 2001 – 2003 suggest that for many locations, particularly in the superficial formations, the predicted drawdowns are significantly exaggerated.

A key aspect in exaggerating watertable drawdowns is the inability of the model to account for increased recharge in response to drawdown. On the coastal plains, the shallow watertables result in the thin soil profile becoming saturated during winter, with watertables rising to or above the surface. Additional recharge from rainfall is effectively rejected. As there is no space for the water to be stored it flows away as surface drainage either to the river drainage systems, or, in the case of the eastern Scott Coastal Plain, towards the dune systems fringing the southern edge of the plain. Any lowering of the watertable in these areas would result in increased recharge during the winter, which has the effect of partially offsetting the drawdown effect. Within the limits of the amount of water being rejected as recharge, the system effectively resets to a “full” condition each year, and winter water levels are maintained. The summer drawdown effects are consequently significantly limited by this resetting effect. This phenomenon has been clearly observed on the Scott Coastal Plain (URS Australia 2005b at Appendix 19, Rockwater 2004c at Appendix 15). The inability of the model to simulate the recovery of rejected recharge is a major contributor to over-prediction of drawdowns on the coastal plains.

The non-accounting for irrigation return flows will also result in over-prediction of watertable drawdowns in the areas under irrigation. Application of irrigation water in summer will partially offset the lowering of the summer watertables.

A second limitation of MODFLOW 2000 is that it can only model continuous saturated flow. The model cannot represent areas with a perched watertable, but simulates vertical flow as if the deeper groundwater system is hydraulically connected with the surface watertable. For these areas, modelling results need to

be interpreted using information on the local hydrogeology not sufficiently represented in the regional model.

Other uncertainties are generated through the local complexity of the hydrogeology of specific areas being represented in a regional model, and the boundary conditions. The cell sizes (both vertical and horizontal) adopted in the model do not allow for accurate representation of water level responses at a highly localised scale. The model results represent a vertical and horizontal averaging of water level responses at the centroid of the cell. This creates some inaccuracies in predicting water level responses in geographically narrow areas, such as some of the incised valley systems.

There is a boundary condition issue relating to the offshore extent of the model. This relates to the uncertainty on how far the off-shore boundary condition (constant head) should be situated to represent discharge from the aquifers, and has implications for aquifer permeability required for calibration. It may be possible to improve the model calibration by shifting the off-shore boundary closer to the shoreline, but in view of the substantial recalibration effort involved, and other uncertainties, it is considered that changes to boundary conditions should be left until there is a longer period of observed data that will allow other model refinements.

Groundwater modelling predictions are indicative and, while they are a major input into decision making, there are always limitations on accuracy that need to be taken into account. Nonetheless, models are extremely useful in identifying and understanding risks associated with particular decisions. Decisions that are taken will always require follow-up monitoring and review to refine understanding of the conceptual hydrogeology and its representation in a mathematical model, so that the model can then be used in an adaptive management context.

This conclusion was supported by a report from an expert panel of hydrogeologists engaged to peer review the model and its results. A summary of the Peer Review Panel report is set out in Section 5.

3.2 APPLICATION OF THE MODEL

The model application stage is the use of the calibrated model to simulate possible future behaviour of the system under a range of scenarios. The range of possible scenarios that can be tested is effectively limitless, as all any parameters can be varied individually, and in and combination with any other parameters. Typical scenarios usually include:

- possible future pumping regimes (in terms of locations, timing and magnitude of pumping)
- possible future climate regimes (in terms of location, timing and magnitude of the resulting recharge).

Changes in land use can be reflected as changes in future pumping and recharge regimes to test their effect on a groundwater system. Where critical assumptions have been made, their effect can also be assessed by changing the relevant parameters and observing the modelled outcome. Assessment of various regimes, and testing of assumptions is an important means of understanding and quantifying the risks associated with decision making based on the modelling.

Alternative Water Corporation wellfield layouts can be tested to determine which layouts will minimise drawdown effects in sensitive areas. Similarly, alternative layouts for potential future private abstraction can also be considered to establish how water availability can be maximised while limiting drawdown effects in sensitive areas.

The model can be used to account for future changes in the climate. A drying climate can be represented by overall lower rates of recharge, and the model used to evaluate the consequences for different future pumping scenarios.

3.2.1 Model scenarios

Water Corporation wellfield configurations

Three different Water Corporation wellfield configurations were tested:

1. *Water Corporation Eastern Unit 3:* Water Corporation abstraction of 45 GL/yr to be taken from four wells constructed with screens in Yarragadee Unit 3 in the eastern wellfield area (Figure 5.23).
2. *Water Corporation Eastern Units 1 & 3 (the “Eastern Split” wellfield):* Water Corporation abstraction of 45 GL/yr to be taken from eight wells (four sites with two wells at each site) in the eastern wellfield area (Figure 5.23). The two wells at each site are to be constructed with one screened in Yarragadee Unit 1 and the other in Unit 3.
3. *Water Corporation Western:* Water Corporation abstraction of 45 GL/yr to be taken from four wells constructed with screens in Yarragadee Unit 3 in the western wellfield area (Figure 5.23).

Figure 5.23 Alternative Water Corporation wellfield locations



The Water Corporation Western configuration was the layout as originally proposed by the Water Corporation. The other configurations were examined to determine if there was an advantage in taking water proximate to the lower permeability formations overlying the Yarragadee Formation in the eastern part of the basin. These layers were expected to provide some level of attenuation in the propagation of Yarragadee Formation drawdown impacts to the watertable. A more eastern location was also expected to reduce the potential for any impacts to transmit to the Reedia Wetlands where a fauna threatened species places a significant environmental constraint on potential drawdowns.

Regional water use (excluding Water Corporation proposal)

Regional growth in groundwater use was based on the growth projections by Economics Consulting Services (2003 at Appendix 24) discussed in Section 2.1.2. For the purpose of modelling the effects of growth in groundwater abstractions for regional use, a straight line rate of growth was assumed. The geographical distribution of future local private demands will be primarily affected by:

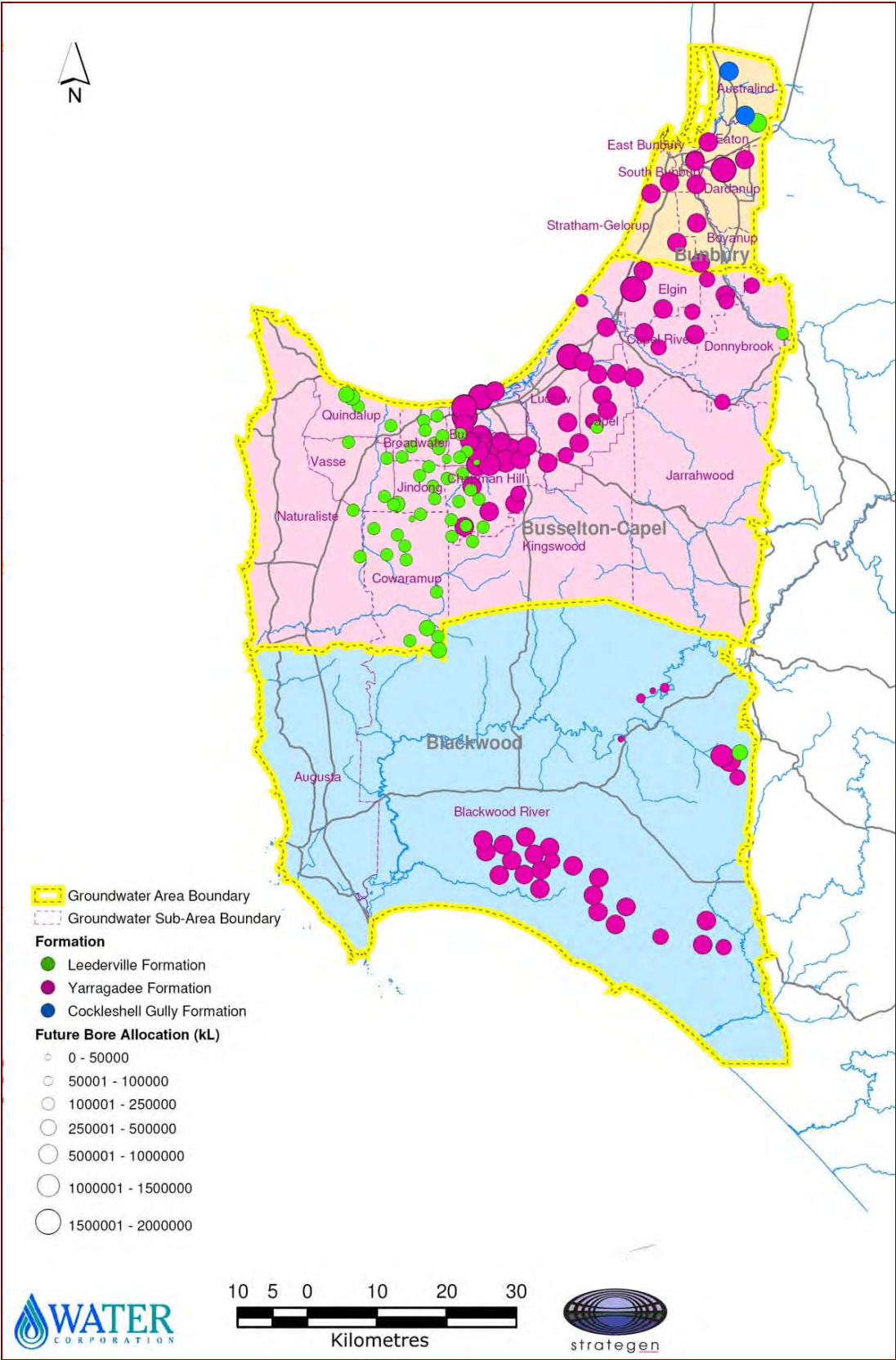
- availability of private land
- use of the most accessible aquifers likely to produce the required yields
- soil types and suitability for various agricultural sectors (horticulture, dairying, etc).

An assumed distribution of future local pumping locations was developed, based on these factors. The initial distribution of regional growth was modified after preliminary modelling showed substantial watertable drawdowns in the Reedia Wetlands area were occurring from projected private abstraction from the Lesueur Sandstone in the area to the south west of the wetlands. This abstraction (13 GL/yr) was subsequently redistributed to the western Scott Coastal Plain to mitigate these drawdown effects.

The resulting distribution of the assumed future growth locations (Figure 5.24) was established and has been used in modelling the various abstraction scenarios involving growth discussed below.

The current abstractions are assumed to continue at their present rates and locations (as shown in Figure 1.1 through Figure 5.12).

Figure 5.24 Location of assumed future regional growth in groundwater abstractions



Modelled scenarios

Seven scenarios were tested through the model, to examine the effects of abstractions over the period January 2004 to December 2033. These scenarios are set out in Table 5.19 and their components are described briefly below.

Table 5.19 Modelled scenarios

Scenario No	Title	Description
1	Current use	2003 abstractions (63.9 GL/yr) continued without variation for the period 2004 – 2033
2	Regional growth	2003 abstractions gradually increasing from 63.9 GL/yr to 158.7 GL/yr over the period 2004 – 2033
3	Water Corporation Eastern Units 1 & 3	Water Corporation abstraction of 45 GL/yr commencing 2004 ²⁰ , with a wellfield abstracting all water from a combination of Yarragadee Units 1 & 3 via the eastern wellfield option, with regional growth as in Scenario 2
4	Water Corporation Eastern Unit 3	Water Corporation abstraction of 45 GL/yr commencing 2004, with a wellfield abstracting all water from Yarragadee Unit 3 via the eastern wellfield option, with regional growth as in Scenario 2
5	Water Corporation Western	Water Corporation abstraction of 45 GL/yr commencing 2004, with a wellfield abstracting all water from Yarragadee Unit 3 via the western wellfield option, with regional growth as in Scenario 2
6	Current use recharge 95%	Same as Scenario 1 with 95% of the recharge applied
7	Current use recharge 90%	Same as Scenario 1 with 90% of the recharge applied

Recharge and climate change

The recharge used for Scenarios 1 to 5 was based on average rainfalls from 1971 – 2003 and held constant each year. This recharge value is slightly lower than that derived for the calibration period (1990 – 2003) and reflects a drier climate than experienced over the longer historical term. The recharge value applied to Scenarios 1 to 5 was based on rainfall at 91% of the long term historical average.

Climate change was addressed by an additional progressive 5% and 10% reduction in recharge applied over the modelled period in Scenarios 6 and 7. This enabled the effects of a progressively reducing recharge to be evaluated. The drawdowns generated from this can be added to the drawdown results of any other scenarios to determine the combined effect.

²⁰ Modelled scenarios have Water Corporation abstraction commencing in 2004 to demonstrate impact of abstraction over a 30 year period. Actual abstraction is not expected to commence until 2009.

4 GROUNDWATER MODELLING RESULTS AND INTERPRETATION

The calibrated SWAMS v2.0 model was used to assess drawdowns under the various scenarios (Table 5.19) of future abstraction over the period 2004 – 2033 to identify areas of potential risk of impact. The focus of the drawdown assessment centred on three aspects:

1. Watertable drawdowns in areas containing potential or known groundwater dependent ecosystems – to allow assessment of the potential environmental, and any associated social impacts.
2. Drawdowns in formations used by existing private and public groundwater users – to determine the potential for drawdown interference and loss of well yield by those users.
3. Impacts on groundwater discharge to the ocean and potential for seawater intrusion.

The drawdown assessment process involved three stages:

1. Modelling the various scenarios at the regional scale to produce hydrographs and drawdown maps of the raw modelling output.
2. Screening of the overall area to eliminate those areas where:
 - the watertable is sufficiently deep that vegetation would not be dependent on the watertable (no groundwater dependent ecosystems)
 - impermeable formations are known to exist such that drawdowns in the Yarragadee Formation would not transmit to the surface aquifers and watertable
 - land uses are such that groundwater dependent ecosystems would not exist (cleared land etc.).
3. Interpretation of the raw modelling results for the remaining risk areas, taking into account the local hydrogeology and known limitations in the modelling at the regional scale, to the extent that these limitations could be quantitatively interpreted with a level of confidence.

Within this process, the effects of continuing current abstractions, potential future regional growth in groundwater abstraction, and the proposal to extract 45 GL/yr for the IWSS were examined.

4.1 RAW MODELLING RESULTS

The raw model results for Scenarios 3, 4 and 5 were examined and ranked in terms of their relative potential for impacts in areas of identified risk, and a preferred option for the Water Corporation wellfield configuration selected through this analysis. Scenario 3 was considered to represent the overall lowest impact (Table 5.20).

Table 5.20 Ranking of impacts of wellfield configuration options

Area of Risk	Scenario 3	Scenario 4	Scenario 5
Swan Coastal Plain (south)	3	1.5	1.5
Swan Coastal Plain (north)	2	2	1
Scott Coastal Plain (east)	2	3	1
Scott Coastal Plain (west)	1	2	3
Reedia Wetlands	1	2	3
Poison Gully	1	2	3
St John Brook	3	2	1
Rosa Brook	1	2	3
Total	17	18.5	19.5

Legend: Rank 1: Lowest ranked potential impact

Rank 3 : Highest ranked potential impact

Note: Rankings are only relative for each location and scenario. There are no relativities in rankings between impact locations.

4.1.1 Watertable drawdowns

Figure 5.25 through Figure 5.27 show the raw, modelled, minimum summer drawdowns in watertable at the end of the modelled period (2033) under Scenario 3. The figures show the total drawdown, the drawdown due to regional groundwater use only, and the drawdown due to Water Corporation abstraction only.

Examination of Figure 5.25 shows that the areas of highest drawdown impacts on the watertable will occur along the Blackwood Valley under the combined effect of Water Corporation and regional abstractions. These areas relate to the Yarragadee Formation outcrop areas, and have the potential to affect the groundwater dependent ecosystems in Poison Gully and Milyeannup Brook, and groundwater discharges to the Blackwood River. Other areas where drawdowns at the watertable will manifest are the coastal plains and St John Brook.

The main modelled drawdown effects resulting from the proposed Water Corporation pumping of 45 GL/yr are in the following areas as indicated by the raw modelling results:

- approximately 2 – 3 m drawdown in Yarragadee outcrop areas in the centre of the Blackwood valley between Layman Brook and Milyeannup Brook
- up to 2 m on the eastern Scott Coastal Plain and the area immediately north
- approximately 0.5 – 1 m in the Yarragadee subcrop area close to Bunbury
- up to 2 m south of Busselton in the Swan Coastal Plain
- up to 2 m in areas along the Blackwood River.

Drawdowns for the 45 GL/yr Water Corp abstraction in the centre of the eastern bore field in layer 7 (at depth of $\sim$ -600 – $\sim$ -900 mAHD) reached 15 m at the top end of the St John's Brook, which gradually reduced outward in a ring shape. The maximum impact at the coast is between Busselton and Bunbury with drawdowns between 2 to 3 m in layer 7. This impact progressively reduced from layer 7 towards layer 1 where the drawdown becomes generally less than 0.25 m.

Figure 5.25 Watertable drawdowns from Water Corporation Eastern Units 1 & 3 wellfield and regional groundwater use (raw model output)

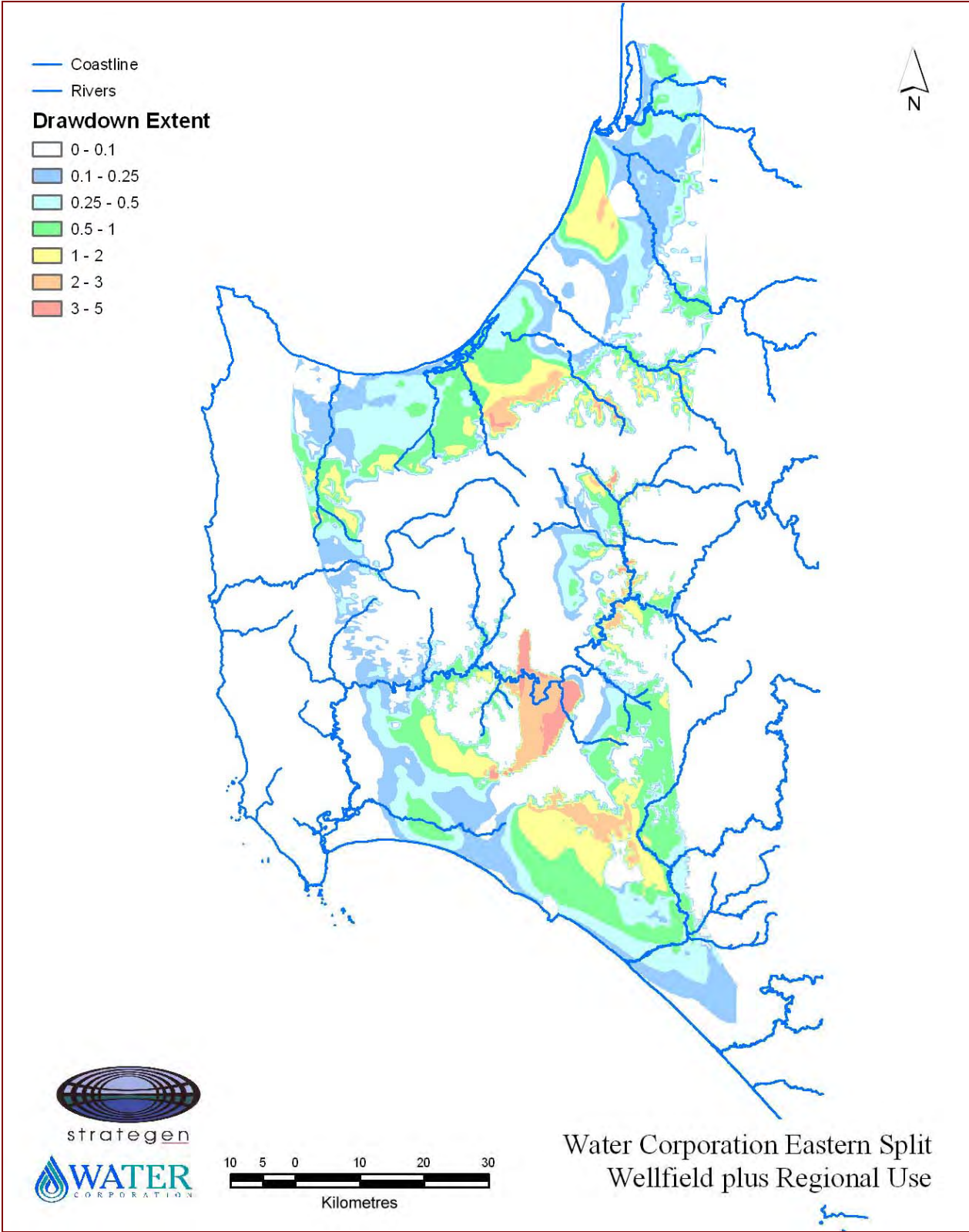


Figure 5.26 Watertable drawdowns from regional groundwater use (raw model output)

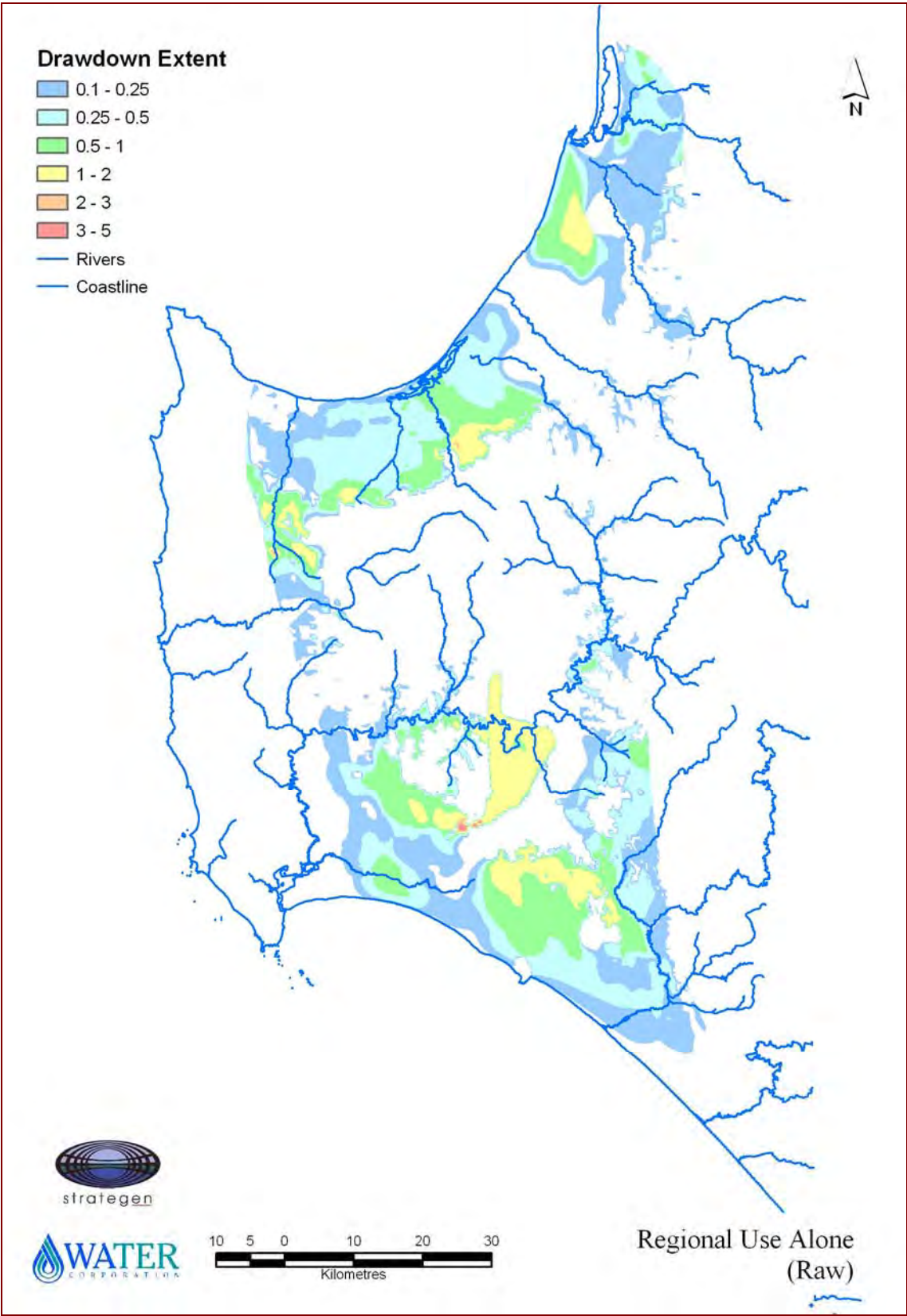
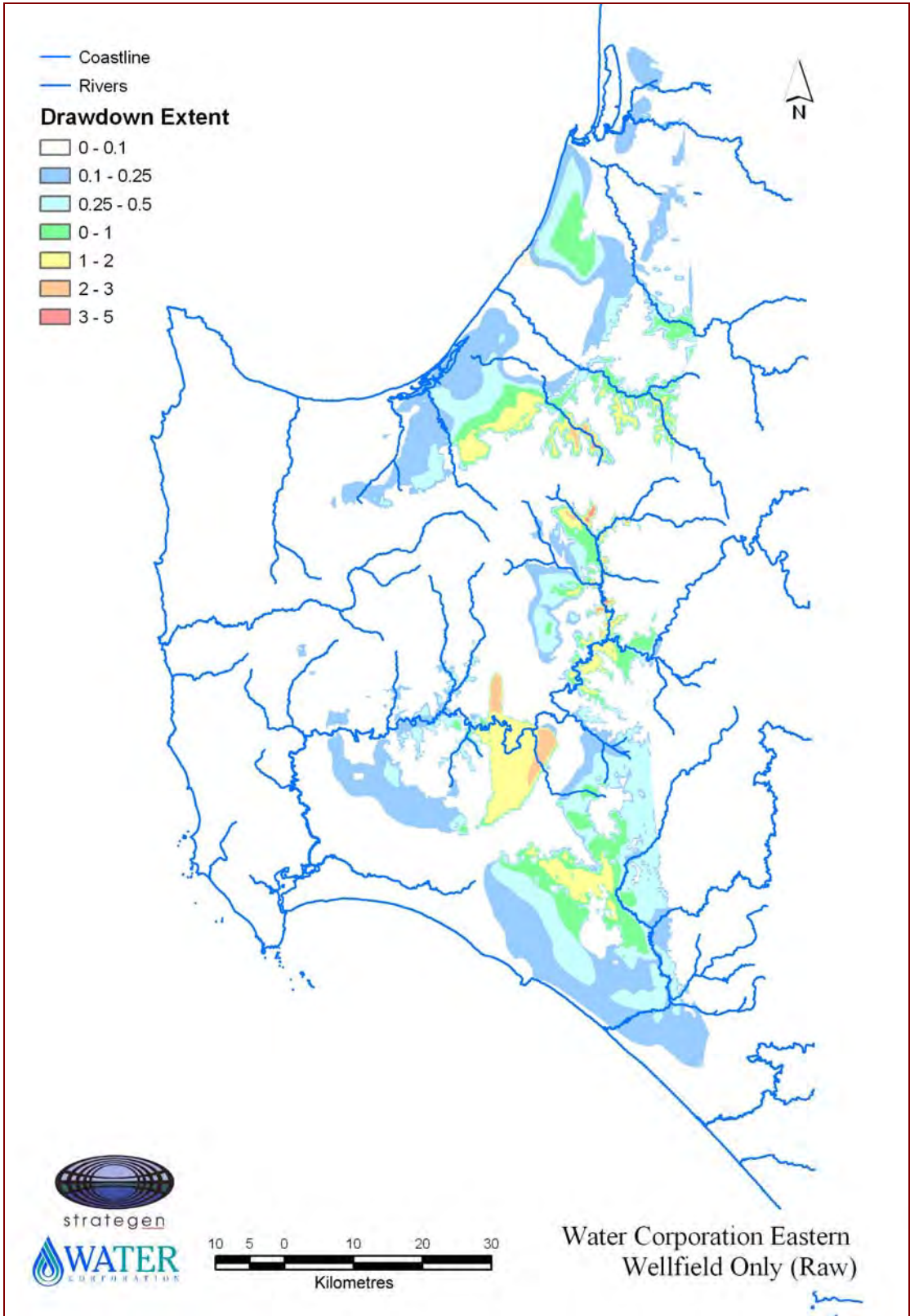


Figure 5.27 Watertable drawdowns from Water Corporation Eastern Units 1 & 3 wellfield (raw model output)



Regional modelling indicated that impacts on the watertable from abstraction by the Water Corporation and regional abstraction for the next 30 years are:

- drawdowns of 3 – 5 m in the Yarragadee outcrop area under the Blackwood River
- drawdowns of generally less than 2 m, with isolated areas reaching 3 m on the coastal plains.

4.2 INTERPRETED MODEL RESULTS

Raw model output requires examination at the local level if the results are to be considered in terms of impact on groundwater dependent ecosystems, particularly in situations where the model is likely to be over-predicting drawdowns because of the conservative nature of the model (as confirmed by the Peer Review Panel; 5). In evaluating these regional-scale results at the local scale it is necessary to account for the complex relationship between the watertable and surface physical processes, and the limitations of the model as discussed in Section 3.1.4.

The extent of privately owned land within potentially affected sensitive areas is shown in Figure 5.28. The majority of this land is cleared and contains limited environmental values.

The influence of several factors not adequately represented in the model (as discussed below) has been taken into account and the modelling results adjusted to develop three drawdown maps considered to represent the effects of the proposal alone, those attributable to future regional growth, and the combined effects of the proposal and future regional growth. For simplicity, only the results of the component abstractions in Scenario 3 are presented here (in Figure 5.29 through Figure 5.31). The full range of results and interpretation methodology is presented in reports by Baddock (2005a, 2005b) and Sun (2005).

4.2.1 Restricted propagation of drawdown effects

Several physical features of the terrain and hydrogeology act to restrict effects from reduced pressures in the Yarragadee Formation from transmitting to the surface environment. The main features are:

- aquitards and perched watertables
- depths to watertable
- presence of the Vasse Member of the Leederville Formation
- increased recharge on the coastal plains through acceptance of previously rejected recharge.

Aquitards and perched watertables

The presence of the Parmelia Formation, Bunbury Basalt and Mowen Member of the Leederville Formation significantly impede upward propagation of drawdowns and effectively isolate the watertable from Yarragadee Formation drawdown effects in the areas where they occur. A significant portion of the Blackwood Plateau contains perched groundwater within the upper formations, which disconnects the watertable from the deeper aquifers. Water may slowly drain downwards from these formations within a recharge process, but drawdowns do not transfer upwards.

Alluvium in the Blackwood River floodplain performs as a significant aquitard, as demonstrated by the pressures in the directly underlying Yarragadee Formation being about 7 m above the summer river level.

Figure 5.28 Private land within potentially affected sensitive areas

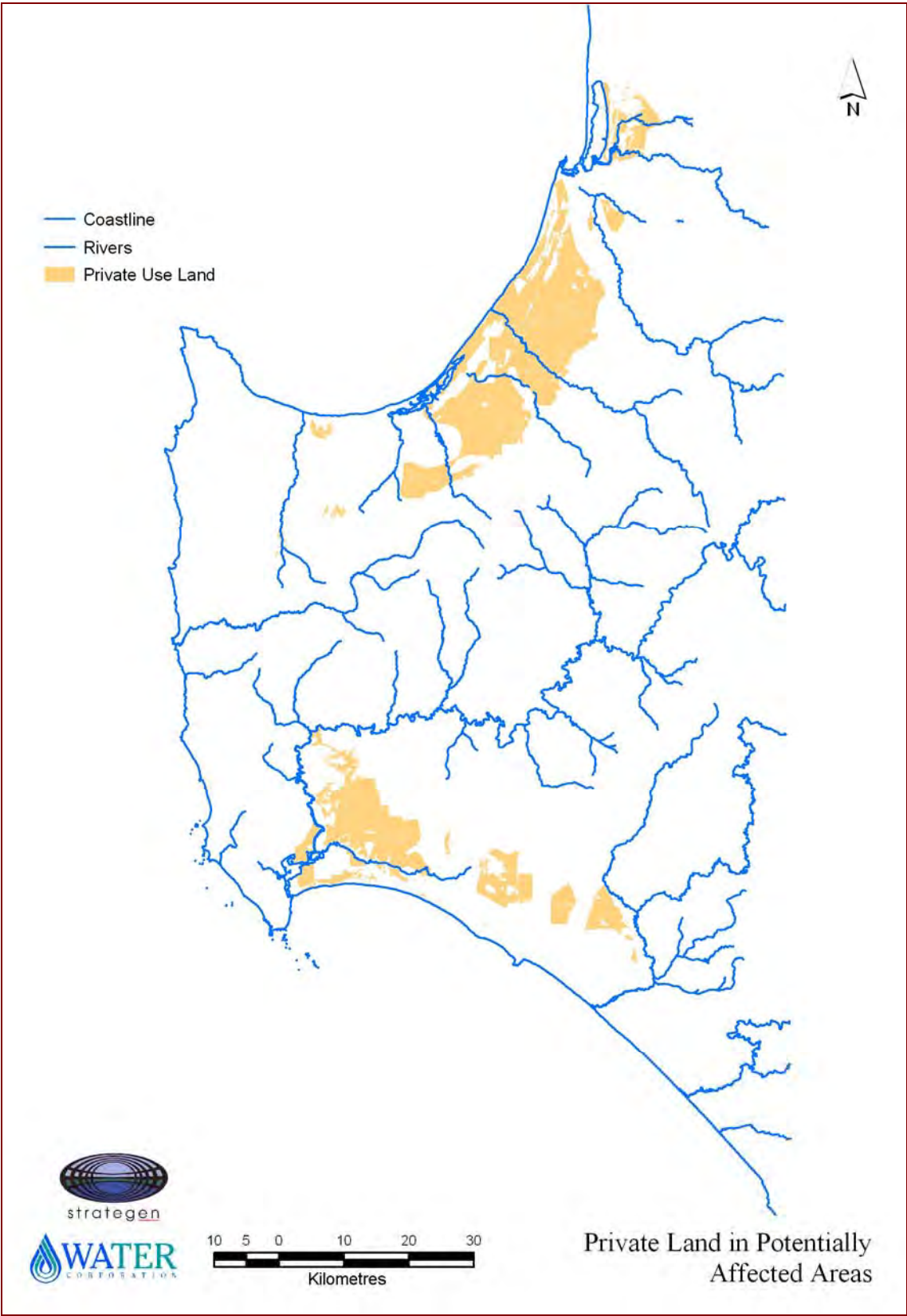


Figure 5.29 Interpreted watertable drawdowns from Water Corporation Eastern Units 1 & 3 wellfield

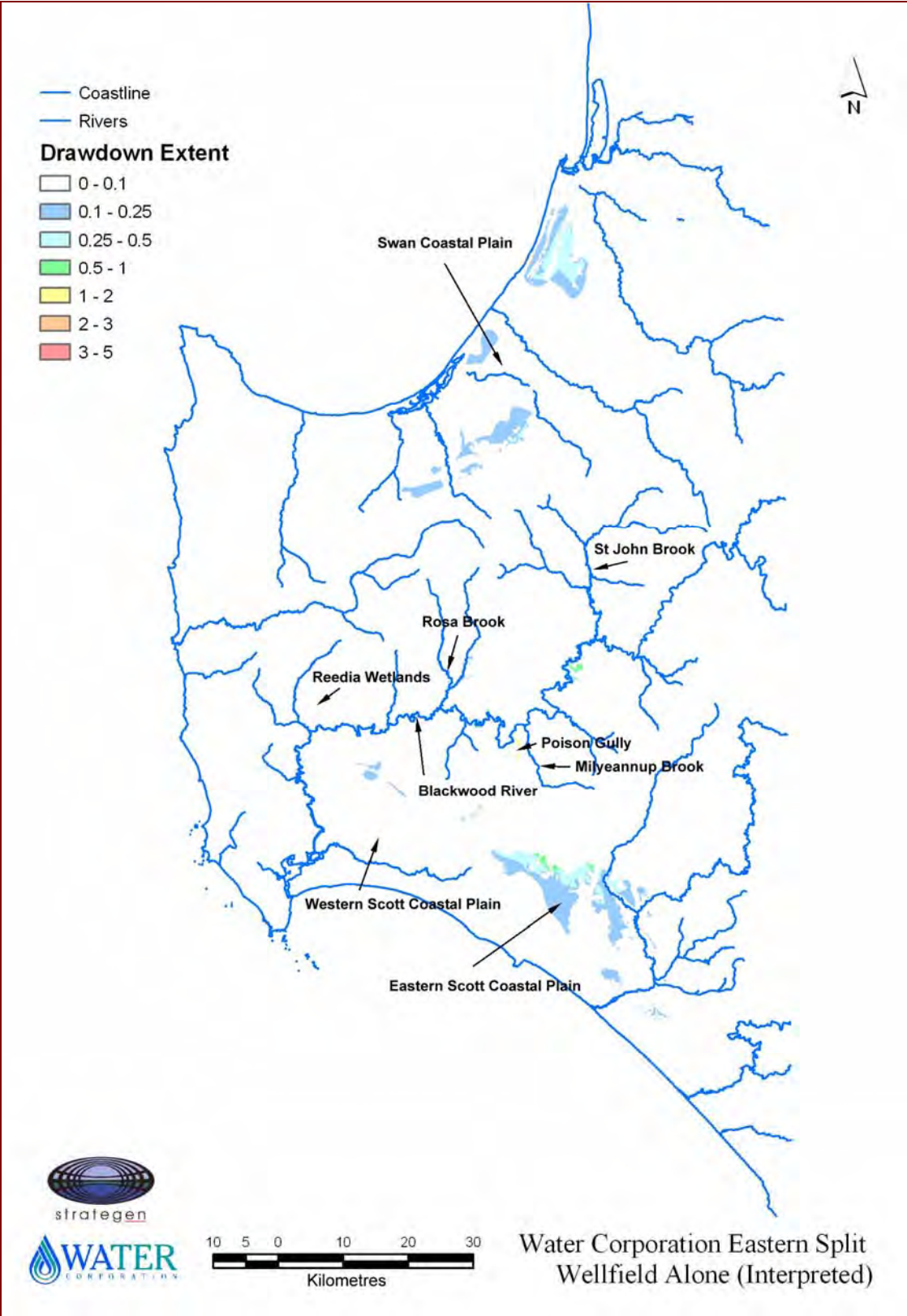


Figure 5.30 Interpreted watertable drawdowns from regional groundwater use

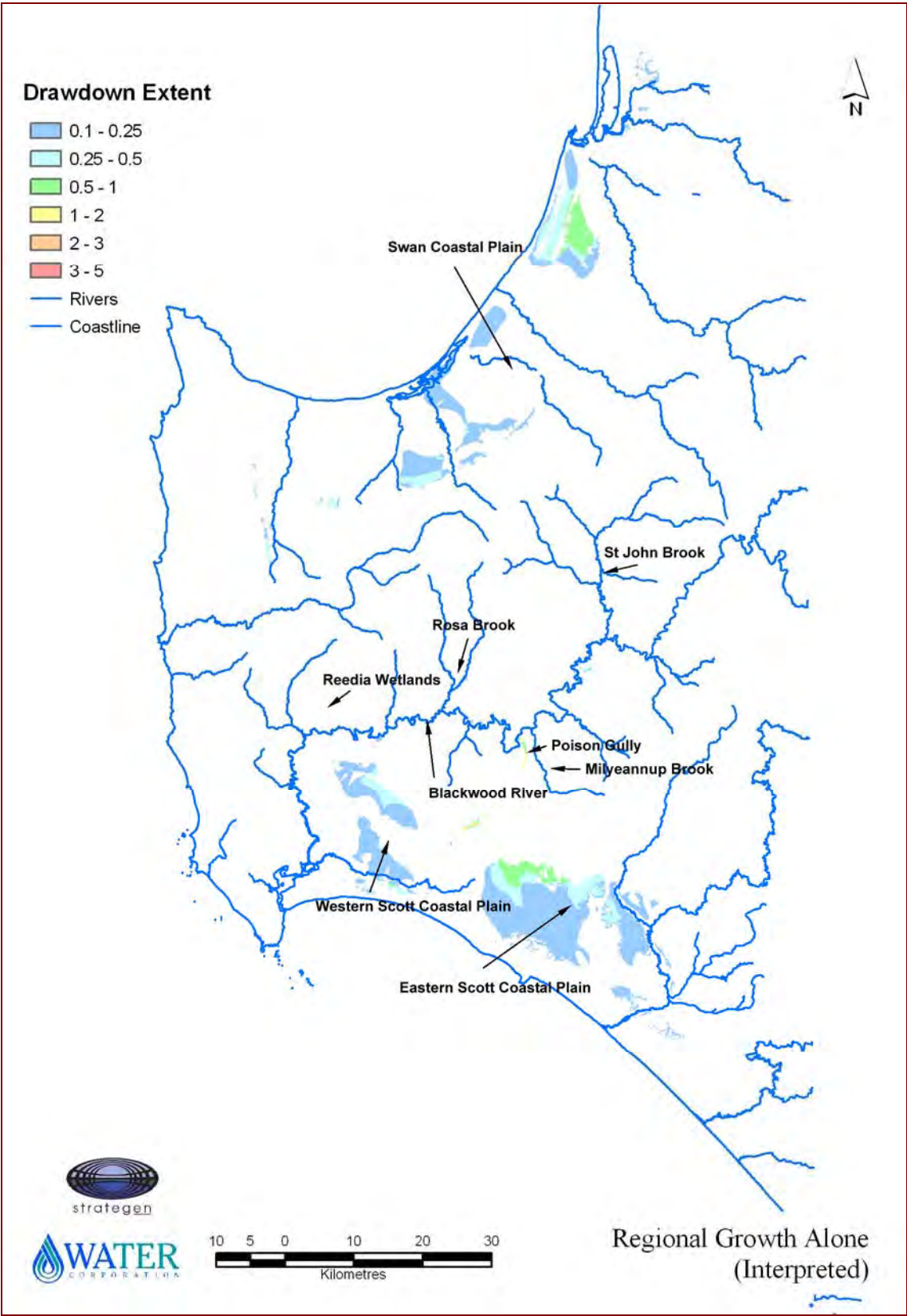
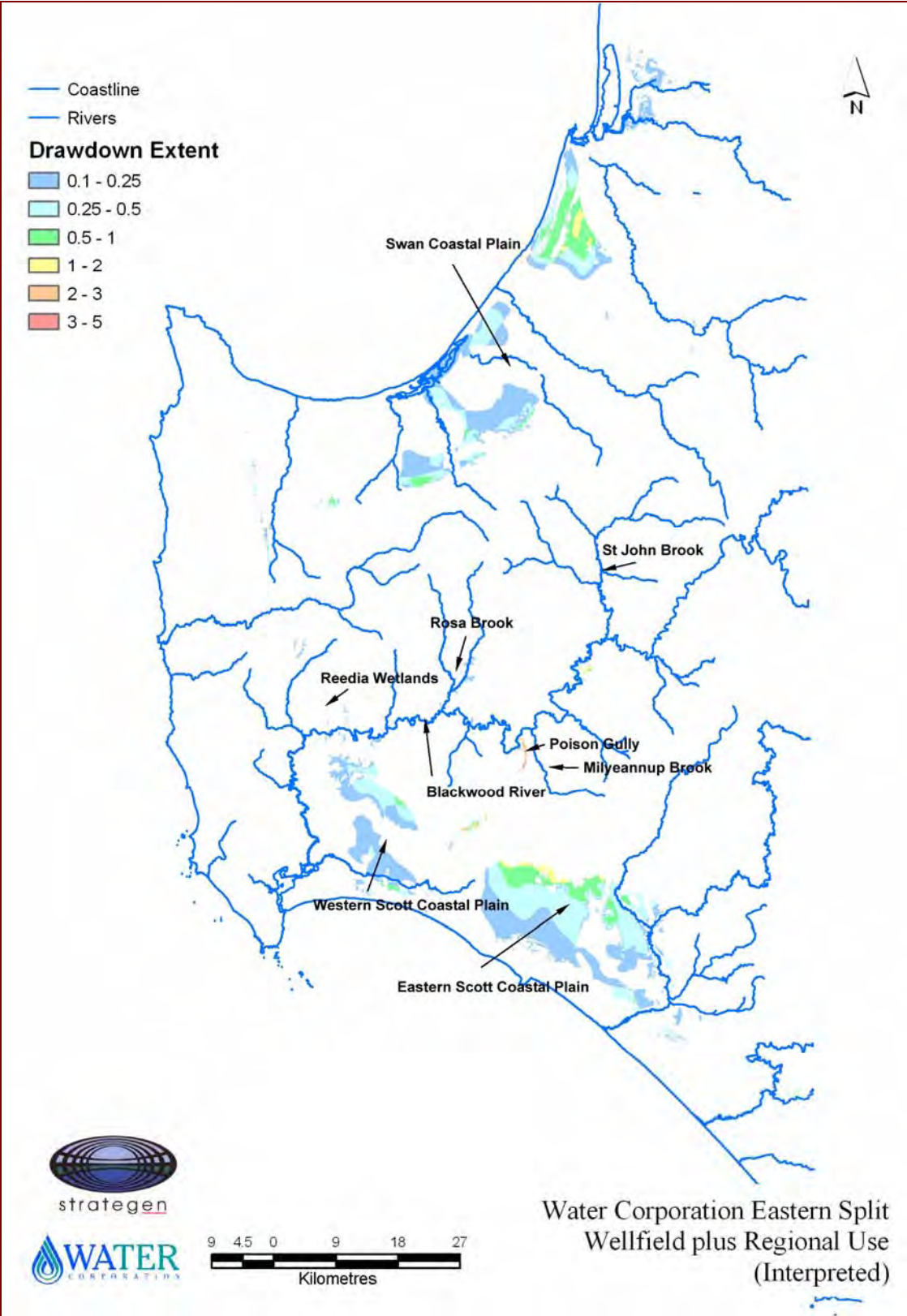


Figure 5.31 Interpreted watertable drawdowns from Water Corporation Eastern Units 1 & 3 wellfield and regional groundwater use combined



Depths to watertable

Surface ecosystems are only dependent on the watertable where it is present at the surface or enables water to be available in the root zone of vegetation. There is negligible ecological dependence on groundwater where the watertable is more than 10 m below the land surface. In these areas, vegetation relies on rainfall and water in the soil profile to provide its moisture needs. Over the Blackwood Plateau, the depth to watertable is highly variable, with most of the areas with shallow watertable corresponding to areas where the Mowen aquitard is present.

Areas on the plateau with a shallow watertable and in the areas most affected by groundwater drawdown are Poison Gully and along the plateau edge, immediately north of the Scott Coastal Plain.

Presence of the Vasse Member of the Leederville Formation

The presence of the Vasse Member of the Leederville Formation inhibits the propagation of drawdowns in underlying formations due to the layering of clay units within the Vasse Member. The ability of this unit to dampen the drawdown effects is dependent on its thickness, which is highly variable, and the spatial distribution of the clay layers. In most situations, surface processes such as drainage, evapotranspiration and shallow groundwater seepage will counteract drawdown effects transmitted vertically through the Leederville Formation.

Acceptance of rejected recharge

As discussed in Section 3.1.4, the model does not account for the increase in recharge that would occur on the coastal plains (if the watertable were drawn down) by accepting recharge that would otherwise be rejected as surface flow because the system is effectively full. The amount of rejected recharge is estimated to be 300 mm on the Swan Coastal Plain and 240 mm on the Scott Coastal Plain (Baddock 2005a). Assuming a storage coefficient of 0.2 for the upper soil profile of the coastal plains, 300 mm and 240 mm of additional recharge can completely offset annual drawdowns of 1.5 m and 1.2 m respectively. In other words, conversion of rejected recharge to actual recharge will be sufficient to return winter water levels to a full condition, as long as the yearly summer minima are not drawn down below historical levels by more than 1.5 m on the Swan Coastal Plain and 1.2 m on the Scott Coastal Plain. Over a 30 year period, 9000 mm of recharge would be rejected on the Swan Coastal Plain, and 7200 mm on the Scott Coastal Plain.

4.2.2 Residual conservatism in model results

There are two significant factors not taken into account in interpreting the results of the model. These amount to a residual conservatism in the interpreted results:

1. Irrigation return water is not accounted for by the model, or in the interpretation of results discussed above. It can contribute a significant volume to the recharge processes in areas under irrigation. About 25% of the volume abstracted for irrigation could return to the watertable as increased recharge to this zone. Based on the 30 year projections for future regional agricultural use of 98 GL/yr, this amounts to a 25 GL/yr increase in recharge, which is significant. This additional recharge will occur in the summer and assist in offsetting drawdown effects on the summer watertables in areas close to groundwater dependent ecosystems (wetlands and vegetation). This effect will be additional to the inducing of additional recharge in the winter through accepting previously rejected recharge. Further work is required to quantify the irrigation return component of the water balance in the region.

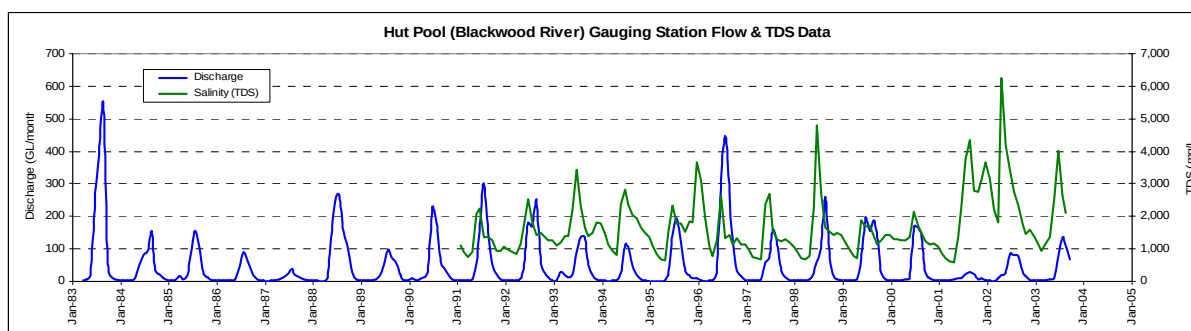
2. Leakage of substantial volumes of water from storage in clay formations within the Yarragadee and Leederville Formations into the producing aquifers has not been accounted for in either the model results or their interpretation. The effect of this will be to slow down the drawdown responses to abstraction, with the effect expected to be significant, given the volumetric and areal extent of these clay formations.

The interpreted results that have been considered in evaluation of the environmental effects of drawdown, therefore, are expected to represent some degree of over-prediction of the actual drawdowns that will occur.

4.3 HYDROLOGY AND GROUNDWATER CONTRIBUTION TO BLACKWOOD RIVER FLOW

The Blackwood River receives groundwater discharge from the Southern Perth Basin aquifers, through discharge of groundwater into the main stem of the river, and through groundwater baseflow to the various tributaries. St John Brook has a relatively low base flow during summer, with significantly greater flow from Milyeannup and Poison Gully. Spearwood and Adelaide Brooks, and other tributaries in the Reedia area contribute some summer baseflow. Rosa Brook and most other tributaries are dry in summer. The upper Yarragadee Formation outcrops within the bed of the Blackwood River along a reach near Jalbarragup (Figure 5.5).

Figure 5.32 Hut Pool (Blackwood River) gauging station flow and salinity



Within the Southern Perth Basin, the Blackwood River is a gaining stream as reflected by a continuous increase in flows downstream in the summer months when there is insignificant contribution from the tributaries. Based on river flow measurements and dilution in salinity in the river (Figure 5.32), Thorpe and Baddock (1994) concluded that about 10 GL/yr of groundwater discharges directly into the Blackwood River in the section from 25 km south-west of Nannup to Darradup. In the present study, groundwater discharge to the Blackwood River has been estimated for different sections of the river using several techniques.

The measured flows and salinity levels in the Blackwood River at Hut Pool are highly seasonal, with high salinity flows occurring with the first major winter flushing flows from the greater catchment (Figure 5.32). Summer salinities decline to less than 1000 mg/L TDS. A salinity peak in excess of 6000 mg/L TDS was measured in the first winter flows of 2002.

Small flows persist in the river at Hut Pool though all summers, indicating that groundwater contributes to the flow regimes in this location. Flow records at Nannup show no summer flows during some years, indicating that the groundwater contribution to summer flow occurs downstream from Nannup.

The end-of-summer flow profiles along the Blackwood River between Nannup and Molloy Island for 2003 and 2004 show that there is a significant increase in flow between Darradup and Layman Brook, with a further increase to Hut Pool (Figure 5.33).

This increase is due to groundwater entering the river along this reach. The salinity profile along the river confirms that a fresh water source is reducing the level of end-of-summer salinities at Nannup from more than 4000 mg/L TDS to 1000 – 1500 mg/L in the river area downstream from Layman Brook.

Figure 5.33 Blackwood River end-of-summer flows

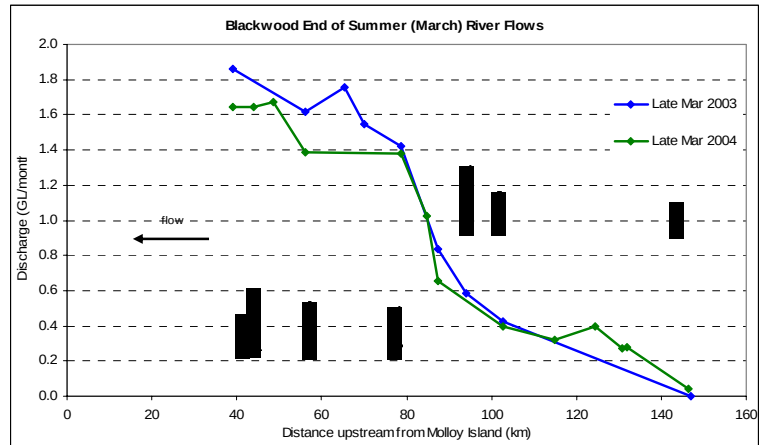
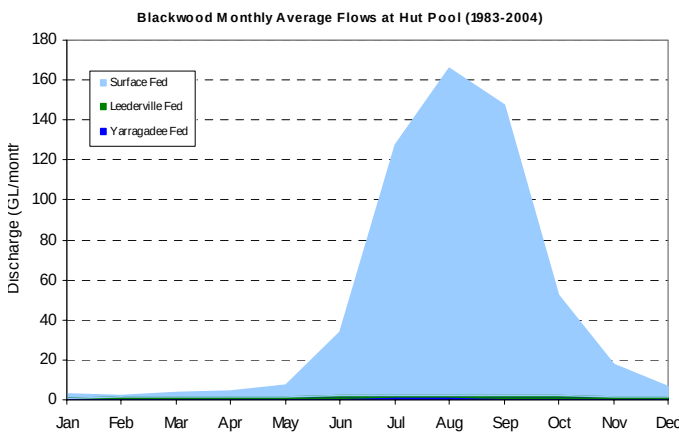


Figure 5.34 Blackwood River average flows at Hut Pool



Based on analyses of riverflow and salinity in the Blackwood River it has been concluded that 30 – 40 GL/yr of groundwater discharges into the Blackwood River and tributaries between Nannup and Hut Pool, from both the Yarragadee Formation and the Leederville Formation. Of this, approximately half (10 – 20 GL/yr) discharges from the Yarragadee Formation and half from the Leederville Formation. The Yarragadee Formation directly discharges about 11 GL/yr to the Blackwood River in the area of outcrop below the river.

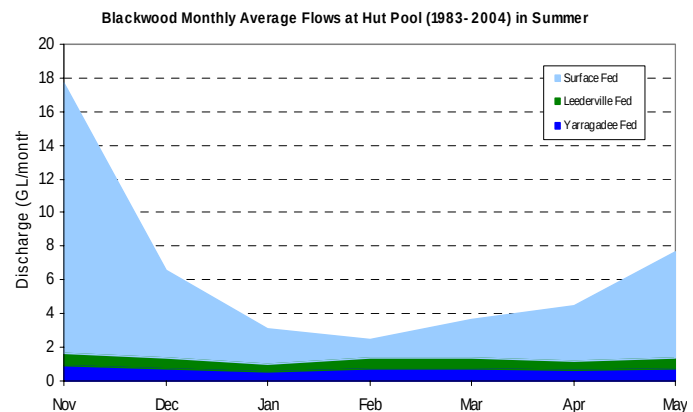
It is likely that groundwater also discharges into the Donnelly River from the aquifer via the overlying superficial aquifer, as the

aquifer is interpreted to subcrop beneath the lower section of the river.

These results provided the indicative range of levels of groundwater discharge to be considered in development of the numerical model of the groundwater system.

A survey of the river tributaries that contribute flow during late summer allowed the hydrograph of the Blackwood River flow to be classified in terms of the sources of water making up that flow. An average hydrograph for the Blackwood River at Hut Pool Figure 5.34 shows that the surface fed flows dominate the flow profile, particularly during the winter months.

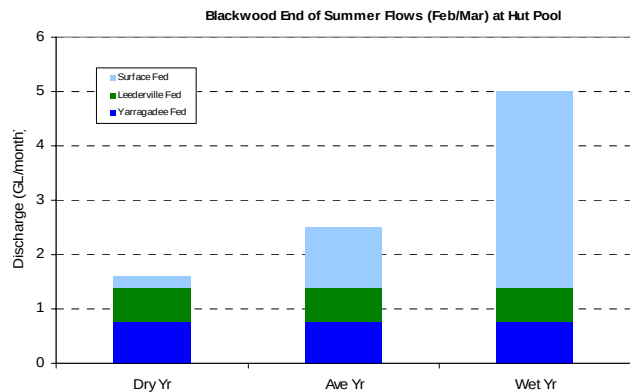
Figure 5.35 Blackwood River average flows at Hut Pool (summer months)



The summer month hydrograph Figure 5.35 provides detail on the relative groundwater contributions during this period. It shows that groundwater only becomes significant from January to March, and that surface fed flows dominate during the rest of the year.

Given the annual variability of streamflow in response to drier and wetter rainfall years, it is necessary to consider the proportion of groundwater contribution to end-of-summer flows in dry and wet years, as well as average years, as shown in Figure 5.36.

Figure 5.36 Blackwood River end-of-summer flow components



4.3.1 Impacts on Blackwood River flows

Drawdown in the Yarragadee Formation, as a result of both the proposal and future regional growth will reduce the upward pressure gradient and so reduce the contribution of groundwater to river flow where the formation outcrops along the Blackwood River.

The Leederville Formation contributes almost half the groundwater derived flow in the river. The Yarragadee Formation contribution would need to be substantially reduced to make a significant difference to the magnitude of summer flows, even in drier years (Figure 5.36).

Modelled drawdown interpretation

The interpreted drawdowns in the Yarragadee Formation near the Blackwood River are such that while they will reduce because of projected groundwater abstractions, the upward pressures will continue and the aquifer will continue to contribute to flow in the river. The Blackwood River flow rate from direct discharge of the Yarragadee Formation alone may reduce by 3 GL/yr over 30 years, of which regional use may contribute 1.3 GL/yr and the proposal 1.7 GL/yr.

The expected reduction in total flow in the Blackwood River at Hut Pool is about 4.8 – 5.8 GL/yr under the combined effect of the proposal and future regional use. About half of the reduction is attributable to proposal. This includes the potential reduction in inflows to the main river from the tributaries. A reduction of 5.8 GL/yr equates to a total reduction of about 13% of the minimum summer flow rate in the driest month of the driest possible summer. The proposal may cause a reduction of about 6% in this flow rate. This reduction is unlikely to be a discernible difference.

A 13% flow reduction in the driest month (February) may cause salinity in the Blackwood River to increase by about 20% during that month if no upland flow from Nannup and above contributes to the streams. For the driest two months (January – February), salinity may increase by an average of 14%. For dry periods of three months or more, salinity impacts of the proposal in the Blackwood River become minimal, as increased stream flow from the upper catchment brings high salinity water and overwhelms the fresh water system. Overall, the impact of the proposal on Blackwood river salinities can be considered insignificant.

Salinities in the river during summer are variable as a consequence of the episodic flows from the catchment upstream of Nannup. The ecological impact of the summer flow salinity changes will largely be masked by the current variability in summer flow salinities and the ongoing increase in salinity of the winter flows of the Blackwood River, which is expected to double over the next 60 years²¹.

4.4 BLACKWOOD RIVER TRIBUTARIES

4.4.1 Groundwater dependent ecosystems

The Blackwood River floodplain and tributaries contain a range of groundwater dependent ecosystems within the river catchment downstream from Nannup and, in particular, in an area about 25 km west of Nannup where the Yarragadee Formation is close to, or at, the land surface. Preliminary screening investigations into the effects of regional groundwater abstraction indicated there might be potential to affect water levels in these areas.

Groundwater dependent ecosystems are associated with the tributaries of Poison Gully and Milyeannup Brook. There are several wetlands along the narrow floodplain of the Blackwood River (Pig Swamp and the Judy area) and the headwaters of Poison Gully (Canebreak Sedgeland) (Figure 5.37).

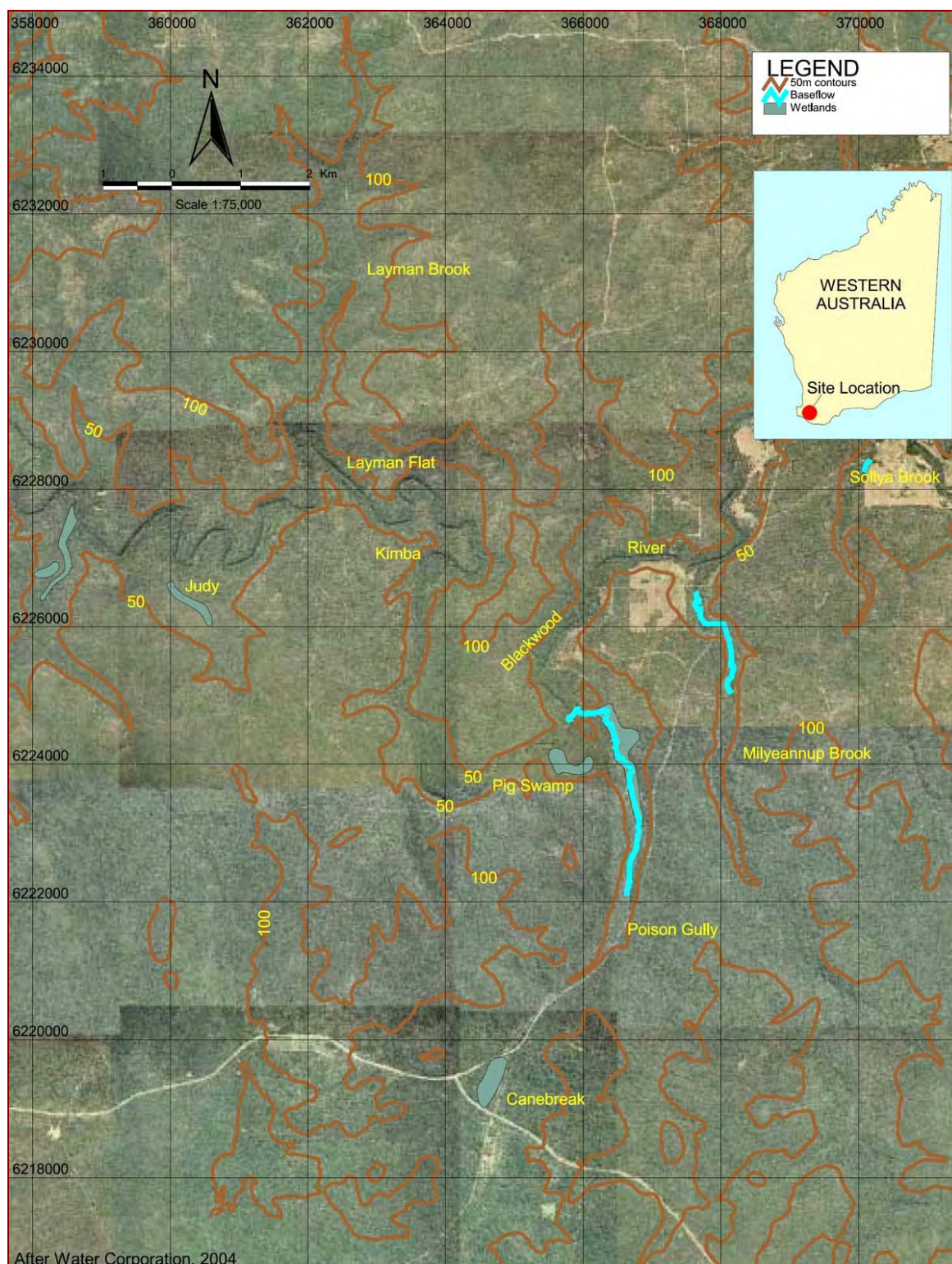
Poison Gully and Milyeannup Brook are perennial tributaries. Pig Swamp and the Canebreak Sedgeland are not associated with perennial streams. The Judy area overlies Leederville Formation strata, while all the others overlie Yarragadee Formation, with thin superficial sediments between the surface and the top of the Yarragadee over some parts.

4.4.2 Investigations in areas of potential impact

An investigation program to examine the relationship between the Blackwood River ecosystems and the local groundwater systems was undertaken by URS Australia during 2004 (Appendix 17). The program involved:

- drilling and logging of investigation wells to depths of up to 60 m to identify the geological formations underlying the ecosystems
- groundwater level measurements to understand water pressures in the geological formations relative to water levels in the wetlands and tributaries, and how groundwater may flow to or from them
- laboratory examination of core samples from the wells to assess the age, permeability and chemical characteristics of the groundwater held within them
- electromagnetic ground surveys to refine the interpretation of surface geology in terms of boundaries and distribution of formation outcrops
- evaluation of flow rate and water quality measurements in the Blackwood River to determine the contribution of groundwater baseflow
- flow rate and water quality measurements in tributary creeks of the Blackwood River to support development of a model of flows in these creeks

²¹ http://www.wrc.wa.gov.au/ribbons/blackwood_region.html [21 September 2005]

Figure 5.37 Groundwater dependent ecosystems of the Blackwood River

Adapted from URS Australia 2004b.

- modelling of surface water flows in the tributaries to determine the extent to which groundwater contributes to those flows
- modelling of groundwater level responses in the Poison Gully area to pumping to examine the potential for changes in the watertable in response to changes in aquifer pressures at depth.

The results of the investigations are summarised below, and presented in detail by URS Australia (2004b at Appendix 17).

4.4.3 Stratigraphy

The Blackwood River tributaries of interest are within the Bunbury Trough, which is generally underlain sequentially by the Leederville Formation, Bunbury Basalt, and the Parmelia and Yarragadee Formations. The Bunbury Basalt and the Parmelia Formation were not encountered in the area associated with this investigation program.

The Yarragadee Formation either outcrops, or is close to the surface below shallow superficial deposits, in the area of the Blackwood River investigation program (Figure 5.38). These areas include:

- the lower reaches of Poison Gully and Milyeannup Brook on the south side of the Blackwood River
- 15 km of the main Blackwood River
- the lower reaches of Layman Brook on the north side of the Blackwood River.

On the higher ground, away from the main Blackwood River and to the east and west, the Yarragadee Formation is overlain by the Leederville Formation. In places, the Parmelia Formation and Bunbury Basalt also variably intervene between the Yarragadee Formation and the Leederville Formation. In the Judy area, the Leederville Formation is more than 72 m thick.

Along Poison Gully, up to 15 m of sediments overlie the Yarragadee Formation. Beneath the narrow floodplain of the Blackwood River in the Kimba and Layman Flat area, sediments of varying thickness form the surface material directly over the Yarragadee Formation.

4.4.4 Groundwater levels and flow

Groundwater in the Yarragadee Formation flows towards the Blackwood River between Milyeannup and the Kimba–Layman Flat area (Figure 5.37). Groundwater from the Yarragadee Formation discharges directly from the springs that form the groundwater sources of Milyeannup Brook and Poison Gully Creek.

Blackwood River floodplain

The Blackwood River floodplain is underlain by sand, clayey sand, sandy clay, and clay sediments. There is an upward pressure gradient²² in the underlying Yarragadee Formation so that water discharges upwards into these sediments. The annual Blackwood River flows refill these sediments each year. The clayey layers retain moisture during the summer months, independent of the upward flow contribution from the Yarragadee Formation. Water availability to ecosystems using moisture from these sediments should not be affected by groundwater drawdown in the underlying Yarragadee Formation because of the soil moisture retention. The watertable beneath the flood plain is fully recharged when water levels in the river rise during winter, with higher flood levels recharging to the Yarragadee Formation in very high flow years. Therefore, the alluvial aquifer and the vegetation it supports are reliant on rainfall rather than the underlying aquifers.

Pig Swamp

The water surface at Pig Swamp is several metres above the local watertable. It is therefore a perched water body, whose levels would not be affected by changes in underlying groundwater levels. The swamp appears to be directly underlain by a grey plastic clay which prevents water in the swamp draining down to the watertable.

Canebreak Sedgeland

The Canebreak Sedgeland is perched about 10 m above the local watertable. Similarly to Pig Swamp, it would not be affected by drawdown in underlying aquifers.

Layman Creek

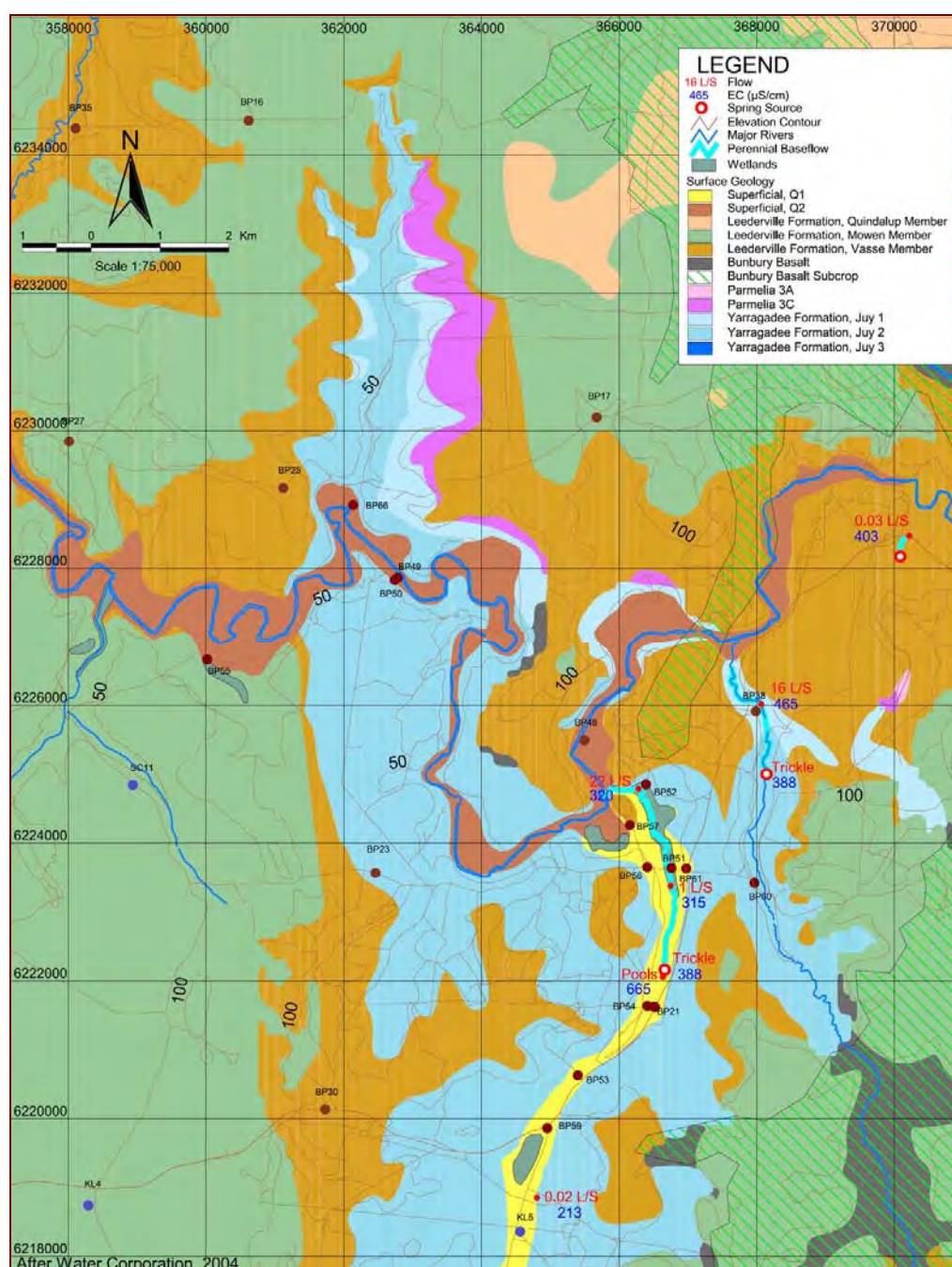
Layman Creek does not maintain a perennial flow, which indicates low groundwater dependency. However, it does have seepage from perched groundwater in the Leederville Formation in its upper reaches. It is not expected to be affected by groundwater abstraction.

Judy area wetlands

The Judy area wetlands are underlain by more than 70 m of Leederville Formation strata, including almost 50 m of the relatively impermeable Mowen Member. This effectively separates the Judy area wetlands from any influence of the underlying Yarragadee Formation.

²² Pressure gradients in aquifers are expressions of differences in water pressure between various parts of the aquifer. These pressure differences are the forces that drive groundwater flow and determine flow directions, both horizontally and vertically. Groundwater moves from areas of high pressure to areas of low pressure. A downward pressure gradient will result in downward movement of groundwater, and vice versa. Large gradients usually occur where the formations are “tight” and their presence is a good indication that water will not move easily between aquifers.

Figure 5.38 Surface geology and surface water measurements April – May 2004



Adapted from URS Australia 2004b.

Kimba and Layman Flat

In the Kimba and Layman Flat area of the Blackwood River floodplain, the Yarragadee Formation discharges to the river. Artesian heads exist in the Yarragadee Formation along the Blackwood River, increasing from about 5 m at Milyeannup Brook to 7 m at Poison Gully – Layman Brook.

At Layman Flat, the watertable is perched above a thin layer of clay at the top of the Yarragadee Formation and probably reflects local recharge from Layman Brook.

Overall, there is a general pattern of discharge of Yarragadee Formation groundwater into the Blackwood River in the Kimba and Layman Flat area, and into downstream sections of Poison Gully and Milyeannup Brook.

4.4.5 Groundwater contribution to tributaries and floodplain

Spring sources along the various Blackwood tributary creeks were examined to identify those with surface elevations that correspond with water levels in the underlying Yarragadee Formation. These springs were assumed to be sourced by groundwater outflow from that formation. A comparison of Yarragadee Formation and tributary water quality measurements confirmed this assumption.

Poison Gully and Milyeannup Brook

Poison Gully and Milyeannup Brook are tributaries whose summer flows are directly sustained by the Yarragadee Formation. Their contribution to the Blackwood River was measured at about 38 L/s (about 0.1 GL/month) at the end of summer in 2004. This is approximately 15% of the Yarragadee Formation contribution to summer flow in the Blackwood River.

Catchment modelling, based on adjusted streamflow data from St John Brook, one-off sampling in Poison Gully and Milyeannup Brook, and topographic information and climate data, has been used to separate the groundwater and rainfall runoff components of streamflow. This modelling indicated a baseflow of 31 L/s from the Yarragadee Formation into Poison Gully, and a minimum outflow into the Blackwood River of 14 L/s (in February). For Milyeannup Brook, the modelling indicated a baseflow input of 43 L/s, and minimum inflow to the Blackwood River of 27 L/s from the Yarragadee Formation. The total modelled inflow to the Blackwood of 41 L/s is close to the measured 38 L/s.

4.4.6 Potential impact on Blackwood River tributaries

Modelled drawdown interpretation

Poison Gully and Milyeannup Brook

Perennial flows in the lower parts of Poison Gully and Milyeannup Brook are maintained by baseflow from the Yarragadee Formation. The Poison Gully tributary of the Blackwood River is within the outcrop area of the Yarragadee Formation, and groundwater directly supports the shallow watertable in its lower part. Poison Gully and Milyeannup Brook are the only areas on the Blackwood Plateau where surface drawdown effects are expected to be observable. In this area, a drawdown of up to 3 – 5 m is expected from the combined effect of the proposal and estimated future regional use after 30 years. This is expected to result in the location of the Poison Gully spring outflow moving downstream by up to 300 m in reasonable rainfall years. The rate of flow in the gully would decrease by about 31%. The contributions to this effect from the proposal, and from future regional groundwater abstraction, are expected to be approximately equal.

Milyeannup Brook is expected to respond in a similar way to Poison Gully; although the spring source will possibly retreat further, due to the marginal artesian heads interpreted along a significant section of the upstream zone of perennial flow.

4.5 ST JOHN BROOK

4.5.1 Groundwater dependent ecosystems

St John Brook is a socially and environmentally important tributary of the Blackwood River (Figure 5.39). Preliminary screening investigations into the effects of regional groundwater abstraction indicated there might be potential for drawdown impacts to affect the groundwater dependent ecosystems associated with the brook.

St John Brook is a perennial tributary of the Blackwood River that enters the river from the north, to the west of Nannup. The brook flows in a deeply incised valley and, as it approaches the Blackwood River, contains several interconnected permanent pools, including Barrabup Pool and Workmans Pool. Both pools are significant tourist attractions and are important recreational areas for the local community.

St John Brook cuts into the Leederville Formation, which occurs at the surface in this area and is the source of groundwater fed summer flow. The perennial flow of about 0.02 GL/month is maintained by groundwater discharge from the Mowen Member of the Leederville Formation, with the source of baseflow situated about 700 m south of the confluence with St Paul Brook.

4.5.2 Investigations

An investigation program to examine the relationship between St John Brook and the local groundwater systems was undertaken by URS Australia (2004c at Appendix 18). The investigation involved:

- drilling and logging of investigation wells at depths up to 348 m to identify the geological strata underlying the brook and how they inter-relate
- groundwater level measurements to understand water pressures in the geological strata relative to water levels in the brook, and how groundwater may flow to or from the brook
- laboratory examination of core samples from the wells to assess their age, permeability and chemical characteristics of the groundwater held within them
- flow rate and water quality measurements in St John Brook to support development of a model of flows in the brook
- modelling of surface water flows in the St John Brook catchment to determine the extent to which groundwater contributes to those flows.

The results of the investigations are summarised below, and presented in detail by URS Australia (Appendix 18).

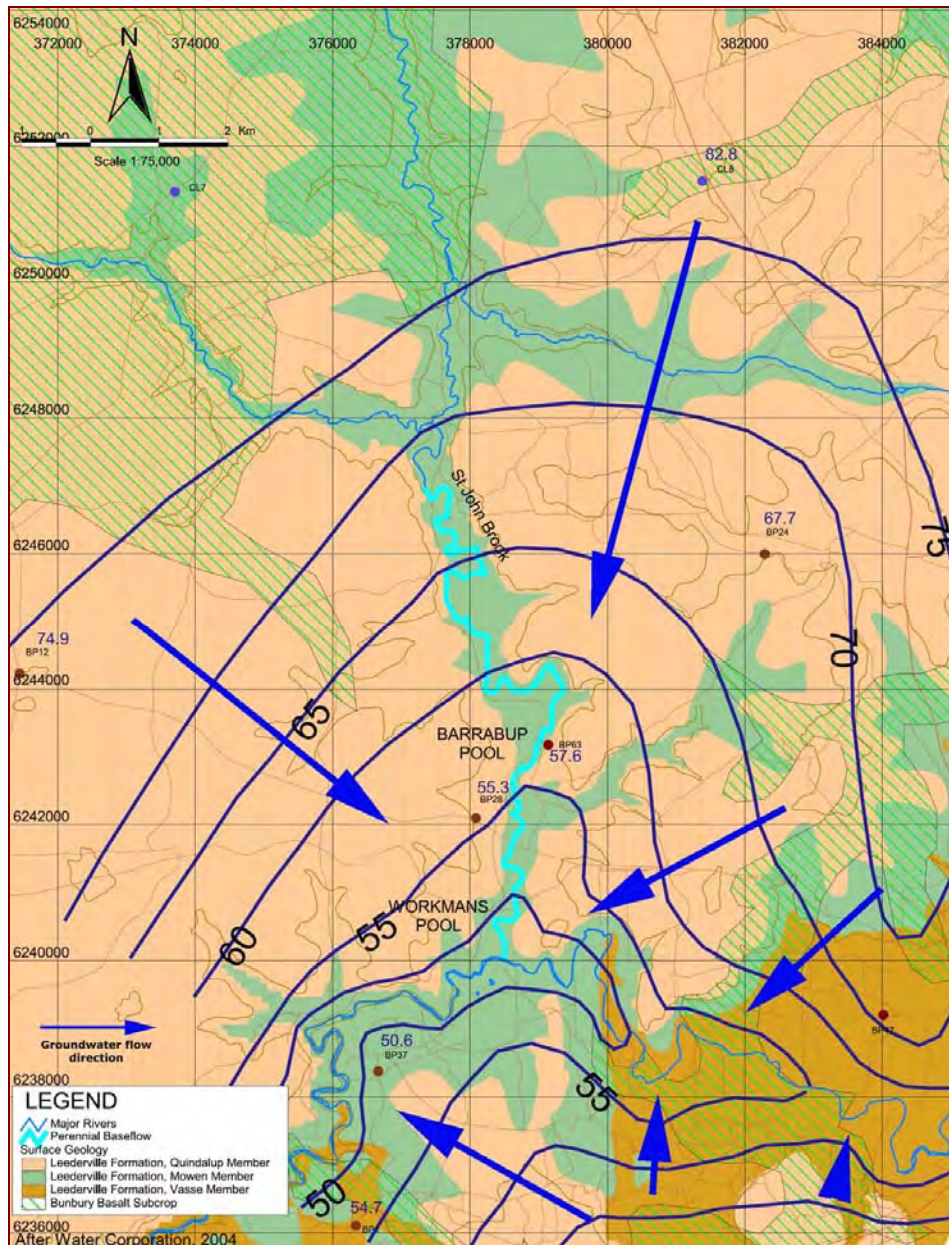
4.5.3 Stratigraphy

The St John Brook area is underlain sequentially by the Leederville, Parmelia and Yarragadee Formations (Figure 5.40). In the general vicinity of the brook, the Quindalup Member of the Leederville Formation forms most of the surface geology. The Quindalup Member is of low permeability, consisting of interbedded clay, silt and sandy clay. The brook cuts through the Quindalup Member into the underlying Mowen Member over most of its length (Figure 5.40). The Mowen Member is about 10 – 25 m thick and is of very low permeability, consisting mainly of clay.

Figure 5.39 St John Brook locality plan



Adapted from URS Australia 2004c.

Figure 5.40 Surface geology and water levels and flows in the Leederville Formation

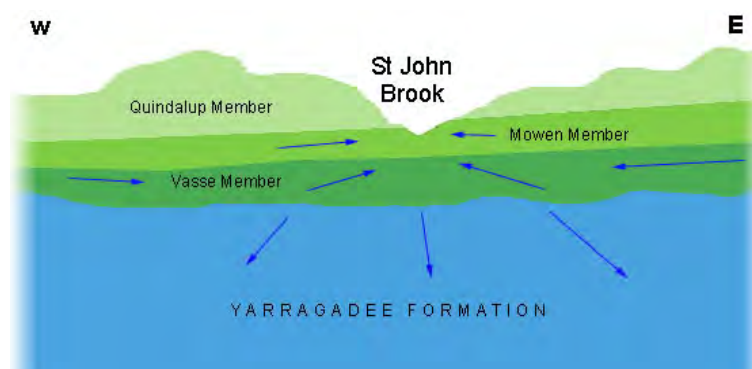
Beneath the Mowen Member, the Vasse Member of the Leederville Formation is about 60 – 80 m thick in this area, and contains interbedded clayey sand, shale and sand, with the sand layers up to 8 m thick, resulting in a relatively permeable formation. In the St John Brook area, the Leederville Formation lies directly on top of the Yarragadee Formation (the Parmelia Formation and Bunbury Basalt are absent in this locality). The clayey upper unit of the Yarragadee Formation was 171 m thick in the investigation well drilled in this area, with the upper 100 m being very clayey and therefore of very low permeability.

The Mowen Member, and low permeability upper layer of the Yarragadee Formation, form barriers to groundwater flow and severely limit the connection between the lower Yarragadee Formation units and the surface aquifer in this area.

4.5.4 Groundwater levels and flow

Groundwater from the Leederville Formation (Mowen Member) contributes a baseflow component to St John Brook (Figure 5.41). There is a significant downward pressure gradient from the lower units of the Leederville Formation (Vasse Member) to the uppermost unit of the Yarragadee Formation, and to the lower units of the Yarragadee Formation. This pressure gradient, and the thickness of the impermeable units of the upper Yarragadee Formation and the Leederville Formation, effectively prevent drawdown effects in the lower Yarragadee Formation affecting the surface hydrology in this area.

Figure 5.41 Diagrammatic representation of groundwater flows under St John Brook



4.5.5 Surface water contribution from groundwater

Catchment modelling, based on available streamflow data from St John Brook, topographic information and climate data, was used to separate the groundwater and rainfall runoff components of streamflow. This modelling indicated that the Leederville Formation contributes a baseflow input to the brook of 27 ML/month (10 L/s), which is about 0.6% of the total streamflow in the brook. This baseflow is important in maintaining flows in the brook during the months of low, or no, rainfall.

4.5.6 Impact on St John Brook

Modelled drawdown interpretation

Raw modelling results suggest that there will be up to 1 m of drawdown of the watertable in the upper reaches of St John Brook after 30 years under Scenarios 4 and 5 (Water Corporation eastern and western wellfield options, respectively combined with regional use).

However, when the abstraction is split between Yarragadee Formation Units 1 and 3 as proposed in Scenario 3 (Water Corporation proposal and regional growth), the raw modelling results indicate a drawdown of up to about 5 m in the upper reaches of the brook after 30 years.

The raw modelled drawdowns are expected to be substantially counteracted by streamflow and shallow groundwater seepage during the winter months. These effects are not accounted for in the model. However, there is a risk that summer declines of the watertable would still occur under Scenario 3, resulting in some small falls in pool levels (smaller than in the adjacent watertable) and a reduction in summer stream flow. The interpreted watertable drawdown upstream of Barrabup Pool after 30 years under Scenario 3 is 1 – 2 m. Most of this drawdown is attributable to the proposed abstraction from the Yarragadee Formation Unit 1.

At Barrabup Pool, the artesian head that exists will provide a buffer to watertable drawdown so that under all scenarios there should be no impact on the pool. If effects do occur, they can be offset through supplementation of the summer streamflow by discharging groundwater from a nearby aquifer into the upper parts of the valley at rates similar to the loss of discharge. The required flow rates are relatively low and could readily be supplied from one well.

There may be some watertable drawdown away from the valley floor below Barrabup Pool, but, winter streamflow and seepage of water down the valley flanks should allow full recovery of watertable levels.

The impact of drawdown in the lower reaches of the brook will be significantly attenuated because of the presence of the extensive clay beds within the upper Yarragadee Formation (Unit 1).

4.6 ROSA BROOK

Rosa Brook is a southward flowing tributary of the Blackwood River situated near the centre of the Blackwood Plateau (Figure 5.42). The brook is not groundwater dependent, typically only flowing from early winter through to late spring.

Most of the catchment surface consists of Mowen Member of the Leederville Formation, comprising largely clay and silt. The lower slope of the valley intersects the Vasse Member of the same formation. Interpretive geology suggests a small area of exposed Yarragadee Formation approximately midway up the eastern branch of the brook, but this has not been confirmed in the field.

An upward pressure gradient exists between the Yarragadee Formation and the surface, with artesian heads occurring in the Yarragadee Formation.

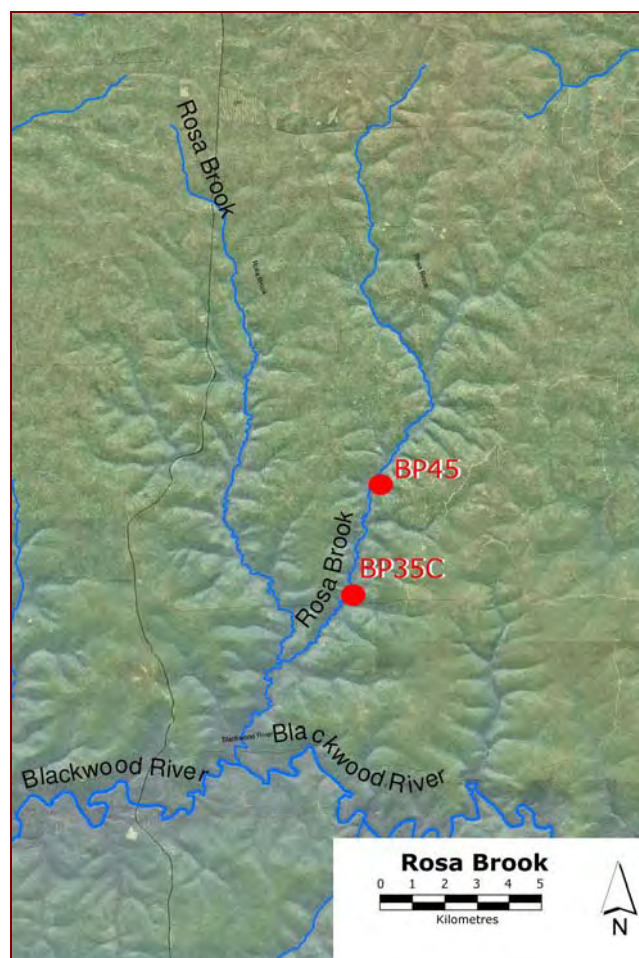
Areas potentially susceptible to watertable drawdown are the lower brook area where it intersects the Vasse Member and the adjacent lower slope of the valley. Up-slope of these areas the watertable is considerably deeper or is perched upon clayey strata.

4.6.1 Impact on Rosa Brook

Modelled drawdown interpretation

Shallow winter seepage and summer evapotranspiration effects are not included in the modelling, both of which will counteract drawdown effects at the watertable. The magnitude of this counter-action will be site specific.

Figure 5.42 Rosa Brook locality plan



Winter watertables are unlikely to be affected by pumping (by the proposal and regional use) because of recharging from winter streamflow and shallow groundwater seepage. There should be no effect on watertables within about 1 km of the Blackwood River, as artesian heads in the underlying Yarragadee Formation would be maintained.

Much of the valley has a significant depth to water but, due to its variability, it is not possible to produce an accurate description of watertable depth. At BP35C the depth to water is about 7 m, and in most areas the watertable depth would be expected to increase moving up the valley slope.

The upper catchment of Rosa Brook contains perched groundwater within the Leederville aquifer or Mowen aquitard (see Figure 2.1). Perched groundwater may be present at BP45, where there appears to be an unsaturated section at 19 – 22 m. There would be no hydraulic connection between the Yarragadee aquifer and the surface watertable in these areas of perched groundwater. There is potential for the expansion of these unsaturated zones through the Leederville aquifer in response to drawdown, increasing the area of surface watertable isolated from any effects within the Yarragadee aquifer.

A summary of modelled drawdown at hydrograph sites after 30 years for regional use and the eastern split wellfield proposal (Scenario 3) are presented in Table 5.21. An estimate is made of the probable degree of simulated drawdown that will eventuate after taking attenuating processes into consideration.

Table 5.21 Rosa Brook modelled hydrographs and attenuated impacts (raw and interpreted) from combined abstraction

Hydrograph site	Raw modelled drawdown after 30 years	Interpreted drawdown after 30 years
ROSA1: Blackwood River	No observable drawdown (<0.1)	No observable drawdown (<0.1)
BP35	Regional growth: 0.36 m Eastern Split Water Corp: 0.49 m	Regional growth: 0.18 m Eastern Split Water Corp: 0.25 m
ROSA2	Regional growth: 0.14 m Eastern Split Water Corp: 0.15 m	Regional growth: 0.03 – 0.04 m Eastern Split Water Corp: 0.04 m
ROSA3: Western branch	Regional growth: 0.36 m Eastern Split Water Corp: 0.42 m	Regional growth: 0.18 – 0.27 m Eastern Split Water Corp: 0.2 – 0.3 m

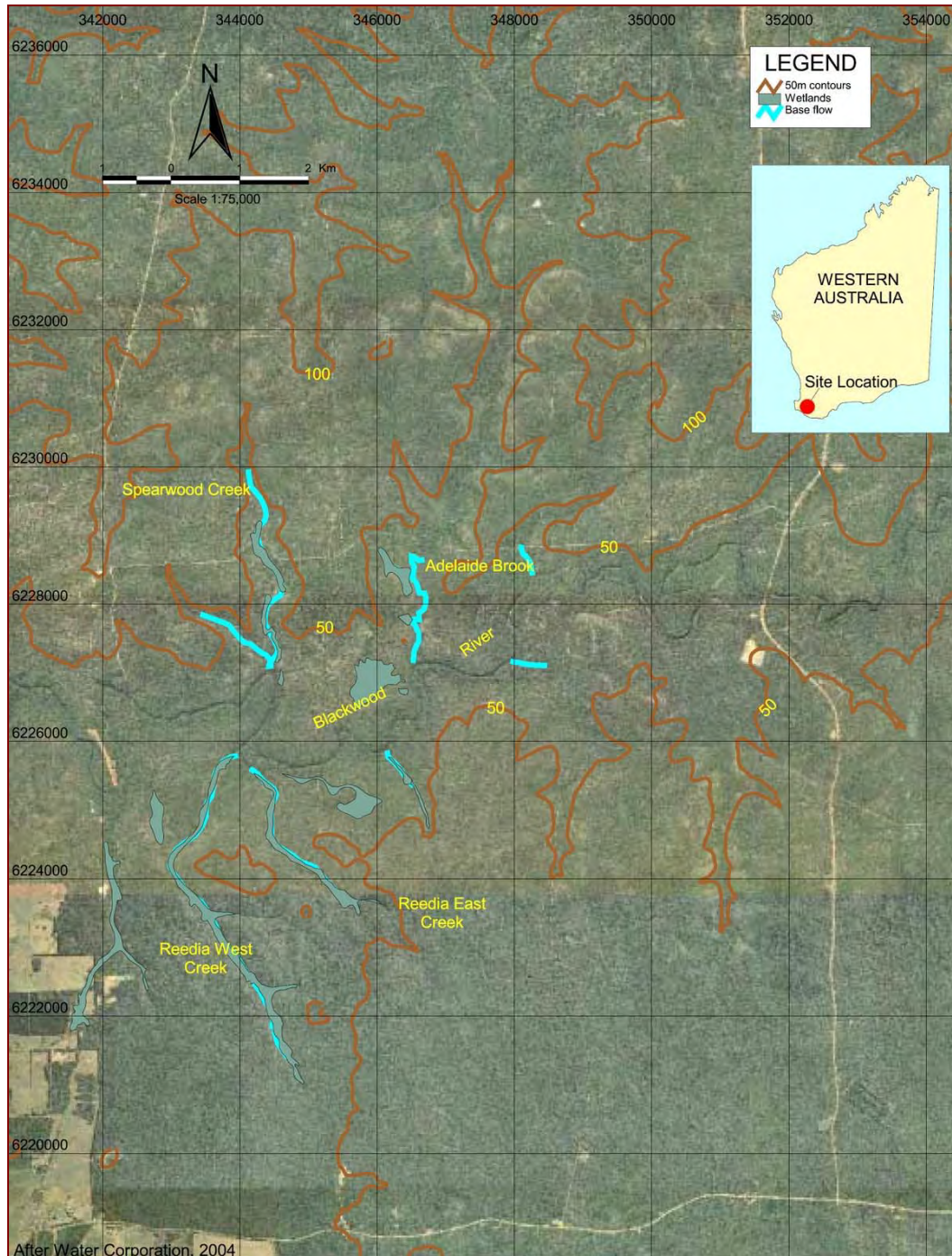
Under regional use and the eastern or eastern split Water Corporation wellfield options (Scenarios 3 and 4 respectively) it is unlikely that any significant effects at the watertable would be observed. The summer minimum watertable may decline by up to 0.2 m from a point about 1 km upstream from the Blackwood River, increasing to about 1 m below the confluence of the eastern and western branches of the brook. Perched watertable conditions are likely within 5 km upstream of the main brook fork, above which there should be no effect observed at the watertable resulting from either eastern wellfield configuration. Significantly greater drawdowns would be expected in this area under the western wellfield option (Scenario 5).

The lower flanks of the lower brook slopes may experience some drawdown at the watertable, even though the brook area does not. The maximum drawdown in these areas is likely to be around 0.5 m. Further up the valley slope the watertable depth becomes deeper and should be beyond rooting depth.

4.7 REEDIA WETLANDS

The Reedia Wetlands are important environmental features associated with perennial tributaries of the Blackwood River (Figure 5.43). Preliminary screening investigations into the effects of regional groundwater abstraction indicated there might be potential for drawdown to affect these ecosystems.

Figure 5.43 Reedia wetland location plan



Adapted from URS Australia 2004d.

The Reedia Wetlands lie on both sides of the Blackwood River upstream from Hut Pool on the Vasse Shelf, where the Vasse Member of the Leederville Formation outcrops at surface. They comprise a series of streams and wetlands. The total catchment area of the Reedia Wetlands is 66 km² which can be separated for analysis into three sub-catchments – the Spearwood Creek and Adelaide Brook catchments to the north of the Blackwood River, and the Reedia Creeks to the south of the Blackwood River.

4.7.1 Investigations

An investigation program to examine the relationship between the Reedia Wetlands and the local groundwater systems was undertaken by URS Australia during 2004 which involved:

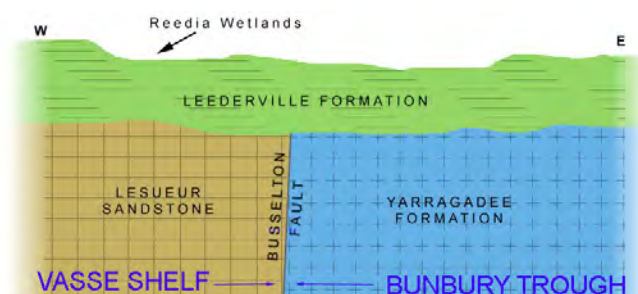
- drilling and logging of investigation wells at depths up to 335 m to identify the geological formations underlying the brook
- wetland and groundwater level measurements to understand how groundwater may flow to, or from, the wetlands
- laboratory examination of rock and soil samples from the wells to assess their age, permeability²³ and chemical characteristics of the groundwater contained in them
- electromagnetic ground surveys to refine the interpretation of surface geology in terms of boundaries and distribution of formation outcrops
- flow rate and water quality measurements in tributary creeks to the Blackwood River to support development of a model of flows in these creeks
- modelling of surface water flows in the Reedia Wetlands catchments to determine the extent to which groundwater contributes to those flows
- modelling of groundwater level responses in the Reedia Wetlands area to examine the potential for changes in the watertable in response to changes in aquifer pressures at depth.

The results of the investigation are summarised below, and presented in detail by URS Australia (2004d at Appendix 16)

4.7.2 Stratigraphy

The Reedia Wetlands area is underlain sequentially by the Leederville Formation, Lesueur Sandstone and the Sue Coal Measures, on the eastern margin of the Vasse Shelf (Figure 5.44). Two members of the Leederville Formation, the upper Mowen Member and the lower Vasse Member, are present. The Mowen Member occupies the higher ground to the east and north, and the Vasse Member occupies the lower ground along the Blackwood River and to the south.

Figure 5.44 Diagrammatic cross section showing Leederville Formation overlying the Busselton Fault



²³ Permeability refers to the measure of the ability of soil or rock to allow water to pass through it. High permeabilities refer to an ability to pass water at high rates, and vice versa.

The Busselton Fault, which separates the Vasse Shelf from the Bunbury Trough, lies to the east of the Reedia Wetlands. The Yarragadee Formation lies in the Bunbury Trough and is not present in the Vasse Shelf area, and therefore does not exist under the Reedia Wetlands (Figure 5.44). The Leederville Formation is geologically younger than the Busselton Fault, which separates the Bunbury Trough from the Vasse Shelf, and therefore overlies both. To the east of the Busselton Fault, the Leederville Formation overlies the Yarragadee Formation in the Bunbury Trough.

The thickest section of Mowen Member encountered in the Reedia Wetlands area in the 2004 drilling is 23 m. It consists mainly of clay and sandy clay, with thin layers of sand and clayey sand. The lower Vasse Member is clayey sand, clay, sand, and gravel, with shale interbeds. Because of the relatively high clay contents, and the presence of shale interbeds in the Vasse Member, these formations are of relatively low permeability and, therefore, limited vertical groundwater flow potential.

4.7.3 Surface water contribution from groundwater

Catchment modelling, based on adjusted streamflow data from St John Brook²⁴, topographic information and climate data, was used to separate the groundwater and rainfall runoff components of streamflow, and applied to the Reedia area streams.

This modelling indicated that an aggregate baseflow of 69 L/s from Spearwood Creek and Adelaide Brook flows into the wetlands and creeks on the northern side of the Blackwood River, and 191 L/s flows into those south of the river. Of this 260 L/s, some water is lost through evaporation and transpiration by vegetation along the stream lines, with the highest losses occurring during the hotter months.

The minimum resultant flow into the Blackwood River occurs in February and has been estimated to be about 127 L/s, in total, from both north and south.

4.7.4 Groundwater levels and flow

The groundwater contours and flow directions in the Leederville Formation are shown in Figure 5.45. The flow directions are derived by consideration of groundwater levels and pressures in the formation.

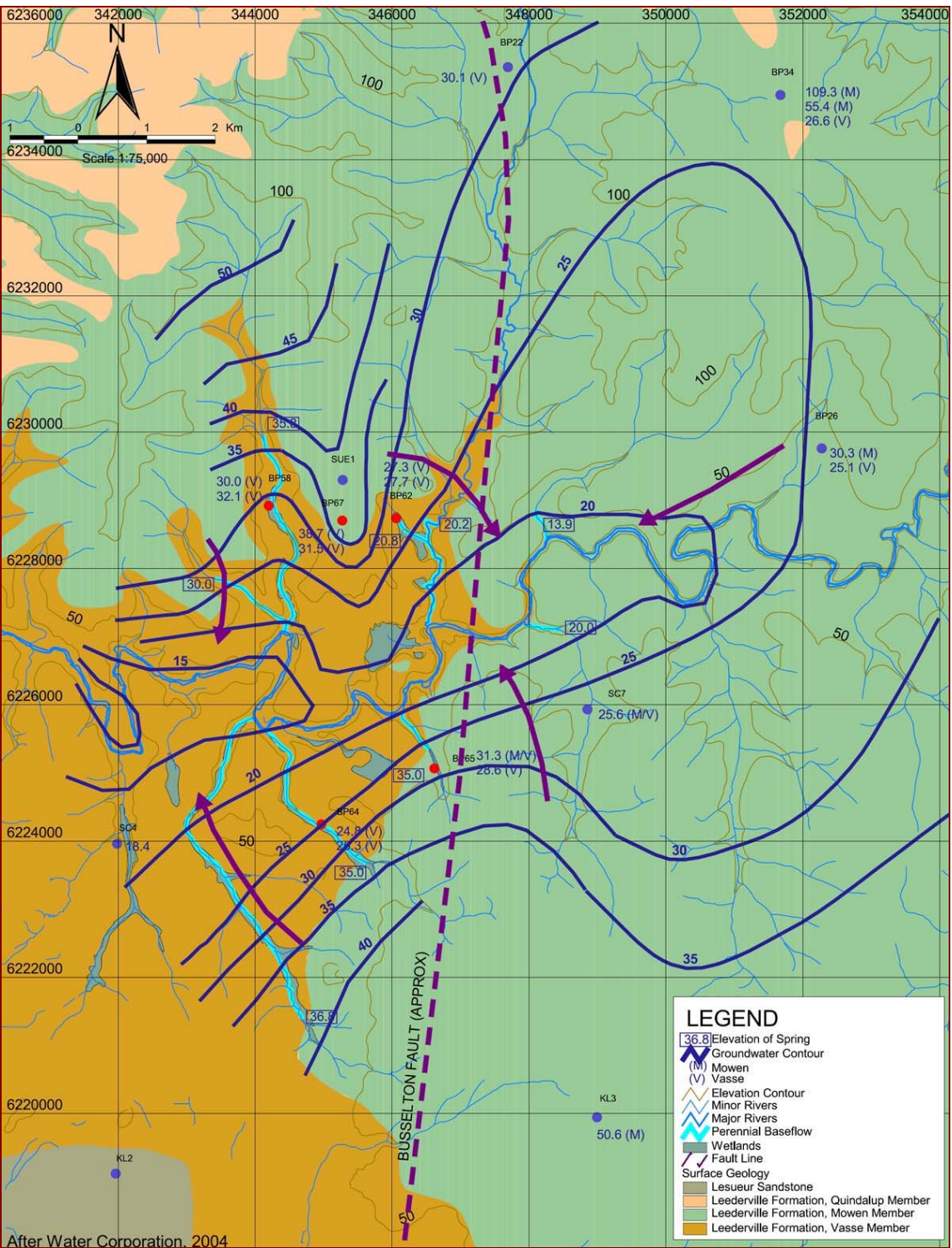
West of the boundary of the outcrop of the overlying Mowen Member, flow is directed towards the Blackwood River and its tributaries (Figure 5.45). There is a general downward flow of groundwater within most of the Leederville Formation. However, in the lower lying areas, there is a local upward flow in the Leederville Formation, which maintains the surface wetlands (Figure 5.46).

In the Reedia Wetlands area, water levels in the Lesueur Sandstone are 6 – 8 m above the levels in the Yarragadee Formation to the east of the Busselton Fault. This may be due to an intervening wedge of low permeability Cockleshell Gully Formation, or the fault zone itself may be of low permeability.

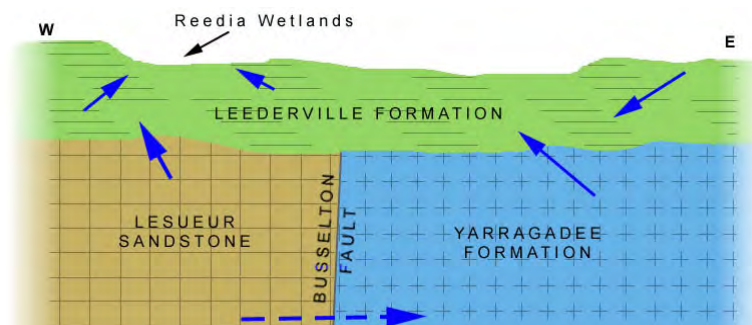
Annual groundwater level variations at different depths in the Lesueur Sandstone are variable in magnitude, and differ in their response to recent years of low rainfall. This indicates a lack of direct hydraulic connectivity between the lower and upper sections of the formation. Water levels in the nearby Yarragadee Formation show different seasonal variations again, confirming low connectivity across the Busselton Fault.

²⁴ Streamflow data from St John Brook was used as being representative of Blackwood tributaries as very limited streamflow data was specifically available for the tributaries in the Reedia Wetlands area.

Figure 5.45 Groundwater contours and flow direction - Leederville Formation – June 2004



Adapted from URS Australia 2004d.

Figure 5.46 Diagrammatic representation of inter-aquifer flows

4.7.5 Impact on Reedia Wetlands

Modelled drawdown interpretation

Any changes in water pressures in the Yarragadee Formation are unlikely to transmit across the Busselton Fault without a considerable reduction. The raw modelling results show less than 0.1 m drawdown in the Reedia Wetlands area from the proposal combined with future regional use. Based on the understanding of the local hydrogeology, no drawdown is expected to occur in the area of the Reedia Wetlands as a result of the proposal under Scenario 3.

The interpreted results suggest there may be some impact in the southern area of the Reedia Wetlands as a result of regional groundwater abstractions on the western Scott Coastal Plain. However, the extent and magnitude of this effect will very much depend on the specific location and magnitude of future private abstractions.

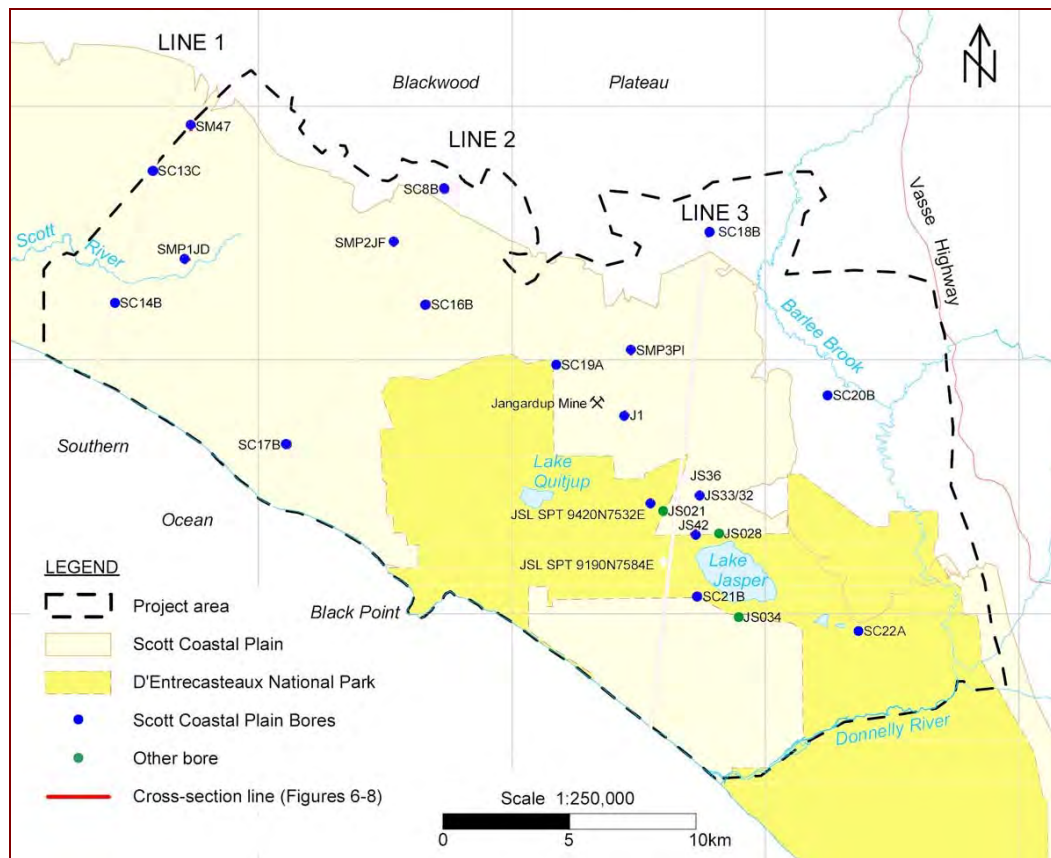
4.8 SCOTT COASTAL PLAIN

The primary area of potential impact of the proposed Water Corporation abstraction on the Scott Coastal Plain is along the northern edge of the eastern plain, at the edge of the Blackwood Plateau escarpment. The eastern Scott Coastal Plain contains several important wetlands (Figure 5.47). The plain is an internally draining area characterised by swamps and lakes. The surface geology comprises largely sandy deposits. The Scott River drains the central and western area of the plain.

A significant area of the western Scott Coastal Plain receives little direct groundwater recharge from rainfall as a result of upward discharges from underlying aquifers. Removal of water by drainage of the area means there is considerable water rejected as groundwater recharge, and 200 – 300 mm/yr of additional recharge is considered potentially available if water levels were lowered.

4.8.1 Investigations

An investigation program was undertaken in 2004 by Rockwater Pty Ltd to examine the potential for drawdown impacts on the eastern Scott Coastal Plain.

Figure 5.47 Eastern Scott Coastal Plain location

Adapted from Rockwater 2004c.

The investigation program examined the relationship between the watertable, wetlands and the local groundwater systems, and involved:

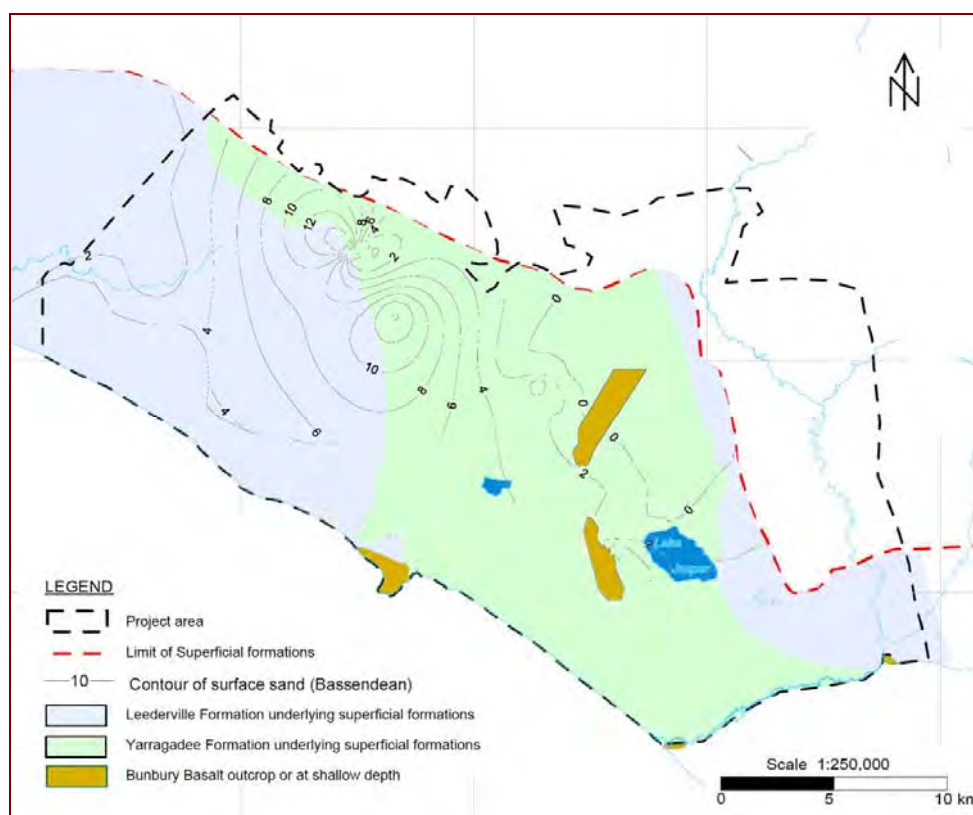
- a review of available hydrogeological data to identify likely impacts on the watertable resulting from drawdowns of water levels in the Yarragadee Formation (including published and unpublished reports, drilling records and groundwater monitoring data)
- pump testing of selected investigation wells to determine the hydraulic characteristics of various geologic formations
- modelling of groundwater leakage to quantitatively examine the potential for changes in the watertable in response to changes in aquifer pressures at depth.

The program was based on existing investigations sites, which were not evenly distributed through the study area. Consequently, some interpolation of conditions between investigations sites has been necessary. The results of this work were reported by Rockwater (2004c at Appendix 15).

4.8.2 Stratigraphy

The superficial formations form the surface on the Scott Coastal Plain where they are about 20 to 30 m thick. Beneath the coastal dune areas they are up to 200 m thick (Figure 5.48). The superficial formations directly overlie the Yarragadee Formation in the central part of the eastern Scott Coastal Plain. At the eastern and western margins of the plain, the superficial formations directly overlie the Leederville Formation. The Bunbury Basalt also underlies the superficial formations in some areas, and outcrops at Black Point. It also outcrops in small areas along the Donnelly River and occurs at shallow depth beneath a few metres thickness of superficial formations in the Jangardup mine area.

Figure 5.48 Thickness of superficial formations and distribution of underlying formations



Adapted from Rockwater 2004c.

In the western part of the study area (central Scott Coastal Plain), the Leederville Formation underlies the superficial formations. In the eastern part (with the exception of the eastern margin), the Leederville Formation is absent and the Yarragadee Formation is in contact with the base of the superficial formations, with some areas of occurrence of Bunbury Basalt.

In the study area, the Leederville Formation consists of alternating layers of shale, siltstone and sandstone. Shale and siltstone are relatively impermeable rocks and their presence impedes potential groundwater movement between the superficial formations and the Yarragadee Formation.

A coffee rock layer occurs locally in the superficial formations, around the zone of watertable fluctuation. It is up to 11 m thick and, where it occurs forms a local barrier to vertical seepage of groundwater.

4.8.3 Groundwater levels and flow

Superficial formations

The watertable on the Scott Coastal Plain is at, or near, the ground surface (except beneath the elevated coastal dunes), and creates a swampy or seasonally inundated environment. There are wetlands throughout the area, wherever the land surface falls below the watertable. Lake Jasper and Lake Quitjup are in the area where the Yarragadee Formation subcrops directly beneath the superficial formations.

Groundwater levels fluctuate seasonally, with fluctuations from less than one metre near the coast to more than three metres inland. The watertable aquifers are recharged by direct infiltration of rainfall. In the north-western part of the study area, and close to the coast, the underlying Leederville and Yarragadee Formations also contribute to the recharge. High evapotranspiration rates prevail in areas of high watertable through direct evaporation from the water surface and through uptake by vegetation. A small lowering of the watertable may result in a significant reduction in this evapotranspiration, largely through reducing the exposure of water to the atmosphere.

The watertable forms a groundwater mound centred around, and north of, the area of basalt near Jangardup. Groundwater flows westward towards the Scott River, eastward towards the Donnelly River and south-westward towards the ocean.

Examination of the strata and water pressures in the Lake Jasper area indicates there is potential for groundwater to leak downward from the superficial formations to the underlying Yarragadee Formation.

Water levels in the superficial formations (measured by the DoE) have remained relatively steady from year to year, with a few exceptions (URS Australia 2005b at Appendix 19). In one case a windmill is operating near a monitoring site and has caused a slight decline of about 0.2 m since 2000. In the another case, the seasonal minimum showed a decline of about 0.4 m since 2001, but with full recovery of levels each winter. The decline is thought to be due either to a nearby blue gum plantation, or to local pumping from the Yarragadee Formation for irrigation.

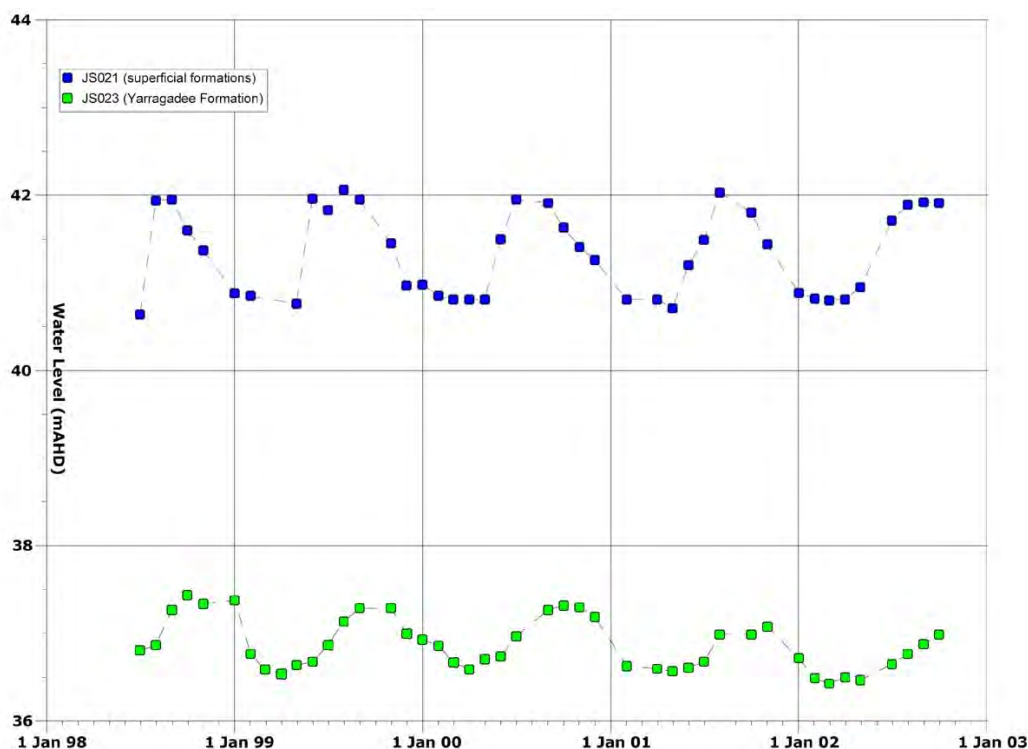
The consistent seasonal maximum watertable levels in superficial aquifer monitoring wells indicate that recharge has not declined in response to recent lower than average rainfall. Watertables in the superficial formations do not appear to have been affected by slight declines in pressures in the underlying Leederville Formation or (with the possible exception mentioned above) in the Yarragadee Formation. This is a strong indication that under average rainfall conditions, recharge is rejected and, if water is drawn from the superficial formations by either pumping or increased downward leakage, then recharge will increase in response.

Yarragadee Formation

Water pressure contours in the Yarragadee Formation show a similar pattern to the watertable, with an area of high pressure extending north from north of Lake Jasper. The Yarragadee Formation water levels show a declining trend, reflecting reduced recharge in recent lower rainfall years, and the impact of groundwater pumping for horticulture and dairying on the eastern Scott Coastal Plain (Figure 5.49). The decline has been of the order of 0.5 m over 5 years.

However, while the minimum water levels in recent years are lower than in previous years, there has been no change in the winter water levels. This indicates that recharge is sufficient to allow full recovery of levels each year. In effect, recharge increases because of the space provided by the lowered summer water levels. As discussed previously, this recharge would otherwise be rejected, as the system is effectively full.

Figure 5.49 Typical hydrographs of superficial formations and Yarragadee Formation monitoring wells



Salinities measured in the Yarragadee Formation near Lake Jasper are lower than in the overlying superficial formations, indicating that the downward leakage rates from the superficial aquifers are not high enough to affect the quality of the underlying water. The downward leakage is low compared to flow rates in the Yarragadee Formation.

4.8.4 Impacts of Yarragadee Formation drawdowns on the watertable

Local modelling of the effects of hypothetical drawdowns in the Yarragadee Formation was used to examine the effects on vertical leakage, and on groundwater levels, in the superficial formations (watertable) in the eastern Scott Coastal Plain (Rockwater 2004c at Appendix 15). This work indicated that recharge to the superficial formations is currently about 13% of rainfall. If water pressures in the Yarragadee Formation were lowered by 1 m, the watertable would lower by 0.74 m over ten years, but only if there was no change in recharge. Recharge would need to increase to 16% of rainfall to offset this lowering of the winter watertable, and would need to increase to 19% to offset the effects of a 2 m drawdown in the Yarragadee Formation. These levels of recharge are achievable within the extent of rejected recharge currently occurring in the area.

Increased recharge in response to drawdown

Any lowering of the watertable is expected to increase recharge through a lower rate of recharge rejection. As discussed previously, a substantial amount of recharge is rejected because the shallow groundwater system is effectively full in winter. A lowered watertable would also reduce evapotranspiration losses, allowing for further increases in recharge. An increase in recharge from 13% to 16% (or even 19%) is well within recharge increases that could be expected in this high rainfall – low evaporation environment. Recharge rates of up to 30% of rainfall have been recorded in areas with similar surface geology and more adverse rainfall–evaporation conditions (pers. comm. Ryan Vogwill DoE, August 2005).

However, as recharge occurs in the winter months, there would be some drawdown of the watertable below current levels during summer months, even if pumping were completely offset by the induced increase in recharge in the winter months.

4.8.5 Effect on wetlands

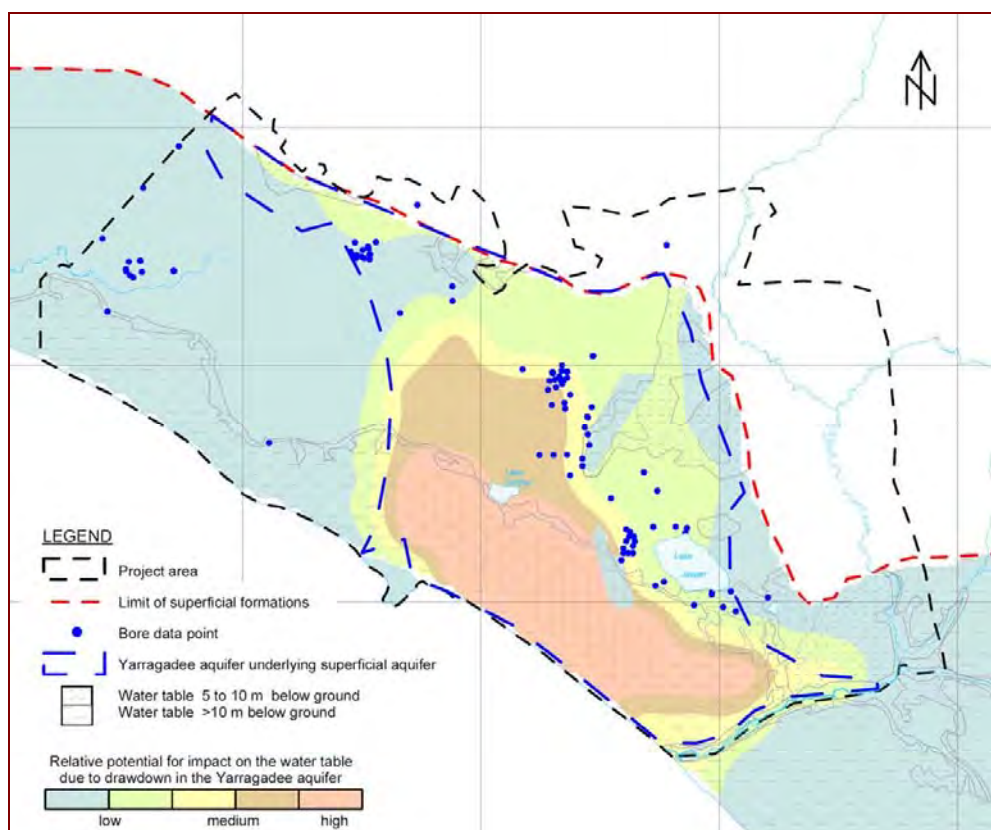
Because of the variability of both surface and underlying geology, and topography, the modelling showed variable responses over the investigation area. In areas where the superficial formations contain silty and clayey layers, such as the Lake Jasper area, it is unlikely that drawdowns of one or two metres in the Yarragadee Formation would have any measurable impact on the watertable. This was confirmed by examination of the response in groundwater levels in this area to local pumping from the Yarragadee Formation for horticultural purposes (Figure 5.49). Yarragadee Formation levels have declined about 0.5 m over the period from 1998 to 2003, while there is no upward or downward trend in the overlying superficial formations monitoring well.

Similarly, where the Bunbury Basalt or Leederville Formation separates the superficial formations and the Yarragadee Formation, small drawdowns in the Yarragadee Formation will not be transmitted to the watertable. In areas of thick Bunbury Basalt or Leederville Formation, it is unlikely that large drawdowns in the Yarragadee Formation would be transmitted through this material.

In areas where sandy superficial formations directly overlie sandstone beds of the Yarragadee Formation, such as the coastal dunes south of Lake Jasper and near the Jangardup mine, drawdowns in the Yarragadee Formation would cause similar declines in the watertable, particularly in summer months. These effects would be reduced in areas where there are coffee rock layers, or where the superficial formations contain clay layers, or where the Bunbury Basalt is present.

The relative potential for impact on the watertable from drawdown in the Yarragadee Formation was assessed in various parts of the eastern Scott Coastal Plain (Appendix 15). This assessment (Figure 5.50) took into account all the factors with potential to affect the transmission of pressure drops in the aquifer to the surface, together with the potential for increased recharge in response to pressure drops.

Lake Jasper is in an area with low potential for drawdown in the Yarragadee Formation to affect the lake level because of the nature of the superficial formations and the downward pressure gradient between the superficial formations and the Yarragadee Formation. Lake Quitjup is in an area with a medium – high potential for such effects. The area of coastal dunes south of Lake Quitjup and Lake Jasper has is a high potential for an impact on the watertable. However, as the land surface in the coastal dunes is well above the watertable, no environmental impact is anticipated. Most of the study area shows very low potential for drawdowns in the Yarragadee formation to affect the watertable.

Figure 5.50 Relative potential for impact on watertable of drawdown in Yarragadee Formation

Adapted from Rockwater 2004c.

Lake Jasper

Available data from the Lake Jasper area show that evaporation, at 84 – 100% of total lake outflow, dominates water losses from the lake (Rockwater 2004 at Appendix 15). The residual loss (up to 16%) is by leakage to groundwater. This leakage includes both horizontal flow into the superficial formations, and downward leakage to the Yarragadee Formation. Downward hydraulic head gradients between the superficial and Yarragadee aquifers have been identified in the Lake Jasper area (Appendix 15). A simple numerical model was used by Rockwater to estimate vertical hydraulic conductivity and likely rates of groundwater leakage in the area around Lake Jasper. The model indicated that drawdowns of one to two metres in the Yarragadee Formation are unlikely to have any measurable impact on watertable levels in areas where the superficial aquifer contains silty or clayey layers. Watertable effects would also be attenuated where there is coffee rock below the watertable.

Water levels in Lake Jasper vary by about 1 m annually, with the maximum level controlled by the geomorphology. No overall trends are evident in the hydrographs that cannot be attributed to rainfall variation in the region.

Lake Quitjup and surrounding wetlands

The hydrology of Lake Quitjup and surrounding wetlands was investigated by URS Australia (2005b at Appendix 19). They noted that the wetlands are seasonally inundated to depths of up to about 1 m. They saw little evidence of water flowing through the wetlands, which suggests that the ponding is largely a direct result of rainfall. At the time of the URS work in (February 2005) the wetlands were dry.

Lake Quitjup is at the boundary of the coastal plain, against the northern edge of the coastal dunes. It is a permanent lake and has maintained its areal extent since first photographed from the air in 1951. The lake salinity is similar to the surrounding shallow groundwater, and the lake level corresponds with regional watertable contours, indicating direct connection with the groundwater. Lake levels are reported to be (Appendix 19) relatively constant (varying only by 0.2 – 0.3 m).

A water balance analysis of Lake Quitjup by URS Australia (Appendix 19) indicates that about half the water inflow is from rainfall and half from groundwater seepage. Outflows are about one-third to evaporation and two-thirds to groundwater seepage, probably towards the dune area in the south.

A water balance analysis of the wetland area indicates high rainfall input and relatively high seepage outflows to groundwater. The high seepage outflows suggest that the wetlands areas are dry for part of the summer. The duration of the dry period would depend on rainfall. The extensive ponding on the Scott Coastal Plain provides a potential source of additional recharge (currently lost to evaporation) which would provide a buffer against lowering of the watertable from future abstraction from the underlying Yarragadee Formation (Appendix 19). Hydrographs from monitoring wells do not show any decline in water level resulting from slightly declining water levels in the underlying Leederville or Yarragadee Formations.

Seasonal wetlands in the area are unlikely to be significantly affected, as recovery of rejected recharge will ensure that these wetlands become fully inundated each winter. The lower summer minimum watertable levels may result in a very small reduction in the duration of inundation, depending on the mechanisms that apply. If the seasonal wetlands fill with rain as it occurs and then drain to the watertable, then the lowered summer watertable is unlikely to cause any delay in the start in the period of inundation, which will be dictated only by the timing and duration of the first winter rains. If the seasonal wetlands rely on the watertable rising to cause inundation (that is, any rainfall drains directly through the base of the wetlands without causing any filling before the watertable reaches the base of the wetland) there may be a small delay in the start of the inundation period. This delay will be short as the amount of additional rainfall required to offset the lowered summer minimum watertable level is only a few millimetres (probably less than 5 mm).

4.8.6 Conclusions drawn from work so far

There is a lack of detailed hydrogeological data in some parts of the eastern Scott Coastal Plain so that existing data had to be interpolated in some areas. Consequently, some caution should be applied to the conclusions drawn in the areas of lower data density. The Water Corporation is committed to adaptively manage the proposal, including ongoing monitoring and research to improve knowledge in these areas.

The investigation work undertaken into the hydrogeology of the eastern Scott Coastal Plain concluded that:

1. The eastern Scott Coastal Plain is an internally draining area characterised by swamps and lakes. The surface is covered largely by sandy deposits (superficial formations). The Scott River drains the central and western area of the coastal plain. Watertable levels beneath the coastal plain are at or near the surface, except beneath the coastal dunes.
2. The sandy superficial formations form the surface of the Scott Coastal Plain. These are variably underlain by the Leederville and Yarragadee Formations, with Bunbury Basalt under some areas. Thickness of the superficial formations varies from 20 to 30 m over most of the area, extending to 200 m in the coastal dunes.

3. Where they exist, the Bunbury Basalt and the impermeable layers within the Leederville Formation impede potential groundwater movement between the superficial formations and the Yarragadee Formation. These layers also impede transfer of drawdowns in the Yarragadee Formation to the watertable.
4. Coffee rock and silty or clayey layers within the superficial formations inhibit the transfer of drawdown effects to the watertable from underlying formations, to the extent that drawdowns of one or two metres would not transmit through this material.
5. Over a substantial proportion of the plain, the watertable is high (at, or close to, the surface) and as a result:
6. Potential recharge to the groundwater systems is rejected, and drains off because the surface aquifers are full
7. recharge will increase in response to drawdowns in the watertable through reduced rejection of recharge and reductions in evapotranspiration losses, and this would substantially offset drawdown effects on the watertable.
8. Lake Jasper is in an area of low potential for drawdowns in the Yarragadee Formation to affect lake levels. Lake Quitjup is in an area with a medium – high potential for such effects. The area of coastal dunes south of Lake Quitjup and Lake Jasper has a high potential for impact. The majority of the investigation area shows very low potential. In the area north of Lakes Jasper and Quitjup, much of the land has been cleared, and the potential for impact on groundwater ecosystems will be limited to small areas. There is little potential for ecological impact on the dune systems because of greater depths to the watertable and low groundwater dependency of dune ecosystems.
9. Additional information in the Lake Quitjup area is not expected to change the interpretation such that there would be evidence of an increase in the potential for impact. It is highly unlikely that additional information would change the interpretation of the potential for impact on Lake Jasper.
10. Given the level of current and potential private use of groundwater on the Scott Coastal Plain, ongoing monitoring of water level behaviour will be necessary to improve detail on the impact potential in the areas of data interpolation. This monitoring should include groundwater levels in the superficial formations and underlying Yarragadee Formation, together with wetland water levels.

4.8.7 Modelled drawdown interpretation

Interpretation of the modelled watertable drawdowns induced by the proposal on the eastern Scott Coastal Plain indicate drawdowns will increase in a northerly direction, with the maximum impact expected to be less than 1 m, and limited to short, narrow areas in a band along the northern boundary of the plain. Drawdowns of up to 0.5 m are expected in a narrow area immediately south of the transition area from the coastal plain to the Blackwood Plateau. Drawdowns of less than 0.25 m are expected over the remainder of the plain.

Modelled drawdowns from the proposal, when combined with future regional water use, show more widespread effects, with drawdown predicted in the western part of the plain as a consequence of anticipated future growth in groundwater use in that area (Figure 5.31). Drawdown from combined abstractions is expected to be up to 1 – 2 m in a narrow band along the very northern edge of the eastern part of the plain. Over the majority of the plain, drawdowns are expected to be less than 0.25 m.

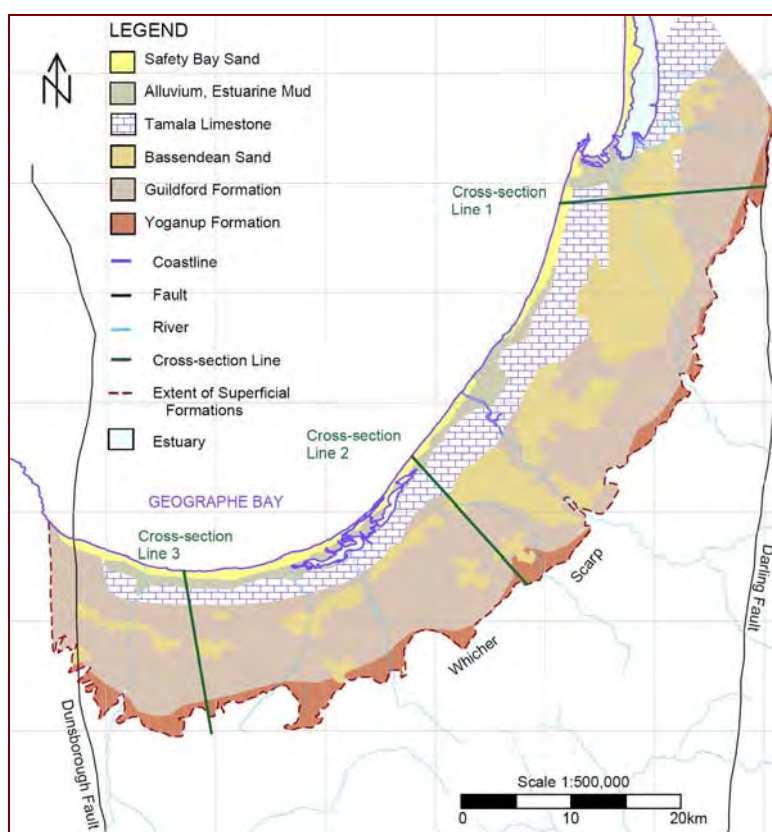
No impacts are expected in Lake Jasper as a consequence of the proposal, as it lies beyond the southern extent of the area of induced watertable drawdowns, and is not hydraulically connected to the underlying Yarragadee Formation.

4.9 SWAN COASTAL PLAIN

Drawdown of the watertable on the Swan Coastal Plain is expected to be variable depending on the local hydrogeology and the extent to which the Yarragadee Formation is in contact with the shallow watertable aquifers of the superficial formations. Given that rejected recharge totals about 300 mm/yr (Baddock 2005b), it is expected that winter watertable levels will not be affected under any of the scenarios modelled. Interpretation of the modelled drawdowns indicates that the lowering of the summer watertable by the proposal is not expected to exceed 0.25 m, with the possible exception of a very limited area along the edge of the Whicher Scarp, where drawdowns of less than 0.5 m are expected, and an area south of Bunbury where similar drawdowns are likely.

When combined with future regional groundwater abstractions, drawdowns of up to 1 – 2 m in the summer watertable are expected over parts of the area. Drawdowns over most of the coastal plain area would be less than 0.5 m.

Figure 5.51 Swan Coastal Plain surface geology



Adapted from Rockwater 2004b.

In the Bunbury area, high potential recharge rates due to urbanisation, agricultural clearing, and rejected recharge removed by drainage, will counteract simulated watertable drawdowns. Summer water levels will decline, while winter water levels are expected to recover fully each year through increased recharge. The extent of summer watertable declines will be substantially less than modelled because of the winter recoveries effectively refilling the system by the end of each winter.

In the area east of Capel, the clay beds contained within the Guildford Formation, which overlies the Yarragadee Formation, will restrict migration of drawdowns to the watertable. The upper Yarragadee units in this area (Yarragadee Formation Units 1 and 2) are vertically resistive to groundwater flow. Clayey Guildford and Yoganup Formations occur extensively at the surface, as reported by Rockwater (2004b) (Figure 5.51).

4.9.1 Effects on groundwater dependent ecosystems

Tutunup Ironstone communities

The Tutunup area, west of the Ludlow River, is ecologically sensitive because of the Tutunup Ironstone vegetation community present in this locality. Modelled drawdowns in this area are considered over-predictions because of the presence of substantial clay layers in the superficial formations, the lower portion of the Vasse Member, and the upper unit of the Yarragadee Formation in this area.

The potentiometric head within Yarragadee Formation Unit 1 at Tutunup is about 15 m higher than within the deeper portion of the Yarragadee Formation (Unit 3), indicating a relatively low vertical permeability in this location. Regional values of vertical permeability for several of the model layers are an order of magnitude higher than those suggested by the local lithology. This is a shortcoming of the model in this locality.

Wonnerup wetlands

The Vasse–Wonnerup wetland system is a linear system along the coastline. The wetlands act as compensating basins for water discharging from the Ludlow, Sabina, Abba and Vasse Rivers, and discharge to the ocean over weirs when the estuary water level rises above sea level.

Water levels in the Wonnerup wetlands are not expected to be affected by the proposal because their proximity to the ocean means that minimum wetland water levels will be controlled by sea level. The wetlands are situated on permeable sand and limestone sediments, with good hydraulic connection between the superficial aquifer and the coast. Salt and brackish groundwater extends inland for a significant distance beneath the wetlands because of low hydraulic heads in the superficial aquifer. The wetlands are fresh in winter as a consequence of surface inflows, becoming brackish during the summer.

4.10 AREAS OF ZERO RISK OF IMPACT

Several areas (other than those covered in Sections 4.3 – 4.9) need to be examined because of concern over possible drawdown impacts expressed by either the regulating agencies or the community. These areas have not been discussed in detail because the potential for drawdown impact is considered to be zero. These areas are listed in Table 5.22 and are each discussed in the following sections.

Table 5.22 Areas of zero risk of impact

Area	Concerned party
Margaret River pools	Community, Department of Environment
Cave systems	Community, Department of Conservation and Land Management
Peel–Yalgorup Wetlands	Department of Environment and Heritage
Lake Toolibin	Department of Environment and Heritage
Becher Point Wetlands	Department of Environment and Heritage
Forrestdale and Thomsons Lakes	Department of Environment and Heritage

The location of the areas raised by the DEH as Ramsar wetlands are shown in Figure 5.52.

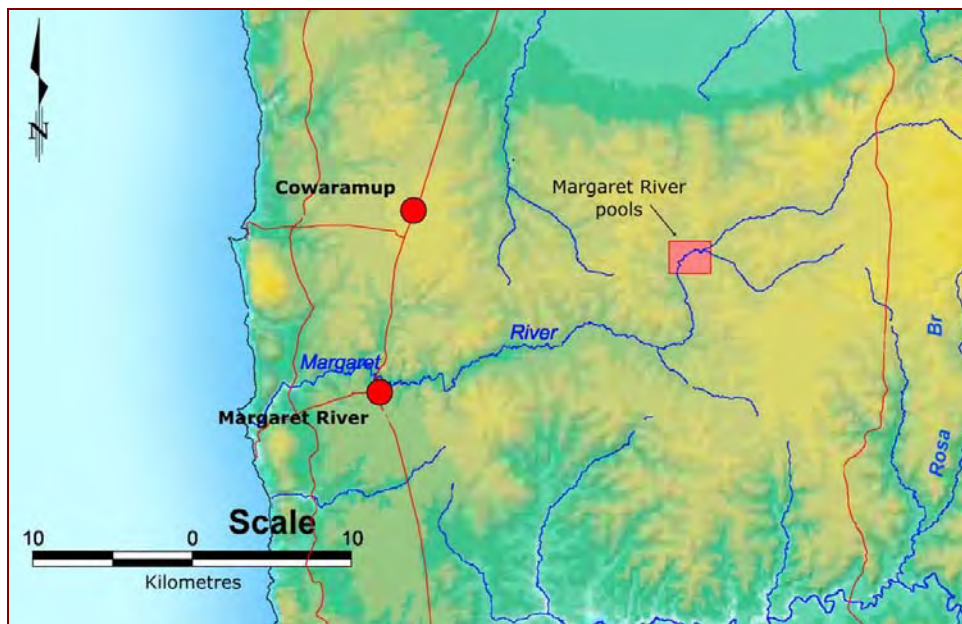
Figure 5.52 Location of Ramsar wetlands²⁵

Margaret River pools

The potential for impacts of the Water Corporation proposal on pools in the Margaret River was raised by the DoE and community members as needing to be addressed. In response, URS Australia Ltd was commissioned by the Water Corporation to assess connectivity of the pools with the regional groundwater system. The four pools in an area known as Canebreak are located within a proposed conservation park (Figure 5.53) at the confluence of two tributaries in an area known as The Rapids.

URS inspected the pools in February 2005 and noted (URS Australia 2005a) that the only visible surface flow into or out of any of the pools was at the top of the most downstream pool in the sequence. The electrical conductivity of the water was similar in all pools and chemical analysis of samples gave almost identical results, indicating that they are probably sustained by groundwater inflow from the upper part of the Leederville Formation. The pool level elevations conform to regional groundwater levels in the upper Leederville Formation suggesting that if watertable levels fall in this area, so too will pool levels.

²⁵ Map taken from <http://www.deh.gov.au/erin/ert/epbc/index.html> [12 October 2005]

Figure 5.53 Location of Margaret River pools

None of the modelled scenarios (interpreted or otherwise) show drawdowns being induced in the watertable in this location as a consequence of the proposal or of future regional use abstractions. An impact is possible, however, under reduced recharge because of climate change, independent of any pumping.

Given that the proposal has been demonstrated as not having any effect on the pools, it was not considered necessary to evaluate this area further.

Cave systems

Community and agency (CALM) concern was expressed on the potential for the proposal to affect water levels in the caves of the Margaret River–Yallingup region. However, these caves are all in limestone areas overlying granitic rocks of the Leeuwin–Naturaliste Ridge. They are hydraulically isolated from the Southern Perth Basin and the effects of groundwater abstraction in the basin. Groundwater abstraction from the Southern Perth Basin will not affect these caves.

Peel–Yalgorup Wetlands

The Peel–Yalgorup Wetlands are the linear chain of coastal wetlands between Bunbury and Mandurah (Figure 5.52), the southern most of which is about 70 km north of the proposed wellfield. They are Ramsar listed wetlands²⁶ identified by the Department of Environment and Heritage as needing to be addressed in the evaluation. No drawdown impacts are expected to extend north of Bunbury (30 km from the proposed wellfield) and the proposal will have no effect on these wetlands.

²⁶ The Ramsar Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.

Lake Toolibin

Lake Toolibin is another Ramsar listed wetland 200 km to the east-north-east of the proposed wellfield (Figure 5.52). The lake is situated in surficial sediments overlying the granitic rocks of the Yilgarn Craton, which is hydraulically separated from the Southern Perth Basin and the effects of groundwater abstraction in the basin. Groundwater abstraction from the Southern Perth Basin will not affect this lake.

Becher Point Wetlands

The Becher Point Wetlands are Ramsar listed wetlands between Mandurah and Rockingham, approximately 150 km north of the proposed wellfield (Figure 5.52). No drawdown impacts are expected to extend north of Bunbury (30 km from the proposed wellfield) and the proposal will have no effect on these wetlands.

Forrestdale and Thomsons Lakes

Forrestdale and Thomsons Lakes are Ramsar listed wetlands immediately south of Perth, approximately 180 km north of the proposed wellfield (Figure 5.52). No drawdown impacts are expected to extend north of Bunbury (30 km from the proposed wellfield) and the proposal will have no effect on these wetlands.

4.11 POTENTIAL FOR DRAWDOWN INTERFERENCE WITH OTHER USERS

The potential drawdowns in Yarragadee Formation Unit 3 (represented in the model as layer 7) have been modelled (Figure 5.54). The extent of potential drawdown interference with existing Yarragadee Formation wells on the Swan Coastal Plain is expected to be 3 m at the most. This drawdown would be greatest in the southern part of the eastern Swan Coastal Plain. It is expected to diminish to the north and west (Figure 5.54).

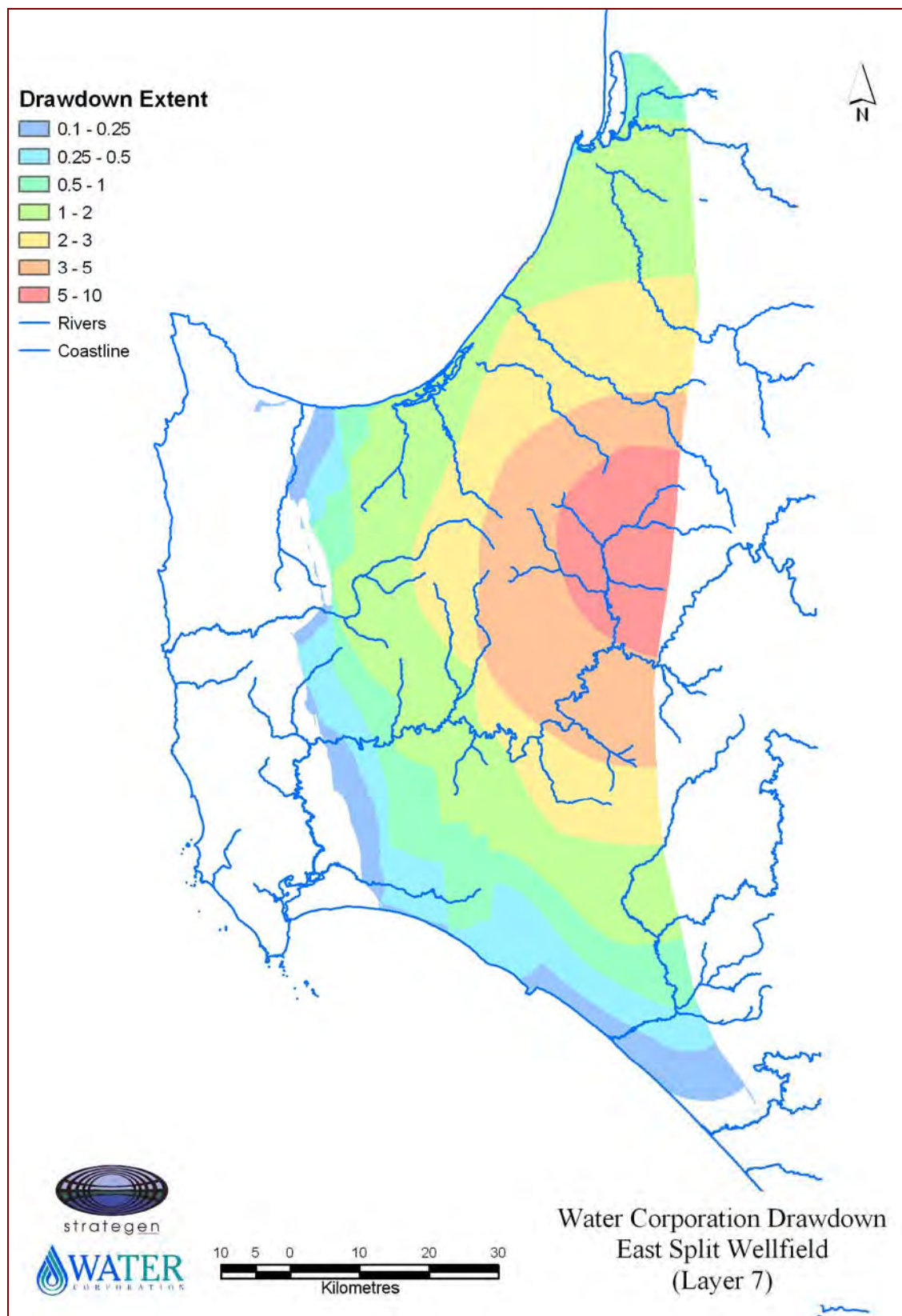
Interference effects with Yarragadee Formation wells on the Scott Coastal Plain would be generally less than one metre (Figure 5.54), with the area of maximum interference being in the northern part of the eastern Scott Coastal Plain.

Interference effects on shallow superficial aquifer wells would be generally less than one metre anywhere within the region (Figure 5.29).

This extent of drawdown is not expected to create detrimental impacts on any other groundwater users, provided those users have constructed their wells to a design that recognises that other users may reasonably utilise the same groundwater resource.

There are presently 146 contracting parties to the Convention, including Australia, with wetland sites designated for inclusion in the Ramsar List of Wetlands of International Importance.

Figure 5.54 Drawdowns in Yarragadee Unit 3 layer from Water Corporation Eastern Units 1 & 3 wellfield



The formal Water and Rivers Commission policy position²⁷ on interference drawdown (Water Authority of Western Australia 1990) notes:

“In general, this situation [drawdown interference] is at the risk of well owners, and they should ensure they construct wells or locate pumps to sufficient depth to tolerate interference drawdown from other users. The principle applying here is, the ability to utilise a resource to its full potential should not be limited by the reluctance of users to recognise or accommodate the impacts of other users sharing the resource. All users should make the necessary arrangements to ensure use of the resource by others can be accommodated by themselves.

The Authority, in licensing new wells in an area where wells exist, should endeavour to locate the new wells to minimise likely interference effects.”

This policy position is consistent with a national Policy Position Paper prepared by the Task Force on Council of Australian Governments (COAG) Water Reform (ARMCANZ 1996). Recommendation four states:

“In preparing groundwater management plans, policies and strategies, States should ensure that the efficient utilisation of groundwater resources is not compromised by protection of existing users with inefficiently designed or constructed wells. This particularly applies to domestic and stock wells.”

The proposal has specifically designed well locations that minimise any likely interference effects on existing and potential future users, in strict accordance with the Water and Rivers Commission policy position. The proposed wellfield has been located at the maximum practicable distance from all known existing users, specifically to avoid or minimise any drawdown interference effects. The wellfield has been located approximately 20 km from the nearest licensed well taking water from the Yarragadee Formation. There are several small wells into the Leederville Formation in the Jarrahwood area, but the effects of Water Corporation pumping on these wells is expected to be mitigated by the low permeability layers between the Yarragadee Formation and upper Leederville Formation.

The Commission has stated (Appendix 2) that if there is a detrimental impact on other groundwater users there needs to be an *“agreed process in place to provide reasonable compensation (monetary or other)”*. The Water Corporation believes that this requirement is contrary to the formal policy position of the Commission. There are no legislative provisions for the application of compensation, and such a requirement would create a difficult precedent.

Drawdown interference effects from future regional use abstractions on existing users are likely to be of a higher magnitude than the effects of the Water Corporation proposal because of the likely proximity of future growth to current abstraction locations.

²⁷ On formation in January 1996, the Board of the Water and Rivers Commission resolved to adopt the relevant policies of the pre-existing agencies until they were superseded by specific Commission policies. This Water Authority policy aspect is understood to not have been superseded at this time and would still apply.

4.12 POTENTIAL FOR SEAWATER INTRUSION

Groundwater discharging into the ocean does so through a freshwater–saltwater interface, the position of which is determined principally by the amount of water flowing towards the ocean (Section 2.4). The interface tends to be wedge shaped, with the toe of the wedge extending inland (Figure 5.55). If that flow is diminished, the toe and face of the wedge move inland in proportion to the reduction in flow.

Management of the interface location requires maintenance of sufficient ocean-ward flow to ensure the interface does not progress inland far enough to intersect with pumping bores, which would then turn saline. Relocation of affected wells can enable more water to be abstracted from the aquifer than might be the case if draw was limited by the locations of existing wells.

Seawater intrusion has historically occurred under the Bunbury peninsula and affected Aqwest wells located close to the coast and screened in the shallow portion of the Yarragadee Formation.

Recent re-drilling and geophysical logging of a monitoring well situated less than 200 m from the shoreline identified a tongue of seawater intrusion at a higher level than observed in the original hole drilled in 1975. These observations confirm that seawater is intruding, but that there has not been a significant change over the last 30 years.

Future pumping scenarios show groundwater discharge to the ocean from the Bunbury area decreases to 78% of the natural groundwater flow because of pumping for regional use. This reduces further to 60% of the natural flow with the Water Corporation preferred option (Scenario 3). These modelled reductions in groundwater flow would be attenuated by the increased recharge captured because of pumping, which would also reduce the inland movement of the seawater interface.

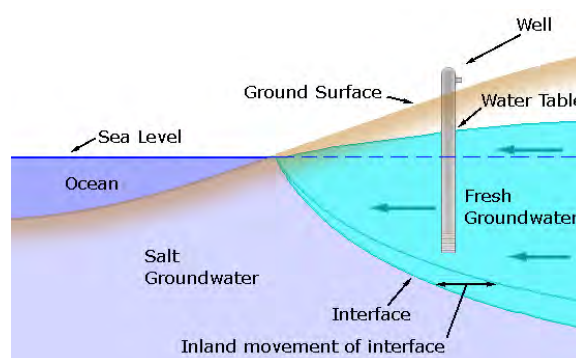
The implications are that these flow reductions will increase the potential exposure of wells within one kilometre of the coast to seawater intrusion effects. The movement of the seawater interface is expected to be extremely slow because of the significant amounts of fresh water in storage that would need to be removed to allow the intrusion to occur. The full movement is likely to occur some considerable time beyond 2033, as the full reduction in modelled groundwater flow would not occur until that time. This will allow considerable time to plan any required modifications to existing wells with potential to be affected. Monitoring of the interface is an essential element in providing for such planning. A monitoring network exists, but its capability may need to be reviewed to ensure its effectiveness as an early warning system is maximised.

Once seawater intrusion has started, in most aquifers the process is difficult to reverse in the short term.

4.13 POTENTIAL EFFECTS OF A DRYING CLIMATE

Climate change predictions for the south-west of Western Australia are generally uncertain, with the prognoses for future annual rainfalls falling in the range of 5% wetter to 20% drier (Section 2.6). The balance of opinion proposes a decline in rainfall.

Figure 5.55 Diagrammatic representation of freshwater–saltwater interface



The modelled predictions of abstraction drawdowns reported in Sections 4.1 and 4.2 are based on recharge values derived from 1971 – 2003 rainfalls. The average rainfall over this period is about 91% of the long-term historical average. This means that a 9% permanent reduction in recharge has already been assumed in the predictive modelling.

To study the potential drawdowns of extreme climate change, scenarios with a progressive 5% and 10% reduction in annual recharge over the period to 2033 were examined (Figure 5.56 and Figure 5.57).

The area of climatic impact extends across almost the entire Southern Perth Basin, as would be expected. The maximum effect from a progressive 5% reduction in recharge would be experienced in the central Blackwood Plateau, near the Yarragadee Formation outcrop area, and would include the Blackwood River valley, Poison Gully and Milyeannup Brook. Drawdowns in the centre of the plateau are interpreted to be as high as 1 – 2 m in the Poison Gully Area. On the coastal plains, drawdowns of up to 0.25 m extend across most of the area, with drawdowns of up to 0.5 m predicted over a small area on the eastern Scott Coastal Plain.

Under a progressive 10% reduction in recharge, the effects are amplified, with areas of the Scott Coastal Plain experiencing drawdown effects greater than 0.25 m, and substantial areas in the range 0.1 – 0.25 m. Drawdowns in the south-eastern corner of the Blackwood Plateau and eastern Scott Coastal Plain are indicated as being in the range 1 – 2 m.

Areas on the Swan Coastal Plain will experience drawdowns of up to 0.25 – 0.5 m, with large areas experiencing drawdowns in the range 0.1 – 0.25 m.

The predicted drawdowns on the coastal plains may be exaggerated because the model does not account for rejected recharge (Section 4.2). The extent to which the other limitations of the model and local hydrogeological conditions may modify these results is difficult to evaluate.

It is important to note that these drawdowns are predicted to occur without any abstraction, and the values are essentially additive to model predictions for all abstraction scenarios. The implications of future climate change and management responses are discussed in detail in Volume 1 Chapter 7 Section 2.1.6.

Figure 5.56 Interpreted 30-year watertable drawdown from 5% progressive reduction in recharge

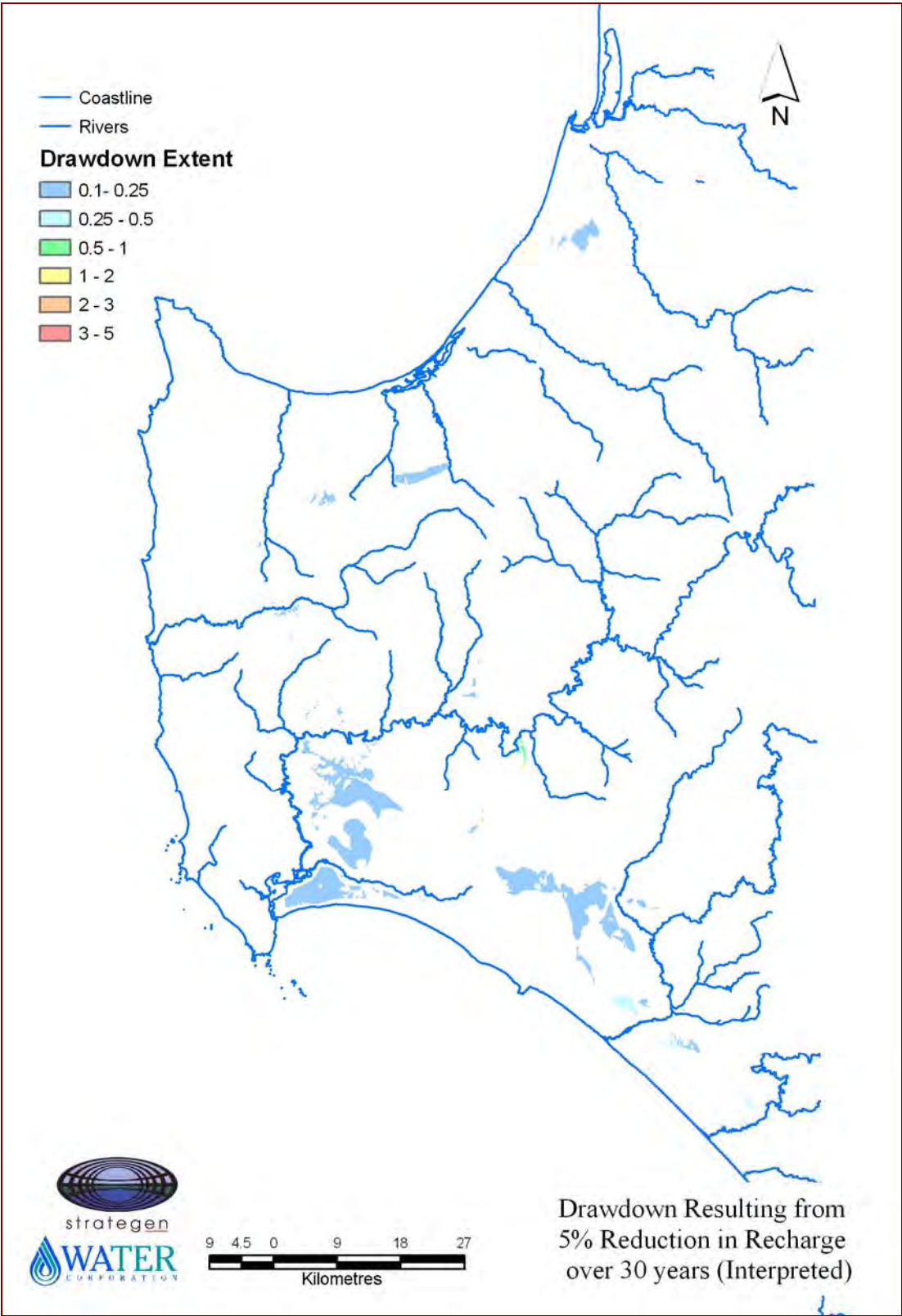
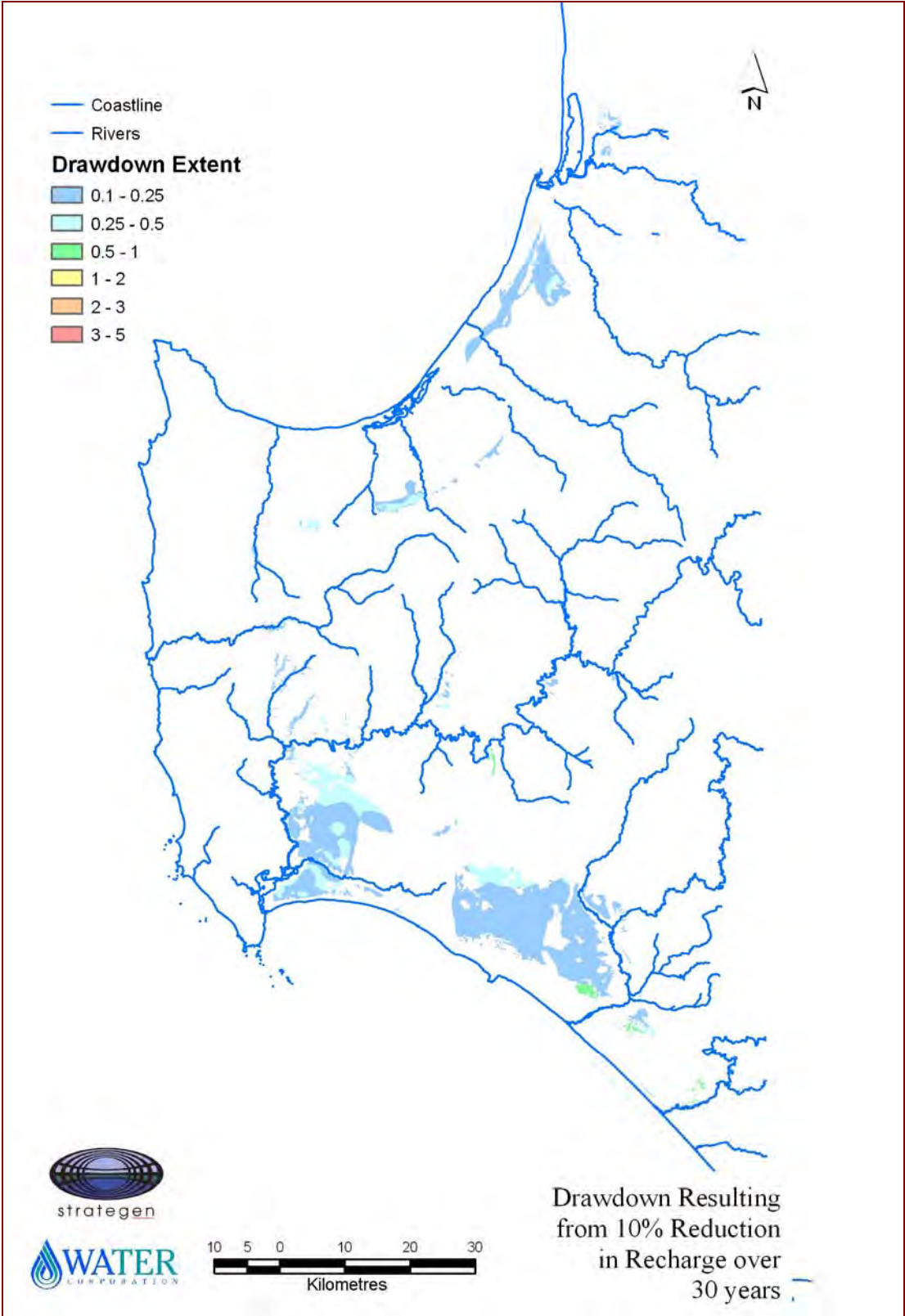


Figure 5.57 Interpreted 30-year watertable drawdown from 10% progressive reduction in recharge

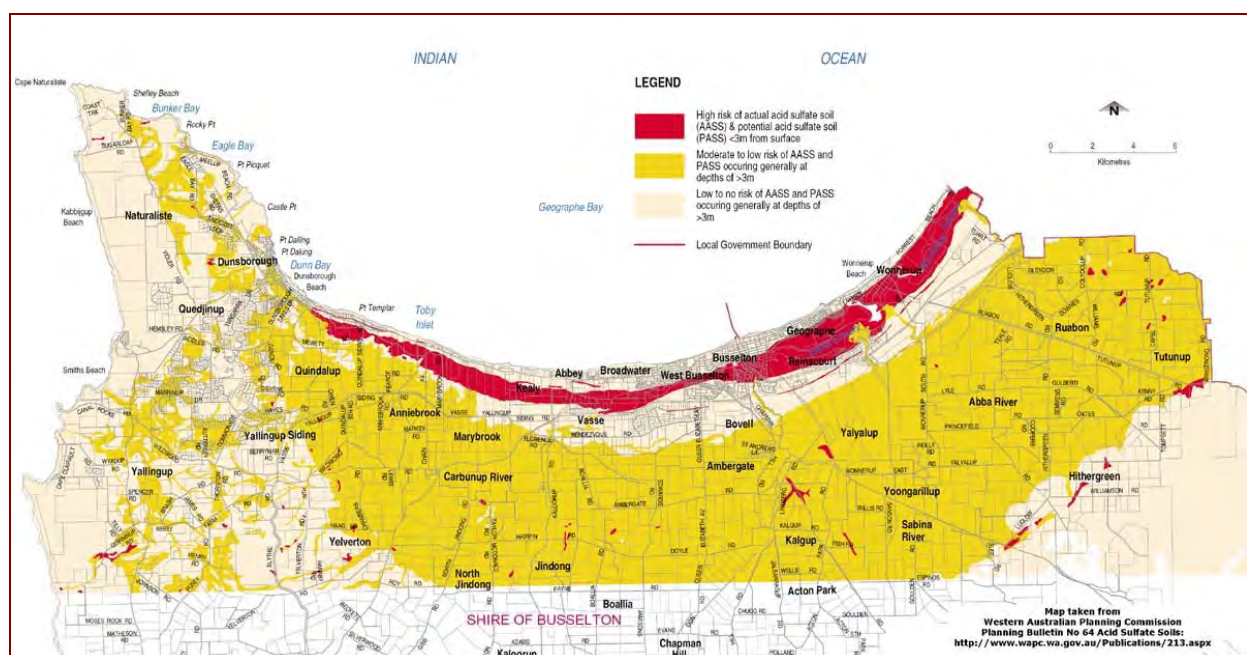


4.14 POTENTIAL FOR ACID SULPHATE SOIL IMPACTS

In Australia, the acid sulphate soils of most concern are those that formed following the last major sea level rise, in the Holocene geological period (the last 10 000 years). These soils are largely associated with estuarine, floodplain and wetland areas. This is considered particularly relevant for the south-west of the State, between Perth and Busselton and on the Scott Coastal Plain (WAPC 2003a).

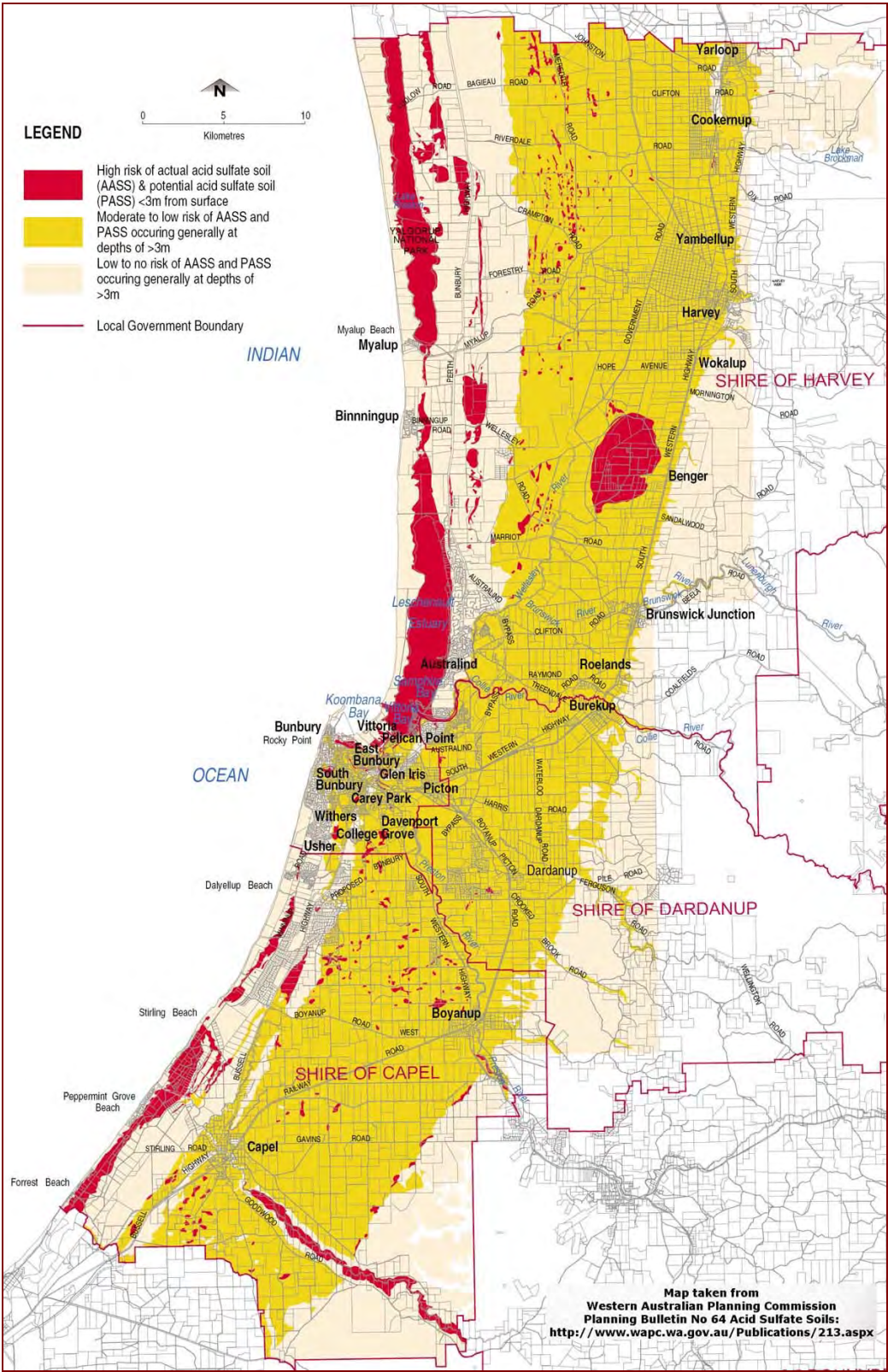
The DoE and Western Australian Planning Commission (WAPC) have produced preliminary maps that indicate acid sulphate soils risk areas on the Swan Coastal Plain (Figure 5.58 and Figure 5.59). Risk areas for the Scott Coastal Plain have not yet been mapped. These maps show there is a potential for acidification of shallow groundwater on the coastal plains if watertables are drawn down sufficiently to expose pyritic sediments that are now below the watertable. There is a moderate acid sulphate soil risk over most of the coastal plains, with the high risk areas tending to be concentrated along the coastal fringe. Small scattered high risk areas occur across the entire plain. A significant high risk area follows the Capel River valley above Capel.

Figure 5.58 Potential acid sulphate soil zones – Busselton region



Investigations strongly suggested the presence of acid sulphate soils within a few metres of the watertable in several areas in the east of the Scott Coastal Plain (Appleyard & Angeloni 2003). The eastern part of the Scott Coastal Plain, where superficial sediments are in direct contact with the Yarragadee aquifer, is potentially susceptible to acidification caused by increased groundwater abstraction for the proposal.

Figure 5.59 Potential acid sulphate soil zones – Bunbury region



4.14.1 Acid generation

The rate at which acid is generated from exposed acid sulphate soils is dependent on a number of factors, including:

- amount and type of sulphide material exposed, and the period for which it is exposed
- natural buffering capacity of the soil
- moisture content and oxygen levels
- rate at which oxidation products are removed
- soil temperature and pH
- presence and type of soil bacteria.

Amount of sulphide material

The unique properties of acid sulphate soils arise from their sulphide (reduced sulphur) content. The iron sulphides react with oxygen (oxidation) and water to form ferrous iron, acid and sulphate.

The maximum potential for acid sulphate soils to generate acid is determined by the oxidisable sulphide content. For example, in a situation where the full oxidation of a tonne of soil typically containing 0.03% sulphides occurs, approximately one kilogram of sulphuric acid would be generated by the reaction. To place this into perspective for a system with a seasonal groundwater level fluctuation of about 1.5 m, this amount of acid could change water with a pH of 4 to a pH of 3.1 to 3.2. Groundwater with a pH of 3 and below is substantially less affected by this volume of acid.

Soil buffer capacity

Not all acid produced by oxidation of sulphides becomes an environmental hazard. Acid generation from exposure of sulphides is a natural event and ecosystems are capable of living with a certain level of acid generation. The acid may be partially neutralised by other materials within the area, such as limestones and other carbonates: it may be buffered²⁸ by humic and fulvic acids in the soil, as well as by the kaolinite clays that are present: or it may be reduced²⁹ back to sulphides, but over a longer timeframe. The acid neutralising capacity of a soil can be readily determined in a laboratory.

Moisture content and oxygen levels

The oxidation of sulphides to form acid requires the presence of both water and oxygen, except at a pH of less than 4³⁰. In many types of sediment, there is a naturally high level of competition for oxygen, from plant roots, soil microbes and decay processes. The amounts of available water and oxygen can strongly influence the rate of acid production, and quantifying these parameters is an important aspect of hazard assessment (Ward et al. 2004).

²⁸ Buffering capacity refers to water's ability to keep the level of acidity or alkalinity (pH) stable as acids or bases are added.

²⁹ Reduction is the opposite process to oxidation.

³⁰ This is not always the case: at pH less than 4 (typically pH 3.5 – 3.8), the ferric iron may react directly with pyrite and generate acid, even in the absence of oxygen

The oxidation reaction may also consume water as fast as it becomes available. The likelihood of maximum potential acid generation will be limited if exposure of the sediments is for a relatively short period.

Role of soil bacteria

Consideration of bacterial behaviour is another important factor when assessing the processes of the oxidation of acid sulphate soils. Micro-organisms (most frequently bacteria) are often integrally involved in the chemical alteration of minerals. The availability of minerals, or intermediate products of their decomposition, may be directly or indirectly necessary to their metabolism. Where minerals are available as soluble trace elements, they serve as specific oxidising substrates³¹, or are electron donors or acceptors in oxidation–reduction reactions. They may be directly involved in cell metabolic activity.

With acid sulphate soils, oxidation of sulphides for energy production and subsequent generation of sulphuric acid is restricted to the bacterial genus *Thiobacillus*, the genus *Thiomicrospira*, and the genus *Sulfolobus*. These bacteria are known to accelerate the generation of acid from pyrite (up to 1 000 000 times) under suitable conditions. Although the optimal habitat pH for the major bacterial agent, *Thiobacillus ferrooxidans*, is a very low 1.5 – 3.5, the activities of other sulphide-reducing bacteria (such as *Thiobacillus thioparus*) may reduce the pH from near-neutral to this level. The activity of such bacteria is also temperature dependent, peaking at 30 – 35°C.

Unlike bacterial catalysed oxidation of acid sulphate soils, which can occur in both aerobic and anaerobic conditions, the direct reduction of sulphate ions to hydrogen sulphide by bacteria of the genera *Desulfovibrio* and *Desulfotomaculum* is strictly an anaerobic process. These sulphate-reducing bacteria (SRB) utilise sulphate, thiosulphate, sulphite or other reducible sulphur-containing ions in their respiratory metabolism. In the process, the sulphur-containing ions are reduced to hydrogen sulphide. The bacteria require an organic substrate which is usually a short chain acid such as lactic or pyruvic acid, generated by the activities of other anaerobic bacteria on more complex organic substrates.

In natural systems, the specific requirement by the SRB for an organic substrate is met by the availability of a complex organic source and a mixed bacterial system.

SRB activity in natural wetlands is capable of metal sulphide precipitation from acid sulphate soil oxidation, as a result of sulphate to hydrogen sulphide reduction. This concept is widely used in the treatment of acid mine drainage using constructed wetlands (USEPA 1994). Depending on the specific circumstances, this concept may support a potential management strategy if significant impacts of potential acid sulphate soils are encountered on the coastal plains.

4.14.2 Risk of acid sulphate soils

Release of acid and metals as a result of the disturbance of acid sulphate soils can potentially cause significant harm to the environment, and to infrastructure. In Western Australia the main impacts associated with acid sulphate soils (WAPC 2003b) have been:

- wetlands degradation
- localised reduction in habitat and biodiversity

³¹ In biochemistry, a substrate is a molecule which is acted upon by an enzyme. The substrate binds with the enzyme's active site and the enzyme catalyses a chemical reaction involving the substrate.

- deterioration of surface and groundwater quality
- loss of groundwater for irrigation
- increased health risks associated with arsenic and heavy metal contamination in surface and groundwater, and acid dust
- risk of long-term infrastructure damage through corrosion of sub-surface pipes and foundations by acid water.

An acid sulphate soils investigation conducted on the Scott Coastal Plain by the DoE in 2003 (Appleyard & Angeloni 2003) identified the existence of potential acid sulphate soils a few metres below the watertable. These soils would not become exposed to oxygen unless the watertable drew down those few metres. For many parts of the wider study area, other factors come into play, further reducing the likelihood of acid being generated at levels that exceed the ecosystem's ability to respond. These factors are described below.

4.14.3 Areas at reduced risk

Areas under agriculture

The hazard that the proposal presents to acid sulphate soils underneath agricultural lands is predicted to be negligible. Areas that are used for grazing, such as beef and dairy cattle, are subject to influences on the chemistry of the soil and underlying groundwater that would typically surpass any changes that may result from the proposed abstraction. Many of these areas are drained or irrigated, which will respectively lower or raise the underlying watertable. The watertable may have already risen as a result of clearing deep-rooted native vegetation prior to farming.

The addition of lime to combat naturally occurring soil acidity is a regular farming practice throughout the Scott and Swan Coastal Plains (AgWA 2003) and would provide additional buffering against changes in groundwater chemistry.

Areas with a perched watertable

The computer model used to predict the extent of drawdown of the watertable in the superficial formations presumes them to be a single layer of uniform hydrogeology. In certain areas, this is not the case³².

In areas of the Scott and Swan Coastal Plains where discrete geological layers such as coffee rock, basalt clay and marl exist within the profile of the superficial formations, two watertables might be present within the superficial formation, if the intervening layers are sufficiently impermeable (Rockwater 2004c at Appendix 15). Typically, the upper of these multiple aquifers is the one used by vegetation and intersected by watercourses. It is unusual for plant roots to survive permanent inundation, so the lower aquifer can be assumed to be essentially inaccessible to vegetation.

In situations where the superficial formations are discontinuous, the response of the upper aquifer to changes in piezometric heads in the underlying Yarragadee Formation is buffered (even isolated) by the impermeable layer. These areas are unlikely to observe the full extent of predicted watertable drawdown, if any at all, and the potential for acid generation as a consequence of the proposal would be very low.

³² This is consistent with the defined purpose of the model to predict watertable responses in a regional context.

Areas with high buffer capacity

Soils types containing large quantities of calcium carbonate, such as sand dunes, and others formed from limestone or shell fragments, are unlikely to contain acid sulphate soils (DoE 2004b).

Groundwater with high levels of tannin, such as peaty swamps and streams, are well-adjusted to successfully living with acidic influxes. The role of tannins and similar organic compounds as buffering agents is well documented (Banfield et al. 2000, Alexander 2000).

Elevated areas

According to DoE (2004b), elevated areas, such as high dunes and areas on the Blackwood Plateau or above the scarp represent a negligible acid risk. This is because the geologic conditions in these areas are not conducive to the formation of potential acid sulphate soils.

4.14.4 Acidity of the Scott River and tributaries

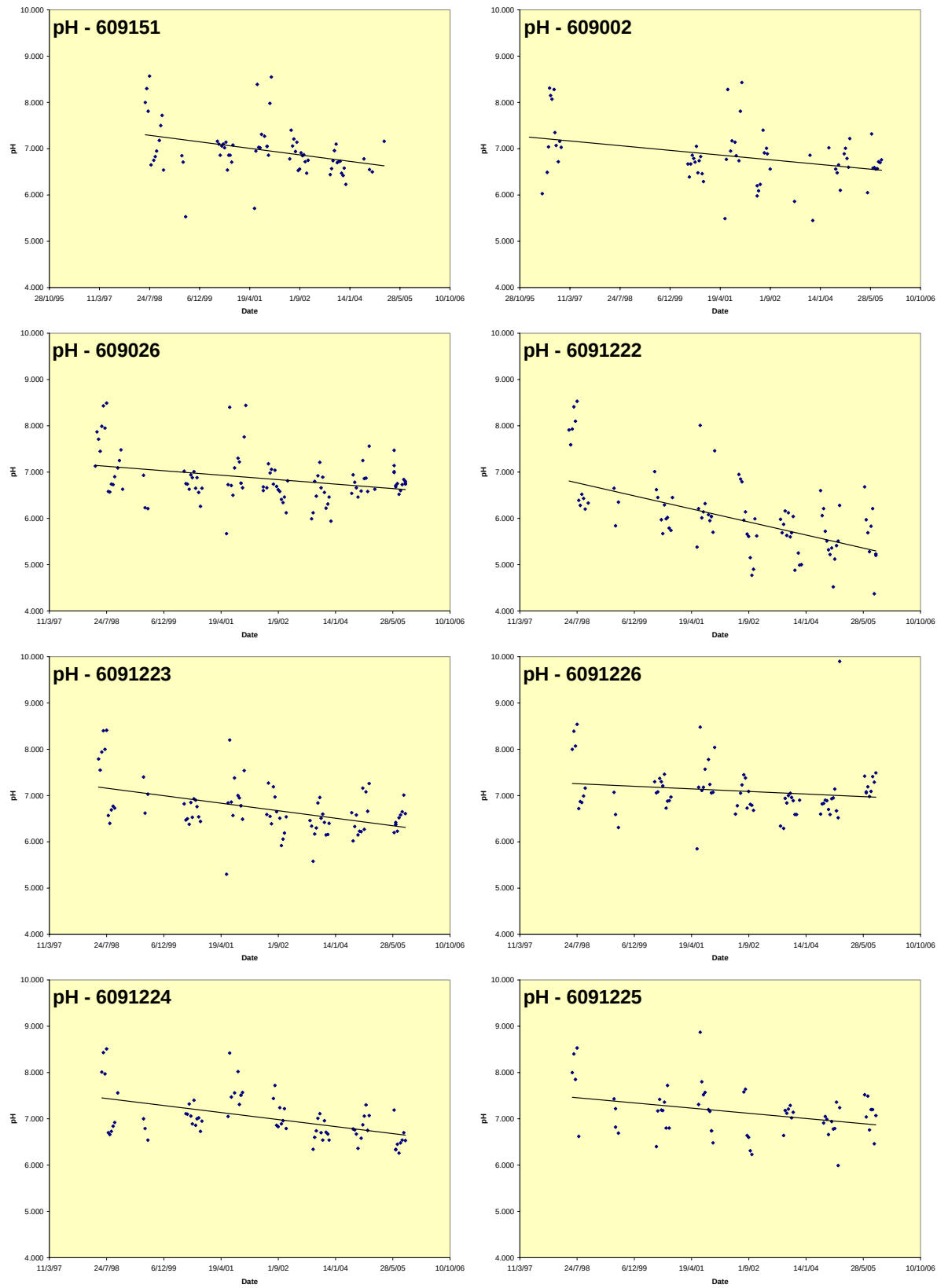
Water quality data from monitoring sites on the Scott River and its tributaries, provided by the DoE, have been analysed to examine trends in pH. The station locations are shown in Figure 5.60. The data shows significant variability, with several interesting trends. Only two of the stations (609151 and 609002) have data taken prior to 1996.

Figure 5.60 Scott River and tributaries water quality monitoring sites



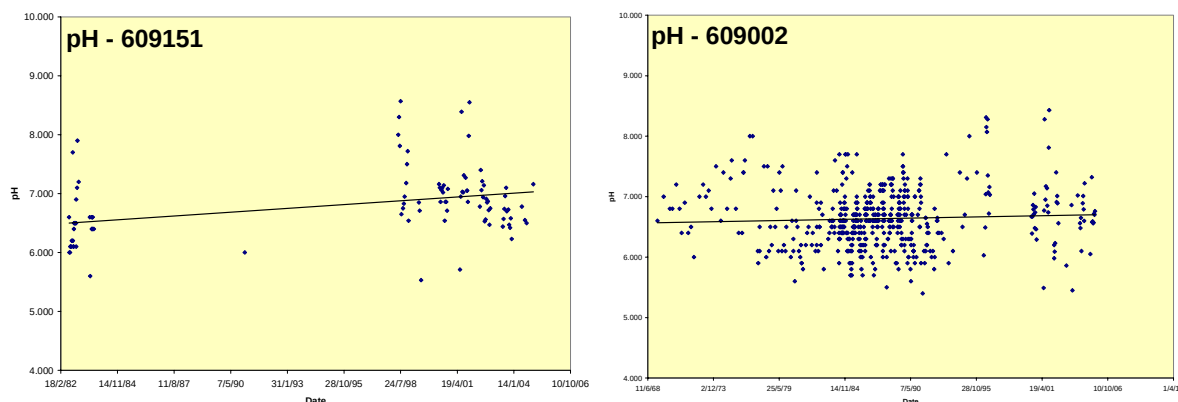
Figure 5.61 presents the pH data obtained from all eight stations since 1995. These plots show substantial variability, but with a generally declining trend since 1995, the steepest trend being associated with Station 6091222 (Scott River Tributary at Four Acres Road, the station furthest upstream). Colour data shows this tributary to be the most highly coloured in the catchment. The staining is believed to be due to naturally occurring humic and fluvic acids, which suggests the tributary should have acidic rather than alkaline pH levels. Land use in this catchment is agricultural grazing and there is still considerable native vegetation cover. The limited colour data available shows a rising trend over the period 1996 – 1998, which may be contributing to the rising pH in this tributary. No post-1998 colour data is available.

Figure 5.61 1995 – 2005 pH data – Scott River and tributaries



While the rising acidity since 1995 may raise some concerns, the longer term data that is available for stations 609151 and 609002 show a trend of falling acidity (Figure 5.62) in the main stream of Scott River. This data suggests that the pH in the catchment varies considerably under natural conditions, and that the declining trend and low pH values being observed over the past ten years are within the range of natural variation.

Figure 5.62 Long-term pH data – Scott River and tributaries



Low rainfalls in recent years, together with land drainage and groundwater abstraction associated with agricultural activities, could be expected to contribute to a lowering of watertables and generation of acid runoff to the river systems. However, the trends in surface water acidity do not show a marked response to these influences and indicate that the system has a reasonable level of resilience in terms of progressive small-scale lowering of the watertable.

Europeans first moved into the Scott River area in the 1860s and developed coastal cattle runs. More permanent European settlement arrived in the 1920s with the Group Settlement program in the west of the area, and when land was occupied around Milyeannup in the east. There was further major development when a number of blocks were cleared in the 1960s. The land was used mainly for dairy in the west and grazing in the east. In the 1990s, dairying spread eastward, substantial blue gum plantations were introduced, and groundwater based irrigation commenced (AgWA 2001). While clearing would have resulted in increased groundwater recharge, drainage systems were progressively developed to ensure productivity of the land, much of which was characterised by shallow depth to watertable.

There is no data available to evaluate the long-term changes in watertable levels in the region. However, since European settlement the progressive development of drainage and groundwater abstraction systems, together with the introduction of blue gum plantations, would be expected to lower the watertable. If this is so, it does not appear to have caused any substantial increase in the acidity of the surface runoff through activation of acid sulphate soils.

4.14.5 Effect of anticipated groundwater drawdown

Scott Coastal Plain

On the Scott Coastal Plain, the area of modelled drawdown is to the east of the Scott River, and over most of the plain is expected to be less than 0.25 m over 30 years. Natural water level variations in the area are in the range of 1 – 3 m annually.

Given the expected full recovery of coastal plain watertable levels each year, and the long period over which declines will occur, the effect of acid sulphate soils is expected to be minimal as exposure of the sediments will only be for short periods. There will also be competition for oxygen from plant roots, soil microbes and decay processes, which will influence the rate of acid production. These will reduce the likelihood of maximum potential acid generation being realised.

There are also understood to be significant areas of the coastal plain where the watertable is perched, and disconnected from the impact of drawdown as result of abstraction from the Yarragadee and Leederville aquifers. No changes to watertables are expected in these areas as a consequence of groundwater pumping.

Drawdowns induced by the proposal over the Scott Coastal Plain are expected to be experienced mainly in the northern part of the eastern Scott Coastal Plain. The extent to which these drawdowns are likely to result in acid generation is not clear, but it is likely to be minimal compared to the potential from other future local abstractions. Agricultural activities over much of the area have the potential to ameliorate the impacts of acidification through the normal application of lime (Section 4.14.3) and the annual full winter watertable recovery will assist in limiting acid generation. The soils have a high organic content, which provides some buffering effect (Section 4.14.3).

Overall, the risk of significant acid generation on the Scott Coastal Plain is considered to be low. However, the proposal recognises a need to ensure that the understanding of the distribution of acid sulphate soils relative to anticipated drawdowns is both comprehensive and correct.

Swan Coastal Plain

The interpreted model results indicate that the proposed Water Corporation abstraction will generate watertable drawdowns on the coastal plains (Figure 5.29 and Figure 5.31). However, the affected areas do not coincide with those designated as being high risk for acid sulphate soils on the Swan Coastal Plain (Figure 5.58 and Figure 5.59).

There is some potential in areas of moderate risk: however; in these areas drawdowns are generally expected to be less than 0.25 m after 30 years pumping. An exception is in an area approximately 10 km south of Bunbury where drawdowns up to 0.5 m may be experienced after 30 years. Given the expectation of full recovery of coastal plain watertable levels each year, the effects of exposure of any existing acid sulphate soils are expected to be minimal and temporary.

Monitoring and potential management contingencies

Although the risk of exposure of acid sulphate soils because of drawdown in the superficial formations from the proposal is considered very low, a monitoring and investigation program will be put in place to adaptively manage the abstraction.

The program will identify areas where acidity may potentially be generated. The parameters to be monitored would include pH, metals such as arsenic, iron and aluminium, and the sulphate: chloride ratio, which is an early-warning indicator of acid sulphate soils being oxidised.

If monitoring indicates that proposal-induced drawdowns are contributing to the generation of acid that is causing any substantial economic or material environmental harm, the Water Corporation has committed to modify its abstraction regime to address the issue, if other management techniques cannot provide adequate control.

Further research into the distribution of acid sulphate soils, both in terms of area and location within the soil profile, will be supported by the Water Corporation, based on advice from the DoW and other stakeholders, such as the WA Acid Sulphate Soils Advisory Committee. The Water Corporation commits to developing and supporting a research project into the palaeo-hydrology and palaeo-climate of the region to assist in understanding the historical occurrence of acid generation in the susceptible areas of the coastal plain. Research into the potential environmental and economic impacts, and potential management strategies will also be strongly supported by the Water Corporation.

5 PEER REVIEW OF GROUNDWATER MODELLING

The conceptual groundwater model, the numerical computer model, and the modelling results were peer reviewed by a panel of independent expert hydrogeologists, who provided a report on their review (Peer Review Panel 2005). The panel comprised:

Paul Whincup	Chairman
Phil Wharton	Member
Richard Martin	Member

The panel was appointed in August 2005 by the Water Corporation. The review utilised data available to the end of August 2005 and has reviewed the SWAMS v2.0 model version.

The same panel had been appointed by the DoE in June 2003 to review an earlier version of SWAMS (v1.2.1) which utilised information available up to August 2004. The report on SWAMS v 1.2.1 was presented to DoE in December 2004 (DoE 2004a). In that report the panel identified deficiencies in the model and further work considered necessary to clarify some uncertainties identified in both the conceptual and numerical models, and to enhance their validity.

5.1 PEER REVIEW PANEL REPORT

The Peer Review Panel (2005) reported that the recommendations for SWAMS v1.2.1 have been implemented and expanded. The panel noted the effort in updating allocation data in terms of aquifer identification and actual abstraction, the review of monitoring data, the refining and updating of the distribution of hydrogeological units, and further investigative drilling in the St John Brook area. The panel acknowledged the modifications of the SWAMS v1.2.1 model incorporated into v2.0, including:

- modification of geology, layering, faults and boundary conditions
- use of environmental heads
- use of a software package to represent all major rivers
- revised zoning of aquifer and recharge parameters
- new time series scaling factors for abstraction and recharge
- introduction of horizontal anisotropy
- representation of evapotranspiration on the coastal plains.

The panel commented:

“The updated SWAMS v 2.0 is therefore a considerable enhancement of SWAMS v1.2.1.

The Panel believes that the investigative work and inputs to the conceptual hydrogeological model particularly in relation to the Yarragadee aquifer (Juy) are of a high standard. The overlying Leederville aquifer, low permeability units between the Leederville and Yarragadee aquifers and adjacent aquifers to the west are more complex than the Yarragadee aquifer itself and are therefore difficult to adequately represent within the conceptual model and by inference into the numerical model.

In general the Panel concludes that the generalities incorporated into the model have built an element of conservatism into SWAMS v2.0.”

The conservatism of the model was acknowledged by the panel as being a result of:

- not accounting for leakage from the clayey sediments in the Leederville Formation overlying the Yarragadee Formation aquifer when groundwater heads reduce during abstraction
- not accounting for the contribution from rejected recharge in high watertable regions of the Swan and Scott Coastal Plains
- not accounting for increasing recharge from recycled irrigation waters on the Swan and Scott Coastal Plains.

The panel commented on the comparison of modelled and observed annual drainages for the Blackwood, Donnelly and Scott Rivers, and the Swan Coastal Plain, and noted that the model indicated much higher drainage than observed in the Donnelly River and in the Blackwood River between Nannup and Hut Pool. The panel noted that flow comparisons for the Blackwood River in the Yarragadee outcrop area, and for the Scott River, showed close agreement between modelled and observed readings, but those for the Swan Coastal Plain did not match. The panel remarked that the disparities for the Blackwood and Donnelly Rivers need further explanation. Since the review panel report was received, this issue has been investigated and an explanation has been provided (Section 3.1.3).

The panel reviewed the model validation based on comparing simulated water flow paths in Yarragadee Formation Unit 3 and the observed Carbon 14 age dating, and commented that the validation exercise provides a realistic confirmation of the use of the model in a broad regional context.

5.1.1 Peer Review Panel conclusions

The Panel concluded that the accuracy of the present calibration is adequate to assess changes in water level under different abstraction and recharge scenarios on a regional scale and is, therefore, a useful management tool for future allocation of licensed abstractions. The panel also commented:

“The Panel concludes that the level of complexity of the aquifer distribution is not yet fully understood and the aquifer parameters for horizontal and vertical permeability are based on sparse data points particularly over the major part of the study area beneath the Blackwood Plateau where private large-scale groundwater abstraction is restricted. This limits the use of the model in defining drawdowns to the more accurate level normally required for assessing absolute impacts to groundwater dependent ecosystems, environmental water flows and other environmentally sensitive areas.

The Panel considers that the probability of substantial leakage to the producing aquifers from adjacent clayey formations, the contribution from rejected recharge in high water table regions of the Swan and Scott Coastal Plains, and the increasing recharge from recycled irrigation waters on the Swan and Scott Coastal Plains all serve to produce a degree of conservatism in the model output. In effect the Panel considers that under average rainfall conditions actual drawdowns will be less than projected.

Taking these factors into consideration the Panel believes that the sustainability of the aquifer in terms of groundwater resources and availability relies on more than solely recharge from rainfall in the outcrop areas.

The Panel considers that SWAMS v 2.0 has been developed to a stage where it can be used with some degree of confidence to evaluate the risks associated with growth in regional groundwater demand and alternative Water Corporation borefield scenarios. Its use should be as a Risk Management Tool whereby potential impacts are predicted, the consequent risks evaluated and where risks are considered untenable, either alternative scenarios are developed or risk monitoring and management procedures are put in place.

The Panel notes that the model has already been used to relocate the proposed Western Borefield to the east-northeast in order to reduce potential impacts to the Blackwood River and Reedia Wetlands. The model has also been used to assess impacts associated with the proposed Eastern Split Borefield in order to minimise drawdowns to existing and future users on the Swan Coastal Plain and potential impact to sensitive environmental areas on the Blackwood Plateau.

The Panel believes that SWAMS 2.0 is a suitable tool for evaluating borefield layout and for development of a local model which in turn can be used to optimise bore abstraction rates and pumping water levels.”

In discussing the suitability of the model for predicting the general drawdown in water levels near other groundwater users, wetlands, and rivers and streams in the project area, and in providing for seasonal variations in such reductions, the Panel commented:

“Model v. 2.0 is unsuitable for determining groundwater-level changes to the accuracy required for determining the impacts of abstraction on groundwater-dependent ecosystems (GDEs). The model can be used to show areas that could be at risk, so that further interpretation can be made and means of overcoming any impacts can be designed.”

This was clearly understood in applying the raw model results to consideration of groundwater drawdown impacts on GDEs as discussed in Section 4. The model limitations were accounted for in interpretation of the raw modelling results for each the potential risk areas, as described in Section 4.2.

5.1.2 Peer Review Panel recommendations

The Panel made a number of suggestions and recommendations:

1. That at the appropriate time a more rigorous evaluation of the Eastern Split Borefield scenario be undertaken using a local and more detailed model based on SWAMS v2.0.
2. That the conceptual hydrogeological model for the Leederville Formation could be simplified into fewer layers (similarly for Yarragadee Formation Units 1, 2, 3 and 4).
3. That the conceptual model within SWAMS v2.0 be updated as more hydrogeological data becomes available from geological mapping and investigative drilling. Similarly, the numerical model should be updated as longer term monitoring of abstraction and water level changes becomes available.
4. That other improvements will result from the elimination of dry cells in the model, simulation of evapotranspiration on the Blackwood Plateau, and incorporation of the impact of flooding and irrigation water returns on the coastal plains.

5. That the very large reserves of stored groundwater need to be assessed in terms of their potential contribution in the event of substantial reductions in long-term rainfall.
6. That SWAMS v2.0 be used to evaluate the impact of reduced long-term rainfalls on water levels and river discharge under existing and projected abstraction scenarios.

Chapter 6 Environmental overview and general responses to watertable drawdown

1 POTENTIALLY AFFECTED AREAS

The results of the groundwater investigations and modelling discussed in Chapter 5 indicated that environmental impacts may occur in several areas as a consequence of the drawdowns generated by the proposal. The potentially affected areas are those with a shallow watertable, and where drawdowns in the Yarragadee Formation would transmit to the surface aquifers and the watertable. These areas are:

- Blackwood River
- Poison Gully and Milyeannup Brook
- Rosa Brook
- St John Brook
- eastern Scott Coastal Plain
- eastern Swan Coastal Plain.

This Chapter provides an environmental overview of these areas and the predicted responses to watertable drawdown.

The Reedia Wetlands is an area where regional groundwater use may impact on a significant ecological system, and it is also discussed. No impact on these wetlands is expected as a result of the Water Corporation proposal. Regional groundwater use may also impact the western Scott Coastal Plain.

2 RELEVANT INVESTIGATIONS

In addition to the hydrological investigations, the following investigations were commissioned by the Water Corporation to investigate the environmental values of the potentially affected areas and their likely groundwater dependence:

1. CENRM (2005a) at Appendix 27 investigated the ecological values of the Blackwood River system and provided an increased understanding of the ecological susceptibility of those values to changes in water regime (both quality and quantity). Nineteen sites were surveyed on the main stem of the Blackwood River. The investigations included fish species, aquatic macroinvertebrates, channel morphology, water quality and a vegetation and foreshore assessment.
2. Morgan et al. (2004) conducted a fauna survey of Rosa Brook, Layman Brook and Adelaide Creek as part of an assessment of groundwater discharge to Rosa Brook from an aquifer test well.
3. Mattiske (2005a) at Appendix 31 evaluated the flora and vegetation values, in winter and spring 2004, at five cross-sectional transects along the main stem of the Blackwood River between Darradup and Hut Pool.

4. Mattiske (2005b) at Appendix 32 evaluated the susceptibility of the flora and vegetation values to groundwater drawdown in the potentially affected areas.
5. Mattiske (2004) conducted a review of the flora and vegetation at two sites on St John Brook.
6. Bamford (2003) at Appendix 28 assessed the fauna species that are likely to live in the areas of potential impact, and assessed their likely groundwater dependence.
7. Bamford (2005) at Appendix 29 undertook a desktop review of the potential impacts of the predicted drawdowns on terrestrial fauna.

The views expressed in these reports are based on the best information available at the time of their publication. In some cases, views expressed were made without full and up to date information on the likely hydrological changes resulting from the proposal.

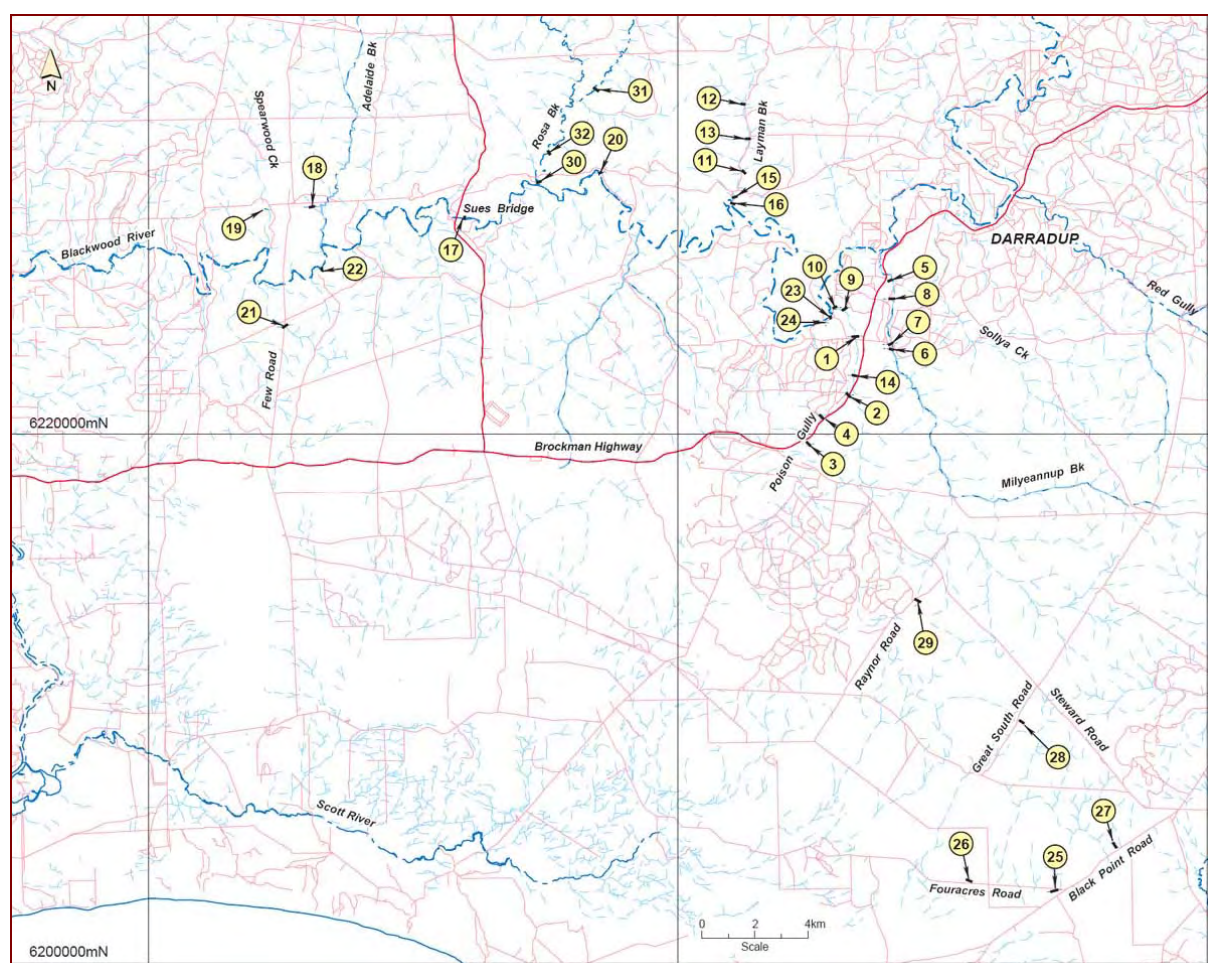
3 VEGETATION AND FLORA

This section describes the vegetation and flora of the Blackwood Plateau, Scott Coastal Plain and Swan Coastal Plain, and provides background to the environmental factors of *Rare and priority flora*, *Threatened ecological communities* and *Other groundwater dependent ecosystems*.

Further detailed discussion of the specific vegetation and flora values, impacts, and management in each of the areas potentially affected by drawdown is provided in Chapter 7.

3.1 VEGETATION

Mattiske (Appendix 31) conducted vegetation surveys in the areas initially identified as potential groundwater drawdown areas (now substantially reduced following further investigation) or areas of high conservation significance (Figure 6.1). The variability of soils, soil moisture availability, and landform was reflected in the diversity of species found in the surveyed areas. A total of 616 vascular plant taxa, from 68 plant families and 232 genera, were recorded from 32 transects. This represents approximately one-fifth of the total number of taxa that occur in the south-west of Western Australia. A total of 21 introduced species were recorded, these were generally small annual species.

Figure 6.1 Vegetation study areas

The variability in the structural formations of the vegetation in the area was large. In general it was found that there was a continuum from the seasonally wet valley floors, where sedges dominate, through closed heaths, low woodlands of paperbarks, to a mixture of forests and woodlands on the sandy to gravelly soils that occur on the drier slopes of the valley systems. Site-vegetation types within the study areas are listed in Table 6.1.

Table 6.1 Summary of site- vegetation types defined for the valley systems

Site-vegetation types ¹	Layman Brook	Poison Gully	Milyeannup Brook	Blackwood River	Rosa Brook	Reedia Wetlands	Scott Coastal Plain	Pig Swamp
S1	X	X	X	X	X	X		X
S2	X	X	X	X	X	X		X
S3							X	
A1		X						
A2		X						X
A3		X						
A4		X						
A5					X	X		

Site-vegetation types ¹	Layman Brook	Poison Gully	Milyeannup Brook	Blackwood River	Rosa Brook	Reedia Wetlands	Scott Coastal Plain	Pig Swamp
A6							X	
A7							X	
B1		X						
D1	X		X					X
D3	X	X						
D4					X	X		
J1							X	
C1	X	X	X					
C4	X	X	X					
C5	X	X	X	X				
C6					X	X		
W1	X		X					X
T1	X	X	X	X				X
Q1	X	X	X	X				
No. of types only found in valley	0	4	0	0	0	0	4	0
Totals	10	13	9	5	5	5	4	6

¹ Site vegetation types described in full in Mattiske (2005a)

Poison Gully

Poison Gully has highly variable vegetation due to the range of landforms, soils and moisture conditions present in the valley system. Sedgelands occur in the upper reaches on clay soils that support seasonally perched water. The valley contains a range of closed heath and low woodlands on leached white sands that are seasonally moist.

The narrow lower valley floor near the Blackwood River has vegetation that is more similar in composition to the other nearby tributaries, with narrow linear communities near the creek lines.

Milyeannup, Layman and Rosa Brooks

These tributaries are similar in the degree of dissection, soil types and local site conditions, and were found to have similar vegetation. They are distinct from Poison Gully as they are more dissected and do not have extensive flats and swamps in the lower reaches. The vegetation is less variable due to the steeper slopes and less variable soil types.

The vegetation is dominated by forests and woodlands of Jarrah (*Eucalyptus marginata* subsp. *marginata*), Sheoak (*Allocasuarina fraseriana*) and Marri (*Corymbia calophylla*) with Peppermint (*Agonis flexuosa*) and dense undergrowth.

Blackwood River

The vegetation along the area where Yarragadee groundwater discharges into the Blackwood River is dominated by forests of *Eucalyptus rudis* and *Agonis flexuosa* with denser patches of *Melaleuca raphiophylla* adjacent to the river. The understorey varies in quality, as large sections have been subjected to human activities and the number of introduced species can be high in some areas.

Reedia Wetlands

The flora and vegetation within the broad valleys supporting the Priority 4³³ *Reedia spathacea* communities are distinct from other swamp vegetation in the area due to the wet clay-loam soils that create specific site conditions. Both heath and sedge communities exist in the swamps, depending on site conditions and possibly fire regimes.

Scott Coastal Plain

The flora and vegetation of the Scott Coastal Plain are highly diverse and include a significant range of Declared Rare and Priority species. The range of species is restricted to this area and typically confined to very narrow niches within the local environment. Large areas of the Scott Coastal Plain have been cleared for agriculture.

Swan Coastal Plain

The Swan Coastal Plain has been extensively cleared and drained for agriculture. Consequently there are many rare and endangered species and communities growing in isolated remnant pockets or strips (road verges) of native vegetation.

3.1.1 Relative vegetation diversity

Table 6.1 shows the similarities and differences between the valley systems, as determined by Mattiske (Appendix 31). Both Layman Brook and Poison Gully were found to have a high diversity of site-vegetation types. Ten were identified in Layman Brook and 13 in Poison Gully. There were also site-vegetation types that were found only in Poison Gully (4) and Scott Coastal Plain (4), whereas all other types were found in several areas. This indicates that the mosaic of vegetation types in Poison Gully and on the Scott Coastal Plain are diverse and unique.

This analysis is not comprehensive as only selected areas were surveyed but it does provide an indication of relative diversity.

3.2 THREATENED ECOLOGICAL COMMUNITIES

The area of the Swan Coastal Plain included in the regional study has ten threatened ecological communities (TEC). These include shrublands on the clay pans, and specific communities of *Eucalyptus calophylla*. Few of these areas remain, as there has been extensive clearing for agriculture.

³³ CALM has lists of Priority species and communities that are not protected under State or Federal Acts but are recognised as significant (Chapter 10 Section 3.6).

The *Reedia* Wetlands, on the Spearwood and Adelaide Brooks is the only TEC listed for the Blackwood Plateau. The community is geographically restricted, and nationally and regionally significant as a result of the presence of the critically endangered *Geocrinia* frog species, the Priority *Reedia spathacea* (Priority 4) species, and the proposed Threatened Ecological Community (Priority 1).

Two TECs are known on the Scott Coastal Plain. The Augusta microbial community includes the “rimstone pools and cave structures formed by microbial activity on marine shorelines” (URS Australia 2004a at Appendix 25). The second is the Scott River Ironstone Association.

3.3 DECLARED RARE AND PRIORITY FLORA

One Declared Rare Flora species was recorded in the vegetation survey by Matiske (Appendix 31). *Daviesia elongata* subsp. *elongata* is gazetted under the *Wildlife Conservation Act 1950* (Wildlife Act) and listed as a Vulnerable species pursuant to s179 of the Commonwealth *Environmental Protection and Biodiversity Act 1999* (EPBC Act). The species was found in one Poison Gully transect on the lower slopes in seasonally moist rather than wet soils.

No other Declared Rare Flora species were recorded by Matiske (Appendix 31) even though more may exist. The fourteen Priority species (eight Priority 3 and six Priority 4) recorded by Matiske (Appendix 31) are shown in Table 6.2.

Table 6.2 Priority species identified in the vegetation surveys

Priority species	Priority	Layman Brook	Poison Gully	Milyeannup Brook	Blackwood River	Rosa Brook	Reedia swamps	Scott Coastal Plain	Pig Swamp
<i>Amperea protensa</i>	3		X				X		
<i>Astartea</i> sp. Scott River (D. Backshall 88233)	4							X	
<i>Boronia crenulata</i> var. <i>angustifolia</i>	4			X					
<i>Conospermum paniculatum</i>	3	X				X		X	
<i>Cyathochaeta stipoides</i>	3		X						
<i>Cyathochaeta teretifolia</i>	3		X	X			X		X
<i>Gonocarpus pusillus</i>	3		X					X	
<i>Meeboldina crassipes</i>	3							X	
<i>Meeboldina thysanantha</i>	3		X	X					
<i>Melaleuca basicephala</i>	4							X	
<i>Reedia spathacea</i>	4						X		
<i>Stylidium barleei</i>	3	X	X		X	X	X	X	
<i>Stylidium</i> aff. <i>ireneae</i>	4							X	
<i>Tyrbastes glaucescens</i> (ms)	4	X	X	X			X		
Total		3	7	4	1	2	5	7	1

The highest numbers of Priority species were found in Poison Gully, and on the Scott Coastal Plain, which is consistent with the high biodiversity of these areas.

3.4 VEGETATION REPRESENTATION

Most of the vegetation complexes³⁴ in the areas surveyed have greater than 30% of their pre-European extent remaining, and are well-represented in the conservation estate. More than 10% of the pre-European extent is represented within the formal and informal reserve systems. The only vegetation complexes that are less than 10% in formal reserves are Layman (LY – 4.76%) and Scott (Sw and Swi – both 0%). Vegetation representation in each potential impact area is detailed in Chapter 7.

The vegetation communities not well represented in the regional context, were the Reedia wetlands, the mosaic of swamp communities in Poison Gully, Pig Swamp and the Scott Coastal Plain.

3.5 POTENTIAL RESPONSE OF VEGETATION AND FLORA TO GROUNDWATER DRAWDOWN

The potential impact on vegetation and flora (other than from clearing for infrastructure) from the proposal is changes to vegetation composition in the areas where there is a risk of substantial drawdown of the watertable that affects access by vegetation to water.

Substantial changes in vegetation composition will only occur if (Naumberg et al. 2005):

- the rate of drawdown is greater than the potential root growth rate
- the extent of drawdown is greater than the maximum potential rooting depth
- there is a large change in groundwater levels.

Therefore, both the extent and the rate of change are important in determining the likely response of the vegetation to the groundwater drawdown.

3.5.1 Depth to groundwater, and rate and extent of drawdown

The most important parameter in determining the groundwater dependence of an ecosystem is the depth to the watertable (Froend & Loomes 2005 at Appendix 30). If groundwater is close to the surface, it is likely that the ecosystem is highly dependent. When the depth to groundwater is greater than 10 m the dependence of the ecosystem on groundwater is likely to be negligible (Appendix 30). The depth to groundwater risk categories used in this evaluation are based on Froend & Loomes (Appendix 30). They are:

- 0 – 3 m (shallow)
- 3 – 6 m (moderately shallow)
- 6 – 10 m (moderately deep).

³⁴ Vegetation complexes are a level of classification that generally represents a mosaic of certain site-vegetation types, which are each not necessarily restricted to one complex or another. The discriminating factors between vegetation complexes are differences in underlying site and climatic conditions which result in consistent patterns in either structure or floristics in the vegetation.

The historical changes in water levels are also important as they reflect the previous stresses that have been placed on the ecosystem.

Froend & Loomes (2004) developed possible responses of vegetation to groundwater drawdown (Table 6.3 for wetland vegetation communities and Table 6.4 for phreatophytic vegetation communities) based on three parameters:

- depth to the watertable
- extent of groundwater drawdown (watertable change)
- rate of drawdown (watertable level change).

3.5.2 Dependence on soil and other site characteristics

The possible levels of response are based on phreatophytic vegetation studies on the Gngangara Mound over the last ten years (Froend et al. 2002).

It is important to note that the soils within the areas of potential groundwater drawdown generally have a much higher moisture retaining capacity than the soils on the Gngangara Mound. Therefore, the extent and rate of the responses described in Table 6.3 and Table 6.4 can be considered conservative.

For this Sustainability Evaluation/ERMP, the levels of response developed by Froend et al. (2002) were used as an initial screening for assessment of potential impact. More detailed examination at the local level was then conducted to determine the risk to vegetation including:

- likely soil condition (moisture retention and storage)
- floristic composition of the vegetation community
- groundwater dependence of keystone species in the vegetation community.

Potential impacts and their mitigation are discussed for each area of groundwater drawdown in (Chapter 7) and in relation to the proposed infrastructure in (Chapter 8).

Table 6.3 Possible response of key elements of wetland vegetation communities to drawdown

Key elements	Level and type of possible response to drawdown			
	Low (no measurable change)	Moderate (small change)	High (moderate change)	Severe (large change)
Ecosystem processes				
Primary production	Rates of primary production are maintained within the limits of natural variation	Some evidence of reduction in rates of primary production in response to drying	Measurable reductions in rates of primary production in response to drying	Severe reductions in rates of primary production in response to drying
Nutrient recycling	Rates of nutrient recycling are maintained within the limits of natural variation	Some evidence of reduction in rates of nutrient recycling in response to drying	Measurable reductions in rates of nutrient recycling in response to drying	Severe reductions in rates of nutrient recycling in response to drying
Food chains	No measurable change in food chains	Some evidence of disruption to food chains	Measurable disruptions to food chains	Severe disruptions to food chains
Sediment stabilisation	No measurable change in sediment stabilisation	No detectable change in sediment stabilisation	Some evidence of sediment destabilisation	Measurable destabilisation of wetland sediments
Pollutant filtration	No measurable change in rates of pollutant filtration	No detectable change in rates of pollutant filtration	Some evidence of change in rates of pollutant filtration	Measurable reductions in rates of pollutant filtration
Biodiversity				
Species composition	No measurable change in species composition	Some evidence of establishment of exotic species as result of disturbance and/or drying	Measurable encroachment of xeric species into wetland	Significant change in dominant populations with terrestrialisation through encroachment of xeric species
Species distribution	No measurable change in distribution of species	Some evidence of changing distribution with disturbance and/or drying allowing establishment of exotic species	Measurable contraction of wetland through changing demographics of more than one species, with encroachment of xeric species into the wetland	Greater than 50% reduction in abundance of dominant species and /or significance change in dominant populations, with terrestrialisation through encroachment of xeric species
Species mortality	No measurable mortality	Some mortality of individuals	Greater than 15% reduction in abundance of dominant species	Greater than 50% reduction in abundance of dominant species
Species richness	No measurable change in species richness	Some evidence of decline in richness of wetland species	Measurable decline in richness of wetland species and/or increase xeric species richness	Significant change in richness of wetland species and replacement by xeric species
Community structure	No measurable change in community structure	Some evidence of change in community structure	Notable change in community structure	Significant change in community structure
Abundances and biomass of biota				
- Vegetation density, cover and frequency	No measurable change in density, cover and abundance	Some evidence of reduced growth in overstorey and/or understorey species	Measurable crown dieback in overstorey species and/or reduction in cover of understorey	Substantial crown dieback in overstorey species and loss of density and cover in understorey
- Vegetation height and diameter	No measurable change in vegetation height and diameter	Some evidence of change in height due to loss of vigour and/or thinning of canopy	Measurable reductions in height due to loss of canopy and/or reduced diameter of adult stems	Significant reductions in height due to loss of canopy and reduced diameter of adult stems
Vertebrate abundance	No measurable change in vertebrate abundance	Some evidence of reduced vertebrate abundance	Measurable changes in vertebrate abundance due to reduction in food and/or habitat availability as result of drying	Greater than 50% reduction in vertebrate abundance due to reduction in food and/or habitat availability as result of drying
Macroinvertebrate abundance	No measurable change in macroinvertebrate abundance	Some evidence of reduced macroinvertebrate abundance	Measurable changes in macroinvertebrate abundance due to reduction in food and/or habitat availability as result of drying	Greater than 50% reduction in macroinvertebrate abundance due to reduction in food and/or habitat availability as result of drying
Quality of water and sediment				
Physical and biochemical properties of sediments and groundwater	Levels of contaminants and other measures of quality remain within limits of natural variation	Small detectable changes beyond limits of natural variation but no resultant effect on biota	Moderate changes beyond limits of natural variation but not to exceed specified criteria	Substantial changes beyond limits of natural variation

From Froend & Loomes (2005)

Table 6.4 Possible response of key elements of phreatophytic vegetation communities to drawdown

Key elements	Level and type of possible response to drawdown			
	Low (no measurable change)	Moderate (small change)	High (moderate change)	Severe (large change)
Ecosystem processes				
Primary production	Rates of primary production are maintained within the limits of natural variation	Some evidence of reduction in rates of primary production in response to drying	Measurable reductions in rates of primary production in response to drying	Severe reductions in rates of primary production in response to drying
Nutrient recycling	Rates of nutrient recycling are maintained within the limits of natural variation	Some evidence of reduction in rates of nutrient recycling in response to drying	Measurable reductions in rates of nutrient recycling in response to drying	Severe reductions in rates of nutrient recycling in response to drying
Food chains	No measurable change in food chains	Some evidence of disruption to food chains	Measurable disruptions to food chains	Severe disruptions to food chains
Sediment/soil stabilisation	No measurable change in soil stabilisation	No detectable change in soil stabilisation	Some evidence of soil destabilisation/erosion	Measurable destabilisation/erosion of soil
Biodiversity				
Species composition	No measurable change in species composition	Some evidence of encroachment of more drought tolerant species	Measurable signs of encroachment of more drought tolerant species	Increased loss of less drought tolerant species from ecosystem, with establishment of exotic species and gradual dominance by more drought-tolerant species
Species distribution	No measurable change in distribution of phreatophytic species (not measurable in past 20 years)	Some evidence of changing distribution and encroachment of more drought tolerant species into areas previously dominated by less drought tolerant species	Measurable change in demographics of some species with encroachment of more drought tolerant species into areas previously dominated by less tolerant species	Overstorey and understorey decline and/or loss of species from ecosystem. Greater than 50% reduction in abundance of dominant populations and/or disturbance allowing exotic species to establish
Species mortality	No measurable mortality	Some mortality of individuals	Greater than 15% reduction in abundance of dominant species	Greater than 50% reduction in abundance of dominant species
Species richness	No measurable changes in species richness	Some evidence of decline in richness of less drought tolerant species	Measurable decline in richness of less drought tolerant species and/or increase xeric species richness	Significant change in richness of less drought tolerant species and replacement by more xeric species
Community structure	No measurable change in community structure	Some evidence of change in community structure	Notable change in community structure	Significant change in community structure
Abundances and biomass of biota				
Vegetation density, cover and frequency	No measurable change in density, cover and abundance	Some evidence of reduced growth in overstorey and/or understorey species	Measurable crown dieback in overstorey species and/or reduction in cover of understorey	Substantial crown dieback in overstorey species and loss of density and cover in understorey
Vegetation height and diameter	No measurable change in vegetation height and diameter	Some evidence of change in height due to loss of vigour and/or thinning of canopy	Measurable reductions in height due to loss of canopy and/or reduced diameter of adult stems	Significant reductions in height due to loss of canopy and reduced diameter of adult stems
Vertebrate abundance	No measurable change in vertebrate abundance	Some evidence of reduced vertebrate abundance	Measurable changes in macroinvertebrate abundance due to reduction in food and/or habitat availability as result of drying	Greater than 50% reduction in macroinvertebrate abundance due to reduction in food and/or habitat availability as result of drying
Macroinvertebrate abundance	No measurable change in macroinvertebrate abundance	Some evidence of reduced macroinvertebrate abundance	Measurable changes in vertebrate abundance due to reduction in food and/or habitat availability as result of drying	Greater than 50% reduction in vertebrate abundance due to reduction in food and/or habitat availability as result of drying

From Froend & Loomes (2005)

4 WETLANDS

4.1 BLACKWOOD PLATEAU

The Blackwood Plateau has extensive valley systems, with both perennial and ephemeral streams feeding into the deeply incised Blackwood River. Many of these are totally dependent on rainfall and have no connection to the Yarragadee aquifer. The tributaries that may be affected by the proposal are discussed in detail in Chapter 7 Sections 2 through 5.

There are several wetlands on the Blackwood Plateau in the areas of interest that are lentic (non-flowing) wetlands. Pig Swamp is west of Poison Gully and south of the Blackwood River. The surface of Pig Swamp is several metres above the watertable and is therefore considered a perched water body whose levels would not be affected by changes in underlying groundwater levels. The swamp appears to be directly underlain by a grey plastic clay, which prevents water in the swamp draining down to the watertable. The Canebreak Sedgeland (Figure 6.2) is perched about 10 m above the local watertable and similarly, would not be affected by drawdown in underlying aquifers.

The Judy area wetlands are underlain by more than 70 m of Leederville Formation strata, including almost 50 m of the relatively impermeable Mowen Member. This effectively isolates the Judy area wetlands from significant effects of drawdown in the underlying Yarragadee Formation.

4.1.1 Reedia Wetlands

The Reedia Wetlands exist north and south of the Blackwood River near the Adelaide and Spearwood Creeks. The wetlands are west of the Busselton Fault and overlie Lesueur Sandstone. The Yarragadee Formation is only found east of the fault line. The Reedia Wetlands have a poor connection to the Lesueur Sandstone, which is in turn poorly connected to the Yarragadee aquifer. Therefore, no effect is expected on the Reedia Wetlands from the proposal. Due to the significance of the wetlands, and the cumulative risk to the area from regional pumping, the environmental risk is addressed in detail in Chapter 7 Section 5.

Figure 6.2 Wetlands of the Blackwood Plateau



Adapted from URS Australia 2004d.

4.2 SWAN COASTAL PLAIN

Wetlands on the Swan Coastal Plain have been affected by grazing, stock access, drainage, groundwater pumping, eutrophication and possible acidification. Two wetland systems that maintain significant conservation value are the Dalyellup and Boyanup Wetlands.

The Boyanup Wetlands are given a high habitat value (Horwitz and Rogan 2003) as they support a rare species of aquatic plant – *Aponogeton hexatepalus*. The Dalyellup Wetlands on the Swan Coastal Plain south of Bunbury are assigned high habitat value as they are connected to pockets of remnant vegetation in an area where most vegetation has been cleared.

The Vasse–Wonnerup Wetlands are on the Ramsar List of Wetlands of International Importance and are protected by the EPBC Act. The wetlands were originally estuaries; however, the wetlands are no longer truly estuarine because inflow of seawater is prevented by floodgates across the inlet of the estuary. The system now acts as a compensating basin for water discharging from the Vasse, Abba, Ludlow and Sabina Rivers.

None of these wetlands are within the potential areas of impact from the proposal.

4.3 SCOTT COASTAL PLAIN

The wetlands of the Scott Coastal Plain and the Blackwood Plateau are in better condition than those of the Swan Coastal Plain. They are particularly significant because of the high level of endemism and diversity in the species present, and the conspicuous presence of Gondwanic elements (Horwitz and Rogan 2003). The area has great diversity due to the relatively high rainfall and humidity, diverse landscape, variable soils and range of vegetation types.

The eastern Scott Coastal Plain is internally draining and characterised by swamps and lakes, which are mainly seasonal. The flora and vegetation of the Scott Coastal Plain are highly diverse and include a range of rare and Priority species.

Lake Jasper is unique in Western Australia as it is a large, deep, fresh water body with clear, good quality water. The lake and surrounding wetlands represent some of the most pristine wetland habitat in the south-west of Western Australia (Pen 1997, cited in Horwitz and Rogan 2003). Lake Jasper has been identified as a wetland suite of outstanding ecological value to fauna. It is known to support Gondwanic groups including flatworms, freshwater crayfish and dragonflies.

Examination of the hydrogeology of the Lake Jasper area indicates there is limited potential for groundwater to leak downward from the superficial formations to the underlying Yarragadee Formation.

Lake Quitjup is a permanent lake, located in a depression at the seaward margin of the Scott Coastal Plain. The lake is effectively a window into the watertable in the superficial aquifer. The lake has maintained its current size and shape since 1951, indicating that it is relatively deep and steep-sided (URS Australia 2005b at Appendix 19).

4.4 ACID SULPHATE SOILS

The exposure of acid sulphate soils that are known to exist on the coastal plains is a threat to wetland ecosystems. If exposed, the acidic and toxic water formed may migrate to sensitive wetland environments and impair ecosystem function. Acid sulphate soils occur naturally in the environment and only become a problem when the soils dry out and become exposed to oxygen. In this situation the sulphides oxidise, and in the presence of water, form sulphuric acid. The acid can have a secondary impact of releasing aluminium, iron and other metals, in toxic concentrations. Lowering groundwater levels in areas with acid sulphate soils may cause this process to occur.

The two factors required to cause acidification from acid sulphate soils are the presence of acid sulphate soils, and a drying event such as a fall in the watertable from pumping or climate change.

Acid sulphate soils are addressed in Chapter 5 Sections 2.5 and 4.14.

4.5 ESTUARINE AND NEAR-SHORE MARINE SYSTEMS

Hardy Inlet forms the mouth of the Blackwood River near Augusta. The Inlet is an area of high environmental and social value, although it has already been significantly affected by the impacts of the urban infrastructure of Augusta, nutrients from agriculture, boating, fishing, and increased sediment loads.

Reduction in groundwater discharge as a result of the proposal, and estimated future regional use, is estimated to be approximately 4.8 – 5.8 GL/yr (Baddock 2005 at Appendix 13). The average flow of the Blackwood River is approximately 940 GL/yr. This reduction is expected to have a negligible effect on the salinity regime in the Hardy Inlet. Estuarine systems are by nature adapted to fluctuations in salinity, so the minimal changes expected will be well within the range of tolerance of these systems.

There are two main species of seagrass in the Hardy Inlet – a *Ruppia* species and *Zostera mucronata*. These grow in shallow water between Point Trafalgar and the Scott River Basin, and in small areas in the shallows of the entrance channel opposite Point Ellis, and in the dead water (URS Australia 2004a at Appendix 25). Seagrass is typically tolerant to a wide range of salinity levels (Appendix 25), but is more sensitive to significant changes in flow volumes, water turbidity, water colour, or water depth. Macroalgae are not expected to be affected because the seasonally low salinity of the estuary is a limiting factor for macro-algal growth. Macroalgae are mostly found in the lower estuary, as they can tolerate salinity only slightly lower than seawater. Any increase in salinity of the Blackwood River would be beneficial to macro-algal populations, although their spread would still be limited by the lack of hard substrates.

Recreational fishing is popular in the Hardy Inlet. There is one commercial fishing licence in operation in the inlet. The most commonly caught fish are black bream, yellow fin whiting, Australian herring, King George whiting, silver bream, tailor, and skipjack trevally (Appendix 25). Two tour operators run predominantly catch-and-release fishing trips on the estuary.

Estuarine fish tolerate broad ranges of salinity and so would not be expected to be affected directly by any changes to the salinity regime. No change in food supply is expected in the Blackwood River as the species in the river have a broad salinity tolerance. The fish also rely on the flow volumes from the river to flush the estuary, keep oxygen levels up, and to provide areas for breeding. Groundwater makes up only a small component of the overall flow of the Blackwood River, so a change in that component is not expected to affect the estuarine fish.

No significant change is expected on the hydrological regime or ecology of Hardy Inlet.

5 FAUNA

This section describes the fauna of the Blackwood Plateau, Scott Coastal Plain, and Swan Coastal Plain. Further detailed discussion of the specific fauna values, potential impacts and their management in the potential groundwater impact areas is provided in Chapter 7.

5.1 INTRODUCTION

The species of fauna, including threatened fauna, that are known or are expected to be found in the region, were assessed by Bamford (2003 at Appendix 28). The species list, including the areas within which they are expected to live, and their level of dependence on groundwater, is included in Appendix 27. Species lists were compiled based on:

- a site inspection incorporating habitat identification, observation of conspicuous species such as birds and large mammals, and dip-netting for freshwater fish
- previous site inspections and trapping programs carried out by Bamford Consulting Ecologists
- Western Australia Museum Faunabase
- CALM Threatened Fauna Database
- available literature and previous studies.

The Centre of Excellence in Natural Resources (CENRM 2005a at Appendix 27) sampled in-stream fauna, and provided an increased understanding of the susceptibility of the Blackwood River and its tributaries to a change in water regime (both quality and quantity).

Morgan *et al.* (2004) conducted a study on the aquatic fauna of Rosa Brook. Morgan & Beatty (2005) carried out further sampling of fish and freshwater crayfish within the Blackwood River and its tributaries.

An assessment of the likely groundwater dependence of fauna species was undertaken by Bamford (2003 at Appendix 28) in the areas previously understood to be at risk. The assessment included an area on the Swan Coastal Plain between Bunbury and Capel, and a second, larger region encompassing the Blackwood River, downstream from Nannup and extending south to include part of the Scott Coastal Plain. This study area included Lake Jasper and associated wetlands. Bamford (2005 at Appendix 29) updated this work with a desktop review of the potential impacts on fauna, based on the predicted drawdowns presented in this report.

The groundwater dependence categories defined by Bamford (2003 at Appendix 28) were:

1. **Low dependence on groundwater.** Species that occur primarily in upland habitats throughout the year, or which show no special preference for groundwater dependent vegetation. Changes to groundwater levels are unlikely to affect such species.

2. **Moderate dependence on groundwater.** Species that make some use of habitats that are themselves moderately dependent on groundwater, such as vegetation not closely associated with wetlands, but in which major components are groundwater dependent. This category was also used for species that make seasonal use of vegetation that is moderately or highly dependent on groundwater. Changes to groundwater levels would affect these fauna species, at least insofar as the vegetation assemblages on which they depend, wholly or seasonally, are affected. The effect may be for both the vegetation and the fauna to move to positions lower in the landscape.
3. **High dependence on groundwater.** Species that are dependent upon phreatophytic vegetation. Because this vegetation occurs low in the landscape, a lowering of groundwater could cause a reduction in habitat area rather than a shift in its position in the landscape. Associated species would therefore decline in local abundance, or locally disappear.
4. **Very high dependence on groundwater.** Species that rely on aquatic habitats in wetlands, and are therefore likely to become locally extinct if a fall in groundwater level leads to the disappearance of surface water in wetlands.

5.2 FISH

The Blackwood River and its tributaries have a relatively diverse freshwater fish community. CENRM (Appendix 27) recorded seven native fish species and one introduced species (the mosquitofish, *Gambusia holbrooki*) in a July 2004 survey. Bamford (2003 at Appendix 28) identified seventeen species of freshwater fish that may live in the region, of which thirteen are likely to be found in the Blackwood River and its tributaries, and three of which are introduced species.

The fish species that have been recorded in the Blackwood River and its tributaries are listed in (Table 6.5). Most species found (with the exception of Balston's pygmy perch and the mud minnow) are considered to be widespread and common throughout the south-west of the State.

Table 6.5 Freshwater fish of the Blackwood River and tributaries

Species	Common name	Source	Conservation status
<i>Galaxias occidentalis</i>	western minnow	CENRM (2005a) and Morgan & Beatty (2005)	-
<i>Tandanus bostocki</i>	freshwater cobbler	CENRM (2005a) and Morgan & Beatty (2005)	-
<i>Bostockia porosa</i>	nightfish	CENRM (2005a) and Morgan & Beatty (2005)	-
<i>Nannatherina balstoni</i>	Balston's pygmy perch	CENRM (2005a) and Morgan & Beatty (2005)	Priority 4
<i>Edelia vittata</i>	western pygmy perch	CENRM (2005a) and Morgan & Beatty (2005)	-
<i>Galaxiella munda</i>	mud minnow	CENRM (2005a) and Morgan & Beatty (2005)	Priority 4
<i>Perca fluviatilis</i>	redfin perch	Bamford (2003)	-
Estuarine species			
<i>Leptatherina wallacei</i>	western hardyhead	Bamford (2003) and Morgan & Beatty (2005)	-
<i>Pseudogobius olorum</i>	Swan River goby	Bamford (2003) and Morgan & Beatty (2005)	-
<i>Afurcagobius suppositus</i>	south-western goby	CENRM (2005a) and Morgan & Beatty (2005)	-

Species	Common name	Source	Conservation status
Introduced species			
<i>Oncorhynchus mykiss</i>	rainbow trout	Morgan et al. (2004)	-
<i>Gambusia holbrooki</i>	mosquitofish	CENRM (2005a), Morgan & Beatty (2005) and Bamford (2003)	-
<i>Carassius auratus</i>		Morgan & Beatty (2005)	-

The information compiled from both CENRM (Appendix 27) and Morgan & Beatty (2005) represent winter and summer “snapshots” of the species in the Blackwood River system (Table 6.6).

Morgan & Beatty (2005) found that the diversity of fish species in the main stem of the Blackwood River in summer was greater within, and downstream of, the main groundwater discharge area (five freshwater species) than upstream of the discharge (one freshwater species).

The tributaries were found to be dominated by the endemic freshwater fish species in both summer and winter. The estuarine species were mostly absent, except for one site in Rosa Brook (Table 6.6). Mosquitofish were largely absent from the tributaries, except at one site in Milyeannup Brook (3 individuals) and one site in Red Gully (460 individuals) (Morgan & Beatty 2005). There was no observable or statistically significant difference (Morgan & Beatty 2005) between the abundance of freshwater fish in tributaries fed by the Yarragadee aquifer, and those fed by the Leederville aquifer.

Milyeannup Brook is an important habitat for Balston’s pygmy perch, which is a Priority 4 species. Sixteen of the eighteen specimens recorded by Morgan & Beatty (2005) were found in Milyeannup Brook.

The most abundant species recorded in winter was the western minnow (*Galaxiella occidentalis*) (Appendix 27). The western minnow and mud minnow, and to a lesser extent the goby, were the most widespread species found within the catchment. With the exception of the mud minnow and Balston’s pygmy perch, most species found are considered widespread and common throughout the state (Allen et al. 2002).

Table 6.6 Fish species recorded in the Blackwood River and tributaries by CENRM (2005a) and Morgan & Beatty (2005)

	Blackwood River		Tributaries upstream of discharge (Leederville aquifer dependent)					Yarragadee discharge tributaries			Tributaries downstream of discharge			
Common name	Upstream of discharge	Downstream of discharge	St John Brook	Sturke Creek	McAfee Brook	Red Gully	Sollya Creek	Milyeannup Brook	Poison Gully	Layman Brook	Ballan Creek	Rosa Brook	Adelaide Brook	Spearwood Creek
S = summer survey W = winter survey														
No of survey points in winter (CENRM 2005a)	4	15	3	1	1	1	1	1	1	1	1	2	1	1
No of survey points in summer (Morgan & Beatty 2005)	4	2	3	1	2	3		2	2	2		4	2	
Freshwater endemics														
western minnow	s	w/s	w/s		s	w/s	w	s	s	w/s		w/s	w/s	
freshwater cobbler	w	s										s		

	Blackwood River		Tributaries upstream of discharge (Leederville aquifer dependent)					Yarragadee discharge tributaries			Tributaries downstream of discharge			
Common name S = summer survey W = winter survey	Upstream of discharge	Downstream of discharge	St John Brook	Sturke Creek	McAfee Brook	Red Gully	Sollya Creek	Milyleannup Brook	Poison Gully	Layman Brook	Ballan Creek	Rosa Brook	Adelaide Brook	Spearwood Creek
nightfish		w/s	w/s		s	s		s	w/s	s		w/s		
Balston's pygmy perch		w/s				s		s						
western pygmy perch		w/s	s		s	s		s	w/s			s		
mud minnow			s	s	s	s		s	w/s	s		s		
Estuarine														
western hardyhead	s	s										s		
Swan River goby	s	s										s		
south-western goby	w/s	w/s										s		
Introduced														
rainbow trout														
mosquitofish	w/s	w/s				s		s				s		
Carassius auratus		s				s								

Species of conservation significance

There are two species of conservation significance in the Blackwood River and tributaries that were confirmed as being present by CENRM (Appendix 27) and Morgan & Beatty (2005).

The mud minnow (*Galaxiella munda*) is a CALM Priority 4 species that is considered rare throughout most of its range, but can be abundant in the lower-order tributaries of rivers, and in shallow pools associated with these streams. The range of the mud minnow has been restricted by loss of suitable habitat and predation by introduced species. The species is relatively small (less than 60 mm in length) and has a one year life-cycle (Morgan et al. 2004).

Figure 6.3 Mud Minnow (*Galaxiella munda*)



Photo reproduced with permission from CENRM (2005a)

The mud minnow was well-represented throughout the tributaries in summer, but was found in Poison Gully only in winter CENRM (Appendix 27). The species was not recorded in the main stem of the river in either summer or winter. In the tributaries fed by the Leederville aquifer that had little or no summer flow, the mud minnow was found in excavated pools that are used as water reserves for fire fighting.

The black-striped minnow (*Galaxiella nigrostriata*) is a CALM Priority 3 species, which is considered rare. CENRM (Appendix 27) could not, without further work, determine whether the species recorded were mud minnows or black-striped minnows. They assumed that all species recorded were mud minnow, as this species is known within the Blackwood system, having been recorded there, and previously at Rosa Brook, by Morgan & Beatty (2005).

Balston's pygmy perch (*Nannatherina balstoni*) is a CALM Priority 4 species and is considered to be the rarest of the South West freshwater fish. It has a distribution between Two Peoples Bay in the east, and Margaret River in the west, with an isolated population at Gingin. In summer 90% of Balston's pygmy perch were captured in Milyeannup Brook. The only winter occurrence recorded was in the main stem of the Blackwood River.

Figure 6.4 Balston's pygmy perch (*Nannatherina balstoni*)



Balston's pygmy perch and the mud minnow have both been designated Vulnerable under the EPBC Act. Photo reproduced with permission from CENRM (2005a)

Introduced species

A rainbow trout (*Oncorhynchus mykiss*) stocking program was carried out in the Blackwood and its tributaries in the winter of 2002 and 2003. A total of 205 000 trout were released into Milyeannup, Carlotta, Hester, Nannup, St John and Rosa Brooks. Morgan et al. (2005) recorded four rainbow trout in Rosa Brook. However, none were found in the CENRM (Appendix 27) survey, or by Morgan & Beatty (2005), and it is possible most did not survive the warmer temperatures of summer. Trout have had an adverse effect on native fish through predation and competition in the eastern states of Australia.

The mosquitofish was introduced to control mosquitoes around Perth in 1936. The fish have spread and are now considered a pest. They have been associated with the decline of native species. High winter flows are thought to regularly reduce the population, allowing its coexistence with indigenous species.

The mosquitofish were recorded exclusively in the Blackwood River during winter, but were also found in three of the tributaries during summer.

5.2.1 Water requirements of fish

Native fish species living in the Blackwood River have a requirement for permanent water of adequate quality, and a suitable habitat. Several of the species readily invade seasonal creeks to reproduce but only the mud minnow can withstand dry stream conditions. However, permanent flow and the maintenance of habitat in the tributaries are likely to be especially important to the mud minnow, as it survives almost exclusively in the tributaries, and was not recorded in the Blackwood River.

Both juveniles and adults in the Blackwood system typically have generalist diets, comprising aquatic and terrestrial insects. Therefore, any changes in insect diversity as a result of changes in the river and streams will not limit the diet of any of the fish species (Appendix 27).

Adults of most fish species were present in the Blackwood River in winter, indicating some tolerance to higher salinities (salinity in July 2004 ranged between 3900 mg/L and 5200 mg/L). However, in both summer and winter the freshwater species were mostly limited to areas downstream of the groundwater discharge, even though the water was brackish.

The tolerance of juveniles to salinity is largely unknown, but the fresher tributaries are likely to play an important role as nursery habitat. Of the native fish recorded, only the mud minnow was not found in the main stem of the Blackwood River.

Fish migration and reproduction are likely to be the aspects of fish biology that are most susceptible to altered flows in the Blackwood River system. Migration and reproduction occur between August and October. Migration is dependent on high flows to provide sufficient depth over riffle zones. The high flows rely on winter and spring rainfall and, during this period, groundwater discharge from the Yarragadee Formation contributes an insignificant volume to stream flows.

Estuarine fish also live in the Blackwood River, but are not addressed in detail here, as they are unlikely to be affected by a reduction in freshwater flows.

5.3 MACROINVERTEBRATES

Macroinvertebrate sampling by CENRM (Appendix 27) in July 2004 indicated that the biodiversity of the Blackwood River system was generally low. Most macroinvertebrate groups expected to be present were represented in both the tributaries and the main channel. A total of 67 species were recorded: 56 of these in the main channel, and 47 in the tributaries. Low numbers were attributed to the time of year, as high winter flows are known to scour the system of organisms. Many species were only represented by juvenile or immature phases.

The fauna recorded in the Blackwood River were dominated by species characterised as tolerant to a wide range of conditions. The species present in the Blackwood River are indicative of saline conditions. The tributaries had higher numbers of local endemic fauna and are thought likely to be refuges for species sensitive to water quality changes in the main channel.

Insects were the most common macroinvertebrates found, representing 70 – 75% of the fauna sampled. In particular, detritivores and predatory aquatic beetles were well-represented. The most common groups were two-winged flies, aquatic beetles and, to a lesser extent, crustaceans. Species that prefer both flowing and non-flowing conditions were present.

Gondwanic (relict) fauna

Gondwanic fauna are relict³⁵ species from approximately 144 – 195 million years ago, when all of the southern continents were joined together as one land mass (Gondwanaland). Gondwanic species are considered to be especially at risk from hydrological changes as they have specialised requirements and habitats that are usually topographically restricted (Appendix 27).

³⁵ Relict species are ancient species that have survived while related species have become extinct

Large numbers of juvenile stoneflies were present at all tributary sites, but only a few individuals were found in the Blackwood River. This Gondwanic group is not well known in Western Australia. Only four species have been described, three of which are endemic³⁶ and restricted to freshwater in upland streams of the South West.

Other Gondwanic species recorded included a dragonfly from Rosa Brook and a small, freshwater snail from Milyeannup Brook. Both these species are endemic to south-west Australia and live in non-permanent streams. The freshwater snail (*Glacidorbis occidentalis*) is restricted to the Northern Jarrah Forest, and is usually found in low numbers in scattered populations. Both species can survive dry periods.

Four of the six freshwater crayfish species endemic to the south-west of Western Australia were recorded by Morgan & Beatty (2005), and three by CENRM (Appendix 27) in the winter of 2004. The crayfish recorded were marron (*Cherax cainii*), gilgies (*Cherax quinquecarinatus* and *Cherax crassimanus*) (Figure 6.5) and koonacs (*Cherax preissii*). Gilgies (*C. quinquecarinatus*) were the most common species captured, followed by koonacs.

The freshwater crayfish were almost totally restricted to tributary sites during the winter sampling period by CENRM (Appendix 27), but were found throughout the main stem of the Blackwood River during summer. In summer, the crayfish were more common downstream of the groundwater discharge area. These results indicate that the freshwater crayfish are sensitive to the lower water quality in the main river.

Figure 6.5 Gilgie (*Cherax quinquecarinatus*)



Photo reproduced with permission from CENRM (2005a)

Most freshwater crayfish can survive temporary dry conditions by burying themselves in mud, but marron are weak burrowers and cannot survive dry conditions.

Table 6.7 Freshwater crayfish recorded in the Blackwood River and tributaries by CENRM (2005a) and Morgan & Beatty (2005)

Species s = summer survey w = winter survey	Blackwood River		Tributaries upstream of discharge (Leederville aquifer dependent)					Yarragadee discharge tributaries			Tributaries downstream of discharge			
	Upstream of discharge	Downstream of discharge	St John Brook	Sturke Creek	McAfee Brook	Red Gully	Sollya Creek	Milyeannup Brook	Poison Gully	Layman Brook	Ballan Creek	Rosa Brook	Adelaide Brook	Spearwood Creek
No of survey points in winter (CENRM)	4	15	3	1	1	1	1	1	1	1	1	2	1	1

³⁶ Endemic species are those that are native or restricted to a particular geographic area.

	Blackwood River		Tributaries upstream of discharge (Leederville aquifer dependent)					Yarragadee discharge tributaries			Tributaries downstream of discharge			
Species s = summer survey w = winter survey	Upstream of discharge	Downstream of discharge	St John Brook	Sturke Creek	McAfee Brook	Red Gully	Sollya Creek	Milyeannup Brook	Poison Gully	Layman Brook	Ballan Creek	Rosa Brook	Adelaide Brook	Speanwood Creek
Appendix 27)														
No of survey points in summer (Morgan & Beatty 2005)	4	2	3	1	2	3		2	2	2		4	2	
Koonacs - <i>Cherax preissii</i>		s	s		s	s		s	s			w/s*		w
Marron - <i>Cherax cainii</i>	s	w/s	w/s		s		w		w/s	w	w	w/s	w	
Gilgie - <i>Cherax quinquecarinatus</i> -	s	w/s	w/s	s	s	w/s		w/s	s			w/s		w
Gilgie - <i>Cherax crassimanus</i>		s			s	s			s			s		
<i>Cherax</i> sp. unidentified species	s				s				s					
Introduced yabby – <i>C. destructor</i>						s								

* *Cherax preissii* was recorded by Morgan et al. (2004)

Variation between the river and the tributaries

Comparison of the macroinvertebrate communities in the Blackwood River with those in its tributary systems, showed fundamental differences (Table 6.7). This is attributed to higher winter flows and higher salinities in the main stem of the river, where species indicative of saline conditions were found. The tributaries had lower species diversity than the Blackwood River, but contained sensitive fauna including crayfish, stoneflies and mud minnow.

5.3.1 Water requirements of aquatic macroinvertebrates

The macroinvertebrates found in the Blackwood River were typically cosmopolitan, generalist species that can tolerate a wide variety of stream conditions. Their existence in the Blackwood River shows that they are tolerant of current salinity in the river.

Macroinvertebrates species that are more sensitive to water quality, and have more specific habitat requirements were typically found in the tributaries in the winter sampling period (CENRM 2005a at Appendix 27). Freshwater crayfish were widespread in summer in both the tributaries and the Blackwood River. Marron are highly sensitive to water quality (nutrients) and are weak burrowers so cannot survive dry conditions.

Macroinvertebrates require a minimum depth of 5 cm of water over riffle zones to support aquatic macroinvertebrate communities in riverine systems. These riffle zones are typically areas of high aquatic insect production and biodiversity. Aquatic fauna are susceptible to low levels of dissolved oxygen. The deep pools of the Blackwood River and major tributaries have very low levels at night, and require constant flow to input oxygenated water (Appendix 27).

Conclusion

The main stem of the Blackwood River is a moderately degraded, brackish to saline river system supporting aquatic fauna that are tolerant of, or adapted to, these conditions. The tributaries in the area of interest are freshwater streams and while they have a lower total biodiversity than the main river, many of the more sensitive species were found only in these areas. The tributaries are thought to act as important refuges for species that would once have lived throughout the Blackwood River system, but are now restricted in habitat by water quality in the main river.

The tributaries are relatively pristine, and the biggest risk to these creeks would be a change in the permanence of their flow (Appendix 27).

5.4 SUBTERRANEAN FAUNA

Subterranean fauna refers to the very small animals and microbes that live in groundwater and caves. Stygofauna³⁷ communities that occur within the groundwater body can be classified as groundwater dependent. Troglobitic³⁸ (cave or karst fauna) can be groundwater dependent if the watertable provides a function in maintaining humidity and moisture levels in the karst or cave system.

Stygofauna are assumed to have significant conservation values due to lack of specific information on their distribution and the known high endemism of these animals and scientific interest. Humphreys (1999) notes that stygofauna might occur in any water-filled subterranean void, which includes interstitial spaces of alluvial deposits, boulder deposits and especially in the crevices, caves, sinkholes and conduits that are commonly found in karstic landforms.

URS (2004a) reports that the Swan and Scott Coastal Plains contain extensive superficial groundwater environments suitable for stygofauna, including Tamala Limestone as well as sandy aquifers and springs. Four threatened ecological communities (diverse stygofauna) occur within the karstified and cavernous limestones on the Leeuwin Block. Because of the lack of hydraulic connection, these communities would not be affected by groundwater level decline within the Yarragadee aquifer.

Groundwater levels in the Tamala limestone formations on the Swan and Scott Coastal Plains are not expected to be impacted by the proposal because of the distance from the points of abstraction. Groundwater levels in the formations will be controlled by the ocean because of their proximity to the coast. Troglobitic fauna are consequently not expected to occur within the area of drawdown impact.

Stygofauna may exist within the superficial formations on the coastal plains. However, the relatively small drawdowns expected, compared to the saturated thicknesses of these formations and the range of natural variation in watertable levels provides assurance that these fauna will not be impacted. Ecological water requirements for stygofauna were not assessed by URS (2004a). They were considered unlikely to be critical as the drawdown criteria to be established for wetlands and vegetation would protect stygofauna.

³⁷ Stygofauna are obligate groundwater-dwelling, aquatic fauna.

³⁸ Troglobytes are obligate cave or karst-dwelling, terrestrial subterranean fauna occurring above the watertable.

Stygofauna sampling of a test production well indicated no stygofauna as being present in the Yarragadee Formation. However, the well construction technique may have affected this result. If stygofauna are present in the confined aquifers, there will be no impact from the proposal because water levels (and consequently available stygofauna habitat) in these aquifers will not change (only pressures will be affected).

While little scientific information is available on the susceptibility of stygofauna to groundwater level change, the fact that many exist within groundwater as Gondwanic relics, strongly suggests they have considerable tolerance to such change. Water dependent troglobitic fauna, because of their clearer dependence on the presence of a watertable, would be expected to be more susceptible to watertable change. Within limits, the rate of change of groundwater level would be expected to be the critical factor, rather than magnitude of change, for troglobytes in particular. Given the significant distance separating the Water Corporation wellfield from any areas of known caves, troglobitic fauna are not expected to be an issue.

5.5 FROGS

Sixteen species of frogs may be present in areas of interest, with species diversity being slightly less on the Swan Coastal Plain than in areas to the south. Four species are found only in the extreme south-west, while a single species (Sandplain Froglet) is confined to the Swan Coastal Plain, and is therefore absent from the southern areas (Bamford 2003 at Appendix 28). Four of the frog species are of conservation significance. These four species are all unusual in that larval development occurs within the egg membrane in moist soil.

The White-bellied Frog (*Geocrinia alba*) is considered to be Critically Endangered (Schedule 1) under the Wildlife Act and Endangered under the EPBC Act. The frog is confined to a small area between Witchcliffe and Karridale, just to the west of the Blackwood River.

The Orange-bellied Frog (*Geocrinia vittalina*) is classed as Vulnerable (Schedule 1) under the Wildlife Act and Vulnerable under the EPBC Act. This frog is considered to be the most range-restricted vertebrate in Australia, as it lives only in a few small areas within the Reedia Wetlands, linked with tributaries (e.g. Spearwood Creek) of the Blackwood River east of Witchcliffe (Bamford 2003 at Appendix 28). This population is considered to be highly significant.

The Roseate Frog (*Geocrinia rosea*) and Nicholls' Toadlet (*Metacrinia nicholli*) are both considered of regional significance as they have a restricted distribution in the extreme south-west.

5.5.1 Groundwater dependence

All frogs have a high dependence on groundwater in areas where it is an important contributor to maintaining the required moisture regime. Bamford (2003 at Appendix 28) categorised frogs at level three for dependence on water (on a scale of 1 to 4 with four being very high dependence). Frogs on the Scott Coastal Plain may be the most sensitive to changes in moisture condition in wetlands, as they are live on broad peaty flats with little relief (Appendix 28). On the Swan Coastal Plain there are fewer frog species, but they may be especially vulnerable due to fragmentation of existing habitat on the plain that prevents their movement between wetlands.

5.6 REPTILES

Forty-three species of reptiles may be present in the areas of interest, with more species on the Swan Coastal Plain than on the Blackwood Plateau or Scott Coastal Plain (Appendix 28). The species that live on the Swan Coastal Plain are at the southern limit of their range. Some of the species on the Blackwood Plateau and Scott Coastal Plain have an extremely limited range. Four species are of conservation significance.

The Carpet Python (*Morelia spilota imbricata* – South West subspecies) has been observed on both the Swan and Scott Coastal Plains. The species is a CALM Priority 4 species and is listed as a Schedule 4 (Fauna Specially Protected for Other Reasons) under the Wildlife Act. The Carpet Python is threatened by clearing, and possibly by introduced predators (Bamford 2003 at Appendix 28).

Egernia pulchra and *Glaphyromorphus gracilipes* are both species of skink that are locally significant because of their restricted occurrence in the far south-western corner of Western Australia.

The Short-nosed Snake (*Elaphognathus minor*) is endemic to Western Australia and is only found on the coastal plains.

5.6.1 Groundwater dependence

Most reptiles have a low dependence on groundwater (Appendix 28) as they exist in upland vegetation communities with no special preference for groundwater dependent vegetation. However, eight of the 43 reptile species thought to live in the area are associated to some degree with wetland vegetation. Some of these, such as the tiger snake, are largely restricted to the margins of wetlands (Appendix 28). The oblong tortoise is aquatic and is dependent on permanent or near-permanent water. Therefore, this species is groundwater dependent where a wetland is supported by groundwater.

5.7 BIRDS

The regional study area is rich in bird species, with 160 species believed to be present (Appendix 27). This includes some species that may only visit occasionally, but does not include wholly marine species or vagrants. There are six additional species that are considered locally extinct. The Swan Coastal Plain has many waterbirds, especially those that use damp and flooded pasture. As the Swan Coastal Plain is extensively cleared, both farmland species and species of woodland and forest dwellers are found. The Blackwood Plateau and Scott Coastal Plain areas have fewer waterbirds, with only a few species living on the Blackwood River and in the densely vegetated swamps.

There are 26 species of birds of conservation significance, but 14 of these are migratory and only occasionally visit the area of interest. Of the remaining 12, there are 6 species that are protected under State or Federal legislation. The other six species are listed as Threatened by CALM or other published literature.

These birds are threatened by a range of factors, mostly relating to habitat loss. Clearing, drainage of wetlands, overgrazing, inappropriate fire regimes, and logging of nesting trees are all factors contributing to population decline. Predation from foxes also contributes to the decline of birds such as the ground-dwelling mallee fowl. Illegal shooting of cockatoos is also a continuing problem.

In general, the mobility of birds means that they are less susceptible to small or gradual changes in ecology.

5.7.1 Groundwater dependence

Of the 160 bird species that may live in or visit the coastal plains and the Blackwood Plateau, 36% are waterbirds that rely on wetlands that are potentially groundwater dependent. Most of the waterbird species are common and are likely to be found on the Swan Coastal Plain (Appendix 28).

About 10% of the bird species that are believed to frequent the area of interest are partially groundwater dependent, as they use wetland associated vegetation (Appendix 28). These species are most likely to be on both the Scott Coastal Plain and the Blackwood Plateau around the margins of lakes and swamps.

The remaining species (around 54%) are found in upland environments and are not considered to be groundwater dependent (Appendix 28).

5.8 MAMMALS

There are 34 mammals that are believed to live in the regional study area, of which seven are introduced. There are also an additional five locally extinct species. Species richness is similar throughout the regional study area, but populations on the Swan Coastal Plain are small and fragmented due to clearing. Eight of the native mammals are of conservation significance. The main threats to mammal populations are predation by introduced predators such as cats and foxes, changed fire regimes, habitat alteration, fragmentation or loss, logging, and degradation of wetlands from salinisation, clearing, fire and overgrazing. Many of the mammals, and most of the mammals of conservation significance, are common lower in the landscape, or live in the dense areas of vegetation around wetlands. Changes in groundwater levels that change this vegetation could affect these species. Upland phreatophytic vegetation, and the mammals that rely on it, also have the potential to be affected.

The Chuditch (*Dasyurus geoffroii*) is classified as Vulnerable by both the EPBC Act and the Wildlife Act. The Chuditch is a carnivore and is threatened by a loss of habitat productivity (resulting in a reduced food base for this carnivorous species) as well as competition and predation from introduced predators. The Chuditch lives in the jarrah forest and may be more common in valleys, possibly because these ecosystems are more productive.

The Nguara, or Western Ringtail Possum (*Pseudocheirus occidentalis*), is classified as Vulnerable by both the EPBC Act and the Wildlife Act. The Nguara lives in remnant Tuart and Peppermint woodlands along the coast, and is locally common east of Augusta.

The Quokka (*Setonix brachyurus*) is classified as Vulnerable by both the EPBC Act and the Wildlife Act. It often lives in dense vegetation surrounding wetlands, possibly for protection from predators. Quokkas are known to live in the Scott River National Park and near a swamp on the Swan Coastal Plain.

The southern Brush-tailed Phascogale (*Phascogale tapoatafa tapoatafa*) is listed as Priority 3 by CALM. The following mammals are listed as Priority 4 by CALM: Quenda, commonly known as the Southern Brown Bandicoot (*Isodon obesulus fusciventer*); Kwoora or Brush Wallaby (*Macropus irma*); Western False Pipistrelle (*Falisticrellus Mackenziei*); and Rakali or Water Rat (*Hydromys chrysogaster*).

5.8.1 Groundwater dependence

The Rakali (or Water Rat) is strongly associated with wetland habitats and is the only mammal species in the area that is considered highly groundwater dependent – if groundwater is required to sustain the wetland habitat (Appendix 28). A further seven species are either associated with dense vegetation around wetlands, or tend to be most abundant low in the landscape. These species were given a moderate groundwater dependence rating. This category includes most of the species of conservation significance.

The remaining mammal species live in upland environments and generally have a low dependence on groundwater.

6 CLIMATE CHANGE

Current research into climate change indicates that the likely future scenario for the south-west of the State is for a drier climate than was experienced during the last century. The extent to which rainfalls will decrease is uncertain. The research suggests prognoses for the South West ranging from 5% increases to 20% declines in annual rainfall by 2030, with the balance of scientific opinion falling on the side of an overall decline.

Some drying of the climate has effectively been included in the modelling used in this Sustainability Evaluation/ERMP, as it has used annual rainfalls rates that are 9% lower than the historical rainfall over the region (Chapter 5 Section 2.6).

If further drying occurs in the South West, there will be implications for the biodiversity and ecological integrity of ecosystems in the area. Productivity, species composition, and ecosystem processes all have the potential to be affected by climate change. Judging acceptability of the impacts of the proposal against a base that is changing in an uncertain manner is problematic. An approach to this issue is proposed in Volume 1 Chapter 7 Section 2.1.6.

Chapter 7 Effects of the proposal on groundwater dependent ecosystems

The main environmental principle that is directly relevant to the impacts of groundwater abstraction is *Biodiversity and ecological integrity*. The principle is:

The proposal will result in a net increase in ecological function or biological diversity in the region.

The impacts of the proposed groundwater abstraction on each of the potential impact areas is discussed in detail in the following sections.

Groundwater abstraction also relates to the *Energy efficiency* principle. These impacts are discussed in Chapter 8 Section 10.

In this chapter, all groundwater drawdowns referred to are the interpreted model results. A full explanation of the model results and their interpretation is included in Chapter 5 Section 4.

1 BLACKWOOD RIVER

This section addresses the environmental assessment of the impacts of the proposal on the main stem of the Blackwood River. Specific impacts on the various tributaries of the river are addressed in Sections 2 to 5 of this Chapter.

Sustainability objectives

The sustainability objective for the *Blackwood River and its tributaries* factor is:

The Water Corporation will seek to increase the ecological integrity of the Blackwood River and its tributaries.

At a minimum, the proposal will have no significant adverse impact on the Blackwood River and its tributaries.

The *Threatened fauna, Flora and fauna, Rare and priority flora (groundwater dependent)* and *Other groundwater dependent ecosystems* factors and their objectives are also addressed in this section.

The EPA objective for wetlands (including rivers) is:

To maintain the integrity, ecological functions and environmental values of wetlands.

1.1 EXISTING ENVIRONMENT

The Blackwood River has the largest catchment in the south-west of Western Australia, covering an area of 22 530 km² (DeSilva et al. 2000) (Figure 7.1). The Blackwood River rises about 330 m inland, in broad acre farming areas on the Yilgarn Plateau, around 380 km above sea level. The catchment is divided into three sections, the largest of which is the upper catchment to the east of the Darling Scarp.

The middle catchment drains the Blackwood Plateau, and the lower catchment is the western Scott Coastal Plain, where the river flows through Hardy Inlet to the Southern Ocean (Figure 7.2).

Dryland salinity has become a major land degradation issue in the upper catchment. Currently 13% of the catchment has been affected. The previously fresh Blackwood River has become brackish to saline and the present salinity levels are expected to double over the next 50 years (CSIRO 2001).

1.1.1 Relevant investigations

The Water Corporation has undertaken an extensive range of studies to identify the values of the Blackwood River and assess the potential impacts of the proposal on the Blackwood River:

1. CENRM (2005a at Appendix 27) investigated the ecological values of the Blackwood River system and provided an increased understanding of the ecological susceptibility of those values to changes in water regime (both quality and quantity). Nineteen sites were surveyed on the main stem of the Blackwood River. The investigations included fish species, aquatic macroinvertebrates, channel morphology, water quality, and a vegetation and foreshore assessment.
2. Mattiske (2005a at Appendix 31) evaluated the flora and vegetation values, in winter and spring 2004, at five cross-sectional transects along the main stem of the Blackwood River between Darradup and Hut Pool.
3. Bamford (2003 at Appendix 27) assessed the fauna species that are likely to live in the areas of potential impact, and assessed their likely groundwater dependence.
4. Synnott Mulholland Management Services (2005 at Appendix 3) conducted a social impact assessment that included consideration of recreational, aesthetic, and sense of place values of the Blackwood River and its tributaries.
5. Water Corporation carried out an intensive investigation into the hydrogeology of the Southern Perth Basin. This included an extensive drilling project and a review of all available information (Baddock 2005a at Appendix 11).
6. Water Corporation constructed, calibrated (Sun 2005 at Appendix 12) and interpreted (Baddock 2005b at Appendix 13) a numerical model of the South West Yarragadee aquifer system that built on the results of a previous joint project by the Water and Rivers Commission and Water Corporation. This model was peer reviewed and found to be suitable for regional-scale groundwater modelling (Peer Review Panel 2005 at Appendix 20).
7. URS Australia (2004b at Appendix 17) assessed the hydrogeology of groundwater dependent ecosystems in the Blackwood River area.
8. Bamford (2005 at Appendix 29) undertook a desktop review of the potential impacts of the predicted drawdowns on terrestrial fauna.

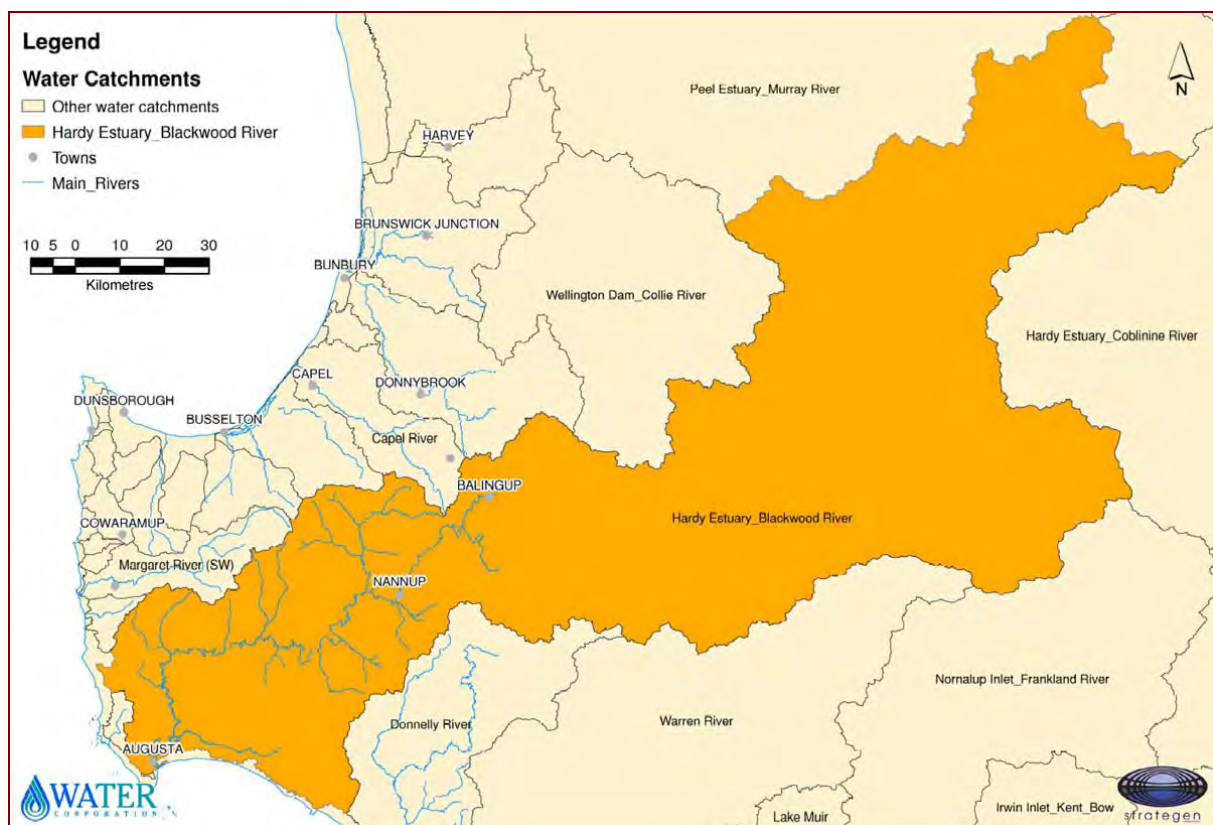
Morgan & Beatty (2005) undertook a baseline aquatic fauna study for the Department of Environment. The information from that study is included in this assessment.

1.1.2 Hydrology

The Blackwood River is seasonal for much of its length, with flows depending directly on rainfall. The river flows continuously downstream of a point between Nannup and Darradup, due to perennial groundwater discharge into the river and some of its tributaries. Tides affect the lower section of the river as far as 42 km inland. The tidal effect often extends past the confluence with Spearwood Creek. The mean annual discharge of the river to Hardy Inlet is approximately 940 GL. Chapman Brook and St John Brook are the most significant tributaries, each contributing approximately 5% of the Blackwood River total flow.

Groundwater from the Yarragadee Formation discharges directly to the Blackwood River along a 15 km stretch of the river upstream of Hut Pool, where Yarragadee Formation outcrops in the riverbed (Figure 5.5). The Yarragadee Formation also discharges to the water courses of Milyeannup Brook and Poison Gully. Approximately 1% of the 940 GL/yr mean annual flow of the Blackwood River is derived from groundwater discharge from the Yarragadee Formation. The groundwater component of the flow only becomes significant during summer when the flow is at its lowest. The groundwater component of total summer flow can vary from almost 100% in an extremely dry summer, to less than 30% in a wet summer. The hydrogeology of the area is described in Chapter 5 Section 1

Figure 7.1 Blackwood River Catchment



1.1.3 Water quality

The historically fresh Blackwood River has become brackish to saline due to dryland salinity in the upper catchment (Table 7.1). The current salinity levels are expected to double in the next 50 years irrespective of the proposal (CSIRO 2001). The river flow and water quality are highly seasonal, with high salt concentrations occurring during winter as salts accumulated in the upper catchment are flushed (Figure 7.3). Summer salinities are lower, as there are minimal surface water contributions from the upper catchment, and fresh groundwater inflows reduce the river salinity. Summer salinities decline to less than 1000 mg/L TDS. A peak salinity in excess of 6000 mg/L TDS was measured in the first winter flows of 2002 (Chapter 5 Section 4.3).

Figure 7.2 Location of the Blackwood River and tributaries

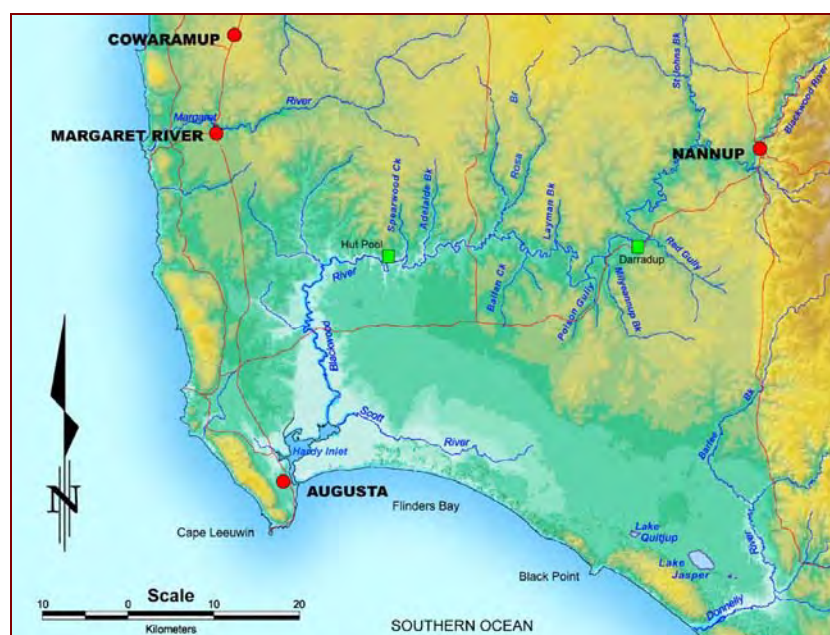
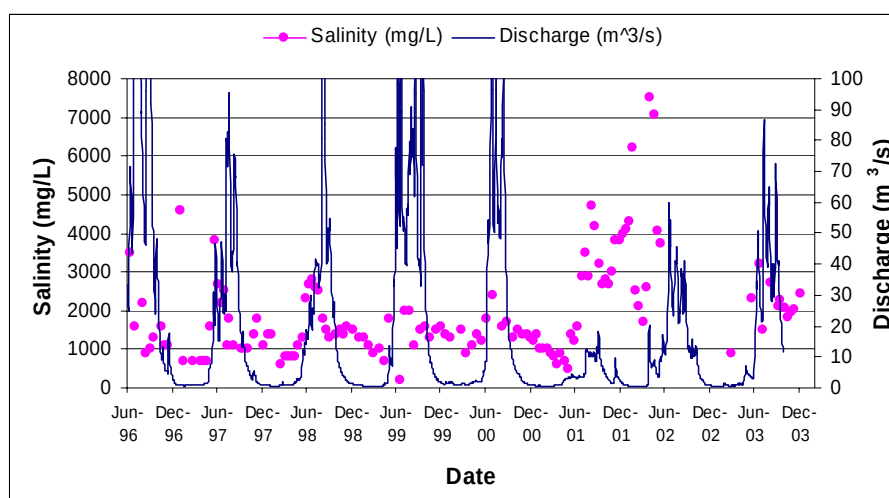


Figure 7.3 Salinity and flows in the Blackwood River 1996 – 2003 measured at Hut Pool



Dissolved oxygen is essential for fish respiration; 2.0 mg/L is considered the critical threshold below which respiration becomes difficult for many fish, especially if maintained for significant periods of time (ARMCANZ/ANZECC 2000). Dissolved oxygen is an issue in many Blackwood River pools, as it reduces to critically low values during the night (Appendix 27). Areas downstream of riffle zones³⁹ recover their oxygen levels much faster than other sites, which highlights the importance of the riffle zones in aerating the water and maintaining river health.

Nutrient levels in the main stem of the river are considerably higher than in its tributaries (Table 7.1). Total nitrogen concentrations in the river exceed low-risk trigger values for slightly disturbed fresh aquatic ecosystems (ANZECC/ARMCANZ 2000). Total nitrogen values in the river are an order of magnitude higher than levels in the tributaries (Table 7.1). Total phosphorous in the main river is higher than in the tributaries, but both are within the recommended guidelines. The measured nutrient levels are consistent with nutrient contributions from agricultural land in the upper Blackwood River catchment.

The water quality of the tributaries is more pristine than in the Blackwood River, consistent with the absence of agricultural activities in the tributary catchments.

Table 7.1 General water quality characteristics of the Blackwood River compared to the tributaries in July 2004

Location	Nutrients Total N (mg/L)	Nutrients Total P (mg/L)	pH	Salinity (mg/L)
St John Brook	0.18 – 0.28	0.01	7.7 – 8.0	210 - 240
Rosa Brook	0.05	0.01	7.5	280 - 360
Poison Gully	0.06	<0.01	7.7	450
Spearwood Creek	0.06	0.01	7.2	250
Adelaide Brook	0.11	<0.01	6.9	280
Blackwood River – upstream	2.1	0.02	7.8	3900
Blackwood River – downstream	1.5	0.02	7.7	4300
ANZECC/ARMCANZ trigger values for lowland rivers in South West Australia	1.2	0.065	6.0 – 8.0	na

CENRM (2005a)

1.1.4 Land use

The land along the Blackwood River from Nannup to Hut Pool has a mix of uses, including State forest with recreational areas, private agricultural land, and private bush blocks. Parts of the State forest have been included in the proposed Blackwood River National Park.

³⁹ Riffle zones are areas of rapid, shallow flow where surface agitation occurs resulting in increased opportunity for oxygenation of the water flow

1.1.5 Riparian vegetation

The vegetation along the Blackwood River is dominated by forests of flooded gums and peppermints, with denser patches of paperbarks adjacent to the river. The vegetation is predominantly of the Blackwood vegetation complex unit. The understorey varies in quality, as large sections have been subjected to human activities, and the number of introduced species is high in some areas. Mattiske (Appendix 31) surveyed cross-sectional transects at five sites along the Blackwood River, labelled 16, 17, 20, 22 and 23 in Figure 6.1.

Mattiske (Appendix 31) recorded one Priority Flora species and no Declared Rare or Endangered species in the five transects surveyed. *Stylidium barleei* is a Priority 3 species that occurs in both drier and moist sites, so is likely to be moderately dependent on the maintenance of groundwater levels. This species is not restricted to the Blackwood River and was also recorded in several other valley systems by Mattiske (Appendix 31).

The site-vegetation types defined by Mattiske (Appendix 31) in the Blackwood River transects were S1, S2, C5, T1 and Q1. These site-vegetation types are similar to the range of types found on the lower reaches of most of the tributaries. Of these, C5 is the most likely to be influenced by any drawdown of the watertable.

Mattiske (Appendix 31) assessed the health of trees along the Blackwood River according to a four point assessment scale:

1. Very sick.
2. Sick.
3. Slightly sick.
4. Healthy.

Tree health data collected by Mattiske (Appendix 31) showed that most trees on the Blackwood River transects were slightly sick to healthy. This is consistent with the normal range of tree health within a healthy system under no unusual stress (Mattiske EM pers. comm. 8 November 2005).

Jarrah trees along the Blackwood River were mostly in upland areas and mostly slightly sick with very sick trees at transect 17 near Sues Bridge. Marri trees were found mainly in upland areas, and were mostly slightly sick to healthy. At transect 16 near Layman Brook, the marri trees were considered sick. Some marri were recorded in intermediate areas, and some were in wetland habitats.

Melaleuca preissiana and *Melaleuca raphiophylla* were both found predominantly in low-lying wetland habitats along the river. At three sites they were slightly sick to healthy and at two sites (transects 22 and 23 near the junctions with Adelaide Brook and Poison Gully) were sick. Flooded gums were all slightly sick to healthy and were noted in a range of habitats from wetland to upland.

1.1.6 Aquatic fauna

CENRM (Appendix 27) and Morgan & Beatty (2005) recorded a total of five endemic freshwater fish, three estuarine fish, and two introduced fish species in the Blackwood River. Morgan & Beatty (2005) found that the diversity of fish species was greater within, and downstream of, the main groundwater discharge area, than upstream of the discharge.

One fish species of conservation significance was recorded in both summer and winter in the Blackwood River. Balston's pygmy perch (*Nanntherina balstoni*) is a CALM Priority 4 species and is considered to be the rarest of freshwater fish in The South West. It has a distribution between Two Peoples Bay in the east, and Margaret River in the west, and an isolated population at Gingin. The other fish species of conservation significance, the mud minnow, was not recorded in the Blackwood River in either the summer or winter sampling period.

The diversity of freshwater fish species decreased upstream of the main groundwater discharge area, with only one species recorded in summer and one in winter.

Mosquitofish were recorded in both summer and winter in the Blackwood River. In contrast, these introduced species were only recorded in three of the tributaries.

Macroinvertebrate sampling indicated that the biodiversity of the Blackwood River system was generally low. A total of 56 species were recorded in the main stem of the Blackwood River by CENRM (Appendix 27) in July 2004. The fauna recorded in the Blackwood River were dominated by species characterised as being able to tolerate a wide range of conditions, with some species being indicators of saline conditions.

Four species of known freshwater crayfish were recorded in summer in the Blackwood River, and two species in winter when the water is more saline (Table 6.7). Only two of these species, and one unidentified *Cherax* sp., were recorded upstream of the groundwater discharge area in the main stem of the Blackwood River (Morgan & Beatty 2005).

1.1.7 Terrestrial fauna

Fifteen frog species, 27 reptile species, 104 bird species, and 31 mammals species were identified by Bamford (2003 at Appendix 28) as potentially living in the Blackwood River area (including tributaries). Far fewer species would be expected to live on the main stem of the Blackwood River within the Yarragadee discharge.

The range of habitats along the main stem of the Blackwood River is fairly limited, due to the often steep banks and narrow extent of riparian vegetation. The tributaries and wetlands near the Blackwood River have a greater variety of habitat types for terrestrial fauna.

1.1.8 Social values

The Blackwood River has high social value for recreation, aesthetics, heritage, and as an icon that contributes to the sense of place of South West residents. It is a major regional tourist attraction. Two canoe operators are based on the river and operate year round, with a peak season in July when the water level and speed of the river is highest. One operator is based at River Road, and the other at Poison Swamp Road, just upstream of Poison Gully.

The Blackwood River retains significant heritage and cultural value for the Aboriginal community. There are numerous sites near the river that are listed on the DIA Register of Aboriginal Sites. This includes sites such as the Hardy Inlet (archaeological deposit, camp), Blackwood River Ochre Deposit, Sues Bridge (meeting place, camp, hunting place) and Blackwood Riverbank (mythological).

1.1.9 Threatening processes

In addition to increasing salinity levels, land clearing and agriculture has contributed to elevated nutrient and sediment levels in the Blackwood River, resulting in occasional blooms of blue-green algae (Appendix 27). High nutrient levels have resulted in recurrent blooms of cyanobacteria in some reaches.

Soil erosion, high turbidity, and pool aggradation (filling with sediment) have also contributed to water quality problems in the Blackwood River, including the increased likelihood of pool anoxia (Appendix 27).

The recent dry rainfall period (and possibly the long-term drying trend due to climate change) is already having a significant impact on the Blackwood River. The DoE collect annual phytoplankton samples at 15 sites along the Blackwood River. Within a five-year period, significant changes to water quality and flora were found, mostly related to low rainfall and the resulting increase in salinity (Appendix 27).

1.2 ASSESSMENT FRAMEWORK AND POLICY CONTEXT

The following policies and legislation are relevant to the impact assessment of the Blackwood River and its associated ecosystems and are described in Chapter 2:

- *Wildlife Conservation Act 1950*
- *Conservation and Land Management Act 1984*
- *Environmental Protection and Biodiversity Conservation Act 1999*
- National Objectives and Targets for Biodiversity Conservation 2001
- Conservation Policy for Western Australia 1997

1.2.1 Key EPA and other policies

The key policies that have been applied to the assessment of the several factors covered in this section, and which provide a critical test of environmental sustainability, are as follows:

- Wetlands Conservation Policy for Western Australia, 1977
- Statewide Policy on Environmental Water Provisions, Water and Rivers Commission 2000
- EPA Position Statement No. 2: Environmental Protection of Native Vegetation in Western Australia 2000.
- EPA Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection 2002.
- EPA Position Statement No. 4: Environmental Protection of Wetlands 2004
- EPA Preliminary Position Statement No. 9 (V2): Environmental Offsets 2005
- Forest Management Plan 2004–2013 (2004).

1.3 POTENTIAL IMPACTS AND MITIGATION

1.3.1 Groundwater drawdown

Modelling results indicated that drawdowns of the watertable could occur along the Blackwood River valley. However, as the Blackwood River valley slopes are steep, with artesian pressure maintaining watertable levels at the valley floor, most of the potential drawdown occurs in mid – upslope areas with deep watertables (deeper than 10 m) where vegetation is unlikely to be groundwater dependent. The river floodplain terrace has a shallow watertable, but the river alluvium isolates the watertable from the underlying Yarragadee aquifer. The watertable in the floodplain alluvial aquifer is maintained largely by infiltration from river bank storage after the annual winter river flood, and from runoff and seepage from the valley flanks (Appendix 13). Therefore, there is likely to be no significant impact on watertable levels along the Blackwood River as a consequence of the proposal.

The main impact will be that reduced pressure in the Yarragadee aquifer will reduce groundwater discharge to the Blackwood River, as described in Section 1.3.3 of this Chapter.

1.3.2 Effects on groundwater dependent vegetation

There is not expected to be any impact on vegetation along the Blackwood River valley as the vegetation on the floodplain is supported by a perched alluvial aquifer, and the slopes of the valleys have deep watertables where vegetation is unlikely to be groundwater dependent.

1.3.3 Stream flows and quality

During winter, the groundwater component of the Blackwood River flow is negligible compared to the amount of surface water flowing through the system. It is only when surface water flow decreases in summer and autumn that the groundwater component of flow becomes significant in volume, and in its contribution to water quality.

The predicted drawdown from the proposed Water Corporation abstraction could potentially result in a 6% reduction in minimum summer flows in the driest years (those with no surface runoff). The maximum cumulative predicted drawdown, after 30 years of the proposed abstraction and estimated regional use, could potentially result in a 13% reduction in the minimum summer flow in the driest years. In most years, there is some summer rainfall in the catchment, so the reduction in flow would be substantially less than 13%.

The salinity of the Blackwood River decreases in summer downstream of Nannup as it is diluted by fresh groundwater. Reducing the groundwater baseflow of the Blackwood River by 13% will tend to increase summer salinities over time (Appendix 13). The summer salinity will be, on average 20% higher than in the driest month but will still be much lower than during the rest of the year. For the driest two months (January – February), salinity may increase by an average of 14%. The Water Corporation proposal by itself would cause an increase in salinity in summer of approximately half that. These changes may not be measurable given the high seasonal fluctuations in flow and quality in the Blackwood River. The predicted change in salinity is not expected to have a significant impact on the ecological values of the already altered Blackwood River. The significance of the change to salinity in the Blackwood River should also be viewed in the context that, without substantial management intervention and land use change, the salinity of the Blackwood River is expected to double over the next 50 years.

1.3.4 Aquatic fauna

The Blackwood River and tributaries require certain flows at different times of the year to maintain ecological processes. These flows can be broadly grouped as peak flows, high winter flows, and summer base flows (Appendix 27). The major water requirements to maintain the current system are:

1. **Channel maintenance:** High and flood flows are required to scour pools and shape the channel to provide a variety of habitats.
2. **Riparian vegetation:** Requires periodic seasonal inundation.
3. **Reproductive flows:** Freshwater fish require reasonably high flows in September and October to enable reproductive migration.
4. **Pool water quality:** Pools within the river system are important habitats and require base flow to prevent dissolved oxygen levels becoming fatally low at night. This issue becomes even more important when erosion causes sedimentation in the pools and reduces the volume of the pool.
5. **Water quality:** Flows need to maintain water quality within the tolerance range of the aquatic fauna in the system.
6. **Flow permanence:** Aquatic macroinvertebrates mostly require permanent flows, especially over riffle zones which are important habitats.
7. **Ecological linkages:** Tree matter from upstream areas contributes energy further down the river systems. Permanent flows are required to maintain these linkages.

As the discharges into the Blackwood River system from groundwater are only significant in summer, only the summer flows have the potential to be affected by groundwater abstraction. Of the above water requirements, only pool water quality, tributary permanence, and ecological linkages are related to the summer flows. As the permanence of the Blackwood River is not at risk, water quality and the flows to maintain it are the potential impacts of the proposal.

The 13% reduction in groundwater discharge to the Blackwood River (6% from the Water Corporation proposal) after 30 years of abstraction may have the following potential impacts on aquatic fauna:

- direct reduction in summer water quality through the reduction in fresh groundwater inputs
- reduction of dissolved oxygen levels in pools, by reducing the flow of water over riffle zones where it is oxygenated before entering the pools.

CENRM (Appendix 27) quantified the flow requirements of the Blackwood River, Rosa Brook and St John Brook, based on the requirements outlined above, the field work undertaken, and the available flow monitoring data. The flow requirements are different for each month but, typically, the flows required to sustain the ecological values of the Blackwood River were 25 – 30% of current flows (Appendix 27). This means that flows would have to reduce by more than half before having the potential to affect the ecological values of the system. The Blackwood River will continue to meet all those defined water requirements even if a 10% reduction in summer baseflows occurs in the driest years.

CENRM (Appendix 27) made water quality measurements in the winter of 2004 at the same sites and times as the fish sampling. The water quality within, and downstream from, the discharge area in July 2004 was saline, with measurements ranging from 3900 mg/L to 5200 mg/L (Appendix 27). This demonstrates that adults of the five endemic freshwater fish species that were recorded at these sites have some tolerance to saline conditions. The tolerance of juveniles to salinity is largely unknown, but the fresher tributaries are likely to play an important role as nursery habitat. The macroinvertebrates recorded in the Blackwood River in winter were dominated by species able to tolerate a wide range of conditions, including saline conditions (Appendix 27). Five species of freshwater crayfish were recorded in the Blackwood River in summer (Morgan & Beatty 2005) and only two were recorded in winter (Appendix 27).

These results demonstrate that the Blackwood River is no longer a permanent habitat for freshwater species that are not salt tolerant. However, there may be summer migration of freshwater species that are sensitive to salinity back into the main stem of the river. If the summer salinity and flows were altered significantly, this summer migration of freshwater species back into main stem could be affected.

The modelled 13% reduction in groundwater flow is predicted to have an associated 14% increase in salinity in the driest two months of the year, but will still be much lower than salinity levels during the rest of the year (just over half of this increase would be caused by the Water Corporation proposal). Given the high seasonal and year-to-year salinity variations (Figure 7.3), the increase in average summer salinity of 14% after 30 years is not expected to have a significant impact on the fauna of the river.

Reduced flows also have the potential to reduce the flushing of deep pools where dissolved oxygen levels already fall to critical levels during the night (Appendix 27). CENRM (2005a) concluded that approximately 30% of the existing summer flows are required to ensure no temporal increase in the existing levels of pool anoxia. At least 80% of the current baseflows will be maintained, so the environmental water requirements (EWRs) defined by CENRM (Appendix 27) are expected to be met within the impacts of the proposal and estimated future regional use.

1.3.5 Terrestrial fauna

The wetland vegetation along the Blackwood River is in an area of seasonal inundation, seepage from bank storage and from an alluvial aquifer that is isolated from the underlying Yarragadee aquifer (Appendix 13). These systems will continue to refill each winter and are not expected to be impacted by the proposal (Appendix 13). Therefore, there are not expected to be changes in the vegetation along the Blackwood River, and consequently no impact on the terrestrial fauna.

1.3.6 Compliance with EPA Offsets Position Statement

The EPA Offsets Position Statement is discussed in Chapter 2 Section 6.1. The following table details the potential impacts of the proposal on the critical assets associated with the Blackwood River.

Table 7.2 Compliance with EPA Offsets Position Statement for the Blackwood River

Critical assets	Prognosis
Declared Rare Flora	Extensive surveys of flora along the Blackwood River have not been carried out. However, the vegetation along the Blackwood River generally is not connected to, or has a low dependence on, groundwater and is not expected to be significantly impacted.
Priority Flora	As for Declared Rare Flora
Threatened Ecological Communities	None present
Vegetation complexes with <30% remaining	None present and negligible impact on the local and regional abundance
Threatened Fauna	Negligible impact on terrestrial habitat or aquatic habitat.
Public conservation reserve system	Partially within the proposed Blackwood River National Park. There are no significant impacts expected on the recreational, aesthetic or ecological values of the Blackwood River. Due to the high social value, a contingency to supplement summer flows to maintain pool levels will be implemented if unexpected and unacceptable impacts occur.
Conservation category wetland	None present
Ecosystems under threat	None present
Indigenous heritage sites	The Hardy Inlet (archaeological deposit, camp), Blackwood River Ochre Deposit, Sues Bridge (meeting place, camp, hunting place) and Blackwood Riverbank (mythological) are listed on the Register of Aboriginal Sites. None of these sites will be either directly or indirectly disturbed by the proposal.
Identified heritage places under EPBC Act	None present

There are no potentially significant impacts expected in the Blackwood River, as shown in Table 7.10. Due to the high social value of the Blackwood River, and as a precautionary risk management option, a contingency measure to supplement summer flows will, however, be developed.

1.3.7 Mitigation

The wellfield location and configuration was chosen to minimise both the environmental impacts and those on other water users. A review of the results of groundwater modelling of the drawdowns, and the associated environmental risks of several different wellfield configurations, resulted in the “Eastern Split” wellfield being chosen as the preferred option. All the wellfield configurations considered had a similarly low risk of impact on the Blackwood River.

No significant impact is expected on the ecological values of the Blackwood River from the proposal. However, to give effect to the sustainability objective for the *Biodiversity and ecological integrity* principle, which seeks to increase the ecological integrity of the Blackwood River, and in recognition of the high social value of the Blackwood River, the following will be undertaken to enhance the environmental outcome and provide a net environmental benefit.

1. The wellfield will be constructed to enable flexibility in the proportion of water abstracted from different layers in the Yarragadee Formation to minimise overall environmental impact.
2. A major regional biodiversity study will be carried out, which will include the Blackwood River, to gain greater knowledge of both terrestrial and aquatic groundwater dependent ecosystems in the area.
3. The Water Corporation proposes to sponsor a program to manage threatening processes (feral animals, weeds, bank instability) in the areas that may be affected by the proposal including the Blackwood River.

If monitoring identifies unexpected and unacceptable impacts are likely on the Blackwood River due to the project, the contingency action will be to supplement flows in the Blackwood River. The triggers for this contingency measure will be defined as part of the adaptive management process in consultation with the proposed Monitoring Review Group.

These mitigating actions will be undertaken by the Water Corporation to offset the combined impacts of the proposal, and other regional abstraction, if the proposal is approved.

Mitigation benefits

There are significant threats to the ecosystems of the Blackwood River, including feral animals, weeds, dieback and climate change. Research is essential to further the understanding of the ecosystem and to allow informed decision making in managing threatening processes. An overarching biodiversity study in the region will add resources to research efforts in the region, and increase the effectiveness of funds already being spent by consolidating existing knowledge.

Feral animal control projects such as the Western Shield program have proved to be effective in increasing the numbers of rare native mammals. However, these programs require ongoing funding to continue to be effective. The Water Corporation proposal to provide resources for the management of feral animals will have a direct biodiversity benefit. In addition to foxes and cats, feral pigs are a known threat to native animals in this area, and their digging in wetland environments is destructive. Targeting this species in a feral animal control program will decrease a significant threat to wetland environments and the flora and fauna they support.

The contingency measure of this proposal, to supplement summer flows in the Blackwood River, adds a degree of protection to these aquatic habitats that would not exist if only private groundwater abstraction was to take place.

1.4 MONITORING, ADAPTIVE MANAGEMENT AND ACCOUNTABILITY

The Water Corporation will develop and implement an extensive biological, hydrological and physical monitoring program for the region, which will include the Blackwood River area. The Water Corporation is also committed to undertaking a comprehensive biodiversity study as part of the South West Yarragadee Sustainability Initiative, which will include the Blackwood Plateau and investigate the relationship between ecosystems and groundwater (Volume 1 Chapter 8 Section 4.1.1).

The outputs of the monitoring program and biodiversity study, together with advice from the Monitoring Review Group, will form the basis of the adaptive management framework for the Blackwood River and other areas of potential impact.

The monitoring program will include a baseline study, to be completed before the operational phase of the project that will allow both hydrological and ecological changes and trends to be assessed. The monitoring program and biodiversity study will be developed in consultation with the proposed South West Yarragadee Monitoring Review Group (Volume 1 Chapter 8 Section 3.2.3). A preliminary outline of a monitoring program for the Blackwood River has been developed (Table 7.3).

Table 7.3 Proposed Blackwood River monitoring program

Parameter	Monitoring	Method
Hydrology	Gauging station (Blackwood River)	Daily flows at the existing gauging stations
Physical	Water quality sampling	Monthly at gauging station sites
	Dissolved oxygen	In selected pools. Monthly in summer for 10 minute intervals over 24 hours
Biological	Aquatic macroinvertebrates	Twice annually during February and September at four sites between Darradup and Hut Pool in the Blackwood River
	Fish recruitment	Annually at four sites between Darradup and Hut Pool in the Blackwood River in October to coincide with breeding
	Riparian assessment	Annually (winter) at a range of sites between Darradup and Hut Pool (~10 sites) in the Blackwood River
	Tree health	Annually at a range of sites between Darradup and Hut Pool.
	Weeds	Annually at a range of sites between Darradup and Hut Pool

Monitoring program based on the recommendations of CENRM (2005a)

The Water Corporation will prepare an annual Sustainability Report (Volume 1 Chapter 8 Section 3.2.4) that will report on the monitoring results. The Monitoring Review Group will review the monitoring results against a set of defined principles and advise whether any changes to the management of the project are needed.

1.5 PROPONENT COMMITMENTS

The Water Corporation is committed to an adaptive management approach and to the following:

1. Undertake a biodiversity and acid sulphate soils study in areas potentially affected by groundwater drawdown resulting from the proposal. The studies will be funded up to the value of \$1.5M, with the capital and any earned interest made available to the studies over a period of ten years.
2. Prepare, and report on the implementation of, abstraction management plans and associated monitoring programs for the groundwater abstraction in accordance with any licence issued pursuant to the RWI Act and the Groundwater Abstraction Management Plan described in Chapter 9 Section 8.
3. The Water Corporation will contribute to a 5 year program to assist the management of threatening processes in areas that may be affected by the proposal. The funding will be up to \$1M with the capital and any earned interest made available to the management program over a period of five years. The program will address weeds, disease, feral animals, erosion and uncontrolled public access issues insofar as they exist within the potentially affected areas including the Blackwood River.

1.6 ENVIRONMENTAL OUTCOME

No impact is expected on the terrestrial or riparian environment along the Blackwood River, as these are reliant on peak surface flows and shallow alluvial aquifers that are isolated from the Yarragadee Formation and will not be affected by the proposal.

The predicted drawdown from the Water Corporation proposal only would result in a 6% reduction in the summer baseflow of the Blackwood River in the driest years (those with no summer surface runoff). The combined cumulative impact from estimated future regional use and the proposal is expected to result in a 13% reduction in the minimum summer flows. In most years, there is some summer rainfall in the catchment, so the reduction in flow would be substantially less than 10%. The cumulative reduced baseflow will continue to meet all the EWRs defined for the Blackwood River.

The Water Corporation proposal alone would cause an increase of less than 10% in salinity during the two driest summer months. This change in salinity is not expected to have a significant impact on the ecological values of the already altered Blackwood River. A 13% reduction in groundwater discharge to the Blackwood River (cumulative impact) is expected to cause a 14% increase in the summer salinity of the river during the driest two months of the year, but will still be much lower than during the rest of the year. The significance of the change to salinity in the Blackwood River should also be viewed in the context that the salinity of the Blackwood River is highly variable, and expected to double over the next 50 years.

Proposed mitigation includes a commitment to supplement summer flows in the Blackwood River if unexpected and unacceptable impacts are likely to occur.

Other commitments to reduce threatening processes in the area will restore ecological values currently affected, or under threat, and enhance biodiversity in the area. The knowledge and data obtained from the proposed biodiversity study and comprehensive monitoring program will improve the understanding of the area and provide for adaptive management to ensure the area is cautiously managed into the future, even in the context of climate change.

2 POISON GULLY AND MILYEANNUP BROOK

Objectives

The sustainability objective for the *Blackwood River and its tributaries* factor is:

The Water Corporation will seek to increase the ecological integrity of the Blackwood River and its tributaries.

At a minimum, the proposal will have no significant adverse impact on the Blackwood River and its tributaries.

The *Threatened fauna, Flora and fauna, Rare and priority flora (groundwater dependent)* and *Other groundwater dependent ecosystems* factors and their objectives are also addressed in this section.

The EPA objective for wetlands (including rivers) is:

To maintain the integrity, ecological functions and environmental values of wetlands.

2.1 EXISTING ENVIRONMENT

2.1.1 Relevant investigations

The Water Corporation has undertaken an extensive range of studies to identify the values and assess the potential impacts of the proposal on Poison Gully and Milyeannup Brook including the following:

1. CENRM (2005a at Appendix 27) investigated the ecological values of the Blackwood River system and provided an increased understanding of the ecological susceptibility of those values to changes in water regime (both quality and quantity). The study included one site each on Poison Gully and Milyeannup Creek, and the investigations included fish species, aquatic macroinvertebrates, channel morphology, water quality, and a vegetation and foreshore assessment. The Milyeannup Brook site was near the Blackwood Road, and the Poison Gully site was near the Brockman Highway.
2. CENRM (2005b at Appendix 26) investigated the aquatic habitat of Milyeannup Brook, Poison Gully and St John Brook and its relationship to hydrological regimes in these streams.
3. Morgan et al. (2004) conducted a fauna survey of Rosa Brook, Layman Brook and Adelaide Creek as part of an assessment of groundwater discharge to Rosa Brook from an aquifer test well.
4. Mattiske (2005a at Appendix 31) evaluated the flora and vegetation values along seven cross-sectional transects in Poison Gully, and four transects along Milyeannup Brook in winter and spring 2004. The transect information, detailed field observations and aerial photograph interpretation were used to undertake vegetation mapping of both valleys to the site-vegetation type level. Upland vegetation was not mapped, as it is not likely to be groundwater dependent.
5. Mattiske (2005b at Appendix 32) evaluated the susceptibility of the flora and vegetation values to groundwater drawdown in the potentially affected areas.
6. Bamford (2003 at Appendix 28) assessed the fauna species that are likely to occur in the potential impact areas and assessed their likely groundwater dependence.
7. Synnott Mulholland Management Service (2005 at Appendix 3) conducted a social impact assessment that included consideration of recreational, aesthetic, and sense of place values of the Blackwood River and its tributaries.

8. Water Corporation carried out an intensive investigation into the hydrogeology of the Southern Perth Basin. This included an extensive drilling project and a review of all available information (Baddock 2005a at Appendix 11).
9. Water Corporation constructed, calibrated (Sun 2005 at Appendix 12) and interpreted (Baddock 2005b at Appendix 13) a numerical model of the South West Yarragadee aquifer system that built on the results of a previous joint project by the Water and Rivers Commission and Water Corporation. This model was peer reviewed and found to be suitable for regional-scale groundwater modelling (Peer Review Panel 2005 at Appendix 20).
10. URS Australia (2004b at Appendix 17) assessed the hydrogeology of groundwater dependent ecosystems in the Blackwood River area.
11. Bamford (2005 at Appendix 29) undertook a desktop review of the potential impacts of the predicted drawdowns on terrestrial fauna.

A complementary baseline aquatic fauna study has been undertaken by Morgan & Beatty (2005) for the Department of Environment. The information from that study is included in this assessment.

2.1.2 Hydrology

Poison Gully is a perennial tributary of the Blackwood River. Groundwater discharging from the Yarragadee Formation maintains the summer baseflow (22 L/s in April 2004) (Appendix 17). The majority of groundwater baseflow is gained in the lower-most portion of the gully where localised pools are maintained throughout the year. The stream is permanent for 3.5 km upstream of its junction with the Blackwood River. Aerial photograph interpretation suggests that in the past the extent of perennial flow extended several hundred metres further up the gully than currently observed (Appendix 13).

Milyeannup Brook is also a perennial tributary with permanent discharge starting 2.5 km from its junction with the Blackwood River. The brook is approximately 17 km long. The channel of the brook is narrow (a few metres wide) and incised to about two metres depth. Permanent pools persist in the lower reaches of Milyeannup Brook throughout the year.

The summer flows of Poison Gully and Milyeannup Brook are directly sustained by the Yarragadee Formation which outcrops in this area. Each tributary contributes in excess of 20 L/s of groundwater derived flow into the Blackwood River (Appendix 13). This amounts to 0.1 GL/month of Yarragadee Formation discharge to the Blackwood River from the two tributaries, which is approximately 15% of the total Yarragadee Formation discharge into the Blackwood River.

2.1.3 Land use

Poison Gully and Milyeannup Brook are both entirely within State forest. The upper catchments of both valleys are within the proposed Milyeannup National Park (Figure 7.15).

2.1.4 Vegetation and flora

The upper reaches of Poison Gully are broad and swampy. The lower valley is narrow and similar to other tributaries in the area. Poison Gully supports a relatively high biodiversity in comparison to the other tributaries in the area, due to the range of soils and soil moisture conditions present in the broad valley (Appendix 31).

Sedgeland is present in the upper reaches of Poison Gully on clay soils that support seasonally perched water⁴⁰. Further down the valley, the vegetation consists of a range of closed heath and low paperbark woodlands on leached white sands that are seasonally moist. Near the Blackwood River, the valley narrows, and the vegetation is similar in composition to that of the other nearby tributaries, with narrow linear communities along the creek-lines (Appendix 31).

The potentially affected vegetation complexes in Poison Gully are in areas where the watertable is at a depth of 10 m or less. These are the Jalbarragup vegetation complex and, to a lesser extent, the Bidella vegetation complex, which occupy the wider parts of the valley. More than 89% of the pre-European extent of these vegetation complexes remains in public land and is largely undisturbed. Approximately 14% of the pre-European extent of the Jalbarragup vegetation complex and 28% of the Bidella vegetation complex are protected in formal conservation reserves (Appendix 32).

Mattiske (Appendix 31) mapped nine site-vegetation types in Poison Gully (Table 7.4 and Figure 7.5, Figure 7.6 and Figure 7.7). Of these, the A1, B1, D3 and C1 site-vegetation types are the most likely to be influenced by any drawdown of the watertable. The A2 and A3 vegetation types in Pig Swamp, and A4 vegetation type on clays in the upper part of Poison Gully, are unlikely to be susceptible to changes in regional watertable as they rely on locally perched watertables.

Table 7.4 Description of site-vegetation types that occur in Poison Gully

Site-vegetation type	Description of vegetation
A1	Closed heath of <i>Taxandria parviceps</i> , <i>Taxandria linearifolia</i> , <i>Hypocalymma angustifolium</i> , <i>Beaufortia sparsa</i> , <i>Hypocalymma cordifolium</i> and <i>Acacia divergens</i> over a range of sedges with pockets of <i>Melaleuca preissiana</i> and <i>Banksia littoralis</i>
A2	Closed heath of <i>Melaleuca lateritia</i> over <i>Baumea vaginalis</i> , <i>Myriophyllum ?limnophilum</i> and <i>Triglochin huegelii</i>
A3	Closed heath of <i>Melaleuca lateritia</i> , <i>Taxandria linearifolia</i> , <i>Hypocalymma angustifolium</i> , <i>Beaufortia sparsa</i> , over a range of sedges with pockets of <i>Eucalyptus rudis</i> and <i>Banksia littoralis</i>
A4	Low sedgeland of <i>Schoenus subfascicularis</i> to open heath of <i>Acacia pulchella</i> var. <i>pulchella</i> , <i>Adenanthos meisneri</i> , <i>Sphaerolobium fornicatum</i> and <i>Daviesia decurrens</i>
B1	Low open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> – <i>Corymbia calophylla</i> – <i>Xylomelum occidentale</i> – <i>Banksia attenuata</i> – <i>Banksia ilicifolia</i> over <i>Taxandria parviceps</i> , <i>Hypocalymma angustifolium</i> and <i>Acacia extensa</i> and a range of low shrubs and herbs
C1	Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> – <i>Corymbia calophylla</i> – <i>Eucalyptus patens</i> over <i>Trymalium floribundum</i> , <i>Taxandria linearifolia</i> , <i>Taxandria parviceps</i> , <i>Hypocalymma cordifolium</i> , <i>Astartea scoparia</i> and <i>Gastrolobium bilobum</i> over <i>Baumea vaginalis</i> and <i>Lepidosperma gladiatum</i>
C4	Open forest of <i>Corymbia calophylla</i> – <i>Eucalyptus patens</i> – <i>Banksia littoralis</i> with occasional <i>Banksia seminuda</i> over <i>Agonis flexuosa</i> , <i>Trymalium floribundum</i> , and <i>Taxandria linearifolia</i> over <i>Bossiaea aquifolium</i> subsp. <i>laidlawiana</i> , <i>Lepidosperma gladiatum</i> , <i>Lepidosperma tetraquetrum</i> and <i>Baumea vaginalis</i>
C5	Open forest of <i>Eucalyptus rudis</i> – <i>Agonis flexuosa</i> – <i>Melaleuca raphiophylla</i> over patches of <i>Melaleuca viminea</i> , <i>Astartea scoparia</i> , <i>Taxandria linearifolia</i> , and <i>Lepidosperma gladiatum</i> , <i>Lepidosperma tetraquetrum</i> and <i>Baumea vaginalis</i>
D3	Woodland of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> – <i>Corymbia calophylla</i> over <i>Baeckea camphorosmae</i> , <i>Hypocalymma angustifolium</i> and <i>Meeboldina</i> species

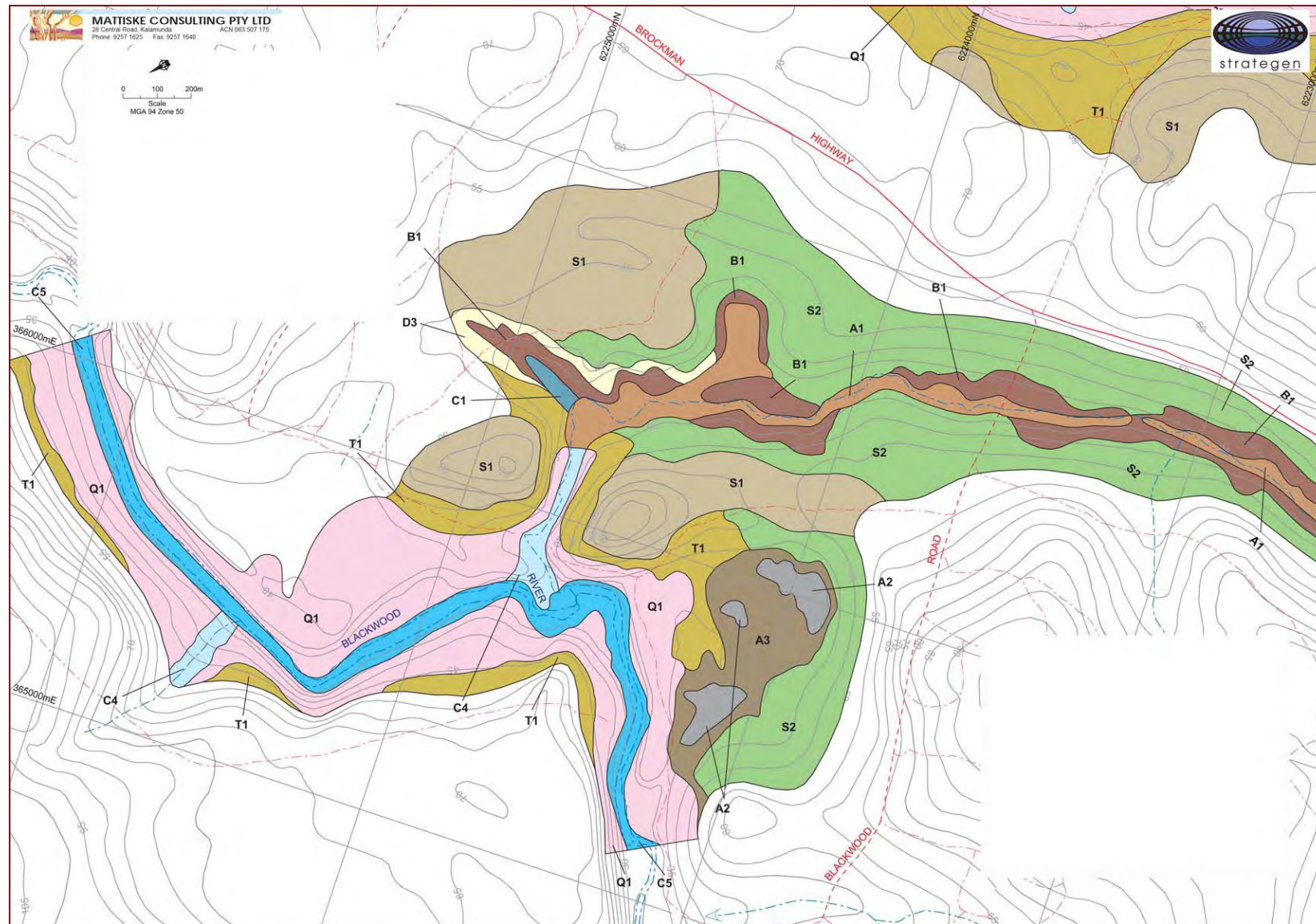
Figure 7.8 shows the central section of Poison Gully, looking north and showing *Beaufortia sparsa*, *Callistemon glaucus*, *Taxandria linearifolia*, *Taxandria fragrans* over mixed sedges on the valley floor, with open forest of jarrah, marri and Sheoak over low shrubs and sedges in the background.

⁴⁰ Perched water is a local water body that occurs above the watertable, and is geologically isolated from the main underlying groundwater bodies.

Figure 7.4 Legend to Poison Gully vegetation mapping (Figure 7.5, Figure 7.6 and Figure 7.7)

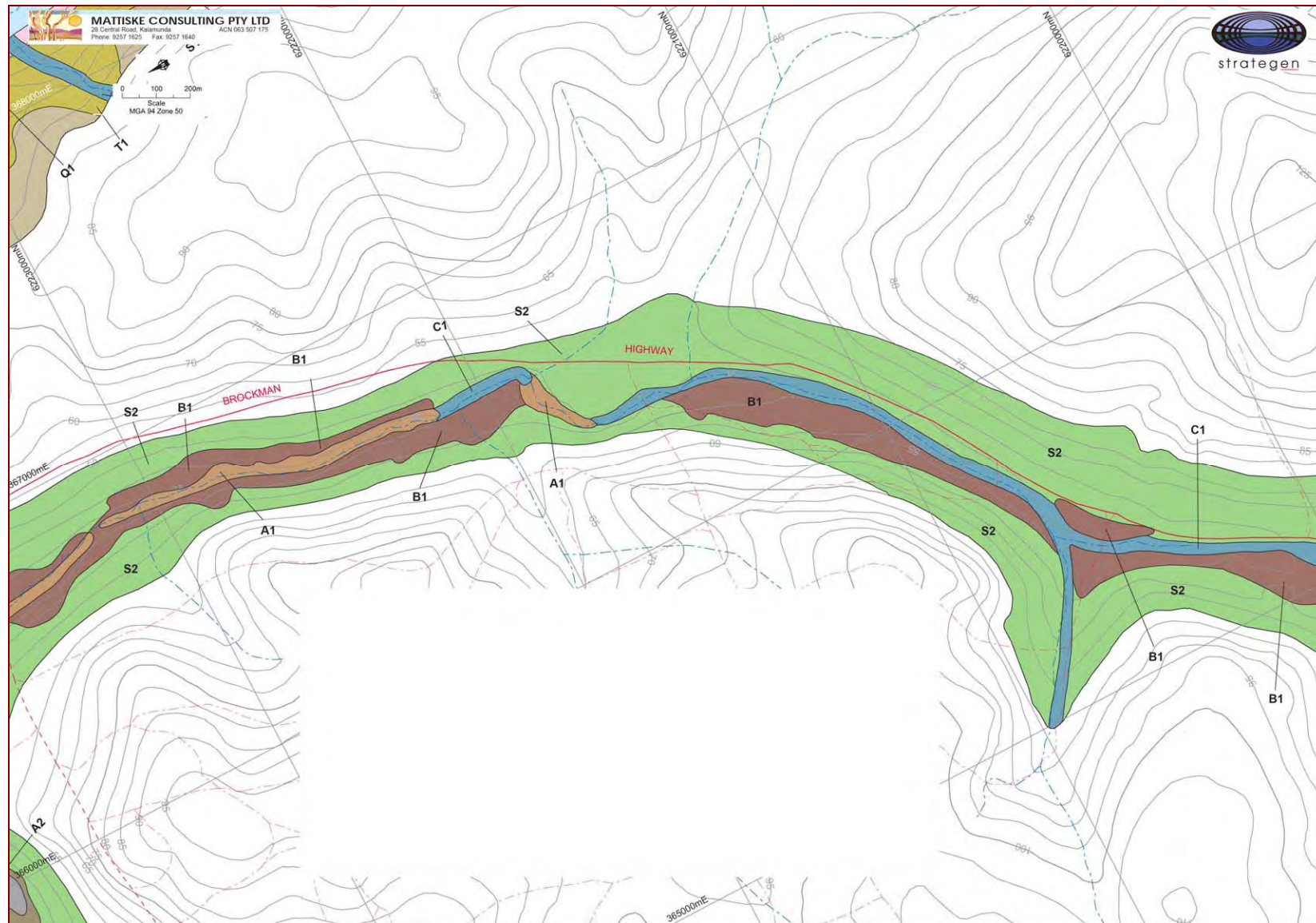
	S1:	Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> - <i>Corymbia calophylla</i> over occasional <i>Banksia grandis</i> over <i>Podocarpus drouynianus</i> , <i>Xanthorrhoea preissii</i> and <i>Macrozamia nedlei</i> .
	S2:	Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> - <i>Corymbia calophylla</i> - <i>Allocasuarina fraseriana</i> - <i>Xylomelum occidentale</i> over <i>Dryandra lindleyana</i> var. <i>lindleyana</i> , <i>Dasypogon hookeri</i> , <i>Hakea amplexicaulis</i> , <i>Adenanthos barbiger</i> and a range of low shrubs and herbs.
	D3:	Woodland of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> - <i>Corymbia calophylla</i> over <i>Baeckea camphorosmae</i> , <i>Hypocalymma angustifolium</i> and <i>Meeboldina</i> species.
	B1:	Low open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> - <i>Corymbia calophylla</i> - <i>Xylomelum occidentale</i> - <i>Banksia attenuata</i> - <i>Banksia ilicifolia</i> over <i>Taxandria parviceps</i> , <i>Hypocalymma angustifolium</i> and <i>Acacia extensa</i> and a range of low shrubs and herbs.
	A1:	Closed heath of <i>Taxandria parviceps</i> , <i>Taxandria linearifolia</i> , <i>Hypocalymma angustifolium</i> , <i>Beaufortia sparsa</i> , <i>Hypocalymma cordifolium</i> and <i>Acacia divergens</i> over range of sedges with pockets of <i>Melaleuca preissiana</i> and <i>Banksia littoralis</i> .
	A2:	Closed heath of <i>Melaleuca lateritia</i> over <i>Baumea vaginalis</i> , <i>Myriophyllum ?limnophilum</i> and <i>Triglochin huegelii</i> .
	A3:	Closed heath of <i>Melaleuca lateritia</i> , <i>Taxandria linearifolia</i> , <i>Hypocalymma angustifolium</i> , <i>Beaufortia sparsa</i> , over range of sedges with pockets of <i>Eucalyptus rudis</i> and <i>Banksia littoralis</i> .
	A4:	Low sedgeland of <i>Schoenus subfascicularis</i> to Open Heath of <i>Acacia pulchella</i> var. <i>pulchella</i> , <i>Adenanthos meisneri</i> , <i>Sphaerolobium fornicatum</i> and <i>Daviesia decurrens</i> .
	C1:	Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> - <i>Corymbia calophylla</i> - <i>Eucalyptus patens</i> over <i>Trymalium floribundum</i> , <i>Taxandria linearifolia</i> , <i>Taxandria parviceps</i> , <i>Hypocalymma cordifolium</i> , <i>Astartea scoparia</i> and <i>Gastrolobium bilobum</i> over <i>Baumea vaginalis</i> and <i>Lepidosperma gladiatum</i> .
	C4:	Open forest of <i>Corymbia calophylla</i> - <i>Eucalyptus patens</i> - <i>Banksia littoralis</i> with occasional <i>Banksia seminuda</i> over <i>Agonis flexuosa</i> , <i>Trymalium floribundum</i> and <i>Taxandria linearifolia</i> over <i>Bossiaea aquifolium</i> subsp. <i>laidlawiana</i> , <i>Lepidosperma gladiatum</i> , <i>Lepidosperma tetraquetrum</i> and <i>Baumea vaginalis</i> .
	C5:	Open forest of <i>Eucalyptus rudis</i> - <i>Agonis flexuosa</i> - <i>Melaleuca raphiophylla</i> over patches of <i>Melaleuca viminea</i> , <i>Astartea scoparia</i> , <i>Taxandria linearifolia</i> and <i>Lepidosperma gladiatum</i> , <i>Lepidosperma tetraquetrum</i> and <i>Baumea vaginalis</i> .
	T1:	Open forest of <i>Corymbia calophylla</i> - <i>Eucalyptus marginata</i> subsp. <i>marginata</i> over occasional <i>Banksia littoralis</i> , <i>Agonis flexuosa</i> over <i>Pteridium esculentum</i> , <i>Clematis pubescens</i> and <i>Leucopogon verticillatus</i> , <i>Leucopogon australis</i> , <i>Bossiaea linophylla</i> and <i>Acacia browniana</i> var. <i>browniana</i> .
	Q1:	Open forest of <i>Corymbia calophylla</i> - <i>Eucalyptus patens</i> - <i>Eucalyptus rudis</i> - <i>Eucalyptus marginata</i> subsp. <i>marginata</i> over occasional <i>Banksia littoralis</i> over <i>Pteridium esculentum</i> , <i>Gastrolobium bilobum</i> , <i>Acacia alata</i> var. <i>alata</i> and <i>Trymalium floribundum</i> .

Figure 7.5 Site-vegetation type mapping along Poison Gully, Map 1 (See Figure 7.4 for legend to vegetation types)

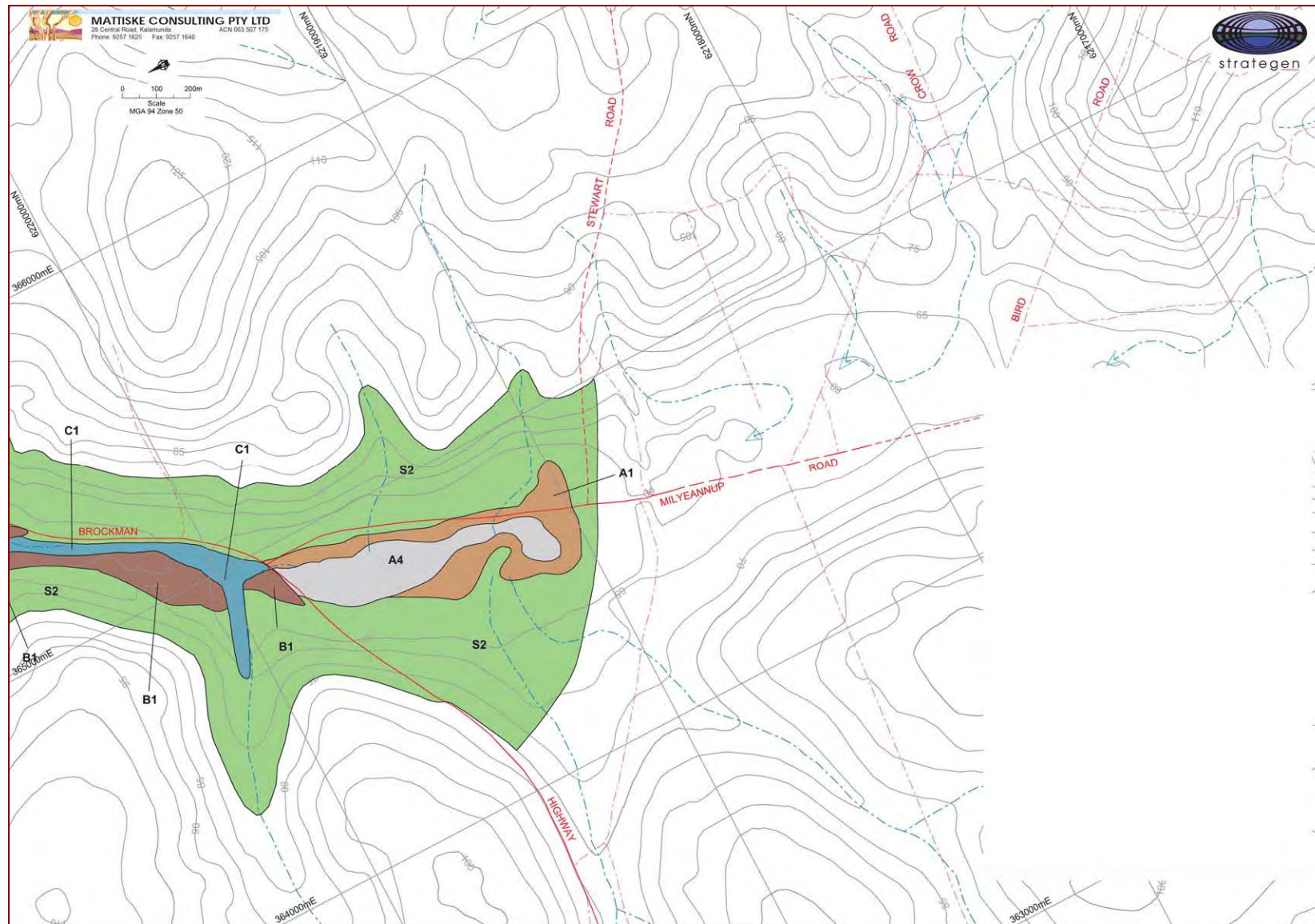


Adapted from Mattiske 2005a.

Figure 7.6 Site vegetation type mapping along Poison Gully, Map 2 (See Figure 7.4 for legend to vegetation types)



Adapted from Mattiske 2005a.

Figure 7.7 Site vegetation type mapping along Poison Gully, Map 3 (See Figure 7.4 for legend to vegetation types)

Adapted from Mattiske 2005a.

Figure 7.8 The central section of Poison Gully looking north

The vegetation of Milyeannup Brook is less variable than at Poison Gully, as the valley slopes are steeper with a more restricted range of soils and moisture conditions. Milyeannup Brook has a linear distribution of plant communities along the valley and is similar to other tributaries, such as Layman Brook and Rosa Brook (Appendix 31), and the lower reaches of Poison Gully. The vegetation is dominated by forests and woodlands of jarrah (*Eucalyptus marginata* subsp. *marginata*) she-oak (*Allocasuarina fraseriana*) and marri (*Corymbia calophylla*) with peppermint (*Agonis flexuosa*) and dense undergrowth.

Table 7.5 Description of site-vegetation types in Milyeannup Brook

Site-vegetation type	Description of vegetation
Q1	Open forest of <i>Corymbia calophylla</i> – <i>Eucalyptus patens</i> – <i>Eucalyptus rudis</i> – <i>Eucalyptus marginata</i> subsp. <i>marginata</i> over occasional <i>Banksia littoralis</i> over <i>Pteridium esculentum</i> , <i>Gastrolobium bilobum</i> , <i>Acacia alata</i> var. <i>alata</i> and <i>Trymalium floribundum</i>
C1	Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> – <i>Corymbia calophylla</i> – <i>Eucalyptus patens</i> over <i>Trymalium floribundum</i> , <i>Taxandria linearifolia</i> , <i>Taxandria parviceps</i> , <i>Hypocalymma cordifolium</i> , <i>Astartea scoparia</i> and <i>Gastrolobium bilobum</i> over <i>Baumea vaginalis</i> and <i>Lepidosperma gladiatum</i>
C4	Open forest of <i>Corymbia calophylla</i> – <i>Eucalyptus patens</i> – <i>Banksia littoralis</i> with occasional <i>Banksia seminuda</i> over <i>Agonis flexuosa</i> , <i>Trymalium floribundum</i> and <i>Taxandria linearifolia</i> over <i>Bossiaea aquifolium</i> subsp. <i>laidlawiana</i> , <i>Lepidosperma gladiatum</i> , <i>Lepidosperma tetraquetrum</i> and <i>Baumea vaginalis</i>
C5	Open forest of <i>Eucalyptus rudis</i> – <i>Agonis flexuosa</i> – <i>Melaleuca raphiophylla</i> over patches of <i>Melaleuca viminea</i> , <i>Astartea scoparia</i> , <i>Taxandria linearifolia</i> and <i>Lepidosperma gladiatum</i> , <i>Lepidosperma tetraquetrum</i> and <i>Baumea vaginalis</i>
W1	Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> – <i>Corymbia calophylla</i> – <i>Eucalyptus patens</i> over <i>Pteridium esculentum</i> and <i>Acacia alata</i> var. <i>alata</i> .

The potentially affected vegetation complexes that occur in Milyeannup Brook in areas where plants may be dependent on the watertable are the Jalbarragup complex and the Bidella complex, as in Poison Gully (Appendix 31).

Mattiske (Appendix 31) mapped five site-vegetation types in the valley of Milyeannup Brook (Table 7.6, Figure 7.10 and Figure 7.11). Of these, the C1 and C4 site-vegetation types are the most likely to be influenced by any changes in local hydrological conditions.

2.1.5 Declared Rare and Priority Flora

Mattiske (Appendix 31) recorded a total of 225 species in the seven transects surveyed in Poison Gully. Eight of these were Declared Rare or Priority Flora with two Priority 3 species considered likely to have a high dependence on regional groundwater⁴¹.

Mattiske (Appendix 31) recorded a total of 180 species in the four transects surveyed in Milyeannup Brook. Four of these were Declared Rare or Priority Flora, with one Priority 3 species considered likely to have a high dependence on regional groundwater.

Daviesia elongata subsp. *elongata* was the only Declared Rare Flora (DRF) species recorded in the survey of Milyeannup Brook and Poison Gully. The species was found in the upper reaches of Poison Gully, on lower slopes in seasonally moist, leached grey sands. The species is a small herbaceous plant existing in an area of greater than 10 m depth to groundwater and is therefore unlikely to be groundwater dependent (Appendix 31) relying on soil moisture rather than groundwater. This taxon is listed as a Vulnerable species pursuant to s179 of the Federal EPBC Act.

Table 7.6 Summary of recorded species and their significance at Milyeannup Brook and Poison Gully

Conservation category	Act	Milyeannup Brook – Regional groundwater dependency			Poison Gully – Regional groundwater dependency		
		High	Moderate	Low	High	Moderate	Low
Endangered	Federal						
Vulnerable	Federal						1
Rare	State						1
Priority 1	State						
Priority 2	State						
Priority 3	State	1	1		2	3	1
Priority 4	State		1	1			
Total species recorded		7	27	146	21	40	164

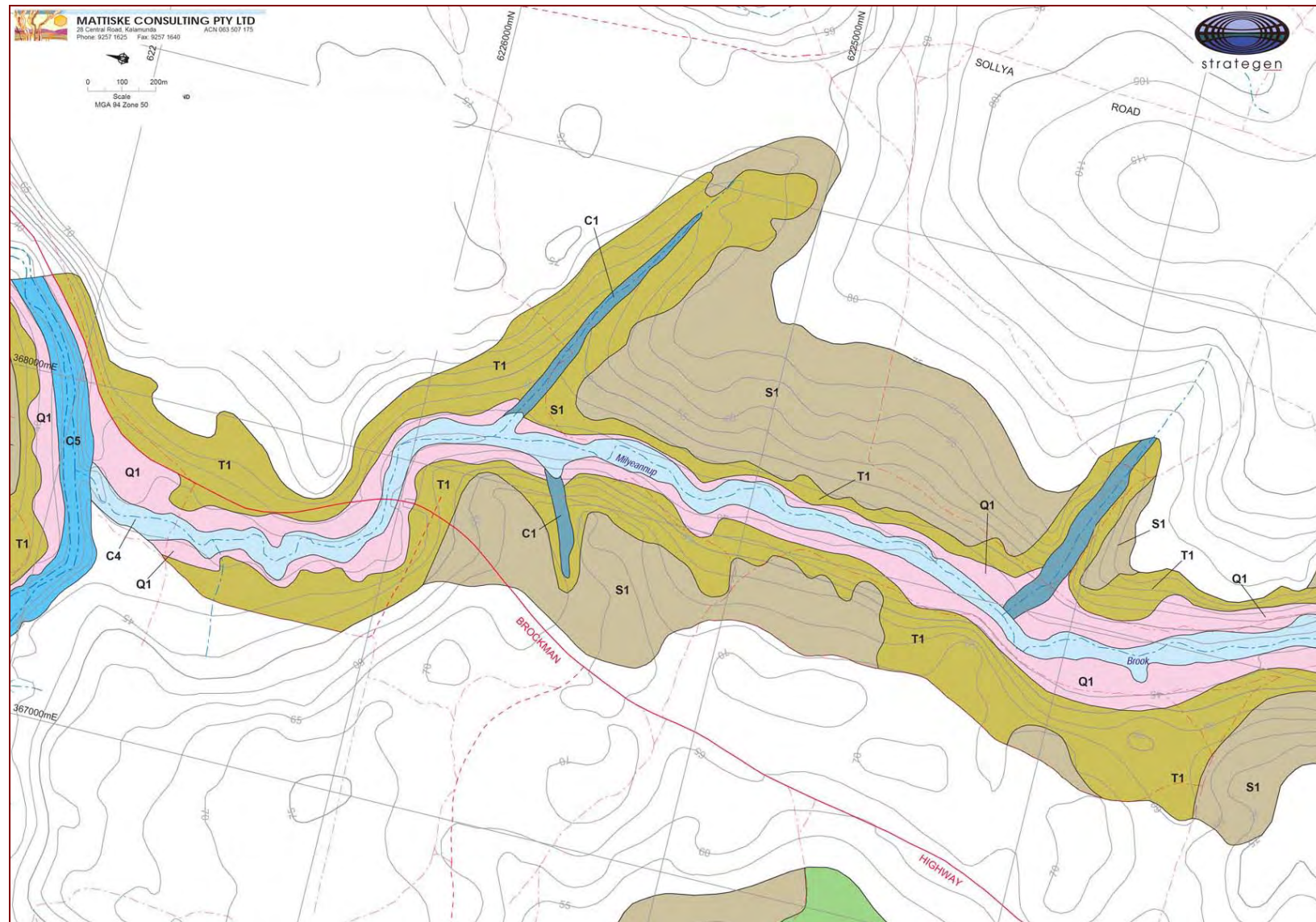
From Mattiske (2005a)

⁴¹ Regional groundwater is the term used to refer to non-perched groundwater in the saturated zone.

Figure 7.9 Legend to Millyeannup Brook vegetation mapping (Figure 7.10, Figure 7.11 and Figure 7.12)

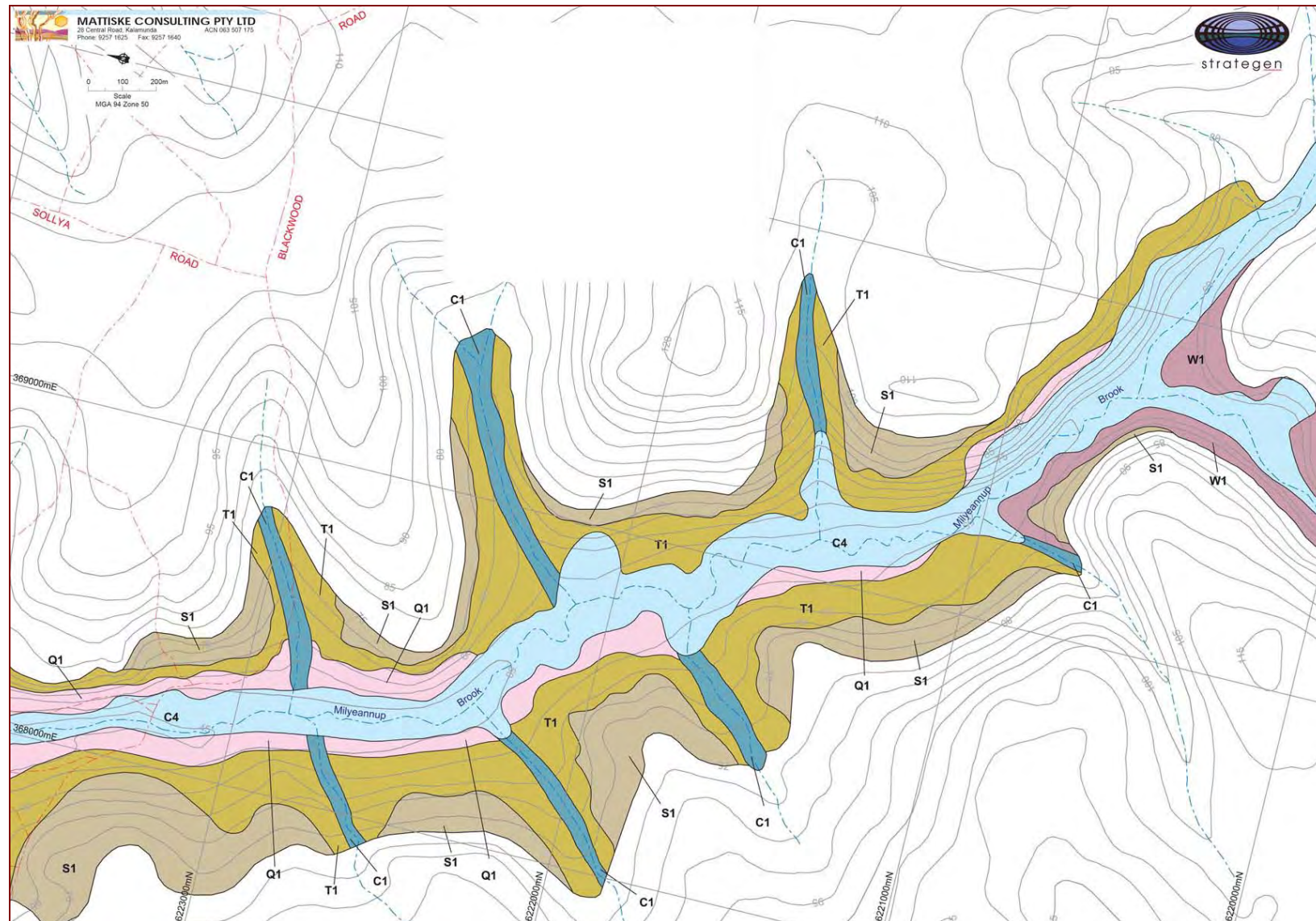
	S1: Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> - <i>Corymbia calophylla</i> over occasional <i>Banksia grandis</i> over <i>Podocarpus drouynianus</i> , <i>Xanthorrhoea preissii</i> and <i>Macrozamia riedlei</i> .
	C1: Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> - <i>Corymbia calophylla</i> - <i>Eucalyptus patens</i> over <i>Trymalium floribundum</i> , <i>Taxandria linearifolia</i> , <i>Taxandria parviceps</i> , <i>Hypocalymma cordifolium</i> , <i>Astartea scoparia</i> and <i>Gastrolobium bilobum</i> over <i>Baumea vaginalis</i> and <i>Lepidosperma gladiatum</i> .
	C4: Open forest of <i>Corymbia calophylla</i> - <i>Eucalyptus patens</i> - <i>Banksia littoralis</i> with occasional <i>Banksia seminuda</i> over <i>Agonis flexuosa</i> , <i>Trymalium floribundum</i> and <i>Taxandria linearifolia</i> over <i>Bossiaea aquifolium</i> subsp. <i>laidlawiana</i> , <i>Lepidosperma gladiatum</i> , <i>Lepidosperma tetraquetrum</i> and <i>Baumea vaginalis</i> .
	W1: Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> - <i>Corymbia calophylla</i> - <i>Eucalyptus patens</i> over <i>Pteridium esculentum</i> and <i>Acacia alata</i> var. <i>alata</i> .
	T1: Open forest of <i>Corymbia calophylla</i> - <i>Eucalyptus marginata</i> subsp. <i>marginata</i> over occasional <i>Banksia littoralis</i> , <i>Agonis flexuosa</i> over <i>Pteridium esculentum</i> , <i>Clematis pubescens</i> and <i>Leucopogon verticillatus</i> , <i>Leucopogon australis</i> , <i>Bossiaea linophylla</i> and <i>Acacia browniana</i> var. <i>browniana</i> .
	Q1: Open forest of <i>Corymbia calophylla</i> - <i>Eucalyptus patens</i> - <i>Eucalyptus rudis</i> - <i>Eucalyptus marginata</i> subsp. <i>marginata</i> over occasional <i>Banksia littoralis</i> over <i>Pteridium esculentum</i> , <i>Gastrolobium bilobum</i> , <i>Acacia alata</i> var. <i>alata</i> and <i>Trymalium floribundum</i> .

Figure 7.10 Site-vegetation type mapping along Milyeannup Brook, Map 1 (See Figure 7.9 for legend to vegetation types)



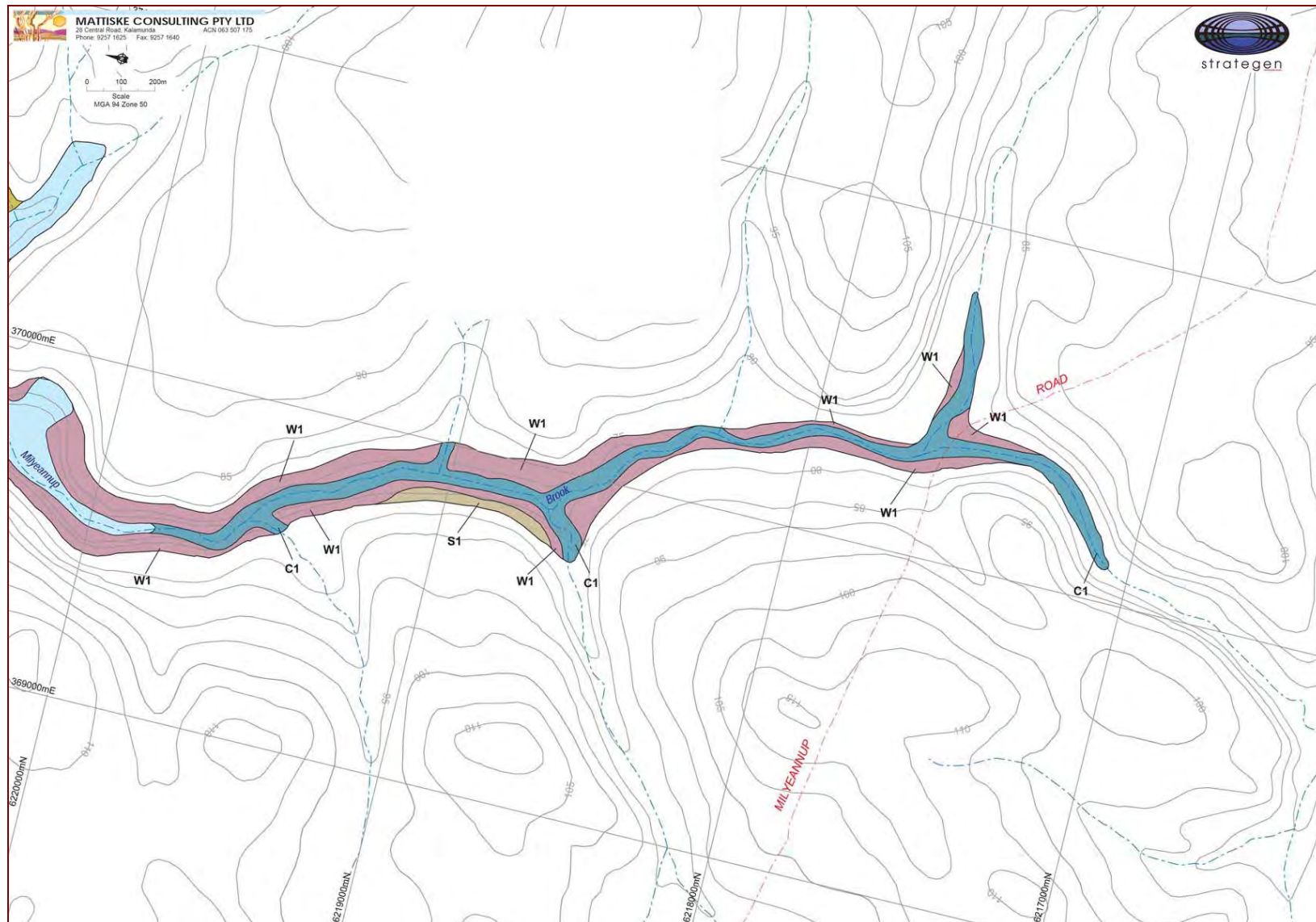
Adapted from Mattiske 2005a.

Figure 7.11 Site vegetation type mapping along Milyeannup Brook, Map 2 (See Figure 7.9 for legend to vegetation types)



Adapted from Mattiske 2005a.

Figure 7.12 Site vegetation type mapping along Milyeannup Brook, Map 3 (See Figure 7.9 for legend to vegetation types)



Adapted from Mattiske 2005a.

On the basis of regional database searches there are 61 Declared Rare and Priority species that may potentially occur near Poison Gully, with 15 of those predicted to have a high groundwater dependence. At Milyeannup Brook there are a total of 62 Rare and Priority species that may grow near the brook, with 14 of those predicted to have a high groundwater dependence (Appendix 32).

2.1.6 Threatened Ecological Communities

No Threatened Ecological Communities have been listed or located in, or near, either Poison Gully or Milyeannup Brook.

2.1.7 Terrestrial fauna

Poison Gully is less steeply dissected than Milyeannup Brook and other Blackwood River tributaries, and has broader valleys with extensive riparian vegetation. The area is expected to support two frog, three or four reptile, 11 – 13 bird, and seven or eight mammal species of conservation significance (Appendix 29). Of these, the frogs, one reptile, four bird and two mammal species are expected to be highly groundwater dependent (Table 7.7). There is one bird species expected to be found in the area that has both high groundwater dependence and high conservation significance (CS1).

Table 7.7 Species of conservation significance (CS) likely to occur in Poison Gully and Milyeannup Brook, and their groundwater dependence (GD)

Species	CS ¹	GD ²	Occurrence
FROGS			
<i>Geocrinia rosea</i>	3	High	Likely
<i>Metacrinia nicholli</i>	3	High	Likely
REPTILES			
<i>Morelia spilota</i>	1	Low	Likely
<i>Egernia pulchra</i>	3	Low	Likely
<i>Glaphyromorphus gracilipes</i>	3	High	Likely
<i>Elapognathus minor</i>	3	Moderate	Uncertain
BIRDS			
<i>Merops ornatus</i> (migratory)	1	Low	Likely
<i>Apus pacificus</i> (migratory)	1	Low	Likely
<i>Falco peregrinus</i>	1	Low	Likely
<i>Calyptorhynchus banksia</i>	1	Low	Likely
<i>Calyptorhynchus latirostris</i>	1	Low	Likely
<i>Calyptorhynchus baudinii</i>	1	Low	Likely
<i>Botaurus poiciloptilus</i>	1	Very high	Uncertain
<i>Ixobrychus minutus</i>	2	Very high	Uncertain
<i>Ixobrychus flavicollis</i>	2	Very high	Likely
<i>Ninox connivens</i>	2	Low	Likely
<i>Tyto novaehollandiae</i>	2	Low	Likely
<i>Falcunculus frontatus</i>	2	Low	Likely
<i>Stagonopleura oculata</i>	3	High	Likely
MAMMALS			
<i>Dasyurus geoffroii</i>	1	Moderate	Likely
<i>Pseudocheirus occidentalis</i>	1	Low	Uncertain

Species	CS ¹	GD ²	Occurrence
<i>Setonix brachyurus</i>	1	Moderate	Likely
<i>Phascogale tapoatafa</i>	2	Moderate	Likely
<i>Isoodon obesulus</i>	2	High	Likely
<i>Macropus irma</i>	2	Moderate	Likely
<i>Falsistrellus mackenziei</i>	2	Low	Likely
<i>Hydromys chrysogaster</i>	2	Very high	Likely

Adapted from Bamford (2005)

¹ Conservation significance: 1 = Species listed under State or Federal Acts, 2 = Species not listed under State or Federal Acts, but listed in publications on threatened fauna or as Priority species by CALM, 3 = Species not listed under Acts or in publications, but considered of at least local significance because of their pattern of distribution

² Likelihood of being groundwater dependent

2.1.8 Aquatic fauna

CENRM (2005a at Appendix 26) found that Poison Gully and Milyeannup Brook had near pristine riparian vegetation, but with some weeds. The foreshore assessment also indicated that there was negligible erosion or slumping of the banks, although some undercutting was noted in Poison Gully. The banks at the sample sites were steep in both tributaries and there was very little sedimentation in the pools.

Poison Gully has approximately 18 km of first order streams, 8 km of second order, and 2 km of third order stream length (Appendix 26). The permanent flow of Poison Gully starts 3.5 km from the Blackwood River in the second order stream. In the first order reaches, Poison Gully is characterised by a narrow channel (less than 1 m wide) with limited aquatic habitats (Appendix 26). The lower reaches of Poison Gully, in the second and third order streams, are the most important areas for aquatic fauna as most pools and riffle zones are in these reaches near the Blackwood River.

Milyeannup Brook has approximately 67 km of first order streams, 20 km of second order, and 6 km of third order stream length, flowing north into the Blackwood River (Appendix 26). The permanent flow of Milyeannup Brook starts 2.5 km from the Blackwood River in the third order stream. There are no pool habitats in the first order sections of the stream, but they do exist in the second and third order streams (Appendix 26).

Five species of endemic freshwater fish were recorded in Milyeannup Brook, and four in Poison Gully by CENRM (Appendix 27) and Morgan & Beatty (2005). Two of these, the mud minnow and Balston's pygmy perch are Priority 4 species. The mud minnow was recorded in Poison Gully, Milyeannup Brook and six other tributaries, but was not recorded by either CENRM (Appendix 27) or Morgan & Beatty (2005) in the main stem of the Blackwood River.

Balston's pygmy perch (*Nanntherina balstoni*) is a CALM Priority 4 species and is considered to be the rarest of freshwater fish in the South West. It has a distribution between Two Peoples Bay in the east, and Margaret River in the west, and an isolated population at Gingin. Balston's pygmy perch was recorded in Milyeannup Brook, Red Gully and two sites in the Blackwood River, but 16 of the 18 specimens (≈90%) recorded by Morgan & Beatty (2005) were caught in Milyeannup Brook within one kilometre of the Blackwood River. Ten of the 16 Balston's pygmy perch caught by Morgan & Beatty (2005) were found near the confluence of the Blackwood River and Milyeannup Brook. The other six specimens were recorded near the Brockman Highway, less than one kilometre from the Blackwood River. The only winter occurrence recorded was in the main stem of the Blackwood River. Milyeannup Brook is considered to be a significant habitat for this species.

Both the Balston's pygmy perch and the mud minnow have been nominated as Vulnerable under the EPBC Act.

Because of the increasing salinity in the Blackwood River, the Poison Gully and Milyeannup Brook tributaries are likely to be important refugia⁴² for aquatic fauna species that are sensitive to saline conditions (Appendix 27). A total of 19 species of macroinvertebrates were recorded by CENRM (Appendix 27) in Poison Gully, and 15 species in Milyeannup Brook. Four species of freshwater crayfish were recorded in Poison Gully and two in Milyeannup Brook.

The small Gondwanic⁴³ freshwater snail *Glacidorbis occidentalis* was collected from Milyeannup Brook. This species is currently listed as vulnerable on the IUCN Red List of Threatened Species. This species is adapted to ephemeral environments and survives dry periods by burrowing into the stream bed (Appendix 27).

2.1.9 Social values

Nannup is the main community on the Blackwood Plateau. Environmental amenity is important in this community and is focused on the Blackwood River (Appendix 3). However, there is a general appreciation of the surrounding environment, which includes the forest and Blackwood River tributaries such as Poison Gully and Milyeannup Brook.

2.2 ASSESSMENT FRAMEWORK AND POLICY CONTEXT

The following policies and legislation are relevant to the impact assessment of Poison Gully and Milyeannup Brook and their associated ecosystems and are described in Chapter 2:

- *Wildlife Conservation Act 1950*
- *Conservation and Land Management Act 1984*
- *Environmental Protection and Biodiversity Conservation Act 1999*
- National Strategy for Conservation of Australia's Biological Diversity 1996
- National Objectives and Targets for Biodiversity Conservation 2001
- National Strategy for Ecologically Sustainable Development 1992
- Conservation Policy for Western Australia 1997

⁴² Refugia are areas that remain unaffected by a general climatic (or other) change and which therefore contain a population of organisms typical of those once spread over a larger region

⁴³ Gondwanic fauna are relict species from approximately 144 to 195 million years ago when all of the southern continents were joined together as one land mass. Gondwanic species are considered to be especially at risk as they originate from a much wetter climate and have specialised requirements and habitats that are usually topographically restricted.

2.2.1 Key EPA and other policies

The key policies that have been applied to the assessment of the several factors considered in this section, and which provide a critical test of environmental sustainability, are as follows:

- EPA Position Statement No. 2: Environmental Protection of Native Vegetation in Western Australia 2000.
- EPA Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection 2002.
- EPA Position Statement No. 4: Environmental Protection of Wetlands 2004
- EPA Preliminary Position Statement No. 9 (V2): Environmental Offsets 2005
- Forest Management Plan 2004–2013 (2004).

2.3 POTENTIAL IMPACTS AND MITIGATION

The groundwater abstraction by the proposal, together with estimated future regional use, is expected to affect the following components of Poison Gully and Milyeannup Brook as a consequence of watertable drawdown:

- the streambed, through a reduction in permanent stream length and base flow rate during summer
- groundwater levels in areas upslope from the streambed, which may contain groundwater dependent ecosystems.

2.3.1 Groundwater drawdown

The predicted watertable drawdown resulting from the proposal, after 30 years, is up to 1 – 2 m in Poison Gully, and up to 2 – 3 m in Milyeannup Brook (Figure 7.13). The total predicted watertable drawdown resulting from the proposal, together with estimated future regional use, in both Poison Gully and Milyeannup Brook after 30 years is up to 3 – 5 m (Figure 7.14).

The drawdowns from estimated future regional water use and the proposal (total predicted watertable drawdown) are predicted to occur gradually and steadily over the 30-year period, with total drawdown rates in the valleys expected to be less than 0.10 m/yr.

The total watertable drawdown near the current spring source for both streams is expected to be almost 3 m. The drawdown will cause the spring source to migrate downstream. There will also be a band of drawdown impact on either side of the valley. The area affected will be determined by the width of the part of the valley where the depth to watertable is less than 10 m⁴⁴. As Poison Gully has a much wider valley floor than Milyeannup Brook, it will have a greater area of impact. The cell size of the drawdown interpretation maps (100 m x 100 m) is too large to show the detailed differences in topography and groundwater depth in Poison Gully and Milyeannup Brook.

⁴⁴ If the depth to groundwater is greater than 10 m the vegetation is unlikely to be groundwater dependent (Froend & Loomes 2005)

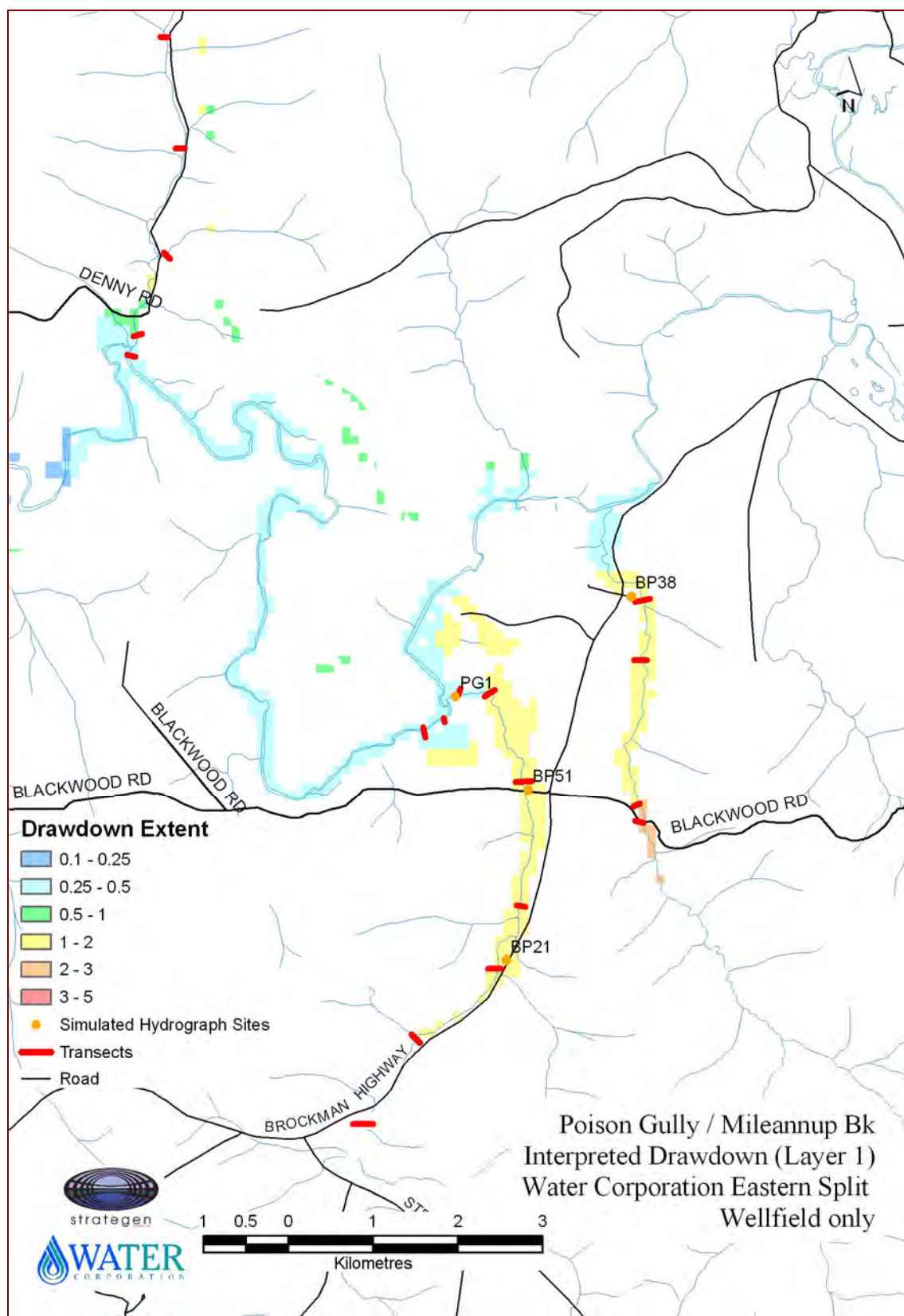
Figure 7.13 Predicted proposal drawdowns in Milyeannup Brook and Poison Gully

Figure 7.14 Predicted proposal and estimated future regional use drawdowns in Milyeannup Brook and Poison Gully

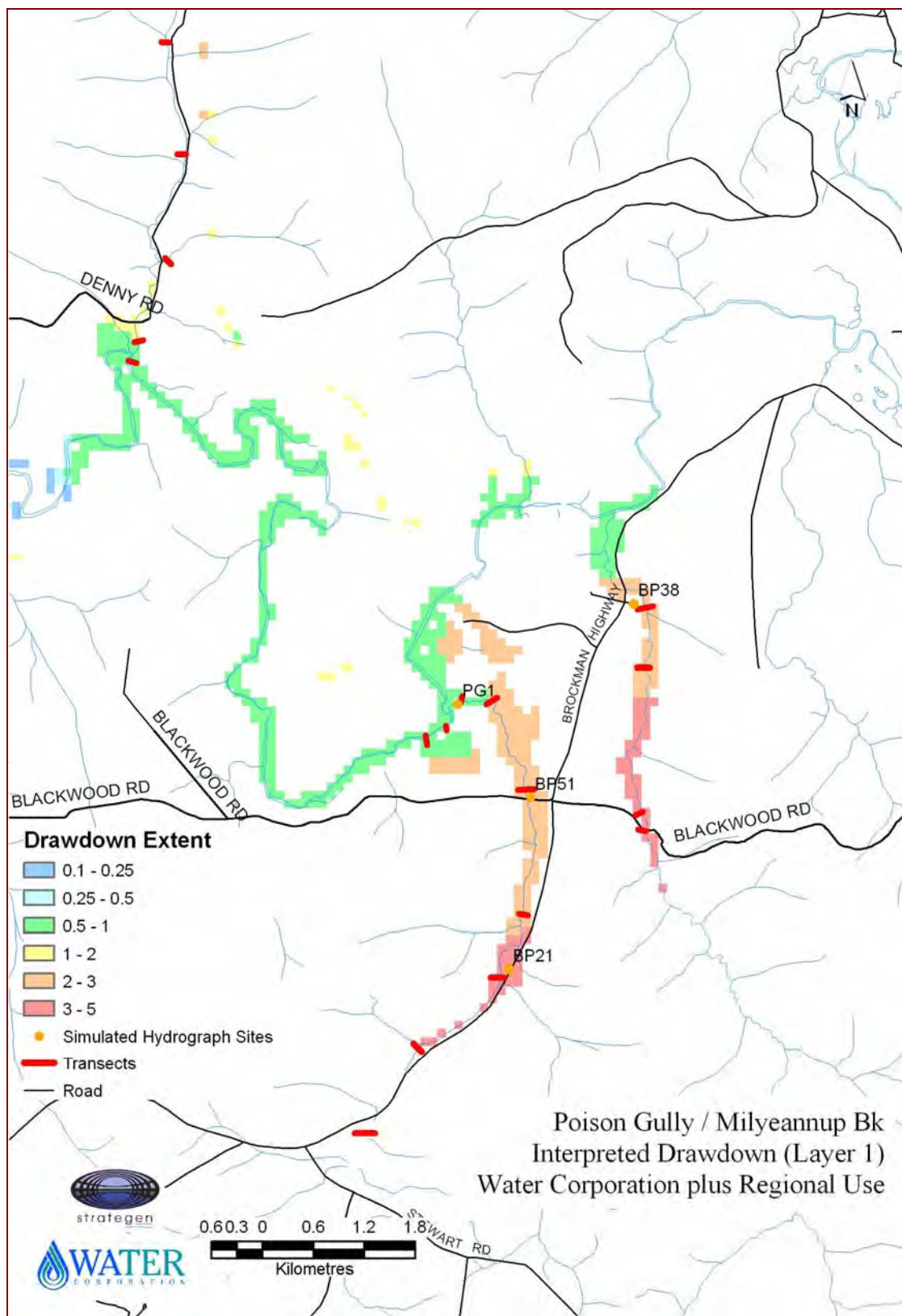
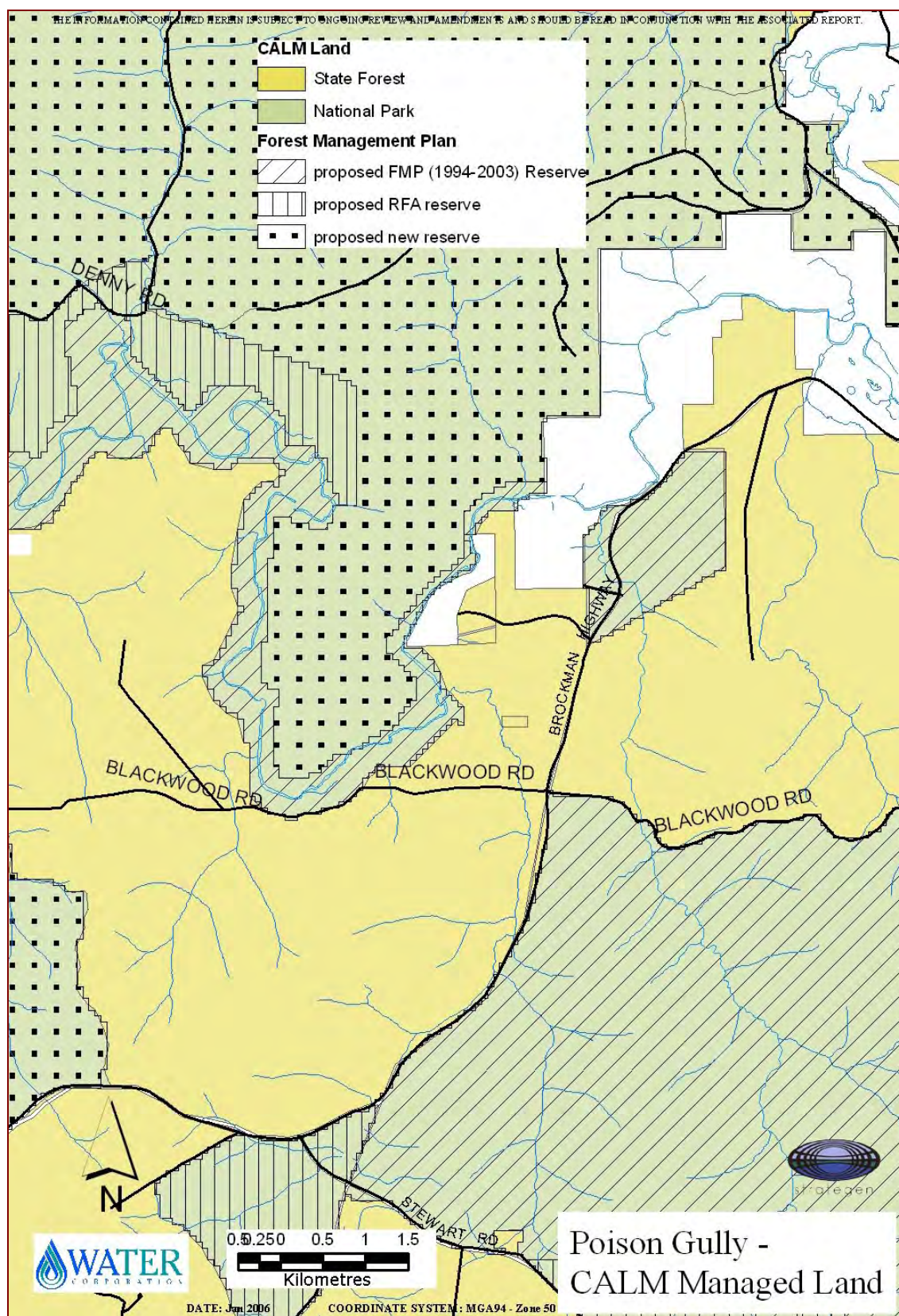


Figure 7.15 Conservation estate within the Poison Gully & Milyeannup Brook area

The groundwater drawdown in the downstream areas of the Poison Gully and Milyeannup Brook valleys will not affect watertable levels, as there is an artesian pressure of approximately 7 m above the valley floor where the tributaries meet the Blackwood River. Groundwater drawdown in these areas will reduce the artesian pressure, and reduce the rate of groundwater discharge. There will be no change in soil moisture availability or depth to the watertable. However, in the adjacent valley slopes above the artesian pressure, there is a risk of watertable drawdown effects increasing in magnitude away from the valley floor. This is offset by the depth to groundwater, and consequently the groundwater dependence of the ecosystem, diminishing progressively away from the valley floor.

Based on predicted drawdowns and the distribution of areas where the watertable is shallower than 10 m, the areas of vegetation expected to be affected by drawdown in Poison Gully and Milyeannup Brook are approximately 177 ha, and 52 ha, respectively.

2.3.2 Groundwater dependent vegetation at risk

Vegetation potentially at risk – screening assessment using Froend & Loomes 2005

There are approximately 177 ha of vegetation in Poison Gully and 52 ha of vegetation in Milyeannup Brook that have the potential to be affected by groundwater drawdowns (areas of remnant vegetation with a watertable within 10 m of the surface). The area at risk is the same for the proposal alone and for the cumulative impacts of the proposal and projected future regional groundwater use.

Using the Froend & Loomes (Appendix 30) screening level approach, the predicted groundwater drawdowns from the proposal place the potentially affected areas in the “high” to “severe” potential impact category. The cumulative drawdowns of the proposal and estimated future regional use would result in “severe” potential impact. Estimated future regional use, with or without the proposal, will result in drawdowns within the next 30 years that have the potential for “severe” impacts on vegetation. However, the drawdowns will happen gradually, at less than 0.10 m/yr, which minimises the risk to vegetation (Froend & Loomes 2004).

Potential effect on vegetation complexes

The main vegetation communities in both valleys are the Jalbarragup and Darradup vegetation complexes. There are also substantial areas of Bidella, Blackwood and Layman vegetation complexes in the potential areas of impact (Table 7.8 and Table 7.9). These complexes are all well-represented in the conservation estate or have more than 30% of their pre-European extent remaining.

Although there will be some change in species composition in Milyeannup Brook and Poison Gully, the vegetation will still be classified within the same vegetation complex.

Table 7.8 Vegetation complexes in areas of potential drawdown in Poison Gully

	Bidella (ha)	Blackwood - BK (ha)	Darradup (ha)	Jalbarragup (ha)	Kingia (ha)	Layman (ha)	Milyeannup (ha)	Totals (ha)
Reserved %:	31	55	45	13	28	5	26	
Remaining %:	93	93	65	90	95	74	98	
0 – 3*	2.5	2.7	9.3	14.9	0.0	1.1	0	30.5
3 – 6*	5.7	3.4	10.9	16.5	1.0	3.6	0	41.2
6 – 10*	14.4	21.9	33.1	12.6	8.3	14.5	0.6	105.5
Totals	22.7	28.0	53.3	44.1	9.3	19.3	0.6	177.3

* Depth to groundwater category

Table 7.9 Vegetation complexes in areas of potential drawdown in Milyeannup Brook

	Darradup (ha)	Jalbarragup (ha)	Milyeannup (ha)	Totals (ha)
Reserved %:	45	13	26	
Remaining %:	65	90	98	
0 – 3*	2.0	8.8	0.0	10.8
3 – 6*	3.0	12.5	0.0	15.6
6 – 10*	5.2	20.0	0.2	25.4
Totals	10.3	41.4	0.2	51.8

* Depth to groundwater category

Potential effect on site-vegetation types

Poison Gully has a diverse range of soil and moisture conditions resulting in a total of 13 site-vegetation types occurring along the wide gully, as defined by Mattiske (Appendix 31). Milyeannup Brook is narrow and has five site-vegetation types occurring in linear bands along the valley system (Appendix 31). All site-vegetation types in the valleys are well-represented locally and in the nearby valley systems. The site-vegetation types can be categorised according to their position in the landscape and the soil characteristics they are associated with. There are three main categories within the potential area of risk: valley floor, lower slope and mid slope. Site-vegetation types within each of these categories will be influenced differently by the predicted groundwater drawdowns.

Different species within a site-vegetation type will also respond differently to changing groundwater levels. The herbaceous annual and short-lived species tend to respond to seasonal rainfall conditions and local spatial heterogeneity in the sites. These species are not groundwater dependent and will not be susceptible to changing groundwater levels. The longer-lived perennial species are less able to adjust to changes in the availability of groundwater. On the basis of previous studies on the Gngangara Mound (Mattiske 2003) it is apparent that the age of the tree and shrub species may influence their ability to adjust to changed soil moisture regimes, with older trees having less ability to adapt to changing conditions.

Poison Gully

The site-vegetation types occupying the valley floor in Poison Gully are the “A” swampland types and the “C” fringing creek line types. The site-vegetation type (A4) within the swamp area in the upper reaches of Poison Gully occurs on extensive clays with a perched watertable, and is not expected to be affected.

The valley floor vegetation is adapted to wet or moist conditions supplied by both a shallow watertable and surface water, including shallow seepage. This vegetation is considered highly susceptible to groundwater drawdown. However, the accumulation of surface water in these low-lying areas, the presence of soils of high moisture storage capacity, and seepage from upslope areas partially buffer the impacts of groundwater drawdown. Studies on the Gngangara Mound have shown that vegetation in the lowest lying areas are not the first to be affected by groundwater drawdowns for these reasons (Mattiske 2003). The groundwater drawdowns are also less severe in these areas due to the concentration of recharge.

The potential impact on the “A” and “C” site-vegetation types on the valley floor is a reduction in the width of these vegetation types across the valley floor. The A1 site-vegetation type occurs upstream of the perennial stream source in Poison Gully, and the C1 site-vegetation type is within the perennial stream section. In Poison Gully where the perennial stream source is expected to migrate downstream (by several hundred metres) a change from the C1 site-vegetation type to an A1 site-vegetation type would be expected. The change in moisture regime may have an associated impact on ecosystem function in these areas, as the rate of decay and nutrient cycling will slow in a drier environment.

There are B1 and D3 site-vegetation types on the lower slopes of Poison Gully. The B1 unit is expected to be the most susceptible to changes in groundwater levels, as the watertable is shallow and the unit occurs on sandy soils with low moisture storage capacity. The D3 unit is less likely to be affected because of its location at the lower end of the valley system, where drawdown will be minimal, and where the soils have higher clay content and, consequently, better moisture storage capacity.

The most likely changes in the B1 unit, over a long period of time, are an opening up of the canopy and a reduction in average height of the overstorey species. Mattiske (Appendix 32) expected that the width of this unit along Poison Gully may decrease and shift closer to the valley floor, with partial replacement by downhill movement of the more upland vegetation unit S2. This lateral shift will be observable through a change in the occurrence of keystone species that are susceptible to watertable change.

Within the B1 site-vegetation type, the herbaceous annual species are unlikely to be affected as they are shallow rooted. Woody perennials will be the most susceptible to groundwater drawdown, although even these can survive a wide range of watertable depths. Although one plant may not be able to adapt to lower watertables (if the roots cannot grow fast enough to follow the watertable down), a new seedling would (as demonstrated by their occurrence further up the slope).

The mid-slope site-vegetation types in Poison Gully are S2 and S1, found in both the mid-slope and upland areas on sandy lateritic soils. They have low groundwater dependence and are not expected to be impacted significantly. There may be a narrow band of impact on this vegetation unit at the B1 and S2 interface.

The Q1 and T1 site-vegetation types occur near the Blackwood River, and on the loamy fertile soils on the low – mid slope. These units are moderately groundwater dependent. Mattiske (Appendix 32) expected only limited impacts in these areas due to the buffering capacity of their soils, which have high moisture storage capacity. The swamp A2 and A3 site-vegetation types are associated with perched watertables near Pig Swamp and will not be affected.

Milyeannup Brook

Milyeannup Brook has a narrower valley than Poison Gully, and the area of impact is likely to be much narrower than shown in Figure 7.11 and Figure 7.13. The impacts in Milyeannup Brook are also likely to be less than in Poison Gully, due to the higher clay content in the local soils and consequent higher moisture retention, and a tendency for perching.

The site-vegetation types on valley floor at Milyeannup Brook are the C4 and C1 creek line types, with the C1 type found on the upper reaches of the creek. There is no change in site-vegetation type in the area where the stream changes from perennial to seasonal. The valley floor vegetation is adapted to wet or moist conditions supplied by both shallow watertables and surface water, including shallow seepage, and is considered susceptible to groundwater drawdown. The accumulation of surface water in these low-lying areas buffers the impacts of groundwater drawdown by concentrating recharge in the area and refilling the soil moisture storage (Mattiske 2003).

The potential impact on the C4 and C1 site-vegetation types is a reduction in the width of these vegetation types across the valley floor. There is not expected to be any change in site-vegetation type in the area where the perennial stream source is predicted to migrate downstream, as there is currently no difference in site-vegetation types above and below the perennial stream source. The change in moisture regime may have an associated impact on ecosystem function in these areas, as the rate of decay and nutrient cycling will slow down in a drier environment.

The lower slopes of Milyeannup Brook consist of the Q1, T1 and W1 site-vegetation types, which usually occur on low – mid slopes on more fertile soils. This lower slope vegetation in Milyeannup Brook is less at risk than that on the lower slopes of Poison Gully. The Milyeannup Brook units exist on better soils, with higher soil moisture retention capacity, and steeper slopes with a much narrower width of shallow watertables. These units can also occur higher in the landscape than B1 (Poison Gully lower slope unit) so are likely to be less groundwater dependent. However, there could be a small shift of these types down-slope as a result of the predicted groundwater drawdowns. The area of impact is likely to be very narrow due to the dissected nature of the valley system.

The mid-slope site-vegetation type at Milyeannup Brook is S1, which occurs in both the mid-slope and upland areas on sandy lateritic soils. This unit has a low groundwater dependence and is not expected to be impacted significantly.

Ecosystem function

The resilience of the ecosystems in Poison Gully and Milyeannup Brook will not be significantly affected, as the whole range of vegetation types will still exist in the valleys. Only their extents may have shifted. If previous conditions return, the vegetation will have the ability to shift again. It is also worth noting that vegetation types occur in a continuum, and shifts in composition up or down-slope are a natural response to climate, fire, disease and other processes.

Conclusion

The impact of the proposal, combined with estimated future regional use, on the local or regional representation, occurrence, or function of vegetation complexes is expected to be insignificant. Similarly, impact on site-vegetation types is likely to be insignificant in a local or regional context, and is therefore unlikely to significantly affect faunal habitat.

2.3.3 Declared Rare and Priority Flora

Consideration of risk at the species level must include consideration of the life form of the species and where they occur in the landscape, both of which give an indication of the likelihood of reliance on soil moisture, which may in turn be groundwater dependent. A deep-rooted perennial species is likely to be dependent on groundwater, whereas a small, herbaceous and shallow-rooted species is likely to be dependent on seasonal rainfall and the associated seasonal soil moisture (Mattiske 2005b at Appendix 32).

Poison Gully

Only one Declared Rare Fauna species was recorded in Poison Gully. *Daviesia elongata* subsp. *elongata* is a small herbaceous plant existing in an area where depth to groundwater is greater than 10 m, so is not considered to be groundwater dependent.

There were seven other Priority or Declared Rare species recorded in Poison Gully:

- two with high potential groundwater dependency
- three with moderate potential groundwater dependency
- two with low potential groundwater dependency.

The two species that are likely to be highly dependent on regional groundwater are the Priority 3 species *Cyathochaeta teretifolia* and *Cyathochaeta stipoides*. These species are not restricted to the Poison Gully area.

Milyeannup Brook

There were four Priority Flora species and no Declared Rare Flora species recorded in Milyeannup Brook with:

- one Priority 3 species (*Cyathochaeta teretifolia*) having high potential groundwater dependency
- two with moderate potential groundwater dependency
- one with low potential groundwater dependency.

Priority 3 refers to taxa which are known from several populations, at least some of which are not believed to be under immediate threat. None of the Priority species recorded in the area are restricted to Poison Gully or Milyeannup Brook (Mattiske 2005a at Appendix 31) and only a small proportion of their range within these valleys will be affected by the drawdowns.

Conclusion

The occurrence or long-term viability of Priority Flora species in Poison Gully and Milyeannup Brook are not expected to be significantly affected by the combined drawdown resulting from the proposal and estimated future regional use. This is because the potential drawdowns will only affect a very small proportion of the range of these species.

2.3.4 Potential effects on creek hydrology

Within Poison Gully and Milyeannup Brook the groundwater fed baseflow may potentially reduce and retreat toward the Blackwood River in response to the combined effect of groundwater abstraction by the proposal and estimated future regional use. The distance of the retreat is likely to be of the order of several hundred metres in Poison Gully, from the current position 3500 m upstream from the confluence with the Blackwood River. The perennial flow in the Milyeannup Brook is likely to retreat by up to 1500 m from the current source, 2500 m from the Blackwood River, to 1000 m from the Blackwood River (Baddock 2005 at Appendix 13).

Watertable levels in the lower reaches of the streams within about 500 m of the Blackwood River are not expected to be significantly affected, as artesian pressures in the Yarragadee Formation in these areas will be maintained at or above the streambed.

Combined abstraction from the proposal and estimated future regional use may reduce the groundwater discharge that forms the summer baseflow of both these streams by about 30% – based on the overall reduction in discharge from the Yarragadee Formation.

In dry summers, this will represent a 30% decrease in summer flows. In average and wet summers, surface water flows will make groundwater discharge a smaller component of overall flows, and the reduction will be less. Detailed predictions of the Water Corporation component of the predicted flow reductions have not been undertaken because of the many variables involved and the high level of uncertainty. However, the proposal is likely to be the cause of about half of the predicted 30% overall reduction in base flows. The remainder will be from estimated future regional abstraction. The full extent of these potential impacts is not expected to be felt until the end of the 30-year project period.

Any significant changes to the hydrological regimes in Milyeannup Brook could have an adverse impact on the significant aquatic fauna that occur in these areas of permanent flow. Therefore a contingency measure is proposed to supplement flow in the creek if unacceptable reductions in flow occur.

Aquatic fauna

The potential contraction of the perennial stream length in Milyeannup Brook and Poison Gully will result in a “compression” of the aquatic fauna into the lower reaches. However, these lower reaches are the most diverse and extensive areas of faunal habitat. The fauna most susceptible to these changes would be fish and crayfish species, as they are commonly associated with pools and rely mostly on permanent water. Many other macroinvertebrate species are more mobile, and have a terrestrial adult stage which allows them to recolonise streams when conditions become suitable (CENRM 2005b at Appendix 26).

Milyeannup Brook

There are two Priority 4 fish species in Milyeannup Brook: Balston’s pygmy perch and the mud minnow. The brook is particularly significant as a habitat for Balston’s pygmy perch as 16 of the 18 specimens recorded by Morgan & Beatty (2005) in the Blackwood River area were found in the lower reaches (within one kilometre of the river) of Milyeannup Brook. Milyeannup Brook is currently perennial for a length of 2500 m upstream from the Blackwood River, but may retreat to approximately 1000 m from the river.

The importance of the stream for aquatic fauna increases in its lower reaches, as these have the highest perennial flows and greatest diversity of habitats, especially in pools (Appendix 26). Therefore, the greatest numbers of aquatic fauna are likely to be found in these areas.

The majority (10 out of 16) of the Balston's pygmy perch in the Milyeannup Brook survey were caught (Morgan & Beatty 2005) near the confluence with the Blackwood River. The other six specimens were recorded near the Brockman Highway, less than one kilometre from the Blackwood River. Therefore, the section of Milyeannup Brook within one kilometre of the Blackwood River is a significant habitat for Balston's pygmy perch. This stretch of the stream will not be affected by the proposal other than by a reduction in baseflow (of about 30%), so no significant impact on fauna is expected (Appendix 26). This will be of impact in those summer months when no runoff-based surface water flow is present. The occurrence of this species upstream (south) of the Brockman Highway is unknown.

Due to the high number of Balston's pygmy perch in Milyeannup Brook, any hydrological change that is likely to significantly reduce the local occurrence of this Priority 4 species within the Blackwood River system, will trigger the contingency measure of supplementing flows in the brook. The water requirement is expected to be small and the valley is narrow and steep. Groundwater of identical quality to that naturally discharging into the Brook will be available. This contingency measure will be triggered if both:

1. Regular sampling prior to commissioning indicates the consistent presence and abundance of Balston's pygmy perch in Milyeannup Brook reaches between 1000 and 2500 m from the Blackwood River.
2. Hydrological monitoring indicates that the habitat extent (based on habitat area rather than stream length) of this species is likely to reduce by more than 20% in Milyeannup Brook.

The contingency will also be triggered if monitoring of abundance indicates any reduction as a consequence of reduced flows in the Brook. Abundance would be measured by statistical analysis of data from non-destructive sampling, based on electrofishing and stop nets.

If this species is not found in significant numbers within the reaches susceptible to a change in permanence of flow (1000 – 2500 m from the Blackwood River) then there would be no significant impact on the occurrence or viability of the species. If the species does occur in these areas, in similar abundance to the lower reaches, implementing the proposed contingency measure as part of the adaptive management approach would ensure that no significant impact occurs.

The mud minnow is more widespread (than Balston's pygmy perch) throughout the Blackwood River tributaries. It was recorded in Milyeannup Brook, Poison Gully, and six other tributaries, but not in the main stem of the Blackwood River. The predicted hydrological changes in these tributaries are not expected to significantly impact the occurrence or viability of this species.

One macroinvertebrate species listed as vulnerable on the IUCN Red List of Threatened Species was recorded in Milyeannup Brook. The small Gondwanic freshwater snail (*Glacidorbis occidentalis*) is adapted to ephemeral environments so is unlikely to be significantly affected by the gradual hydrological changes associated with the proposal.

Poison Gully

Four fish species were recorded in Poison Gully including the Priority 4 mud minnow. Balston's pygmy perch was not found in this tributary. The permanent stream length of Poison Gully currently extends 3500 m from the Blackwood River, and is likely to retreat several hundred metres. This will cause a small reduction in the total aquatic habitat area available in this stream. This is not expected to have a significant impact on the occurrence or viability of any aquatic fauna and no contingency of flow supplementation is proposed.

The geomorphology of Poison Gully also makes it unsuitable for flow supplementation. The stream bed is sandy in some areas and added surface flows in summer would contribute to recharge rather than streamflow.

Concentration of fauna into a shorter permanent stream length may lead to secondary impacts, such as increased sensitivity to other threats (e.g. pollution). As both Poison Gully and Milyeannup Brook are in relatively undisturbed environments, secondary impacts are unlikely to be significant.

Within the reaches of Milyeannup Brook and Poison Gully that retain perennial flow, a 30% reduction in minimum summer flows is predicted (in a dry year, when there are no surface inflows). This reduction in flow is not expected to change the depth of pools to a degree that would impact on the resident fauna (Appendix 26).

Riffles are the shallow areas of a stream, and are significant as pool connections and habitats for macroinvertebrate diversity. The changes that will occur to the riffles are largely unknown. The cross section profile of riffles in Milyeannup Brook and Poison Gully show a flat streambed, so a reduction in flow will reduce the depth rather than the width of the active channel. CENRM (Appendix 27) calculated that the flow required to maintain riffles with a depth of 0.05 m is 15 L/s in Milyeannup Brook, and 11 L/s in Poison Gully. The current flows are in excess of 20 L/s in both streams (Appendix 13), so these environmental water requirements (EWRs) would essentially be satisfied in Milyeannup Brook, even with a 30% decrease in summer baseflows.

Conclusion

The reduction in permanent stream length of Milyeannup Brook will potentially cause a significant reduction in aquatic habitat for this stream and, locally, for the Priority 4 Balston's pygmy perch. The predicted reduction in permanent stream length in Poison Gully is a much smaller proportion of total stream length and is not expected to have a significant impact on any species.

The potential 30% reduction in summer minimum flows, from the proposal and estimated future regional use, in both streams is not expected to affect pool habitats, but may only just meet the riffle depth "environmental water requirement" defined by CENRM (Appendix 27) in a dry year in Milyeannup Brook. A contingency measure is proposed to supplement flows in Milyeannup Brook if hydrological changes are likely to reduce the habitat available in the brook for Balston's pygmy perch.

2.3.5 Terrestrial fauna

The shift of vegetation to a drier system in the areas of groundwater drawdown may have the following potential impacts on terrestrial fauna:

- reduction in the extent of dense undergrowth used by fauna for protection and habitat along affected sections of the creek line

- reduction in the abundance of particular flora species that are a source of food
- reduction in the overall productivity of drier ecosystems may also affect the availability of food.

Both Milyeannup Brook and Poison Gully will remain permanent streams so the full range of habitats (from riparian to upslope) will still exist. The main impact is expected to be a small contraction of the riparian and phreatophytic lower slope vegetation. This change in habitat area will happen very gradually over thirty years.

Of the fauna species of conservation significance that are likely to live in Poison Gully and Milyeannup Brook, two frog, one reptile, four bird, and two mammal species are expected to be highly groundwater dependent (depend on phreatophytic or riparian vegetation). Of these only the bird species, the Australasian bittern (*Botaurus poiciloptilus*) is listed under State or Federal Acts.

The contraction of vegetation types is not expected to affect the occurrence or long-term viability of these species due to:

- the potential impacts represent a change rather than a loss of habitat
- the areal extent of the potential impacts represents a very small proportion of the total habitat area used by these fauna.

2.3.6 Compliance with EPA Offsets Position Statement

The EPA Offsets Position Statement is discussed in Chapter 2 Section 6.1. The following table details the potential impacts of the proposal on critical assets along Poison Gully and Milyeannup Brook.

Table 7.10 Compliance with EPA Offsets Position Statement

Critical assets	Prognosis
Declared Rare Flora	1 species recorded in Poison Gully, but is not groundwater dependent and will not be affected
Priority Flora	7 priority flora species recorded in Poison Gully and 4 in Milyeannup Brook. The occurrence and viability of these species are not expected to be significantly effected.
Threatened Ecological Communities	None present
Vegetation complexes with <30% remaining	None present and negligible impact on the local and regional abundance
Threatened Fauna	Negligible impact on terrestrial habitat, reduction in aquatic habitat for the two Priority 4 species; Balston's pygmy perch and mud minnow
Public conservation reserve system	The proposed Milyeannup National Park includes the upper catchments of Poison Gully and Milyeannup Brook. There are no impacts expected in this proposed National Park.
Conservation category wetland	None present
Ecosystems under threat	None present
Indigenous heritage sites	None present
Identified heritage places under EPBC Act	None present

2.3.7 Mitigation

Modelling of several different wellfield configurations was carried out to determine which would have the lowest overall environmental impact. At Poison Gully and Milyeannup Brook, the preferred “Eastern Split” wellfield configuration resulted in the least drawdown of the watertable.

In the absence of the proposal, estimated future regional use will also cause significant drawdowns in Poison Gully and Milyeannup Brook. However, the following mitigating actions will be undertaken by the Water Corporation to offset the combined impacts of the proposal and other regional abstraction if the proposal is approved.

If the proposal were not to proceed, the extent of mitigation that could feasibly be offered by the relatively the low economic value uses of the resource (such as irrigated agriculture) would be considerably less than that being offered by the proposal.

Mitigation of the anticipated impact from the proposal on the Poison Gully and Milyeannup Brook environment will be adaptively managed and will include:

1. The wellfield will be constructed to enable flexibility in the proportion of water abstracted from different layers in the Yarragadee Formation to minimise overall environmental impact.
2. The Water Corporation will conduct a major regional biodiversity study, that will include Poison Gully and Milyeannup Brook, to gain greater knowledge of the groundwater dependence of ecosystems at risk from the proposal, and to allow informed decision making on the management of other threatening processes.
3. If unexpected reductions in flows in Milyeannup Brook occur and are likely to significantly reduce the habitat available for Balston’s pygmy perch, the Water Corporation will supplement summer flows in accordance with the Groundwater Abstraction Management Plan (Chapter 9 Section 8).
4. The Water Corporation proposes to sponsor a program to manage threatening processes (feral animals, weeds, bank instability) in the areas that may be affected by the proposal including Poison Gully and Milyeannup Brook.
5. The comprehensive monitoring of Poison Gully and Milyeannup Brook will improve knowledge of the ecosystem in the area.

Mitigation benefits

There are significant threats to the ecosystems of the Blackwood Plateau including feral animals, dieback and climate change. Research is essential for furthering the understanding of the ecosystem, and to allow informed decision making for the management of threatening processes. An overarching biodiversity study in the region will add resources to research in the region and, by consolidating existing knowledge, increase the effectiveness of funds already being spent.

Feral animal control projects, such as Western Shield, have proved to be effective in increasing the numbers of rare native mammals. However, these programs require ongoing funding to remain effective. The Water Corporation proposal to provide resources to the management of feral animals will have a direct biodiversity benefit. In addition to foxes and cats, feral pigs are a known threat to native animals in this area, where their digging in wetland environments is destructive. Targeting this species in a feral animal control program will decrease a significant threat to wetland environments and the flora and fauna they support.

The contingency measure to supplement summer flows in Milyeannup Brook adds a degree of protection to the aquatic habitat of the Priority 4 Balston's pygmy perch that would not otherwise exist if only private groundwater abstraction takes place.

2.4 MONITORING, ADAPTIVE MANAGEMENT AND ACCOUNTABILITY

The Water Corporation will develop and implement an extensive biological, hydrological and physical monitoring program for the region including the Poison Gully and Milyeannup Brook area. The Water Corporation is also committed to undertaking a comprehensive biodiversity study as part of the Sustainability Initiative (Volume 1 Chapter 7 Section 4.1.1) which will include the Blackwood Plateau, and will investigate the relationship between ecosystems and groundwater.

The outputs of the monitoring program and biodiversity study, together with advice from the Monitoring Review Group, will form the basis of the adaptive management framework for Poison Gully and Milyeannup Brook and other areas of potential impact.

The monitoring program will include a baseline study, which will be completed before the operational phase of the project, that will allow both hydrological and ecological changes and trends to be assessed. The monitoring program and biodiversity study will be developed in consultation with the Monitoring Review Group (Volume 1 Chapter 8 Section 3.2.3). A preliminary outline of a monitoring program has been developed (Table 7.11).

The Water Corporation will prepare an annual Sustainability Report (Volume 1 Chapter 8 Section 3.2.4) that will report on the monitoring results. The Monitoring Review Group will review the monitoring results against a set of defined principles and advise whether any changes need to be made to the management of the project.

Table 7.11 Proposed Poison Gully and Milyeannup Brook monitoring program outline

Field	Parameter	Methods
Hydrology	Length of permanent streamflow	Measured monthly from January to April by recording the coordinates of the start of the stream flow
	Flow	Measure weekly in summer using data loggers (gauging stations not recommended, as they are a barrier to fish migration) CENRM (Appendix 26)
	Groundwater levels	Monitor watertable levels and levels in the underlying Yarragadee Formation monthly for the first few years (at least 2) of the project and then once every two months
	Groundwater quality	Monitor electrical conductivity and chloride in all wells annually (June)
Physical	Water quality	Salinity, conductivity, pH, nutrients (N and P), sampled monthly
Aquatic fauna	Fish recruitment	Annual sampling during October with a particular focus on finding out the range and occurrence of Balston's pygmy perch
	Macroinvertebrates	Sample twice annually during February and September
Vegetation	Tree health	Permanent transects surveyed annually
	Species composition	Permanent quadrats surveyed annually
	Vegetation condition	Permanent quadrats surveyed annually
Terrestrial fauna	Fauna	Terrestrial fauna surveys near the stream lines annually

The biological monitoring of the vegetation will form an important part of the monitoring program in Poison Gully and Milyeannup Brook due to the potential extent of the predicted groundwater drawdowns in the area. Permanent transects and quadrats will be set up using the previous baseline

work carried out by Matiske (Appendix 31). Tree health, species composition and recruitment will be monitored. A range of keystone species that may be influenced by groundwater drawdown will be selected based on available literature, known site preferences, and their life form. Significant changes in these species, together with watertable monitoring, can be used to trigger adaptive management if unexpected and unacceptable impacts are likely to occur.

The contingency measure to supplement flows in Milyeannup Brook will be triggered if hydrological monitoring indicates that the permanent aquatic habitat extent (based on habitat area rather than stream length) of Balston's pygmy perch is likely to reduce by more than 20% in Milyeannup Brook.

If supplementation is required, the rates of flow will be designed to mimic natural flows and water quality conditions.

2.5 PROPONENT COMMITMENTS

The Water Corporation is committed to an adaptive management approach and to the following:

1. Undertake a biodiversity and acid sulphate soils study in areas potentially affected by groundwater drawdown resulting from the proposal. The studies will be funded up to the value of \$1.5M, with the capital and any earned interest made available to the studies over a period of ten years.
2. Prepare, and report on the implementation of, abstraction management plans and associated monitoring programs for the groundwater abstraction in accordance with any licence issued pursuant to the RWI Act and the Groundwater Abstraction Management Plan described in Chapter 9 Section 8.
3. The Water Corporation will contribute to a 5 year program to assist the management of threatening processes in areas that may be affected by the proposal. The funding will be up to \$1M with the capital and any earned interest made available to the management program over a period of five years. The program will address weeds, disease, feral animals, erosion and uncontrolled public access issues insofar as they exist within the potentially affected areas including Poison Gully and Milyeannup Brook.

2.6 ENVIRONMENTAL OUTCOME

Watertable drawdowns in Poison Gully are expected within a localised area, and will potentially pose a risk to groundwater ecosystems within 10 m of the watertable.

The proposal alone may potentially result in a drawdown of 1 – 2 m in Poison Gully and up to 2 – 3 m in Milyeannup Brook. Drawdowns from the proposal, in combination with estimated future regional use, are predicted to be 3 – 5 m. The drawdowns may potentially affect up to 230 ha of vegetation with the likely response being a change in the composition of species in some groundwater dependent vegetation types over the long term.

No extensive vegetation deaths are expected due to drawdown as the rate of drawdown is slow. Over time species composition may change, depending on the adaptability of species.

The localised change in vegetation composition will not significantly affect any significant flora or fauna species, or the local or regional occurrence of any vegetation complex. The composition of some site types may change in a small part of the Milyeannup Brook and Poison Gully area, but there

will be no significant loss of keystone species, ecosystem function (including faunal habitat) or resilience.

The spring in Poison Gully, 3.5 km upstream from the Blackwood River, may migrate several hundred metres downstream, with a 30% reduction in groundwater baseflow from the combined effects of the proposal and estimated future regional use. The perennial stream length of Milyeannup Brook is predicted to reduce from 2.5 km to 1 km, with approximately 30% reduction in groundwater flow from the combined effects of the proposal and estimated future regional use. These tributaries are important refugia for significant freshwater fish species. All the defined ecological water requirements are predicted to be met and the instream ecology is not expected to be significantly affected.

Proposed mitigation includes a commitment to supplement summer flows in Milyeannup Brook if the habitat of Balston's pygmy perch is at risk.

Commitments to reduce threatening processes within the area will restore ecological values currently affected, or under threat, and enhance biodiversity in the area.

The knowledge and data obtained from the proposed biodiversity study, and comprehensive monitoring program, will not only improve the understanding of the area, but will provide for adaptive management to ensure the area is cautiously managed into the future, even in the context of climate change.

3 ROSA BROOK

Sustainability objective

The sustainability objective for the *Blackwood River and its tributaries* factor is:

The Water Corporation will seek to increase the ecological integrity of the Blackwood River and its tributaries.

At a minimum, the proposal will have no significant adverse impact on the Blackwood River and its tributaries.

The *Threatened fauna, Flora and fauna, Rare and priority flora (groundwater dependent)* and *Other groundwater dependent ecosystems* factors and their objectives are also addressed in this section.

The EPA objective for wetlands is:

To maintain the integrity, ecological functions and environmental values of wetlands.

3.1 EXISTING ENVIRONMENT

3.1.1 Relevant investigations

The Water Corporation has undertaken an extensive range of studies in the area that includes Rosa Brook:

1. CENRM (2005a at Appendix 27) investigated the ecological values of the Blackwood River system and provided an increased understanding of the ecological susceptibility of those values to changes in water regime (both quality and quantity). Two sites on Rosa Brook were surveyed. The investigations included fish species, aquatic macroinvertebrates, channel morphology, water quality, and a vegetation and foreshore assessment.
2. Morgan et al. (2004) conducted a detailed fish and freshwater crayfish survey, sampling a total of eight sites on Rosa Brook between August and December 2003, as part of an assessment of groundwater discharge to Rosa Brook from an aquifer test well.
3. Bamford (2003 at Appendix 28) assessed the fauna species that are likely to occur in the potential impact areas and assessed their likely groundwater dependence.
4. Mattiske (2005a at Appendix 31) evaluated the flora and vegetation values at three cross-sectional transects along Rosa Brook in spring 2004. The transect information, detailed field observations, and aerial photograph interpretation were used to undertake vegetation mapping of the valley to the site-vegetation type level.
5. Mattiske (2005b at Appendix 32) evaluated the susceptibility of the flora and vegetation values to groundwater drawdown in the potentially affected areas.
6. Synnott Mulholland Management Services (2005 at Appendix 3) conducted a social impact assessment that included consideration of recreational, aesthetic, and sense of place values of the Blackwood River and its tributaries.

7. Water Corporation carried out an intensive investigation into the hydrogeology of the Southern Perth Basin. This included an extensive drilling project and a review of all available information (Baddock 2005a at Appendix 11).
8. Water Corporation constructed, calibrated (Sun 2005 at Appendix 12) and interpreted (Baddock 2005b at Appendix 13) a numerical model of the South West Yarragadee aquifer system that built on the results of a previous joint project by the Water and Rivers Commission and Water Corporation. This model was peer reviewed and found to be suitable for regional-scale groundwater modelling (Peer Review Panel 2005 at Appendix 20).
9. URS Australia (2004b at Appendix 17) assessed the hydrogeology of groundwater dependent ecosystems in the Blackwood River area.
10. Bamford (2005 at Appendix 29) undertook a desktop review of the potential impacts of predicted watertable drawdowns on terrestrial fauna.

A complementary baseline aquatic fauna study has been undertaken by Morgan & Beatty (2005) for the Department of Environment. The information from that study is included in this assessment.

3.1.2 Hydrology

Rosa Brook is a fourth order stream and minor tributary of the Blackwood River with a total flow of approximately 8.1 GL/yr (Appendix 27). It flows south into the Blackwood River and is fed by two main sub-catchments. Rosa Brook is not perennial and generally flows for six months from early winter to late spring. Localised pools persist in the brook throughout the year.

Rosa Brook cuts into the Leederville aquifer and artesian pressures in the underlying Yarragadee Formation are above the streambed for approximately 1.7 km upstream from its confluence with the Blackwood River. An artesian pressure of 9 m is interpreted at the Blackwood River where Rosa Brook enters.

3.1.3 Land use

Rosa Brook is in the centre of the Blackwood Plateau and its catchment is entirely within State forest and areas of proposed National Park. It is one of the least disturbed tributaries of the Blackwood. The southern section of Rosa Brook (south of Crouch Road) is within the proposed Butler National Park.

3.1.4 Vegetation and flora

Milyeannup Brook, Layman Brook and Rosa Brook have similar vegetation. They are all minor tributaries with well-defined channels, and with about a metre (or more) drop into the main channel in some areas.

Figure 7.16 Rosa Brook – downstream



Photo reproduced with permission from CENRM (2005a)

The generally steep slopes and consistent soils within these valleys result in a linear distribution of site-vegetation types along each side of the valley (Figure 7.18 and Figure 7.19).

The vegetation is dominated by forests and woodlands of jarrah (*Eucalyptus marginata*), marri (*Corymbia calophylla*) with peppermint (*Agonis flexuosa*), and dense undergrowth (Figure 7.16 and Figure 7.17).

There are five vegetation complexes in the Rosa Brook area, including the Blackwood River (BK) and Darradup (DP) complexes, which are creek-line fringing woodlands and forest complexes. The areas of shallow watertable (0 – 6 m depth) are most likely in the Darradup vegetation complex, and to a lesser extent the Blackwood vegetation complex. These complexes are both well-represented (greater than 42%) in the conservation estate (Appendix 32).

Figure 7.17 Rosa Brook – upstream



Photo reproduced with permission from CENRM (2005a)

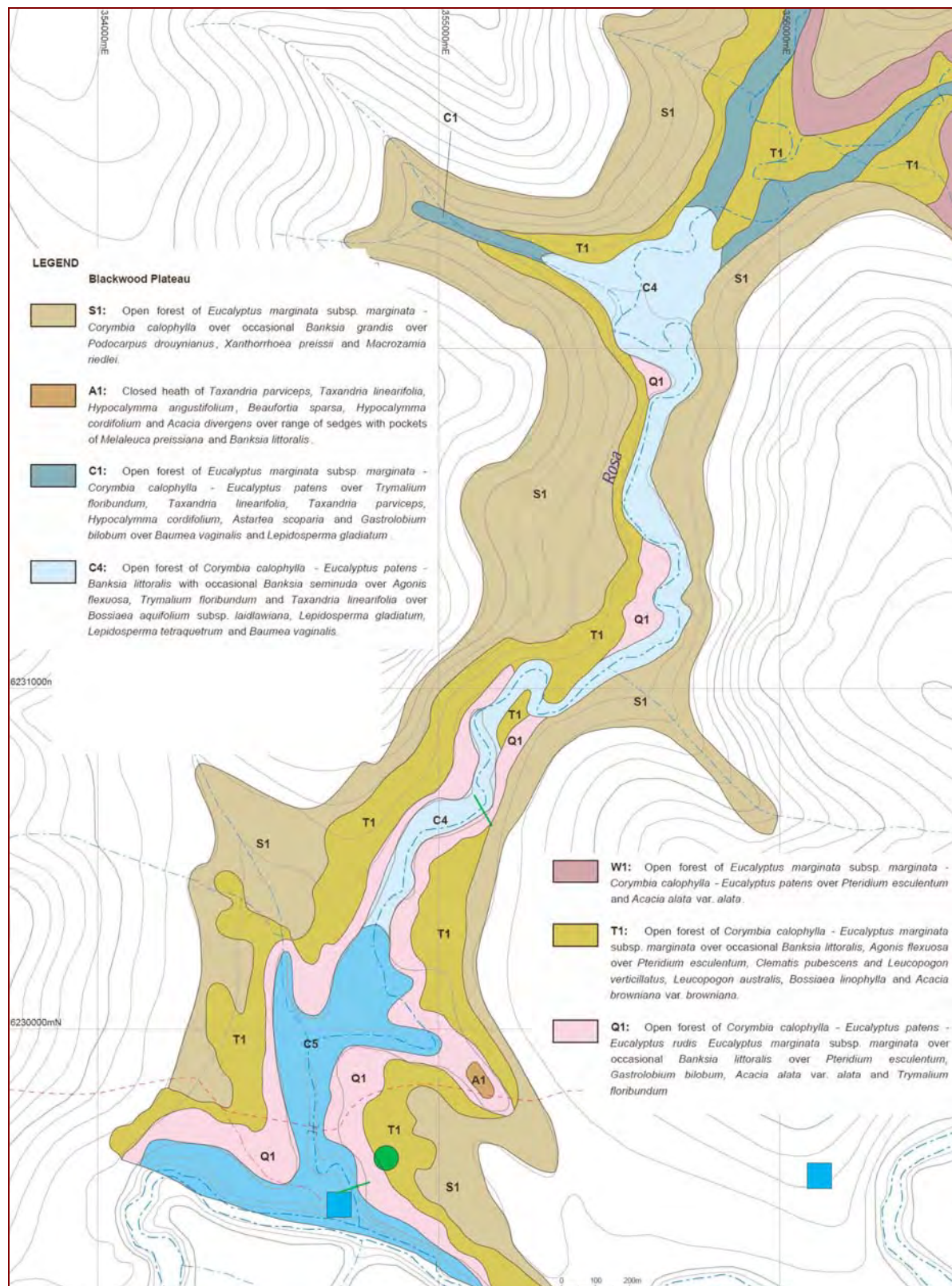
The upper gullies on the tributaries of Rosa Brook also support woodlands and forests of the Bidella, Jalbarragup and Kingia vegetation complexes.

Mattiske (Appendix 31) mapped a total of six site-vegetation types on the lower slopes and valley floors of Rosa Brook (Table 7.12, Figure 7.18 and Figure 7.19). Of these, the C1, C4 and C5 types are the most likely to be influenced by any drawdown of the watertable. The other site-vegetation types are typically associated with clay-loam soils with higher soil moisture retaining capacity.

All of these site-vegetation types are also well-represented in nearby valley systems.

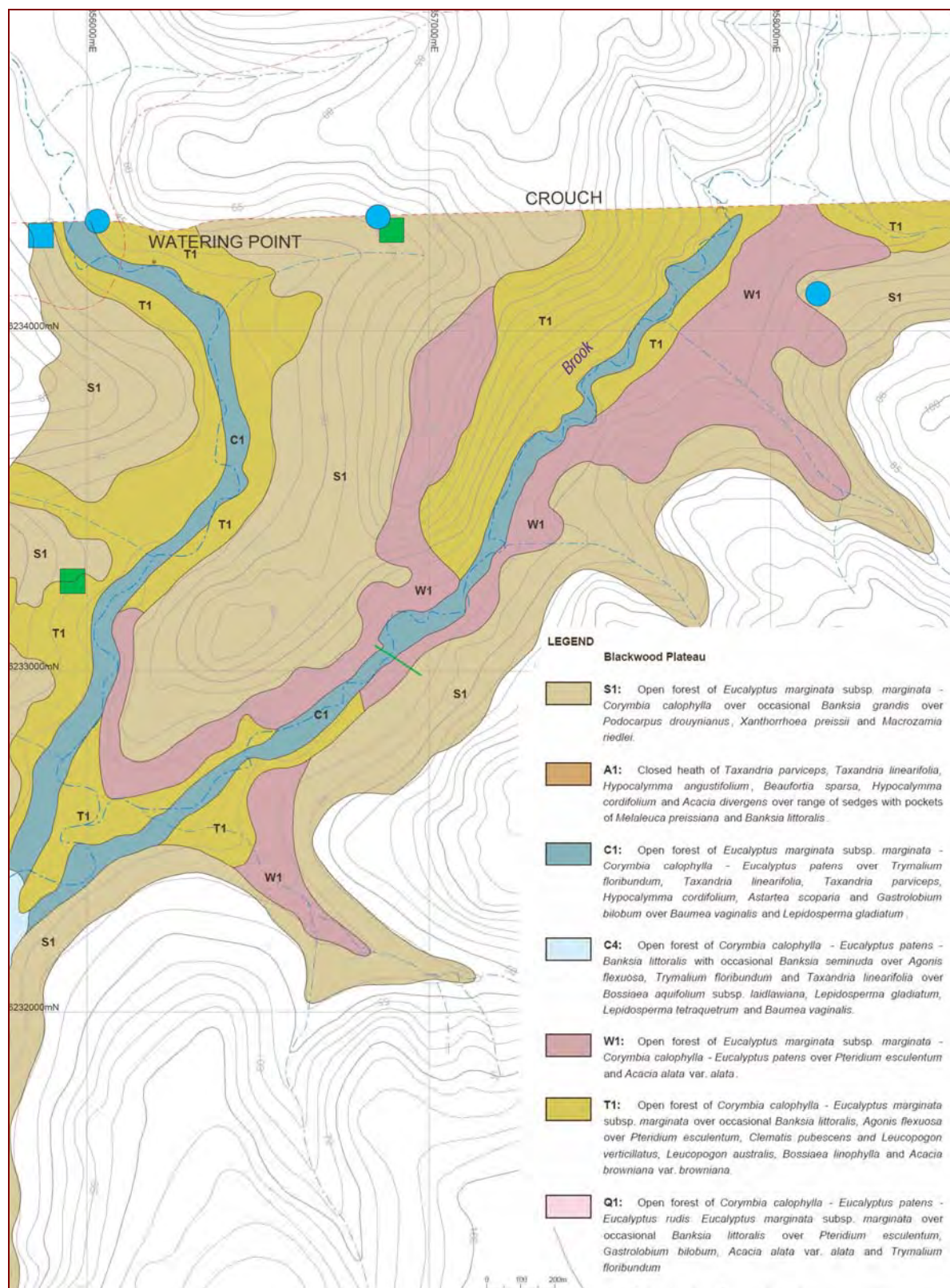
Mattiske (Appendix 31) recorded 169 plant species in the Rosa Brook valley. Only a small proportion of these species are considered to be highly dependent on regional groundwater, due to the narrowness of the valley with only a small area having a sufficiently shallow watertable.

Figure 7.18 Site-vegetation types along Rosa Brook, Map 1



Adapted from Mattiske 2005a.

Figure 7.19 Site vegetation types along Rosa Brook, Map 2



Adapted from Mattiske 2005a.

Table 7.12 Description of the site-vegetation types that occur at Rosa Brook

Site-vegetation type	Description of vegetation
C1	Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> – <i>Corymbia calophylla</i> – <i>Eucalyptus patens</i> over <i>Trymalium floribundum</i> , <i>Taxandria linearifolia</i> , <i>Taxandria parviceps</i> , <i>Hypocalymma cordifolium</i> , <i>Astartea scoparia</i> , and <i>Gastrolobium bilobum</i> over <i>Baumea vaginalis</i> and <i>Lepidosperma gladiatum</i>
C4	Open forest of <i>Corymbia calophylla</i> – <i>Eucalyptus patens</i> – <i>Banksia littoralis</i> with occasional <i>Banksia seminuda</i> over <i>Agonis flexuosa</i> , <i>Trymalium floribundum</i> , and <i>Taxandria linearifolia</i> over <i>Bossiaea aquifolium</i> subsp. <i>laidlawiana</i> , <i>Lepidosperma gladiatum</i> , <i>Lepidosperma tetraquetrum</i> and <i>Baumea vaginalis</i>
C5	Open forest of <i>Eucalyptus rudis</i> – <i>Agonis flexuosa</i> – <i>Melaleuca raphiophylla</i> over patches of <i>Melaleuca viminea</i> , <i>Astartea scoparia</i> , <i>Taxandria linearifolia</i> and <i>Lepidosperma gladiatum</i> , <i>Lepidosperma tetraquetrum</i> and <i>Baumea vaginalis</i>
W1	Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> – <i>Corymbia calophylla</i> – <i>Eucalyptus patens</i> over <i>Pteridium esculentum</i> and <i>Acacia alata</i> var. <i>alata</i>
T1	Open forest of <i>Corymbia calophylla</i> – <i>Eucalyptus marginata</i> subsp. <i>marginata</i> over occasional <i>Banksia littoralis</i> , <i>Agonis flexuosa</i> over <i>Pteridium esculentum</i> , <i>Clematis pubescens</i> and <i>Leucopogon verticillatus</i> , <i>Leucopogon australis</i> , <i>Bossiaea linophylla</i> and <i>Acacia browniana</i> var. <i>browniana</i>
Q1	Open forest of <i>Corymbia calophylla</i> – <i>Eucalyptus patens</i> – <i>Eucalyptus rudis</i> – <i>Eucalyptus marginata</i> subsp. <i>marginata</i> over occasional <i>Banksia littoralis</i> over <i>Pteridium esculentum</i> , <i>Gastrolobium bilobum</i> , <i>Acacia alata</i> var. <i>alata</i> and <i>Trymalium floribundum</i>

3.1.5 Declared Rare and Priority Flora

Mattiske (Appendix 31) recorded a total of 169 species in three transects surveyed in Rosa Brook. Three of these are Priority Flora and likely to be moderately dependent on the maintenance of groundwater levels (Appendix 31):

1. *Stylidium barleei* (Priority 3) occurs in both drier and moist sites
2. *Tyrbastes glaucescens* (Priority 4) occurs in seasonally waterlogged and dry areas
3. *Conospermum paniculatum* (Priority 3) occurs in minor gullies, swamps and dry areas.

Table 7.13 Summary of recorded species and their significance in Rosa Brook

Status	Act	Regional groundwater dependency		
		High	Moderate	Low
Endangered	Federal			
Vulnerable	Federal			
Rare	State			
Priority 1	State			
Priority 2	State			
Priority 3	State		2	
Priority 4	State		1	
Total species recorded		8	39	122

Very few of the species recorded are likely to have high dependence on regional groundwater (Table 7.13). This reflects the narrow width of the creek-line vegetation (Appendix 31).

On the basis of regional database searches there are 57 Declared Rare and Priority species that potentially occur near Rosa Brook. Fifteen of those are predicted to have a high dependency on the watertable. Only one Declared Rare species (*Verticordia plumosis* var. *vassensis*) that may occur around Rosa Brook is likely to have a high dependency on the watertable (Appendix 31).

3.1.6 Threatened Ecological Communities

No Threatened Ecological Communities have been listed, or located in or near Rosa Brook.

3.1.7 Terrestrial fauna

Rosa Brook is steeply dissected with a narrow band of riparian vegetation between the creek line and upland vegetation. The area is expected to support two frog, three or four reptile, 11 – 13 bird, and seven or eight mammal species of conservation significance (Table 7.14) (Appendix 29). Of these, the frogs, one reptile, four bird, and two mammal species are expected to be highly groundwater dependent, based on the groundwater dependence of their preferred habitat. There is one bird species expected to be found in the area that has both high groundwater dependence and high conservation significance (CS1).

Table 7.14 Species of conservation significance (CS) likely to occur in Rosa Brook and their level of groundwater dependence (GD)

Species	CS*	GD	Occurrence
FROGS			
<i>Geocrinia rosea</i>	3	High	Likely
<i>Metacrinia nicholli</i>	3	High	Likely
REPTILES			
<i>Morelia spilota</i>	1	Low	Likely
<i>Egernia pulchra</i>	3	Low	Likely
<i>Glaphyromorphus gracilipes</i>	3	High	Likely
<i>Elapognathus minor</i>	3	Moderate	Uncertain
BIRDS			
<i>Merops ornatus</i> (migratory)	1	Low	Likely
<i>Apus pacificus</i> (migratory)	1	Low	Likely
<i>Falco peregrinus</i>	1	Low	Likely
<i>Calyptorhynchus banksia</i>	1	Low	Likely
<i>Calyptorhynchus latirostris</i>	1	Low	Likely
<i>Calyptorhynchus baudinii</i>	1	Low	Likely
<i>Botaurus poiciloptilus</i>	1	Very high	Uncertain
<i>Ixobrychus minutus</i>	2	Very high	Uncertain
<i>Ixobrychus flavicollis</i>	2	Very high	Likely
<i>Ninox connivens</i>	2	Low	Likely
<i>Tyto novaehollandiae</i>	2	Low	Likely
<i>Falcunculus frontatus</i>	2	Low	Likely
<i>Stagonopleura oculata</i>	3	High	Likely
MAMMALS			
<i>Dasyurus geoffroii</i>	1	Moderate	Likely
<i>Pseudocheirus occidentalis</i>	1	Low	Uncertain

<i>Setonix brachyurus</i>	1	Moderate	Likely
<i>Phascogale tapoatafa</i>	2	Moderate	Likely
<i>Isodon obesulus</i>	2	High	Likely
<i>Macropus irma</i>	2	Moderate	Likely
<i>Falsistrellus mackenziei</i>	2	Low	Likely
<i>Hydromys chrysogaster</i>	2	Very high	Likely

Adapted from Bamford (2005)

*: Conservation significance: 1 = Species listed under State or Federal Acts, 2 = Species not listed under State or Federal Acts, but listed in publications on threatened fauna, or as Priority species by CALM, 3 = Species not listed under Acts or in publications, but considered of at least local significance because of their pattern of distribution

3.1.8 Aquatic fauna

CENRM (Appendix 27) found that Rosa Brook had near pristine riparian vegetation with some weeds. The foreshore assessment also indicated that there was negligible erosion or slumping of the steep banks. The upstream site had up to 25 cm of sediments in the pools.

Five of the six species of endemic freshwater fish known to occur in the Blackwood River system were recorded in Rosa Brook (Appendix 27, Morgan & Beatty 2005 and Morgan et al. 2004). One of those, the mud minnow is a Priority 4 species with conservation significance. The mud minnow was also recorded in seven of the other Blackwood River tributaries (Morgan & Beatty 2005).

Four species of endemic freshwater crayfish were recorded in Rosa Brook by CENRM (Appendix 27), Morgan & Beatty (2005) and Morgan et al. (2004). The most abundant species in all three studies was the gilgie (*Cherax quinquecarinatus*). This species was present at all eight sites, on all sampling occasions, in the study carried out by Morgan et al. (2004).

A total of 24 species of macroinvertebrates were recorded at two sites along Rosa Brook (Appendix 27). The Gondwanic dragonfly species *Archaeosynthemis macrostigma* was recorded only in Rosa Brook. This species is endemic to south-western Australia and is known to live in ephemeral systems (Appendix 27).

3.1.9 Social values

Nannup is the main community on the Blackwood Plateau. Environmental amenity is important in this community and is focused on the Blackwood River (Appendix 3). However, there is a general appreciation of the surrounding environment, which includes the forest and Blackwood River tributaries such as Rosa Brook.

3.2 ASSESSMENT FRAMEWORK AND POLICY CONTEXT

The following policies and legislation are relevant to the impact assessment of Rosa Brook and their associated ecosystems and are described in Chapter 2:

- *Wildlife Conservation Act 1950*
- *Conservation and Land Management Act 1984*
- *Environmental Protection and Biodiversity Conservation Act 1999*
- *National Strategy for Conservation of Australia's Biological Diversity 1996*

- National Objectives and Targets for Biodiversity Conservation 2001
- National Strategy for Ecologically Sustainable Development 1992
- Conservation Policy for Western Australia 1997.

3.2.1 Key EPA and other policies

The key policies that have been applied to the assessment of the several factors considered in this section, and which provide a critical test of environmental sustainability, are as follows:

- EPA Position Statement No. 2: Environmental Protection of Native Vegetation in Western Australia 2000.
- EPA Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection 2002.
- EPA Position Statement No. 4: Environmental Protection of Wetlands 2004
- EPA draft Position Statement No. 9 (V2): Environmental Offsets 2005
- Forest Management Plan 2004 –2 013 (2004).

3.3 POTENTIAL IMPACTS AND MITIGATION

The groundwater abstraction by the proposal, together with estimated future regional use, is expected to draw down the watertable along Rosa Brook, which may affect groundwater dependent ecosystems.

3.3.1 Groundwater drawdown

The watertable drawdown expected to occur as a result of the proposal after 30 years is between 0.1 m and 0.25 m with small areas of drawdown in the 0.25 – 0.5 m range near Crouch Road (Figure 7.20 and Figure 7.21). The total predicted watertable drawdown resulting from the proposal together with estimated future regional use in Rosa Brook after 30 years is up to 0.5 m (with a few very small areas with a drawdown in the 0.5 – 1 m range).

Along much of Rosa Brook the watertable is not near the surface. The coarseness of the watertable mapping in this area has made prediction of the extent of potential impact on vegetation difficult.

In the upper reaches of Rosa Brook, perched watertables exist on clayey strata, effectively isolating these areas from any impact from pressure changes in the Yarragadee Formation. Due to the regional resolution of the groundwater model, the area of potential impact is exaggerated by the modelling.

The predicted drawdowns in Rosa Brook are expected to occur at a steady rate over the project life (30 years) with total drawdown rates in the valleys expected to be less than 0.05 m/yr.

3.3.2 Creek hydrology

The Yarragadee Formation does not outcrop in Rosa Brook and the stream is not permanent, so the proposal will have no discernible impact on the hydrology of the stream.

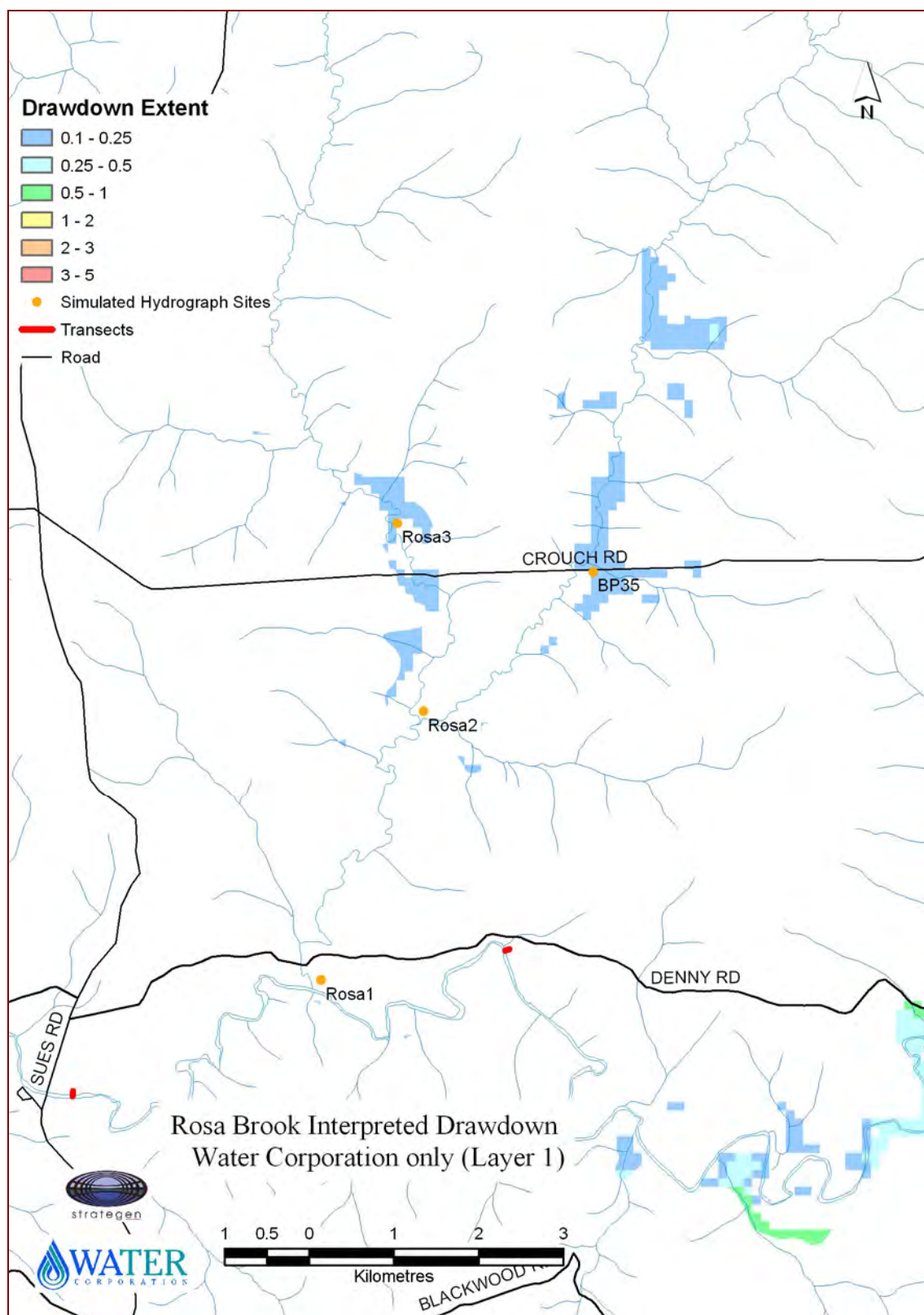
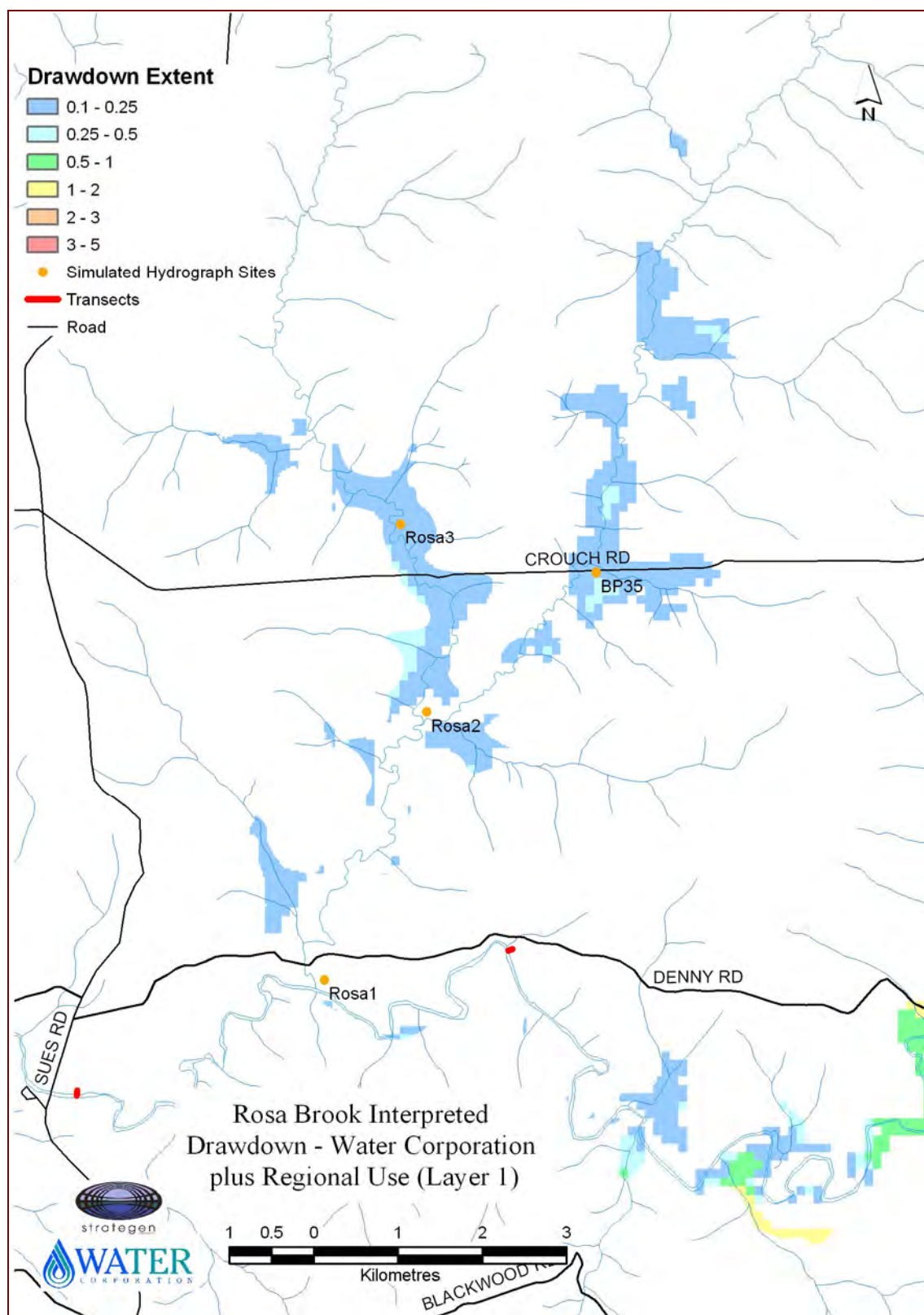
Figure 7.20 Predicted proposal drawdowns in Rosa Brook

Figure 7.21 Predicted proposal and estimated future regional use drawdowns in Rosa Brook

3.3.3 Groundwater dependent vegetation at risk

Vegetation potentially at risk – screening assessment using Froend & Loomes 2005

There is approximately 190 ha within the Rosa Brook tributary system where the watertable is within 10 m of the surface and there is potential for vegetation to be affected by groundwater drawdowns from the proposal alone (Table 7.15). The area potentially affected from the cumulative impacts of the proposal and the estimated future regional use is 520 ha.

Drawdowns of less than 0.5 m from the proposal alone result in “low – no measurable change” potential impact for most of the Rosa Brook valley, as defined by Froend & Loomes (2004). The total groundwater drawdowns of 0.1 – 0.5 m in Rosa Brook place most of the potentially impacted areas in the “low – no measurable change” or “moderate – small change” potential impact categories. This means that in the worst-affected areas after 30 years of cumulative impacts there is likely to be some evidence of change to a drier system, as described in detail in Table 6.3.

Potential impact on vegetation complexes

The vegetation complexes in the Rosa Brook valleys with potential to be impacted by the proposal are the riverine fringing woodlands and forests on the Blackwood River (BK) complex and, to a lesser extent the fringing creek-line woodlands and forests of the Darradup (DP) complex, which occupy the narrower valley floors. The riparian vegetation along the creek line is largely dependent on seasonal creek flows fed by rainfall, and will not be affected by groundwater drawdowns.

There are also substantial areas of the Blackwood and Darradup vegetation complexes in the Rosa Brook valley, as shown in Table 7.15. The vegetation complexes are all well-represented in conservation reserves. The remaining percentage of the pre-European extent of each complex is Bidella 93%, Blackwood (BK) 93%, Darradup 65%, and Kingia 95%.

Table 7.15 Vegetation complexes in areas of potential drawdown from the proposal at Rosa Brook

	Bidella (ha)	Blackwood River (ha)	Darradup (ha)	Kingia (ha)	Total (ha)
Reserved %	31	55	45	28	
Remaining %	93	93	65	95	
0 – 3*	0.0	41.9	59.0	0.0	100.9
3 – 6*	0.0	52.1	14.4	4.5	71.0
6 – 10*	4.8	12.2	0.0	0.0	17.0
Total	4.8	106.3	73.4	4.5	188.9

* Depth to groundwater category

The effect of the estimated drawdown on the composition of these complexes is expected to be either not measurable or small. The expected impacts will not change the vegetation complexes at Rosa Brook and will have no significant impact on the vegetation complexes at a local or regional scale.

Potential impact on site-vegetation types

The potential impacts on site-vegetation types in Rosa Brook are very small (resulting in no measurable change) due to the small predicted drawdown. Rosa Brook is a dissected valley system, so the width of vegetation that would be susceptible to a groundwater drawdown is small. Rosa Brook is ephemeral (seasonal) so there are no predicted changes to surface moisture conditions.

The six site-vegetation types and their occurrence along Rosa Brook are very similar to those at Milyeannup Brook (Appendix 31). The C site-vegetation types and the lower slope site-vegetation types (Q1, T1 and W1) will be the most susceptible to groundwater drawdowns at Rosa Brook (Appendix 32). However, as there are no significant hydrological changes predicted to occur in Rosa Brook, there are also unlikely to be any significant or even measurable changes in vegetation type along Rosa Brook.

All of the site-vegetation types at Rosa Brook are well-represented in the nearby valley systems so, at the site-vegetation type scale, any impact will not be significant (Appendix 31).

Conclusion

The impact of the proposal, combined with estimated future regional use, at Rosa Brook is likely to have no significant impact, either locally or regionally, on the vegetation complexes and site-vegetation types present.

3.3.4 Declared Rare and Priority Flora

No Declared Rare Flora species, two Priority 3⁴⁵ species (*Stylidium barleei* and *Conospermum paniculatum*) and one Priority 4⁴⁶ species (*Tyrbastes glaucescens*) were recorded at Rosa Brook. These species are not restricted to the Rosa Brook area and were recorded from several other valley systems in the survey by Mattiske (Appendix 31). As the Priority Flora are likely to be moderately dependent on regional groundwater there is potential for some local impacts.

Due to the predicted low to medium potential impact associated with the total predicted drawdowns, the moderate groundwater dependence of the Priority Flora, and their regional occurrence, the long-term viability of these and other potentially occurring significant species are not expected to be affected by the proposal.

3.3.5 Terrestrial fauna

Rosa Brook is a seasonal stream with vegetation on the valley floor relying on seasonal inundation and soil moisture storage. There is expected to be low potential for impact, with no measurable change in most areas at Rosa Brook. Therefore, there will be minimal change in habitat type or extent along the valley.

⁴⁵ Priority 3 refers to taxa which are known from several populations, at least some of which are not believed to be under immediate threat.

⁴⁶ Priority 4 species are considered to have been adequately surveyed and are not currently threatened by any identifiable factors.

Of the fauna species of conservation significance that are likely to occur at Rosa Brook, two frog, one reptile, four bird, and two mammal species are expected to be highly groundwater dependent (dependent on phreatophytic or riparian vegetation). Of these, only the bird species (the Australasian bittern – *Botaurus poiciloptilus*) is listed under State or Federal Acts (Appendix 29).

The low predicted impacts are not expected to affect the occurrence or long-term viability of any of these species.

3.3.6 Compliance with the EPA Offsets Position Statement

The EPA Offsets Position Statement is discussed in Chapter 2 Section 6.1. The following table details the potential impacts of the proposal on critical assets at Rosa Brook. There are no potentially significant impacts on the critical assets associated with Rosa Brook (Table 7.16).

Table 7.16 Compliance with EPA Offsets Position Statement at Rosa Brook

Critical assets	Prognosis
Declared Rare Flora	None present
Priority Flora	3 priority flora species recorded at Rosa Brook. The occurrence and viability of these species are not expected to be significantly effected.
Threatened Ecological Communities	None present
Vegetation complexes with <30% remaining	None present and negligible impact on the local and regional abundance
Threatened Fauna	Negligible impact on terrestrial habitat, negligible impact on the aquatic habitat of the Priority 4 mud minnow as Rosa Brook is not perennial
Public conservation reserve system	No significant impact expected on the conservation or recreational values of the proposed Butler National Park
Conservation category wetland	None present
Ecosystems under threat	None present
Indigenous heritage sites	None present
Identified heritage places under EPBC Act	None present

3.3.7 Mitigation

Modelling of several wellfield configurations (location and units in the Yarragadee Formation) was conducted to determine the configuration that would have least effect on other water users, and lowest environmental impact on potentially sensitive areas in the region (Chapter 5 Section 4.1). The “Eastern Split” wellfield configuration was selected and found to have the least overall environmental impact, and is expected to cause less drawdown at Rosa Brook than other options.

Mitigation of the anticipated potential impact from the proposal on the Rosa Brook environment will be adaptively managed and will include:

1. The wellfield will be constructed to enable flexibility in the proportion of water abstracted from different layers in the Yarragadee Formation to minimise overall environmental impact.
2. A major regional biodiversity study will be conducted, that will include Rosa Brook, to gain greater knowledge of the groundwater dependence of ecosystems at risk from the proposal.

3. The Water Corporation proposes to sponsor a program to manage threatening processes (feral animals, weeds, bank instability) in the areas that may be affected by the proposal including Poison Gully and Milyeannup Brook.

3.4 MONITORING, ADAPTIVE MANAGEMENT AND ACCOUNTABILITY

The Water Corporation will develop and implement an extensive biological, hydrological and physical monitoring program for the region, including the Rosa Brook area. The Water Corporation is also committed to undertaking a comprehensive biodiversity study, which will include the Blackwood Plateau and will investigate the relationship between ecosystems and groundwater.

The outputs of the monitoring program and biodiversity study, together with advice from the Monitoring Review Group, will form the basis of the adaptive management framework for Rosa Brook and other areas of potential impact.

The monitoring program will include a baseline study, to be completed before the operational phase of the project, that will allow both hydrological and ecological changes and trends to be assessed. The monitoring program and biodiversity study will be developed in consultation with the Monitoring Review Group. A preliminary outline of a monitoring program has been developed (Table 7.22).

The Water Corporation will prepare an annual Sustainability Report that will report on the monitoring results. The Monitoring Review Group will review the monitoring results against a set of pre-defined principles and determine whether any changes need to be made to the management of the project.

Table 7.17 Proposed Rosa Brook monitoring program outline

Field	Parameter	Methods
Hydrology	Groundwater levels	Monitor watertable levels and levels in the underlying Yarragadee Formation monthly for the first few years (at least 2) of the project and then once every two months
	Groundwater quality	Monitor electrical conductivity and chloride in all wells annually (June)

If groundwater monitoring indicates that unexpected changes are occurring in the watertables along Rosa Brook in comparison to control sites, a biological monitoring program will be triggered.

3.5 PROPONENT COMMITMENTS

The Water Corporation is committed to an adaptive management approach and to the following:

1. Undertake a biodiversity and acid sulphate soils study in areas potentially affected by groundwater drawdown resulting from the proposal. The studies will be funded up to the value of \$1.5M, with the capital and any earned interest made available to the studies over a period of ten years.
2. Prepare, and report on the implementation of, abstraction management plans and associated monitoring programs for the groundwater abstraction in accordance with any licence issued pursuant to the RWI Act and the Groundwater Abstraction Management Plan described in Chapter 9 Section 8.

3. The Water Corporation will contribute to a 5 year program to assist the management of threatening processes in areas that may be affected by the proposal. The funding will be up to \$1M with the capital and any earned interest made available to the management program over a period of five years. The program will address weeds, disease, feral animals, erosion and uncontrolled public access issues insofar as they exist within the potentially affected areas including Rosa Brook.

3.6 ENVIRONMENTAL OUTCOME

The predicted groundwater drawdowns are small in Rosa Brook and the proposal is likely to result in a “low – no measurable change” potential impact through most of the valley. The creek line is narrow and there are relatively few species with high groundwater dependence. Any vegetation change that does occur will not significantly affect the conservation status of any significant flora or fauna species, or the local or regional occurrence of any vegetation complex. There may be small changes in some site-vegetation types, but their regional occurrence will not be significantly affected.

Rosa Brook is ephemeral and its streamflows are driven by rainfall, so it will not be affected by the proposal.

Proposed commitments to reduce threatening processes in the area, and in the proposed Blackwood River National Park, will restore ecological values currently affected or under threat, and enhance biodiversity in the area. The knowledge and data obtained from the proposed biodiversity study and comprehensive monitoring program will not only improve the understanding of the area, but provide for adaptive management to ensure the area is cautiously managed into the future even in the context of climate change.

The proposed mitigation measures are anticipated to provide for a net improvement in the biodiversity of the area.

4 ST JOHN BROOK

Sustainability objectives

The sustainability objective for the *Blackwood River and its tributaries* factor is:

The Water Corporation will seek to increase the ecological integrity of the Blackwood River and its tributaries.

At a minimum, the proposal will have no significant adverse impact on the Blackwood River and its tributaries.

The *Threatened fauna, Flora and fauna, Rare and priority flora (groundwater dependent)* and *Other groundwater dependent ecosystems* factors and their objectives are also addressed in this section.

The EPA objective for wetlands is:

To maintain the integrity, ecological functions and environmental values of wetlands.

4.1 EXISTING ENVIRONMENT

4.1.1 Relevant investigations

The Corporation has undertaken an extensive range of studies that included St John Brook:

1. CENRM (2005a at Appendix 27) investigated the ecological values of the Blackwood River system and provided an increased understanding of the ecological susceptibility of those values to changes in water regime (both quality and quantity). The study included three sites on St John Brook and the investigations included fish species, aquatic macroinvertebrates, channel morphology, water quality, and a vegetation and foreshore assessment. The sampling sites used were on St Paul Brook (upper), at Barrabup Pool (mid) and at Mowen Road (lower).
2. CENRM (2005b at Appendix 26) assessed the impact of hydrological changes on the habitat values of the Blackwood River tributaries.
3. Mattiske (2004) conducted a review of the flora and vegetation at two sites on St John Brook.
4. Mattiske (2005b at Appendix 32) evaluated the susceptibility of the flora and vegetation values to groundwater drawdown in the potentially affected areas.
5. Bamford (2003 at Appendix 28) assessed the fauna species that are likely to occur in the potential impact areas, and assessed their likely groundwater dependence.
6. Synnott Mulholland Management Service (2005 at Appendix 3) conducted a social impact assessment that included consideration of recreational, aesthetic, and sense of place values of the Blackwood River and its tributaries.
7. Water Corporation carried out an intensive investigation into the hydrogeology of the Southern Perth Basin. This included an extensive drilling project and a review of all available information (Baddock 2005a at Appendix 11).

8. Water Corporation constructed, calibrated (Sun 2005 at Appendix 12) and interpreted (Baddock 2005b at Appendix 13) a numerical model of the South West Yarragadee aquifer system that built on the results of a previous joint project by the Water and Rivers Commission and Water Corporation. This model was peer reviewed and found to be suitable for regional-scale groundwater modelling (Peer Review Panel 2005 at Appendix 20).
9. URS Australia (2004c at Appendix 18) conducted a hydrogeological assessment of groundwater dependent ecosystems at St John Brook.
10. Bamford (2005 at Appendix 29) undertook a desktop review of the potential impacts of the predicted drawdowns on terrestrial fauna.

A complementary baseline aquatic fauna study was undertaken by Morgan & Beatty (2005) for the Department of Environment. The information from that study is included in this assessment.

4.1.2 Hydrology

St John Brook is a fresh, perennial tributary of the Blackwood River that enters the river from the north, to the west of Nannup. St John Brook is the largest tributary of the Blackwood River on the Blackwood Plateau, with a mean annual flow of approximately 43.8 GL/yr (Appendix 27) and a 583 km² catchment.

The brook is deeply incised into the surrounding landscape, and contains a number of pools within 10 km of the Blackwood River, including Barrabup Pool and Workmans Pool. Most water flows into St John Brook in winter and spring when it is fed by St Paul Brook, Mill Brook, Harrington Brook, Padbury Brook, Rocky Gully and a number of smaller tributaries (CALM 2004). During summer, the brook reduces to a series of permanent pools along the lower parts of the watercourse (Appendix 13).

St John Brook cuts into the Leederville Formation, which occurs at the surface in this area and is the source of groundwater fed summer flow in the brook. The source of baseflow is situated about 700 m south of St Paul Brook (Appendix 13), approximately 13 km upstream from the junction with the Blackwood River. The Leederville Formation contributes a baseflow input to the brook of approximately 0.3 GL/yr (10 L/s), which is approximately 0.6% of the mean annual flow in the brook (Appendix 18).

St John Brook has a poor connection with the Leederville aquifer due to the clayey nature of the creek line and this results in the low summer flows. These characteristics make supplementation of flows in this stream a feasible management option.

The upper Yarragadee unit (Unit 1) has a reasonable connection with the Leederville aquifer in this area. There are artesian pressures in the Yarragadee Formation along the lower parts of St John Brook. At Barrabup Pool, the artesian pressure is about 4 m above the surface of the pool.

The water quality of St John Brook is high, with low salinity, and generally high dissolved oxygen levels. The brook had higher total nitrogen readings in a July 2004 measurement (Appendix 27) than the other Blackwood River tributaries, probably due to agricultural runoff from the upper catchment.

4.1.3 Land use

The catchment of St John Brook is mainly State forest and most of the valley is included in proposed conservation reserves. A total of 16% of the catchment has been cleared for agricultural practices, mainly grazing beef cattle (CALM 2004).

The proposed St John Brook Conservation Park (3440 ha) is approximately 7 km north-west of Nannup, and the proposed Jarrahwood Conservation Park (160 ha) is approximately 18 km north-west of Nannup (Figure 7.26). The proposed parks will be managed primarily for conservation purposes, but with sustainable recreation incorporated.

4.1.4 Vegetation and flora

The vegetation of St John Brook is dominated by open forest with an overstorey of marri (*Corymbia calophylla*) and jarrah (*Eucalyptus marginata* subsp. *marginata*) in the valleys, and jarrah on the lateritic slopes (CALM 2004). The vegetation of St John Brook is further described by CALM (2004) as follows:

“The valley floors and broad terraces associated with St John Brook consist of open forest woodlands of marri and some jarrah, as well as fringing woodlands of flooded gum (*E. rudis*), river banksia (*B. seminuda*), moonah (*Melaleuca preissiana*) and peppermint (*Agonis flexuosa*). Along the edge of watercourses are tall shrublands of swamp peppermint (*Taxandria linearifolia*) and wonnich (*Callistachys lanceolata*). Minor tributaries leading into St John Brook comprise low woodlands of holly-leaved banksia (*B. illicifolia*) and *Hakea lasianthoides* on the valley floors and open forest and woodlands of jarrah, marri and blackbutt (*E. patens*) on the slopes.”

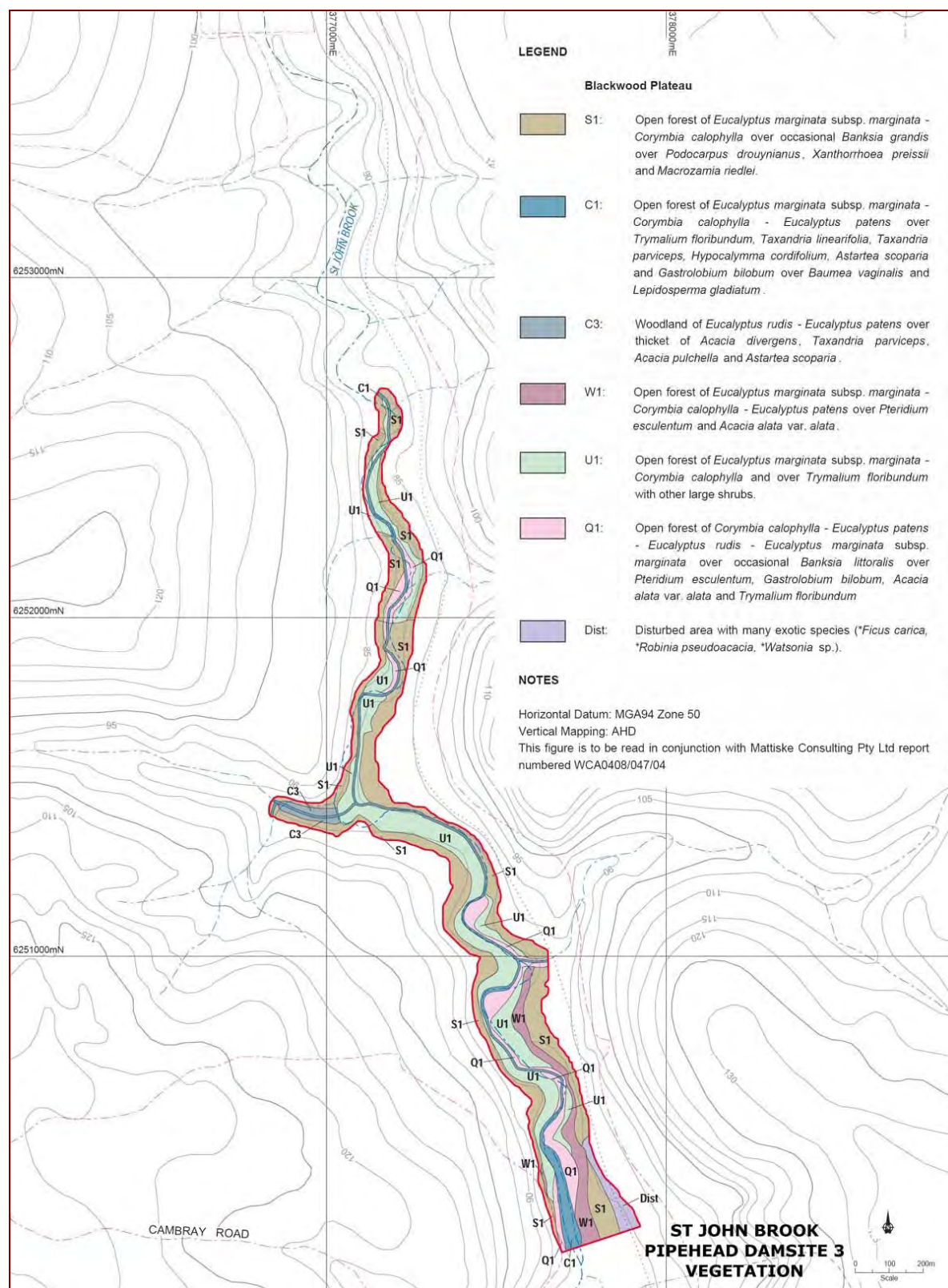
The vegetation complexes in the St Johns Brook valley potentially affected by the proposal are the Blackwood, Darradup and Jalbarragup vegetation complexes (Mattiske 2004). These vegetation complexes are all well-represented in the formal reserve system.

Mattiske (2004) mapped eight site-vegetation types at two sites along St John Brook (Table 7.18, Figure 7.22 and Figure 7.23). All of the site-vegetation types are also found in nearby valley systems (Mattiske 2004).

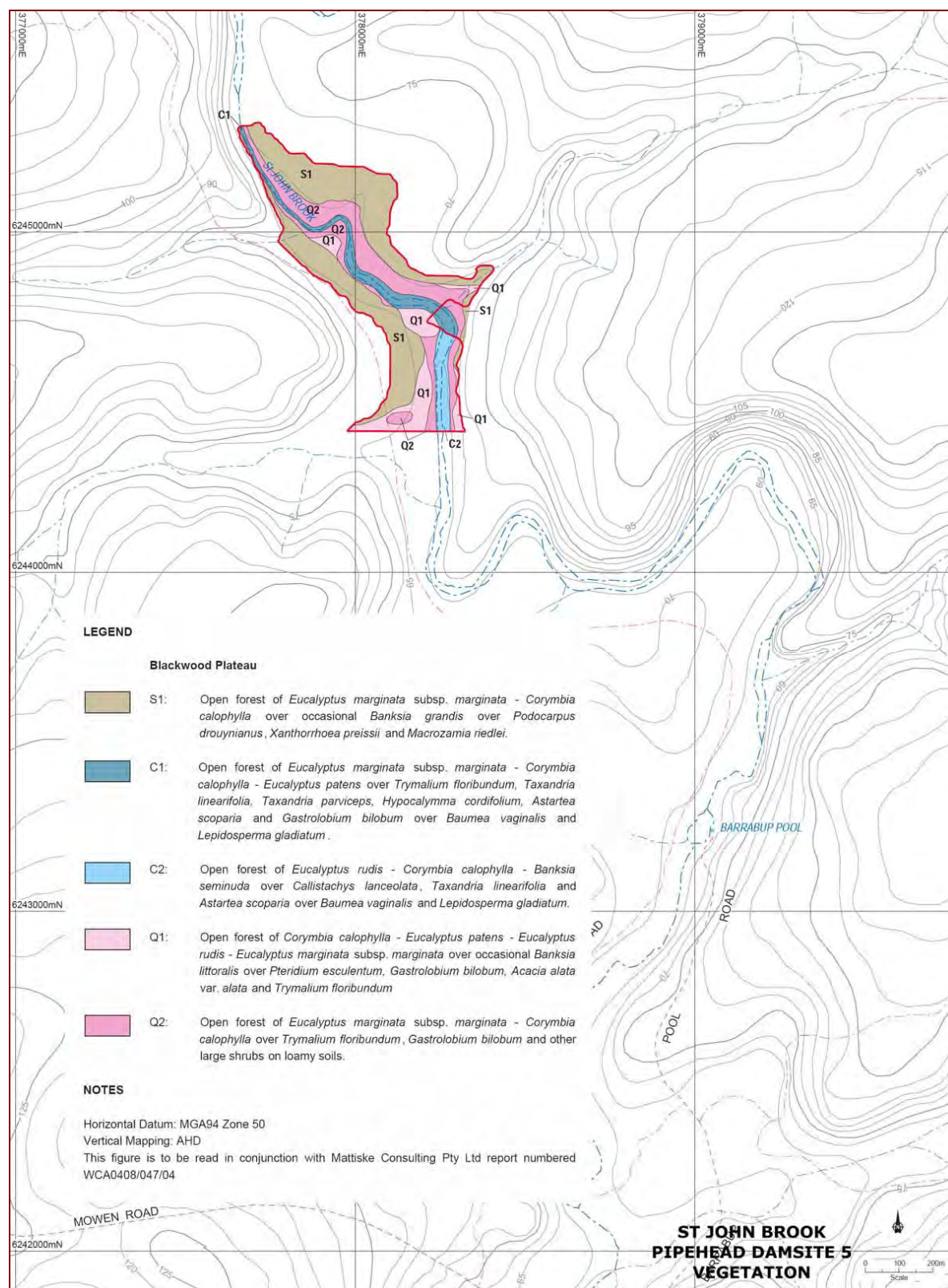
Table 7.18 Description of site-vegetation types at St John Brook

Site-vegetation type	Description of vegetation
S1	Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> – <i>Corymbia calophylla</i> over occasional <i>Banksia grandis</i> over <i>Podocarpus drouynianus</i> , <i>Xanthorrhoea preissii</i> and <i>Macrozamia riedlei</i>
C1	Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> – <i>Corymbia calophylla</i> – <i>Eucalyptus patens</i> over <i>Trymalium floribundum</i> , <i>Taxandria linearifolia</i> , <i>Taxandria parviceps</i> , <i>Hypocalymma cordifolium</i> , <i>Astartea scoparia</i> and <i>Gastrolobium bilobum</i> over <i>Baumea vaginalis</i> and <i>Lepidosperma gladiatum</i>
C2	Open forest of <i>Eucalyptus rudis</i> – <i>Corymbia calophylla</i> – <i>Banksia seminuda</i> over <i>Callistachys lanceolata</i> , <i>Taxandria linearifolia</i> and <i>Astartea scoparia</i> over <i>Baumea vaginalis</i> and <i>Lepidosperma gladiatum</i>
C3	Woodlands of <i>Eucalyptus rudis</i> – <i>Eucalyptus patens</i> over thickets of <i>Acacia divergens</i> , <i>Taxandria parviceps</i> , <i>Acacia pulchella</i> and <i>Astartea scoparia</i>
W1	Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> – <i>Corymbia calophylla</i> – <i>Eucalyptus patens</i> over <i>Pteridium esculentum</i> and <i>Acacia alata</i> var. <i>alata</i>
U1	Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> – <i>Corymbia calophylla</i> over <i>Trymalium floribundum</i> with other large shrubs
Q1	Open forest of <i>Corymbia calophylla</i> – <i>Eucalyptus patens</i> – <i>Eucalyptus rudis</i> – <i>Eucalyptus marginata</i> subsp. <i>marginata</i> over occasional <i>Banksia littoralis</i> over <i>Pteridium esculentum</i> , <i>Gastrolobium bilobum</i> , <i>Acacia alata</i> var. <i>alata</i> and <i>Trymalium floribundum</i>
Q2	Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> – <i>Corymbia calophylla</i> over <i>Trymalium floribundum</i> , <i>Gastrolobium bilobum</i> and other large shrubs on loamy soils

Mattiske (2004) recorded 221 plant species at St John Brook. Only a small proportion of these are considered to be highly dependent on regional groundwater. None of these plant taxa are restricted to the St John Brook valley.

Figure 7.22 Site-vegetation type mapping on St John Brook, Site 1

Adapted from Mattiske 2004.

Figure 7.23 Site-vegetation type mapping on St John Brook, Site 2

Adapted from Mattiske 2004.

CENRM (Appendix 27) found that St John Brook had near pristine riparian vegetation with some weeds at the three sites sampled. The foreshore assessment also indicated that there was some erosion at the upstream and downstream sites, with negligible erosion at the midstream site. The banks, both upstream and downstream, were steep with very little sedimentation.

4.1.5 Declared Rare and Priority Flora

No Declared Rare Flora species were recorded in the two areas surveyed on St John Brook. One site was approximately 1.5 km upstream of Barrabup Pool, and the other was north of St Paul Brook. Both were within the Leederville outcrop area. The following Priority Flora species were recorded by Matiske (2004):

1. *Stylidium barleei* (Priority 3) is a perennial herb that grows on white to grey sands, and extends from Augusta to Busselton (including locations near Augusta, Cane Break Road, Great Northern Road, Sues Road, Nannup, Whicher Range and Busselton). Where it is found, this species is locally numerous (Matiske 2004) and is likely to have low groundwater dependence (Appendix 32).
2. *Tyrbastes glaucescens* (Priority 4) is a perennial rhizomatous tufted herb that has previously been recorded in a range of swampy areas on flats and along stream embankments. It grows on a range of soil types, from peat to sands to loams and clayey-sands, and its range extends from Augusta to the southern coastal areas south of Nannup, and onto wetter sites on the Blackwood Plateau. This species dominates the edges of stream zones (Matiske 2004) and is likely to have high groundwater dependence (Appendix 32).

On the basis of regional database searches there are 57 Declared Rare and Priority Flora that could potentially occur in the St John Brook valley. Fifteen of these are likely to be highly dependent on regional groundwater (Appendix 32). As only two sections of St John Brook were surveyed by Matiske (2004), a more extensive survey would be likely to find further significant species in the valley. Matiske (Appendix 32) identified two Priority Flora species, *Cyathochaeta teretifolia* (Priority 3) and *Meeboldina thysanantha* (Priority 3), which are also found in nearby tributaries in a similar valley environment. Both these Priority Flora species are likely to have high groundwater dependence.

4.1.6 Threatened Ecological Communities

No Threatened Ecological Communities have been listed or located in, or near, St John Brook.

4.1.7 Terrestrial fauna

CALM (2004) recognises the riverine vegetation, thickets and wetland habitats along the valley system as important shelter for fauna species. The upland jarrah forest is also recognised as an important habitat.

Mammal species of conservation significance known at St John Brook (CALM 2004) are:

1. The chuditch (*Dasyurus geoffroii*) is classified as Vulnerable by both the EPBC Act and the Wildlife Act. The chuditch is a carnivore and is threatened by a loss of habitat productivity as well as competition and predation from introduced predators. The chuditch lives in the jarrah forest and may be more common in valleys, possibly because the valley ecosystem is more productive (Appendix 28). The chuditch was given a moderate groundwater dependence rating, due to its likely preference for valley habitats.
2. The western brush wallaby (*Macropus irma*), is classified as Priority 4 by CALM, and tends to shelter in dense vegetation around wetlands and damplands. Therefore, this species was given a moderate groundwater dependence rating (Appendix 28).
3. The quenda or southern brown bandicoot (*Isodon obesulus fusciventer*) is classified as Priority 4 by CALM with a moderate to high groundwater dependence rating due to its association with dense vegetation around wetlands (Appendix 28).
4. The brush tailed phascogale (*Phascogale tapoatafa*) is classified as Priority 3 by CALM and tends to live in dense vegetation near wetlands. This species was given a moderate groundwater dependence rating (Appendix 28).
5. The rakali or water rat (*Hydromys chrysogaster*) is classified as Priority 4 by CALM. The rakali is the only mammal species in the area that is considered highly groundwater dependent, as it is strongly associated with wetland habitats (Appendix 28).

All of the above species are expected to be found on both the coastal plains and on the Blackwood Plateau.

Significant bird species known at St John Brook are the Baudin's black-cockatoo (*Calyptorhynchus baudinii*), Carnaby's black-cockatoo (*C. latirostris*) and the Peregrine falcon (*Falco peregrinus*), Forest red-tailed black-cockatoo (*C. banksii naso*) and Western False Pipstrelle (*Falsistrellus mackenziei*) (CALM 2004).

Bamford (Appendix 29) listed the species of conservation significance that are likely to be found at St John Brook. The area is expected to support two frog, three or four reptile, 11 – 13 bird, and seven or eight mammal species of conservation significance (Appendix 29). Of these, the frogs, one reptile, four bird, and two mammal species are expected to be highly groundwater dependent. There is one bird species expected to occur in the area that has both high groundwater dependence and high conservation significance (CS1).

Table 7.19 Species of conservation significance (CS) likely to occur at St John Brook indicating their groundwater dependence (GD)

Species	CS*	GD	Occurrence
FROGS			
<i>Geocrinia rosea</i>	3	High	Likely
<i>Metacrinia nichollsi</i>	3	High	Likely
REPTILES			
<i>Morelia spilota</i>	1	Low	Likely
<i>Egernia pulchra</i>	3	Low	Likely
<i>Glaphyromorphus gracilipes</i>	3	High	Likely
<i>Elapognathus minor</i>	3	Moderate	Uncertain

Species	CS*	GD	Occurrence
BIRDS			
<i>Merops ornatus</i> (migratory)	1	Low	Likely
<i>Apus pacificus</i> (migratory)	1	Low	Likely
<i>Falco peregrinus</i>	1	Low	Likely
<i>Calyptorhynchus banksia</i>	1	Low	Likely
<i>Calyptorhynchus latirostris</i>	1	Low	Likely
<i>Calyptorhynchus baudinii</i>	1	Low	Likely
<i>Botaurus poiciloptilus</i>	1	Very high	Uncertain
<i>Ixobrychus minutus</i>	2	Very high	Uncertain
<i>Ixobrychus flavicollis</i>	2	Very high	Likely
<i>Ninox connivens</i>	2	Low	Likely
<i>Tyto novaehollandiae</i>	2	Low	Likely
<i>Falcunculus frontatus</i>	2	Low	Likely
<i>Stagonopleura oculata</i>	3	High	Likely
MAMMALS			
<i>Dasyurus geoffroii</i>	1	Moderate	Likely
<i>Pseudocheirus occidentalis</i>	1	Low	Uncertain
<i>Setonix brachyurus</i>	1	Moderate	Likely
<i>Phascogale tapoatafa</i>	2	Moderate	Likely
<i>Isodon obesulus</i>	2	High	Likely
<i>Macropus irma</i>	2	Moderate	Likely
<i>Falsistrellus mackenziei</i>	2	Low	Likely
<i>Hydromys chrysogaster</i>	2	Very high	Likely

Adapted from Bamford (2005)

*: Conservation significance: 1 = Species listed under State or Federal Acts, 2 = Species not listed under State or Federal Acts, but listed in publications on threatened fauna or as Priority species by CALM, 3 = Species not listed under Acts or in publications, but considered of at least local significance because of their pattern of distribution.

4.1.8 Aquatic fauna

St John Brook has approximately 18 km of first order streams, 7 km of second order streams, and 2 km of third order streams. The current permanent spring source is about 700 m south of St Paul Brook (Appendix 13), which is approximately 13 km upstream and within the first order stream section. Even with the low perennial flows in this upstream section, the first order stream has limited habitat diversity (Appendix 26) mainly due to the lack of pool and riffle zones.

Four of the six species of endemic freshwater fish known to live in the Blackwood River system were recorded in St John Brook (Appendix 27, Morgan & Beatty 2005). One of those, the mud minnow, is a Priority 4 species with conservation significance. The mud minnow was also recorded in seven of the other Blackwood River tributaries (Morgan & Beatty 2005), but not in the main stem of the Blackwood River (Table 6.6). This species has also been nominated as Vulnerable under the EPBC Act.

The other fish recorded in St John Brook were the nightfish, western pygmy perch, and the western minnow, which are also found in six, five and eight other tributaries, respectively (Morgan & Beatty 2005, Appendix 27). These species were also found in the main stem of the Blackwood River.

Three species of endemic freshwater crayfish were recorded in St John Brook by CENRM (Appendix 27) and Morgan & Beatty (2005). The most abundant species was the gilgie (*Cherax quinquecarinatus*). Morgan & Beatty (2005) sampled three sites along St John Brook and freshwater crayfish were only found at the Mowen Road site, which is the closest site to the Blackwood River.

The number of macroinvertebrates recorded at the three sites along St John Brook by CENRM (Appendix 27) were consistent with those found at other tributaries, with between 17 and 20 species recorded at each site.

4.1.9 Social values

Nannup is the main population centre on the Blackwood Plateau. Environmental amenity is important to this community with a focus on the Blackwood River (Appendix 3). The proposed St John Brook Conservation Park recognises the high environmental and social value of the area. Water-based recreation activities are concentrated on Barrabup and Workmans Pools. There is also a general appreciation of the surrounding environment, which includes the forest and Blackwood River tributaries including St John Brook.

The proposed St John Brook and Jarrahwood Conservation Parks are significant for members of the Bibbulmun Tribal Group, as St John Brook was a travel route along the Blackwood River (Appendix 3). People of this group employed a mobile lifestyle, moving along river systems in search of food sources. River pools were particularly significant as sources for food and as camping locations. Barrabup and Workmans Pools were identified by Goode (Appendix 23) as sites of mythological significance, in association with Waugal beliefs. The Nannup Scarred Trees site is within the proposed Jarrahwood Conservation Park, and is registered under the AH Act.

The area around Barrabup Pool is currently being considered for registration under the AH Act.

4.2 ASSESSMENT FRAMEWORK AND POLICY CONTEXT

The following policies and legislation are relevant to the impact assessment of St John Brook and their associated ecosystems and are described in Chapter 2:

- *Wildlife Conservation Act 1950*
- *Conservation and Land Management Act 1984*
- *Environmental Protection and Biodiversity Conservation Act 1999*
- National Strategy for Conservation of Australia's Biological Diversity 1996
- National Objectives and Targets for Biodiversity Conservation 2001
- National Strategy for Ecologically Sustainable Development 1992
- Conservation Policy for Western Australia 1997.

4.2.1 Key EPA and other policies

The key policies that have been applied to the assessment of the factors considered in this section, and which provide a critical test of environmental sustainability, are as follows:

- EPA Position Statement No. 2: Environmental Protection of Native Vegetation in Western Australia 2000.
- EPA Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection 2002.
- EPA Position Statement No. 4: Environmental Protection of Wetlands 2004
- EPA draft Position Statement No. 9 (V2): Environmental Offsets 2005
- Forest Management Plan 2004-2013 (2004)
- Proposed St John Brook and Jarrahwood Conservation Parks Draft Management Plan 2004. The vision of this management plan is:

“The St John Brook and Jarrahwood Conservation Parks capture the essence of the Jarrah Forest, with their picturesque pools, gently flowing brook systems and peaceful ambience. They attract people from the local and wider community, who come to the area to recreate around the Brook and enjoy the tranquillity of the natural environment. To manage increased visitor use in the future, the parks will offer a range of sustainable recreational pursuits and provide interpretation and education focussing on the vibrant cultural and natural heritage. Management will focus on conservation of the park’s habitats, flora and fauna, and in 2014 the parks’ condition will be the same or better than in 2004.”

4.3 POTENTIAL IMPACTS AND MITIGATION

The groundwater abstraction by the proposal, and by estimated future regional use, is expected to affect the following components of St John Brook as a consequence of watertable drawdown:

- the streambed through a reduction in permanent stream length and base flow rate at the end of summer
- areas upslope from the streambed which may contain groundwater dependent ecosystems.

4.3.1 Groundwater drawdown

The total watertable drawdown resulting from the proposal alone or together with estimated future regional use, is predicted to be 1 – 2 m, after 30 years, in the area upstream of Barrabup Pool. Most of this drawdown will be attributable to the Water Corporation proposal (Figure 7.24 and Figure 7.25). There is unlikely to be any drawdown of the watertable downstream of Barrabup Pool, as artesian pressures will continue to be maintained above the pool (Appendix 13). Some drawdown of the watertable may occur away from the valley floor, as artesian pressures diminish with elevation of the watertable. The flanks of the St John Brook valley are generally steep, so that depth to the watertable increases very quickly away from the valley floor. This limits the potential area of impact of drawdown on ecosystems dependent on regional groundwater. Winter streamflow and seepage of water down the valley flanks are expected to provide for full recovery of watertable levels in the valley floor each year.

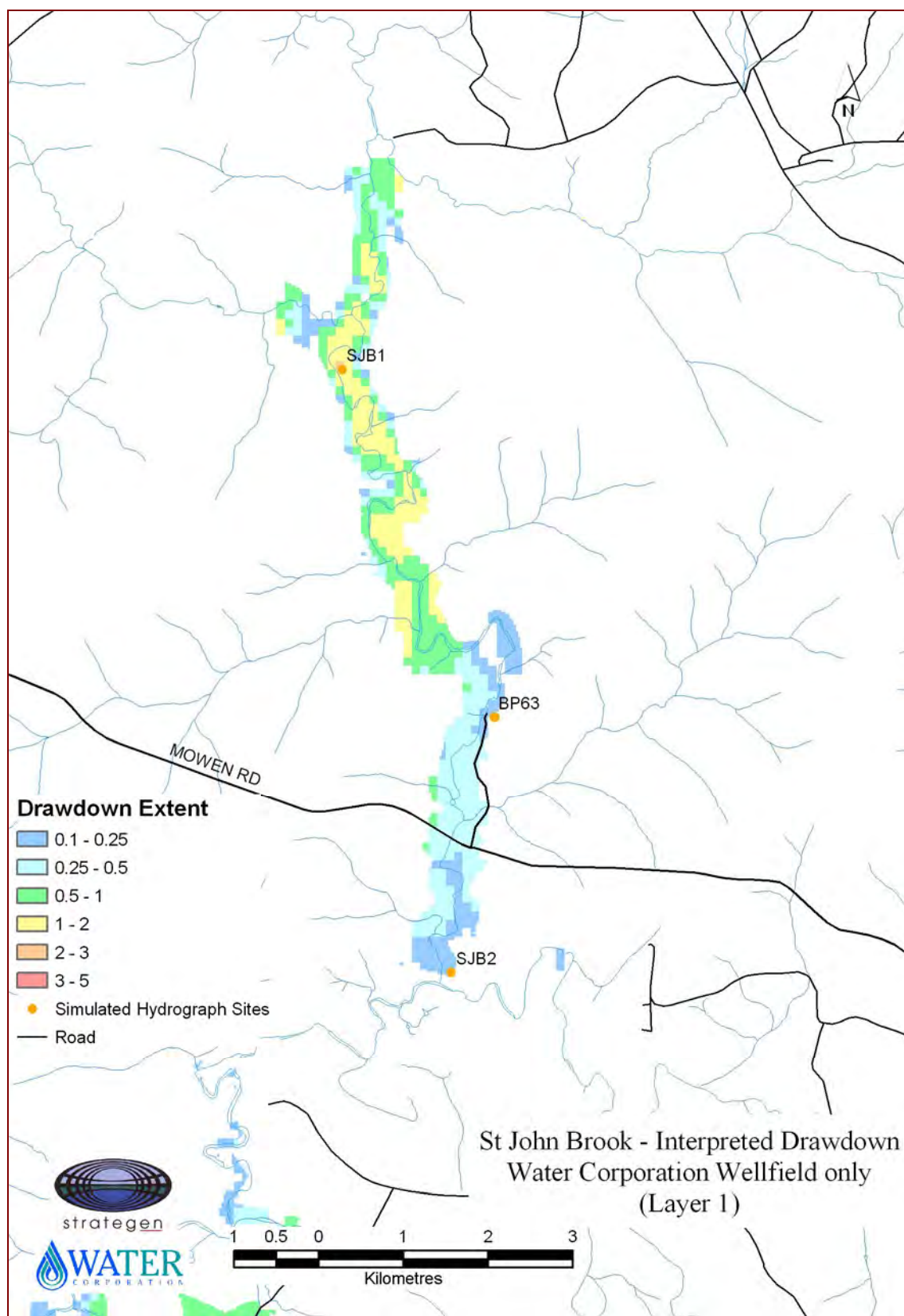
Figure 7.24 Predicted proposal drawdowns at St John Brook after 30 years

Figure 7.25 Predicted proposal and estimated future regional use drawdowns at St John Brook after 30 years

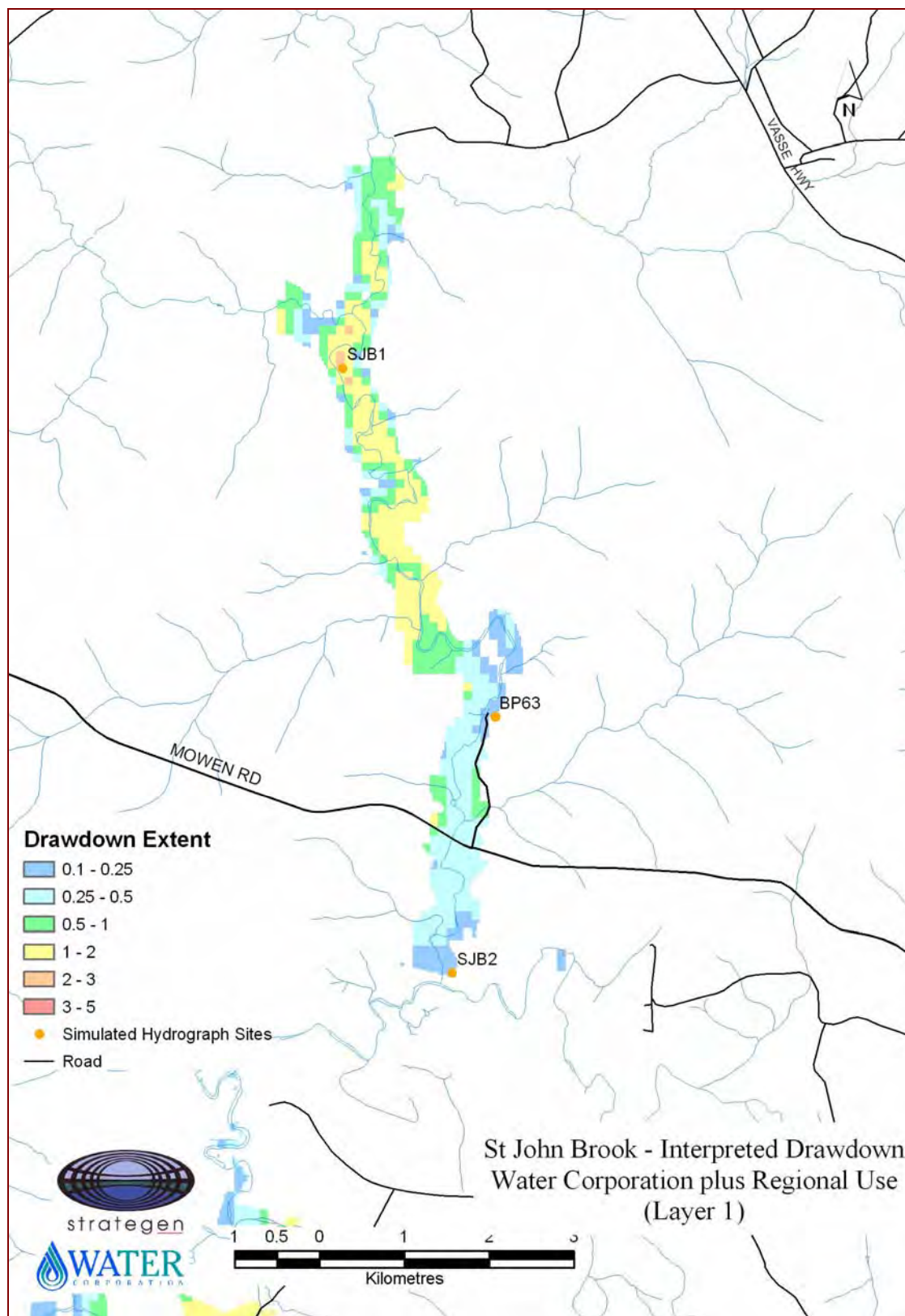
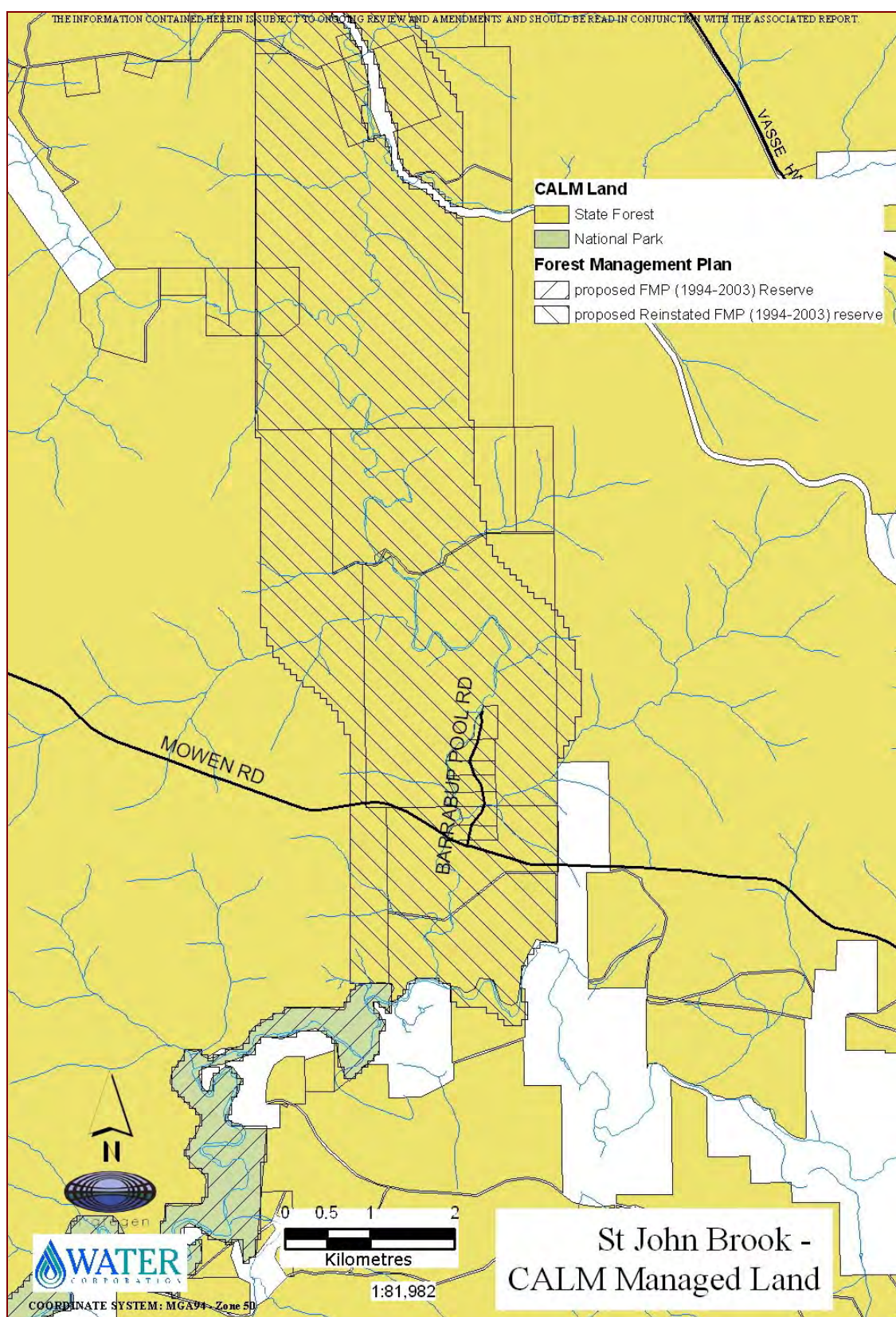


Figure 7.26 Conservation estate within the St John Brook area



4.3.2 Groundwater dependent vegetation at risk

Vegetation potentially at risk – screening assessment using Froend & Loomes 2005

There is approximately 700 ha of vegetation at St John Brook where the interpreted drawdowns occur and the watertable is within 10 m of the surface. Only a small proportion of this area may actually be affected as the scale of the groundwater contours and the model cells are much broader than the narrow valley system and the areas of groundwater dependent ecosystems within it. This broadly defined risk area is the same for the proposal alone, and when considered together with future regional use.

Using the Froend & Loomes (Appendix 30) screening level approach, the predicted groundwater drawdowns from the proposal place this area in St John Brook in the possible “high” potential impact category. The cumulative drawdowns of the proposal and estimated future regional use also result in possible “high” potential impact category. The drawdowns will happen gradually, at less than 0.10 m/yr, which minimises the risk to vegetation (Froend & Loomes 2004).

Potential effect on vegetation complexes

The Darradup vegetation complex within St John Brook is most susceptible to watertable drawdown. The wider valleys occupied by the Blackwood (BK) complex are less susceptible (Appendix 32). Although there will be some change in composition within these vegetation complexes at St John Brook, the changes are within the range of vegetation included in that type and will therefore not change the vegetation complex classifications in the valley. Neither of these vegetation complexes have been extensively cleared and they are well-represented in the conservation estate (Table 7.20). The expected impact on vegetation complexes at St John Brook is not considered to be significant, as the compositional change will be gradual and will stay within the ranges of the existing vegetation complexes.

Table 7.20 Vegetation complexes in areas of potential drawdown at St John Brook

	Bidella (ha)	Blackwood - BK (ha)	Darradup (ha)	Jalbarragup (ha)	Layman (ha)	Milyeannup (ha)	Total (ha)
Reserved %	31	55	45	13	5	26	
Remaining %	93	93	65	90	74	98	
0–3 ²	1.5	99.5	179.4	0.0	0.0	14.7	295.2
3–6 ²	27.5	91.4	55.7	4.4	62.1	23.6	267.3
6–10 ²	18.4	69.4	23.8	11.6	2.2	10.2	138.4
Total	47.4	260.3	258.9	16.1	64.3	48.5	700.9

* Depth to groundwater category

Note: Vegetation complexes occupying less than 10 ha in the area (a total of 5.5 ha) have not been included in this table

Potential effect on site-vegetation types

St John Brook is a narrow valley with eight site-vegetation types mapped at two sites by Mattiske (2004). All the site-vegetation types in the valley are well represented locally and in the nearby valley systems. The site-vegetation types can be categorised according to their position in the landscape and the characteristics of the soils they are associated with.

There are three main categories: valley floor, lower slope and mid slope. Site-vegetation types within each of these categories will be influenced differently by the predicted groundwater drawdowns.

The site-vegetation types in the very narrow valley floor of St John Brook are the C1, C2 and C3 fringing creek-line types. The valley floor vegetation is adapted to wet or moist conditions supplied by a shallow watertable and surface water, including shallow seepage. This vegetation is considered susceptible to groundwater drawdown. However, the accumulation of surface water in these low-lying areas, the high moisture storage capacity of the soils, and seepage from upslope areas partially buffers the impact of groundwater drawdown in these areas. Studies on the Gnangara Mound have shown that vegetation in the lowest lying areas are not the first to be affected by groundwater drawdowns, for these reasons (Mattiske 2003). The groundwater drawdowns are also less severe in these areas due to the concentration of recharge along the narrow creek line.

The potential impact on the C vegetation types fringing the creek line are expected to be very low. If the permanence of summer flows in St John Brook is affected by the proposal, then supplementation of the surface flows is proposed. This will maintain moisture conditions in the valley floor. Alternatively, if the contingency measure is not needed because the summer flows are not being significantly affected, then the natural creek flows will maintain moisture conditions in the narrow valley floor.

The Q1, Q2, W1 and U1 site-vegetation types occupy the lower slopes of St John Brook. These units usually occur on low – mid slopes on more fertile soils. This vegetation is less at risk than that on the lower slopes of Poison Gully, as St John Brook units have better soils with higher soil moisture retention capacity, and the St John Brook valley has steeper slopes with a much narrower area of shallow watertables. Furthermore, these units are generally higher in the landscape than at Poison Gully, so are likely to be less groundwater dependent. However, groundwater drawdown may cause a small down slope shift of these vegetation types. Due to the dissected nature of the valley system the shift is likely to be confined to a narrow area.

The mid-slope site-vegetation type at St John Brook is S1, and it occupies areas of sandy lateritic soils on the mid-slope and upland areas. This unit has a low groundwater dependence and is not expected to be affected by drawdown.

The impacts on site-vegetation types in St John Brook are not expected to be significant, as the full range of site-vegetation types will still exist in the valley, and only small shifts in extent expected. All the site-vegetation types are well represented in nearby valley systems and their local abundance is not expected to be affected.

Ecosystem function

The resilience of the ecosystem at St John Brook will not be significantly affected, as the current range of vegetation types will still exist in the valley, only their extents may shift slightly. If watertable conditions later return to the current state, the site-vegetation types would expand back up the valley slope to their current extents. The lack of disturbance in these Blackwood Plateau valleys increases the resilience of the ecosystem to change, as the area is not influenced by other threatening processes such as weed encroachment. The vegetation types exist in a continuum, and shifts in composition up or down-slope are natural responses to climate, fire and other processes.

Conclusion

The impact of the proposal, combined with estimated future regional use, on the local or regional representation, occurrence, or function of vegetation complexes is expected to be insignificant. Similarly, impact on site-vegetation types is likely to be insignificant in a local or regional context, and unlikely to significantly affect faunal habitat. Therefore, the proposal will have no significant impact on groundwater dependent ecosystems.

4.3.3 Declared Rare and Priority Flora

No Declared Rare Flora and two Priority species were recorded in the two areas surveyed on St John Brook. One site was approximately 1.5 km upstream of Barrabup Pool, and the other was north of St Paul Brook, both within the Leederville outcrop area. The Priority 3 species *Stylidium barleei* is likely to have low groundwater dependence (Appendix 32) and is unlikely to be affected.

The Priority 4 species *Tyrbastes glaucescens* dominates the edges of stream zones and is likely to have a high groundwater dependence (Appendix 32). However, moisture conditions in the valley floor in St John Brook are unlikely to change significantly as surface flows will be maintained. Therefore, this and other Priority species that potentially occur on the valley floor, are unlikely to be significantly affected. This species has a range from Augusta to the southern coastal areas south of Nannup, and on wetter sites on the Blackwood Plateau, so any localised effects in St John Brook will not significantly impact the overall occurrence or viability of the species.

There are other Declared Rare and Priority species that potentially occur in St John Brook. As the full range of site-vegetation types are expected to be maintained in the valley, with only small shifts in extent expected (Section 4.3.2 of this Chapter), the potential impacts on any significant species that occur in the valley will be minor.

4.3.4 Potential effects on creek hydrology

Most of the flow in St John Brook occurs from winter to spring. It is largely generated by rainfall, with a minor contribution from groundwater discharge. The groundwater discharge component of the flow only becomes significant in late summer and autumn when there is very little surface flow from rainfall. The summer baseflow in St John Brook about 0.02 GL/month.

Artesian pressure in the Yarragadee Formation at, and downstream of, Barrabup Pool is greater than the predicted reduction in pressure resulting from the combined abstraction of the proposal and estimated future regional use. Water levels at Barrabup Pool, Workmans Pool, and other pools downstream are not expected to be affected because the artesian pressure will maintain watertable levels.

Drawdown above Barrabup Pool is expected to cause a reduction in summer water levels in permanent pools, and to reduce summer streamflow. The reduction is likely to be greatest in the reach from upstream of Barrabup Pool to the junction with St Paul Brook. As the summer flows are already very low, there is potential that the groundwater discharge will cease in the upper section of the brook within the first order stream section (Appendix 13).

4.3.5 Aquatic fauna

The perennial spring source of St John Brook is predicted to migrate downstream from its current position, 13 km from the Blackwood River. The risk of impact on aquatic fauna is greatest in the upper section, in the first order stream, where habitat diversity is low.

CENRM (Appendix 26) concluded that if a previously perennial first order stream became ephemeral, the risk to regional aquatic biodiversity would be considered low, for the following reasons:

- first order streams have low flow, with gentle channel slope, and lack the pool and riffle zones that provide important aquatic habitats in second and third order streams
- fish biodiversity is concentrated in pool habitats in second and third order streams
- any macroinvertebrates in the first order reaches would also be found downstream (Appendix 26).

If the perennial stream source migrates more than four kilometres downstream into the second order stream section, then there would be an effect on the aquatic habitat values of the stream. A contingency measure to supplement stream flows in St John Brook can be implemented if the permanence of the second and third order stream sections is affected.

There is expected to be a reduction in baseflow and pool water levels above Barrabup Pool. As the perennial flows are already very low, the reduction in baseflow will not have a large impact on the volume of flows. Most flow enters the stream in the lower reaches of St John Brook. CENRM (Appendix 26) recommended that flow should be supplemented if the permanence of the stream in the second and third order reaches was at risk. Supplementary flows can be provided by discharging water from a nearby well into the top of the second order stream section.

4.3.6 Terrestrial fauna

The shift of vegetation to a drier system in the affected areas may have the following potential impacts on terrestrial fauna:

- reduction in the extent of dense undergrowth used by fauna for protection and habitat along affected sections of the creek line
- reduction in the abundance of particular flora species that are a source of food
- reduction in the overall productivity of the drier ecosystems may also affect the availability of food.

The main risk of the proposal is a possible small contraction of the riparian and phreatophytic lower slope vegetation. This change in habitat area will happen gradually over thirty years.

Of the fauna species of conservation significance that are likely to be found at St John Brook, two frog, one reptile, four bird, and two mammal species are expected to be highly groundwater dependent (dependent on phreatophytic or riparian vegetation). Of these, only the bird species (the Australasian bittern, *Botaurus poiciloptilus*) is listed under State or Federal Acts (Appendix 29). The contraction of habitat is not expected to affect the occurrence or long-term viability of these species.

4.3.7 Social impacts

The water levels in Barrabup Pool and Workmans Pool will be naturally maintained by the artesian pressures in the underlying Yarragadee Formation in this stretch of St John Brook. Therefore, there will be no impact on the recreational, cultural or aesthetic values of these pools.

The Nannup Scarred Trees are well outside the area of predicted impact and will not be affected.

4.3.8 Compliance with the EPA Offsets Position Statement

The EPA Offsets Position Statement is discussed in Chapter 2 Section 6.1. The following table details the potential impacts of the proposal on critical assets in St John Brook. There are no potentially significant impacts on the critical assets associated with St John Brook, as shown in Table 7.21.

Table 7.21 Compliance with EPA Offsets Position Statement in St John Brook

Critical assets	Prognosis
Declared Rare Flora	None present
Priority Flora	Two Priority Flora species recorded in St John Brook. The occurrence and viability of these species are not expected to be significantly effected.
Threatened Ecological Communities	None present
Vegetation complexes with less than 30% remaining	None present and negligible impact on the local and regional abundance
Threatened Fauna	Negligible impact on terrestrial habitat, negligible impact on the aquatic habitat of the Priority 4 mud minnow, due to the contingency measure of supplementing flows if the permanence of the stream is at risk
Public conservation reserve system	No significant impact expected on the conservation or recreational values of the proposed St John Brook Conservation Park
Conservation category wetland	None present
Ecosystems under threat	None present
Indigenous heritage sites	Barrabup Pool is currently being considered for registration under the <i>Aboriginal Heritage Act 1972</i> . The Nannup Scar Trees are within the Jarrahwood Conservation Park and are registered under the <i>Aboriginal Heritage Act 1972</i> . There will be no significant impact on either of these sites.
Identified heritage places under EPBC Act	None present

4.3.9 Mitigation

Modelling of several different wellfield configurations (different locations and units of the Yarragadee Formation to be drawn from) was conducted to determine the configuration that would have the lowest effect on other water users, and the lowest environmental impact on potential sensitive areas in the region (Chapter 5 Section 4.1). The “Eastern Split” wellfield configuration was selected and found to have the least overall environmental impact, but is expected to have a greater drawdown risk at St John Brook than other options.

The estimated future regional groundwater use will also potentially cause drawdowns at St John Brook, irrespective of the Water Corporation proposal proceeding. However, the following mitigating actions will be undertaken by the Water Corporation to offset the combined impacts of the proposal and other regional abstraction, if the proposal is approved.

Mitigation of anticipated potential impact on the St John Brook environment will include:

1. Supplementation of flow in St John Brook to maintain pool levels and riparian habitat if summer flow is reduced.
2. The Water Corporation proposes to sponsor a program to manage threatening processes (feral animals, weeds, bank instability) in the areas that may be affected by the proposal including St John Brook.

Mitigation benefits

There are significant existing threats to the ecosystems of the Blackwood Plateau, including feral animals, weeds, dieback and climate change. Research is essential for furthering the understanding of the ecosystem, and to allow informed decision making on the management of threatening processes. An overarching biodiversity study in the region will add resources to research in the region, and increase the effectiveness of funds already being spent by consolidating existing knowledge.

Feral animal control programs (such as Western Shield) have proved to be effective in increasing the numbers of rare native mammals. However, these programs require ongoing funding to remain effective. The Water Corporation proposal to provide resources for the management of feral animals will have a direct biodiversity benefit. In addition to foxes and cats, feral pigs are a known threat to native animals in this area and their digging in wetland environments is destructive. Targeting this species in a feral animal control program will decrease a significant threat to wetland environments and the flora and fauna they support.

The contingency measure to supplement summer flows in St John Brook adds a degree of protection to the aquatic habitats, that will not exist if only private groundwater abstraction takes place. Monitoring will not distinguish between impacts from the Water Corporation abstraction and from other abstraction, so all the abstraction impacts on St John Brook flows will be offset by this contingency measure.

4.4 MONITORING, ADAPTIVE MANAGEMENT AND ACCOUNTABILITY

The Water Corporation will develop and implement an extensive biological, hydrological and physical monitoring program for the region, including the St John Brook area. The Water Corporation is also committed to undertaking a comprehensive biodiversity study as part of the Sustainability Initiative (Volume 1 Chapter 7 Section 4.1.1) which will include the Blackwood Plateau, and will investigate the relationship between ecosystems and groundwater.

The outputs of the monitoring program and biodiversity study, together with advice from the Monitoring Review Group, will form the basis of the adaptive management framework for the St John Brook and other areas of potential impact.

The monitoring program will include a baseline study, to be completed before the operational phase of the project, that will allow both hydrological and ecological changes and trends to be assessed. The monitoring program and biodiversity study will be developed in consultation with the Monitoring Review Group (Volume 1 Chapter 8 Section 3.2.3). A preliminary outline of a monitoring program has been developed (Table 7.22).

The Water Corporation will prepare an annual Sustainability Report that will report on the monitoring results. The Monitoring Review Group will review the monitoring results against a set of defined principles, and determine whether any changes need to be made to the management of the project.

Table 7.22 Proposed St John Brook monitoring program outline

Field	Parameter	Methods
Hydrology	Length of permanent streamflow	Measured monthly from December to April by recording the coordinates of the start of the stream flow
	Stream flow	Gauging station
	Groundwater levels	Monitor watertable levels and levels in the underlying Yarragadee Formation monthly for the first few years (at least 2) of the project and then every two months
Physical	Water quality	Salinity, conductivity, pH, nutrients (N and P) sampled monthly
	Dissolved oxygen	In selected pools. Monthly in summer for 10 minute intervals over 24 hours
Aquatic fauna	Fish recruitment	Annual sampling during October
	Macroinvertebrates	Twice annually during February and September
Vegetation	Tree health	Permanent transects surveyed annually
	Species composition	Permanent quadrats surveyed annually
	Vegetation condition	Permanent quadrats surveyed annually
Terrestrial fauna	Fauna	Terrestrial fauna surveys near the brook annually

The biological monitoring of the terrestrial vegetation will form an important part of the monitoring program at St John Brook. Permanent transects and quadrats will be set up using previous baseline work carried out by Mattiske (2004). Tree health, and species composition and recruitment will be monitored. A range of keystone species that may be influenced by groundwater drawdown will be selected on the basis of available literature, known site preferences, and their life form. Significant changes in these species, together with watertable monitoring, can be used to trigger adaptive management if unexpected and unacceptable impacts are likely to occur.

The contingency measure of supplementing flows in St John Brook will be triggered if hydrological monitoring indicates that the permanence of the brook at the start of the second order stream section is at risk. If supplementation is required, the rates of flow will be designed to mimic natural flows and water quality conditions.

4.5 PROPONENT COMMITMENTS

The Water Corporation is committed to an adaptive management approach and to the following:

1. Undertake a biodiversity and acid sulphate soils study in areas potentially affected by groundwater drawdown resulting from the proposal. The studies will be funded up to the value of \$1.5M, with the capital and any earned interest made available to the studies over a period of ten years.
2. Prepare, and report on the implementation of, abstraction management plans and associated monitoring programs for the groundwater abstraction in accordance with any licence issued pursuant to the RWI Act and the Groundwater Abstraction Management Plan described in Chapter 9 Section 8.

3. The Water Corporation will contribute to a 5 year program to assist the management of threatening processes in areas that may be affected by the proposal. The funding will be up to \$1M with the capital and any earned interest made available to the management program over a period of five years. The program will address weeds, disease, feral animals, erosion and uncontrolled public access issues insofar as they exist within the potentially affected areas including St John Brook.

4.6 ENVIRONMENTAL OUTCOME

The proposal has the potential to cause some groundwater drawdown within a general 700 ha area along St John Brook. This may change the composition of some vegetation on the lower slopes of the valley within this broad area through the contraction in the distribution of phreatophytic flora species, and increased abundance of more drought tolerant (xeric) species. The change in vegetation composition will not significantly affect the conservation status of any significant flora or fauna species, or the occurrence of any vegetation complex, but will affect the local occurrence of some site-vegetation types in a small section of the brook. The impacts of the combined proposal and estimated future regional use would potentially affect approximately 720 ha.

Reduction in artesian pressures in the Yarragadee Formation below some sections of the brook has the potential to reduce summer flow from groundwater discharge, and to lower pool levels above Barrabup Pool. Barrabup Pool itself, and other pools below it, are not expected to be affected.

Proposed mitigation includes a commitment to supplement summer flows in the brook to maintain pool levels, if abstraction causes any significant change to summer baseflows. Commitments to reduce threatening processes in the area, and the proposed St John Brook Conservation Park, will restore ecological values currently affected or under threat, and enhance biodiversity in the area.

The knowledge and data obtained from the proposed biodiversity study and comprehensive monitoring program will improve the understanding of the area, and provide for adaptive management to ensure the area is cautiously managed into the future, particularly in the context of climate change.

The proposed mitigation measures are anticipated to provide for a net improvement in the biodiversity of the area, notwithstanding the anticipated changes in composition of vegetation along a narrow section of St John Brook.

5 REEDIA WETLANDS

Sustainability objectives

The sustainability objective for the *Wetlands* factor is:

The Water Corporation will seek to increase the ecological integrity of wetlands in the region.

At a minimum, the proposal will have no significant adverse impact on wetlands

The *Threatened fauna, Flora and fauna, Rare and priority flora (groundwater dependent)* and *Other groundwater dependent ecosystems* factors and their objectives are also addressed in this section.

The EPA objective for wetlands is:

To maintain the integrity, ecological functions and environmental values of wetlands.

5.1 EXISTING ENVIRONMENT

The Reedia Wetlands lie on both sides of the Blackwood River upstream from Hut Pool, and include parts of Spearwood Creek and Adelaide Brook. They comprise a series of streams and wetlands, in forest reserves, and support some unique and highly significant ecological values.

5.1.1 Relevant investigations

The Water Corporation has undertaken an extensive range of studies to identify the values and assess the potential impacts of the proposal on the Reedia Wetlands:

1. Mattiske (2005a at Appendix 31) evaluated the flora and vegetation values at three cross-sectional transects in the Reedia Wetlands in winter and spring 2004. The site-vegetation types were defined for each transect but were not mapped.
2. Synnott Mulholland Management Service (2005 at Appendix 3) conducted a social impact assessment that included consideration of recreational, aesthetic, and sense of place values of the Blackwood River and its tributaries.
3. Bamford (2003 at Appendix 28) assessed the fauna species that are likely to occur in the potential impact areas and assessed their likely groundwater dependence.
4. URS Australia (2004d at Appendix 16) investigated the relationship between the Reedia Wetlands and the local groundwater systems.
5. Water Corporation carried out an intensive investigation into the hydrogeology of the Southern Perth Basin. This included an extensive drilling project and a review of all available information (Baddock 2005a at Appendix 11).
6. Water Corporation constructed, calibrated (Sun 2005 at Appendix 12) and interpreted (Baddock 2005b at Appendix 13) a numerical model of the South West Yarragadee aquifer system that built on the results of a previous joint project by the Water and Rivers Commission and Water Corporation. This model was peer reviewed and found to be suitable for regional-scale groundwater modelling (Peer Review Panel 2005 at Appendix 20).
7. Bamford (2005 at Appendix 29) undertook a desktop review of the potential impacts of the predicted drawdowns on terrestrial fauna.

5.1.2 Hydrology

The Reedia Wetlands are in State forest, both north and south of the Blackwood River between Hut Pool and Adelaide Brook. The wetlands consist of narrow channels of creek-line flow, and small permanent pools that are maintained by groundwater flows from the Leederville Formation and supported by artesian heads from the underlying Lesueur Sandstone.

Perennial groundwater flow from the Reedia Wetlands, via (Spearwood Creek and Adelaide Brook) has been estimated at 127 L/s (Appendix 16).

5.1.3 Land use

The Reedia Wetlands are entirely within State forest, some of which is included in the proposed Blackwood River National Park (Figure 7.28).

5.1.4 Vegetation and flora

The Reedia Wetlands are named after the Priority 4 *Reedia spathacea* species that is found there. The broad valley floors, with small permanent pools, are significant in the Reedia Wetlands, as they support a (proposed) Threatened Ecological Community, and the habitat for a critical frog species.

The flora and vegetation within the broad valleys of the Reedia Wetlands are distinct. They differ from the swamp vegetation on the Scott Coastal Plain and in Poison Gully, mostly due to their wet, clay-loam soils, and the dependence of the vegetation on moisture in those soils. Conditions in the wetlands are variable and the balance between sedges and heath species appears to be related to subtle changes in site conditions and possibly fire regimes (Matiske 2004).

The important vegetation complexes in the area are the woodlands and swamps of the Jalbarragup vegetation complex, in the upper gullies of the side tributaries, and the Nillup vegetation complex in swamps within the valley systems. There is approximately 14% and 30% respectively, of the original extents of these vegetation complexes within the formal reserve system, and they are consequently considered well-represented.

Matiske (Appendix 31) defined the site-vegetation types along three transects surveyed in the Reedia Wetlands (Table 7.23). Each transect was located in a different wetland, and was chosen on the basis of conservation significance within groundwater dependent areas. No mapping of the site-vegetation types was attempted, as the purpose of the survey was to further understand the flora and vegetation values of the Reedia Wetlands and their relationship to local hydrological conditions.

Table 7.23 Description of site-vegetation types that occur in the Reedia Wetlands

Site-vegetation type	Description of vegetation
A5	Sedgeland of <i>Reedia spathacea</i> , <i>Meeboldina</i> species and <i>Leptocarpus tenax</i> to open heath of <i>Taxandria linearifolia</i> , <i>Hypocalymma angustifolium</i> , <i>Beaufortia sparsa</i> and <i>Astartea scoparia</i>
C6	Open forest of <i>Eucalyptus megacarpa</i> over <i>Astartea scoparia</i> , <i>Anarthria prolifera</i> , <i>Cyathochaeta teretifolia</i> and <i>Leptocarpus tenax</i>
D4	Woodland of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> – <i>Corymbia calophylla</i> over <i>Taxandria parviceps</i> , <i>Acacia divergens</i> , <i>Acacia browniana</i> var. <i>browniana</i> , <i>Cyathochaeta teretifolia</i> and <i>Leptocarpus tenax</i>
S1	Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> – <i>Corymbia calophylla</i> over occasional <i>Banksia grandis</i> over <i>Podocarpus drouynianus</i> , <i>Xanthorrhoea preissii</i> and <i>Macrozamia riedlei</i>
S2	Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> – <i>Corymbia calophylla</i> – <i>Alocasuarina fraseriana</i> – <i>Xylomelum occidentale</i> over <i>Dryandra lindleyana</i> var. <i>lindleyana</i> , <i>Dasypogon hookeri</i> , <i>Hakea amplexicaulis</i> , <i>Adenanthos barbiger</i> and a range of low shrubs and herbs

The site-vegetation types most likely to be influenced by changes in regional groundwater levels are A5 and D4, and to a lesser extent the fringing creek-line vegetation type C6 (Appendix 32). The D4 and C6 types are well-represented in nearby valley systems, but the A5 community is very restricted and under consideration for listing as a Threatened Ecological Community (Appendix 31).

5.1.5 Declared Rare and Priority Flora

Mattiske (Appendix 31) recorded a total of 175 species in the three transects surveyed in the Reedia Wetlands (Table 7.24). Five of these were Priority Flora with two Priority 3 species and one Priority 4 species considered likely to have a high dependence on regional groundwater. The five Priority Flora species described by Mattiske (Appendix 31) are:

1. *Stylidium barleei* (Priority 3) is a perennial herb that occurs on white to grey sands and extends from Augusta to Busselton (including locations near Augusta, Cane Break Road, Great Northern Road, Sues Road, Nannup, Whicher Range and Busselton). This species is locally numerous where it occurs. This species occurs on the fringes of the valley system and is unlikely to be influenced markedly by any changes to regional groundwater levels
2. *Amperea protensa* (Priority 3) is known from a range of locations from the southern coast area and was recorded in both Poison Gully and the Reedia Wetlands in the survey by Mattiske (Appendix 31). This perennial herb occurs on sandy soils on seasonally wet flats and gullies from Augusta to Albany. This species was recorded in the swamp floors and on the lower slopes, and therefore may be influenced by changes in regional groundwater levels.
3. *Reedia spathacea* (Priority 4) is a robust tufted perennial grass-like herb (sedge). It is geographically restricted in occurrence and occurs in localised pockets so these populations are significant. It has been recorded in others studies on the southern coastal areas and in targeted studies near the Blackwood River. The species was recorded in the wetland floors and on the lower slopes and therefore may be influenced by changes in regional groundwater levels.
4. *Cyathochaeta teretifolia* (Priority 3) is known from a range of locations from Ellenbrook near Perth, to Margaret River and the Blackwood Plateau. It was recorded at Poison Gully, Milyeannup Brook, and Pig Swamp as well as in the Reedia Wetlands (Appendix 31). It is a rhizomatous, clumped, robust perennial sedge that occurs on grey sands and sandy clays within wetlands and near creek edges. The species may be influenced by changes in regional groundwater levels.
5. *Tyrbastes glaucescens* (Priority 4) extends from Augusta to the southern coastal areas south of Nannup and the Blackwood Plateau. It was recorded by Mattiske (Appendix 31) in Poison Gully, Milyeannup Brook, and Layman Brook as well as in the Reedia Wetlands. This perennial rhizomatous tufted herb occurs on a range of soil types in swampy areas on flats, and along stream embankments, and may be influenced by changes in regional groundwater levels.

Based on regional database searches there are 62 rare and Priority species that potentially occur near the Reedia Wetlands. Sixteen of them are predicted to have high dependency on regional groundwater (Appendix 31).

Table 7.24 Summary of recorded species and their significance in the Reedia Wetlands

Status	Act	Regional groundwater dependency		
		High	Moderate	Low
Endangered	Federal			
Vulnerable	Federal			
Rare	State			
Priority 1	State			
Priority 2	State			
Priority 3	State	2	1	
Priority 4	State	1	1	
Total species recorded		23	46	106

5.1.6 Threatened Ecological Communities

The Reedia Wetland community is listed as a Priority 1 Threatened Ecological Community by the Department of Conservation and Land Management (CALM 2005a). The community is geographically restricted, and nationally and regionally significant as a result of the presence of the critically endangered *Geocrinia* frog species, the Priority *Reedia spathacea* (Priority 4) species and the proposed Threatened Ecological Community (Appendix 31). This community has not yet been formally listed by the Minister for the Environment, and is therefore not listed as a Threatened Ecological Community under the EPBC Act.

5.1.7 Threatened fauna

The orange-bellied Frog (*Geocrinia vittalina*) is classed as Schedule 1 (Vulnerable) under the Wildlife Act and Vulnerable under the EPBC Act. This frog is considered to be the most range-restricted vertebrate in Australia. It lives only in a few small swamps in the Reedia Wetlands, linked with tributaries (Spearwood Creek and Adelaide Brook) of the Blackwood River east of Witchcliffe (Appendix 28). The white-bellied frog is also expected to live in the Reedia Wetlands. Both species were classified as highly groundwater dependent by Bamford (Appendix 28).

Bamford (Appendix 29) listed the other species of conservation significance that are likely to occur in the Reedia Wetlands (Table 7.25). The area is expected to support four frog, three or four reptile, 11 – 13 bird, and eight mammal species of conservation significance (Appendix 29). Of these, the frogs, one reptile, four bird, and two mammal species are expected to be highly groundwater dependent. There is also one bird species expected to occur in the area that has both high groundwater dependence and high conservation significance (CS1).

Table 7.25 Species of conservation significance (CS) likely to occur in the Reedia Wetlands, and their groundwater dependence (GD)

Species	CS*	GD	Occurrence
FROGS			
<i>Geocrinia alba</i>	1	High	Likely
<i>Geocrinia vittellina</i>	1	High	Certain
<i>Geocrinia rosea</i>	3	High	Likely
<i>Metacrinia nicholli</i>	3	High	Likely
REPTILES			
<i>Morelia spilota</i>	1	Low	Likely
<i>Egernia pulchra</i>	3	Low	Likely
<i>Glaphyromorphus gracilipes</i>	3	High	Likely
<i>Elapognathus minor</i>	3	Moderate	Uncertain
BIRDS			
<i>Merops ornatus</i> (migratory)	1	Low	Likely
<i>Apus pacificus</i> (migratory)	1	Low	Likely
<i>Falco peregrinus</i>	1	Low	Likely
<i>Calyptorhynchus banksia</i>	1	Low	Likely
<i>Calyptorhynchus latirostris</i>	1	Low	Likely
<i>Calyptorhynchus baudinii</i>	1	Low	Likely
<i>Botaurus poiciloptilus</i>	1	Very high	Uncertain
<i>Ixobrychus minutus</i>	2	Very high	Uncertain
<i>Ixobrychus flavicollis</i>	2	Very high	Likely
<i>Ninox connivens</i>	2	Low	Likely
<i>Tyto novaehollandiae</i>	2	Low	Likely
<i>Falcunculus frontatus</i>	2	Low	Likely
<i>Stagonopleura oculata</i>	3	High	Likely
MAMMALS			
<i>Dasyurus geoffroii</i>	1	Moderate	Likely
<i>Pseudocheirus occidentalis</i>	1	Low	Likely
<i>Setonix brachyurus</i>	1	Moderate	Likely
<i>Phascogale tapoatafa</i>	2	Moderate	Likely
<i>Isoodon obesulus</i>	2	High	Likely
<i>Macropus irma</i>	2	Moderate	Likely
<i>Falsistrellus mackenziei</i>	2	Low	Likely
<i>Hydromys chrysogaster</i>	2	Very high	Likely

Adapted from Bamford (2005 at Appendix 29)

* Conservation significance: 1 = Species listed under State or Federal Acts, 2 = Species not listed under State or Federal Acts, but listed in publications on threatened fauna or as Priority species by CALM, 3 = Species not listed under Acts or in publications, but considered of at least local significance because of their pattern of distribution.

5.1.8 Social values

There is a high level of appreciation in the South West of the high biodiversity in the region and its national and international significance. Although there are no direct social values associated with the Reedia Wetlands as they are in an isolated area, rare and endangered species are considered to have a high intrinsic value by the general community.

5.2 ASSESSMENT FRAMEWORK AND POLICY CONTEXT

The following policies and legislation are relevant to the impact assessment of the Reedia Wetlands and their associated ecosystems and are described in Chapter 2:

- *Wildlife Conservation Act 1950*
- *Conservation and Land Management Act 1984*
- *Environmental Protection and Biodiversity Conservation Act 1999*
- National Strategy for Conservation of Australia's Biological Diversity 1996
- National Objectives and Targets for Biodiversity Conservation 2001
- National Strategy for Ecologically Sustainable Development 1992
- Conservation Policy for Western Australia 1997.

5.2.1 Key EPA and other policies

The key policies that have been applied to the assessment of this factor and a critical test of environmental sustainability are as follows:

- EPA Position Statement No. 2: Environmental Protection of Native Vegetation in Western Australia 2000.
- EPA Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection 2002.
- EPA Position Statement No. 4: Environmental Protection of Wetlands` 2004
- EPA draft Position Statement No. 9 (V2): Environmental Offsets 2005
- Forest Management Plan 2004-2013 (2004)

5.3 POTENTIAL IMPACTS AND MITIGATION

In preliminary screening investigations into the effects of regional groundwater abstraction, the Reedia Wetlands were identified as an area where there was potential for drawdown impacts to affect ecosystems.

The investigations undertaken by the Water Corporation have shown that the groundwater abstraction from the Yarragadee will not transfer across the Busselton Fault and affect watertable levels in the Reedia Wetlands (Chapter 5 Section 4.7.5). Therefore, the Water Corporation proposal is expected to have no impact on the Reedia Wetlands. The modelled drawdown from estimated future regional use shows small areas of less than 0.25 m drawdown (Figure 7.27) near the Reedia Wetlands.

5.3.1 Compliance with EPA Offsets Position Statement

The proposal will not have any effect on the critical assets of the Reedia Wetlands and compliance with the EPA Offsets Position Statement is not relevant.

Figure 7.27 Predicted cumulative drawdowns from the proposal and estimated future regional use after 30 years

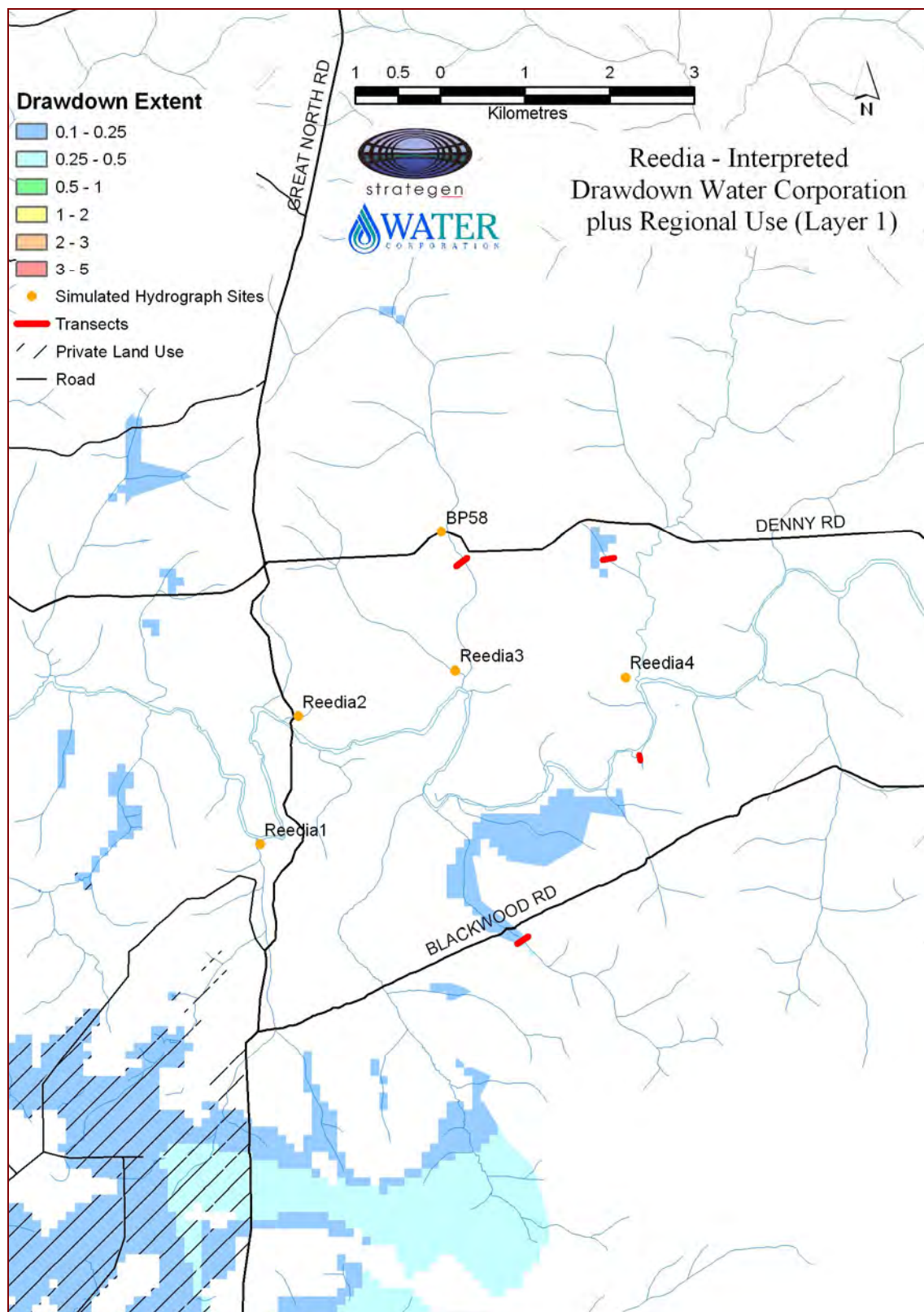
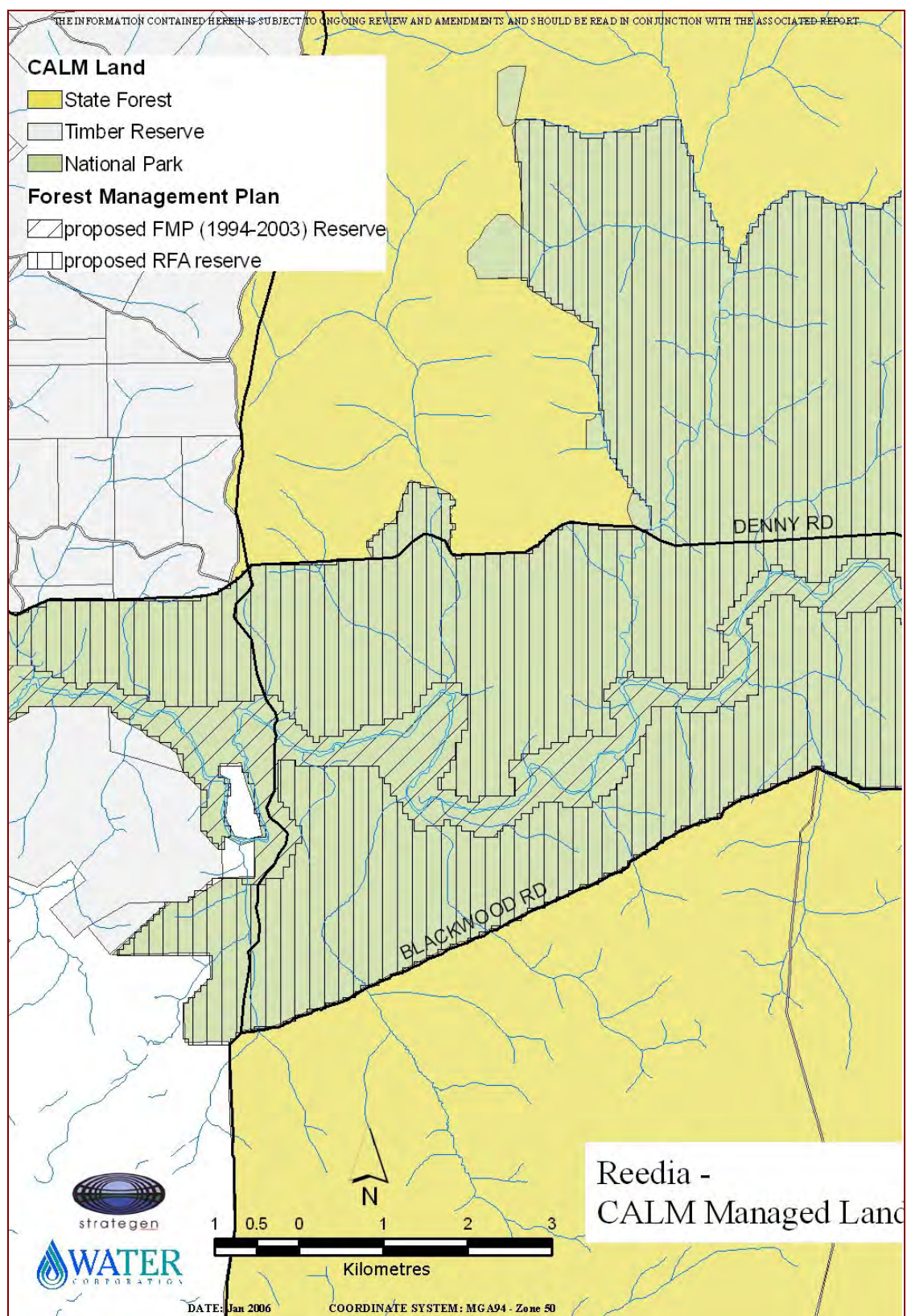


Figure 7.28 Conservation estate within the Reedia wetlands area

5.3.2 Mitigation

Modelling of several different wellfields was carried out to determine the wellfield configuration that would have the lowest environmental impact. At the Reedia Wetlands, the “Eastern Split” wellfield chosen resulted in no drawdown at the watertable from the Water Corporation proposal. The choice of this wellfield has effectively avoided impacts from the proposal at the Reedia Wetlands.

The investigations into the hydrogeology of the Reedia Wetlands have improved the available information on the groundwater dependence of the wetlands. Although largely isolated from the Yarragadee aquifer, the wetlands are connected to other aquifers, and the information generated by this project can be used to make informed management decisions about abstraction in these areas.

5.4 MONITORING, ADAPTIVE MANAGEMENT AND ACCOUNTABILITY

The Reedia Wetlands have high conservation significance. Groundwater monitoring will be carried out to confirm the modelling results and their interpretation and to ensure that no changes in water levels occur in the Reedia Wetlands as a result of the Water Corporation proposal. Streamflow monitoring of Adelaide Brook will also be undertaken.

The Water Corporation will prepare an annual Sustainability Report that will report on the monitoring results. The Monitoring Review Group will review the monitoring results against a set of defined principles and determine whether any changes need to be made to the management of the project.

5.5 PROPONENT COMMITMENTS

The Water Corporation is committed to an adaptive management approach, and to monitoring the proposed groundwater abstraction, the performance of the groundwater resource, climate change effects, potentially affected groundwater dependent ecosystems and control areas in accordance with the Groundwater Abstraction Management Plan (Chapter 9 Section 8).

5.6 ENVIRONMENTAL OUTCOME

No impact from the Water Corporation proposal is expected on the Reedia Wetlands. Groundwater monitoring will be carried out to ensure that no unexpected changes in water levels occur as a result of the project. This will provide an early warning system if the aquifers do not perform as predicted. There is a risk of a water level impact from future growth in other groundwater abstraction in the region. The highest risk is associated with groundwater abstraction in areas west of the Busselton Fault, close to the Reedia Wetlands.

The investigations to date and the proposed ongoing hydrological monitoring of the Reedia Wetlands will provide increased knowledge of other threats to the wetlands that will help in making informed management decisions that reduce the risk to the environment.

6 SCOTT COASTAL PLAIN

Sustainability objectives

The sustainability objective for the *Wetlands* factor is:

The Water Corporation will seek to increase the ecological integrity of wetlands in the region.

At a minimum, the proposal will have no significant adverse impact on wetlands

The *Threatened fauna, Flora and fauna, Rare and priority flora (groundwater dependent), Threatened ecological communities and Other groundwater dependent ecosystems* and their objectives are also addressed in this section.

The EPA objective for wetlands is:

To maintain the integrity, ecological functions and environmental values of wetlands.

6.1 EXISTING ENVIRONMENT

6.1.1 Relevant investigations

The Water Corporation has conducted an extensive range of studies to identify the values and assess the potential impacts of the proposal on the Scott Coastal Plain:

1. Mattiske (2005a at Appendix 31) evaluated the flora and vegetation values at five cross-sectional transects in the Scott Coastal Plain in winter and spring of 2004. The site-vegetation types were defined for each transect.
2. Mattiske (2005b at Appendix 32) evaluated the susceptibility of the flora and vegetation values to groundwater drawdown in the potentially affected areas.
3. Synnott Mulholland Management Service (2005 at Appendix 3) conducted a social impact assessment that included consideration of recreational, aesthetic and sense of place values of the region.
4. Bamford (2003 at Appendix 28) assessed the fauna species that are likely to occur in the potential impact areas including the Scott Coastal Plain, and assessed their likely groundwater dependence.
5. Rockwater (2004c at Appendix 15) assessed the hydrogeology, drainage and potential effect on the watertable of a drawdown in the Yarragadee aquifer on the Eastern Scott Coastal Plain.
6. Water Corporation carried out an intensive investigation into the hydrogeology of the Southern Perth Basin. This included an extensive drilling project and a review of all available information (Baddock 2005a at Appendix 11).
7. Water Corporation constructed, calibrated (Sun 2005 at Appendix 12) and interpreted (Baddock 2005b at Appendix 13) a numerical model of the South West Yarragadee aquifer system that built on the results of a previous joint project by the Water and Rivers Commission and Water Corporation. This model was peer reviewed and found to be suitable for regional-scale groundwater modelling (Peer Review Panel 2005 at Appendix 20).
8. Bamford (2005 at Appendix 29) undertook a desktop review of the potential impacts of the predicted drawdowns on terrestrial fauna.

9. URS Australia (2005b at Appendix 19) assessed the hydrogeology and hydrology of Lake Quitjup and the surrounding area.

6.1.2 Hydrogeology

The Scott Coastal Plain lies south of the Blackwood Plateau and north of the coastal dune system. The eastern Scott Coastal Plain is internally draining and characterised by swamps and lakes. The surface geology comprises largely sandy deposits. The central and western parts of the coastal plain are drained by the Scott River.

The watertable is at, or near, the ground surface, except beneath the elevated coastal dunes, creating a swampy or seasonally inundated environment. There are wetlands throughout the area due to shallow watertables, low evaporation rates, and high rainfall. Most lakes are immediately inland of the coastal dunes, which block seaward drainage of surface water. Lake Jasper and Lake Quitjup are in the area where the Yarragadee Formation subcrops directly beneath the superficial formations (Chapter 5 Section 4.8.2). The hydraulic gradient is low and decreases towards the coast. Watertable levels fluctuate seasonally, with the range of fluctuation being less than one metre near the coast to more than three metres inland.

Over recent years the watertable levels in the Yarragadee Formation have shown a slight declining trend, as a result of reduced recharge in recent low rainfall years, as well as the impact of groundwater pumping for horticulture and dairying on the eastern Scott Coastal Plain. The decline has been about 0.5 m over five years. Although the minimum watertable levels in recent years are lower than previously, there has been no change in the winter water levels at the surface. This indicates that additional recharge is available to allow full recovery each year (Chapter 5 Section 4.8.3).

6.1.3 Wetlands

The Scott Coastal Plain has extensive wetland environments. The wetlands of the eastern Scott Coastal Plain have been mapped and classified by Semeniuk (1997) as shown in Table 7.26. The wetlands are predominantly formed on Tertiary or Pleistocene sediments and the types that occur are (Semeniuk 1997):

- lakes: permanently inundated basins such as Lake Jasper and Lake Quitjup
- sumplands: seasonally inundated basins that commonly occur just north of the coastal dunes
- palusplains: seasonally waterlogged flats that make up most of the Scott Coastal Plain.

The seasonal basins are inundated to depths of 0.3 m to 1 m in winter, predominantly due to direct rainfall (Appendix 19).

Semeniuk (1997) classified all the wetlands on the eastern Scott Coastal Plain to be of outstanding value, as the area is largely undisturbed, other than areas used for agriculture and mining. Most of the wetland values related to their condition, habitat diversity, and representativeness. Some wetlands also had high value based on the scarcity of that wetland type, faunal values, or geomorphic features. The Lake Jasper Suite, the Donnelly River and its floodplain, and the Donnelly River estuary are all recognised as wetlands with important faunal habitat values.

Table 7.26 Wetland suites of the eastern Scott Coastal Plain

SUITE	Geologic/geomorphic framework	Description of wetlands	Stratigraphy
AD1 Donnelly River and Floodplain suite	Holocene alluvial flats	Leptoscale meandering river with floodplain	Underlain by alluvium comprising clay, sand and loam
AD2 Bolghinup Lake suite	Pleistocene limestone dunes	One microscale linear sumpland	Underlain by calcrete
AD3 Balgamup suite	Pleistocene quartz sand dunes, overlying Tertiary estuarine sediments	Microscale to mesoscale sumplands and damplands in the blowout areas of the coastal dunes	Underlain by quartz sand
AD4 Pneumonia Road suite	Pleistocene alluvial flats	Numerous leptoscale sumplands close together in a palusplain; vegetation maculiform	Sumplands underlain by clay. palusplains underlain by alluvial deposits of sands, muddy sands and laterite
AD5 Cleave Road suite	Pleistocene alluvial flats	Microscale rounded sumplands located on a floodplain and palusplain	Underlain by muddy sands and laterite
AD6 Double Creek suite	Pleistocene colluvial flats and slopes	Leptoscale creeks and associated microscale flats and slopes; sumplands	Underlain by colluvium and laterite
AD7 Lake Jasper suite	Contact of Pleistocene limestone/Pleistocene quartz sand dunes/Tertiary estuarine flats	Macroscale to microscale ovoid to linear lakes and sumplands; vegetation bacataform	Underlain by quartz sand
AD8 Donnelly River Estuary	Contact of Pleistocene limestone dunes/cretaceous rock head	Meandering linear estuary; vegetation peripheral	-
AD9 D'Entrecasteaux suite	Tertiary estuarine flats	Extensive palusplain, macroscale to leptoscale irregular and sometime coalescing sumplands and damplands and linear dunes; vegetation maculiform	Underlain by estuarine sediments, fine/medium and very coarse sand and ferricrete
AD10 Alamein suite	Tertiary estuarine flats	Macroscale to mesoscale damplands	Underlain by estuarine sediments
AD11 Fly Brook suite	Tertiary alluvial/lacustrine flats	Slopes associated with creeks	Underlying alluvial sediments are strongly laterised
AD12 Storry Road suite	Tertiary sandy alluvial flats	Paluslopes; freshwater	Underlain by quartz sand
AD13 Jack and Jill suite	Tertiary complex association of laterite, pisolithic gravel, sand, alluvial and colluvial flats, slopes and ridges	Macroscale to leptoscale irregular sumplands and damplands	Underlain by quartz sands and gravelly and sandy muds

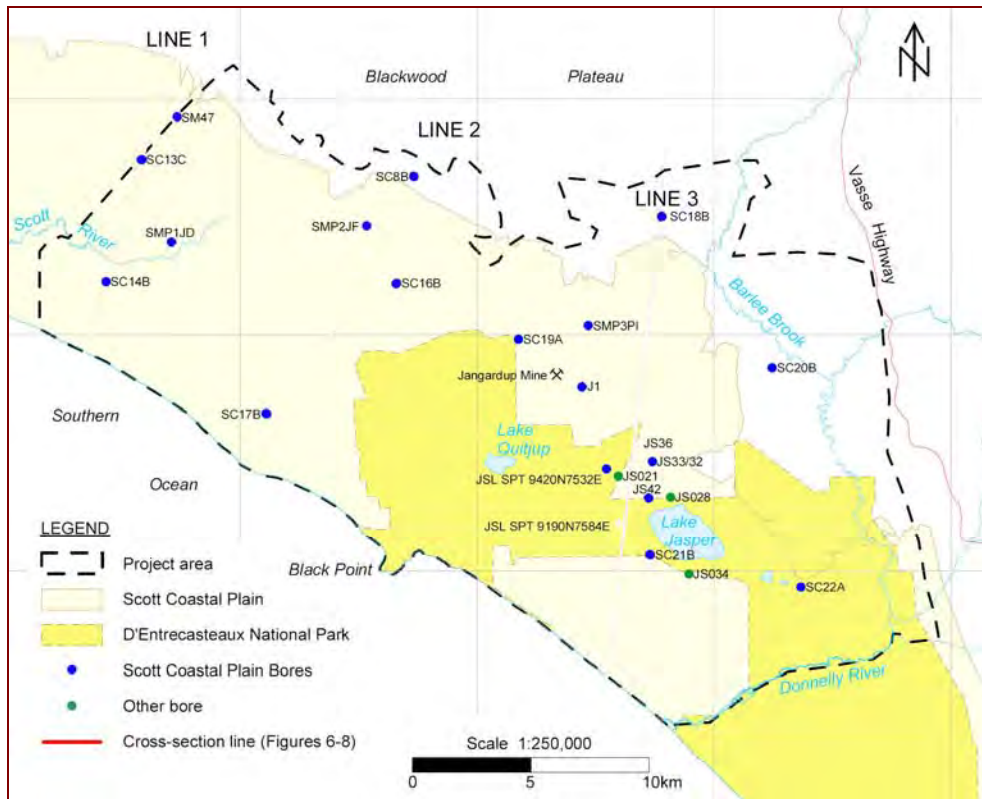
Adapted from Semeniuk (1997)

6.1.4 Land use

The D'Entrecasteaux National Park covers a large area of the south-eastern Scott Coastal Plain and includes Lake Jasper, Lake Quitjup and the lower parts of Barlee Brook and the Donnelly River (Figure 7.29). The conservation estate in the eastern Scott Coastal Plain is shown in Figure 7.32 and the western Scott Coastal Plain is shown in Figure 7.35.

The Scott Coastal Plain has been partially cleared for agriculture, which includes dairy cattle, horticulture, and blue gum plantations. There has also been some mining of mineral sands on the eastern Scott Coastal Plain.

Figure 7.29 Eastern Scott Coastal Plain location plan



Adapted from Rockwater 2004c.

6.1.5 Vegetation and flora

Although the Scott Coastal Plain is partially cleared for agriculture, large areas of remnant native vegetation remain. The flora and vegetation on the plain are highly diverse and specialised, and many species have a restricted range.

The plain is a mixture of erosional soils and sandy deposits with a diverse mosaic of vegetation communities occupying areas ranging from scattered small rises to extensive low lying damplands and sumplands (Appendix 32). The vegetation within the extensive swamps is highly variable. Subtle changes in elevation and moisture conditions result in rapid changes in flora and vegetation within the swamps. The variation in underlying soil types, from ironstone to sands, makes an important contribution to vegetation diversity.

Eight vegetation complexes have been identified (Appendix 32) on the Scott Coastal Plain that may be susceptible to changes in groundwater levels. They include:

- upper gullies of the northern fringe tributaries supporting woodlands and swamps in Cleave (CV) and Coate (CE)
- the swamps within the Nillup (Nw) valley systems

- the swamps within the Scott Coastal Plain (Sd and Swd)
- Jangardup (JN) supporting a range of swamp vegetation types.

All these vegetation complexes have more than 30% of their pre-European extent remaining, and are well-represented in the conservation estate (Table 7.27 and Table 7.28). The Scott – Swi ironstone communities, which support a large range of rare and endangered species, have been more extensively cleared, and only 10% remain. This vegetation complex is not within the area potentially affected by groundwater drawdown.

Table 7.27 Vegetation complexes in areas of potential drawdown from the proposal in the eastern Scott Coastal Plain

	Barlee (ha)	Cleave (ha)	Coate (ha)	D'Entrecasteaux – Dd5 & Dd	Jangardup (ha)	Kingia (ha)	Nillup – Nd & Nw	Scott – Sd & Swd	Total
Reserved %	12	63	28	>76	48	28	>30	>27	
Remaining %	65	81	88	>94	81	95	>72	>47	
0-3 m*	7	11	41	157	345	169	38	2611	3379
3-6 m*	2	58	28	128	637	250	104	1272	2479
6-10 m*	0	5	13	94	418	426	43	289	1289
Total	9	73	82	379	1401	845	185	4172	7147

* Depth to groundwater category

Table 7.28 Vegetation complexes in areas of potential drawdown from the proposal in the western Scott Coastal Plain

	Nillup – Nd & Nw	Scott - Sd	Grand Total (ha)
Remaining %	>30	27	
Reserved %	>72	47	
0-3 m*	29.9	0.3	30.2
3-6 m*	36.1	0.0	36.1
6-10 m*	41.0	0.0	41.0
Grand Total	106.9	0.3	107.2

* Depth to groundwater category

Mattiske (Appendix 31) defined the site-vegetation types on five transects surveyed on the Scott Coastal Plain (Figure 6.1). The transects were on the north-east Scott Coastal Plain, where preliminary predictions indicated there could be drawdowns as a result of the proposal. Extensive mapping was not undertaken, as the extent of the drawdown risk was ill-defined at the time of the vegetation survey. The purpose of the transects on the north-east Scott Coastal Plain was to further understand the flora and vegetation values in the area.

Four site-vegetation types were identified in the five transects, with three of these likely to be susceptible to changes in groundwater levels, (Table 7.29) as they are found low in the landscape. The site-vegetation types most likely to be influenced by changes in regional groundwater levels are A6 and A7, and to a lesser extent the fringing creek-line vegetation type J1 (Appendix 32). The A types occur extensively in the area, but are vulnerable to very subtle changes in groundwater and soil moisture levels. The seasonal flooding of the sedgeland within these systems is critical to the survival of some of these species (Appendix 31).

Table 7.29 Description of site-vegetation types that occur on the Scott Coastal Plain

Site-vegetation type	Description of vegetation
S3	Open forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> – <i>Corymbia calophylla</i> over <i>Acacia myrtifolia</i> , <i>Taxandria parviceps</i> , <i>Mesomelaena graciliceps</i> , <i>Anarthria prolifera</i> , <i>Dasypogon bromeliifolius</i> and <i>Pericalymma ellipticum</i> var. <i>ellipticum</i> and a range of low shrubs and herbs
A6	Open heath of <i>Melaleuca lateritia</i> over <i>Triglochin huegelii</i> , <i>Myriophyllum ?limnophilum</i> , <i>Baumea vaginalis</i> and a range of fringing sedges of <i>Meeboldina</i> species
A7	Open heath of <i>Astartea scoparia</i> , <i>Taxandria linearifolia</i> , <i>Homalospermum firmum</i> over patches of dense sedges including <i>Cyathochaeta teretifolia</i> , <i>Lepidosperma ?longitudinale</i> , patches of <i>Reedia spathacea</i> and species of <i>Meeboldina</i> and <i>Leptocarpus</i>
J1	Open woodland of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> – <i>Corymbia calophylla</i> – <i>Nuytsia floribunda</i> over <i>Anarthria prolifera</i> , <i>Anarthria scabra</i> , <i>Dasypogon bromeliifolius</i> , <i>Hypolaena exsulca</i> and <i>Euchilopsis linearis</i> over a range of low shrubs and herbs

6.1.6 Threatened Ecological Communities

The Scott River Ironstone Association vegetation communities are listed as Endangered by the Department of Conservation and Land Management (CALM 2005a) (Figure 7.38). This community has not yet been formally listed by the State Minister for Environment, and is not listed as a Threatened Ecological Community under the EPBC Act. This community is equivalent to the Scott – Swi vegetation complex, and small patches of ironstone within the Sw, Swd and Sd vegetation complexes (Figure 7.37).

6.1.7 Declared Rare and Priority Flora

Mattiske (Appendix 31) recorded a total of 231 species in the five transects surveyed on the Scott Coastal Plain. Seven of these were Priority Flora with one Priority 4 species considered likely to have high dependence on regional groundwater. The seven Priority Flora species described by Mattiske (Appendix 31) are:

1. *Stylidium barleei* (Priority 3) is a perennial herb that occurs on white to grey sands and extends from Augusta to Busselton (including locations near Augusta, Cane Break Road, Great Northern Road, Sues Road, Nannup, Whicher Range and Busselton). It is locally numerous in areas where it occurs. This species occurs on the fringes of the valley system and is unlikely to be influenced markedly by any changes to watertable levels.
2. *Stylidium* aff. *ireneae* (Priority 4) has been recorded previously near Dwellingup, and near Augusta, and was only recorded by Mattiske (Appendix 31) in one transect on the Scott Coastal Plain. The species occurs on the fringes of the swamps and is unlikely to be influenced markedly by any changes to watertable levels.
3. *Gonocarpus pusillus* (Priority 3) is known from a range of locations from Albany to Dunsborough near the coast, and occurs on grey sands and sandy clays within swamps and near creek edges. Mattiske (Appendix 31) recorded this species in Poison Gully and on the Scott Coastal Plain. It occurs on the drier sites and is therefore unlikely to be influenced by any changes to watertable levels.
4. *Melaleuca basicephala* (Priority 4) has been recorded in other study areas on the Scott Coastal Plain and the south coast. This species is common in wet areas, although scattered, and can be locally abundant. This taxon was recorded from the drier sites and is therefore unlikely to be influenced by any changes to watertable levels.

5. *Astartea* sp. Scott River (Priority 4) is a shrub that is known at a range of locations from the southern coast area, and occurs as scattered plants on sandy soils on seasonally wet flats. This species was recorded in two transects on the Scott Coastal Plain, on the swamp floors and on the lower slopes, and therefore may be influenced by changes in watertable levels. This species is geographically restricted to the Scott Coastal Plain and westwards to Augusta.
6. *Conospermum paniculatum* (Priority 3) is known to occur on the Scott Coastal Plain and the Blackwood Plateau, and was recorded by Mattiske (Appendix 31) in Layman Brook, Rosa Brook and the Scott Coastal Plain. This perennial herb occurs on white to grey sands and was recorded on the fringes of swamps, and is unlikely to be influenced markedly by any changes to watertable levels.
7. *Meeboldina crassipes* (Priority 3) is known from a range of locations from the south coast area to the east, and this occurrence is an extension to its current known range. The species is a rhizomatous, robust clumped perennial herb (rush-like) and occurs on sands and peats in seasonally inundated areas. The species was recorded on the fringes of the swamps and is unlikely to be influenced markedly by any changes to watertable levels.

Table 7.30 Summary of recorded species and their significance on the Scott Coastal Plain

Scott Coastal Plain	Act	Regional groundwater dependency		
		High	Moderate	Low
Endangered	Federal			
Vulnerable	Federal			
Rare	State			
Priority 1	State			
Priority 2	State			
Priority 3	State		3	1
Priority 4	State	1		2
Total species recorded		9	50	172

Based on regional database searches there are 70 Declared Rare and Priority species that potentially occur near the Scott Coastal Plain. Thirty-three of those are considered to have high dependency on regional groundwater (Appendix 31).

6.1.8 Terrestrial fauna

The Scott Coastal Plain has low topography, extensive seasonal wetlands and damplands, and is partially cleared for agriculture. Bamford (Appendix 28) considered the area would support 13 frog, 26 reptile, 137 bird, and 31 mammal species. Of these, two frog, three reptile, 27 – 30 bird, and eight mammal species are of conservation significance (Table 7.31). The area is rich in birds, including a range of significant waterbird species.

Frogs

Two species of frogs of conservation significance (but not Declared Rare or Priority species) are likely to occur on the Scott Coastal Plain and the Blackwood Plateau (Appendix 28). Semeniuk (1997) listed an additional five frog species that are known to occur on the Scott Coastal Plain. The roseate frog (*Geocrinia rosea*) and the Nicholls' toadlet (*Metacrinia nichollsi*) both have a restricted distribution in the extreme south-west. These species have larval development within the egg membrane and rely on moist soil, so were given a high groundwater dependence rating (Appendix 28).

Frogs on the Scott Coastal Plain are likely to live in wetlands associated with broad peaty flats with little relief. The moisture regimes of these wetlands could change markedly with small changes in watertable levels. However, the large areas of uncleared vegetation on the Scott Coastal Plain mean that there is also greater potential for dispersal and movement between wetlands (Appendix 28).

Reptiles

Reptiles of conservation significance that are likely to live on the Scott Coastal Plain are:

- carpet python (*Morelia spilota imbricata*) – this priority 4 species has low groundwater dependence and is widespread
- skink (*Glaphyromorphus gracilipes*) has a restricted distribution and is only found in the far south-western corner of Western Australia. The species has high groundwater dependence as is associated with wetlands.

The short-nosed snake (*Elaphognathus minor*) is endemic to Western Australia and lives only on the coastal plains. It has moderate groundwater dependence.

Birds

Fewer species of waterbirds are found on the Scott Coastal Plain than on the Swan Coastal Plain. However, there are 29 species of conservation significance that are likely to occur on the Scott Coastal Plain. Fifteen of these are migratory species.

Mammals

Eight mammals of conservation significance are likely to live on the Scott Coastal Plain (Table 7.31). Only the water rat (rakali, *Hydromys chrysogaster*) may have very high groundwater dependence, as it is heavily reliant on permanent water.

Fish

Lake Jasper is known to contain the following fish species (Semeniuk 1997):

- *Bostockia porosa* (nightfish)
- *Edelia vittata* (western pygmy perch)
- *Nannatherina balstoni* (Balston's pygmy perch)
- *Galaxias occidentalis* (western minnow)
- *Tandanus bostocki* (freshwater cobbler)
- *Pseudogobius olorum* (Swan River goby)
- *Favonogobius suppositus*

Tortoises and marron also occur in the lake.

Table 7.31 Species of conservation significance (CS) likely to occur on the Scott Coastal Plain indicating their groundwater dependence (GD)

Species	CS ¹	GD	Occurrence
FROGS			
<i>Geocrinia rosea</i>	3	High	Likely
<i>Metacrinia nichollsi</i>	3	High	Likely
<i>Litoria adelaidensis</i>			Certain (Semeniuk 1997)
<i>Crinia glauerti</i>			Certain (Semeniuk 1997)
<i>Limnodynastes dorsalis</i>			Certain (Semeniuk 1997)
<i>Geocrinia leai</i>			Certain (Semeniuk 1997)
<i>Crinia georgiana</i>			Certain (Semeniuk 1997)
REPTILES			
<i>Morelia spilota</i>	1	Low	Likely
<i>Glaphyromorphus gracilipes</i>	3	High	Likely
<i>Elapognathus minor</i>	3	Moderate	Likely
BIRDS			
<i>Ardea alba</i> (migratory)	1	Very high	Likely
<i>Haliaeetus leucogaster</i> (migratory)	1	Very high	Likely
<i>Tringa stagnatalis</i> (migratory)	1	Very high	Likely
<i>Tringa nebularia</i> (migratory)	1	Very high	Likely
<i>Tringa glareola</i> (migratory)	1	Very high	Likely
<i>Actitis hypoleucos</i> (migratory)	1	Very high	Likely
<i>Calidris ruficollis</i> (migratory)	1	Very high	Likely
<i>Calidris subminuta</i> (migratory)	1	Very high	Likely
<i>Calidris acuminata</i> (migratory)	1	Very high	Likely
<i>Calidris ferruginea</i> (migratory)	1	Very high	Likely
<i>Rostratula benghalensis</i> (migratory)	1	Very high	Likely
<i>Sterna caspia</i> (migratory)	1	High	Likely
<i>Sterna bergii</i> (migratory)	1	High	Likely
<i>Merops ornatus</i> (migratory)	1	Low	Likely
<i>Apus pacificus</i> (migratory)	1	Low	Likely
<i>Leipoa ocellata</i>	1	Low	Uncertain
<i>Falco peregrinus</i>	1	Low	Likely
<i>Calyptorhynchus banksia</i>	1	Low	Likely
<i>Calyptorhynchus latirostris</i>	1	Low	Likely
<i>Calyptorhynchus baudinii</i>	1	Low	Likely
<i>Pezoporus wallicus</i>	1	Moderate	Uncertain
<i>Botaurus poiciloptilus</i>	1	Very high	Likely
<i>Ixobrychus minutus</i>	2	Very high	Likely
<i>Ixobrychus flavicollis</i>	2	Very high	Likely
<i>Burhinus grallarius</i>	2	Moderate	Uncertain
<i>Ninox connivens</i>	2	Low	Likely
<i>Tyto novaehollandiae</i>	2	Low	Likely
<i>Falcunculus frontatus</i>	2	Low	Likely
<i>Stagonopleura oculata</i>	3	High	Likely

Species	CS ¹	GD	Occurrence
MAMMALS			
<i>Dasyurus geoffroii</i>	1	Moderate	Likely
<i>Pseudocheirus occidentalis</i>	1	Low	Likely
<i>Setonix brachyurus</i>	1	Moderate	Likely
<i>Phascogale tapoatafa</i>	2	Moderate	Likely
<i>Isodon obesulus</i>	2	High	Likely
<i>Macropus irma</i>	2	Moderate	Likely
<i>Falsistrellus mackenziei</i>	2	Low	Likely
<i>Hydromys chrysogaster</i>	2	Very high	Likely

Adapted from Bamford (2005)

¹ Conservation significance: 1 = Species listed under State or Federal Acts, 2 = Species not listed under State or Federal Acts, but listed in publications on threatened fauna or as Priority species by CALM, 3 = Species not listed under Acts or in publications, but considered of at least local significance because of their pattern of distribution.

6.1.9 Social values

The Scott National Park abuts the Hardy Inlet near Molloy Island. The Scott River passes through the national park.

Lake Jasper, located within the D'Entrecasteaux National Park, is highly valued as a pristine waterway. It is a tourist destination for four wheel drive enthusiasts, and is popular with water skiers and nature lovers. As the largest freshwater lake in the South West it is a wetland with conservation significance. There is a CALM operated campground at Lake Jasper. Much of the rest of the park is managed for its wilderness values, so few other facilities are provided.

Lake Jasper has been listed on the Register of the National Estate since 1978 (Class: Indigenous; Status: Registered). It is an Aboriginal archaeological site of international significance as it contains Australia's only underwater prehistoric site of human habitation (Western Australian Forest Alliance 2005).

6.2 ASSESSMENT FRAMEWORK AND POLICY CONTEXT

The following policies and legislation are relevant to the impact assessment of the Scott Coastal Plain and its associated ecosystems, and are described in Chapter 2:

- *Wildlife Conservation Act 1950*
- *Conservation and Land Management Act 1984*
- *Environmental Protection and Biodiversity Conservation Act 1999*
- National Strategy for Conservation of Australia's Biological Diversity 1996
- National Objectives and Targets for Biodiversity Conservation 2001
- National Strategy for Ecologically Sustainable Development 1992
- Conservation Policy for Western Australia 1997.

6.2.1 Key EPA and other policies

The key policies that have been applied to the assessment of this, factor and which provide a critical test of environmental sustainability, are as follows:

- EPA Position Statement No. 2: Environmental Protection of Native Vegetation in Western Australia 2000.
- EPA Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection 2002.
- EPA Position Statement No. 4: Environmental Protection of Wetlands 2004
- EPA draft Position Statement No. 9 (V2): Environmental Offsets 2005
- Forest Management Plan 2004-2013 (2004).

6.3 POTENTIAL IMPACTS AND MITIGATION

6.3.1 Groundwater impacts

The primary area of potential impact from the proposed Water Corporation abstraction is restricted to the northern edge of the eastern Scott Coastal Plain near the edge of the Blackwood Plateau escarpment.

Eastern Scott Coastal Plain

The Water Corporation induced drawdowns of watertables on the eastern Scott Coastal Plain are expected to be mostly less than 0.25 m after 30 years. The greatest drawdowns are expected to occur in the northern part of the coastal plain with the maximum impact expected to be less than one metre after 30 years (Figure 7.30).

Drawdowns from Water Corporation abstraction, together with the estimated future regional water use, are expected to be more widespread. Drawdowns of up to 1 – 2 m are expected along the very northern edge of the eastern Scott Coastal Plain. The estimated future regional growth in local abstraction on the Scott Coastal Plain is expected to result in more widespread drawdowns further south and west of that predicted to result from the Water Corporation proposal (Figure 7.31). Over most of the eastern plain, the cumulative drawdown from the proposal and estimated future regional use are expected to be less than 0.5 m after 30 years.

Western Scott Coastal Plain

The Water Corporation induced drawdowns on the western Scott Coastal Plain are predicted to be minor, and are expected to be less than 0.25 m after 30 years. The area of drawdown occurs in a small area north of Brockman Highway and east of Dennis Road (Figure 7.33).

Figure 7.30 Predicted drawdowns from the proposal on the eastern Scott Coastal Plain after 30 years

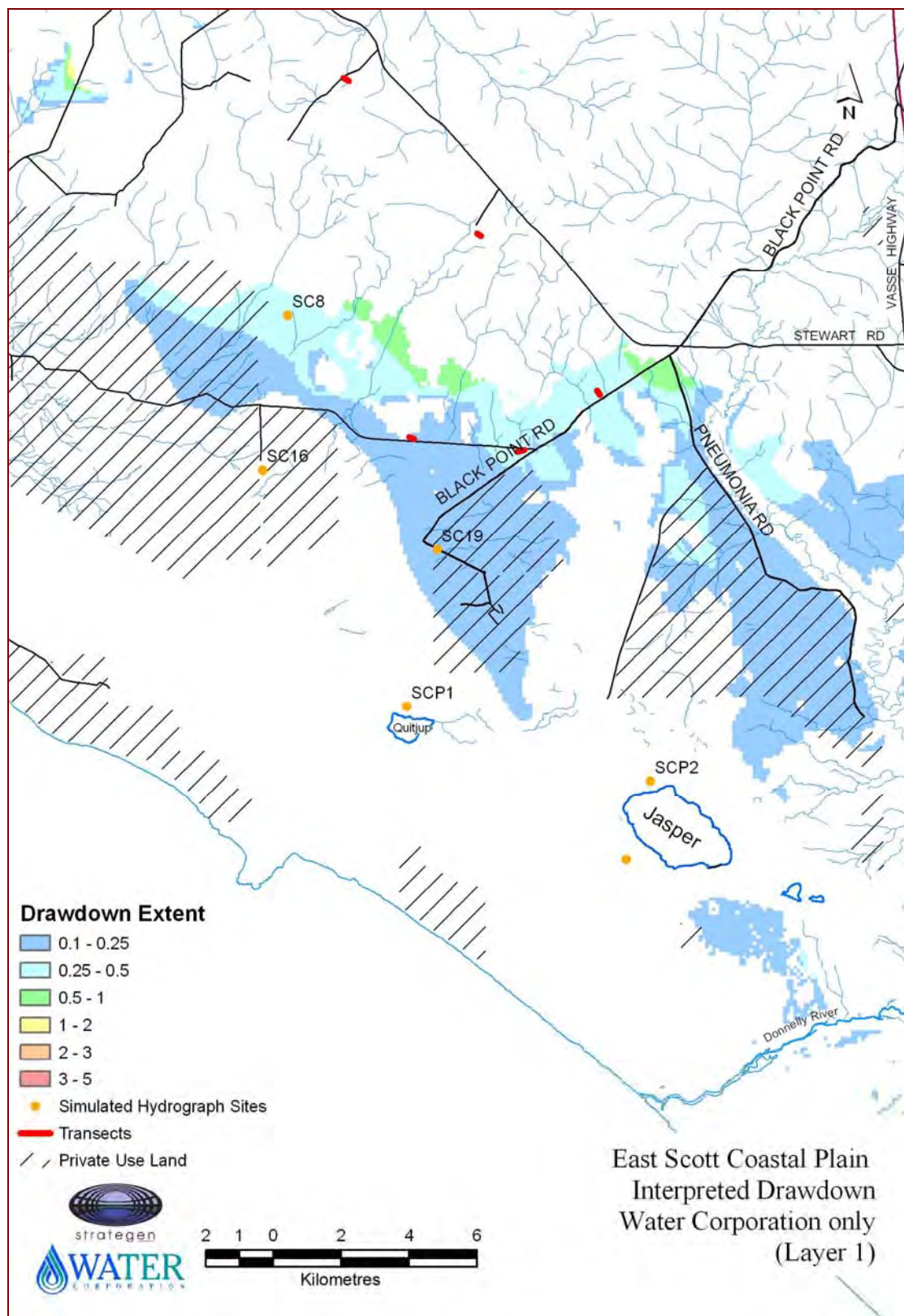


Figure 7.31 Predicted drawdowns from the proposal and estimated future regional use on the eastern Scott Coastal Plain after 30 years

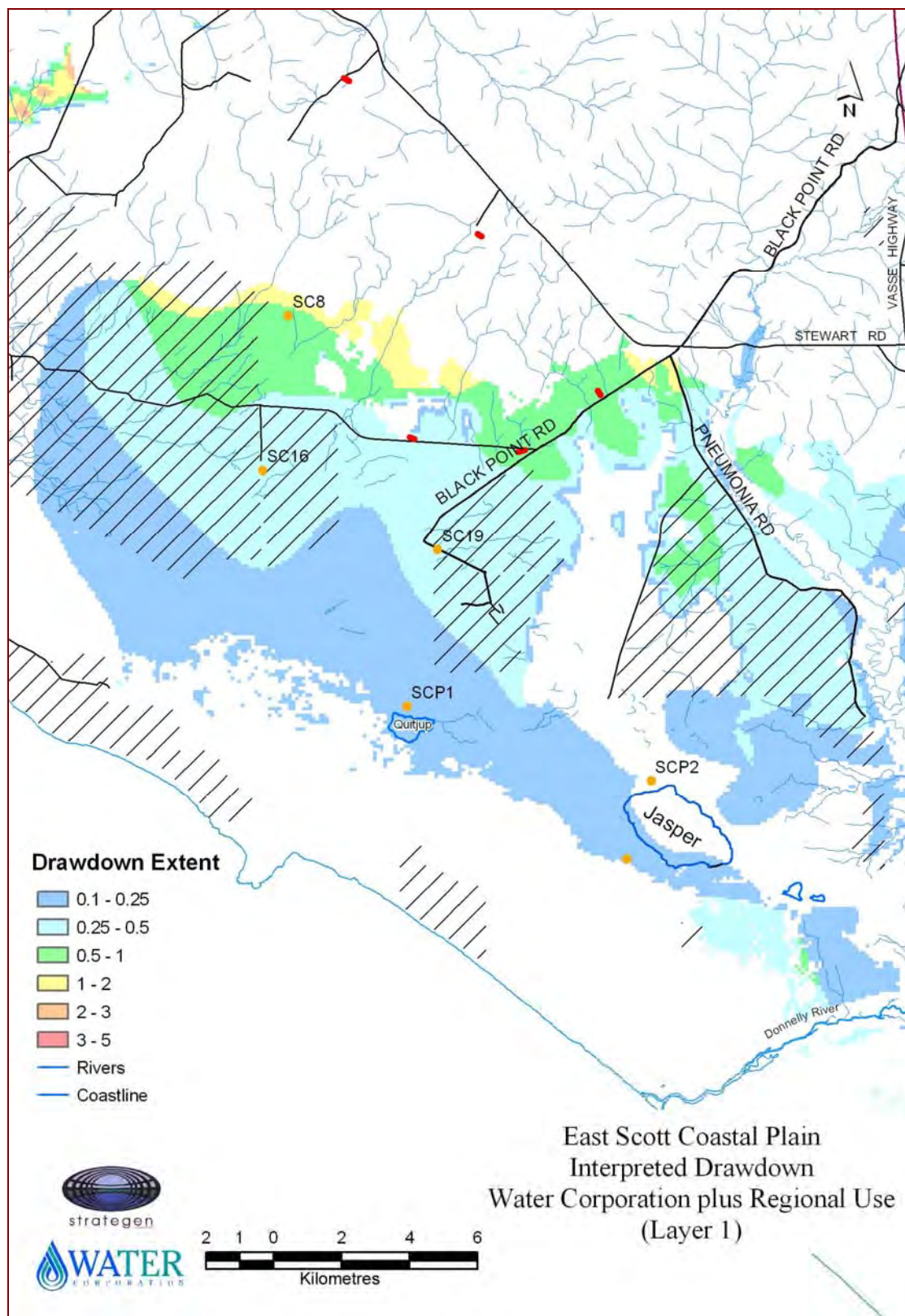


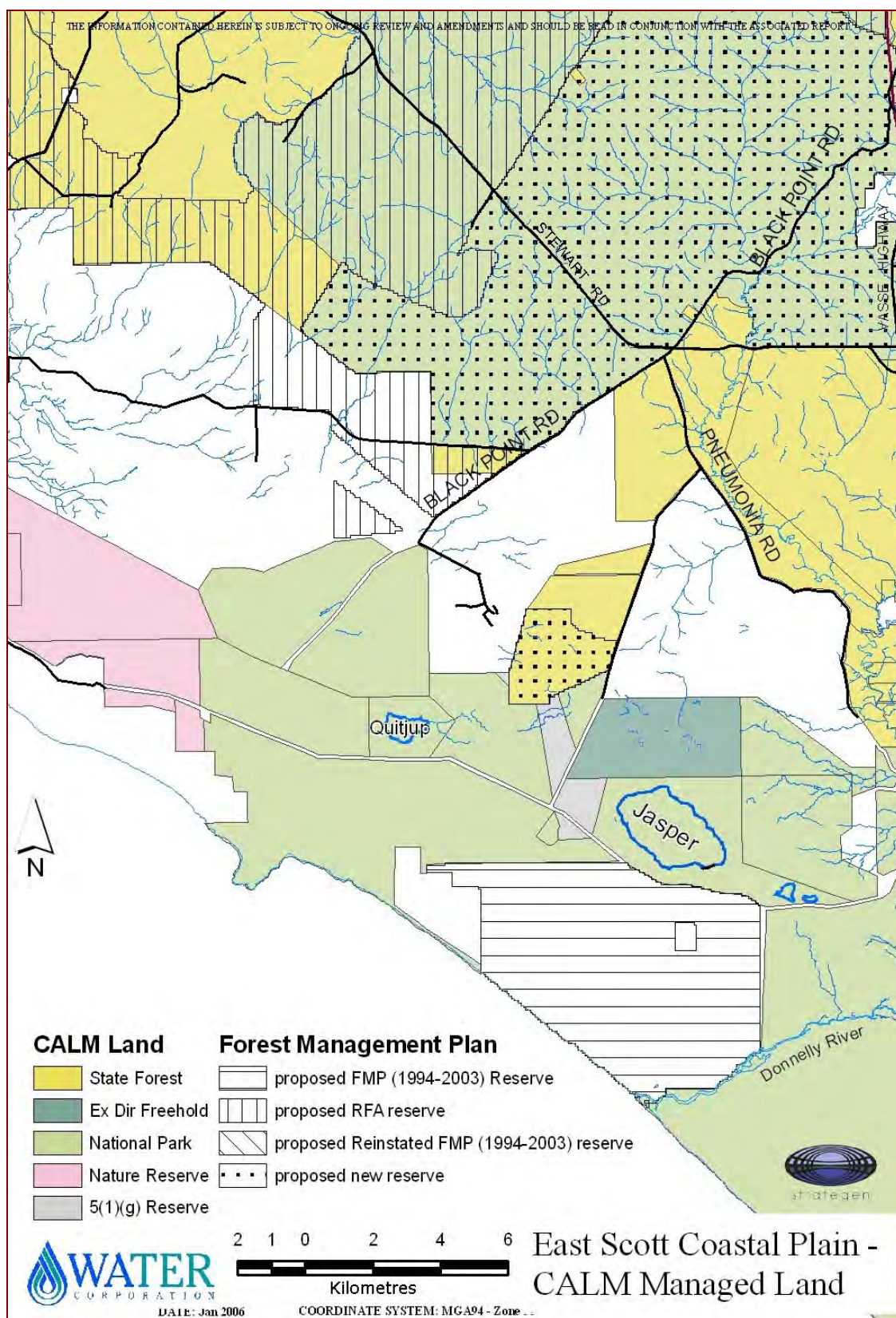
Figure 7.32 Conservation estate within the eastern Scott Coastal Plain

Figure 7.33 Predicted drawdowns from the proposal on the western Scott Coastal Plain after 30 years

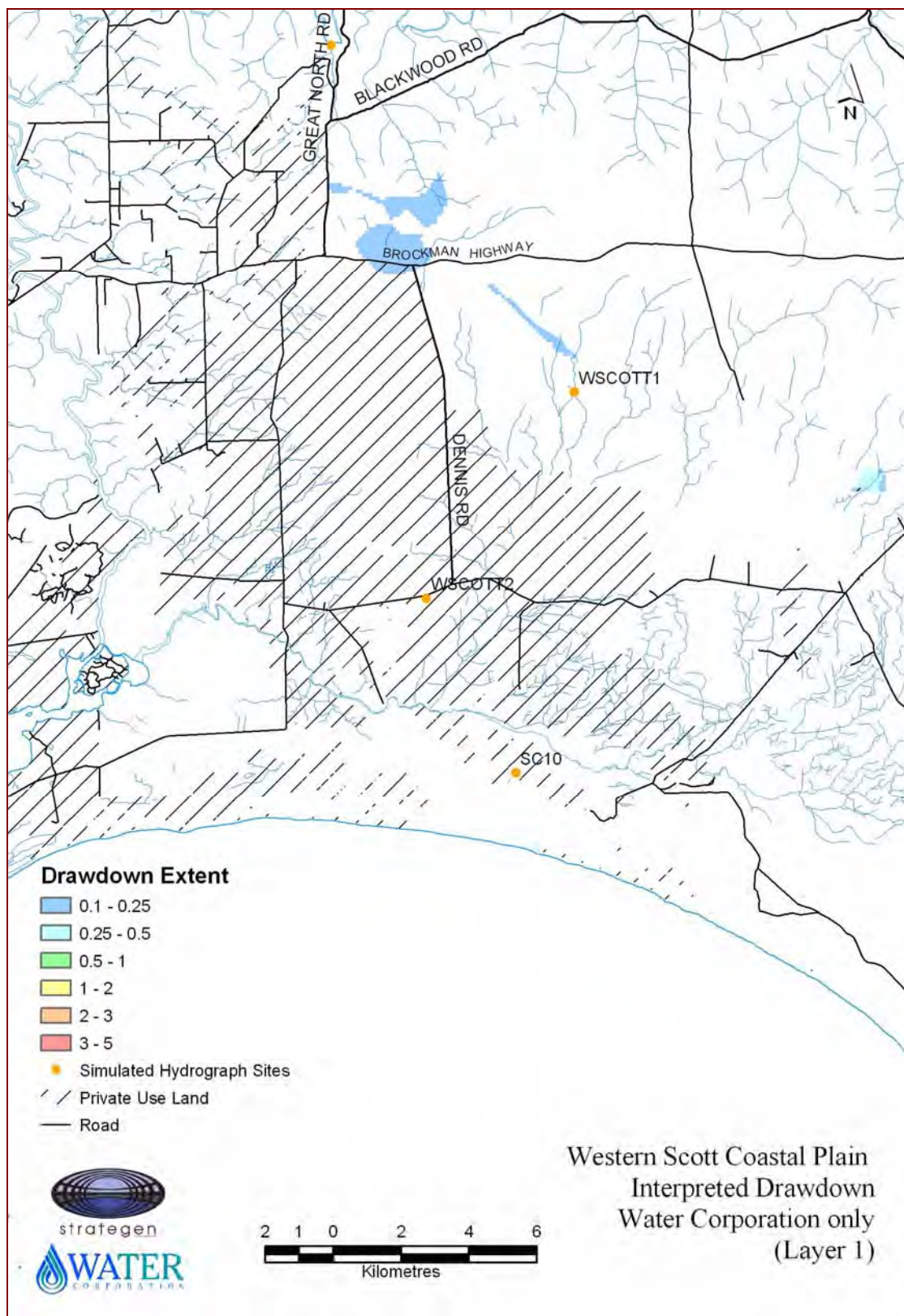


Figure 7.34 Predicted drawdowns from the proposal and estimated future regional use on the western Scott Coastal Plain after 30 years

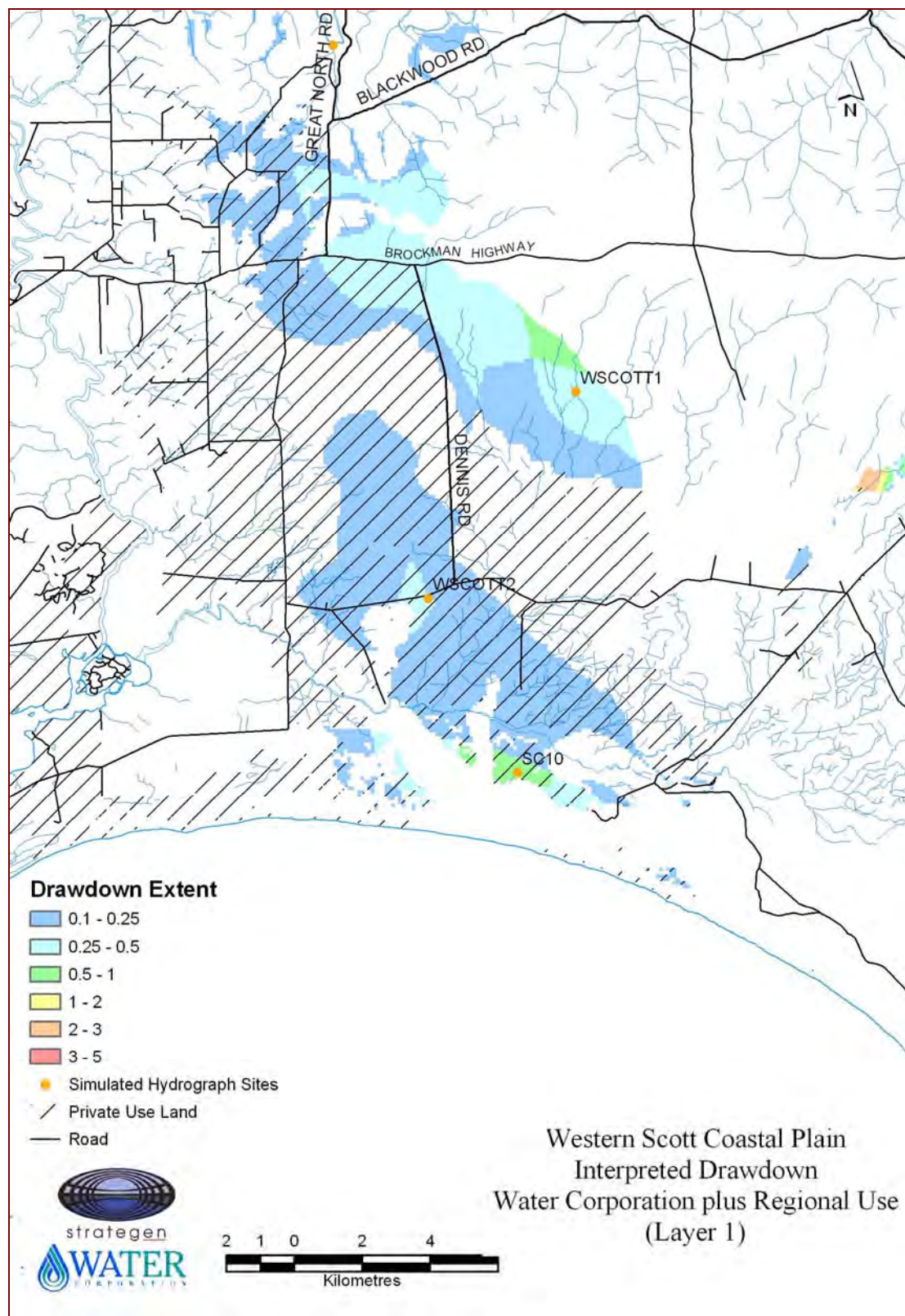
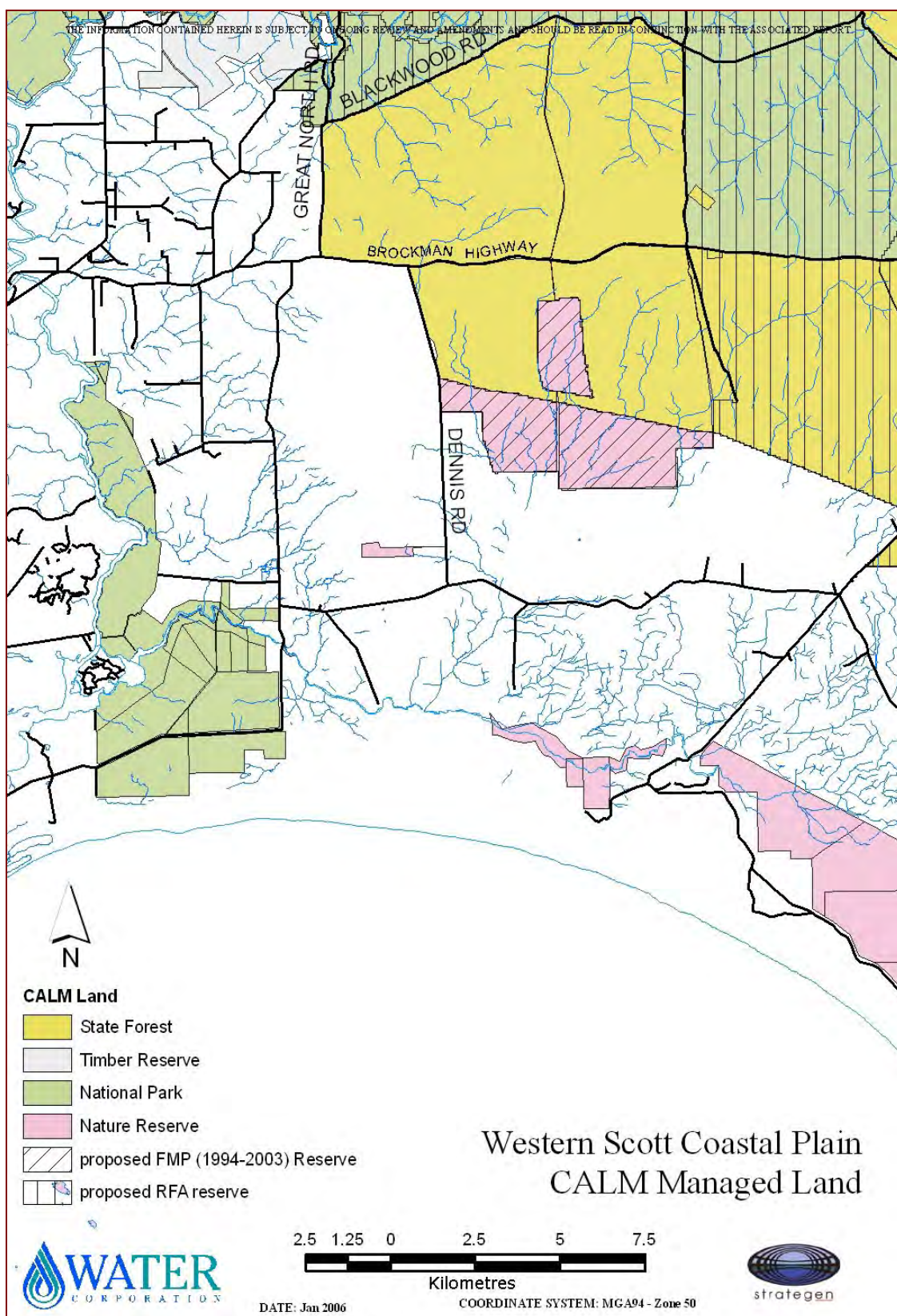


Figure 7.35 Conservation estate within the western Scott Coastal Plain

Drawdowns from the proposal, together with estimated future regional water use, are expected to extend much further south and have drawdowns up to one metre in the north-eastern areas. The estimated future regional use includes increased irrigation for agriculture on the western Scott Coastal Plain. This estimated future local abstraction will result in much greater drawdown in this area than will be generated from the proposal. The cumulative drawdown over most of the impact area is still predicted to be less than 0.25 m after 30 years (Figure 7.34).

Wetlands

The Water Corporation proposal is not expected to have an impact on watertable levels in the Lake Jasper area (Figure 7.30). However, the combined estimated future regional use and proposal are predicted to cause summer watertable levels to decline by up to 0.2 m, albeit with full recovery during winter. This drawdown of the watertable will cause a much smaller change in the water levels of the lake itself. Water levels in Lake Jasper are dominated by rainfall and evaporation, and the lake is not hydraulically connected to the underlying Yarragadee Formation.

No impacts are expected to be experienced in Lake Quitjup as a consequence of the proposed Water Corporation abstractions. When the Water Corporation proposal is combined with estimated future regional abstraction, the drawdowns at Lake Quitjup are in the range of 0.1 – 0.25 m. Lake Quitjup is a relatively deep, steep sided lake that has not changed in extent since the early 1950s (Appendix 19). A drawdown of less than 0.25 m after 30 years will not cause a significant change in water area.

There will be no impact on water levels along the Donnelly River, as this system is not connected to the Yarragadee aquifer (Appendix 13).

The wetland suites that occur within the area of drawdown from the proposal are (Semeniuk 1997):

- AD4: Pneumonia Rd Suite
- AD9: D'Entrecasteaux Suite
- AD10: Alamein Suite
- AD13: Jack & Jill Suite

These wetlands are seasonal and are only in contact with the watertable in winter, so will not be affected by a drop in summer watertable minima. Winter watertable levels are expected to recover fully each winter as previously rejected recharge refills the aquifer (Chapter 5 Section 4.8.3). The extra recharge required to refill the aquifer each year, with an annual drawdown of 66 mm, is around 13 mm of rainfall (assuming a specific yield of 0.2 for the Scott Coastal Plain soils). This equates to around 1% of rainfall, or 5% of the currently rejected recharge of approximately 240 mm (Appendix 13). Therefore, the seasonal wetlands of the Scott Coastal Plain will not be measurably affected, as the winter surface water levels will recover fully each year.

Perched wetlands also exist on the Scott Coastal Plain but will not be affected by the proposal, as they are not hydraulically connected to the underlying aquifers.

Conclusion

The proposal will result in no change in the water levels of the permanent lakes, as the proposal is not expected to affect watertables near these lakes. The proposal will result in small drawdowns of the summer watertables on the Scott Coastal Plain, but the extra recharge required each winter to refill the aquifer is small compared with the total amount of rejected recharge. There will be no significant change in the inundation area or water level in seasonal wetlands.

6.3.2 Groundwater dependent vegetation

Eastern Scott Coastal Plain

Approximately 7150 ha of vegetation on the eastern Scott Coastal Plain has the potential to be affected by the groundwater drawdowns as a result of the Water Corporation proposal. This is the area where the watertable is within 10 m of the surface (Table 7.27). The area potentially affected from the cumulative impacts of the proposal and estimated future regional use is 17 400 ha. These figures refer to the broad area where there may be effects, but do not represent an estimated area of impact.

Drawdowns of less than 0.25 m from the proposal alone result in “low” potential impact, as defined by Froend & Loomes (2004), as there is likely to be “no measurable change” in ecological processes or species composition and abundance. In the very northern part of this area, drawdowns from the proposal are predicted to be up to 0.5 – 1 m, corresponding to a “high” potential impact on vegetation, according to the screening level assessment, which also takes into account depth to groundwater and rate of drawdown.

The total predicted drawdowns of up to 1 – 2 m in the eastern Scott Coastal Plain, combined with the shallow watertables, puts the northern part of this area in the “severe” potential impact category as defined by Froend & Loomes (2004).

The areas with “high” potential impacts may have drawdowns that will cause ecosystem processes and parameters to be “measurably” altered with a “notable change in community structure” (Appendix 30). The abundance of less drought tolerant species is likely to decrease and, as drawdown will occur gradually, there may be a gradual shift to a more xeric environment.

The areas at risk are indicative only and highly conservative, as local site conditions and the amount of drawdown will vary and influence whether an impact actually occurs. Areas with substantial amounts of coffee rock, and silty or clayey layers, will cause perching and prevent drawdowns affecting local watertable levels. Where they exist, impermeable layers within the Leederville Formation impede vertical groundwater movement. Local perching occurs in these areas effectively isolating the watertable from the underlying aquifer (Appendix 13).

In areas where watertable drawdowns do occur, the actual impact on the vegetation will depend on the vegetation type, soil types, and local hydrological conditions. There are two key factors that will mitigate impacts. These are the full recovery of watertables during winter, and the extensive clay and silt beds within the superficial sediments, which will impede water flow and reduce the magnitude of the drawdown of the watertable. The Scott Coastal Plain has high seasonal watertable variations, ranging from one metre near the coast to up to three metres further inland. The vegetation is adapted to dry summers and wet winters, so small changes in summer minima are likely to be within the natural variation of the system, particularly given the very low rate of change.

The model, and the interpretation of the model, assume that water will be abstracted on the Scott Coastal Plain for agriculture. However, the extra recharge in summer that occurs due to the return of a portion of the irrigation has not been incorporated into the model. This will be an important process that will partially offset summer drawdowns. On the Gnangara Mound approximately 25% of water abstracted for irrigation is estimated to return to the watertable (pers comm. DoE August 2005).

Potential effect on vegetation complexes

The main vegetation communities on the eastern Scott Coastal Plain are the Scott Sd and Swd vegetation complexes. They have 47% and 69%, respectively, of their pre-European extent remaining. These complexes are also well-represented in conservation reserves. All the vegetation complexes on the eastern Scott Coastal Plain have more than 30% of their pre-European extent remaining. With the exception of the *Kingia* vegetation complex, the vegetation complexes present in the area are all well-represented in conservation reserves. At a regional scale, the potential impacts on these vegetation complexes will not change their overall viability to any significant extent.

Potential effect on site-vegetation types

Mattiske (Appendix 31) surveyed five transects on the northern Scott Coastal Plain to provide an indication of the species and vegetation communities there. The surveys were not extensive enough to allow the vegetation units to be mapped. The site-vegetation types identified were A6, A7 and J1, with the two A site-vegetation types mostly likely to be influenced by any changes in local hydrological conditions.

The potential changes to the site-vegetation types if the local hydrological conditions become drier will be a reduction in size and extent of the swamps (A6 and A7) (Appendix 32). The A site-vegetation types are extensive in the area, but are vulnerable to subtle changes in groundwater and soil moisture levels. However, this vegetation is adapted to dry summer conditions and the small drawdown of the watertable predicted from the proposal is unlikely to significantly alter the soil moisture regime. The seasonal flooding of the sedgelands within these systems, which is critical to the survival of some of these species (Appendix 32), is not expected to be affected.

Western Scott Coastal Plain

The modelled drawdowns in the western Scott Coastal Plain are almost completely due to the estimated future regional groundwater abstraction. The Water Corporation proposal influences only a small proportion of the total area of potential drawdown (Figure 7.33 and Figure 7.34). The proposal is expected to affect around 110 ha of vegetation, with drawdowns all within the “low” potential impact category. “Low” potential impact corresponds to “no measurable change” in the vegetation response categories defined by Froend & Loomes (Appendix 30).

The total predicted groundwater drawdowns of 0.1 to 1.0 m after 30 years are widespread on the western Scott Coastal Plain (up to 2370 ha) and place the potentially impacted areas mostly in the “low” potential impact category, with small areas in the “medium” to “severe” potential impact categories.

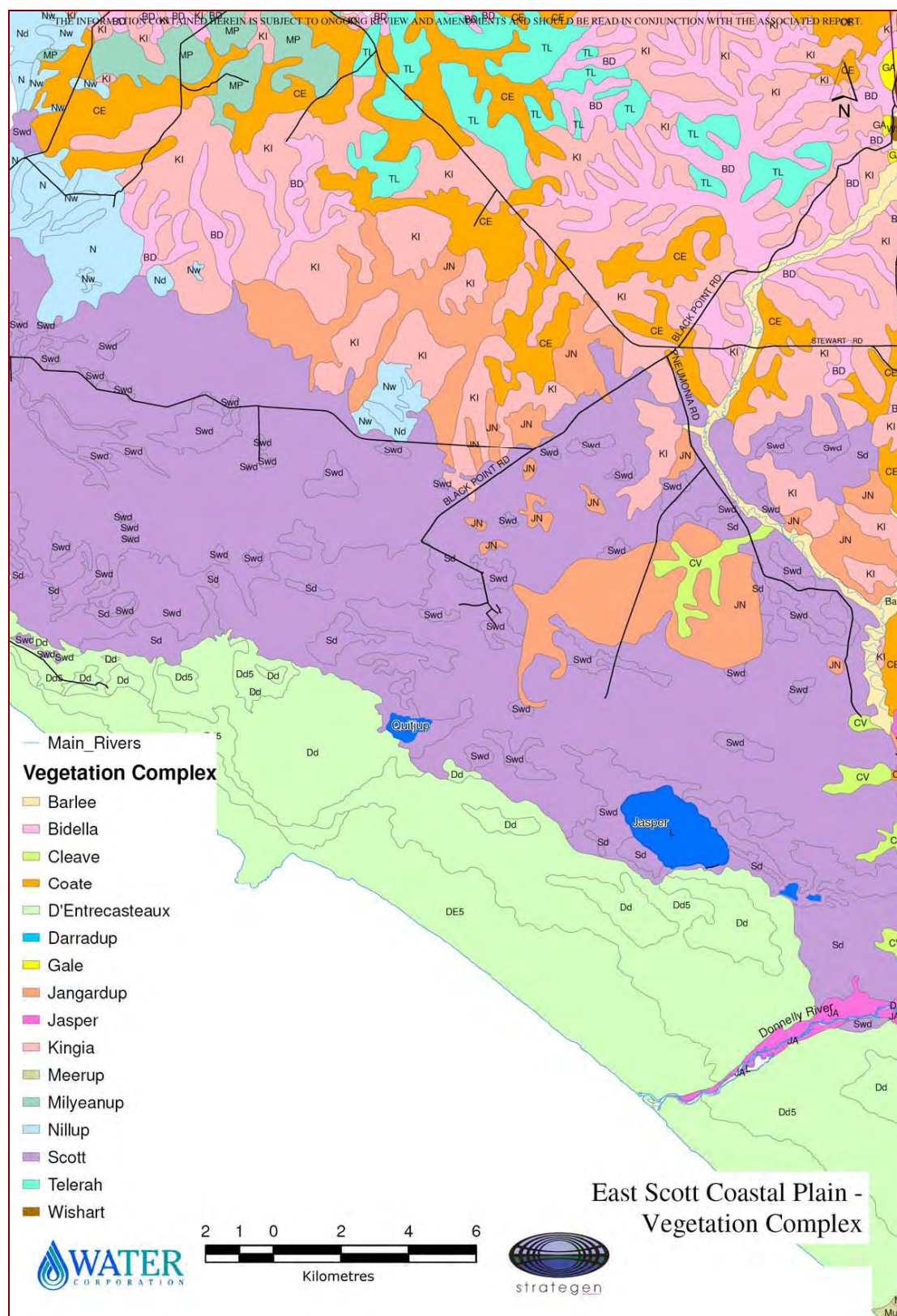
Figure 7.36 Vegetation complexes of the eastern Scott Coastal Plain

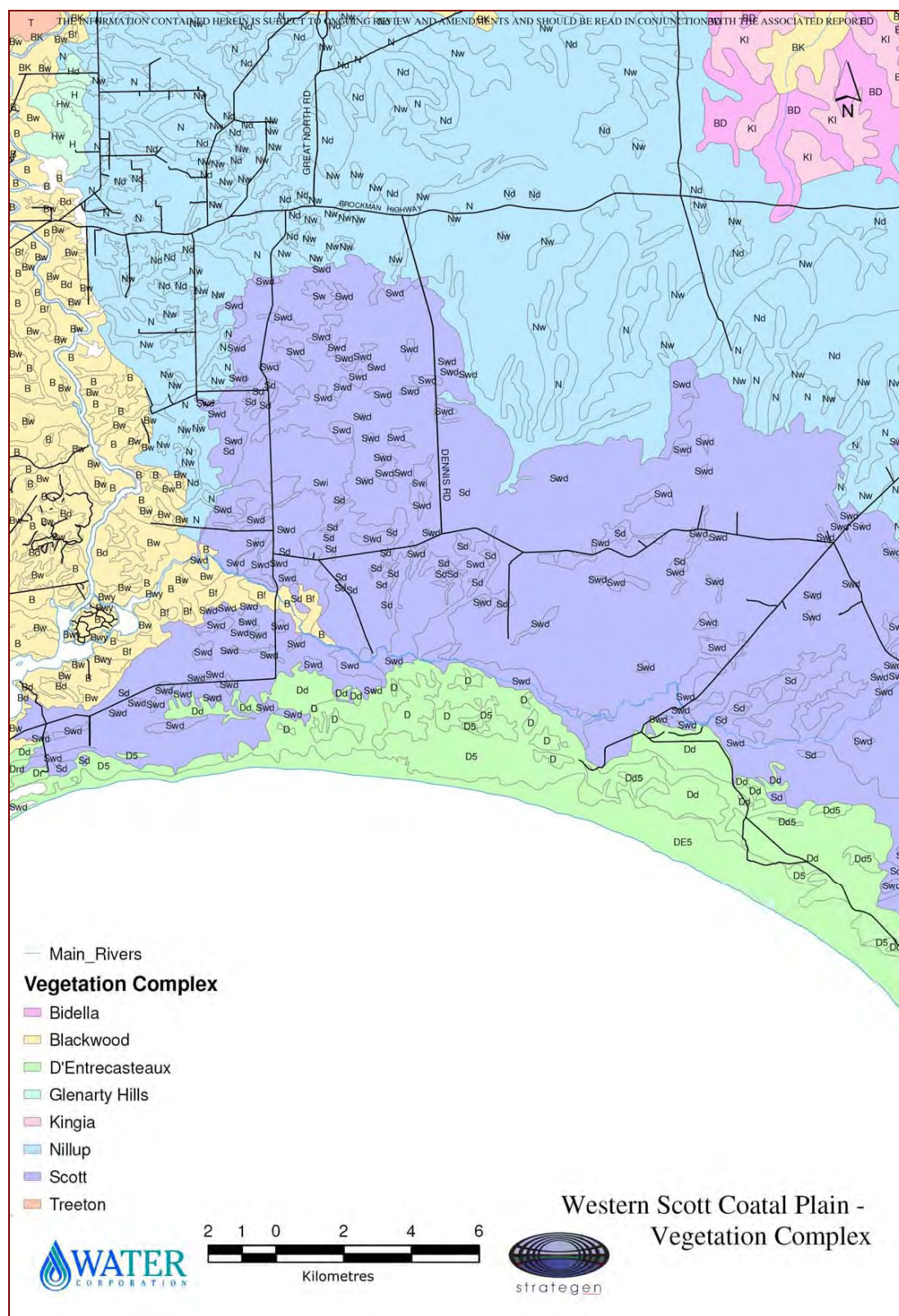
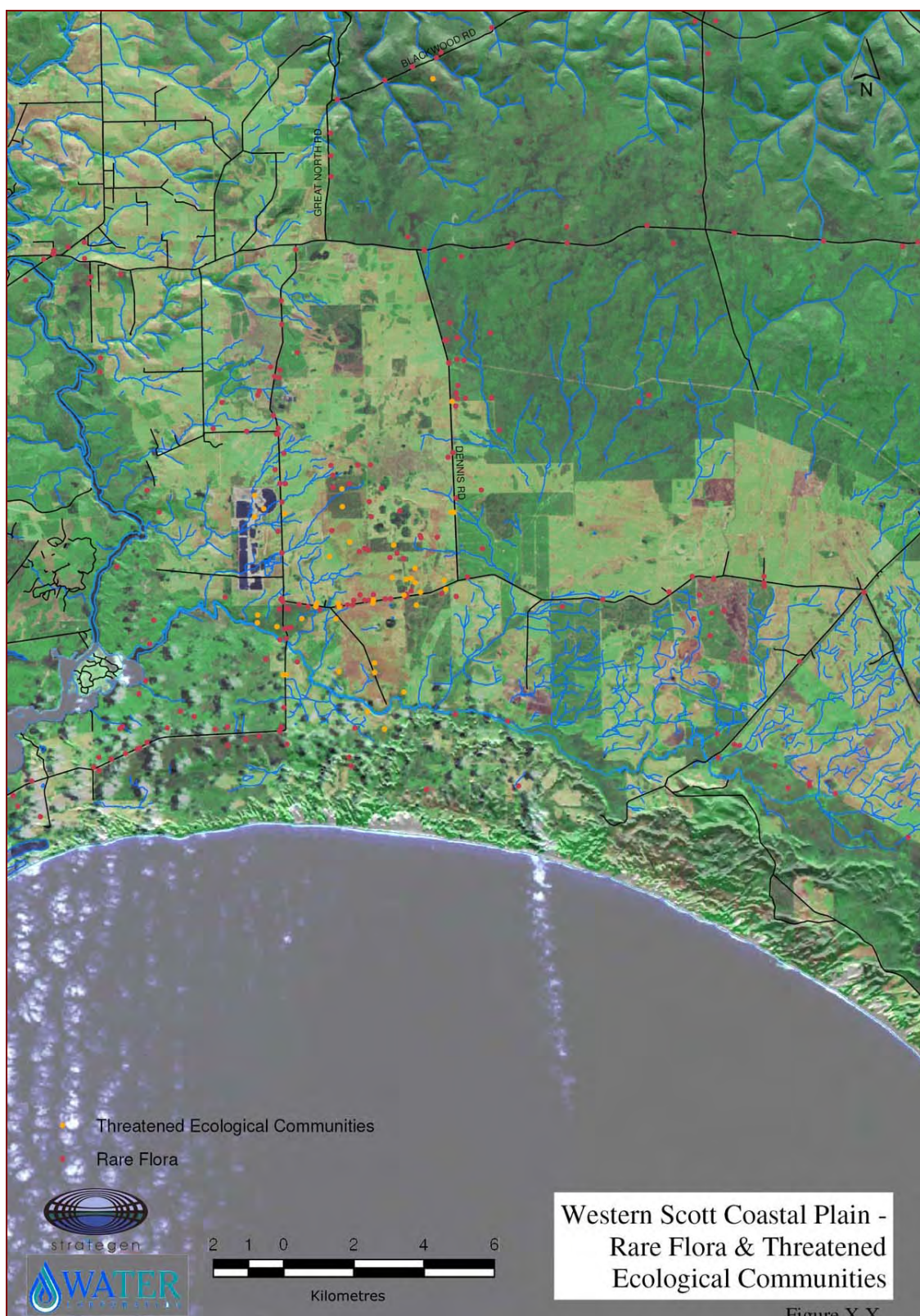
Figure 7.37 Vegetation complexes of the western Scott Coastal Plain

Figure 7.38 Threatened ecological communities on the western Scott Coastal Plain

Potential effects on vegetation complexes

The vegetation complexes in the area potentially affected by drawdown from the proposal are shown in Table 7.28. There are 107 ha of vegetation potentially affected by the proposal only drawdowns, and 2370 ha of vegetation potentially affected by the cumulative drawdowns (Table 7.28). The total drawdowns will not change the occurrence of vegetation complexes in the area, although some components of the vegetation may change. This would not be a significant impact at a regional scale (Appendix 32).

The effect of the estimated future regional use is expected to result in drawdowns on the western Scott Coastal Plain of up to one metre after 30 years. This may result in measurable vegetation changes on the north-western Scott Coastal Plain. Over most of the area, cumulative drawdowns will be less than 0.25 m and there is unlikely to be measurable or significant change.

Table 7.32 Vegetation complexes in areas of potential drawdown from the proposal and estimated future regional use on the western Scott Coastal Plain

	D'Entrecasteaux – Dd5 & Dd	Nillup – Nd & Nw	Scott – Sd & Swd	Total (ha)
Remaining %	>76	>30	>27	
Reserved %	>94	>72	>47	
0 – 3 m*	12	1122	392	1526
3 – 6 m*	47	431	12	489
6 – 10 m*	115	235	1	351
Total	175	1788	405	2367

* Depth to groundwater category

Potential effects on Threatened Ecological Communities

The Scott – Swi vegetation complexes are associated with the ironstone communities on the western Scott Coastal Plain, and have high conservation significance as they support a large range of Rare Flora and Threatened Ecological Communities (Figure 7.38). These communities and the TECs are outside the potential impact areas of both the proposal and estimated future regional use.

6.3.3 Terrestrial fauna

The shift to drier vegetation types in the areas of groundwater drawdown may have the following potential impacts on terrestrial fauna:

- reduction in the extent of dense undergrowth used by fauna for protection and habitat within affected low-lying areas
- reduction in the abundance of particular flora species that are a source of food
- reduction in the overall productivity of the drier ecosystems may also affect the availability of food
- reduction in the extent of wetlands or the length of periods of inundation.

The western Scott Coastal Plain is predicted to have only very small drawdowns (less than 0.25 m) as a result of the Water Corporation proposal (more from estimated future regional use) and the impacts on fauna are likely to be slight (Appendix 29).

Drawdowns on the eastern Scott Coastal Plain from the Water Corporation proposal are predicted to be higher (up to one metre) although in most areas less than 0.25 m. Watertable levels have a high seasonal fluctuation up to three metres in the northern part of the plain. The vegetation and fauna are adapted to this dynamic moisture regime and slight modifications are not likely to have a significant impact on fauna.

Wetlands are important habitats for the fauna of the Scott Coastal Plain. There is not likely to be any significant changes to water levels in the permanent lakes as these are not within the drawdown area from the proposal. As described in Section 6.3.1 of this Chapter, the reduction in surface water due to extra recharge of the superficial aquifer will be minimal and the peak flows and inundations of the ephemeral wetlands are not likely to be affected. Therefore, the wetland habitat values are unlikely to be affected by the proposal.

None of the fauna species of conservation significance expected to occur on the Scott Coastal Plain are restricted to the area, so any changes that do result from the proposal are not expected to affect the occurrence or viability of any of these fauna species.

6.3.4 Acid sulphate soils

The potential impacts of acid sulphate soils (ASS) on biodiversity and ecological integrity are:

- increased acidity can release previously inert toxic heavy metals into the environment
- precipitation of iron can smother wetland vegetation and microhabitats
- low pH causes a deficiency in plant base minerals such as calcium, magnesium and potassium, or a deficiency in plant nutrient availability
- an increase in attack by plant pathogens and a decrease in soil microbes, particularly those responsible for nitrogen fixation
- physiological damage to plants such as the stunting of roots; this can produce water stress, even in situations where the plant appears to have adequate water
- increased risk of erosion where plant growth has been affected.

On the Scott Coastal Plain, the area of drawdown is to the east of the Scott River and over most of the plain is expected to be less than 0.25 m. Natural water level variations in the area are in the range of one to three metres annually, depending on the location. Given the expected full recovery of coastal plain watertable levels each year and the long period over which declines will occur, the effects of acid sulphate soils are expected to be minimal because exposure of the sediments will only be for short periods (Chapter 5 Section 4.8.3).

6.3.5 Social impacts

The coastal environment, Lake Jasper and the Scott River are not expected to be impacted by the Water Corporation proposal. Therefore, the proposal is not expected to affect the community enjoyment or appreciation of the natural environment and its values.

6.3.6 Compliance with EPA Offsets Statement

The EPA Offsets Position Statement is discussed in Chapter 2 Section 6.1. There are no potentially significant impacts on critical assets associated with the Scott Coastal Plain, as shown in Table 7.33.

Table 7.33 Compliance with EPA Offsets Position Statement on the Scott Coastal Plain

Critical asset	Prognosis
Declared Rare Flora	None recorded
Priority Flora	Four Priority 3 and three Priority 4 species recorded
Threatened Ecological Communities	The “Scott River Ironstone Association” TEC is listed as Endangered by CALM, but is not yet listed under the EPBC Act. The proposal is not expected to cause drawdowns where this TEC occurs.
Vegetation complexes with less than 30% remaining	The Scott – Swi ironstone communities have only 10% remaining with none protected in the formal reserve system. The proposal is not expected to cause drawdowns where this vegetation complex occurs.
Threatened Fauna	The carpet python (<i>Morelia spilota</i>), 15 migratory bird species, 7 non-migratory bird species, the chuditch (<i>Dasyurus geoffroii</i>), the quokka (<i>Setonix brachyurus</i>) and the western ringtail possum (<i>Pseudocheirus occidentalis</i>) are threatened fauna species that potentially occur on the Scott Coastal Plain and are listed under State or Federal Acts. Of these, 13 of the migratory bird species and one other bird species are classified as having high groundwater dependence. No significant impact is expected on the aquatic or terrestrial habitats on the Scott Coastal Plain.
Public conservation reserve system	“No measurable change” is predicted within the D’Entrecasteaux National Park from the proposal
Conservation category wetland	None present
Ecosystems under threat	None present
Indigenous heritage sites	Lake Jasper is listed on the Register of the National Estate as it contains Australia’s only underwater prehistoric site of human habitation. The water levels of Lake Jasper are not expected to be impacted by the proposal.
Identified heritage places under EPBC Act	None present

6.3.7 Mitigation

Modelling of several different wellfield configurations (location and units to be drawn from in the Yarragadee Formation) was carried out to determine the configuration that would minimise the effect on other water users, and the environmental impact on potential sensitive areas in the region (Chapter 5 Section 4.1). In the western Scott Coastal Plain, the “Eastern Split” wellfield configuration resulted in the least drawdown at the watertable. In the eastern Scott Coastal Plain, the “Eastern Split” wellfield configuration resulted in the second lowest drawdown at the watertable⁴⁷.

The “Eastern Split” wellfield location is more than 50 km from the Scott Coastal Plain.

The estimated future regional groundwater use has the potential to cause significant drawdowns on the Scott Coastal Plain, irrespective of the Water Corporation proposal proceeding.

Mitigation of anticipated potential impacts from the proposal on the Scott Coastal Plain environment will involve the application of an adaptive management approach (Section 6.4 of this Chapter) which will include application of a combination of the following offsets:

⁴⁷ The comparison of the wellfield configurations and the decision-making process are detailed in Volume 2 Chapter 3 Section 2.1.

1. A South West Yarragadee Sustainability Initiative (Volume 1 Chapter 7 Section 4.1.1) that includes:
 - a) research into the magnitude and possible means of management of irrigation return water
 - b) investigations into the effects of changing land use on water demand, availability and quality
 - c) investigation of the ecological values of the Scott Coastal Plain as part of a major regional biodiversity study, including the potential effects of threatening processes
 - d) support for investigations into the potential for acidification from acid sulphate soils, and potential means of management.
2. The Water Corporation proposes to sponsor a program to manage threatening processes (feral animals, weeds, unrestricted public access) in the areas that may be affected by the proposal the Scott Coastal Plain.

Mitigation benefits

Climate change has the potential to induce substantial changes to ecosystems in the South West and is likely to have a greater impact on the coastal plain ecosystems than the proposal. Improving knowledge of the relationship between ecosystems and climate, with the ultimate goal of maintaining the resilience, biodiversity and function of these systems under a changing climate regime, is considered an appropriate focus for mitigation of the increased risk of drought stress associated with this proposal.

The South West Yarragadee Sustainability Initiative will support research into improving water management on the Scott Coastal Plain. It may be possible to use outcomes of this initiative to reduce the impact of local water users on the Scott Coastal Plain environment. The Sustainability Initiative will also support research into acidification from acid sulphate soils, which is another threatening process on the Scott Coastal Plain.

Other significant threats to the ecosystems of the Scott Coastal Plain include feral animals, weed encroachment, uncontrolled access, and dieback. Research is essential for furthering the understanding of the ecosystem and supporting informed decision making on the management of threatening processes. The proposed biodiversity study in the region will both add resources to research in the region and increase the effectiveness of funds already being spent by adding to and consolidating existing knowledge.

Feral animal control projects (e.g. Western Shield) have proved to be effective in increasing the numbers of rare native mammals. However, these programs require ongoing funding to remain effective. The Water Corporation proposal to provide resources for the management of feral animals (Volume 1 Chapter 5 Section 1.2) will have a direct biodiversity benefit.

6.4 MONITORING, ADAPTIVE MANAGEMENT AND ACCOUNTABILITY

The Water Corporation will develop and implement an extensive biological, hydrological and physical monitoring program for the region, including the Scott Coastal Plain. The Water Corporation is also committed to undertaking a comprehensive biodiversity study, which will include the Scott Coastal Plain and investigate the relationship between ecosystems and groundwater.

A preliminary outline of a monitoring program has been developed (Table 7.34). The monitoring program will include a baseline study using the same parameters as shown in Table 7.34 but with more intense sampling regimes. The baseline study will be completed before the operational phase of the project and will allow both hydrological and ecological changes and trends to be assessed. The monitoring program will be developed in consultation with the Monitoring Review Group (Volume 1 Chapter 8 Section 3.2.3).

Table 7.34 Proposed Scott Coastal Plain monitoring program

Field	Parameter	Methods
Hydrology	Surface water levels	Measure water levels in Lake Quitjup and Lake Jasper monthly over summer
	Groundwater levels	Monitor watertable levels and levels in the underlying Yarragadee Formation monthly for the first few years (at least 2) of the project and then every two months.
	Groundwater quality	Monitor electrical conductivity and chloride in all wells annually (June)
Physical	Acid sulphate soils	Monthly shallow watertable sampling
Biological	Tree health	Establish permanent transects with tagged trees
	Species composition	Establish permanent quadrats for monitoring of species diversity and abundance
	Vegetation condition	Monitor vegetation condition according to the Keighery rating scale
	Fauna	Terrestrial fauna surveys near selected wetlands

The Water Corporation will prepare an annual Sustainability Report that will report on the monitoring results. The Monitoring Review Group will review the monitoring results against a set of defined principles and recommend whether any changes need to be made to the management of the project.

6.5 PROPONENT COMMITMENTS

The Water Corporation is committed to an adaptive management approach and to the following:

1. Undertake a biodiversity and acid sulphate soils study (as part of the Sustainability Initiative) in areas potentially affected by groundwater drawdown resulting from the proposal. The studies will be funded up to the value of \$1.5M, with the capital and any earned interest made available to the studies over a period of ten years.
2. Undertake a South West Yarragadee Sustainability Initiative that includes:
 - the biodiversity and acid sulphate soils studies above
 - sponsor a research program up to the value of \$0.5M on the magnitude and potential means of management of irrigation return water and the effects of changing land use on water demand, availability and quality.
3. Prepare, and report on the implementation of, abstraction management plans and associated monitoring programs for the groundwater abstraction in accordance with any licence issued pursuant to the RWI Act and the Groundwater Abstraction Management Plan described in Chapter 9 Section 8.

4. The Water Corporation will contribute to a 5 year program to assist the management of threatening processes in areas that may be affected by the proposal. The funding will be up to \$1M with the capital and any earned interest made available to the management program over a period of five years. The program will address weeds, disease, feral animals, erosion and uncontrolled public access issues insofar as they exist within the potentially affected areas including the Scott Coastal Plain.

6.6 ENVIRONMENTAL OUTCOME

The areas on the eastern Scott Coastal Plain with potential to be affected by predicted groundwater drawdowns from the Water Corporation proposal are mainly in the “low – no measurable change” potential impact category, as defined by Froend & Loomes (2004), with some smaller areas in the “moderate” to “high” potential impact categories. The predicted drawdowns apply only to summer minimums and there will be full winter recovery of the watertable over the majority of the area where there is a shallow watertable. The drawdowns will occur slowly, at rates that will allow gradual adjustment of the vegetation and associated habitat. In the northern part of the eastern Scott Coastal Plain there may be gradual local changes to some site-vegetation types, but this will not significantly affect the conservation status of any significant flora or fauna species, or the presence of any vegetation complexes.

The drawdown resulting from the proposal is expected to be less than 0.25m over most of the plain, and will be in an area with high seasonal watertable fluctuations. The decline in watertable levels will occur gradually over a long period of time, and full recovery of coastal plain watertable levels is expected each year. The effects of acid sulphate soils are therefore expected to be minimal, because exposure of the sediments will be limited and only for short periods.

No impact from the proposal is expected on either Lake Quitjup or Lake Jasper. However, the cumulative drawdown from the proposal and estimated future regional use is predicted to be in the range 0.1 – 0.25 m near both of these lakes. The proposal will result in no significant impact on the seasonal wetlands of the Scott Coastal Plain, as the amount of extra recharge required to replenish the watertable each winter is smaller than the total amount of rejected recharge each year.

The predicted groundwater drawdowns from the proposal on the western Scott Coastal Plain are minimal and there is not expected to be a measurable impact from the proposal. The Scott River Ironstone Association TEC and the significant Scott (Swi) vegetation complex are not within the area predicted to be affected by the proposal.

The cumulative predicted drawdowns as a result of the proposal and estimated future regional use are up to 1 – 2 m on the eastern Scott Coastal Plain, and up to 0.5–1 m on the western Scott Coastal Plain. They have the potential for significant impact over a substantial area, irrespective of the impact of the proposal, and will require management in their own right.

Proposed mitigation commitments to reduce threatening processes within the area, and in the D’Entrecasteaux National Park, will help protect and restore ecological values currently affected or under threat, and enhance biodiversity in the area. The knowledge and data obtained from the proposed biodiversity study and comprehensive monitoring program will improve the understanding of the area and provide for adaptive management to ensure the area is cautiously managed into the future, particularly in the context of climate change.

7 SWAN COASTAL PLAIN

Sustainability objectives

The sustainability objective for the *Wetlands* factor is:

*The Water Corporation will seek to increase the ecological integrity of wetlands in the region.
At a minimum, the proposal will have no significant adverse impact on wetlands*

The *Threatened fauna, Flora and fauna, Rare and priority flora (groundwater dependent), Threatened ecological communities* and *Other groundwater dependent ecosystems* factors and their objectives are also addressed in this section.

The EPA objective for wetlands is:

To maintain the integrity, ecological functions and environmental values of wetlands.

7.1 EXISTING ENVIRONMENT

The Swan Coastal Plain extends along the coast from Dunsborough to Geraldton. Within this section of the Sustainability Evaluation/ERMP, the area covered is that part of the Swan Coastal Plain south of Bunbury.

7.1.1 Relevant investigations

The Water Corporation has undertaken an extensive range of studies to identify the values and assess the potential impacts of the proposal on the Swan Coastal Plain:

1. Mattiske (2005b at Appendix 32) evaluated the susceptibility of the flora and vegetation values on the Swan Coastal Plain to effects of the proposal.
2. Synnott Mulholland Management Services (2005 at Appendix 3) conducted a social impact assessment that included consideration of recreational, aesthetic, and sense of place values of the region.
3. Bamford (2003 at Appendix 28) assessed the fauna species that are likely to occur in the potential impact areas including the Swan Coastal Plain, and assessed their likely groundwater dependence.
4. Water Corporation carried out an intensive investigation into the hydrogeology of the Southern Perth Basin. This included an extensive drilling project and a review of all available information (Baddock 2005a at Appendix 11).
5. Water Corporation constructed, calibrated (Sun 2005 at Appendix 12) and interpreted (Baddock 2005b at Appendix 13) a numerical model of the South West Yarragadee aquifer system that built on the results of a previous joint project by the Water and Rivers Commission and Water Corporation. This model was peer reviewed and found to be suitable for regional-scale groundwater modelling (Peer Review Panel 2005 at Appendix 20).
6. Rockwater (2004b) assessed the hydrogeology of the superficial aquifer on the Swan and Scott Coastal plains.
7. Bamford (2005 at Appendix 29) undertook a desktop review of the potential impacts of the predicted drawdowns on terrestrial fauna.

7.1.2 Hydrogeology

The Swan Coastal Plain is bounded to the west by the Indian Ocean and Geographe Bay and in the south and east, respectively, by the Blackwood Plateau and the Darling Range. It is a relatively flat plain about 16 km wide that slopes gently towards the coast. The Vasse–Wonnerup wetland system is a linear system along much of this coastline. The Swan Coastal Plain has shallow, highly seasonal watertables, and is prone to seasonal flooding and waterlogging.

The surface geology comprises Quaternary alluvial and dune sediments to a depth of 20 – 30 m, termed the superficial formations. In inland areas, the superficial formations contain a relatively thin and poorly permeable aquifer, which becomes more permeable close to the coast. Groundwater flow is towards the coast with seasonal watertable fluctuations of 0.5 to 2.0 m. Greater fluctuations can occur near the Whicher Scarp where the sediments are particularly clayey (Rockwater 2004b).

Near Busselton the superficial formations overlie the Vasse Member of the Leederville Formation. In the Bunbury area the superficial sediments are underlain by the Yarragadee Formation, with Bunbury Basalt sub-cropping in a small area at Bunbury.

7.1.3 Wetlands

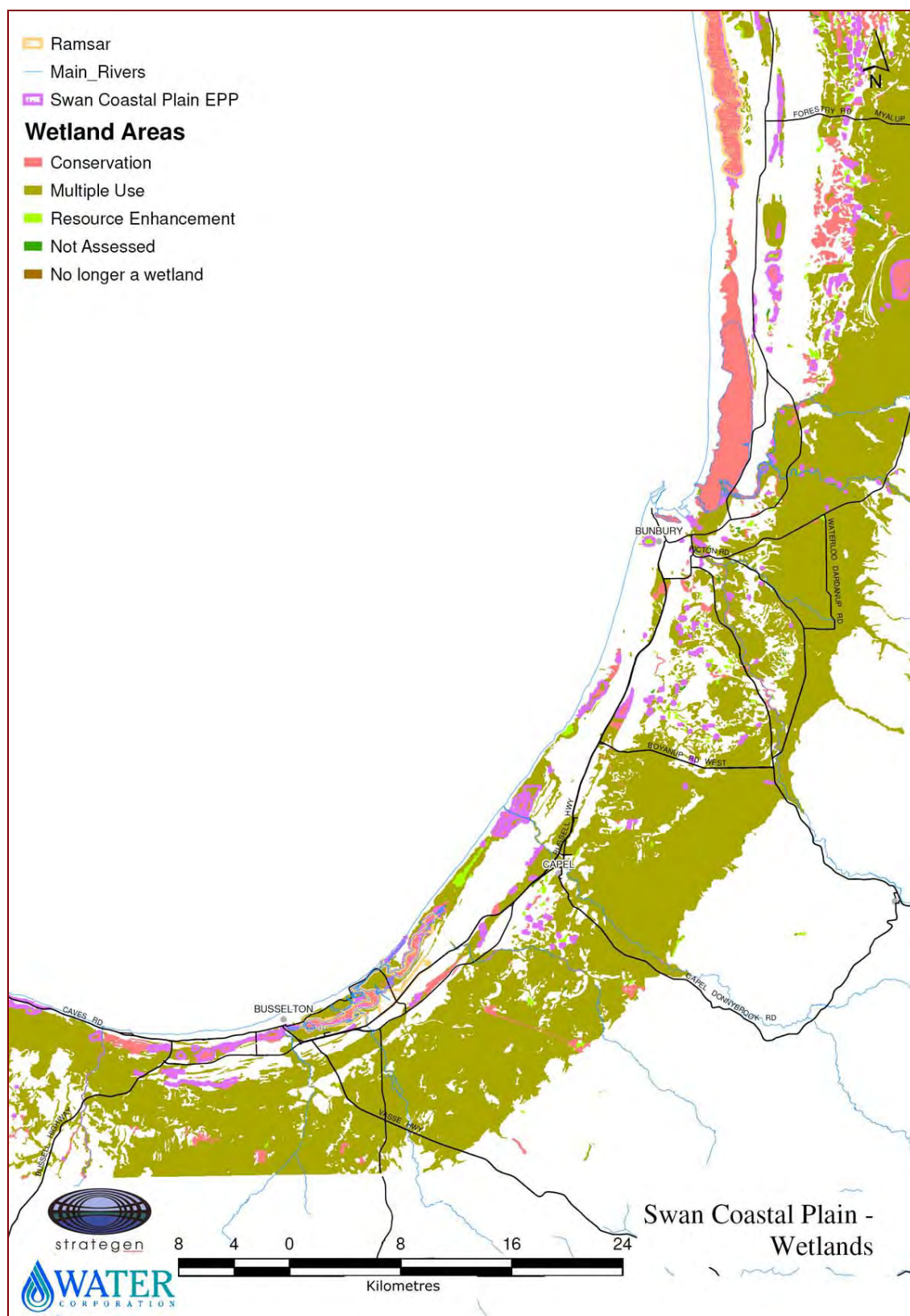
The Vasse–Wonnerup Wetlands were originally the Wonnerup and Vasse Estuaries, but are no longer true estuaries as the inflow of seawater is prevented by weirs across Wonnerup Inlet. The wetlands act as compensating basins for water discharging from the Ludlow, Sabina, Abba and Vasse Rivers, and only discharge through the weirs when the estuary water level rises above sea level. The valves in the weir close when the water level drops, preventing the inflow of seawater. The wetland system is shallow, with a maximum water depth of less than one metre. They are predominantly fresh in winter, but become brackish or dry in summer. The wetland system is listed on the Ramsar List of Wetlands of International Importance.

The Swan Coastal Plain also has extensive seasonal wetlands that form in areas of shallow watertable after heavy winter rainfall (Figure 7.39).

7.1.4 Land use

South of Bunbury, the southern Swan Coastal Plain has been almost totally cleared and extensively drained for agriculture. Grazing is the most common agricultural enterprise followed by intensive animal production, cropping and horticulture. Other land uses are mineral sands mining, expanding urban development, and some forestry.

The Vasse–Wonnerup Wetland system covers 740 hectares along the coast to the east of Busselton. Approximately 120 hectares of this is protected in a Conservation Park (Figure 7.43). The 2049 hectare Tuart Forest National Park lies between Busselton and Capel.

Figure 7.39 Wetlands on the Swan Coastal Plain

7.1.5 Vegetation and flora

The Swan Coastal Plain has been extensively cleared for agriculture and urban development. Remnant vegetation in this area is highly significant and contains several listed Threatened Ecological Communities. There are thirteen vegetation complexes known in this section of the Swan Coastal Plain. The key vegetation complexes that may be influenced by longer term drawdowns in the area, as defined by Mattiske (Appendix 32), are:

1. the sumplands, damplands and wetlands within the low-lying areas of the Bassendean complex and of the Karrakatta Central and South complexes, north of Boyanup Road and south of the Preston River.
2. woodlands along creeks and minor gullies of the Guildford complex
3. woodlands, shrublands, heaths and sedgelands in swamps and seasonally inundated areas in the Abba (in particular Aw and AB) and Yoongarillup (in particular Yw and Y) complexes.

7.1.6 Threatened Ecological Communities

There are six TECs that are within the potential drawdown areas on the Swan Coastal Plain (Table 7.35 and Figure 7.40). The following descriptions and discussion of susceptibility to long-term declines of the watertable is taken from Mattiske (Appendix 32):

1. *Shrublands on southern Swan Coastal Plain Ironstones (Busselton area)* (10b based on Gibson et al. 1994). This TEC occurs on the Pinjarra Plain below the Whicher Scarp. This community occurs south east of Busselton (Figure 7.40). The values in this community include a large range of rare and Priority species that are listed as “Critically Endangered” at the State level under the Wildlife Act and “Endangered” at the Federal level under the EPBC Act. This community is restricted to localised pockets and is threatened by other land uses in the area.
2. *Shrublands on calcareous silts of the Swan Coastal Plain* (18 based on Gibson et al. 1994). This TEC is listed as “Vulnerable” at the State level under the Wildlife Act and occurs mostly on the calcareous silts associated with lake deposits on the Swan Coastal Plain. There are two areas of this TEC that are within the potential drawdown area just south of Bunbury.
3. *Southern wet shrublands, Swan Coastal Plain* (2 based on Gibson et al. 1994). This TEC occurs on the seasonally wet and inundated areas on the Pinjarra Plain on the Swan Coastal Plain to the south and southeast of Busselton. This TEC is listed as “Endangered” under the Wildlife Act. The values in this community also include a range of Declared Rare and Priority species. This community is at high risk from minor changes in groundwater levels. This community is restricted to localised pockets and is threatened by other land uses in the area.
4. *Herb rich saline shrublands in clay pans of the southern Swan Coastal Plain* (7 based on Gibson et al. 1994). This TEC occurs on seasonally wet and inundated clay pans on the Swan Coastal Plain. This TEC is listed as “Vulnerable” at the State level under the Wildlife Act and may include a range of Declared Rare and Priority species. This community occurs in the area southeast and east of Busselton and near Mandurah. This community is at moderate to high risk from minor changes in groundwater levels. There is a need to further clarify the extent these clay pans are perched above the groundwater systems, and therefore the connection of this system to the underlying groundwater systems. This community is restricted to localised pockets and is threatened by other land uses in the area.

5. *Herb rich shrublands in clay pans of the southern Swan Coastal Plain* (8 based on Gibson et al. 1994). This TEC occurs on clay pans on the Pinjarra Plain, which are seasonally wet and inundated areas on the Swan Coastal Plain. This TEC is listed as “Vulnerable” at the State level under the Wildlife Act and may include a range of Declare Rare and Priority species. This community is at moderate to high risk from minor changes in local and regional groundwater levels. There is a need to further clarify the extent these clay pans are perched above the groundwater systems, and therefore the relative reliance on moister soils following seasonal rains versus moisture from groundwater systems. This community is restricted to localised pockets and is threatened by other land uses in the area.
6. *Shrublands on dry clay flats of the southern Swan Coastal Plain* (10a based on Gibson et al. 1994). This TEC occurs on dry clay flats on the Swan Coastal Plain. This TEC is listed as “Endangered” at the State level under the Wildlife Act and may include a range of Declare Rare and Priority species. This community is at low to moderate risk from minor changes in local and regional groundwater levels. There is a need to further clarify the extent these clay pans are perched above the groundwater systems, and therefore the relative reliance on moister soils following seasonal rains versus moisture from groundwater systems. This community is restricted to localised pockets and is threatened by other activities in the area.

Table 7.35 Summary of Threatened Ecological Communities that may be influenced by drawdown on the Swan Coastal Plain

No.	Description	Gibson <i>et al.</i> (1994)	State (CALM 2005b) ¹	Federal (EPBC Act)*	Likely groundwater dependence
1.	Shrublands on southern Swan Coastal Plain Ironstones (Busselton area)	10b	CR	EN	High+
2.	Shrublands on calcareous silts of the Swan Coastal Plain	18	VN	-	Low
3.	Southern wet shrublands, Swan Coastal Plain	2	EN	-	High
4.	Herb rich saline shrublands in clay pans of the southern Swan Coastal Plain	7	VN	-	Mod-High
5.	Herb rich shrublands in clay pans of the southern Swan Coastal Plain	8	VN	-	Mod-High
6.	Shrublands on dry clay flats of the southern Swan Coastal Plain	10a	EN	-	Low-Mod

* VN = Vulnerable, CR= Critically endangered, EN = Endangered,

Figure 7.40 Threatened Ecological Communities on the Swan Coastal Plain

7.1.7 Declared Rare and Priority Flora

Based on regional database searches there are 130 Declared Rare and Priority species that potentially could occur on the southern Swan Coastal Plain. A significant number of these species are likely to occur in groundwater dependent ecosystems (Appendix 32), only some of which may be affected by the proposal.

Table 7.36 Summary of Declared Rare and Priority species that potentially occur on the southern Swan Coastal Plain

Category	Act	Regional groundwater dependency		
		High	Moderate	Low
Endangered	Federal	7	4	2
Vulnerable	Federal	2	5	1
Rare	State	14	9	5
Priority 1	State	6	4	6
Priority 2	State	6	8	3
Priority 3	State	14	18	9
Priority 4	State	9	11	8
Total potential species		58	59	34

7.1.8 The Terrestrial fauna

Swan Coastal Plain has been extensively cleared for agriculture, with the remaining habitats ranging from coastal dune systems in the west, through tuart and peppermint woodlands to eucalypt and banksia woodlands in the east. Important habitat areas include extensive, low-lying damplands, several river systems, the Vasse–Wonnerup Wetland system, and inter-dunal seasonal wetlands, most of which have been altered through clearing and drainage (Appendix 29).

Although the fauna has undoubtedly been affected by extensive clearing and draining, Bamford (Appendix 28) predicted the area is still likely to support 10 – 11 frogs, 23 reptiles, 158 birds, and 31 mammals. Of these, one frog, two reptiles, 25 – 26 birds, and eight mammal species are of conservation significance (Table 7.37). The area is likely to be rich in significant bird species because of the presence of migratory waterbirds in estuaries (Appendix 28). In general, faunal habitats on the Swan Coastal plain are small and fragmented due to extensive clearing.

Table 7.37 Species of conservation significance (CS) likely to occur on the Swan Coastal Plain and their groundwater dependence (GD)

Species	CS*	GD	Swan Coastal Plain
FROGS			
<i>Metacrinia nichollsi</i>	3	High	Uncertain
REPTILES			
<i>Morelia spilota</i>	1	Low	Likely
<i>Glaphyromorphus gracilipes</i>	3	High	Likely

Species	CS*	GD	Swan Coastal Plain
BIRDS			
<i>Ardea alba</i> (migratory)	1	Very high	Likely
<i>Ardea ibis</i> (migratory)	1	Very high	Likely
<i>Plegadis falcinellus</i> (migratory)	1	Very high	Likely
<i>Haliaeetus leucogaster</i> (migratory)	1	Very high	Likely
<i>Tringa stagnatalis</i> (migratory)	1	Very high	Likely
<i>Tringa nebularia</i> (migratory)	1	Very high	Likely
<i>Tringa glareola</i> (migratory)	1	Very high	Likely
<i>Actitis hypoleucos</i> (migratory)	1	Very high	Likely
<i>Calidris ruficollis</i> (migratory)	1	Very high	Likely
<i>Calidris subminuta</i> (migratory)	1	Very high	Likely
<i>Calidris acuminata</i> (migratory)	1	Very high	Likely
<i>Calidris ferruginea</i> (migratory)	1	Very high	Likely
<i>Rostratula benghalensis</i> (migratory)	1	Very high	Likely
<i>Sterna caspia</i> (migratory)	1	High	Likely
<i>Sterna bergii</i> (migratory)	1	High	Likely
<i>Merops ornatus</i> (migratory)	1	Low	Likely
<i>Apus pacificus</i> (migratory)	1	Low	Likely
<i>Falco peregrinus</i>	1	Low	Likely
<i>Calyptorhynchus banksia</i>	1	Low	Likely
<i>Calyptorhynchus latirostris</i>	1	Low	Likely
<i>Calyptorhynchus baudinii</i>	1	Low	Likely
<i>Botaurus poiciloptilus</i>	1	Very high	Likely
<i>Ixobrychus minutus</i>	2	Very high	Likely
<i>Ixobrychus flavicollis</i>	2	Very high	Uncertain
<i>Ninox connivens</i>	2	Low	Likely
<i>Tyto novaehollandiae</i>	2	Low	Likely
<i>Stagonopleura oculata</i>	3	High	Likely
MAMMALS			
<i>Dasyurus geoffroii</i>	1	Moderate	Likely
<i>Pseudocheirus occidentalis</i>	1	Low	Likely
<i>Setonix brachyurus</i>	1	Moderate	Certain
<i>Phascogale tapoatafa</i>	2	Moderate	Likely
<i>Isodon obesulus</i>	2	High	Likely
<i>Macropus irma</i>	2	Moderate	Likely
<i>Falsistrellus mackenziei</i>	2	Low	Likely
<i>Hydromys chrysogaster</i>	2	Very high	Likely

Adapted from Bamford (2005)

*: Conservation significance: 1 = Species listed under State or Federal Acts, 2 = Species not listed under State or Federal Acts, but listed in publications on threatened fauna or as Priority species by CALM, 3 = Species not listed under Acts or in publications, but considered of at least local significance because of their pattern of distribution.

Mammals

The populations of mammals on the Swan Coastal Plain are small and fragmented due to clearing. There are eight mammal species of conservation significance that are expected to occur on the Swan Coastal Plain (Table 7.37). Only the water rat (rakali, *Hydromys chrysogaster*) may have very high groundwater dependence, as it is heavily reliant on permanent water.

Birds

The Swan Coastal Plain has many waterbirds, especially those that use damp and flooded pasture. As the Swan Coastal Plain is extensively cleared within the project area, there are both farmland species and species of woodland and forest dwellers present.

Reptiles

The Swan Coastal Plain has more reptile species of conservation significance than the Blackwood Plateau or the Scott Coastal Plain. The species expected within the project area would also be found to the north on the Swan Coastal Plain.

The carpet python (*Morelia spilota imbricata* – South West subspecies) has been observed on both the Swan and Scott Coastal Plains. It is a CALM Priority 4 species and is listed as a Schedule 4 Fauna Specially Protected for Other Reasons under the Wildlife Act. The carpet python is threatened by clearing, and possibly by introduced predators (Appendix 28).

Glaphyromorphis gracilipes is a skink that is locally significant because of its restricted occurrence in the far south-western corner of Western Australia.

Frogs

Ten or eleven species of frogs may be present on the southern Swan Coastal Plain, with species diversity being slightly less on the Swan Coastal Plain than in areas further to the south. The Nicholls' toadlet (*Metacrinia nicchollsi*) occurs only in the South West and is the only frog species of conservation significance on the Swan Coastal Plain.

7.1.9 Social values

The natural environment is highly valued on the southern Swan Coastal Plain, with the rapidly increasing population largely attracted by the “sea change” lifestyle. The coastal environments are especially valued for their lifestyle, aesthetic and recreational amenity. There is appreciation within the community of the high biodiversity in the region (Appendix 31).

In Busselton, the Vasse–Wonnerup Wetlands are highly valued and a particular focus for conservation by the community. The community recognises the global significance of the wetlands through their listing in the Ramsar List of Wetlands of International Importance.

7.2 ASSESSMENT FRAMEWORK AND POLICY CONTEXT

The following policies and legislation are relevant to the impact assessment of the Swan Coastal Plain and its associated ecosystems, and are described in Chapter 2:

- *Wildlife Conservation Act 1950*
- *Conservation and Land Management Act 1984*
- *Environmental Protection and Biodiversity Conservation Act 1999*
- National Strategy for Conservation of Australia's Biological Diversity 1996
- National Objectives and Targets for Biodiversity Conservation 2001
- National Strategy for Ecologically Sustainable Development 1992
- Conservation Policy for Western Australia 1997.

7.2.1 Key EPA and other policies

The key policies that have been applied to the assessment of this factor and which provide a critical test of environmental sustainability are as follows:

- EPA Position Statement No. 2: Environmental Protection of Native Vegetation in Western Australia 2000.
- EPA Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection 2002.
- EPA Position Statement No. 4: Environmental Protection of Wetlands 2004
- EPA draft Position Statement No. 9 (V2): Environmental Offsets 2005
- Forest Management Plan 2004-2013 (2004)
- Ramsar Convention on Wetlands 1971

7.3 POTENTIAL IMPACTS AND MITIGATION

7.3.1 Groundwater drawdown

The predicted drawdowns from the proposal alone are all less than 0.5 m south of Bunbury, and less than 0.25 m east of Busselton (Figure 7.41). The areas of drawdown resulting from the proposal are less widespread than the areas affected by the cumulative drawdown from the proposal and estimated future regional use. The total predicted drawdowns on the Swan Coastal Plain after 30 years from estimated future regional use and the proposal are mostly less than one metre, with small areas of drawdown in the 1 – 2 m range (Figure 7.42).

The drawdowns shown refer to the predicted reduction in the summer watertable minima only. The winter watertables are expected to fully recover due to the infiltration of rainfall that currently discharges as surface runoff (Chapter 5 Section 3.1.4).

Figure 7.41 Predicted groundwater drawdowns from the proposal on the Swan Coastal Plain after 30 years

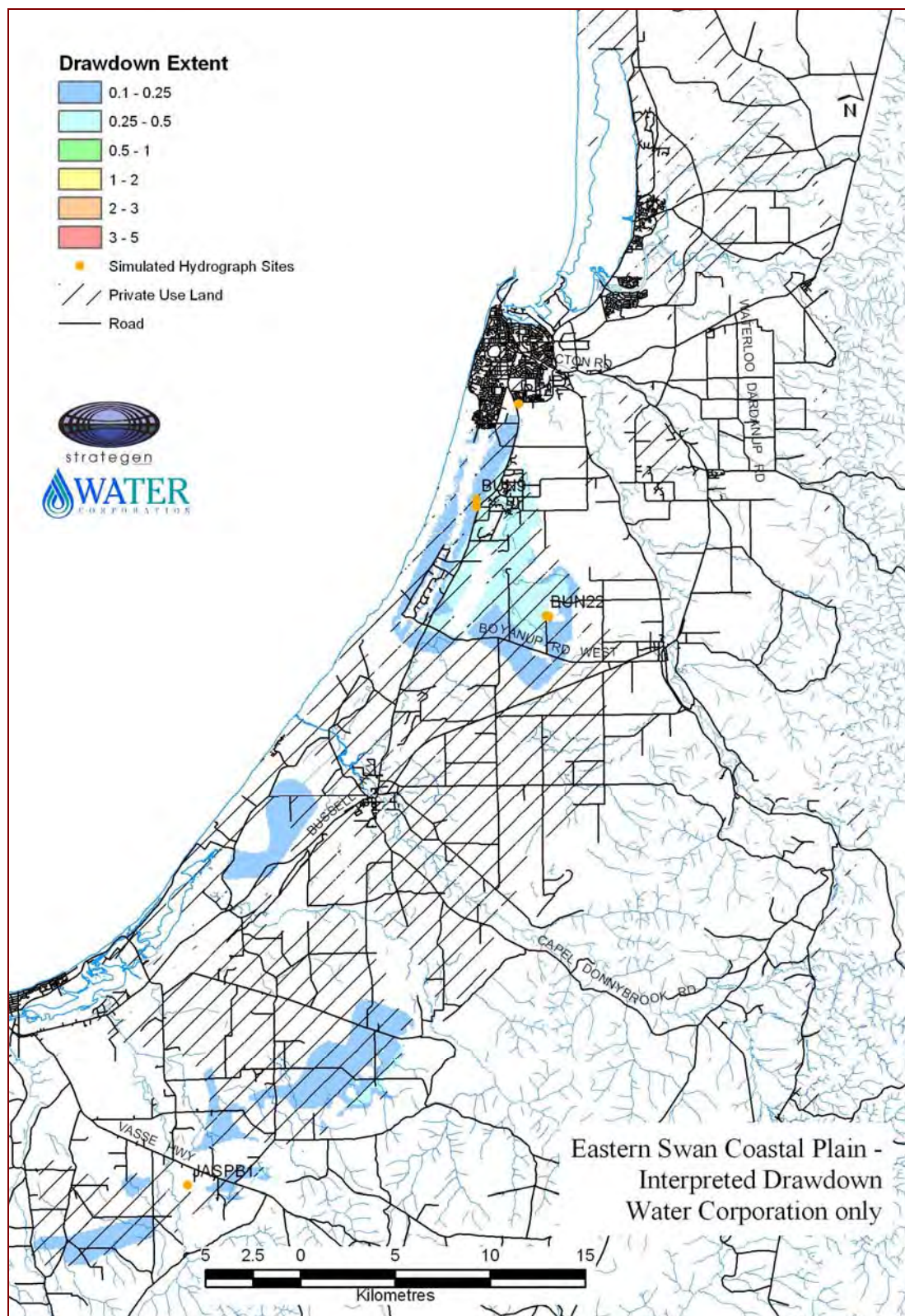


Figure 7.42 Predicted groundwater drawdowns from the proposal and estimated future regional use on the Swan Coastal Plain after 30 years

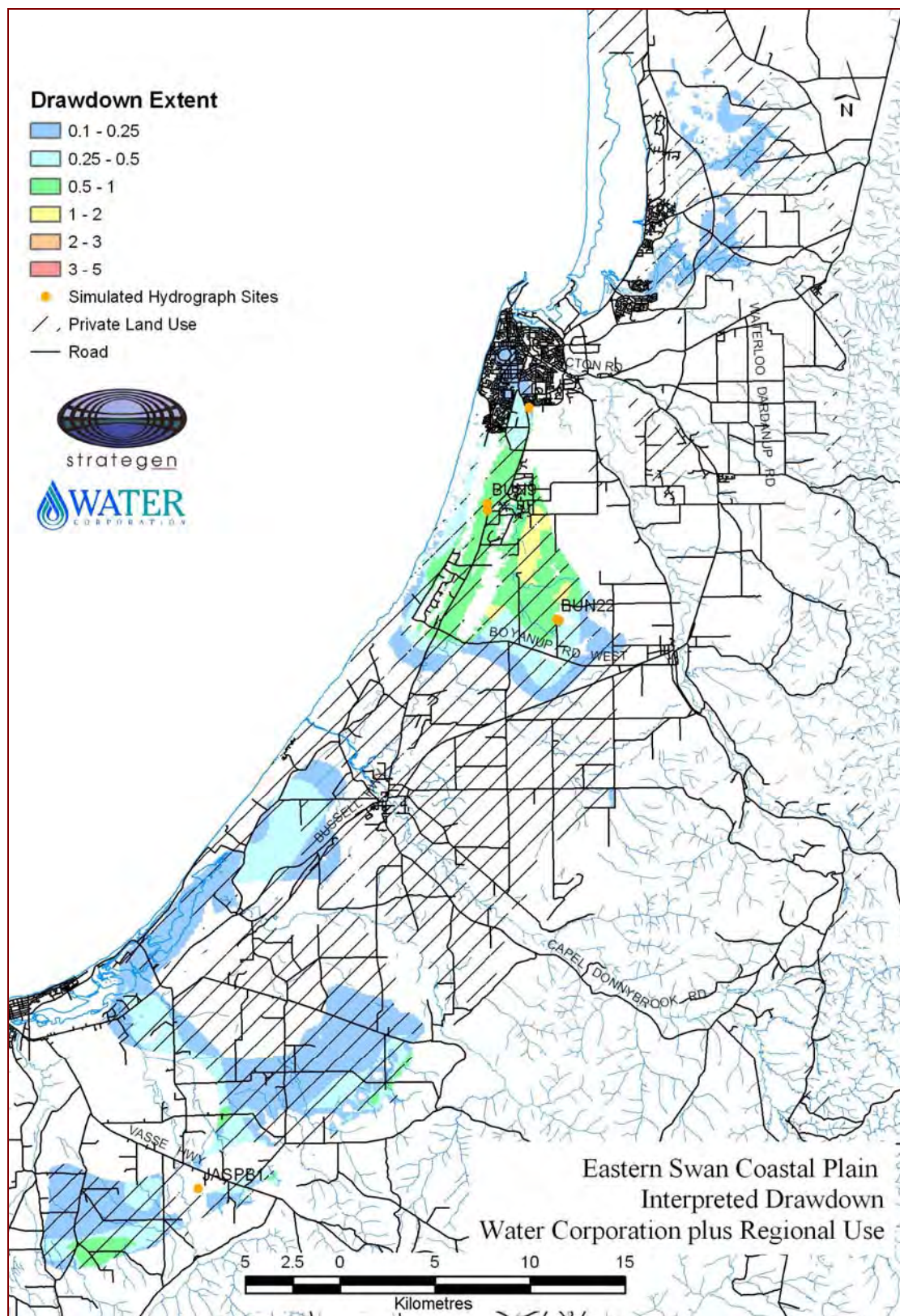
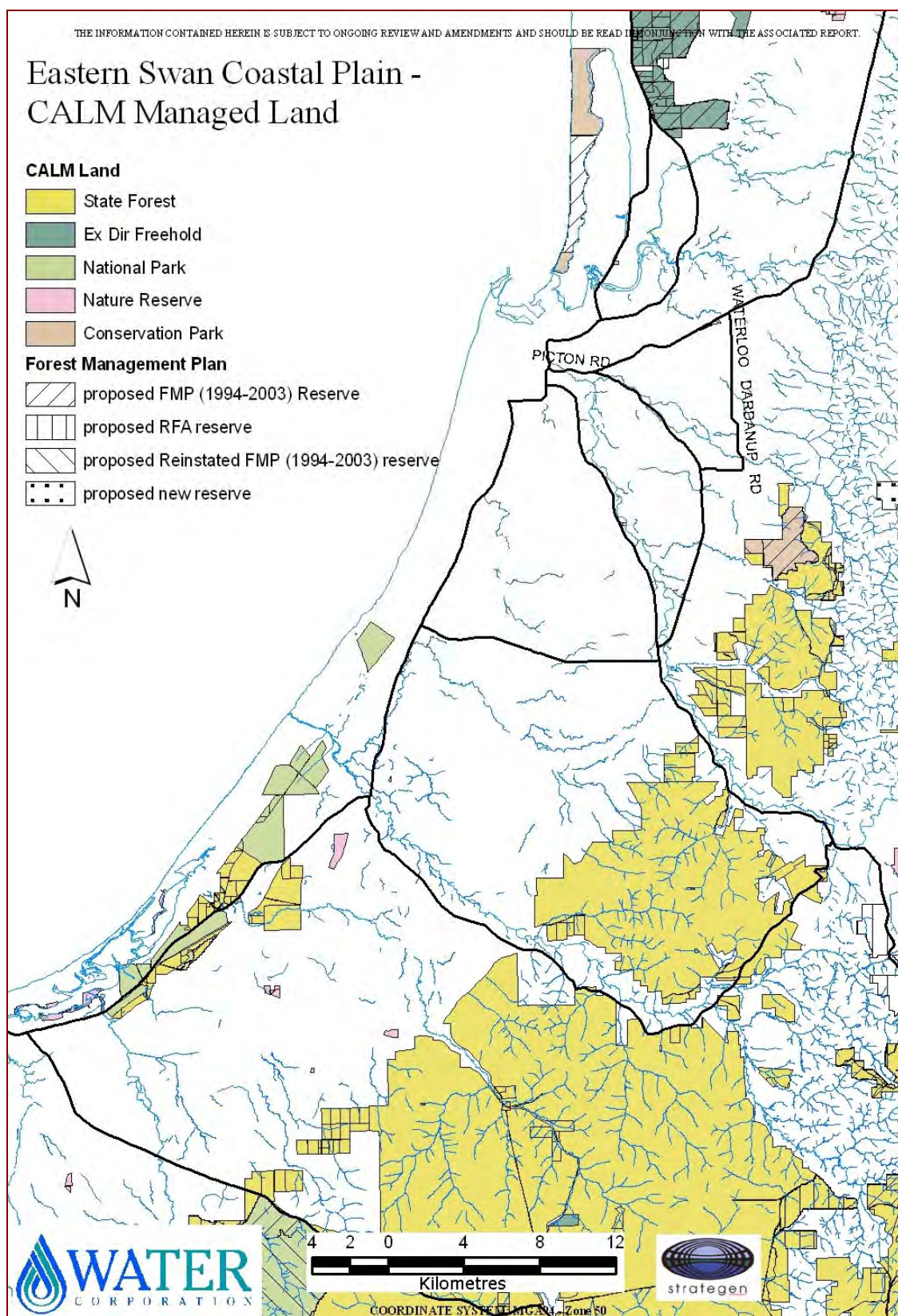


Figure 7.43 Conservation estate within the Swan Coastal Plain

In the Tutunup Ironstone communities, west of the Ludlow River, the drawdowns are considered an over-prediction due to the low vertical permeability of the surface sediments that was not adequately accounted for in the modelling. This is demonstrated by the 15 m head difference between the near surface Yarragadee layers and the deeper layers of the Yarragadee Formation (Chapter 5 Section 4.9.1).

7.3.2 Wetlands

Water levels in the Vasse–Wonnerup Wetlands are not expected to be affected by drawdowns from the proposal because their proximity to the ocean, within the highly permeable superficial formation, means that their water levels are controlled by sea level. The wetlands are situated on permeable sand and limestone sediments with good hydraulic connection between the superficial aquifer and the coast. Saline and brackish groundwater extends inland for a significant distance beneath the wetlands because of low hydraulic heads in the superficial aquifer.

The Swan Coastal Plain also contains extensive seasonal wetlands that are either perched, or only in contact with the watertable in winter. These will not be affected by a lowering of the summer watertable. Watertable levels are expected to recover fully each winter as previously rejected recharge refills the aquifer. The extra recharge required to refill the aquifer each year, to compensate for the cumulative drawdowns of the proposal and regional use, is around 13 mm of rainfall (assuming a specific yield of 0.2 for the Swan Coastal Plain soils). This equates to around 1% of rainfall, or around 4% of the currently rejected recharge of approximately 300 mm (Appendix 13). Therefore, the seasonal wetlands of the Swan Coastal Plain are not expected to be measurably affected, as surface water levels and areas of inundation will fully recover each winter.

7.3.3 Groundwater dependent vegetation

Vegetation potentially at risk – screening assessment using Froend & Loomes 2005

The area of vegetation on the Swan Coastal Plain that has the potential to be affected by groundwater drawdowns as a result of the proposal is 2770 ha. This comprises areas of remnant vegetation where the watertable is within 10 m of the surface. The drawdowns will occur gradually, at less than 0.10 m/yr, which minimises the risk to vegetation (Froend & Loomes 2004).

The predicted drawdowns just south of Bunbury, as a result of the proposal and estimated regional use after 30 years, will be up to 1 – 2 m and in the “high” potential impact category as defined by Froend & Loomes (2004). The proposal component of this drawdown alone would result in “low” potential impact, and would suggest there is likely to be “no measurable change” in ecological processes, or species composition and abundance (Table 6.3). Therefore, the proposal is not expected to have any significant impact on the vegetation of the Swan Coastal Plain.

Potential effect on vegetation complexes

A total of 2270 ha of remnant vegetation on the Swan Coastal Plain is within areas of potential drawdown from the proposal (Table 7.38). The proposal and future regional use is predicted to affect 3705 ha of remnant vegetation (Table 7.39). The vegetation complexes on the Swan Coastal Plain have been affected by clearing. Many are significant as there is less than 30% of their pre-European extent remaining, and less than 10% represented in conservation reserves. However, as the proposal is not expected to result in a measurable change in the vegetation of the Swan Coastal Plain, there will be no impact on the vegetation complexes in the area.

Table 7.38 Vegetation complexes in areas of potential drawdown from the proposal on the Swan Coastal Plain

	Abba (ha)	Bassendean Central & South (ha)	Cartis (ha)	Guildford (ha)	Karrakatta Central & South (ha)	Quindalup (ha)	Serpentine River (ha)	Southern River (ha)	Vasse (ha)	Yoongarillup (ha)	Ludlow (ha)	Yelverton Y & Yw (ha)	Total
Reserved %²	0.1	0.7	0	0.2	2.5	5.2	2.8	1.5	11.0	13.9		>1	
Remaining %	6.0	27	69.5	5.0	29.5	47.1	10.6	19.8	29.4	45		>12	
0 – 3 ¹	18	25	0	2	240	32	0	71	60	11	2	7	468
3 – 6 ¹	31	50	11	8	488	24	4	18	25	53	206	27	945
6 – 10 ¹	5	38	15	11	661	20	6	0	22	28	19	33	857
Grand Total	54	112	26	21	1389	76	10	90	107	92	227	66	2270

1. Depth to groundwater category

2. % from EPA (2003)

Table 7.39 Vegetation complexes in areas of potential drawdown from the proposal and estimated future regional use on the Swan Coastal Plain

	Abba (ha)	Bassandean Central & South (ha)	Cartis (ha)	Guildford (ha)	Karrakatta Central & South (ha)	Quindalup (ha)	Serpentine River (ha)	Southern River (ha)	Vasse (ha)	Yoongarillup (ha)	Ludlow (ha)	Yelverton (ha)	Total
Reserved %²	0.1	0.7	0	0.2	2.5	5.2	2.8	1.5	11.0	13.9		>1	
Remaining %	6.0	27	69.5	5.0	29.5	47.1	10.6	19.8	29.4	45		>12	
0 – 3 ¹	23	35	1	2	255	37	0	139	60	29	70	9	660
3 – 6 ¹	39	109	21	8	693	34	4	67	26	106	540	43	1689
6 – 10 ¹	10	128	17	11	846	31	6	69	22	45	116	55	1356
Grand Total	73	272	38	21	1794	103	10	274	108	180	726	106	3705

1. Depth to groundwater category

2. % from EPA (2003)

7.3.4 Threatened Ecological Communities

The predicted drawdowns from the proposal, and the cumulative drawdowns from estimated future regional use and the proposal, for each of the TEC locations on the Swan Coastal Plain (Figure 7.40) are shown in Table 7.40. The combined drawdowns are up to 0.5 m after 30 years (but mostly below 0.25 m) at 15 TEC sites, while the proposal alone would potentially affect seven sites with drawdowns of less than 0.25 m.

These drawdowns refer to summer minima and reflect a gradual decline in the summer watertable. The winter watertable is expected to fully recover each year through infiltration of some of the previously rejected recharge. Many of the TEC sites are on clay pans or ironstones that may have perched watertables. The sites with perched watertables will be isolated from any changes in the underlying aquifer and will not be affected. Even without fully perched watertables, heavy soils will partially buffer the effects of groundwater drawdown as they have high moisture storage capacity. The soil moisture store will also provide a water source for vegetation during summer.

Drawdowns of less than 0.25 m in an area with high seasonal watertable variations are unlikely to have a significant impact on vegetation. Drawdowns of this level fall within the “low potential impact – no measurable change” category as defined by Froend & Loomes (2004). As a consequence of the small drawdown and buffering effects of the soils, there is likely to be no measurable impact on TECs on the southern Swan Coastal Plain as a result of the proposal. The cumulative effects of the proposal and estimated future regional use increase the potential impact on TECs, but it is still low in most areas.

Table 7.40 Threatened Ecological Communities within predicted drawdown areas on the Swan Coastal Plain

TEC ¹	Location	Total predicted drawdown	Impact ² on TEC	Proposal only predicted drawdown	Impact ² on TEC
10b: Shrublands on southern Swan Coastal Plain Ironstones (Busselton area)	Five known areas on the Southern Swan Coastal Plain, east of Busselton	Six sites: 0.1 – 0.25 m One site: 0.25–0.5 m	Low	Two sites 0.1 – 0.25 m	Low
18: Shrublands on calcareous silts of the Swan Coastal Plain	Two known areas just south of Bunbury	0.25 – 0.5 m	High	0.1 – 0.25 m	Low
2: Southern wet shrublands, Swan Coastal Plain	One known area south-east of Busselton	0.1 – 0.25 m	Low	No drawdown	-
10a: Shrublands on dry clay flats of the southern Swan Coastal Plain	One site south-east of Busselton	0.1 – 0.25 m	Low	No drawdown	-
7: Herb rich saline shrublands in clay pans of the southern Swan Coastal Plain	One site south-east of Busselton	0.1 – 0.25 m	Low	No drawdown	-
8: Herb rich shrublands in clay pans of the southern Swan Coastal Plain	Three sites just south of Bunbury	0.25 – 0.5 m	High	0.1 – 0.25 m	Low

1. Code based on Gibson et al. 1994

2. based on Froend & Loomes (2004)

7.3.5 Terrestrial fauna

The shift of vegetation to a drier system in the areas of groundwater drawdown may have the following potential impacts on terrestrial fauna:

- reduction in the extent of dense undergrowth used by fauna (e.g. quenda on the Swan Coastal Plain) for protection and habitat in low-lying areas
- reduction in the abundance of particular flora species that are a source of food
- reduction in the overall productivity of the drier ecosystems may also affect the availability of food
- reduction in the extent of wetlands or the length of periods of inundation.

The Vasse–Wonnerup Wetlands and seasonal wetlands on the Swan Coastal Plain were identified by Bamford (Appendix 29) as important habitats where any change in hydrological regime would have a significant effect on fauna. As described in Section 0 of this Chapter, there will be no impact on these wetlands from the predicted groundwater drawdowns.

Drawdowns from the Water Corporation proposal on the Swan Coastal Plain are expected to be mostly less than 0.25 m after 30 years, and the impacts on fauna are expected to be slight (Appendix 29).

The predicted cumulative drawdowns of estimated future regional use and the proposal after 30 years are up to 1 – 2 m just south of Bunbury, and up to 0.5 m east of Busselton (Chapter 5 Section 4.9). This may have measurable impacts on vegetation, but as the changes will be gradual, and in an area adapted to high seasonal variations in watertable level, there is unlikely to be a significant impact on habitat values.

None of the fauna species of conservation significance expected on the Swan Coastal Plain are restricted to the area of drawdown impact, so any changes that do occur from the proposal are not expected to affect the occurrence or viability of any fauna species.

7.3.6 Acid sulphate soils

The potential impacts of acid sulphate soils on biodiversity and ecological integrity are:

- increased acidity can release previously inert toxic heavy metals into the environment
- precipitation of iron can smother wetland vegetation and microhabitats
- low pH causes a deficiency in plant base minerals such as calcium, magnesium and potassium, or a deficiency in plant nutrient availability
- an increase in attack by plant pathogens and a decrease in soil microbes, particularly those responsible for nitrogen fixation
- physiological damage to plants such as the stunting of roots; this can produce water stress, even in situations where the plant appears to have adequate water
- increased risk of erosion where plant growth has been affected.

On the Swan Coastal Plain, the areas of predicted drawdowns generally do not coincide with areas designated as being high risk for acid sulphate soils. There are some areas with a moderate risk of acid sulphate soils that coincide with predicted drawdowns of less than 0.25 m after 30 years pumping.

An exception is in an area approximately 10 km south of Bunbury, where drawdowns of up to 0.5 m may be experienced after 30 years. Given the expectation of full recovery of coastal plain watertable levels each winter, the effects of exposure of any existing acid sulphate soils are expected to be minimal and temporary (Chapter 5 Section 4.14).

7.3.7 Social impacts

The coastal environment and the Vasse–Wonnerup Wetlands will not be impacted by groundwater drawdowns. The proposal results in a low risk for vegetation in some areas of the Swan Coastal Plain so is not expected to affect community enjoyment or appreciation of the natural environment.

7.3.8 Compliance with EPA Offsets Statement

The EPA Offsets Position Statement is discussed in Chapter 2 Section 6.1. The following table details the potential impacts of the proposal on critical assets on the Swan Coastal Plain.

Table 7.41 Compliance with EPA Offsets Position Statement on the Swan Coastal Plain

Critical assets	Prognosis
Declared Rare Flora	There are potentially 21 DRF species that occur on the Swan Coastal Plain. No significant impact on these species is expected.
Priority Flora	There are potentially 130 Priority species that occur on the Swan Coastal Plain. No significant impact on these species is expected.
Threatened Ecological Communities	There are three TECs that occur within the areas of potential drawdown from the proposal. One of the TECs, the “Shrublands on southern Swan Coastal Plain Ironstones”, is listed as Endangered under the Federal EPBC Act. The proposal is expected to cause less than 0.25 m drawdown in these areas after 30 years. This is not expected to have a measurable or significant impact on the TECs.
Vegetation complexes with less than 30% remaining	The vegetation complexes that occur on the Swan Coastal Plain have been largely cleared and many are significant as they have less than 30% of their pre-European extent remaining and/or they have less than 10% represented in conservation reserves (Table 7.38). However, as the proposal is not expected to result in a measurable change in the vegetation of the Swan Coastal Plain, there will be no impact on the vegetation complexes that occur in the area.
Threatened Fauna	There are one frog, two reptiles, 25 – 26 birds (of which 17 are migratory) and eight mammal species of conservation significance expected to occur on the Swan Coastal Plain. Of these, one frog, 15 migratory birds, 4 non-migratory birds and one mammal species are likely to be highly groundwater dependent. No significant impact is expected on the aquatic or terrestrial faunal habitats on the Swan Coastal Plain.
Public conservation reserve system	The Vasse–Wonnerup Wetland system is partially within a Conservation Park and the Tuart Forest National Park lies south of Bunbury. The aesthetic, recreational and ecological values of these reserves are not expected to be significantly affected.
Conservation category wetland	The Vasse–Wonnerup wetland system is outside of the area of potential groundwater drawdown.
Ecosystems under threat	None present
Indigenous heritage sites	None present
Identified heritage places under EPBC Act	None present

7.3.9 Mitigation

Modelling of several different wellfield configurations (well locations and units to be drawn from in the Yarragadee Formation) was conducted to determine the configuration that would minimise the effect on other water users, and environmental impact on potential sensitive areas in the region (Chapter 5 Section 4.1). The “Eastern Split” wellfield configuration was selected and found to have the least overall environmental impact, but is expected to have a slightly greater drawdown on the Swan Coastal Plain than other options⁴⁸.

Estimated future regional use is predicted to cause the major proportion of drawdown impact on the Swan Coastal Plain.

Mitigation of anticipated potential impacts from the proposal on the Swan Coastal Plain environment will involve the application of an adaptive management approach (Section 7.4 of this Chapter) which will include application of a combination of the following offsets:

1. Undertake a South West Yarragadee Sustainability Initiative (Volume 1 Chapter 7 Section 4.1.1) that includes:
 - research into the magnitude and possible means of management of irrigation return water
 - investigations into the effects of changing land use on water demand, availability and quality
 - investigation of the ecological values of the Swan Coastal Plain as part of a major regional biodiversity study, including the potential effects of threatening processes
 - support for investigations into the potential for acidification from acid sulphate soils, and potential means of management.
2. The Water Corporation proposes to sponsor a program to manage threatening processes (feral animals, weeds, unrestricted public access) in the areas that may be affected by the proposal the Swan Coastal Plain.

Mitigation benefits

There are significant threats to the ecosystems of the Swan Coastal Plain, including feral animals, weed encroachment, fragmentation, and extensive clearing. The remaining vegetation is generally of high conservation significance although much is degraded. Research is essential to further the understanding of the ecosystem and to allow informed decision making on management of threatening processes. The proposed biodiversity study in the region will both add resources to research in the region and increase the effectiveness of funds already being spent by consolidating existing knowledge.

Feral animal control projects (e.g. Western Shield) have proved to be effective in increasing the numbers of rare native mammals. However, these programs require ongoing funding to remain effective. The Water Corporation proposal to provide resources for the management of feral animals will have a direct biodiversity benefit.

⁴⁸ The comparison of the wellfield configurations and the decision making process are detailed in Volume 2 Chapter 2, Section 1.

7.4 MONITORING, ADAPTIVE MANAGEMENT AND ACCOUNTABILITY

The Water Corporation will develop and implement an extensive biological, hydrological and physical monitoring program for the region, including the Swan Coastal Plain. The Water Corporation is also committed to implementing the South West Yarragadee Sustainability Initiative that includes a comprehensive biodiversity study which will include the Swan Coastal Plain and investigate the relationship between ecosystems and groundwater.

The outputs of the monitoring program and the proposed biodiversity study, together with advice from the Monitoring Review Group will form the basis of the adaptive management framework for the Swan Coastal Plain and other areas of potential impact.

The monitoring program will include a baseline study using the same parameters as shown in Table 7.42 but with more intense sampling regimes. The baseline study will be completed before the operational phase of the project and will allow both hydrological and ecological changes and trends to be assessed. The monitoring program and biodiversity study will be developed in consultation with the Monitoring Review Group (Volume 1 Chapter 8 Section 3.2.3). A preliminary outline of a monitoring program has been developed (Table 7.42).

The Water Corporation will prepare an annual Sustainability Report that will report on the monitoring results. The Monitoring Review Group will review the monitoring results against a set of defined principles and recommend whether any changes need to be made to the management of the project.

Table 7.42 Proposed Swan Coastal Plain monitoring program

Field	Parameter	Methods
Hydrology	Surface water levels	Measure water levels in the Vasse Wonnerup Wetlands (monthly)
	Groundwater levels	Monitor watertable levels and levels in the underlying Yarragadee Formation monthly for the first few years (at least two) of the project and then every two months
	Groundwater quality	Monitor electrical conductivity and chloride in all wells annually (June)
Physical	Acid sulphate soils	Soil and shallow watertable sampling (monthly)
Biological (TECs)	Tree health	Establish permanent transects with tagged trees in TECs
	Species composition	Establish permanent quadrats for monitoring of species diversity and abundance in TECs
	Vegetation condition	Monitor vegetation condition according to the Keighery rating scale in TECs (annual)
	Terrestrial fauna	Conduct terrestrial fauna surveys near the Vasse–Wonnerup Wetlands (annual)

7.5 PROPONENT COMMITMENTS

The Water Corporation is committed to an adaptive management approach and to the following:

1. Undertake a biodiversity and acid sulphate soils study (as part of the Sustainability Initiative) in areas potentially affected by groundwater drawdown resulting from the proposal. The studies will be funded up to the value of \$1.5M, with the capital and any earned interest made available to the studies over a period of ten years.

2. Undertake a South West Yarragadee Sustainability Initiative that includes:
 - the biodiversity and acid sulphate soils studies above
 - sponsor a research program up to the value of \$0.5M on the magnitude and potential means of management of irrigation return water and the effects of changing land use on water demand, availability and quality.
3. Prepare, and report on the implementation of, abstraction management plans and associated monitoring programs for the groundwater abstraction in accordance with any licence issued pursuant to the RWI Act and the Groundwater Abstraction Management Plan described in Chapter 9 Section 8.
4. The Water Corporation will contribute to a 5 year program to assist the management of threatening processes in areas that may be affected by the proposal. The funding will be up to \$1M with the capital and any earned interest made available to the management program over a period of five years. The program will address weeds, disease, feral animals, erosion and uncontrolled public access issues insofar as they exist within the potentially affected areas including the Swan Coastal Plain.

7.6 ENVIRONMENTAL OUTCOME

The areas of predicted drawdown from the proposal alone after 30 years are mostly expected to result in “no measurable change”, with small areas south of Bunbury in the “moderate – small change” category of potential impact on vegetation. As the drawdowns will recover fully each winter, the proposal will have no significant impact on the vegetation of the Swan Coastal Plain.

The predicted drawdowns on the Swan Coastal Plain from the proposal alone are all less than 0.5 m after 30 years, and less than 0.25 m in the area east of Busselton. The total predicted drawdowns, from estimated future regional use and the proposal, on the Swan Coastal Plain after 30 years are more widespread. Total drawdowns are predicted to be mostly less than 1 m with small areas of drawdown in the 1–2 m range.

On the Swan Coastal Plain, the areas of predicted drawdowns generally do not coincide with areas designated as being high risk for acid sulphate soils. There are some areas with a moderate risk of acid sulphate soils that coincide with predicted drawdowns of less than 0.25 m after 30 years pumping. Given the expectation of full recovery of coastal plain watertable levels each winter, the effects of exposure of any existing acid sulphate soils are expected to be minimal and temporary.

There are three TECs in areas of potential drawdown from the proposal. The predicted drawdown at all sites is less than 0.25 m after 30 years and there is not expected to be a measurable or significant impact at any of these sites. Six TECs are in areas of potential drawdown from the cumulative effects of the proposal and estimated future regional use. The predicted drawdowns at all these sites are less than 0.5 m, and most sites fall in the “low – no measurable change” category. Two sites fall in the “high” category with some “measurable change” possible (Appendix 30). As the watertable levels and soil moisture will recover fully each winter, the cumulative impacts on TECs are not expected to be significant.

No impact from groundwater abstraction is expected on the Vasse–Wonnerup Wetland system as the water levels are connected to and controlled by the ocean. The proposal will result in no significant impact on the seasonal wetlands of the Swan Coastal Plain as surface water levels will recover fully each winter.

Proposed mitigation commitments to reduce threatening processes within the area will help protect and restore ecological values currently affected or under threat, and enhance biodiversity in the area. The knowledge and data obtained from the proposed South West Yarragadee Sustainability Initiative, the proposed biodiversity study, and the comprehensive monitoring program will improve the understanding of the area and provide for adaptive management to ensure the area is cautiously managed into the future, particularly in the context of climate change.

Chapter 8 Environmental Review of Proposal Infrastructure

1 BACKGROUND

The infrastructure will be designed to deliver a constant flow of water to the IWSS as a base load source, operated continually except during maintenance periods. Other sources will supply peak demands to the IWSS as required.

The development footprint for this proposal includes the wellfield, treatment plant, storage tank, and the pipeline to join with the Stirling Trunk Main at Harvey.

1.1 ENVIRONMENTAL OBJECTIVE FOR INFRASTRUCTURE FOOTPRINT

The impact of this infrastructure on the *Biodiversity and ecological integrity* sustainability principle is examined in relation to the environmental *Development footprint* factor with the objective:

The construction of the proposal will cause minimal permanent disturbance.

1.2 PLANNING AND CONSTRAINTS STUDY

The first step in the EPA preferred mitigation sequence is avoidance. The following environmental values were considered as constraints for proposed infrastructure and were avoided wherever possible:

- clearing of native vegetation – the pipeline and treatment plant could not be constructed through a significant area of remnant vegetation unless no viable alternative existed
- wetlands – infrastructure could not be constructed within 50 m of Environmental Protection Policy lakes,⁴⁹ or wetlands categorised for conservation or resource enhancement unless no viable alternative existed
- Threatened Ecological Communities and Declared Rare Flora – infrastructure to avoid areas supporting Threatened Ecological Communities or Declared Rare Flora
- Aboriginal heritage sites – to be avoided wherever possible.

Further to the absolute requirements to avoid the above areas, preference was given to pipeline routes based on the following environmental and social considerations:

- preferential use of cleared corridors with the widest current clearing and highest use
- minimise the loss of remnant vegetation
- maintain a buffer distance of at least 50 m (absolute constraint), and preferably greater than 200 m between the pipeline and significant wetlands

⁴⁹ Wetlands that are gazetted under the Environmental Protection (Swan Coastal Plain lakes) Policy 1992

- minimise impacts on wetlands and waterways
- minimise disturbance or removal of any structures or plantings that are considered to have value to the local community
- avoid where possible or minimise disturbance of any European heritage sites
- avoid where possible or minimise disturbance of any archaeological and ethnographic heritage sites
- minimise long-term disturbance to land uses through which the pipeline runs
- minimise the nuisance to residents that may be associated with construction activities such as noise, dust and vibrations from machinery
- minimise the chances of encountering areas of high risk of acid sulphate soils
- avoid spreading dieback through construction of the infrastructure.

After consideration and avoidance where possible of the above, the general pipeline route will have the following potential impacts:

- clearing of 50 ha of vegetation (as detailed in Section 2 of this Chapter)
- effects of clearing on local terrestrial flora and fauna
- impacts on riparian vegetation, flora and habitat at five river crossings
- risk of encountering acid sulphate soils at locations along the route of the excavation trench.

1.3 INFRASTRUCTURE DESCRIPTION

1.3.1 Pipeline

The pipeline route passes through the Blackwood Plateau and Swan Coastal Plain. The pipeline will run from an elevation of 175 mAHD on the plateau down to 20 mAHD on the Swan Coastal Plain. The Blackwood Plateau is undulating to hilly and deeply incised, with defined ephemeral watercourses that intersect the pipeline route. The Swan Coastal Plain is an area of low relief formed on Quaternary dune-sand deposits, and clayey alluvial deposits of the Guildford Formation. The area is naturally poorly drained and much of the plain has been cleared and drained for agriculture.

The pipeline will be approximately 105 km long. It will be constructed of 1400 mm diameter steel pipeline and buried to a depth of approximately 750 mm for almost its entire length, including river crossings where possible. One exception is at the crossing of the Harvey Diversion Drain at Eckersley Road, west-southwest of the Harvey townsite, which will be an elevated crossing.

The alignment of the pipeline is shown in Volume 1, Figures 1.7, 1.10 and 1.11.

Vegetation

The vegetation complexes along the pipeline route consist mostly of open woodlands dominated by jarrah, marri and wandoo.

Rare and Priority Flora

The proposed pipeline route crosses road and rail reserves along the Swan Coastal Plain, many of which support Rare or Priority Flora which is generally in poor condition. There is potential to encounter Rare and Priority Flora elsewhere along the pipeline route.

Threatened Ecological Communities

Mattiske (2004) identified the TEC community (SCP3a) “*Eucalyptus calophylla* – *Kingia australis* woodlands on heavy soils, Swan Coastal Plain” as present within the vicinity of the proposed pipeline. These patches of the SCP3a community are highly degraded.

Threatened Fauna

A desktop study of threatened fauna that may be found in the area was carried out by GHD (2003b) and Mattiske (2004) and included a search on the CALM rare fauna database. Species gazetted under the Wildlife Act and/or the EPBC Act that may occur along the route include the chuditch, western ringtail possum, quokka and Baudin’s black-cockatoo in the forests of the Blackwood Plateau, and Carnaby’s black-cockatoo and carpet snakes on the Swan Coastal Plain.

Wetlands and rivers

The proposed pipeline route avoids conservation wetlands and resource enhancement wetlands according to the environmental constraints defined above (Section 1.2). The proposed route extends through a considerable length of multi-use wetlands on farmland on the Swan Coastal Plain. The majority of the wetlands that may be affected are seasonally waterlogged palusplain wetlands, most of which are either highly degraded or substantially cleared. All wetlands of conservation significance have been avoided.

The pipeline route crosses five rivers: the Capel, Ferguson, Preston, Collie and Brunswick Rivers. The Preston River riparian zone is a conservation category wetland. All river crossing locations have been selected to have the lowest possible impact, and will require approval by the Department of Water. The vegetation along the rivers is often of poor quality, mostly due to grazing, clearing and weed invasion (GHD 2003a).

1.3.2 Wellfield

The preferred wellfield location and configuration was decided at the end of the Water Corporation internal sustainability evaluation process. No specific flora and fauna studies have as yet been carried out at the sites as the location and configuration of the wellfield is significantly different to the original proposal. Surveys will be carried out prior to construction and sites adjusted if Rare or Priority Flora or Fauna are found to be present.

1.3.3 Treatment plant & storage tank

The treatment plant will occupy approximately 42 ha of an area vested in the Conservation Commission and currently planted with pine trees. The storage tank site will require clearing of approximately 5 ha near the treatment plant within native vegetation. The layout of the areas required for the treatment plant and storage tank is presented in Volume 1, Figures 1.8 and 1.9. The hydraulic performance of the treatment plant and storage tank will be further investigated to optimise the location such that native vegetation clearance could possibly be reduced.

2 TERRESTRIAL FLORA AND FAUNA

2.1 SETTING

2.1.1 Pipeline

The proposed pipeline route extends south from the forested areas near Jarraewood through the Blackwood Plateau, and then on to the Swan Coastal Plain where it will run through mainly cleared agricultural lands to the connection with the existing Stirling Trunk Main.

Within the Blackwood Plateau region, the pipeline route will use existing cleared and gazetted roads throughout the forested areas, with clearing limited to widening of the existing corridors by up to 20 m to enable the construction of the pipelines.

The pipeline route on the Swan Coastal Plain is mainly in private cleared land and will minimise further clearing of remnant vegetation.

Wellfield

The wellfield is located on the Blackwood Plateau and the proposed well sites are, wherever possible, on private cleared land, or existing cleared areas such as gravel pits.

Treatment plant & storage tank

The treatment plant has been located on Goodwood Road to provide an elevated location for the storage tank site which will ensure the hydraulic performance of the structure. The treatment plant site is within an existing pine plantation. The tank site requires clearing of approximately 5 ha of remnant native vegetation.

2.2 ASSESSMENT FRAMEWORK AND POLICY CONTEXT

Priority Flora

CALM defines Priority Flora as follows:

Priority 1 taxa are defined as taxa which are known from one or a few (generally less than 5) populations which are under threat, either due to small population size, or being on lands under immediate threat.

Priority 2 taxa are defined as taxa which are known from one or a few (generally 5) populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered).

Priority 3 taxa are defined as being Poorly Known Taxa – taxa which are known from several populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered).

Priority 4 taxa are defined as being taxa which are considered to have been adequately surveyed and which, whilst being rare (in Australia), are not currently threatened by any identifiable factors.

The assessment of the significance of impacts on Declared Rare and Priority Flora was based on the following:

- change in the distribution and abundance of Declared Rare and Priority Flora species genotypes;
- compliance with the *Wildlife Conservation Act 1950*.

Fauna

In this assessment fauna species were considered rare or vulnerable if they are protected species under State or Federal legislation, the subject of international agreements, or are on the CALM Priority Fauna List.

2.3 POTENTIAL IMPACTS AND MITIGATION

2.3.1 Clearing for pipeline

Vegetation

The proposed pipeline route has been designed to minimise impacts on remnant native vegetation and is mostly within agricultural areas or along existing infrastructure corridors. Some clearing will be required to widen the existing cleared routes. The clear width necessary for the pipeline construction is 20 m, but 10 – 12 m clearing will be sufficient alongside the existing clearing provided by the roads. The total clearing requirements for the route are less than 50 ha as detailed in Table 8.1 and Table 8.2.

The vegetation of the Blackwood Plateau is largely uncleared and most is managed by CALM as State forest. Most of the clearing will be along Goodwood Road where an additional 12 m width is required to allow construction of the pipeline. An additional 10 m width is required along Vasse Highway and 10 m on the Capel–Donnybrook Road. The majority of the vegetation to be cleared is within the Kingia and Bidella vegetation complexes, both of which have more than 90% of their pre-European extent remaining.

The vegetation of the Swan Coastal Plain has been largely cleared and drained for agriculture. Only 14% of the southern Swan Coastal Plain remains uncleared. Less than 4 ha of vegetation, mostly in poor condition, will need to be cleared for the pipeline (Table 8.2), mostly in the Abba, Guildford or Cannington Complexes. Small areas will need to be cleared for crossings in road and rail reserves that are mostly narrow and in poor condition after a long history of disturbance and weed invasion. Several of the affected vegetation complexes on the Swan Coastal Plain complexes have less than 10% of their original extent remaining, making all remnants significant. However, the clearing proposed will affect a maximum of 0.06% of the remaining vegetation of any complex. This is considered to be insignificant, as the clearing will only be required adjacent to existing cleared areas.

Rehabilitation of vegetation along the pipeline route will be undertaken, where possible, although space for access to the pipeline will need to be maintained. Rehabilitation of landforms and revegetation will be essential to reduce the risk of wind and water erosion along the pipeline.

Although the environmental impact of clearing is not expected to be significant, the Water Corporation proposes to contribute land to the conservation estate to offset the clearing in State forest. The land contributions will be carried out in liaison with CALM and the Conservation Commission using a loss/gain ratio of 1:1.5 and the principle of “like for like or better”.

Table 8.1 Vegetation to be cleared on the Blackwood Plateau along the proposed pipeline route

Vegetation complex	Clearing area (ha)	% remaining of pre-European extent	% remaining disturbed by proposal
Bidella	10.0	93	0.02
Blackwood	3.2	93	0.02
Darradup	0.5	65	0.02
Jalbarragup	3.2	90	0.02
Kingia	16.1	97	0.02
Preston	0.1	48	0.002
Rosa	6.6	74	0.05
Telerah	3.9	92	0.02
Whicher Scarp	0.3		
Yelverton	0.9	35	0.15
Total	44.8		

Table 8.2 Vegetation to be cleared on the Swan Coastal Plain along the proposed pipeline route

Vegetation complex	Clearing area (ha)	% remaining of pre-European extent	% remaining disturbed by proposal
Guildford	1.23	5	0.03
Abba	0.88	6	0.03
Cannington	1.03	10	0.06
Serpentine River	0.13	11	0.01
Swan	0.33	16	0.01
Dardanup	0.15	8	0.02
Southern River	0.10	20	0.00
Bassendean – Central and South	0.00	27	0.00
Swan Coastal Plain – Total	3.83	14	0.01

Rare and Priority Flora

In most cases where Declared Rare or Priority Flora are present in the vicinity, the pipeline route will be modified, in consultation with CALM, to avoid direct impacts. Habitat trees will also be avoided wherever possible along the pipeline route.

A detailed survey of flora in all areas to be cleared will be carried out prior to clearing. All Declared Rare and Priority plants will be avoided if possible, and relocated if avoidance is not feasible.

Threatened Ecological Communities

The proposed pipeline route does not pass through any known Threatened Ecological Communities (TECs). Should the flora survey identify any TECs along the pipeline route, the route will be modified to avoid disturbing them.

Threatened Fauna

Riparian habitats are especially important to vertebrate fauna because of their structural complexity and relative density. These areas often support large numbers of birds and provide habitat to a number of rare, threatened or vulnerable species. The potential impacts on fauna along the proposed pipeline routes has already been minimised by choosing the routes where least clearing is required and avoiding, where possible, riparian habitats that are important to fauna.

Wetlands and rivers

The pipeline route has been aligned to avoid wetlands of conservation significance.

The pipeline route crosses the Capel, Ferguson, Preston, Collie and Brunswick Rivers. The pipeline may need to be installed under or over the rivers, depending on the outcome of Aboriginal heritage surveys to be carried out by the Water Corporation. This would also avoid the disturbance of riparian vegetation. Any rivers not registered as heritage sites will be crossed using open cut techniques to install the pipeline below the watercourse.

Rehabilitation of the riparian zone will be undertaken, as will bank stabilisation and revegetation of other disturbed areas.

If the pre-construction vegetation and flora survey identifies vegetation in good condition at a proposed crossing, other options, such as relocation to a degraded area, will be considered.

2.3.2 Clearing for wellfield

The wellfield will be located in State forest near Jarrahwod straddling the boundary of the Nannup and Busselton Shires. There will be ten wells installed at five sites. An additional three sites have been identified as contingency sites as part of the adaptive management process.

Construction of a well requires a clearing of 80 x 40 m. The area required for maintenance is only 20 x 20 m, so the unused area will be rehabilitated following construction. The total cleared area that will remain after rehabilitation is two hectares for the five well sites. No clearing will be required along access routes as existing roads or logging tracks will be used. The clearing associated with the collector mains has been described in the previous section.

A detailed survey of the flora of all areas to be cleared will be carried out prior to clearing. If necessary, the position of wells will be changed to avoid disturbance of any Declared Rare and Priority flora that may be identified.

2.3.3 Clearing for treatment plant & storage tank

The treatment plant will require the clearing of 20 ha of pine plantation in State forest. The storage tank site will require clearing of approximately 5 ha, and is near the treatment plant within native vegetation. A detailed survey of the flora of all areas to be cleared will be carried out prior to clearing. All Declared Rare and Priority plants will be avoided if possible, and relocated if avoidance is not feasible.

2.3.4 Forest disease

The dieback fungus, *Phytophthora cinnamomi* has been recorded extensively over the Blackwood Plateau (GHD 2003a). However, it is very difficult to determine the presence or absence of dieback disease for much of the vegetation on the Swan Coastal Plain as it is highly degraded and sometimes lacks suitable indicator species. A Forest Disease Management Plan approved by CALM will be applied in forested areas during construction and operation to minimise the risk of spread of jarrah dieback disease. Construction will largely be carried out during summer, which will reduce the potential for spread of dieback.

2.4 PROPONENT COMMITMENTS

The proponent will

1. The Water Corporation will not, unless otherwise approved by the Minister for the Environment on advice of the Environmental Protection Authority, construct the proposed infrastructure so as to cause or contribute to the direct or indirect disturbance of the following:
 - TECs (including candidate TECs)
 - Declared Rare Flora unless the disturbance is approved under the Wildlife Conservation Act 1950
 - significant habitat for Threatened or Priority listed fauna.
2. The Water Corporation will ensure that the proposal construction activities do not cause or contribute to the following:
 - acidification of land or surface water through the exposure of acid sulphate soils to the extent that it adversely affects native vegetation or streams
 - an increase in severity status of weeds or pests in State forest
 - the spread of dieback disease to previously unaffected areas
 - placing any species or ecological community into a higher category of threat.
3. Undertake the following surveys along the pipeline route:
 - a soil sampling program to further define the risk of exposure of acid sulphate soils
 - a detailed flora and fauna habitat survey to identify species and communities of conservation significance.

2.5 ENVIRONMENTAL OUTCOME

The proposal involves the clearing of less than 50 ha of native vegetation for the pipeline, wellfield, treatment plant and storage tank. This will not result in the reduction of any vegetation complex below 30% of its pre-European extent. Some clearing of mostly degraded remnant vegetation will be required on the Swan Coastal Plain along roadsides in vegetation complexes that have less than 10% of their pre-European extent remaining. The total clearing on the Swan Coastal Plain will be less than 4 ha and will reduce the remaining area of these vegetation complexes by a maximum of 0.06%.

There are no known Threatened Ecological Communities along the proposed pipeline route. Clearing of Declared Rare and Priority Flora will be avoided where possible, and individual plants will be relocated if modification of the pipeline route is not feasible. Therefore, no significant impacts are expected on significant species.

No significant impact on fauna is expected due to the limited clearing requirements, which will be restricted to areas that have already been disturbed.

3 WETLANDS AND RIVERS

3.1 SETTING

Most of the wetlands that may be affected by infrastructure are palusplain wetlands on farmland of the Swan Coastal Plain. Palusplain wetlands are seasonally waterlogged areas and those along the pipeline route are mostly highly degraded and many have been cleared. The pipeline route extends through some wetlands classified as multiple use wetlands. All wetlands of conservation significance have been avoided by the proposed route with the exception of the Preston River.

The pipeline route crosses five rivers: the Capel, Ferguson, Preston, Collie and Brunswick Rivers. The Preston River riparian zone is a conservation category wetland. Much of the vegetation along the other rivers is of poor quality, due mostly to grazing, clearing and weed invasion. An assessment will be made of the best possible method and location for all crossings and all will require approval by the Department of Water.

3.2 ASSESSMENT FRAMEWORK AND POLICY CONTEXT

The main legislation applicable to infrastructure impacts on wetlands and river is the *Rights in Water and Irrigation Act 1914* (RWI Act)

3.3 POTENTIAL IMPACTS AND MITIGATION

The pipeline route has been aligned to avoid wetlands of conservation significance. The only exception to this is the Preston River.

The pipeline route crosses the Capel, Ferguson, Preston, Collie and Brunswick Rivers. The pipeline may be installed under or over the rivers without disturbance, depending on the outcome of the Aboriginal heritage surveys to be carried out by the Water Corporation. This may also avoid the disturbance of riparian vegetation. Any rivers and streams not registered as heritage sites will be crossed using open cut techniques to install the pipeline below the watercourse.

Rehabilitation of the riparian zone will be undertaken, as will bank stabilisation and revegetation of other disturbed areas.

If the pre-construction vegetation and flora survey identifies vegetation in good condition at a proposed crossing, other options, such as relocation to a degraded area, will be explored in consultation with the DoW.

Detailed geotechnical, flora, fauna and heritage surveys will be undertaken at each proposed crossing. This information will be required to obtain DoW approval for the proposed works.

3.4 PROPONENT COMMITMENTS

The Water Corporation commits to:

1. Seek approval for the water pipeline crossings of all streams from the Department of Water pursuant to the RWI Act.

3.5 ENVIRONMENTAL OUTCOME

No long-term disturbance of watercourses or riparian vegetation is expected from the construction of infrastructure.

4 NOISE AND VIBRATION

4.1 SETTING

Pipeline

Most of the pipeline route will be located at a distance from residences. Near residences, the pipeline will generally be along roads with existing traffic noise. The pipeline will be buried and blasting to dig the trench may be required along some sections.

Wellfield

The proposed wellfield is located 0.3 km from the nearest residence.

Treatment plant

The proposed treatment plant is located more than 3.5 km from the nearest residence.

4.2 ASSESSMENT FRAMEWORK AND POLICY CONTEXT

4.2.1 Construction noise

The following regulations are from the Environmental Protection (Noise) Regulations 1987.

Construction may be carried out between 0700 and 1900 hours on any day except Sunday and public holidays provided:

- the construction work is carried out in accordance with Section 6 of the Australian Standard 2436–1981 “Guide to Noise Control on Construction, Maintenance and Demolition Sites”
- the equipment used is the quietest reasonably available
- a noise management plan is submitted at the request of the Chief Executive Officer of the DoE.

Construction may occur outside these hours or on Sundays or public holidays provided the above conditions are met and:

- all nearby residents are advised of the work to be done at least 24 hours before it commences
- the proponent demonstrates that it is reasonably necessary for the work to be done out of hours
- the proponent submits to the Chief Executive Officer of the DoE or the relevant Shire, for approval, a noise management plan at least seven days before the work starts. The noise management plan would be required to include details of the need for the work, type of work, predicted noise levels, control measures, noise and vibration monitoring and complaint response procedures
- the work is carried out in accordance with an approved noise management plan.

Blast noise overpressure and vibration

Blasting produces two related components:

- air-blast over-pressure, which is the part of the blast that is heard and which can rattle windows and fittings in man-made structures
- ground vibration, which is less likely to be sensed by humans, particularly at locations that are remote from the blast itself.

Whilst air-blast noise may appear to be destructive, it does not cause structural damage; however, ground vibration has the potential to cause permanent damage.

Air-blast over-pressure

Air-blast levels prescribed by the Environmental Protection (Noise) Regulations 1997 are shown in Table 8.3.

Table 8.3 Air blast criteria

Day	Time	Maximum level ^(a)	Level	Compliance frequency
Days other than Sundays and public holidays	7am – 6pm	125 Db L _{linear, peak}	120 Db L _{linear, peak}	For nine in any 10 consecutive blasts, regardless of the interval between blasts
Sundays and public holidays	7am – 6pm	120 Db L _{linear, peak}	115 Db L _{linear, peak}	For nine in any 10 consecutive blasts, regardless of the interval between blasts
All other times	6pm – 7am	90 Db L _{linear, peak}	-	-

^(a)Applies to all blasts.

Ground vibration

There are no statutory standards for vibration in Western Australia. Blast vibration criteria for structures are, however, set by Australian Standard AS 2187.2 (1993) Part 2. Table 8.4 shows the potential structural damage for different levels of peak particle velocity and, in particular, the level of ground vibration that will damage a typical residential structure.

Table 8.4 Potential for damage to structures from ground vibration of structures

Peak particle velocity (mm/sec)	Level of damage	Structure
<5	No damage	
5 – 10	Damage unlikely	
10 – 20	Potential minor damage (plaster cracks)	Houses and low rise residential structures may be damaged above 10 mm/sec
20 – 30	Minor damage (plaster cracks)	Commercial and industrial structures may be damaged above 25 mm/sec
30 – 50	Minor structural damage (concrete cracks)	
>50	Potential major damage	

The peak particle velocities where blasting is carried out are specified in conditions placed on licensed premises under the EP Act. The criteria used in licence conditions normally specify a peak particle velocity of 5 mm/s for nine in any ten consecutive blasts and 10 mm/s for any blast where blasting is carried out during the day. These criteria will be used in the Noise and Vibration Management Plan within the Construction Environmental Management System (CEMS) (Chapter 9 Section 1.2) for blasts that take place within one kilometre of residences.

Transport Noise

The assessment of traffic noise impacts was based on the criteria described in “EPA Policies for EIA No. 14 – Road and Rail Transportation Noise (Draft Version 3)”.

The criteria described in the Guidance Note⁵⁰ for a proposed increase in road traffic requires that a maximum pass-by noise level for any vehicle ($L_{A\text{design}}$) is set. This maximum is based on existing traffic (number and noise levels from existing heavy vehicle traffic) and the total heavy vehicle traffic that will be associated with the proposal.

4.2.2 Operational noise

The criteria used for the assessment of noise impacts from noise emitting premises such as the water treatment plant are specified in the *Environmental Protection (Noise) Regulations 1997* that apply to all areas of Western Australia.

The regulations define maximum allowable outdoor noise levels at various types of receiving premises (including residences) by considering the sensitivity of the premises to noise impacts, and the proximity of nearby industrial and commercial areas, and transportation routes.

The maximum outdoor noise levels for residences according to the Regulations are shown in Table 8.5. The assigned noise levels allow for the incorporation of “influencing factors” to take into account the presence of nearby industrial and commercial land, and roads. The influencing factor applicable to the residences nearest to the proposal is considered to be zero; therefore, the levels as shown in Table 8.5 apply.

Table 8.5 Assigned outdoor noise levels for residences

Time of day	L_{A10} (Db)	L_{A1} (Db)	L_{Amax} (Db)
0700 to 1900 hours Monday to Saturday	45 + IF	55 + IF	65 + IF
0900 to 1900 hours Sunday and public holidays	40 + IF	50 + IF	65 + IF
1900 to 2200 hours all days	40 + IF	50 + IF	55 + IF
2200 hours on any day to 0700 hours Monday to Saturday and 0900 hours Sunday and public holidays	35 + IF	45 + IF	55 + IF

“IF” refers to an influencing factor to take into account the presence of nearby industrial and commercial land, and roads. The influencing factor applicable to the nearest residences to this project is zero.

⁵⁰ Guidance for the assessment of noise impacts is contained in “Guidance for the Assessment of Environmental Factors – Environmental Noise (Draft)” (EPA 1998).

If noise emissions from a premises has any annoying characteristics (such as whining and droning, banging and thumping, or a siren), then the impact of the noise at a residence is considered to be greater. This is not expected to be the case with any of the noise associated with the proposal.

Guidance for the assessment of noise impacts is contained in “Guidance for the Assessment of Environmental Factors – Environmental Noise (Draft)” (EPA 1998).

4.3 POTENTIAL IMPACTS AND MITIGATION

4.3.1 Pipeline

Construction of the pipeline will result in an increase in traffic as well as noise associated with the operation of heavy machinery during assembly of the pipeline.

As the pipeline will be buried to a depth of at least 750 mm, there is the potential for solid rock to be encountered. The extent of any rock encountered will be determined during a geotechnical investigation of the pipeline route. On the Blackwood Plateau, blasting and rock breaking may be required in areas of near-surface massive laterite, which is a strongly cemented and high strength material. On the Swan Coastal Plain, laterite cemented sands or duricrust (coffee rock) at shallow depths may also require local blasting or rock breaking.

Any blasting along the pipeline route will employ best practice methods and minimise noise and vibration. All blasting will require approval by the Water Corporation (for every location) and the contractor responsible will have to demonstrate that best practice methods will be adhered to including:

- investigating methods which do not require high-noise blasting operations, such as rock breakers
- for each blast designing specific initiation, charge weight per delay, and overall blast size characteristics to meet noise and vibration criteria at all residences
- carrying out the blasting at approximately the same time each day, determined in consultation with the local community
- restricting blasting to Mondays to Saturdays between 0900 and 1700 hours and excluding public holidays
- monitoring blast noise in accordance with DoE requirements
- monitoring vibration levels (at reference points or at the nearest residence) for blasts that take place within one kilometre of residences.

The Noise and Vibration Management Plan (Chapter 9 Section 14) contains measures to control noise levels and vibration at sensitive premises. As the pipeline is generally located along roads with existing traffic, and away from residences, there is expected to be no additional significant impact on residents from noise or vibration.

4.3.2 Wellfield

Construction

Drilling of the wells has the potential to create elevated noise levels. There are no residences near the wellfield area, however, best practice drilling methods will be used to minimise any noise impacts on the environment.

Operation

The location of the wellfield is well away from residences and the noise of wells in operation will be designed such that there is no impact on any residences.

4.3.3 Treatment plant

Construction

Construction of the treatment plant will result in an increase in traffic, as well as noise associated with the operation of heavy machinery and the building of the treatment plant. Some small-scale blasting may also be required to level ground.

The greatest potential for noise disturbance is likely to be the movement of trucks transporting materials to the site. This is not expected to be significant as roads in the area are either designed for heavy traffic, or are remote from residences.

Measures to manage heavy vehicle noise will include limiting speeds in residential areas and not using engine braking in sensitive areas.

Operation

The location of the treatment plant is well away from residences and the noise of the day-to-day running of the plant will not impact on any residences. Traffic noise will be minimal during operations, due to limited deliveries and low staffing requirements of the plant.

4.4 PROPONENT COMMITMENTS

The Water Corporation commits to:

1. All construction and operational activities will comply with the *Environmental Noise Regulations 1997*.

4.5 ENVIRONMENTAL OUTCOME

The remoteness of the proposal infrastructure limits the potential impacts of noise and vibration associated with construction and operation. The temporary nature of the construction activities will be managed with the appropriate plans. In areas near residences, compliance with guidelines will ensure there are no significant impacts from either construction or operation activities.

5 DUST

5.1 SETTING

Pipeline

Most of the pipeline route will be well away from residences. When near residences the pipeline will generally be along existing roads.

Wellfield

The proposed wellfield is located 0.3 km from the nearest residence.

Treatment plant

The proposed treatment plant is located more than 3.5 km from the nearest residence.

5.2 ASSESSMENT FRAMEWORK AND POLICY CONTEXT

A National Environment Protection Measure for Ambient Air was endorsed by the National Environment Protection Council in June 1998.

The other relevant guideline for dust management is the EPA Guidance for the assessment of environmental factors – Prevention of air quality impacts from land development sites, No. 18.

5.3 POTENTIAL IMPACTS AND MITIGATION

The pipeline route on the Swan Coastal Plain is close to some residences and there is potential for dust emissions to create a nuisance. To minimise the need for dewatering, pipeline construction will be carried out in summer. This will increase the risk of dust emissions. The relatively small scale of the operations, and the short period for which the pipeline trench will be left open, will minimise the risk of dust emissions.

Construction of the treatment plant has the potential to create dust emissions as a result of clearing, excavation, blasting and vehicle traffic. Dust emissions are not expected to create a nuisance because of the distance to the nearest residence.

The wellfield will be located well away from residences, and it is not expected that significant dust will be created during construction.

The potential for airborne dust will be controlled by:

- use of watering tankers or carts, temporary windbreak fencing and hydro-mulching, as necessary and depending on the nature of the soil and wind conditions at the site
- rehabilitation of cleared areas as soon as practicable
- minimisation of area of exposed surfaces such as stockpiles and cleared areas at all times

- restriction of vehicle speeds and number of vehicle movements on unsealed roads during hot, dry and windy conditions.

Greatest attention is likely to be needed in unsealed trafficked areas, and in the handling of dusty materials during dry, windy conditions. Traffic speeds will be reduced and water will be applied in order to prevent dust lift-off.

There will be continuous visual monitoring of dust. Details of dust monitoring and potential corrective actions are detailed in the Dust Management Plan (Chapter 9 Section 16).

5.4 PROPONENT COMMITMENTS

The Water Corporation will ensure that the proposal construction activities do not cause or contribute to visible dust at sensitive premises.

5.5 ENVIRONMENTAL OUTCOMES

Most construction will be well away from sensitive areas and, with the application of control measures described in the Air Quality Management Plan dust emissions, will be kept to acceptable levels.

6 ABORIGINAL HERITAGE

6.1 DESCRIPTION

The Noongar people of the South West are Western Australia's largest indigenous population. Aboriginal artefacts recorded in the South West can be traced back as far as 29 500 BC (SWALSC 2005). The infrastructure development footprint provides the potential for heritage sites to be encountered, particularly adjacent to wetlands, rivers and streams.

6.2 ASSESSMENT FRAMEWORK AND POLICY CONTEXT

The Minister for Indigenous Affairs is responsible for the administration of the AH Act. The Minister's responsibility is to ensure that all places in Western Australia that are of traditional or current sacred, ritual or ceremonial significance to Indigenous people should be recorded and their importance evaluated on behalf of the community. Under section 17 of the AH Act, it is an offence to disturb any heritage site without consent under section 18 of that Act. The consent of the Minister is required under section 18 of the AH Act if a development is likely to impact a site.

The Minister considers recommendations from the Aboriginal Cultural Material Committee (ACMC) and the general interests of the community when making a decision on disturbance to a site. The Minister may also impose conditions on the approval.

The Registrar of the Aboriginal Sites is responsible for maintaining the Register of Aboriginal Sites. The DIA has a database of all recorded sites.

6.3 POTENTIAL IMPACTS AND MITIGATION

The pipeline route crosses the Capel, Ferguson, Preston, Collie and Brunswick Rivers. These are all registered as Aboriginal heritage sites or proposed to be registered (Capel River). There may also be Aboriginal heritage sites elsewhere in or near the pipeline alignment, or close to the treatment plant and wellfield.

The Water Corporation is committed to undertaking a detailed survey of areas potentially affected in consultation with representatives of the local Aboriginal community, before construction commences. This survey will include:

- a review of previous research
- field survey of all areas to be disturbed
- recording of any archaeological sites located.

In the event that sites of cultural or archaeological importance are identified during this detailed survey in any area affected by the proposal the proponent will undertake the following in accordance with the detailed Aboriginal Heritage Management Plan:

- consult with the local Indigenous communities
- avoid site disturbance wherever practicable

- apply for permission to disturb sites pursuant to Section 18 of the AH Act in situations where disturbance cannot be practicably avoided.

Unavoidable crossing of rivers that are registered heritage, sites may require the installation of the pipeline under or over the rivers without disturbance, depending on the outcome of the heritage surveys to be carried out prior to construction. If disturbance is unavoidable, an application for permission to disturb sites will be submitted under Section 18 of the AH Act.

6.4 PROPONENT COMMITMENTS

The Water Corporation commits to:

1. Conduct a detailed Aboriginal heritage survey of the proposed infrastructure footprint before construction of proposal infrastructure in consultation with the local Indigenous community and in accordance with the requirements of the DIA.
2. Seek approval for any disturbance of identified heritage sites under s18 of the AH Act.

6.5 ENVIRONMENTAL OUTCOMES

All heritage sites potentially affected by the proposal will be identified prior to construction and appropriate action taken in compliance with the AH Act and in consultation with the local Indigenous communities.

7 WATER QUALITY

7.1 SETTING

Pipeline

The pipeline crosses five rivers: the Capel, Ferguson, Preston, Collie and Brunswick Rivers. The excavation of the pipeline route has the potential to intersect with shallow groundwater.

Wellfield

Construction of the wellfield is within the undeclared water catchment area that results in recharge to the Yarragadee Formation.

Treatment plant and storage tank

The treatment plant is located within the undeclared water catchment area that results in recharge to the Yarragadee Formation.

7.2 ASSESSMENT FRAMEWORK AND POLICY CONTEXT

The EP Act requires the prevention of environmental harm and of polluting activities. The policy objective is to maintain or improve the quality of surface and groundwater to ensure that the existing and potential uses, including ecosystem maintenance and public water supply, are protected consistent with the draft Western Australian Water Quality Guidelines for Fresh and Marine Waters, the NH&MRC/ARMCANZ Water Quality Guidelines, and the State Water Quality Management Strategy (Government of Western Australia nd).

7.3 POTENTIAL IMPACTS AND MITIGATION

7.3.1 Pipeline

Watercourses

Rivers and streams will generally be crossed by using open cut techniques. This may have a temporary impact on water quality during construction. In conjunction with the Aboriginal heritage consultation, and where the impact is expected to be significant, alternatives such as trenchless drilling of the pipeline beneath the watercourse will be considered.

Any disturbance to the channel and riparian vegetation will be stabilised and rehabilitated to minimise erosion and water quality impacts from sediment.

Dewatering

The pipeline will be constructed over the summer months when groundwater levels will be lower. However, in a small number of areas, there may be high water levels such that dewatering is necessary before the pipeline can be laid and jointed.

Water obtained from dewatering operations will be discharged in accordance with the Dewatering Management Plan (Chapter 9 Section 15). It has been estimated that approximately 14 km of the route on the Swan Coastal Plain and 3 – 4 km of the route along the Blackwood Plateau will require dewatering.

7.3.2 Wellfield

During construction of the wellfield, each well will need to be developed. The water from this process is very turbid, both from clay in the aquifer and from the drilling mud used, and will also be warm and possibly low in dissolved oxygen. The disposal of this water will be carefully managed to avoid impacts on streams. During hydrogeological investigations of the Yarragadee aquifer for the purposes of this project, pumping tests were carried out on a test well. The disposal of this water was successfully managed with settling tanks, aeration and Ph adjustment. The stream environment was also monitored to ensure ANZECC guideline limits were not exceeded. Management of this aspect is detailed in the Wellfield Construction Management Plan in Chapter 9 Section 21.

7.3.3 Treatment plant

In the operation of the filtration plant, between 1% and 4 % of production water is used to backwash the filters. The backwash water will be sent to a backwash recovery tank, and then to sludge drying beds on the site. There are several disposal options for the water recovered from the backwash process including:

- discharge to a watercourse
- supply to local landowners for irrigation of their land
- treat and used for water supply.

Discharge of backwash water to a watercourse is not the favoured option because of its turbidity and bacteria content. The most practical solution is treatment and use in the water supply.

A Treatment Plant Operation Management Plan will be prepared as part of the application process for the licensing of the facility. This plan will ensure that the environment is not impacted by the day-to-day operation of the treatment plant.

7.4 PROPONENT COMMITMENTS

The proponent commits to:

1. Operate the treatment plant in accordance with conditions of any licence or works approval issued pursuant to Part V the EP Act.
2. Work with the DoW and CALM to arrange declaration of a public water supply catchment area over the relevant portions of the Yarragadee aquifer recharge zones.

7.5 ENVIRONMENTAL OUTCOMES

The construction of the infrastructure for the project is not expected to impact on water quality. The day-to-day operation of the plant will be managed to prevent any impact on the environment.

8 ACID SULPHATE SOILS

8.1 DESCRIPTION AND EXISTING ENVIRONMENT

The risk of acid sulphate soils occurring on the Swan Coastal Plain varies from low to high (Figure 5.59). The pipeline route on the coastal plain will traverse areas of moderate and high risk, in the vicinity of Capel River, and excavation and dewatering activities may expose acid sulphate soils to the atmosphere resulting in acid generation, either in situ, or in the dewatering discharge.

8.2 ASSESSMENT FRAMEWORK AND POLICY CONTEXT

The *Environmental Protection Act 1986* requires the prevention of environmental harm and of polluting activities. The policy objective is to maintain or improve the quality of surface and groundwater to ensure that the existing and potential uses, including ecosystem maintenance and public water supply, are protected consistent with the draft Western Australian Water Quality Guidelines for Fresh and Marine Waters, the NH&MRC/ARMCANZ Water Quality Guidelines and the State Water Quality Management Strategy (Government of Western Australia nd).

Achievement of this policy objective will require either the prevention of acid generation, or its containment and treatment.

The Water Corporation will comply with the relevant statutory requirements and any policies concerning acid sulphate soils. These include:

- The Department of Environment Acid Sulphate Soils Guideline Series (DoE 2004b, 2004c).
- *Metropolitan Water Supply, Sewerage and Drainage Act 1909* for the Underground Water Pollution Control Area over Jandakot Mound.
- *Contaminated Sites Act 2003*
- Planning Bulletin 64. Acid Sulphate Soils (WAPC 2003b)

8.3 POTENTIAL IMPACTS AND MITIGATION

The occurrence of acid sulphate soils along the route will only be an issue if they occur within 2.5 m of the soil surface in an area where dewatering of the pipeline trench is required. If acid sulphate soils are encountered, management will be in accordance with the Dewatering Management Plan (Chapter 9 Section 15) and Acid Sulphate Soils Management Plan (Chapter 9 Section 20). In general, management will consist of lime dosing if, and where, acid generation occurs. No significant impact is expected as excavation and dewatering activities will be of relatively short duration.

The pipeline route has been selected to avoid areas of high risk of acid sulphate soil occurrence wherever possible, but in the case of the Capel River, the linear nature of the pipeline will cross through a high risk zone.

8.4 PROPONENT COMMITMENTS

The Water Corporation commits to:

1. Undertake the a soil sampling program of the pipeline route to further define the risk of exposure of acid sulphate soils
2. The Water Corporation will ensure that the proposal construction activities do not cause or contribute to acidification of land or surface water through the exposure of acid sulphate soils to the extent that it adversely affects native vegetation or streams.

8.5 ENVIRONMENTAL OUTCOMES

The soil sampling program and the preparation of an appropriate Dewatering Management Plan will ensure that no significant impacts occur due to acid sulphate soils during construction of the proposal.

9 PUBLIC SAFETY

9.1 DESCRIPTION

During construction increased traffic and other construction activities will need to be managed to prevent any risk to public safety.

A 135 ML/day capacity water treatment plant including a pump station and chlorination system will be constructed near Jarrahwood. The treatment plant complex will include chlorination and fluoridation facilities, sludge drying beds and a clear water pump station. The treatment plant is more than 3.5 km from any residences (>3.5 km).

9.2 ASSESSMENT FRAMEWORK AND POLICY CONTEXT

Chlorine dosing facility

The EPA has issued a guidance statement for “Risk Assessment and Management: Offsite Individual Risk from Hazardous Industrial Plant”. This statement set the following offsite individual risk criteria for fatalities from hazardous industrial plant as acceptable to EPA:

1. A risk level in residential zones of one in a million per year or less.
2. A risk level in “sensitive developments”, such as hospitals, schools, childcare facilities and aged care housing facilities of 0.5 in a million per year or less.
3. A risk level target at the site boundary for each individual industry of 50 in a million per year and the cumulative level imposed upon an industry of 100 in a million per year or less.
4. A risk level for any non-industrial activity located in a buffer zone between industrial facilities and residential zones of 10 in a million per year or less.
5. A risk level for commercial developments, including offices, retail centres and showrooms located in buffer zones between industrial facilities and residential zones of 5 in a million per year or less.

The guidance statement also indicates the following:

- Best practice – the facility should be based on best practicable engineering design and operated according to best industry practice management systems.
- Risk minimisation – risks should be reduced to as low as reasonably practicable. This requires consideration of alternative sites, technologies and a management system which may reduce or eliminate public risks.

The Water Corporation has established a standard (SG017 Standard for chemical storage buffers 1998) that prescribes acceptable buffer areas around chlorination facilities. The buffer area for the proposed plant is likely to be:

- 150 m hazard zone (where no housing is allowed)
- 300 m evacuation zone (where residences may be present but evacuation procedures have to be developed).

The chlorination facility will require a licence from the Department of Consumer and Employment Protection (DoCEP) and a works approval under the EP Act before construction commences. Water treatment facilities (greater than 1 ML/d) are required to be registered with the DoE before construction.

9.3 POTENTIAL IMPACTS AND MITIGATION

Construction

Due to the use of heavy machinery and earthmoving equipment there is a need to prevent direct public interaction with construction activities. Where there is any risk of public injury (e.g. open trenches or dewater pits) the construction site will be fenced or otherwise cordoned off. Machinery and plant will be kept in locked compounds when the site is not in use. All sites will be appropriately signed to warn of hazards.

All construction vehicles will travel along designated routes and adhere to speed limits. Public notification of construction activities, particularly to nearby residents, will be given prior to commencement of works in each area.

Operation

The dosing plant will use the hazardous material chlorine. There is potential for chlorine to escape and pose a risk to public safety if accidental spillage or leakage takes place.

The facility will be designed to minimise the amount of operator intervention in normal operations, and to present as low a level of risk as is practicable to the community and the environment. Chlorine will be stored in liquid form in drums and will be contained in a room designed to ensure containment of any chlorine gas in the event of drum leakage. The building will also be fitted with chlorine gas detectors.

The DoCEP will review the design of the facility and the proponent will meet all appropriate safety requirements. Based on a preliminary assessment, the separation distances to sensitive areas including residences and public roads, comply with the EPA criteria and the Water Corporation Standard as described in the Section 9.2 above.

The proponent will conduct a quantitative risk assessment to ensure that the plant conforms to the above criteria before seeking a licence, for the facility, from the DoCEP.

A Treatment Plant Operation Management Plan will be prepared as part of the process of obtaining the operating licences. This will contain further detail on management actions during operations.

9.4 PROPONENT COMMITMENTS

The Water Corporation commits to:

1. Operate the treatment plant in accordance with conditions of any licence or works approval issued pursuant to Part V of the EP Act.

9.5 OUTCOME

The treatment plant is located well away from sensitive areas and well beyond the anticipated required buffer zone for the facility. The facility will not pose a significant risk to public safety.

Public safety risk due to construction will be managed with prior notice, signage and fencing where required.

10 ENERGY EFFICIENCY

The sustainability objective for *Energy efficiency* principle is:

The proposal will be designed and operated according to Australian best practice regarding greenhouse gas emissions.

10.1 DESCRIPTION

Groundwater will be extracted from each well and pumped to the treatment plant and holding tank. The treated water will then be gravity fed from the holding tank to Harvey and on to Perth for use. Power will be required for each well and at the treatment plant, and will be sourced from the South West Interconnected System (SWIS).

Energy consumption for pumping and operation of the treatment plant will amount to approximately 4.6 MW.

There will also be a small one-off power requirement associated with the construction of the 100 km pipeline.

It is generally accepted that the global climate is warming and that this presents problems for current and future generations. Warming is linked to increased greenhouse gases (GHG), primarily carbon dioxide (CO₂), which is directly linked to energy production.

10.2 ASSESSMENT FRAMEWORK OR POLICY CONTEXT

Kyoto Protocol

Australia became a party to the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. The Kyoto Protocol, an international and legally binding agreement to reduce greenhouse gases emissions world wide, entered into force on 16 February 2005. Australia adopted the Kyoto Protocol in December 1997 but is not a signatory. Under the protocol, Australia's target is to restrict greenhouse gas emissions to an 8% increase in emissions from its 1990 levels during the first commitment period from 2008 to 2012 (i.e. the average emissions over these 5 years). This represents a reduction of nearly 30% in emissions from "business as usual" projections.

The Western Australian State Government supports, and has urged the Federal Government to ratify, the Kyoto Protocol. The Western Australian Government has set renewable energy targets to increase its renewable energy contribution to electricity grid power outputs to 6% by 2010.

From the 2006 – 07 financial year, the Water Corporation will be required by the State Government to report annually on its GHG emissions and declarations of its plans to reduce GHG emissions. No actual target levels have as yet been set.

The Water Corporation is readily meeting renewable energy targets set by the State Government and will meet the Australian Kyoto Protocol target until around 2010 without further GHG abatement actions.

State Greenhouse Strategy

The *Western Australian Greenhouse Strategy* was released in September 2004. The Strategy sets out the State Government response to the effects of climate change. The State recognises the weaknesses and limitations of the Kyoto Protocol, but believes the Protocol represents an essential step towards dealing with climate change. The Western Australian State Government advocates the ratification of the Kyoto Protocol by the Federal government, and will support national measures to meet the Kyoto Protocol target that recognise Western Australia's circumstances and interests.

Environmental Protection Authority guidance

The EPA has released a Guidance Statement that sets out its objectives regarding the minimisation of greenhouse gas emissions from new or expanding operations (EPA 2002).

The EPA environmental objective for greenhouse gas management is to reduce emissions to a level which is as low as is practicable. To achieve this, the EPA environmental assessment objective is to ensure that potential greenhouse gas emissions emitted from proposed projects are adequately addressed in the planning, design and operation of projects and, amongst other things, that best practice is applied to maximise energy efficiency and minimise emissions.

10.3 POTENTIAL IMPACTS AND MANAGEMENT

The proposal will utilise 4.6 MW of energy by way of electricity from the Western Power South West Integrated System. Implementation of the proposal will consequently contribute to a resultant increase in greenhouse emissions. The increase in emissions is estimated to be 41 000 t/yr CO₂e⁵¹ based on an assumed indicative carbon intensity of the Western Power South West Integrated System of 1032 kg CO₂/MWhr⁵². This is an indicative figure, as the carbon intensity of the grid is changing as the overall configuration of power stations within the grid changes. The proposed retirement of Muja A and B power stations and commissioning of the proposed new 300 MW gas turbine stations will substantially change the overall intensity of the grid over the period leading up to commissioning of this proposal.

Sinclair Knight Merz (2002) discussed greenhouse gas considerations related to Western Power's recent Power Procurement Process and plant retirement and replacement program in some detail. The review noted that actions by Western Power have resulted in the carbon intensity of electricity sent out in the SWIS to fall to 0.85 tonnes CO₂e/MWhr in 2004 (a decrease of 13% on 1990 levels).

Sinclair Knight Merz (2002) examined two potential scenarios for power procurement in terms of estimating the change in carbon intensity and overall greenhouse emissions, accounting for a plant replacement and retirement program. Assessment of a scenario involving a CCGT generation plant concluded that the SWIS carbon intensity will continue to decrease to 2010 by 0.70 tonnes CO₂e/MWhr.

⁵¹ CO₂e – carbon dioxide equivalent.

⁵² Carbon intensity value for the SWIS used for the Environmental Protection Statement prepared for the Perth Metropolitan Desalination Proposal (Welker Environmental Consultancy 2002).

The Water Corporation energy use, and thus potential GHG emissions will increase due to business growth. This increase will be compounded by an increase in energy intensity (energy used per unit of water service) due to:

- more remote water sources
- more energy intensive resources (i.e. desalination)
- increased regulatory requirements
- increased customer expectations for water quality.

The Water Corporation has set an aspirational target of being carbon-neutral by 2030. This will be achieved through a program that considers all of the Corporation emissions (a portfolio approach) to reduce the Corporation emissions profile and gain the greatest practical energy efficiencies across the business.

As part of the GHG management portfolio approach, a Greenhouse Emissions Reduction Plan will be developed to manage GHG emissions consistent with the Water Corporation vision of “sustainable management of water services to make Western Australia a great place to live”.

Since joining the Australian Greenhouse Challenge in 2001, the Water Corporation has achieved significant GHG emission abatement (between 19 and 25% depending upon the year). This has been achieved through carbon sequestration, water use education and enforcement (less water and hence less energy used), establishment of an Energy Management Unit, capture and combustion of methane generated by digesters at wastewater treatment plants (21 times more greenhouse intensive than CO₂), fuel switching (e.g. use of fuel that produces less GHG), and increased use of renewable energy.

In addition, the Corporation recently agreed to offset all of its vehicle fleet emissions through biomass carbon sequestration for 2005 – 2006 as a further interim step to reducing net GHG emissions.

10.3.1 Potential limits on availability of renewable energy

Energy for the Perth Seawater Desalination Plant in Kwinana will be generated by wind turbines from the Emu Downs wind farm near Cervantes. Renewable energy contracts, however, may be difficult to obtain for future infrastructure developments such as the South West Yarragadee proposal, and a second desalination plant for Perth, because the small Western Australian electricity network cannot cost-effectively accommodate additional intermittent power sources.

10.3.2 Aspirational target

Setting an aspirational GHG emissions target of being carbon-neutral by 2030 will encourage significant eco-efficiencies and emissions reductions across the Water Corporation’s business. By using a portfolio approach, the Corporation envisages greater opportunities (and greater net benefits) to reduce and offset GHG emissions than from mitigation of GHG emissions for individual large projects. Therefore, the Corporation will develop a Greenhouse Emissions Reductions Plan to achieve carbon-neutrality by 2030 that explicitly allows for business-wide offsets for all Corporation activities.

This plan is expected to reduce and/or offset Corporation net GHG emissions by:

1. Addressing a number of options or alternatives ranging from revegetation with a greenhouse-biodiversity focus; low rainfall area plantings for GHG offsets; salinity mitigation; revegetation of lost or degraded native vegetation; and expanded areas of plantations for treated wastewater disposals.
2. Encouraging innovative ways of economically reducing or offsetting GHG emissions, and obtaining secondary benefits such as improved water quality opportunities, synergy with treated waste water utilisation, contribution to salinity management, conservation of biological diversity and habitat protection, positive groundwater recharge for some managed catchments, and carbon trading to leverage plantation changes in areas where benefits can be optimised.
3. Setting interim GHG targets, monitoring and reporting mechanisms (including reporting performance to the State, the Federal Greenhouse Office, publicly, and in the proposed annual Sustainability Report).

10.4 PROPONENT COMMITMENTS

No specific commitment regarding energy efficiency is proposed. The Water Corporation will continue to strive to reduce greenhouse emissions and improve energy efficiency in all its projects.

10.5 OUTCOMES

Implementation of the proposal will indirectly contribute to increased energy use in Western Australia and a potential resultant increase in greenhouse emissions. The Corporation will utilise best practice in the design and operation of the infrastructure to minimise energy use, and will pursue its carbon-neutral policy with the expected longer term outcome of no increase in greenhouse gas emissions.

Implementation of the project will delay the need for future desalinated projects that are significantly more energy intensive.

Chapter 9 Environmental Management Program

1 INTRODUCTION

The South West Yarragadee water Supply Development project will extend the Integrated Water Supply Scheme into the south-west of Western Australia by developing the Yarragadee aquifer in the Southern Perth Basin. In summary, the key components of the proposal are:

- construction of the infrastructure
- long-term abstraction of 45 GL/yr from the South West Yarragadee aquifer.

The required infrastructure is:

- a wellfield within an area north-north-west of Nannup
- a filtration-based treatment plant and storage tank to be located north of the source works
- a transfer main (pipeline) to take water from the treatment plant to the existing Stirling Trunk Main at Harvey.

Operational aspects of the proposal are abstraction of groundwater at the wellfield, and operation of the treatment plant.

1.1 CORPORATE ENVIRONMENTAL POLICY

The Water Corporation has a strong commitment to environmental protection and sustainability. The Water Corporation commitment towards the environmental management of all its activities is outlined in its Environmental Policy (Appendix 6).

Corporation-wide implementation of the Environmental Policy is facilitated through the Corporate Environmental Management System (EMS). The Corporate EMS is consistent with the international EMS Standard, ISO 14001 and the Australian Water Industry Guidelines for Environmental Management.

1.2 PURPOSE AND SCOPE OF THE ENVIRONMENTAL MANAGEMENT PROGRAM

The overall purpose of the Environmental Management Program (EMP) is to describe measures to protect significant environmental features that may be affected by the construction and operation of the proposal. This program covers the following component phases of the project:

- pipeline, wellfield, and treatment plant construction
- groundwater abstraction of 45 GL/yr from the Yarragadee aquifer.

The main objective of this EMP is to:

Ensure that incidents of significant and potentially significant environmental impacts are appropriately managed.

This EMP has been prepared for the purpose of the environmental assessment and approval process. The plans related to construction of infrastructure in the EMP will be further developed to provide detail suitable for use by construction personnel. These more detailed management plans will together form a Construction Environmental Management System (CEMS).

1.3 ENVIRONMENTAL MANAGEMENT PROGRAM STRUCTURE

The EMP divides the component management plans in line with the two distinct phases of the project which are:

- long-term abstraction of groundwater and subsequent treatment processes
- construction of the infrastructure

Each component management plan:

- defines EPA objectives and decision making criteria for the factors it addresses
- describes the potential impacts of the proposal
- describes management measures required to give effect to the environmental commitments and to achieve environmental objectives related to the environmental factor
- provides a description of monitoring and review processes to evaluate achievement of environmental commitments and objectives related to the construction and operational environmental management plans as outlined below
- provides a description of the contingencies for unexpected adverse outcomes.

The construction related plans contained here will be developed to provide detail suitable for use by construction personnel. These more detailed management plans will together form a CEMS.

The operating plans detail the way in which the Water Corporation proposes to manage the operational phase of the project including monitoring, decision-making processes, contingencies and risk management. Further abstraction management plans and associated monitoring programs for the groundwater abstraction will be prepared in accordance with any licence issued pursuant to the RWI Act and the Groundwater Abstraction Management Plan described in Chapter 9 Section 12.

1.4 OPERATIONAL PHASE MANAGEMENT PLANS

The following component management plans have been identified for the operational phase providing the basis for meeting the objectives of the EMP:

- Groundwater Abstraction Management Plan
- Treatment Plant Environmental Management Plan.

These component management plans are discussed in Section 12 and 13.

1.5 CONSTRUCTION PHASE MANAGEMENT PLANS

The following component management plans have been identified for the construction phase, providing the basis for meeting the objectives of the EMP:

- Incident Management Plan
- Audit Plan
- Terrestrial Flora and Fauna Management Plan
- Weed Management Plan
- Forest Diseases Management Plan
- Noise and Vibration Management Plan
- Dewatering Management Plan
- Acid Sulphate Soils Management Plan
- Air Quality Management Plan
- Waste Management Plan
- Spills Management Plan
- Heritage Management Plan
- Wellfield Construction Management Plan
- Rehabilitation Management Plan.

These component management plans constitute the Construction Environmental Management Plan, and are discussed in Sections 14 – 27.

2 REVIEW AND REVISION OF MANAGEMENT PLANS

The overall Environmental Management Program and component environmental management plans will be periodically reviewed and revised in line with the adaptation of procedures to achieve objectives consistent with emerging situations and changing knowledge. The review and update process will be undertaken in consultation with key stakeholders to ensure that acceptable environmental management measures are prepared and implemented.

Minor changes to operational practices will be made from time to time, and will necessitate changes to the EMP. The EMP will also require periodic amendments to account for changes in statutory environmental requirements and policies, operational experience, and initiatives for environmental management and improvement.

Once an amendment has been approved the Water Corporation will distribute amended sections to relevant Water Corporation staff to allow replacement of out-dated sections.

The CEMS will be continually reviewed and revised during construction, based on feedback from audits and from day-to-day operations. Reviewing of the CEMS will determine whether the system is functioning adequately, which areas of the system need improvement and any alternative procedures that may be more effective than those currently in place.

In order to provide effective feedback, the CEMS should ensure that:

- regular inspections of key areas highlighted in the Construction Environmental Management Plan are undertaken
- environmental incidents (e.g. major chemical spills, unintended disturbance to vegetation) are reported and rectified.

Through periodic review of the CEMS, continuous improvements can be made and the potential for environmental issues can be minimised.

3 RESPONSIBILITIES

3.1 CONSTRUCTION ENVIRONMENTAL MANAGEMENT

Environmental management is the responsibility of all Water Corporation personnel and contractors. Overall environmental management during the construction phase will be the responsibility of the Project Manager. The responsibilities of the Project Manager will be to:

- implement the Water Corporation Environmental Policy with respect to this project
- understand environmental requirements and ensure compliance
- recommend environmental objectives and targets
- assign the individuals responsible for environmental management, who will then have direct access to the site managers
- direct the activities of Water Corporation employees, contractors and subcontractors to ensure that environmental performance requirements are met
- obtain goods and services that conform with relevant legal, permit and contract requirements, accepted standards, and Water Corporation specifications
- ensure that management aims and monitoring responsibilities relating to the project areas are met
- provide information and training to Water Corporation employees, contractors and sub contractors regarding their environmental obligations
- liaise with contractors, other Water Corporation staff, Government agencies and the public as required.

A CEMS is commissioned and endorsed by the Water Corporation for specific projects and details the contractual requirements that will enable the project (and therefore Water Corporation) to meet its environmental requirements as agreed with the public, stakeholders, the DoE and the EPA. The CEMS is based on information gathered on the project and will be referred to the EPA prior to a project commencing. Relevant mitigation and contingency procedures will be included in the CEMS should environmental management guidelines be breached.

The CEMS for this proposal will be based on the management plans covered in Sections 12 – 25 of this Chapter, but will contain more detailed versions that can be used directly by construction contractors. The CEMS will be approved prior to works commencing on site, and will outline the management procedures, strategies and methods that will be used by the Water Corporation to ensure effective management of all environmental aspects relating to the construction of the infrastructure.

There must be continuous review of the CEMS to ensure that environmental objectives are being met and to ensure that the relevant environmental issues are being appropriately managed.

3.2 OPERATIONAL ENVIRONMENTAL MANAGEMENT

Environmental management is the responsibility of all Water Corporation personnel and contractors. Overall environmental management during the operational phase will be the responsibility of the Regional Business Manager.

The responsibilities of the Regional Business Manager will be to:

- implement the Water Corporation Environmental Policy with respect to this project
- understand environmental requirements and ensure compliance
- recommend environmental objectives and targets
- assign the individuals responsible for environmental management, who will then have direct access to the site managers
- direct the activities of Water Corporation employees, contractors and subcontractors to ensure that environmental performance requirements are met
- obtain goods and services that conform with relevant legal, permit and contract requirements, accepted standards, and Water Corporation specifications
- ensure that management aims and monitoring responsibilities relating to the project areas are met
- provide information and training to Water Corporation employees, contractors and subcontractors
- liaise with contractors, other Water Corporation staff, Government agencies and the public as required.

4 INCIDENT MANAGEMENT PLAN

A detailed incident response procedure will be prepared prior to construction to manage incidents that are significant or potentially significant. The procedure will address the following:

1. Responsibilities and accountabilities of contractor and Water Corporation personnel for incidents.
2. Definition of an incident.
3. A procedure to be followed in the event of an incident including:
 - incident reporting time limits
 - structure and content of incident reports
 - assessment of significance of incidents
 - discontinuation of work giving rise to the incident
 - recording of incidents (incident log)
 - when further investigations are required
 - reporting of incidents to regulatory authorities
 - remediation or mitigation of impacts
 - identification of opportunities for improvements to work practices to minimise the potential for incidents to recur.

Construction contractors will be required to prepare and submit to the Water Corporation an incident response procedure that addresses the above measures.

5 AUDIT PLAN

Internal auditing is an important part of implementing an EMP to ensure that specified management procedures are complied with and performance criteria are met. Where auditing identifies non-conformances, corrective action will be taken.

The Water Corporation will appoint an environmental representative to conduct or supervise environmental audits during and following construction in accordance with an audit plan. The audit team will include Water Corporation officers and independent auditors.

The Water Corporation will prepare an audit plan following receipt of environmental approval of the proposal. The audit plan will include:

- timing and frequency of audits
- scope and types of environmental audits (system, process compliance, site and facility audits)
- audit procedure
- rating system (if any)
- structure and content of audit reports
- audit protocols or guidelines to be used
- facilities and processes to be audited
- composition of audit teams
- training for audit team members
- responsibilities for audits.

Contractors will be required to carry out environmental audits to check their own internal environmental performance and procedures. These audits will be in addition to any carried out by the Water Corporation.

For the preparation of the audit plan, liaison will be required with DoE, DoW, CALM, DoCEP and relevant local authorities.

6 PUBLIC REPORTING AND TRANSPARENCY

The Water Corporation has the following process principle as one of the thirteen sustainability principles that have been designed for this proposal:

The Corporation will report publicly on its sustainability performance and provide public access to information on the proposal.

The Water Corporation will prepare an Annual Sustainability Review specifically for the South West Yarragadee Water Supply Development. The Annual Sustainability Review will report on sustainability performance including environmental performance, monitoring results, any environmental incidents that have occurred and any changes in environmental management procedures.

A community based South West Yarragadee Monitoring Review Group will be established to review monitoring programs and results and to oversee the adaptive management process including performance measures, management objectives and contingency actions. The Monitoring Review Group will report publicly to the Water Corporation on any assessments it makes, and this information will be made available to the regulatory agencies, relevant Ministers, and the Cabinet Subcommittee on Water through the State Water Council.

7 REVIEW AND REVISION OF MANAGEMENT PLANS

The overall Environmental Management Program and component environmental management plans will be periodically reviewed and revised in line with the adaptation of procedures to achieve objectives consistent with emerging situations and changing knowledge. The review and update process will be undertaken in consultation with key stakeholders. In particular the Monitoring Review Group will ensure that acceptable environmental management measures are prepared and implemented.

Minor changes to operational practices will be made from time to time necessitating changes to the EMP. The EMP will also require periodic amendments to account for changes in statutory environmental requirements and policies, operational experience, and initiatives for environmental management and improvement.

Once an amendment has been approved, the Water Corporation will distribute amended sections to relevant Water Corporation staff to allow replacement of out-dated sections.

8 GROUNDWATER ABSTRACTION MANAGEMENT PLAN

8.1 CONTEXT AND SCOPE

Up to ten wells will be drilled into the Yarragadee Formation in an area near Jarrahwod. These wells will be distributed across five well sites, with two wells at each site. Contingency sites to provide for modification of distribution of the pumping regime between aquifers have been selected. Wells will not be constructed at these contingency sites unless monitoring indicates they are required.

Each well site is located adjacent to an existing cleared road and will not require clearing other than that required for the construction area for each site. Collector mains will be located within the cleared areas following existing roads. The roads will be used for maintenance access without modification.

The Groundwater Abstraction Management Plan describes the management approach to groundwater abstraction to prevent any significant unexpected and adverse damage to the groundwater dependent ecosystems of the region that might result from groundwater abstraction.

Groundwater drawdown impacts will potentially affect watertable levels in several potential risk areas. The impacts of the drawdowns that are expected to occur as a result of the proposal alone are considered to be insignificant. Future growth in regional groundwater use will add to the effects. The fundamental approach of the Water Corporation to managing the cumulative drawdown impacts in these areas is to take full responsibility for offsetting and management in those areas where the Water Corporation is the major contributor to the drawdown effect. In those areas where the Water Corporation is a minor contributor to drawdowns, involvement will be limited to monitoring, reporting, and offsetting the impacts of the Water Corporation proposal. This effectively means the Corporation will be responsible for offsetting all groundwater drawdown impacts on the eastern Blackwood Plateau. The Water Corporation does not propose to take responsibility for managing the drawdown impacts of regional users on the coastal plains, or on the Blackwood Plateau west of the Busselton Fault.

8.2 EPA OBJECTIVES

The overall objective of the EPA with respect to groundwater abstraction is:

To maintain the quantity of water so that existing and potential environmental values, including ecosystem maintenance, are protected.

Specific objectives related to the various environmental factors potentially affected by groundwater abstraction are:

Flora and fauna

The Water Corporation will seek to achieve a net increase in flora and fauna in the region. At a minimum, the proposal will have no adverse impact on flora and fauna in the region.

Rare and Priority Flora (groundwater dependent)

The Water Corporation will seek to achieve a net increase in priority and rare flora in the region. At a minimum, the proposal will have no adverse impact on priority and rare flora in the region.

Threatened Fauna

The Water Corporation will seek to achieve a net increase in the viability of threatened fauna populations in the region. At a minimum, the proposal will have no adverse impact on the distribution and viability of threatened fauna populations in the region.

Threatened Ecological Communities (TECs – groundwater dependent)

The Water Corporation will seek to achieve a net increase in the viability of threatened ecological communities in the region. At a minimum, the proposal will have no adverse impact on the distribution and viability of threatened ecological communities in the region.

Blackwood River and tributaries

The Water Corporation will seek to increase the ecological integrity of the Blackwood River and its tributaries. At a minimum, the proposal will have no significant adverse impact on the Blackwood River and its tributaries.

Wetlands

The Water Corporation will seek to increase the ecological integrity of wetlands in the region. At a minimum, the proposal will have no significant adverse impact on wetlands.

Other Groundwater Dependent Ecosystems (GDEs)

The Water Corporation will seek to increase the ecological integrity of other groundwater dependent ecosystems in the region. At a minimum, the proposal will have no significant adverse impact on other groundwater dependent ecosystems.

8.3 POTENTIAL IMPACTS

As the Yarragadee Formation is highly transmissive, the drawdown within the aquifer will extend throughout those parts of the Southern Perth Basin where the Formation exists. The pressure changes in the Yarragadee Formation will affect the shallow watertables in some areas as described in Chapter 5 Section 4.

The areas where abstraction may affect shallow watertables are:

- where the Yarragadee Formation outcrops west of Nannup under the Blackwood River and several tributaries
- on the coastal plains in the areas where the Yarragadee Formation directly underlies the superficial formations.

A detailed impact assessment of the abstraction impacts has been undertaken and is described in Chapter 7.

The potential impacts of the proposed abstraction include:

- watertable drawdown under groundwater dependent ecosystems may cause a change in vegetation composition
- a minor reduction in the discharge of groundwater to the Blackwood River and tributaries
- minor drawdown interference with other water users

- gradual long-term inland migration of a seawater interface in the Bunbury area.

8.4 MANAGEMENT ACTIONS

The wellfield has been designed to minimise impacts on other water users and on the environment. The Blackwood Plateau was chosen as the general location for the wellfield as the Yarragadee aquifer is largely deep and confined in the area, there is little existing groundwater abstraction, and the area is remote from other groundwater users. The location of the wells within this broad area was refined using groundwater modelling to determine which configurations would both minimise groundwater drawdowns in environmentally sensitive areas, and minimise the impacts on other water users (Chapter 5 Section 4.1).

The wellfield will draw from two units of the Yarragadee Formation to spread the drawdown effects vertically. Five wells will be drilled into the shallowest, most confined Yarragadee unit (Yarragadee Unit 1) at around 400 m depth, and five wells will be drilled into a deeper unit (Yarragadee Unit 3) at around 700 m depth. Six wells operating at full capacity should provide 45 GL/yr. The additional wells will be drilled to allow for continued abstraction during maintenance, and flexibility in the proportion of water abstracted from the different layers in the Yarragadee Formation. This flexibility is important to allow for adaptive management of the abstraction regime based on the monitoring results.

Potential impacts have been avoided and minimised as far as possible through the investigations, modelling, and final wellfield configuration. When operational, management of abstraction will be undertaken within an adaptive management approach based on responding to information provided through an extensive monitoring program detailed in Section 8.6 of this Chapter.

Other management actions that have been committed to and form a major component of the overall Groundwater Abstraction Management Plan are:

1. Establishment of the South West Yarragadee Monitoring Review Group (Volume 1 Chapter 8 Section 3.2.3).
2. Implementation of the South West Yarragadee Sustainability Initiative (Volume 1 Chapter 7 Section 4.1.1).
3. Preparation of an annual Sustainability Report (Volume 1 Chapter 8 Section 3.2.4).

South West Yarragadee Monitoring Review Group

A stakeholder based South West Yarragadee Monitoring Review Group will be formed and will have a pivotal role in the adaptive management process. The proposed terms of reference for this group are to independently review and provide public advice and recommendations to the Water Corporation and other relevant Government agencies on:

1. Management objectives and social, economic and environmental performance indicators as proposed by the Water Corporation.
2. Monitoring programs and results including the South West Yarragadee Sustainability Initiative.
3. Proposed contingency measures in the event of unforeseen adverse impacts.
4. The performance of the Water Corporation in meeting objectives and performance standards as presented in the proposed annual Sustainability Report.

The group will be provided with administrative support and financial resources to provide access to independent technical support and expertise where necessary to conduct the reviews.

The membership of this group is to be determined in consultation with the stakeholders, but is proposed to be based on the following elements:

- maximum membership of 12
- independent chair from within region
- membership will for three years on a rotational basis, with members being able to apply for re-appointment
- membership based on interests and expertise rather than being representative of a constituency
- membership will have a majority of community members (agency membership limited to non-regulatory agencies).

The regulatory agencies will not be represented on the group because of a potential conflict of interest. The arrangements for the committee will be reviewed after three years and modified if necessary. It is anticipated that the group will meet two or three times per year.

The Water Corporation response to the review by the monitoring review group will form part of its annual Sustainability Report to Government.

The proponent also commits to establish a South West Yarragadee Interpretive Centre in the South West to provide information to the community and visitors about development of the aquifer. This centre could be utilised by the Monitoring Review Group as one of several avenues to make its advice public.

South West Yarragadee Sustainability Initiative

The Water Corporation will implement a South West Yarragadee Sustainability Initiative intended to enhance the information base and to provide for maximisation of water availability in the region. This initiative will provide information on key ecological and social aspects and risk areas to complement the information already made available through development of the proposal.

The South West Yarragadee Sustainability Initiative will be an element of the proposed adaptive management framework (Volume 1 Chapter 7 Section 4.1.1) and involves commitment to a range of actions to obtain information to refine the existing models of the groundwater system and associated dependent ecosystems and to achieve net benefit outcomes.

Activities undertaken under the initiative will include:

1. A major biodiversity study of groundwater dependent ecosystems of the Scott and Swan Coast Plains and the Blackwood River area potentially affected by the development, which will enhance the baseline against which changes can be assessed.
2. Supporting investigations into the potential for acidification from acid sulphate soils and potential means of management.
3. Research into the magnitude and possible means of management of irrigation return water.
4. Investigations into the effects of changing land use on water demand, availability and quality.

The initiative will be funded through a capital investment of \$2 million with the capital and any interest made available to the initiative over a period of ten years.

The Water Corporation will prepare and publish an annual Sustainability Report outlining the following:

- compliance with statutory requirements of environmental approval and the water licence for abstraction from the Yarragadee aquifer
- assessment of performance against key performance indicators
- implementation of Water Corporation commitments
- summary of environmental and socio-economic monitoring information
- progressive results from the proposed biodiversity study
- stakeholder engagement.

This report will be submitted to the Stakeholder Monitoring Review Group for review before presentation to relevant Government agencies with a response to advice from the monitoring group.

8.5 MONITORING, REVIEW AND REPORTING PROGRAM

The Water Corporation will implement an extensive biological, hydrological and physical monitoring program for the areas potentially affected by the proposed groundwater abstraction, together with control areas to allow differentiation of causes and effects. The detailed program is set out in Section 8.6 of this Chapter.

The proposed South West Yarragadee Monitoring Review Group will review the monitoring results against a set of defined principles and advise whether any changes need to be made to the management of the project. The Water Corporation will prepare a public Sustainability Report that will report on the monitoring results and proposed management responses if analysis of those results indicates a response is necessary. The Sustainability Report will be prepared annually during construction and for the first five years of abstraction. The reporting frequency will then be reviewed in consultation with the DoE, DoW and the Monitoring Review Group.

The monitoring programs and ongoing requirements will be reviewed every three years in consultation with the proposed Monitoring Review Group, and modifications will be proposed as necessary, for approval by the DoW.

The Water Corporation will provide opportunities for indigenous people to be employed in undertaking monitoring programs.

8.6 DETAILED MONITORING PROGRAMS

The Department of water is currently undertaking a range of groundwater and surface water monitoring activities in the region that will overlap with the following detailed monitoring program which will be undertaken by the Water Corporation. The Water Corporation will take responsibility for ensuring all monitoring within its proposed program is carried out.

8.6.1 Hydrology

The objectives of hydrologic monitoring are to:

1. Provide information on aquifer performance in areas of potential impact in terms of:
 - ecological system responses
 - acid sulphate soil responses
 - interference drawdowns
 - streamflow responses
 - response to climate change.
2. Validate the understanding of the conceptual hydrogeology and its interpretation in the SWAMS model.
3. Validate and improve the interpretation of the SWAMS model outputs if considered necessary by the Water Corporation.
4. Provide information for further improvement of the South West Aquifer Modelling System (SWAMS) model to minimise the need for interpretation of the results, if considered necessary by the Water Corporation.

The information obtained should be sufficient to allow differentiation of the effects of short-term climatic variation and longer term climate change, and the impacts of groundwater abstractions other than those of the Water Corporation.

Groundwater abstraction

Water Corporation wells will be individually metered and monthly abstractions recorded.

Groundwater levels and water quality

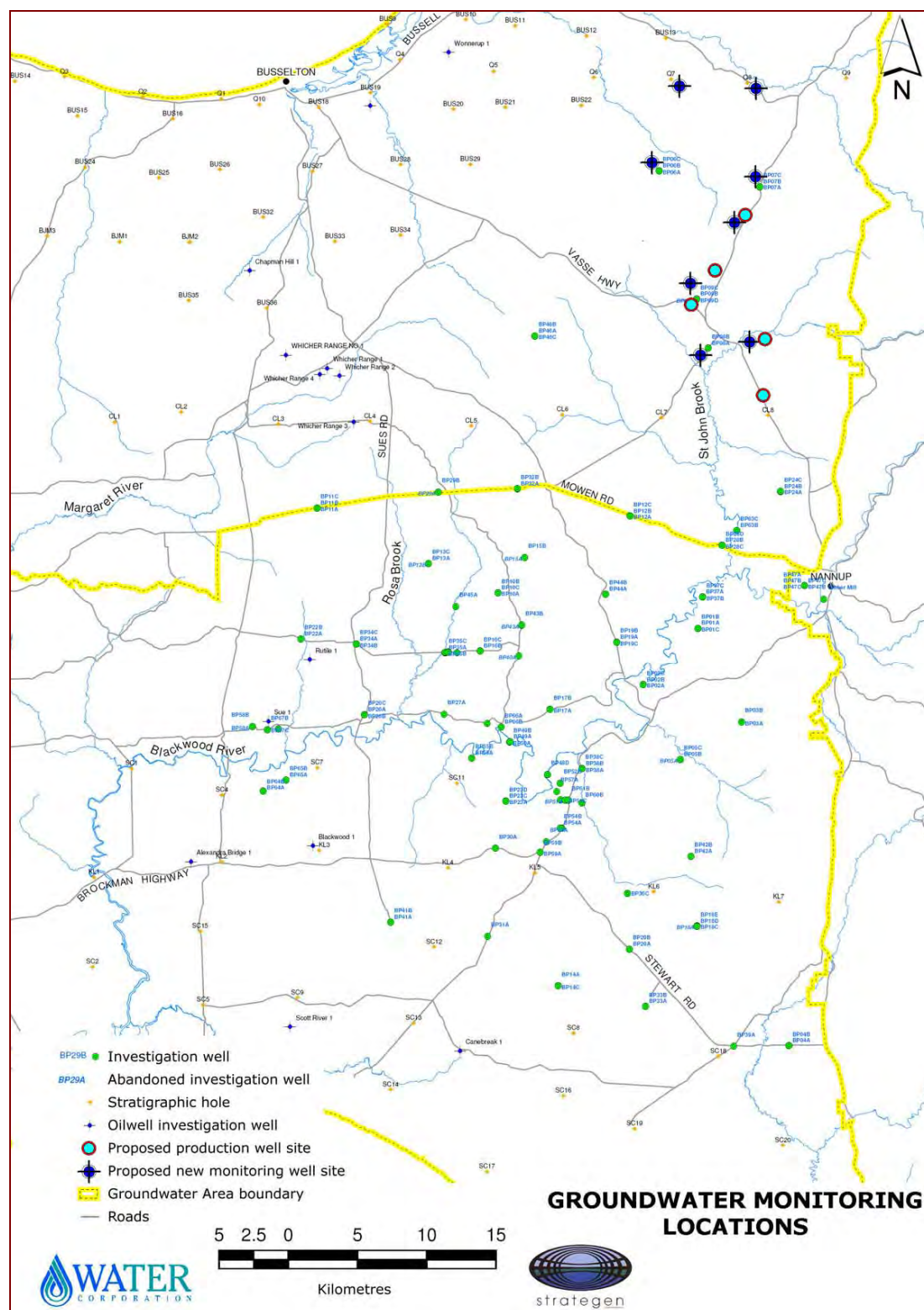
The Water Corporation will establish a monitoring network and undertake baseline monitoring prior to commissioning of the wellfield. Watertable levels and levels in the underlying formation(s) will be monitored monthly for two years following commissioning of the wellfield, and then once every two months. Electrical conductivity and chloride levels in all wells will be monitored annually (June).

The groundwater level monitoring network will comprise all existing investigation wells at the locations shown in Figure 9.1, and will include monitoring of all aquifer intervals available at those sites. Continuous water level recording will be undertaken through data loggers installed in selected wells as outlined below.

The monitoring network will include control sites in areas that are not expected to be affected by the proposal.

Most of the wells to be used for monitoring already exist. Additional wells will be drilled in the vicinity of the proposed wellfield to monitor the local impacts, and to fill gaps in the existing network. The additional monitoring wells are proposed to be drilled at BP06, BP07, BP08, BP09 (two new wells at each site, into Yarragadee Unit 1 and Yarragadee Unit 2) and at Quindalup sites Q7 and Q8 (one new well to 400 m depth at each location, as these zones are not monitored) near the proposed production wellfield. Two additional monitoring well sites are proposed to be drilled near the production wellfield, with two wells at each site to monitor Yarragadee Units 1 and 3.

Figure 9.1 Groundwater monitoring well locations



Data loggers will be installed on the wells listed in Table 9.1.

Table 9.1 Wells to be fitted with water level data loggers

Locality	Wells to be fitted with data loggers
Poison Gully–Milyeannup Brook	BP48 and BP56
Reedia Wetlands	BP67
Rosa Brook	BP10
Swan Coastal Plain	BUS 12
Scott Coastal Plain	SC8, SC19
Water Corporation wellfield	Q7, Q8, BP06, BP07, BP08, BP09, 2 new well sites

The Water Corporation will work with the DoW to develop and implement a program for monitoring seawater intrusion in the Bunbury area.

Stream flow and stream water quality

Monthly gauging of summer streamflow will be undertaken in St John Brook, Poison Gully, Milyeannup Brook and Adelaide Brook from January to April each year at locations close to the confluence of these streams with the Blackwood River. Inflow into St John Brook will be gauged at the point of inflow into Barrabup Pool and Workmans Pool.

Control sites will also be monitored in perennial streams that are not connected to the Yarragadee aquifer. These may include Red Gully, Sollya Creek and a permanent tributary of the Donnelly River.

Annual snapshot gauging will be undertaken in early April each year in the Blackwood River, both upstream and downstream of the Yarragadee outcrop area.

Gauging and water quality sampling of the Blackwood River at Hut Pool and Darradup, and of the Donnelly River and Barlee Brook is undertaken by the DoW as part of a regional water resource monitoring program.

Field electrical conductivity will be measured monthly during summer at all gauged sites. Dissolved oxygen will be measured monthly during summer in pools in the Blackwood River and St John Brook (at 10 minute intervals for a 24-hour period in the mid-depths of each pool).

Length of permanent streamflow in tributaries

St John Brook, Poison Gully, Milyeannup Brook and Adelaide Brook will be observed monthly from January to April each year, and the location of the spring flow source will be recorded.

Surface water levels

Wetland water levels will be measured monthly in the following wetlands:

- Lake Jasper
- Lake Quitjup
- Vasse–Wonnerup Wetlands.

Acid sulphate soils

Monthly sampling and analysis will be undertaken from the superficial formations at the following wells on the eastern Scott Coastal Plain to provide information on potential acid sulphate soil impacts: SC08, SC12, SC17, SC18, SC19, SC20, SC21 and SC22 (Figure 9.1). The sample analysis may include field pH, electrical conductivity, redox potential, sulphate: chloride ratio and the levels of arsenic, iron and aluminium metals present. A similar program of sampling and analysis from the superficial formations will be undertaken for the following wells in the eastern Swan Coastal Plain: BUS6, BUS7, BUS12, BUS20, BUS21, BUS22 and BUS29 (Figure 9.1).

Monitoring of pH and salinity in the Scott River and tributaries is undertaken by DoW at the following monitoring sites (Figure 9.2):

- 609002 • 609151 • 6091223 • 6091225
- 609026 • 6091222 • 6091224 • 6091226

Figure 9.2 Scott river pH sampling locations



8.6.2 Aquatic fauna

The objective of the aquatic fauna monitoring program is to observe trends in the populations and distribution of aquatic fauna in potential impact areas and control areas.

Fish recruitment

Annual sampling of fish in the Blackwood River, Poison Gully, Milyeannup Brook, St John Brook, and at control sites, will be undertaken during September or October. Control sites will be identified that are perennial streams connected to the Leederville aquifer and may include Red Gully and Sollya Creek.

Macroinvertebrates

Macroinvertebrates will be sampled in February and September each year in the Blackwood River, Poison Gully, Milyeannup Brook, St John Brook and at control sites. Control sites will be identified that are perennial streams connected to the Leederville aquifer and may include Red Gully and Sollya Creek.

8.6.3 Terrestrial fauna

The objective of the terrestrial fauna monitoring program is to observe trends in the populations and distribution of terrestrial fauna in potential impact areas.

Fauna

Annual terrestrial fauna surveys of groundwater dependent habitat will be undertaken in the following wetlands:

- Lake Jasper
- Lake Quitjup
- St John Brook
- Poison Gully
- Milyeannup Brook
- Vasse–Wonnerup Wetlands.

8.6.4 Vegetation

The objective of the terrestrial vegetation monitoring program is to observe trends in the health, species composition and condition of vegetation in potential impact areas and control areas.

Further investigation will be required to identify control sites. Appropriate sites will have similar vegetation types to those of the potentially affected areas, but will be in areas expected to be unaffected by the proposal. Aerial photography, contour maps, soil information (if available) and groundwater levels will be used to identify potential control sites. A vegetation survey will be required to determine whether the sites are similar to the potentially affected areas at a site vegetation type level. On the Blackwood Plateau, control sites are likely to be valley systems that are not in connection with the Yarragadee aquifer. On the Coastal Plains, sites with perched watertables and compatible vegetation may be suitable.

Riparian assessment

There will be an annual winter assessment of the condition of riparian vegetation at selected sites along the Blackwood River from Nannup to Hut Pool.

Tree health

Annual monitoring of tagged trees will be undertaken at the established transects associated with the Blackwood River, Poison Gully, Milyeannup Brook, St John Brook, Swan and Scott Coastal Plains and control sites.

Weeds

Annual monitoring of permanent transects along the Blackwood River will be undertaken.

Species composition

There will be annual monitoring of species composition at permanent quadrats at St John Brook, Poison Gully, Milyeannup Brook, Swan and Scott Coastal Plains and control sites.

Vegetation condition

Annual monitoring of vegetation condition will be undertaken in accordance with the Keighery condition rating scale at permanent quadrats at St John Brook, Poison Gully, Milyeannup Brook, on the Swan and Scott Coastal Plains, and at control sites.

Table 9.2 Proposed monitoring program outline

Field	Parameter	Areas	Methods
Hydrology	Length of permanent streamflow	Poison Gully, Milyeannup Brook, St John Brook, Adelaide Brook (Reedia Wetlands)	Measured monthly from January to April by recording the coordinates of the start of the stream flow
	Stream flow	Poison Gully, Milyeannup Brook, St John Brook, Adelaide Brook and control sites	Measure weekly in summer using data loggers (gauging stations not recommended, as they are a barrier to fish migration CENRM (Appendix 26))
	Surface water levels	Lake Jasper, Lake Quitjup and Vasse–Wonnerup Wetlands	Wetland water levels will be measured monthly
	Groundwater levels and groundwater quality	Poison Gully, Milyeannup Brook, St John Brook, Reedia Wetlands, Rosa Brook, Swan Coastal Plain and Scott Coastal Plain and control sites	Monitor watertable levels and levels in the underlying Yarragadee Formation monthly for the first few years (at least 2) of the project and then every two months. Monitor electrical conductivity and chloride levels in all wells annually (June)
Physical	Water quality	Blackwood River, Poison Gully, Milyeannup Brook, St John Brook and control sites	Salinity, conductivity, pH, nutrients (N and P), sampled monthly
	Dissolved oxygen	Blackwood River, St John Brook	Monthly in summer for 10 minute intervals over 24 hours in selected pools and results analysed weekly
	Acid sulphate soils	Swan Coastal Plain, Scott Coastal Plain	Shallow watertable sampling
Aquatic fauna	Fish recruitment	Blackwood River, Poison Gully, Milyeannup Brook, St John Brook and control sites	Annual sampling during September or October
	Macroinvertebrates	Blackwood River, Poison Gully, Milyeannup Brook, St John Brook and control sites	Twice annually during February and September

Field	Parameter	Areas	Methods
Vegetation	Tree health	Blackwood River, Poison Gully, Milyeannup Brook, St John Brook, Reedia Wetlands, Scott Coastal Plain, Swan Coastal Plain (TECs) and control sites	Permanent transects surveyed annually
	Species composition	Poison Gully, Milyeannup Brook, St John Brook, Reedia Wetlands, Scott Coastal Plain, Swan Coastal Plain (TECs) and control sites	Permanent quadrats surveyed annually
	Vegetation condition	Poison Gully, Milyeannup Brook, St John Brook, Reedia Wetlands, Scott Coastal Plain, Swan Coastal Plain (TECs) and control sites	Permanent quadrats surveyed annually
	Riparian assessment	Blackwood River	Permanent quadrats surveyed annually
	Weeds	Blackwood River	Permanent quadrats surveyed annually
Terrestrial fauna	Fauna	St John Brook, Poison Gully, Milyeannup Brook, Lake Jasper, Lake Quitjup and Vasse-Wonnerup Wetlands	Terrestrial fauna surveys near the wetlands

8.7 ADAPTIVE MANAGEMENT RESPONSES INCLUDING CONTINGENCIES

If monitoring indicates that unexpected and significant impacts are likely, the Water Corporation, in consultation with the regulatory agencies and the Monitoring Review Group, will implement an appropriate contingency action within an adaptive management framework as discussed in Volume 1 Chapter 8 Section 3.2.3. Key elements of the adaptive management approach that will be applied in the operation of the South West Yarragadee Water Supply Development are:

1. Management objectives and performance measures will be regularly revisited and, where necessary, revised in agreement with the regulatory agencies following consultation with the South West Yarragadee Monitoring Review Group.
2. System model(s) will be used to explain responses to management actions and to help identify gaps and the limits of scientific and other knowledge.
3. The range of possible response choices will be developed and evaluated in terms of the extent to which each choice would be likely to achieve the management objectives, and the extent to which it will generate new information or foreclose future choices.
4. Monitoring will focus on significant and detectable indicators of progress toward management objectives. Monitoring will also help distinguish between natural perturbations and perturbations caused by management actions. The proposed Monitoring Review Group will be involved in the assessment of monitoring programs and their results.
5. A mechanism(s) for incorporating learning into future decisions.
6. A collaborative structure for stakeholder participation and learning. The Water Corporation intends to achieve meaningful stakeholder involvement that will enable active learning.

The proposed approach to adaptive management of the proposal will ensure that the potential benefits of the proposal will be realised, and the ecological systems dependent on the resource will be protected.

8.7.1 Hierarchy of contingency actions

The proposed contingency measures are hierarchical, ordered by response to impacts of increasing severity as follows:

1. Site specific contingencies as described in Section 8.7.3 of this Chapter. These contingencies include supplementation of flows in the Blackwood River, St John Brook and Milyeannup Brook if unacceptable flow reductions are recorded in any of these systems.
2. Adjustment of the abstraction regime by altering the proportion of water abstracted from the different units of the Yarragadee Formation. If major adjustment of abstraction is required, additional wells will be drilled at identified contingency well sites.
3. Contingencies developed in consultation with the Monitoring Review Group and the regulatory agencies in response to environmental monitoring suggesting unacceptable impacts may occur.
4. Temporary reduction in abstraction rates while further investigations into potentially unacceptable and unexpected occurrence are undertaken.
5. Permanent reduction in abstraction rates where determined appropriate either by the Water and Rivers Commission or the Water Corporation.
6. Cease abstraction and investigate alternative sources.

8.7.2 Contingency triggering process

Monitoring will focus on:

- groundwater drawdown or streamflow (hydrologic) responses
- biological responses.

The process for determining the need for triggering contingency actions for each form of response is set out in Figure 9.3.

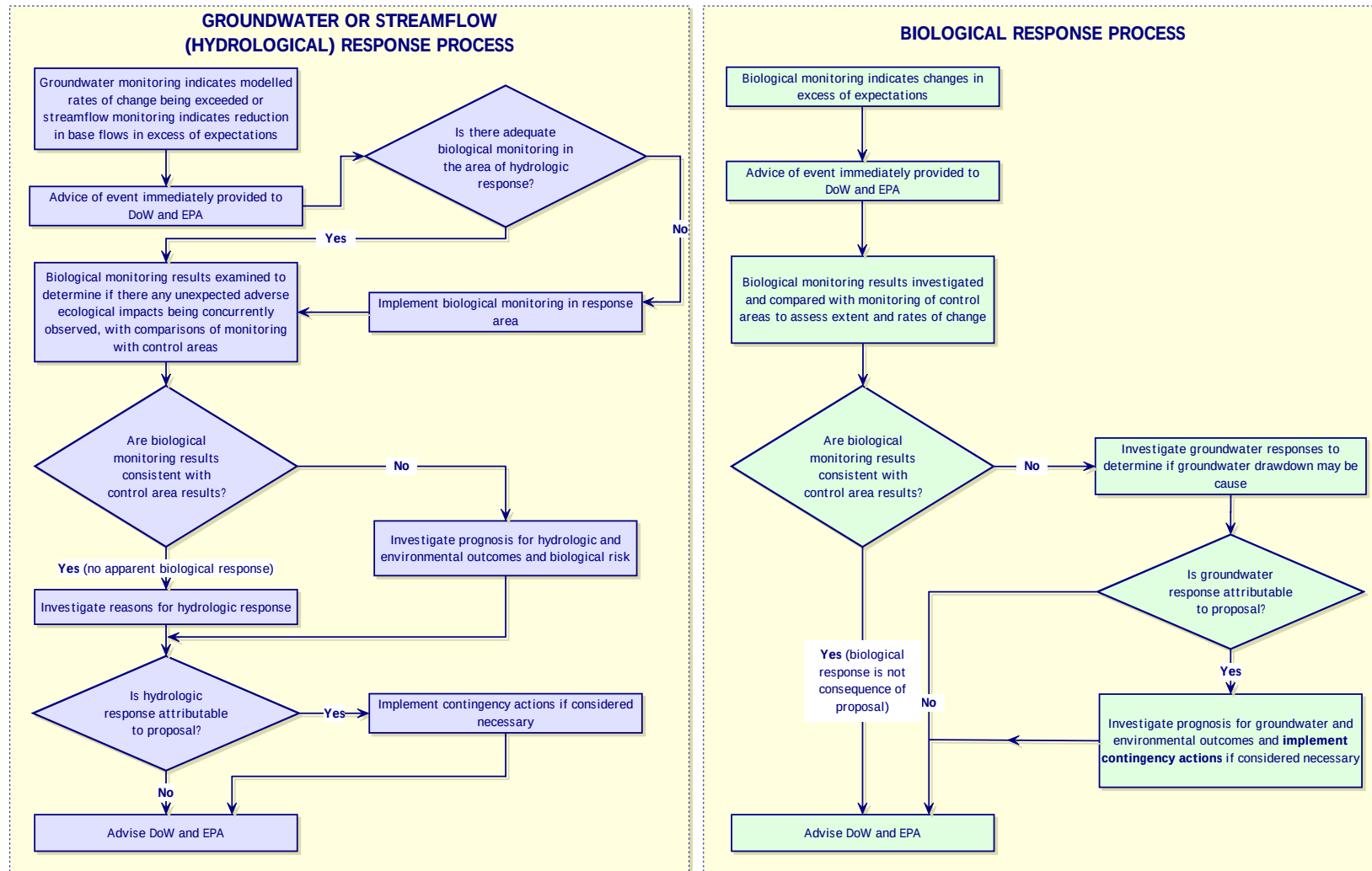
8.7.3 Site specific contingencies

There are several areas where there is an identified expectation of an observable impact, and if that impact exceeds the limits of expectation, then consideration of contingency actions will be triggered. The primary triggers for taking site specific contingency actions are:

- an observed groundwater response occurs at a rate greater than indicated by the modelling
- an observed biological response occurs which is inconsistent with expectations.

Of the areas in which there is potential risk of impact, the areas of Yarragadee Formation outcrop and subcrop beneath the Blackwood River, Poison Gully and Milyeannup Brook are considered the most sensitive to abstraction effects from the proposal. St John Brook is an area of high social and environmental value where the anticipated impacts are small, but would need to be offset if greater impacts than expected were to occur.

Figure 9.3 Flow charts showing action process for responding to hydrological or biological monitoring triggers



The Reedia Wetlands is an important ecological area where no impacts are expected, but would need to be managed if impacts are detected. Groundwater level and environmental responses in other areas of potential impact, such as the coastal plains, will be considered on their merits in terms of extent and cause at the time, as these areas are expected to be impacted by local regional groundwater abstractions to a greater extent than by the proposal.

The specific contingency action and triggering process for each of these potential risk areas is set out in Table 9.3, to be read in conjunction with Figure 9.3.

Table 9.3 Trigger levels and contingency actions

Feature	Response trigger level	Contingency action
Direct groundwater discharge to Blackwood River from Yarragadee Formation	End-of-summer snapshot river gauging indicates decline in Yarragadee Formation direct discharge at rate in excess of modelled prediction	Construct well into upper Yarragadee Formation near upstream extremity of Yarragadee outcrop and supplement summer flows as required to offset difference between predicted and observed discharge rate
Groundwater dependent vegetation on Blackwood Plateau: - Poison Gully - Milyeannup Brook - Rosa Brook - St John Brook	Groundwater level monitoring indicates rate of watertable decline in excess of modelled prediction	Increase vegetation monitoring frequency to quarterly to determine if vegetation response in the specific locality(s) is within the expected range, or exceeds acceptable change*. If response is beyond expected range, decrease Water Corporation abstraction from Yarragadee Unit 3 and increase abstraction from Unit 1. Continue groundwater and vegetation monitoring to observe response. Develop further response options depending on results. If groundwater decline rate is more than twice the rate of modelled predictions, abstraction regime to be modified immediately and investigated
	Monitoring of vegetation changes indicates that change is occurring that is beyond expectations and exceeds limit of acceptable change*	Decrease Water Corporation abstraction from Yarragadee Unit 3 and increase abstraction from Unit 1. Continue groundwater and vegetation monitoring to observe response. Develop further response options depending on results
St John Brook baseflow and pools	St John Brook baseflow falls below historical minimum flow rate	Construct well into Leederville Formation and supplement summer flows to historical minimum flow rates
Balston's pygmy perch habitat in Milyeannup Brook	If both: - regular sampling indicates the consistent presence and abundance of Balston's pygmy perch in Milyeannup Brook between 1000 m and 2500 m from the Blackwood River - hydrological monitoring indicates that the habitat extent (based on habitat area not stream length) of this species is likely to reduce by more than 20% in Milyeannup Brook	Construct well into Leederville Formation and supplement summer flows to reinstate habitat area

Feature	Response trigger level	Contingency action
Reedia Wetland water levels and habitat	Analysis of groundwater level monitoring indicates groundwater level changes that are attributable to proposal	Decrease Water Corporation abstraction from Yarragadee Unit 3 and increase abstraction from Unit 1. Continue monitoring and evaluate to observe effects and determine cause. Develop response options in consultation with regulatory agencies if impact prognosis is likely to be unacceptable
	Monitoring of vegetation changes indicate water-stress related change is occurring inconsistent with control sites	Develop response options in consultation with regulatory agencies if impact prognosis is likely to be unacceptable and changes are clearly attributable to proposal

*Acceptable vegetation change to be characterised by:

- retention of full range of vegetation types (upland to wetland) although areas may change
- continuum of vegetation types is maintained without significant areas of vegetation being in poor health, compared to control sites.

The groundwater modelling used to provide the basis for assessment of environmental impacts has predicted rates of groundwater level change in both the Yarragadee Formation and in the watertable, and consequential changes in groundwater contributions to streamflows. Comparison of the observed and modelled response will be evaluated in accordance with the process in Figure 9.3.

If required, the process step involving “*Investigate prognosis for hydrologic and environmental outcomes and implement contingency actions if considered necessary*” will be undertaken in close consultation with the regulatory agencies and with consideration by the South West Yarragadee Monitoring Review Group.

9 TREATMENT PLANT MANAGEMENT PLAN

9.1 CONTEXT AND SCOPE

The purpose of the Treatment Plant Management Plan is to manage any impacts on the environment, or on human health, resulting from the ongoing operation of the proposed treatment plant. The preferred location for the proposed water treatment plant is approximately 3.5 km from the nearest residence.

A detailed Treatment Plant Operation Management Plan will be prepared for use by treatment plant operators, based on the matters discussed in this section.

9.2 OBJECTIVES AND POLICY CONTEXT

The EPA has issued a guidance statement on Risk Assessment and Management: Offsite Individual Risk from Hazardous Industrial Plant. This statement set the following offsite individual risk criteria for fatalities from hazardous industrial plant as acceptable to EPA:

1. A risk level in residential zones of one in a million per year or less.
2. A risk level in “sensitive developments”, such as hospitals, schools, childcare facilities and aged care housing facilities of 0.5 in a million per year or less.
3. A risk level target at the site boundary for each individual industry of 50 in a million per year and the cumulative level imposed upon an industry of 100 in a million per year or less.
4. A risk level for any non-industrial activity located in a buffer zone between industrial facilities and residential zones of 10 in a million per year or less.
5. A risk level for commercial developments, including offices, retail centres and showrooms located in buffer zones between industrial facilities and residential zones of 5 in a million per year or less.

The guidance statement also indicates the following:

- Best practice – the facility should be based on best practicable engineering design and operated according to best industry practice management systems
- Risk minimisation – risks should be reduced to as low as reasonably practicable. This requires consideration of alternative sites, technologies and a management system which may reduce or eliminate public risks.

9.3 POTENTIAL IMPACTS

As a result of the operation of the filtration plant, between 1 and 4 % of production is used to backwash the filters. This backwash water will be sent to a backwash recovery tank and then to sludge drying beds on the site. Discharge of backwash water to a watercourse is not the favoured option because of its turbidity and bacterial content. The water recovered from the backwash will be treated and used for public water supply, as the most practical solution.

The treatment plant is to be constructed such that storage of chemicals, and treatment processes with a potential for adverse impacts on human health, or the environment, are fully contained within the treatment plant building. Therefore, the potential for chemical leaks as a result of the operation of the treatment plant is considered remote. However, a potential still exists and there is an additional possibility for chemical spills to occur during delivery. The potential impacts posed by such leaks or spills include:

- contamination of soil, surface water and groundwater that is within a water supply catchment area
- public exposure to chlorine.

Discharge of filter backwash water may result in water quality impacts in the receiving environment.

9.4 MANAGEMENT ACTIONS

The Water Corporation has established a standard (SG017) that prescribes acceptable buffer areas around chlorination facilities that meet the EPA guidance statement requirements (Water Corporation 1998). The buffer areas in the standard are:

- 150 m hazard zone (where no housing is allowed)
- 300 m evacuation zone (where residences may be present but evacuation procedures must be developed).

As there are no residences nearby, a buffer of 150 m will be sufficient around the treatment plant.

The chlorination facility will require a licence from DoCEP and a works approval under the EP Act before construction commences. Water treatment facilities (more than 1 ML/d) are required to be registered with DoE before construction.

The dosing plant will use hazardous materials including chlorine, fluoride (fluorosilic acid) and caustic soda. In its gaseous phase, there is potential for chlorine to escape and pose a risk to public safety during accidental spillage or leakage.

The facility will be designed to minimise the amount of operator intervention in normal operations, and to present as low a level of risk as is practicable to the community and the environment. Chlorine will be stored in liquid form in drums and will be contained in a room designed to contain any chlorine gas in the event of drum leakage. The building will also be fitted with chlorine gas detectors.

Other hazardous materials will be handled with standard design and work practices according to the licence agreement.

The DoCEP will review design of the facility and the proponent will meet all of its requirements. Based on a preliminary assessment, the separation distances to sensitive areas (including residences and public roads) will ensure that the proposed location of the facility complies with the EPA criteria and the Water Corporation standard.

The Water Corporation will conduct a quantitative risk assessment to ensure that the plant conforms to the above criteria before seeking a licence for the facility from the DoCEP.

Filter backwash water will be treated and used for water supply. Filter backwash sludge will be dried on-site and removed to an appropriate landfill.

A Treatment Plant Operation Management Plan will be submitted to the DOCEP. The plan will provide detail on management of the day-to-day running of the plant.

9.5 MONITORING, REVIEW AND REPORTING PROGRAM

As part of the Treatment Plant Operation Management Plan, an incident register will be maintained to record any incidents or near misses and used to regularly update management practices. Reporting requirements are expected to be specified by the DOCEP and will be complied with.

9.6 CONTINGENCIES

The management of any spills or leaks will be detailed in the Treatment Plant Operation Management Plan. The general process will involve:

- control of the spill
- containment of the spill
- clean up of the spill
- reporting and notification.

10 TERRESTRIAL FLORA AND FAUNA MANAGEMENT PLAN

10.1 CONTEXT AND SCOPE

The Southern Perth Basin supports locally and regionally significant vegetation communities that provide habitat for flora and fauna of conservation significance, some of which are protected by law. The vegetation communities themselves may also be environmentally significant or have legal protection.

The proposed pipeline routes and location of other infrastructure have been designed to minimise impacts on remnant native vegetation and are mostly kept within agricultural areas or along existing infrastructure corridors. Some clearing will be required to widen the existing routes, and where the pipeline alignment will traverse vegetated areas including State forest.

The Terrestrial Flora and Fauna Management Plan describes the management measures to be implemented during the construction of the pipeline, treatment plant and wellfield infrastructure. This plan describes actions that are required for the Water Corporation to meet its objectives for management of vegetation, flora and fauna, but does not include the management of abstraction impacts.

10.2 OBJECTIVES

The EPA objectives regarding protection of flora and fauna are:

To maintain the abundance, diversity, geographic distribution and productivity of flora and fauna at species and ecosystem levels through the avoidance or management of impacts and improvement in knowledge.

To ensure, as far as practicable, that rehabilitation achieves a stable and functioning landform which is consistent with the surrounding landscape and other environmental values.

Additional objectives of the Terrestrial Flora and Fauna Management Plan are to:

- protect Declared Rare and Priority Flora, consistent with the provisions of the Wildlife Act
- protect Specially Protected Fauna, Priority Fauna and other regionally significant fauna, and their habitats, consistent with the provisions of the Wildlife Act and the EPBC Act and
- comply with Environmental Protection (Clearing of Native Vegetation) Regulations (2004).
- avoid or minimise the potential impact of feral animals on the environment.

Under these Acts and Regulations any disturbance or destruction of native flora without prior approval or specific exemptions is an offence. Some species are afforded additional protection. Additionally under these Acts, any disturbance or destruction of native fauna over and above that reasonably required for construction works and access is an offence.

10.3 POTENTIAL IMPACTS

10.3.1 Pipeline Construction

The primary means of minimising the impacts on native vegetation from the construction of the pipeline has been the selection of a corridor alignment that avoids native vegetation wherever possible. To limit construction impacts, all construction works through areas of native vegetation will be required to maintain a restricted working width of 15 – 20 m.

As discussed in Chapter 8 Section 2.4, a flora survey will be carried out along the pipeline route, prior to construction, to identify any Declared Rare or Priority Flora species, and any trees that provide faunal habitat. These will be avoided wherever possible (e.g. by deviating the route to the other side of the road, or narrowing clearing width for a short length). Should there be no opportunity to deviate the route, application will be made to relocate specimens in accordance with the requirements of the Wildlife Act.

Major watercourses and smaller drainage line crossings will be located away from significant fringing vegetation where possible (i.e. subject to geotechnical and engineering considerations) to limit the need to remove vegetation.

Following construction, the pipeline route will be rehabilitated, with the exception of the area required for maintenance, including a track adjacent to the pipeline alignment.

10.3.2 Treatment plant and storage tank

The treatment plant will be constructed within pine plantations managed by CALM. Due to elevation requirements, the storage tank will need to be constructed within an area of native vegetation.

The Water Corporation will conduct a flora survey of the storage tank site prior to construction to identify any Declared Rare or Priority species in the area. If such species are identified, it may be necessary to relocate those plants as the storage tank location is constrained by site requirements. In that instance, application will be made to relocate specimens in accordance with the requirements of the Wildlife Act.

10.3.3 Wellfield construction

All the well sites have been chosen close to access roads to allow ease of access and minimise disturbance and clearing requirements. At each site, some clearing will be required to allow for construction of the well. As discussed in Chapter 8 Section 2.4, a flora survey will be carried out at each well site prior to construction to identify any Declared Rare or Priority Flora species, and any trees that provide faunal habitat. If significant species are recorded within the area to be cleared, the well site will be moved to avoid disturbance.

The area required for operation and maintenance of the well at each site will be less than that required for construction. Therefore, in most instances there will be the opportunity for the early rehabilitation of areas that have been cleared for construction purposes.

10.3.4 Vegetation and flora

Removal of vegetation from the proposed pipeline corridor, treatment plant locations and well sites has the potential to:

- disturb Declared Rare and Priority Flora
- change the abundance, species diversity, geographic distribution and productivity of vegetation communities
- compromise the conservation values through impacts on regionally significant flora and vegetation communities
- introduce weed species
- introduce forest diseases.

10.3.5 Fauna

The potential impacts of the proposed pipeline corridor, treatment plant locations and well sites on fauna are largely temporary and include:

- loss of habitat
- fragmentation of habitats and interruption of access to feeding grounds and water supplies
- lack of cover for desiccation-prone species such as frogs
- increased predation in cleared areas due to lack of cover
- improved access for feral predators, such as cats and foxes, into bushland areas via cleared tracks
- introduction of vermin into previously vermin-free areas
- injury or death through falling into and becoming trapped in open trenches
- injury and death through accidental collisions with construction vehicles.

10.4 MANAGEMENT ACTIONS

10.4.1 Vegetation clearing

The Water Corporation will ensure that the following actions are implemented:

1. Clearing zones will be shown on construction plans and, prior to disturbance, marked by pegs or flagging.
2. The Corporation will develop detailed construction procedures, and a clearing checklist, to minimise clearing of native vegetation. The checklist will include hold points that require further approval by a qualified environmental officer.
3. Approved Water Corporation personnel will mark trees that must not be damaged in any way, and trees whose trunks are to be retained for rehabilitation.
4. The Corporation will not destroy, remove, or clear trees, timber, or scrub to any extent greater than that approved. The Corporation will not carry out any activity outside the areas defined for clearing, unless otherwise approved.

5. Cleared native vegetation will be chipped and retained on site for rehabilitation.
6. No cleared vegetation will be burnt.

10.4.2 Management of significant flora

The current alignment of pipeline corridors has been chosen to avoid currently listed significant flora. A baseline spring flora survey will be undertaken to ascertain if any priority species will be removed as a result of the pipeline construction. If there is a need to remove plants, the Water Corporation will obtain approvals, where required, as well as agreeing with the relevant stakeholders on options for seed collection and re-establishment.

Agreement will be reached with CALM regarding requirements for re-establishment of any significant flora removed.

10.4.3 Removal and storage of topsoil

Topsoil is a valuable resource that must be carefully protected where possible, or otherwise removed, stored, and re-used where appropriate. The following actions will be undertaken:

1. Topsoil under significant, marked trees will not be disturbed or compacted.
2. Topsoil along the pipeline disturbance zone, and other areas of earthworks will be stripped to a depth of 150 mm and temporarily stockpiled in a windrow adjoining its area of origin. If topsoil extends to a depth greater than 150 mm, a second layer of topsoil will be removed to a depth of 200 mm, and stockpiled in a separate windrow adjacent to the first windrow.
3. Overburden will be removed and placed in a separate windrow.
4. Where necessary, to avoid damage to adjoining vegetation, stripped topsoil or overburden will be temporarily removed from the construction site and stored as close as possible to its place of origin.
5. Areas of native vegetation with weed-free understorey will be identified and the boundary marked so that topsoil stripping operations in those areas are kept separate. Stripping operations will not continue across the boundary from pastured or weedy areas into native vegetation. Similarly, stripping operations will not continue across the boundary between dieback infested and dieback free topsoil.
6. Machines used for pushing and heaping operations will be fitted with root rakes, or similar equipment, and operated such that as little topsoil as possible is removed and heaped with cleared vegetation material.
7. Topsoil that has been removed and cannot immediately be used will be stockpiled in approved locations. These stockpiles will be as close as possible to the site of origin, and in areas that will not restrict or interfere with existing site drainage or vegetation.
8. Compaction of topsoil during stockpiling will be avoided. Topsoil will be left in the stockpiles for a maximum period of four months.
9. The quality of topsoil in stockpiles will be maintained by measures including protection against contamination from other materials, minimising stockpiling periods, and prevention of erosion by surface runoff or wind.
10. Monitoring for erosion and erosion risk will be undertaken regularly to ensure that any erosion that does occur is promptly mitigated.

11. Any spoil will be replaced in the area from which it was removed. Any excess spoil will be removed from site and taken to a site agreed by the relevant Local Authority.
12. Management of acid sulphate soils is discussed in Section 20 of this Chapter.

10.4.4 Fauna management

The approved fauna management procedures will include, but not be limited to, the following:

1. The Water Corporation will ensure that all staff are educated in relation to the risks of fauna deaths and management of animals that are injured or displaced. Any native fauna found injured will be taken to a veterinary clinic or a designated CALM wildlife carer as soon as is practicable. Contact numbers for the veterinary clinics and designated carers will be available and easily accessible on site.
2. A designated, trained person will be available to remove fauna from the construction areas. The Corporation will ensure all on-site workers are aware of the presence of any rare and priority species in the area (as outlined in this ERMP) and understand their responsibilities in the event of an animal being found. The Corporation will ensure all on-site workers have access to a list of preferred carers and veterinarians and their contact details.
3. No private firearms, other weapons, or pets will be allowed on the construction site under any circumstances.
4. No native fauna (including venomous snakes) will be impaired or killed by construction personnel. Fauna can only be destroyed as a last resort by a designated, trained person with CALM authorisation.
5. Destruction of faunal habitat will be minimised by minimising clearing, and ensuring no dead, standing or fallen timber is unnecessarily removed. Where existing fallen logs partially overlay the clearing zone they will be cut at the boundary to preserve that part of the log that remains outside the clearing zone.
6. Pipe ends will be sealed when work is not in progress to prevent fauna entering the pipeline.
7. The Corporation will ensure litter and rubbish at the site is removed, especially food scraps, to prevent the increase in numbers of undesirable fauna species.

10.4.5 Trench management

The Water Corporation will ensure that:

1. The pipeline trench is kept open for the minimum period required to undertake works.
2. The Corporation will ensure temporary fencing or barriers are placed along the pipeline trench in areas that are likely to be used as fauna corridors (e.g. possible linkages between areas of bushland) such that animals will be directed around the excavation.
3. Where it is not possible to close a trench or fence it off, and the trench will be open for periods longer than 10 hours, or will be unattended or not in use, then soil ramps should be provided to facilitate the escape of trapped wildlife.
4. The pipeline trench will be checked daily for fauna, and any fauna within it will be removed as soon as possible without damage to the animal.

10.4.6 Rehabilitation of faunal habitat

Rehabilitation of the construction zone aims to provide a safe environment for fauna and to replace and enhance pre-existing faunal habitat within the area. The Water Corporation will ensure that:

1. Soil is replaced in a manner that blends with existing soil contours, and avoids creating ridges and holes.
2. Topsoil and chipped vegetation is replaced over the rehabilitation zones.
3. Any logs or other material that has value for faunal habitat is replaced within the rehabilitation zone.
4. All fencing is restored to its original condition to the satisfaction of CALM or the relevant land manager.

10.5 MONITORING, REVIEW AND REPORTING PROGRAM

The key monitoring requirements are:

- a baseline flora survey prior to construction
- monitoring and reconciliation of all clearing activities against approved clearing limits
- incident monitoring to include accidental over-clearing, clearing of Declared Rare Flora or Priority Flora, and death of Priority and other native fauna
- monitoring of rehabilitation performance.

10.6 CONTINGENCIES

The Terrestrial Flora and Fauna Management Plan will set out contingency actions to be taken in the event that monitoring shows that clearing or construction activities have breached or may be in breach of requirements and may result in detrimental effects on terrestrial flora or fauna. Such actions are likely to include:

- immediate cessation of activity
- notification of appropriate regulatory agencies
- review of clearing control procedures
- re-education of the workforce.

11 WEED MANAGEMENT PLAN

11.1 CONTEXT AND SCOPE

Weed species can compete with, replace, or compromise native species. In agricultural areas they can reduce farm productivity and product quality. Areas that are particularly vulnerable to weed infestation include watercourses, where higher moisture levels may encourage rapid infestations, and agricultural areas, where species competition is limited and soil disturbance is high.

The proposed pipeline, wellfield and treatment plant developments have the potential to introduce and spread weed species. Therefore, management plans are required to minimise the potential impacts of weed infestations at all stages of construction and operation of the proposed project.

11.2 OBJECTIVES

The objective for weed management throughout the proposed development is:

Avoid or minimise the potential for the spread of weeds

11.3 POTENTIAL IMPACTS

Construction activities may provide conditions for opportunistic weed species to invade and thrive in disturbed soils at the wellfield, along the pipeline route, and on the treatment plant site. This problem is compounded by the fact that many weed seeds remain dormant in soil until the area is disturbed (APIA 1998). The linear development of the pipeline route also introduces the potential for weeds to be spread along the corridor and carried into previously weed-free areas.

11.4 MANAGEMENT ACTIONS

Prior to construction, the Water Corporation will develop a Weed Management Plan as part of the Construction Environmental Management Plan to ensure that weed species are not introduced to, or spread along the pipeline, wellfield and treatment plant areas. A weed survey will be completed prior to the development of the plan to ensure the inclusion of relevant information.

The Weed Management Plan will be developed in consultation with the Western Australia Department of Agriculture (AgWA) and CALM, and will include:

1. Delineation of areas of weed infestation on construction plans.
2. Identification of appropriate sites for the location of vehicle and equipment clean-down areas.
3. Methods to avoid or minimise disturbance to areas that may be vulnerable to weed infestation.
4. Identification of practical vehicle and equipment hygiene measures to be implemented as required along the proposed pipeline length.

5. Procedures to ensure that soil from the areas where Declared Plants⁵³ and other identified, significant, environmental weeds are identified will be isolated and will remain at the source location and will be replaced in that area.
6. Procedures to ensure that any spoil containing Declared Plants, or from areas where they were present, will be disposed to an area which is not at threat from weed infestation, or from which the weeds cannot spread (e.g. a designated landfill site).
7. Segregation of topsoil from agricultural and remnant vegetation areas to ensure that pasture or agricultural crop species are not carried into vegetated areas.
8. Measures to ensure that all imported construction materials (e.g. topsoil, straw bales, revegetation material) are certified weed-free by the supplier prior to acceptance onto the proposed development area.

11.5 MONITORING, REVIEW AND REPORTING PROGRAM

To determine if the activities of the Water Corporation are spreading or encouraging weed growth and establishment, pre- and post-disturbance monitoring of weed species is required. Components of the monitoring program will include:

- identification of baseline weed numbers, distribution, and species along the proposed pipeline corridor and treatment plant areas
- regular monitoring of weed growth and distribution throughout the development process
- development of reporting procedures to ensure that any Declared Plants located during construction are reported promptly to AgWA.

The effectiveness of the Weed Control Program will be assessed by the following performance indicators:

- incidences of weeds within the infrastructure development and access areas
- the extent of workforce compliance with hygiene requirements.

11.6 CONTINGENCIES

If weed encroachment associated with the project is identified through the monitoring and review process, the following contingency measures should be put in place:

- development of appropriate measures for the treatment of weed infestations, possibly including treatment with appropriate herbicides
- training and induction programs for project staff and contractors to ensure that weed control measures are appropriately implemented and that key weed species can be readily identified and treated.

⁵³ A Declared Plant is a weed that has been “Declared” under the *Agriculture and Related Resources Protection Act 1976*.

12 FIRE MANAGEMENT PLAN

12.1 CONTEXT AND SCOPE

There is some risk that fires will be started as a result of construction activities, especially as some sections of pipeline will require welding. There is also a risk due to vehicle movement, hot works and sparks, vegetation clearing, and careless disposal of matches.

Construction activities will be managed to minimise the risk of fire. Fire protection measures must also include emergency response procedures. Fire management measures are required to prevent impact on people, property, and the environment.

12.2 OBJECTIVES

To minimise the risk of fire and to be able to respond effectively should a fire occur.

Fire management requirements of local authorities, the Fire and Emergency Services of Western Australia (FESA) and CALM will be complied with where relevant. This includes consideration of the following acts:

- *Bush Fires Act 1954*
- *Conservation and Land Management Act 1984.*

12.3 MANAGEMENT ACTIONS

The Fire Management Plan will include the following procedures and requirements:

1. All on-site personnel (unless escorted) will have been inducted and will be familiar with the fire management requirements of the site.
2. All site personnel will abide by the *Conservation and Land Management Act 1984* and the *Bush Fires Act 1954* and to Regulations made under those Acts for the purpose of controlling fires.
3. Personnel will comply with any statutory limitations regarding fire risk, including restrictions on lighting fires in the open, on equipment that can be used, and on the scope of work that can take place. This includes specific restrictions on declared days of “high”, “very high” or “extreme” fire danger. At these times there may be restrictions on certain activities, such as cutting and grinding, and on using naked flames of any kind.
4. Maintenance of regular contact with CALM and the Bureau of Meteorology for daily bushfire danger ratings and weather forecasts. Daily fire weather forecasts will be displayed in the site office during the high fire risk months (usually November to April).
5. If a large number of bushfires are burning in the area and causing the depletion of fire fighting resources, CALM may discuss curtailing the works. In these circumstances contractors will maintain regular liaison with CALM and FESA.

6. Contractors, or any person employed by contractors, will take all necessary precautions to prevent the occurrence or spread of fire. Contractors will be liable for suppression costs and damage caused by any fire on, or extending from, the construction area, unless they can prove to the satisfaction of the contract Superintendent that the fire originated outside the construction areas(s) and/or arose through some cause beyond their control. The Water Corporation will not accept any liability for the loss or damage by fire, however started, of any equipment or property owned or operated by a contractor or any of his employees.
7. Contractors will carry out a Fire Risk Assessment for all construction activities (including vehicle and plant movement, welding and cutting, fuel storage, cigarette smoking). The results of the Fire Risk Assessment will be used to develop plans for the location of fire extinguishers and water tankers on an ongoing basis.

12.4 IGNITION PREVENTION

In the performance of work under contract, the Water Corporation will ensure that:

1. All personnel will dispose of cigarette butts and matches in a careful and appropriate manner (ashtrays or a designated area).
2. Any activity that may cause a fire or produce sparks (e.g. welding, cutting steel) will be supported by a 500 litre water tank on stand-by within 1000 m of the work area, fitted with pumps and hoses, and with at least one additional operator present at all times to operate the fire fighting equipment.
3. Where fuels, oils or electrical devices are present, which may ignite in the event of a fire, the contractor will ensure that a functional fire extinguisher of the appropriate type and capacity is on hand for immediate use.
4. All vehicles and plant used on site will be checked and serviced regularly to prevent or repair oil and fuel leaks.
5. Plant operators will be responsible for monitoring and immediately reporting any vehicle or plant defects.
6. No vehicles with catalytic converters will be permitted to drive in grassy areas during “extreme” fire risk conditions, or to park in highly grassed areas. On declared days of “very high” and “extreme” fire danger, a ban on vehicle movement may be declared. On such days CALM may discuss curtailing operations for all or part of the day.
7. Maintenance of equipment will include the removal of combustible material from radiators, tracks, guards and the undercarriage of all vehicles and plant on a daily basis.
8. Tractors, bulldozers and road graders will not be used during prohibited burning times, unless they are fitted with a vertical exhaust system which is maintained in a sound and efficient condition and fitted with a spark arrestor (*Bush Fires Act 1954*).
9. Flammable liquids and materials will be stored in safe, designated areas only.
10. Approved, serviceable fire extinguishers, of sufficient capacity will be appropriately positioned during refuelling operations.

12.5 CONTINGENCIES

In the performance of the construction works, the Water Corporation will:

1. Delegate responsibility to a Site Fire Officer.
2. Immediately report any fires arising from construction work to FESA and CALM where appropriate.
3. Have available such equipment as may be required by FESA, CALM and local bush fire brigades for the fighting of fires.
4. Be responsible for the initial fighting of any fire that has been started.
5. Communicate the emergency response and evacuation procedure to all personnel.

13 FOREST DISEASES MANAGEMENT PLAN

13.1 CONTEXT AND SCOPE

Pipeline, wellfield and treatment plant construction activities have the potential to introduce and spread forest diseases such as jarrah dieback (*Phytophthora cinnamomi*) and armillaria root disease (*Armillaria luteobubalina*).

Both jarrah dieback and armillaria root disease are soil borne diseases which cause root rot in a wide variety of plants and therefore restrict water uptake by infected plants. Both diseases are spread very slowly through the soil and are most commonly introduced to an area by infected plants, roots or mulches being brought into an unaffected area. Armillaria is thought to be able to survive in the soil for up to 50 years.

Symptoms of jarrah dieback and armillaria diseases are similar and include dieback of the limbs and branches, yellowing of foliage, splits in the trunk, poor vigour, the leaking of sap from the trunk, scars on the trunk, and darkening of the larger roots. Stresses such as drought, flooding, and disturbance or compaction of soil through clearing and land development, can weaken the defence systems of plants and trees and increase the chances of infection.

13.2 OBJECTIVES

The objective of the Forest Diseases Management Plan is:

To avoid the incidence and spread of forest disease through construction activities

13.3 POTENTIAL IMPACTS

The clearing of vegetation and movement of machinery associated with the development of the proposed pipeline, wellfield and treatment plant has the potential to introduce or spread jarrah dieback and other forest diseases. Specific aspects of the proposed development that have the potential to spread forest diseases include:

- vehicle and machinery movements associated with surveying, clearing of vegetation, soil disturbance, pipeline construction and other associated activities
- personnel with contaminated soil and plant material on boots and equipment
- movement of contaminated soil to areas that are disease free
- use of infected seedlings in rehabilitation.

13.4 MANAGEMENT ACTIONS

The main priorities for the minimisation of forest disease in infrastructure development and access areas include:

- detection of existing forest disease prior to construction
- planning operations to minimise disease risks, including assurance that all imported construction material (e.g. topsoil, straw bales, revegetation material) are certified disease-free by the supplier prior to acceptance into construction areas

- establishment of blowdown or wash down areas in infected areas. All vehicles, machinery and equipment exiting infected areas will be cleaned to remove soil. The Water Corporation is required to ensure that only clean vehicles enter disease free areas.
- segregation of topsoil and vegetation from dieback-free areas from those removed from infected areas
- reinstatement of diseased and/or disease free material to its place of origin
- prevention of infected material (vegetation or topsoil) being stockpiled adjacent to watercourses
- management of drainage from infected areas to prevent drainage into disease-free areas
- sourcing of water for dust suppression and bushfire control from dieback free sources, or sterilisation of prior to application
- scheduling construction activities to minimise works in wet conditions.
- education of the workforce about forest disease.

To ensure that the legal and policy requirements and management objectives relevant to forest disease control are met, the Water Corporation will develop and implement a Forest Disease Management Plan as part of its CEMS. This plan will detail the planning, operational and monitoring requirements necessary to prevent the spread of forest disease by construction activities for the wellfield, pipeline and treatment plant.

13.5 MONITORING, REVIEW AND REPORTING PROGRAM

To determine if the activities of the Water Corporation are affecting the rate of spread of forest disease, and to determine appropriate management strategies, pre-disturbance and post-disturbance monitoring will be required. Monitoring of the health of jarrah dieback indicator species will be carried out for interpretable areas of forest. This method has limited applicability in detecting armillaria root disease, as some areas have no indicator species for this disease.

The effectiveness of the Forest Disease Management Plan in achieving its objective will be evaluated by the following performance indicators:

- no introduction of dieback to previously dieback-free areas
- the extent of workforce compliance with hygiene requirements.

Both monitoring activities and preparation the Forest Diseases Management Plan will be carried out in accordance with the requirements of CALM.

The results of monitoring will be reported in the Water Corporation's publicly available Annual Sustainability Review.

13.6 CONTINGENCIES

No contingencies are considered necessary.

14 NOISE AND VIBRATION MANAGEMENT PLAN

14.1 CONTEXT AND SCOPE

Construction of the treatment plant and wellfield is in an area within State forest where potential noise and vibration impacts will be low.

The proposed pipeline construction has the greatest potential for noise and vibration impact. Most of the pipeline construction will be along existing road alignments and within agricultural areas. It is not expected that construction will be in close proximity to many residences. However, activities such as blasting and earthworks do have a potential to impact on nearby residences. The level of impact from noise and vibration through the construction of the wellfield, pipeline and treatment plant will be determined by:

- the proximity of the noise source to residences
- prevailing weather conditions
- the characteristics of the sounds emitted.

This plan describes the management of noise and vibration from the construction of the pipeline and treatment plant associated with the proposal.

14.2 OBJECTIVES

The relevant EPA objectives regarding noise and vibration include:

To protect the amenity of nearby residents from noise impacts resulting from activities associated with the proposal by ensuring the noise levels meet statutory requirements and acceptable standards.

Relevant statutory requirements include the Australian Standard 2436-1981 “Guide to Noise Control on Construction, Maintenance and Demolition Sites”.

14.3 POTENTIAL IMPACTS

Pipelines are to be installed underground, so blasting or rock breaking may be required to create the trench in areas where hard rock is encountered. Operations are not likely to regularly take place near residences, but there is still a low potential for noise and vibration to affect nearby residents from:

- blasting or rock breaking
- equipment operation associated with earthmoving and drilling
- vehicle operation which may result in increased traffic levels.

14.4 MANAGEMENT ACTIONS

Blasting will be used as a last resort. Other less disruptive methods are expected to be sufficient in most circumstances.

The noise levels stipulated in the Environmental Protection (Noise) Regulations 1997 apply only to construction activities carried out between 7 am and 7 pm on Sundays and public holidays, provided that:

- a noise management plan is submitted to the Chief Executive Officer of the DoE
- construction work is carried out in accordance with Section 6 of the Australian Standard 2436-1981 Guide to Noise Control on Construction, Maintenance and Demolition Sites
- the equipment used is the quietest reasonably available.

Management actions may also include:

- equipping construction equipment with appropriate noise-control devices, and maintaining all plant and machinery in good working order
- locating fixed noise-generating equipment (e.g. generators, compressors) at appropriate distances from residences, and/or within noise enclosures as necessary
- providing noise-attenuation screens as appropriate
- controlling vibration levels to prevent possible damage to buildings or structures.

For any construction work to be undertaken other than between 7 am and 7 pm on any day which is not a Sunday or public holiday:

- the occupants of all nearby residences will be advised of the work at least 24 hours before it commences
- the work will be undertaken in accordance with a separate noise management plan which addresses:
 - justification for the work being done outside normal hours
 - types of activity which could be noisy
 - predictions of noise levels
 - control measures for noise and vibration
 - monitoring for noise
 - response to complaints.

14.5 MONITORING, REVIEW AND REPORTING PROGRAM

A noise monitoring program will be designed which will provide for continual monitoring and regular review of operations. The review process will identify the most appropriate timing and conditions for noisy operations. Examples of the noise monitoring and review process include:

- if rock breaking or blasting is required within 100 m of any residences or buildings, ground vibration will be measured and kept to recognised standards
- noise levels and air-blast overpressure will be recorded for selected blasting events, and the most appropriate timing and conditions for blasting determined.

As part of the review and reporting process, weekly reports will be provided by the Site Manager to a Water Corporation environmental representative. The Water Corporation environmental representative will liaise daily with the Site Manager, and any complaints will be managed in accordance with a documented complaints response procedure to be determined at a later date.

The effectiveness of noise management measures will be indicated by compliance with the guidelines and the number of noise complaints.

14.6 CONTINGENCIES

If monitoring data suggests noise and vibration levels are in excess of guidelines, the following contingencies will be implemented:

1. Works may be stopped while appropriate noise and vibration controls are implemented.
2. Works may be stopped until a more appropriate time during the day (or night) or until more appropriate weather conditions prevail.
3. Modification of operating practices and/or machinery to reduce noise emissions and associated impacts.

15 DEWATERING MANAGEMENT PLAN

15.1 CONTEXT AND SCOPE

The pipeline will be constructed below ground and dewatering may be required to allow its construction. It is unlikely that extensive dewatering will be required as it will only be necessary in areas with shallow watertables and where the pipeline crosses beneath rivers.

The Dewatering Management Plan applies to the construction of the collector mains and the transfer mains to Harvey. The plan describes those actions which are required for the Water Corporation to meet management objectives and requirements.

15.2 OBJECTIVES

The specific objectives for dewatering during construction of pipelines are:

To ensure dewatering does not cause erosion of soils and natural drainage lines or adversely affect vegetation and fauna through contamination.

To minimise the impact of storm water run-off on the dewatering operation.

15.3 POTENTIAL IMPACTS

Approximately 14 km of the pipeline route on the Swan Coastal Plain, and 3 – 4 km on the Blackwood Plateau, will require dewatering. Water discharged through dewatering may cause the following impacts:

- loss of environmental values of receiving waters, or significant threat to those values
- harm to native vegetation, or erosion of structures or services
- soil erosion or local flooding
- sediment build-up in drains, waterways or wetlands
- nuisance to the local community (e.g. foul odours, impacts on plants, properties, or other hazards to the public)
- acid generation through exposure of acid sulphate soils.

The impacts of watertable drawdown on vegetation are expected to be negligible due to the temporary nature of dewatering.

15.4 MANAGEMENT ACTIONS

Management of dewatering activities will include consideration of:

1. Identification of locations (prior to construction) along the pipeline where dewatering activities will be required.
2. Characteristics of the affected aquifer, including hydraulic conductivity and potential zone of drawdown impact.
3. The commencement date, duration, anticipated quantity and frequency of de-water discharge.

4. Determination of the quality of water to be discharged, including contaminant concentrations based on natural groundwater contaminants and the local land use history.
5. Determination of chemical characteristics of the soil and the likelihood of acid sulphate release in the de-water process.
6. Assessment of the need for, and viability of, water treatment of water to be discharged (e.g. settling, biological stabilisation, pH adjustment, chemical flocculation or filtration) or sediment settling requirements.
7. Baseline assessments of the receiving environment (before dewatering), including water flow and quality.
8. Verification that discharge water quality will consistently comply with the indicative criteria set out by the Department of Environment in their Water Quality Protection Note “Dewatering of Soil” (August 2003).
9. Proposed containment and disposal methods.
10. A monitoring framework for groundwater quality and quantity, and appropriate contingency measures.

The quality of groundwater along the pipeline route is to be determined prior to commencement of dewatering, and the results used to determine appropriate management methods. Wherever practicable, dewatering water will be discharged into an area that will allow infiltration into the aquifer from which it was extracted. An expert environmental scientist will provide advice on the location and manner of ongoing dewatering discharges.

The requirement for dewatering will be minimised, as far as practicable, by measures such as undertaking the construction of the pipeline during summer, and minimising the construction period.

Acceptable water quality criteria for any discharges will be determined prior to construction in consultation with the DoE and DoW.

15.5 MONITORING, REVIEW AND REPORTING PROGRAM

Monitoring of dewatering discharge will consist of testing dewatering water as follows:

- on-site, before dewatering, with results compared to pre-determined acceptable release criteria
- at regular intervals during off-site discharge, to provide confidence in continued effectiveness of the chosen management method
- following treatment, to determine the effectiveness of the treatment method.

Monitoring results will be regularly reviewed to determine the appropriateness of management actions. The Site Manager will provide weekly reports on dewatering activities and monitoring to the responsible Water Corporation officer.

15.6 CONTINGENCIES

Where the quality of dewatering discharge water exceeds the water quality criteria determined in consultation with the Department of Environment, potentially leading to adverse impacts to environmental values or land use activities, the discharge water will either be stored in a contained system for treatment before discharge, or otherwise disposed off-site.

16 DUST MANAGEMENT PLAN

16.1 CONTEXT AND SCOPE

Dust is expected to be generated by clearing of vegetation, earthworks and blasting during the construction of the pipeline, wellfield and treatment plant. To limit the potential for dewatering, the pipeline will be constructed predominantly during summer, which will increase the potential for dust during construction.

The Dust Management Plan applies to the construction of the pipeline, wellfield and treatment plant associated with this proposal, and describes those actions which are required for Water Corporation to meet its management objectives and requirements.

16.2 OBJECTIVES

The main EPA objective for dust management is:

To ensure that emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.

16.3 POTENTIAL IMPACTS

Dust emissions may be produced from the construction of the wellfield pipeline and treatment plant through a number of construction activities including:

- vegetation clearance and removal
- topsoil removal and storage
- trench line excavation
- movement of construction machinery on the wellfield site, along the pipeline route or over the designated treatment plant area
- drilling
- post-construction rehabilitation of disturbed areas.

Dust may also be generated, when no site works are occurring, by the action of wind on stockpiles and denuded areas.

The main impacts associated with dust generation are loss of visual amenity, nuisance, and potential health issues. Dust generation may also degrade agricultural produce.

No vegetation removed from the pipeline route will be burnt, in accordance with EPA and DoE guidelines, so no impacts associated with smoke generation will occur during construction.

16.4 MANAGEMENT ACTIONS

The Water Corporation will implement dust control provisions and contingencies as required for the level of risk classification in the DEP (1996) guidelines. These may include:

- use of watering tankers or carts, temporary windbreak fencing and hydro-mulching, as required by soil types and wind conditions

- rehabilitation of cleared areas as soon as practicable
- minimisation at all times of area of exposed surfaces such as stockpiles and cleared areas
- restriction of vehicle speeds, and the number of vehicle movements, on unsealed roads during hot, dry and windy conditions.

During construction, the site noticeboard is to be updated daily with 2-day weather forecasts of temperatures and winds for all contractors to take into account during the construction phase. All contractors will look out for dust generation, and report any dust being visibly carried off-site.

16.5 MONITORING, REVIEW AND REPORTING PROGRAM

The Dust Management Program will allow consideration of any complaints about dust (including soiling of vehicles) from neighbouring residential and commercial premises to guide future decision making and the implementation of appropriate contingencies.

For areas of high risk of dust generation, dust monitoring equipment may be required upon the direction of the Water Corporation environmental representative.

16.6 CONTINGENCY ACTIONS

If monitoring of dust levels indicates that performance criteria are not being met, or are unlikely to be met, appropriate management actions will be initiated. Action may consist of:

- erection of mesh fences to prevent dust from leaving the site
- increasing the application of water to work areas to prevent dust generation
- ceasing work until weather conditions improve.

17 WASTE MANAGEMENT PLAN

17.1 CONTEXT AND SCOPE

The production of waste such as packaging, sewage and hydrocarbons, is associated with all construction sites will take place during construction of the pipeline, wellfield and treatment plant.

17.2 OBJECTIVES

The objective for the management of waste on construction sites is:

To dispose of waste in an environmentally acceptable manner.

17.3 POTENTIAL IMPACTS

Liquid and solid wastes will be generated during construction of the pipeline, wellfield and treatment plant. Typical wastes include:

- site office rubbish, paper, packaging and rubbish from the site
- spent welding rods, grinding wheels, visors and shot blast from welding operations
- spoil and surplus rock from boring activities or backfilling
- chemical spills (see Section 18 of this Chapter)
- sewage from temporary toilets, both at the site and throughout the proposed development area
- used lubricating oils from machinery maintenance.

Inappropriate waste disposal has the potential to:

- contaminate soil, surface water or groundwater
- affect post-construction land uses
- affect visual amenity.

17.4 MANAGEMENT ACTIONS

Prior to construction of the pipeline, wellfield and treatment plant, the Water Corporation will prepare a detailed Waste Management Plan, which will address all regulatory and Shire requirements. The plan will identify the likely wastes arising during construction, and appropriate handling and methods of disposal.

The Waste Management Plan will be based on the following principles, which are in accordance with the Australian Pipeline Industry Association Code of Environmental Practice (1998) and are listed in order of priority:

1. Reduction of wastes at the source.
2. Reuse of materials wherever possible.
3. Recycling of wastes where practicable.
4. Disposal of wastes appropriately and responsibly.

Waste should be regularly collected from within the pipeline corridor, wellfield location, and treatment plant construction area, and placed in appropriate containers at designated points for later disposal.

All waste collected from construction sites that is suitable for use as landfill will be disposed of at the nearest municipal landfill site. Any waste unsuitable for disposal at these facilities will be segregated and disposed of at an appropriate alternative location in accordance with procedures outlined in the Waste Management Plan.

A workforce education program will be included as part of the induction process, to make personnel aware of personal responsibilities, and of the location of waste disposal facilities.

17.5 MONITORING, REVIEW AND REPORTING PROGRAM

Regular monitoring of appropriate waste disposal will take place as part of regular site inspections, and reports will be provided to the Site Manager and a designated environmental officer at the Water Corporation.

17.6 CONTINGENCIES

If waste is not disposed of appropriately, the following actions will be taken:

- mitigation of impacts
- investigate the cause
- alter management actions accordingly
- re-inform all personnel of revised management actions and responsibilities
- compile an environmental incident report.

18 SPILLS MANAGEMENT PLAN

18.1 CONTEXT AND SCOPE

During construction of the pipeline, wellfield and treatment plant, fuels and oils may be stored on site and there is therefore a potential for spills to occur.

Managing the risk of spills in the treatment plant, when it is operational, will be included in the Treatment Plant Management Plan (Section 9 of this Chapter).

18.2 OBJECTIVES

The objectives with respect to the management of spills in construction sites are:

No significant spills or escape of hazardous materials

Continued compliance with relevant standards and regulations

Spills are quickly and effectively cleaned up

18.3 POTENTIAL IMPACTS

Storage and use of chemicals on site during construction of the pipeline, wellfield and treatment plant have the potential to result in spills. In general, chemicals will be stored on site in small quantities, so as not to constitute an impact if spillage occurs. However, there are likely to be significant quantities of fuels and oils stored on site. Accidental spillage may occur during:

- handling and storage
- refuelling
- maintenance.

Spillages have the potential to:

- contaminate soil, surface water and groundwater
- impact personnel and public safety
- create an ignition source.

18.4 MANAGEMENT ACTIONS

Management actions will emphasise the prevention of spills through careful handling and storage of hazardous material, as well as minimising the quantity and range of chemicals stored on site. A fuel register will be maintained to record all fuel deliveries. Induction for workforce personnel will include briefing on the handling and storage of fuels and chemicals, transferring of fuel and refuelling of vehicles and machinery, vehicle maintenance, and details of the location of the Hazardous Material Register. The Hazardous Material Register will be maintained for all hazardous materials kept onsite.

Specific management actions will also be implemented to minimise the severity of any spill that may occur, such as:

1. Storage of contaminants above ground will be in a spill containment area (bund) to minimise the risk of spillage into the environment, in accordance with the relevant legislation and Australian standards.
2. Spill containment areas will not be located within 200 m of any wetland.
3. Designated service areas for large machinery will be established on-site and will be located on flat land, at least 200 m from wetlands, and will be banded to ensure accidental spillages are collected immediately.
4. Spill response kits will be provided at strategic locations, particularly environmentally sensitive areas such as near wetlands, and carried on major plant and equipment.
5. Material Safety Data Sheets will be in easily found, protected areas adjacent to the materials to which they apply.
6. All spills will be immediately contained and cleaned up.

18.5 MONITORING, REVIEW AND REPORTING PROGRAM

Significant spills of fuels, oils or other contaminants will be reported immediately to the DoE, and a register of all incidents and near misses will be kept on site, along with details of follow up actions taken. All significant spills will be reported in the Annual Sustainability Review.

All hazardous material deliveries will be recorded and amounts delivered reconciled with amounts used to determine if there has been any leakage.

18.6 CONTINGENCIES

All spills will be cleaned up immediately and, if appropriate, DoE will be consulted to verify that the spill has been effectively dealt with. Storage facilities and handling procedures will be reviewed to determine the cause of any spills, and changes made to minimise the risk of a repeat occurrence.

19 ABORIGINAL HERITAGE MANAGEMENT PLAN

19.1 CONTEXT AND SCOPE

The pipeline infrastructure footprint provides the potential for heritage sites to be encountered, particularly adjacent to wetlands, rivers and streams. The Noongar people of the South West are Western Australia's largest indigenous population. Aboriginal artefacts recorded in the South West can be traced back as far as 29 500 BC (SWALSC 2005).

19.2 OBJECTIVES

The objectives with respect to Aboriginal Heritage values and proposed developments include:

Ensure that the proposed development plan complies with the requirements of the Aboriginal Heritage Act 1972.

Ensure that changes to the biological and physical environment resulting from the proposed development are minimised and do not adversely affect cultural associations of the areas along and adjacent to the pipeline corridor.

19.3 POTENTIAL IMPACTS

The construction of the pipeline, wellfield and treatment plant has the potential to disturb or destroy both known and unknown Aboriginal heritage sites. Desktop archaeological and ethnographic surveys have identified four sites within the study area that may be disturbed by construction. These sites are the Capel, Ferguson, Brunswick, Collie and Preston Rivers. The AH Act makes provision for the preservation, on behalf of the community, of places and objects customarily used by, or traditional to, the original inhabitants of Australia or their descendents.

Under section 17 of the AH Act it is an offence to:

- excavate, destroy, conceal, remove or in any way alter an Aboriginal site
- assume the possession, custody or control of any object on or under an Aboriginal site.

unless these acts occur under the authorisation of the Registrar of Aboriginal Sites under section 16, or the consent of the Minister for Indigenous Affairs under section 18, of the AH Act.

19.4 MANAGEMENT ACTIONS

A Heritage Agreement will be developed, with assistance from representatives of relevant indigenous groups, for all construction works. It will be designed to protect Indigenous heritage during construction.

The Water Corporation and contractors will implement Aboriginal heritage management procedures as defined in the Heritage Agreement that will include, but not be limited to, the matters contained within this Aboriginal Heritage Management Plan.

1. The Water Corporation will conduct a heritage survey of the entire infrastructure footprint, prior to construction, to identify heritage sites. Sites will be avoided if possible, or an application to disturb under s18 of the AH Act will be sought.

2. The Water Corporation and contractors will engage Aboriginal heritage monitors during all ground disturbing works in the vicinity of known Aboriginal sites (i.e. wetlands).
3. Contractors will take into account any matters raised by Aboriginal consultants during the course of any monitoring of the ground disturbing works but, other than where a potential Aboriginal site (as defined in the AH Act) is located, the contractor and the Water Corporation will be under no obligation to cease the works in other areas.
4. If any archaeological material, not previously identified, is found during the construction, work will cease immediately within a nominal 20 metres of the find. The Water Corporation will engage a qualified archaeologist to undertake appropriate recording or protection measures, and advise the relevant stakeholders as required.
5. If any skeletal material is uncovered the Water Corporation contractor will advise the contract Superintendent's representative immediately. The Police Department will be contacted by the Water Corporation and the site immediately secured by the contractor.
6. All personnel will be informed of the requirements for dealing with Aboriginal heritage sites prior to the commencement of construction activities, and will also be made aware of their responsibilities under the AH Act.
7. All personnel will be briefed on heritage protection issues and their obligations under the AH Act.

19.5 MONITORING, REVIEW AND REPORTING PROGRAM

Heritage surveys will be carried out prior to construction in all areas to be disturbed by infrastructure. During earthworks in the vicinity of known Aboriginal sites, a heritage monitor will be present to watch for any archaeological material disturbed during construction.

19.6 CONTINGENCIES

The Aboriginal Heritage Management Plan will highlight the correct protocol to be followed if any further heritage sites are discovered during the construction phase. This will involve immediate cessation of work and consultation with representatives of the relevant Aboriginal group(s).

20 ACID SULPHATE SOILS MANAGEMENT PLAN

20.1 CONTEXT AND SCOPE

With the exception of the pipeline section along the Blackwood Plateau, the desktop study of the risk of occurrence of acid sulphate soils along the alignment indicates that most of the section on the Swan Coastal Plain is medium risk. The section through the Capel River valley is considered to be high risk. The Blackwood Plateau section is low to zero risk.

In areas of high risk, there is “moderate to high risk of actual acid sulphate soil occurring less than 3 m from the soil surface”. In areas of medium risk, there is a “moderate to high risk of actual acid sulphate soil and potential acid sulphate soil more than 3 m from the surface, and no risk of occurrence less than 3 m from the soil surface” (WAPC 2003b).

20.2 OBJECTIVES

To minimise the potential environmental impacts from the disturbance of Acid Sulphate Soils.

The Water Corporation will comply with the relevant statutory requirements and any policies concerning acid sulphate soils. These include:

- The Department of Environment Acid Sulphate Soils Guideline Series.
- *Contaminated Sites Act 2003*
- Planning Bulletin 64. Acid Sulphate Soils (WAPC 2003b)

An Acid Sulphate Soils Management Plan will be further developed by the Water Corporation and implemented for the duration of construction.

20.3 MANAGEMENT ACTIONS

As construction of the pipeline requires excavation of potential acid sulphate soils, the soils and associated groundwater must be managed to limit the potential for adverse environmental effects. In accordance with the DoE Acid Sulphate Soils Guideline Series, the preparation of an Acid Sulphate Soils Management Plan is required before commencement of any works on the pipeline route.

The Water Corporation will carry out a sampling program to determine the location of acid sulphate soils.

During excavation, the fill materials and soil materials not requiring acid sulphate soil management will be segregated and stockpiled separately for re-use on site. The surplus material will be assessed in accordance with Guidelines for Disposal of Solid Waste to Landfill (DoE 2002) to determine the appropriate disposal options. Identification and treatment of acid sulphate soils will be managed in accordance with DoE Guidelines (DoE 2004b, 2004c).

Pumping and discharge of water from dewatering will be managed according to both the Acid Sulphate Soils and Dewatering Management Plans.

Groundwater monitoring of selected bores near excavation and dewatering operations will be conducted by the contractor, and remedial measures taken if necessary.

Management of acid sulphate soils will be included in induction programs for all personnel involved in construction activities on the Swan Coastal Plain.

21 WELLFIELD CONSTRUCTION MANAGEMENT PLAN

21.1 CONTEXT AND SCOPE

Drilling will be required as part of the wellfield construction. Up to ten bores will be drilled at five sites. All will be located within State forest. An additional three contingency sites have been identified to allow flexibility in the wellfield configuration for the adaptive management process. The wells are expected to be drilled using mud rotary drilling methods (dependent on the outcome of the tender process). This plan describes the management of the drilling and installation of the bores.

21.2 OBJECTIVES

The relevant objectives of the EPA with respect to drilling include:

Protect Declared Rare and Priority Flora, consistent with the provisions of the Wildlife Act and EPBC Act.

Maintain the abundance, species diversity, geographic distribution and productivity of vegetation communities.

Maintain the abundance, diversity and geographical distribution of fauna.

Protect Specially Protected Fauna, Priority Fauna and other regionally significant fauna, and their habitats, consistent with the provisions of the Wildlife Act and the EPBC Act.

Ensure well development does not cause erosion of soils and natural drainage lines or adversely affect vegetation and fauna through contamination.

21.3 POTENTIAL IMPACTS

The potential environmental impacts posed by the drilling operation are mostly associated with clearing of vegetation, and waste materials produced during the drilling process. Clearing requirements for the wellfield are discussed in Section 8 of this Chapter. Drill cuttings and water are brought to the surface during drilling. Drilling will require the use of drilling fluids for circulation to raise drill cuttings, and to hold the hole open while drilling. When each well has been installed, it has to be developed (pumped until the water runs cleanly and the yield capacity of the well has been tested). This water is referred to as waste water in this section, and is not suitable for use, and must be discharged to the environment.

The potential environmental impacts posed by the drilling operation include:

- impact on flora
- impact on fauna
- cross contamination between aquifers
- erosion at the waste water discharge site
- changes in the receiving environment of the waste water including water quality, temperature and flows
- contamination from the cuttings produced.

21.4 MANAGEMENT ACTIONS

21.4.1 Terrestrial fauna

Impacts on terrestrial fauna are considered manageable, given the small clearing zone and the temporary nature of the works. As an integral part of providing a secure compound, the drilling contractor will erect a security fence which will also prevent terrestrial fauna from being harmed by the drilling operations.

Should fauna be encountered within the works compound, the animals will not be harmed, and will be removed under advice from CALM. Any injured fauna will be reported to CALM immediately.

21.4.2 Aquatic fauna

It is expected that wastewater from the construction and development of wells will be discharged into nearby watercourses. Impacts on aquatic fauna are considered manageable. The waste water will be treated to ensure it is compatible with the quality of water in the watercourse and with the aquatic biota. Diffusers will be installed to eliminate erosion effects.

A monitoring and management system will be put in place to ensure that the discharge of water during development and test pumping is managed to minimise the impacts on the aquatic fauna.

21.4.3 Well construction

Wells will be constructed in accordance with DoW RWI Act licensing requirements to ensure aquifer cross-contamination is avoided, including cement grouting of the annulus between the finished well casing and the outer perimeter of the drilled hole, as required.

All other RWI Act well construction licensing conditions will be complied with.

21.4.4 Drilling slurry

Drilling fluid and cuttings will be circulated through a mud pit constructed adjacent to the drilling rig to ensure material is managed and retained within a contained area during the drilling process.

Drill cuttings, which will consist mostly of sand (Yarragadee Formation), and drilling mud will be dried on site, removed and disposed of in consultation with the relevant local authority.

Only drilling fluids approved for use in contact with potable water will be used.

On completion of well construction, drill sites will be cleared of all debris and the mud pit filled in.

21.4.5 Construction and development water

Construction water will be decanted into ponds and holding tanks for cooling and then gravity discharged to a nearby watercourse. Flow rates are expected to be steady, constant and low force to prevent erosion and turbidity in the receiving watercourse. Water quality will be monitored and maintained at all times.

21.5 MONITORING, REVIEW AND REPORTING PROGRAM

Monitoring of both discharged waste water and the receiving environment will be undertaken to ensure no adverse impacts result from discharge of waste water. Monitoring will include water quality, and any impact on watercourses and associated fauna and vegetation.

A site inspection will be carried out after construction is completed to ensure that all debris has been removed and mud pits filled in.

21.6 CONTINGENCIES

In the event of monitoring indicating any adverse impacts from waste water discharge, discharge will be ceased and not recommenced until an appropriate management action has been implemented.

22 REHABILITATION MANAGEMENT PLAN

22.1 CONTEXT AND SCOPE

The construction of the pipeline, wellfield and treatment plant will involve clearing of native vegetation in varying condition. Areas of pastureland, road reserves, street verges and roads will also be disturbed during pipeline construction works.

This plan describes the rehabilitation of areas cleared.

22.2 OBJECTIVE

Rehabilitation and restoration works will aim to reinstate a stable landform that supports a plant community that is self-sustaining and that approaches the density, diversity and species richness of the pre-existing community.

Restoration works in non-bushland areas will return the land to a condition equal to, or better than, its previous condition.

22.3 MANAGEMENT MEASURES

22.3.1 Vegetation restoration

The Water Corporation will engage the services of suitably qualified and experienced revegetation personnel to undertake native vegetation restoration in certain areas along the pipeline route.

Water Corporation contractors will undertake the necessary earthworks and site management to prepare the ground for vegetation restoration works in accordance with the requirements of the revegetation contractors.

The vegetation contractors will undertake the necessary rehabilitation works in sections along the pipeline route where vegetation currently exists.

22.3.2 Topsoil management

Following installation of the pipeline and backfilling of the trench, stockpiled topsoil will be returned and evenly respread without delay.

Stripped topsoil will be replaced in the reverse order to that in which it was removed. The windrows of topsoil will not be mixed, but will be placed back in layers.

Topsoil replacement will ensure that the surface is reinstated to original levels and that isolated high or low points do not remain.

The depth of topsoil replaced will be not less than 150 mm.

The filled trench line will be topped up with soil where settlement has resulted in ponding or poor drainage. Top up soil will be sourced locally and will be from an area of similar vegetation type. In dieback-free areas top up soils will be from dieback-free areas only.

Following re-spreading of overburden and topsoil, land along the alignment will be re-shaped to fit the previously existing natural ground levels by removing any ridges, depressions or pits.

Compacted areas will be ripped or tined to a nominal depth of 200 mm, except over the backfilled trench and retained access tracks, and will closely follow natural contours wherever possible.

22.3.3 Mulching and seeding

Chipped vegetation will be re-spread as evenly as possible over rehabilitated areas. Vegetation mulch will be re-spread within the same vegetation community type that it came from.

Logs and rocks will be re-spread in their source areas.

Direct seeding will be undertaken in areas where there is little likelihood of natural recruitment of plants from adjoining vegetation. Direct seeding will be by hand spreading of bulked up seed at a rate per hectare agreed with the land manager.

The cleared zone, and any disturbed zones not required for access tracks, will be hand seeded immediately after ripping. Seed will be from locally collected native species. Seed varieties to be used will be determined from the spring flora surveys.

Seeds will be pre-tested for germination percentage, and relevant germination techniques (such as smoke treatment) will be implemented where required.

Pre- and post-seeding weed control will be undertaken where weed species comprise more than 20% of pre-existing ground cover. Weed control will target the weed types present and use selective herbicides if required.

22.3.4 Monitoring and further works

The success of revegetation works will be monitored for a period of two years following implementation. Monitoring will assess the density and diversity of regeneration of native species, as well as the density and prevalence of weed species. Monitoring of revegetation works will be undertaken in consultation with CALM.

Final revegetation compliance will be achieved when plants are established at a rate and diversity that has been agreed to by the relevant land manager, and included in the detailed Rehabilitation Management Plan that will be submitted as part of the CEMS.

If revegetation works have not achieved the compliance criteria, work will be continued until such time as compliance has been achieved, or until agreement is reached with the relevant land manager.

In non-bushland areas, the contractor will return the land to a condition as good as, or better than, the pre-construction condition, unless otherwise agreed with the land manager for that area.

23 TRAFFIC AND PUBLIC SAFETY MANAGEMENT PLAN

23.1 CONTEXT AND SCOPE

The pipeline will be constructed within existing road reserves and will cross other roads. Some partial road closures will be required, and increased traffic volumes arising from the movement of construction and transport vehicles may result in some short-term adverse impacts on local residents and traffic movement.

Procedures are required to ensure construction traffic is appropriately and safely managed and to ensure public safety risks due to traffic, and to other aspects of the construction phase, are minimised.

Construction of the pipeline will involve deep earthworks, temporary spoil storage, materials storage and handling, use of heavy equipment, welding and cutting, and pipe testing using hyper-chlorinated water. These activities may pose a risk to members of the public accessing the site. Safety risks must therefore be assessed and managed.

23.2 OBJECTIVES

The objectives of the Traffic and Public Safety Management Plan are to:

Ensure that the traffic created by the pipeline construction is effectively managed and impacts on residents and road users are minimised.

Ensure traffic is managed in such a way as to minimise the potential for accidents and other safety risks.

Protect the general public and local residents from any risks associated with the construction of the pipeline.

23.3 LEGAL REQUIREMENTS

Contractors will comply with the statutory requirements and relevant guidelines that apply to the traffic issues. The applicable legislation includes:

- *Local Government Act 1995*
- *Main Roads Act 1930*
- *Road Traffic Act 1974.*

23.4 MANAGEMENT MEASURES

23.4.1 Traffic management

Traffic management measures include:

1. Construction vehicles will travel along specifically designated routes that have been selected to minimise disturbance of other traffic and the community.

2. Public notification of construction activities will be given, particularly to nearby residents, before commencement of works in each area.
3. Appropriate approvals or permits will be obtained.
4. Road access will be maintained in the project area by the use of signed detours and/or single lane access.
5. Any material spilled from haulage vehicles leaving the site will be cleaned up as soon as possible.
6. When site work is being undertaken within or adjacent to designated road reserves, advisory road signs will be placed on both local and main roads.

23.4.2 General safety

Management of general safety will include:

1. Where there is any risk of public injury (e.g. open trenches or dewater pits) the construction site will be fenced or otherwise cordoned off.
2. Machinery and plant will be kept in locked compounds when the site is not in use.
3. Spoil and mulch heaps will be no higher than 2 m.
4. Advisory warning boards will be placed on fenced construction zones and compounds. The warning boards will state the nature of the hazard and give an emergency contact telephone number.

Chapter 10 Consolidated proposal commitments

The following sections set out the full range of commitments made by the proponent to be implemented in proceeding with the proposal if approved. The subset of these commitments expected to form part of the conditions of formal environmental approval of the proposal is presented in Table 10.1.

1 LEGAL REQUIREMENTS TO BE FULFILLED UNDER OTHER LEGISLATION

This section outlines actions and procedures that the Water Corporation is committed to undertaking under legislation or regulations other than Part IV of the EP Act.

Rights in Water and Irrigation Act 1914

1. Seek approval for the water pipeline crossings of all streams from the Department of Water pursuant to the RWI Act.
2. Prepare, and report on the implementation of, abstraction management plans and associated monitoring programs for the groundwater abstraction in accordance with any licence issued pursuant to the RWI Act and the Groundwater Abstraction Management Plan described in Volume 2 Chapter 9 Section 8.

Aboriginal Heritage Act 1972

3. Conduct a detailed Aboriginal heritage survey of the proposed infrastructure footprint before construction of proposal infrastructure in consultation with the local Indigenous community and in accordance with the requirements of the DIA.
4. Seek approval for any disturbance of identified heritage sites under s18 of the AH Act.

Environmental Protection Act 1986 Part V

5. Operate the treatment plant in accordance with conditions of any licence or works approval issued pursuant to Part V the EP Act.

Environmental Protection (Noise) Regulations 1987

6. All construction and operational activities will comply with the Noise regulations.

2 GENERAL COMMITMENTS

This section outlines commitments made by the Water Corporation that are not likely to be conditions of approval issued under Part IV of the EP Act and are not necessarily requirements under other legislation. These commitments will be publicly reported on and independently audited by an accredited Environmental Auditor every five years.

1. Work with the DoW and CALM to arrange declaration of a public water supply catchment area over the relevant portions of the Yarragadee aquifer recharge zones.
2. The Water Corporation will establish and support a South West Yarragadee Monitoring Review Group with the following functions:
 - 2.1. regular review and advice to the Water Corporation on monitoring programs, monitoring objectives and performance measures for the operation of the proposal
 - 2.2. review and provide public advice to the Water Corporation on monitoring results and provide comment on adaptive management measures
 - 2.3. review any changes to management of groundwater abstraction from the Yarragadee aquifer by the Water Corporation and provide advice on the acceptability of these changes.
3. Establish a South West Yarragadee Interpretive Centre in the South West to provide information to the community and visitors about development of the aquifer.
4. If existing Aqwest (formerly Bunbury Water Board) or Busselton Water Board public water supply wells are affected by saltwater intrusion (to the extent that they no longer meet the water quality criteria for potable use) caused by the Water Corporation groundwater abstraction from the Yarragadee aquifer, the Water Corporation will provide alternative means for accessing an equivalent amount of potable water at an equivalent cost, through either:
 - 4.1. provision of funding to install new wells into the Yarragadee aquifer further inland
 - 4.2. direct supply of water to the relevant company by the Water Corporation.
5. Develop and implement a landowner engagement program to finalise the pipeline alignment, management of pipeline construction and ongoing maintenance procedures.
6. Act within the provisions of the *Land Administration Act 1997* for the pipeline easement interest, but wherever possible, agree on compensation for the interest in land, for loss or for compensation through negotiation.
7. The water from the proposal will be available to any consumer prepared to enter the standard access arrangements (user pays cost of connection or as otherwise supported by the Government) and the uniform tariff pricing policy that applies to other IWSS water users in the State.
8. If the groundwater abstraction is reduced by the Water Corporation in accordance with the adaptive management program, or the Water and Rivers Commission reduces the licence allocation in the future, the Water Corporation commits to develop alternative strategies to address any shortfall in IWSS supply to IWSS consumers including those in the south west⁵⁴.

⁵⁴ It is understood that the development of alternative sources to meet supply shortfalls would be subject to the usual approvals, and no approval of contingencies would be implied by approval of this proposal.

9. Undertake a South West Public Water Supply Future Planning Study to provide a plan for meeting the future public water supply needs in the South West. This plan would be undertaken in conjunction with Aqwest and Busselton Water Board and involve extensive consultation and market surveys of community satisfaction with the water planning and management. The plan would investigate and address the following:
 - 9.1. future public water supply demand
 - 9.2. potential sources for public water supply
 - 9.3. source development program for public supply
 - 9.4. assessment of quality and security of existing public water supplies
 - 9.5. program for upgrading existing quality and security of public water supplies where required
 - 9.6. program for new connections to the extended IWSS or other sources.
10. Undertake a South West Yarragadee Sustainability Initiative that includes:
 - 10.1. the biodiversity and acid sulphate soils studies in Environmental Commitment 2
 - 10.2. sponsor a research program up to the value of \$0.5M on:
 - 10.2.1. the magnitude and potential means of management of irrigation return water
 - 10.2.2. the effects of changing land use on water demand, availability and quality.
11. Provide opportunities for indigenous people to be employed in undertaking monitoring programs.

3 ENVIRONMENTAL COMMITMENTS

Table 10.1 Consolidated environmental commitments

No	Commitment	Factor	Timing	Seek advice from
1.	Implementation of the following environmental offsets: - The Water Corporation will contribute to a 5 year program to assist the management of threatening processes in areas that may be affected by the proposal. The funding will be up to \$1M with the capital and any earned interest made available to the management program over a period of five years. The program will address weeds, disease, feral animals, erosion and uncontrolled public access issues insofar as they exist within these areas: - along the Blackwood River - Poison Gully and Milyeannup Brook valleys - the proposed Blackwood National Park - the proposed St John Brook Conservation Park - the Scott Coastal Plain - Swan Coastal Plain. - Protect the conservation value of selected land establishing conservation covenants or incorporate land into the conservation estate by the freehold transfer of land to the Executive Director of CALM to offset clearing of native vegetation in areas of State Forest for the project infrastructure using a clearing loss/gain ratio of 1:1.5 and of comparable or higher conservation value.	TECs, Rare and Priority flora, Other GDEs, Flora and fauna, Threatened fauna, Wetlands, Development footprint.	To commence prior to operation	DoE, CALM
2.	a) Undertake a biodiversity and acid sulphate soils study in areas potentially affected by groundwater drawdown resulting from the proposal. The studies will be funded up to the value of \$1.5M, with the capital and any earned interest made available to the studies over a period of ten years. The biodiversity component of the study may include but not be limited to the following (subject to the detailed scoping of the study in Commitment 3): - the occurrence, condition, spatial extent and groundwater dependence of floristic and vegetation communities at local and regional scale - the occurrence, condition, spatial extent and groundwater dependence of TECs - the occurrence and spatial extent of significant aquatic fauna - investigate the genetic diversity of significant aquatic fauna that use the tributaries as refugia - the identification and spatial extent of terrestrial fauna habitat - the occurrence and abundance of vertebrate fauna, including specifically, threatened fauna as defined in the Wildlife Conservation Act 1950 and the EPBC Act, Priority fauna as defined and listed by CALM b) The acid sulphate soils component of the study will be restricted to vulnerable areas on the Scott and southern Swan Coastal Plain to determine the occurrence, spatial extent and depth of acid sulphate soils. The studies will be scoped in consultation with CALM, any biodiversity and acid sulphate soils study technical steering committee, DoE and DoW and will be documented and made publicly available.	Blackwood River and tributaries, TECs, Rare and Priority flora, Other GDEs, Flora and fauna, Threatened fauna, wetlands	This commitment will be completed within 10 years of the commencement of construction	Send finalised reports to CALM, DoE & DoW

No	Commitment	Factor	Timing	Seek advice from
3.	Prepare and publish in a Water Corporation Sustainability Report on the following relating to the South West Yarragadee Water Supply Development: - compliance with environmental conditions and commitments - assessment of environmental performance and environmental management response - implementation of environmental management plans - summary of environmental monitoring information - summary of progressive results from the proposed biodiversity and acid sulphate soils studies - stakeholder engagement - Water Corporation response to the advice and recommendations on environmental issues from the Monitoring Review Group.	Blackwood River and tributaries, TECs, Rare and Priority flora, Other GDEs, Flora and fauna, Threatened fauna, wetlands	Annually during construction and for the first five years of operation. The frequency of reporting will then be reviewed.	DoE, DoW
4.	a) The Water Corporation will not, unless otherwise approved by the Minister for the Environment on advice of the Environmental Protection Authority, construct the proposed infrastructure so as to cause or contribute to the direct or indirect disturbance of the following: - TECs (including candidate TECs) - Declared Rare Flora unless the disturbance is approved under the Wildlife Conservation Act 1950 - significant habitat for Threatened or Priority listed fauna b) The Water Corporation will ensure that the proposal construction activities do not cause or contribute to the following: - acidification of land or surface water through the exposure of acid sulphate soils to the extent that it adversely affects native vegetation or streams - an increase in severity status of weeds or pests in State Forest - the spread of dieback disease to previously unaffected areas - placing any species or ecological community into a higher category of threat - visible dust at sensitive premises. - breach of noise regulations	As above	Prior to and during construction	CALM, DoE
5.	Undertake the following surveys along the pipeline route: - a soil sampling program to further define the risk of exposure of acid sulphate soils - a detailed flora and fauna habitat survey to identify species and communities of conservation significance.	As above	Prior to construction	CALM, DoE
6	Ensure independent third party audit of compliance of with commitment 5b above at quarterly intervals. Auditor reports will be made publicly available and submitted to DoE.	As above	During construction	DoE
7.	Finalise the suite of environmental management plans required for the proposal, as outlined in Volume 2 Chapter 9, and implement those plans.	As above	Plans to be finalised prior to construction. Implementation to be undertaken during construction and operation, as appropriate.	DoE, DoW

Chapter 11 References and abbreviations

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2 SHORT TITLES AND ACRONYMS

Table 11.1 sets out the short titles and acronyms used in this report

Table 11.1 Short titles and acronyms

Short Title or Acronym	Long Title
ABS	Australian Bureau of Statistics
ACMC	Aboriginal Cultural Material Committee
AgWA	Department of Agriculture
AH Act	<i>Aboriginal Heritage Act 1972</i>
Aqwest	Bunbury water service provider (formerly Bunbury Water Board)
ARCWIS	Australian Research Centre for Water in Society
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASS	Acid Sulphate Soil
BK	Blackwood River
CALM	Department of Conservation and Land Management
CCGT	Combined Cycle Gas Turbine
CEMS	Construction Environmental Management System
CENRM	Centre of Excellence in Natural Resource Management
COAG	Council of Australian Governments
Commission	Water and Rivers Commission
Corporation	Water Corporation
CS	Conservation Significance
CSIRO	Commonwealth Scientific Industry and Research Organisation
DIA	Department of Indigenous Affairs
DO	Dissolved Oxygen
DoCEP	Department of Consumer and Employment Protection
DoE	Department of Environment
DoF	Department of Fisheries
DoIR	Department of Industry and Resources
DoW	Department of Water
DP	Darradup
DRF	Declared Rare Flora
ECS	Economics Consulting Services
EIA	Environmental Impact Assessment
EMP	Environmental Management Program
EMS	Environmental Management System
EP Act	<i>Environmental Protection Act 1986</i>
EPA	Environmental Protection Authority
EPBC Act	<i>Federal Environmental Protection and Biodiversity Conservation Act 1999</i>
ERMP	Environmental Review and Management Programme
EWR	Environmental Water Requirement
FESA	Fire and Emergency Services Authority
GD	Groundwater Dependence
GDE	Groundwater dependent ecosystem
GHG	Greenhouse Gases
GIS	Geographical Information System
GL	Gigalitre
HFB	Horizontal Flow Barrier
IOCI	Indian Ocean Climate Initiative
IUCN	International Union for the Conservation of Nature and Natural Resources
IWSS	Integrated Water Supply Scheme

Short Title or Acronym	Long Title
Kl	Kilolitre
mAHD	Metres Above Sea Level in Australia Height Datum
NH&MRC	National Health and Medical Research council
RFA	Regional Forest Agreement
RWI Act	<i>Rights in Water and Irrigation Act 1914</i>
SRB	Sulphate reducing bacteria
SWALSC	South West Aboriginal Land and Sea Council
SWAMS	South West Aquifer Modelling System
SWDC	South West Development Commission
SWIS	South West Interconnected System
TDS	Total Dissolved Salts
TEC	Threatened Ecological Community
WA	Western Australia
WAPC	Western Australia Planning Commission
Wildlife Act	<i>Western Australia Wildlife Conservation Act 1950</i>
WRC	Water and Rivers Commission